

|                        |                                                                                                               |
|------------------------|---------------------------------------------------------------------------------------------------------------|
| <b>Title</b>           | <b><i>Reference Design Report for a 10 W Dual Output Power Supply Using InnoSwitch3™-EP INN3672C-H602</i></b> |
| <b>Specification</b>   | 90 VAC – 265 VAC Input<br>5 V, 0.3 A and 12 V, 0.7 A Outputs                                                  |
| <b>Application</b>     | Dual Output Open Frame Industrial Power Supply                                                                |
| <b>Author</b>          | Applications Engineering Department                                                                           |
| <b>Document Number</b> | RDR-611                                                                                                       |
| <b>Date</b>            | May 02, 2018                                                                                                  |
| <b>Revision</b>        | 1.2                                                                                                           |

### **Summary and Features**

- InnoSwitch3-EP - industry first AC/DC ICs with isolated, safety rated integrated feedback
- Built in synchronous rectification for >85% efficiency at nominal AC input
- All the benefits of secondary side control with the simplicity of primary side regulation
  - Insensitive to transformer variation
  - Extremely fast transient response independent of load timing
- Meets output cross regulation requirements without linear regulators
- Primary sensed output overvoltage protection (OVP) eliminates optocoupler for fault protection
- Accurate thermal protection with hysteretic shutdown
- Input voltage monitor with accurate brown-in / brown-out and overvoltage 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.powerint.com](http://www.powerint.com). Power Integrations grants its customers a license under certain patent rights as set forth at <http://www.powerint.com/ip.htm>.

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**Important Note:**

Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

## 1 Introduction

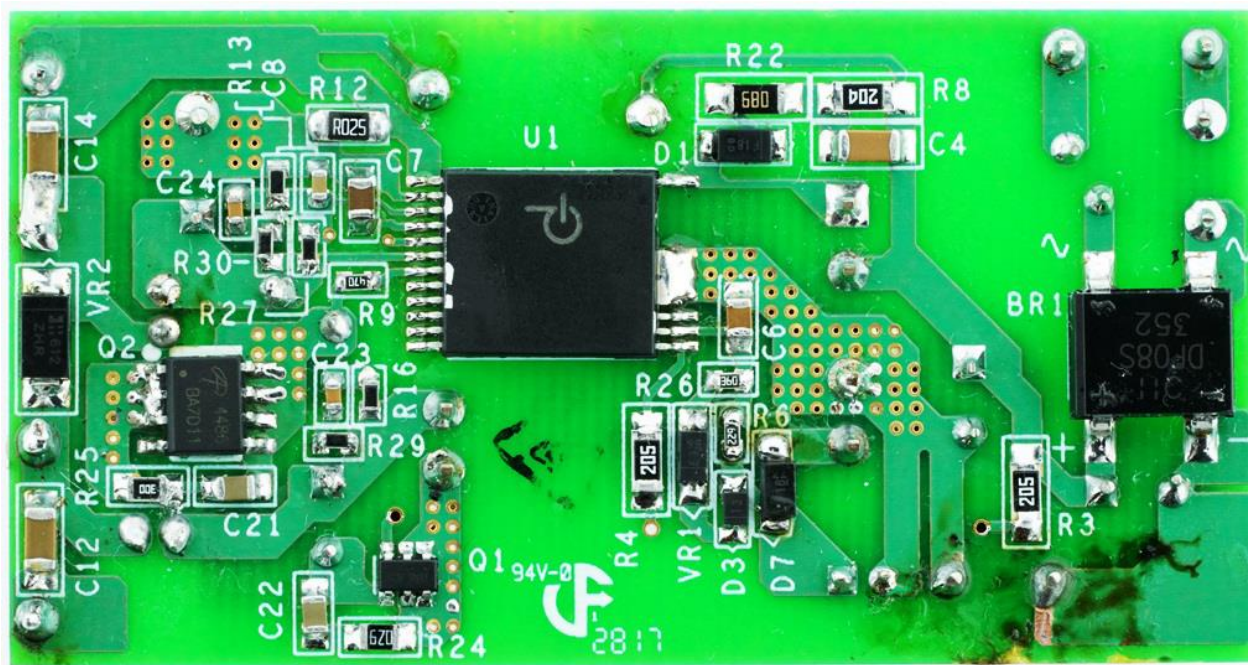
This document is an engineering report describing a 0.3 A, 5 V and 0.7 A, 12 V dual output embedded power supply utilizing INN3672C-H602 from the InnoSwitch3-EP family of ICs.

This design shows the high power density and efficiency that is possible due to the high level of integration while still providing exceptional performance.

The 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 Input.                                                                            |
| Frequency                      | $f_{LINE}$    | 47                                                                    | 50/60 | 63   | Hz    |                                                                                          |
| <b>Output</b>                  |               |                                                                       |       |      |       |                                                                                          |
| Output Voltage 1               | $V_{OUT1}$    | 4.75                                                                  | 5     | 5.25 | V     | ±5 %                                                                                     |
| Output Ripple Voltage 1        | $V_{RIPPLE1}$ |                                                                       |       | 50   | mV    | 20 MHz Bandwidth.                                                                        |
| Output Current 1               | $I_{OUT1}$    | 0                                                                     |       | 0.3  | A     |                                                                                          |
| Output Voltage 2               | $V_{OUT2}$    | 10.2                                                                  | 12    | 13.8 | V     | ±15 %, (±10 % with 10% Min Load on 12 V.)                                                |
| Output Ripple Voltage 2        | $V_{RIPPLE2}$ |                                                                       |       | 120  | mV    | 20 MHz Bandwidth.                                                                        |
| Output Current 2               | $I_{OUT2}$    | 0                                                                     |       | 0.7  | A     |                                                                                          |
| <b>Total Output Power</b>      |               |                                                                       |       |      |       |                                                                                          |
| Continuous Output Power        | $P_{OUT}$     |                                                                       |       | 10   | W     |                                                                                          |
| <b>Efficiency</b>              |               |                                                                       |       |      |       |                                                                                          |
| Full Load                      | $\eta$        | 85                                                                    |       |      | %     | Measured at 110 / 230 VAC, $P_{OUT}$ 25 °C.                                              |
| No Load Input Power            |               |                                                                       |       | 30   | mW    | $V_{IN}$ at 230 VAC.                                                                     |
| <b>Environmental</b>           |               |                                                                       |       |      |       |                                                                                          |
| Safety                         |               | Meets CISPR22B / EN55022B<br>Designed to meet IEC950, UL1950 Class II |       |      |       |                                                                                          |
| Surge<br>Differential          |               | 1                                                                     |       |      | kV    | 1.2/50 $\mu$ s surge, IEC 1000-4-5, Series Impedance:<br>Differential Mode: 2 $\Omega$ . |
| Surge<br>Common mode Ring Wave |               | 2                                                                     |       |      | kV    | 100 kHz Ring Wave, 12 $\Omega$ Common Mode.                                              |
| Ambient Temperature            | $T_{AMB}$     | 0                                                                     |       | 40   | °C    | Free Convection, Sea Level.                                                              |



## 4 Circuit Description

### 4.1 Input EMI Filtering

Fuse F1 isolates the circuit and provides protection from component failure and thermistor RT1 limits inrush current and for surge protection. Bridge rectifier BR1 rectifies the AC line voltage and provides a full wave rectified DC across the filter consisting of C2 and C3. The differential inductance of L1 with capacitors C2 and C3 provide differential noise filtering.

### 4.2 InnoSwitch3-EP Primary

One side of the transformer primary is connected to the rectified DC bus, the other is connected to the integrated 725 V power MOSFET inside the InnoSwitch3-EP IC (U1).

A low cost RCD clamp formed by D1, R22, R8, and C4 limits the peak drain voltage due to the effects of transformer leakage inductance.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor, C6, when AC is first applied. During normal operation the primary side block is powered from an auxiliary winding on the transformer. The output of this is configured as a flyback winding which is rectified and filtered using diode D7 and capacitor C5, and fed in the BPP pin via a current limiting resistor R6. The primary side overvoltage protection is obtained using Zener diode VR1. In the event of overvoltage at output, the increased voltage at the output of the bias winding cause the Zener diode VR1 to conduct and triggers the OVP latch in the primary side controller of the InnoSwitch3-EP IC.

Resistor R3 and R4 provide line voltage sensing and provide a current to U1, which is proportional to the DC voltage across capacitor C3. At approximately 100V DC, the current through these resistors exceeds the line under-voltage threshold, which results in enabling of U1. At approximately 460V DC, the current through these resistors exceeds the line over-voltage threshold, which results in disabling of U1.

### 4.3 InnoSwitch3-EP IC Secondary

The secondary side of the InnoSwitch3-EP provides output voltage, output current sensing and drive to a MOSFET providing synchronous rectification.

Total output current is sensed by R12 between the IS and GND pins with a threshold of approximately 35 mV to reduce losses. Once the current sense threshold is exceeded the device adjusts the number of switch pulses to maintain a fixed total output current.

Output rectification for the 5 V output is provided by SR FET Q1. Very low ESR capacitor C18 provides filtering, and inductor L3 and capacitor C12 form a second stage filter that significantly attenuates the high frequency ripple and noise at the 5 V output.



Output rectification for the 12 V output is provided by SR FET Q2. Very low ESR capacitors C19 provides filtering, and Inductor L2 and capacitor C14 form a second stage filter that significantly attenuates the high frequency ripple and noise at the 12 V output.

RC snubber networks comprising R24 and C22 for Q1, R25 and C21 for Q2 damp high frequency ringing across SR FETs, which results from leakage inductance of the transformer windings and the secondary trace inductances.

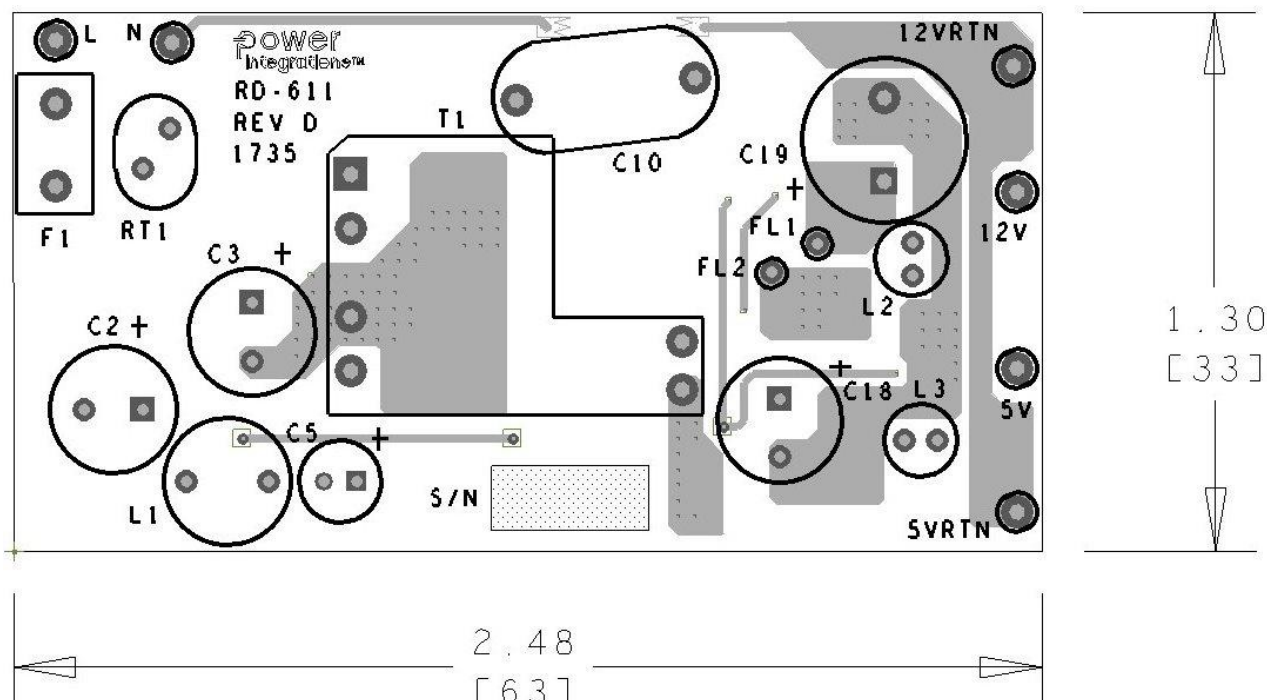
The gates of Q1 and Q2 are turned on based on the winding voltage sensed via R9 and the FWD pin of the IC. In continuous conduction mode operation, the power MOSFET is turned off just prior to the secondary side controller commanding a new switching cycle from the primary. In discontinuous mode the MOSFET is turned off when the voltage drop across the MOSFET falls below a threshold ( $V_{SR(TH)}$ ). Secondary side control of the primary side MOSFET ensure that it is never on simultaneously with the synchronous rectification MOSFET. The MOSFET drive signal is output on the SR pin.

The secondary side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. The output voltage powers the device, fed into the VO pin and charges the decoupling capacitor C7 and an internal regulator. The unit enters auto-restart when the sensed output voltage is lower than 3 V.

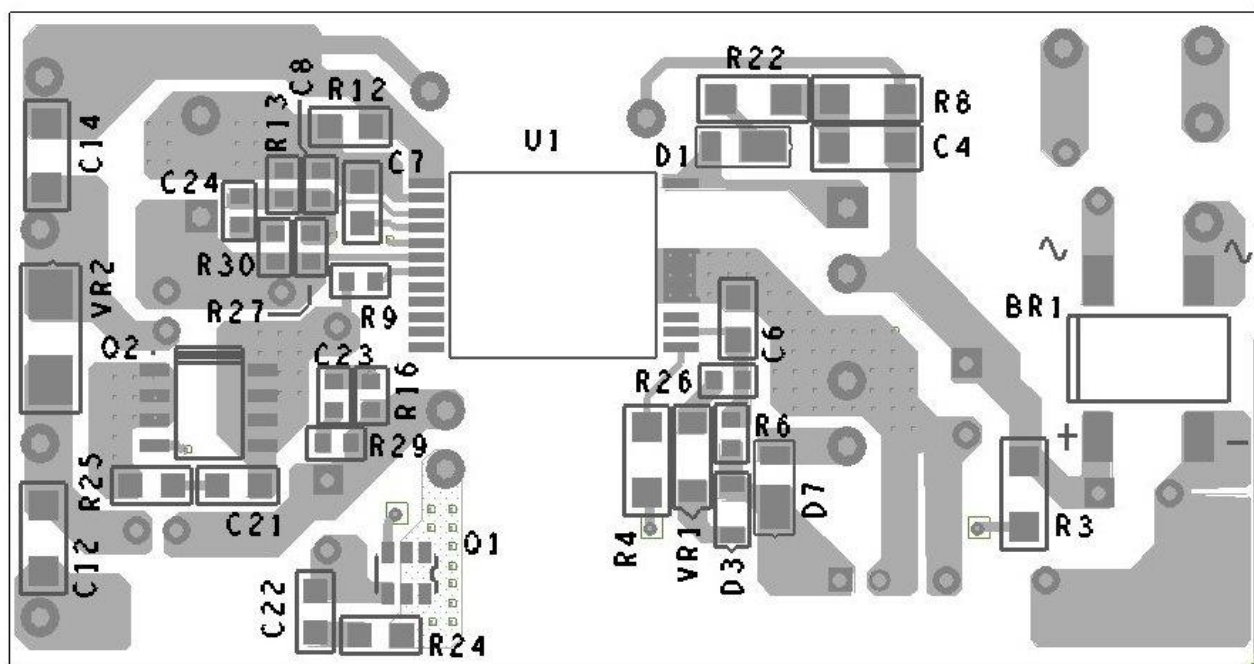
Resistor R16, R27 and R13 form a voltage divider network that senses the output voltage from both outputs for better cross-regulation. Zener diode VR2 improves the cross regulation when only the 5 V output is loaded, which results in the 12 V output operating at the higher end of the specification. The InnoSwitch3-EP IC has an internal reference of 1.265 V. Feedback compensation networks comprising capacitors C23, C24 and resistors R29, R30 reduce the output ripple voltage. Capacitor C8 provides decoupling from high frequency noise affecting power supply operation.

## 5 PCB Layout

PCB copper thickness is 2 oz (2.8 mils / 71  $\mu\text{m}$ ) unless otherwise stated.



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



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

## 6 Bill of Materials

| Item | Qty | Ref Des   | Description                                                                    | Mfg Part Number       | Mfg                                       |
|------|-----|-----------|--------------------------------------------------------------------------------|-----------------------|-------------------------------------------|
| 1    | 1   | BR1       | 800 V, 1 A, Bridge Rectifier, SMD, DFS                                         | DF08S                 | Diodes, Inc.                              |
| 2    | 2   | C2 C3     | 10 $\mu$ F, 400 V, Electrolytic, (8 x 14)                                      | EW2H2GM100F140T       | Aishi                                     |
| 3    | 1   | C4        | 1000 pF, 630 V, Ceramic, X7R, 1206                                             | C1206C102KBRCTU       | Kemet                                     |
| 4    | 1   | C5        | 22 $\mu$ F, 50 V, Electrolytic, (5 x 11)                                       | UPW1H220MDD           | Nichicon                                  |
| 5    | 1   | C6        | 4.7 $\mu$ F, 16 V, Ceramic, X7R, 0805                                          | GRM21BR71C475KA73L    | Murata                                    |
| 6    | 1   | C7        | 2.2 $\mu$ F, 25 V, Ceramic, X7R, 0805                                          | C2012X7R1E225M        | TDK                                       |
| 7    | 1   | C8        | 330 pF 50 V, Ceramic, X7R, 0603                                                | CC0603KRX7R9BB331     | Yageo                                     |
| 8    | 1   | C10       | 470 pF, 250 VAC, Film, X1Y1                                                    | CD95-B2GA471KYNS      | TDK                                       |
| 9    | 2   | C12 C14   | 2.2 $\mu$ F, 25 V, Ceramic, X7R, 1206                                          | TMK316B7225KL-T       | Taiyo Yuden                               |
| 10   | 1   | C18       | 560 $\mu$ F, 6.3 V, Electrolytic, Radial, Low ESR (8 x 13)                     | 6.3ZLG560MEFC8X11.5   | Rubycon                                   |
| 11   | 1   | C19       | 680 $\mu$ F, 16 V, Electrolytic, Radial, Low ESR, 26 m $\Omega$ , (10 x 16)    | EEU-FM1C681           | Panasonic                                 |
| 12   | 2   | C21 C22   | 1 nF, 200 V, Ceramic, X7R, 0805                                                | 08052C102KAT2A        | AVX                                       |
| 13   | 2   | C23 C24   | 2.2 nF 50 V, Ceramic, X7R, 0603                                                | C0603C222K5RACTU      | Yageo                                     |
| 14   | 1   | D1        | 600 V, 1 A, Rectifier, Glass Passivated, POWERDI123                            | DFLR1600-7            | Diodes, Inc.                              |
| 15   | 1   | D3        | 250 V, 0.2 A, Fast Switching, 50 ns, SOD-323                                   | BAV21WS-7-F           | Diodes, Inc.                              |
| 16   | 1   | D7        | 200 V, 1 A, Rectifier, Glass Passivated, POWERDI123                            | DFLR1200-7            | Diodes, Inc.                              |
| 17   | 1   | F1        | 1 A, 250 V, Slow, Long Time Lag, RST 1                                         | RST 1                 | Belfuse                                   |
| 18   | 1   | L1        | 330 $\mu$ H, 0.55 A, 9 x 11.5 mm                                               | SBC3-331-551          | Tokin                                     |
| 19   | 2   | L2 L3     | Inductor, 10 $\mu$ H, Unshielded, Wirewound, 950mA, 140 m $\Omega$ Max, Radial | 11R103C               | Murata Power                              |
| 20   | 1   | Q1        | MOSFET, N-CH, 60V, 4.2A, 6T50P                                                 | AO6420                | Alpha & Omega Semi                        |
| 21   | 1   | Q2        | MOSFET, N-CH, 100 V, 4.2A (Ta), 3.1W (Ta), 79 m $\Omega$ @ 3 A, 10 V, 8SOIC    | AO4486                | Alpha & Omega Semi                        |
| 22   | 1   | R3        | RES, 2.00 M $\Omega$ , 1%, 1/4 W, Thick Film, 1206                             | ERJ-8ENF2004V         | Panasonic                                 |
| 23   | 1   | R4        | RES, 1.80 M $\Omega$ , 1%, 1/4 W, Thick Film, 1206                             | ERJ-8ENF1804V         | Panasonic                                 |
| 24   | 1   | R6        | RES, 6.2 k $\Omega$ , 5%, 1/10 W, Thick Film, 0603                             | ERJ-3GEYJ622V         | Panasonic                                 |
| 25   | 1   | R8        | RES, 200 k $\Omega$ , 5%, 1/4 W, Thick Film, 1206                              | ERJ-8GEYJ204V         | Panasonic                                 |
| 26   | 1   | R9        | RES, 47 $\Omega$ , 5%, 1/10 W, Thick Film, 0603                                | ERJ-3GEYJ470V         | Panasonic                                 |
| 27   | 1   | R12       | RES, 0.02 $\Omega$ , 1%, 1/4 W, Thick Film, 0805                               | RL0805FR-7W0R02L      | Yageo                                     |
| 28   | 1   | R13       | RES, 33.2 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603                            | ERJ-3EKF3322V         | Panasonic                                 |
| 29   | 1   | R16       | RES, 133 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603                             | ERJ-3EKF1333V         | Panasonic                                 |
| 30   | 1   | R22       | RES, 68 $\Omega$ , 5%, 1/4 W, Thick Film, 1206                                 | ERJ-8GEYJ680V         | Panasonic                                 |
| 31   | 1   | R24       | RES, 62 $\Omega$ , 5%, 1/8 W, Thick Film, 0805                                 | ERJ-6GEYJ620V         | Panasonic                                 |
| 32   | 1   | R25       | RES, 30 $\Omega$ , 5%, 1/8 W, Thick Film, 0805                                 | ERJ-6GEYJ300V         | Panasonic                                 |
| 33   | 1   | R26       | RES, 36 $\Omega$ , 5%, 1/10 W, Thick Film, 0603                                | ERJ-3GEYJ360V         | Panasonic                                 |
| 34   | 1   | R27       | RES, 1.20 M $\Omega$ , 1%, 1/16 W, Thick Film, 0603                            | ERJ-3EKF1204V         | Panasonic                                 |
| 35   | 2   | R29 R30   | RES, 100 $\Omega$ , 5%, 1/10 W, Thick Film, 0603                               | ERJ-3GEYJ101V         | Panasonic                                 |
| 36   | 1   | RT1       | NTC Thermistor, 10 $\Omega$ , 0.7 A                                            | MF72-010D5            | Cantherm                                  |
| 37   | 1   | T1        | Bobbin, EE1621, Vertical, 8 pins, 4pri, 4sec Transformer                       | EE-1621<br>POL-INN031 | Shen Zhen Xin Yu Jia<br>Premier Magnetics |
| 38   | 1   | U1        | InnoSwitch-3EP, InSOP24D                                                       | INN3672C-H602         | Power Integrations                        |
| 39   | 1   | VR1       | DIODE ZENER 5.1V 500MW SOD123                                                  | MMSZ5231B-7-F         | Diodes, Inc.                              |
| 40   | 1   | VR2       | DIODE, ZENER, 8.2 V, $\pm$ 5%, 1 W, DO-214AC, SMA                              | SMAZ8V2-13-F          | Diodes, Inc.                              |
| 41   | 1   | 12V       | Test Point, PC MINI, .040" (1.02mm)D, YELLOW, THRU-HOLE MOUNT                  | 5004                  | Keystone                                  |
| 42   | 2   | 12VRTN, L | Test Point, BLK, Miniature THRU-HOLE MOUNT                                     | 5001                  | Keystone                                  |
| 43   | 1   | 5V        | Test Point, RED, Miniature THRU-HOLE MOUNT                                     | 5000                  | Keystone                                  |
| 44   | 2   | 5VRTN, N  | Test Point, WHT, Miniature THRU-HOLE MOUNT                                     | 5002                  | Keystone                                  |

## 7 Transformer (T1) Specification

### 7.1 Electrical Diagram

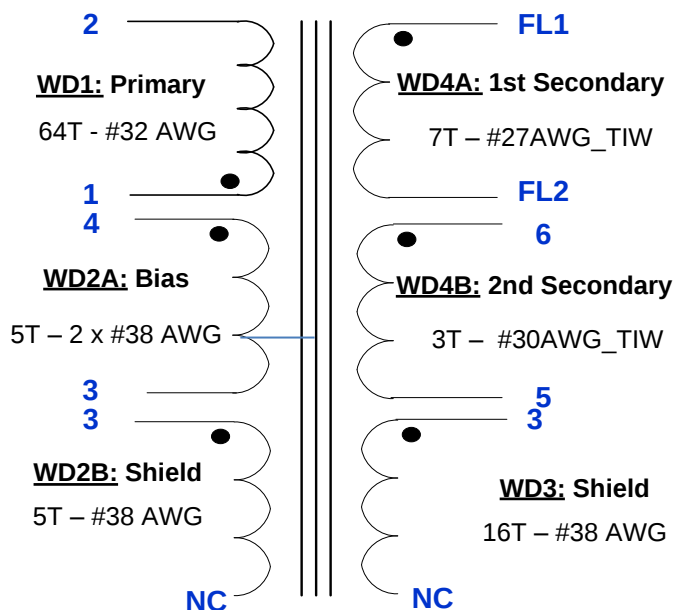


Figure 6 – Transformer Electrical Diagram.

### 7.2 Electrical Specifications

| Parameter                  | Condition                                                                                                          | Spec.                 |
|----------------------------|--------------------------------------------------------------------------------------------------------------------|-----------------------|
| Nominal Primary Inductance | Measured at 1 V <sub>PK-PK</sub> , 100 kHz switching frequency, between pin 1 and 2, with all other windings open. | 1180 $\mu$ H $\pm$ 7% |
| Primary Leakage Inductance | Between pin 1 and 2, with FL1, FL2, 5, 6 shorted.                                                                  | 40 $\mu$ H (Max).     |

### 7.3 Material List

| Item | Description                                                                                      |
|------|--------------------------------------------------------------------------------------------------|
| [1]  | Core: EE1621; Hong Kong Magnetics, ME 95 or Equivalent; Gapped for ALG of 218nH/T <sup>2</sup> . |
| [2]  | Bobbin: EE1621-Vertical – 8 pins (4/4), SHEN ZEN XIN YU JIA Technology LTD.                      |
| [3]  | Magnet Wire: #32 AWG, Double Coated.                                                             |
| [4]  | Magnet Wire: #38 AWG, Double Coated.                                                             |
| [5]  | Magnet Wire: #27 AWG, Triple Insulated Wire.                                                     |
| [6]  | Magnet Wire: #30 AWG, Triple Insulated Wire.                                                     |
| [7]  | Barrier Tape: 3M 1298 Polyester Film, 1 mil Thickness, 5.5 mm Wide.                              |
| [8]  | Copper Foil: 2 mil Thick, 4.0mm x 20.0 mm.                                                       |
| [9]  | Tape: 3M Polyester Film, 1 mil Thick, 7 mm Wide.                                                 |
| [10] | Varnish: Dolph BC-359.                                                                           |

## 7.4 Transformer Build Diagram

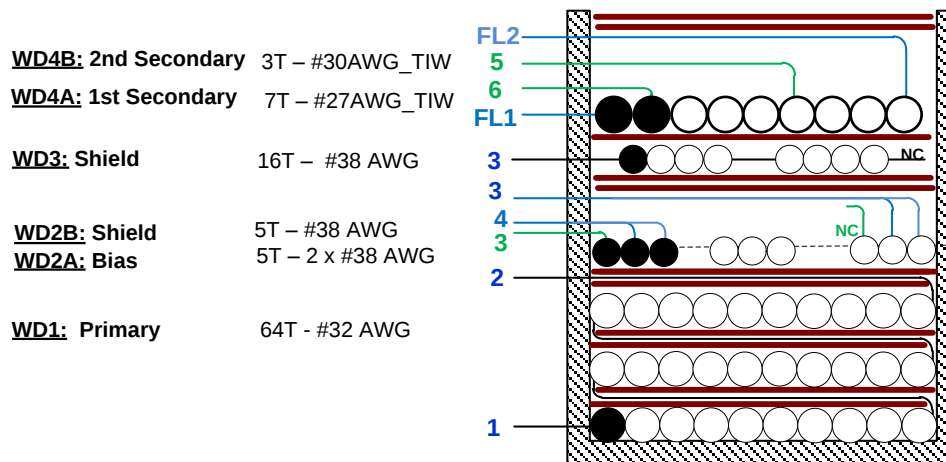
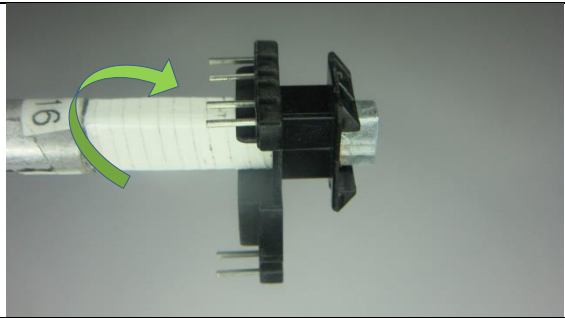
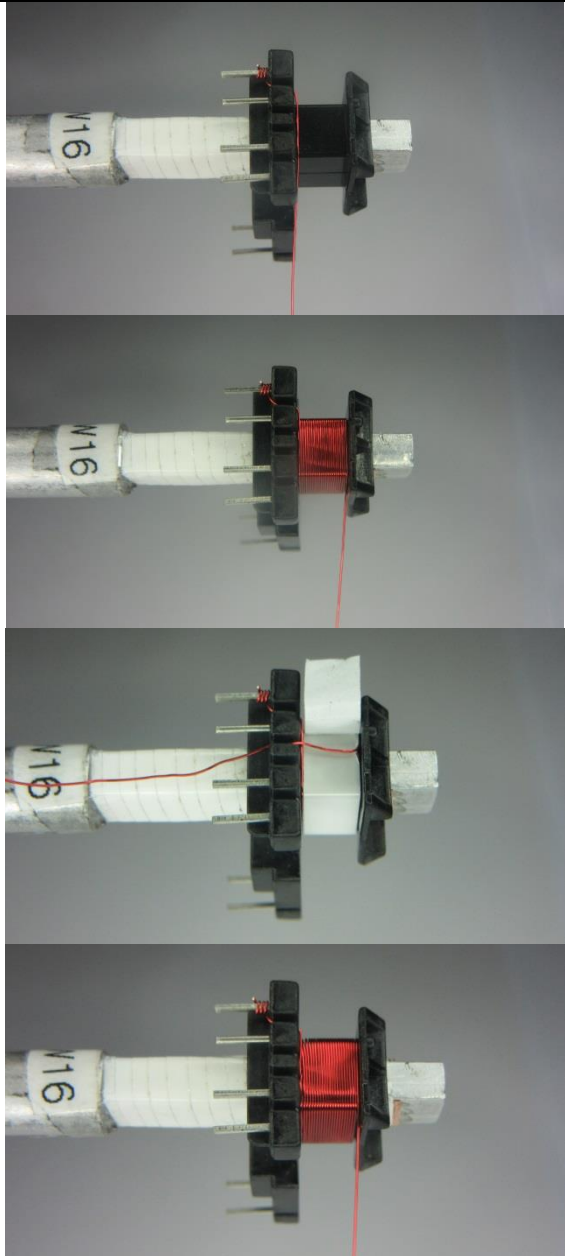


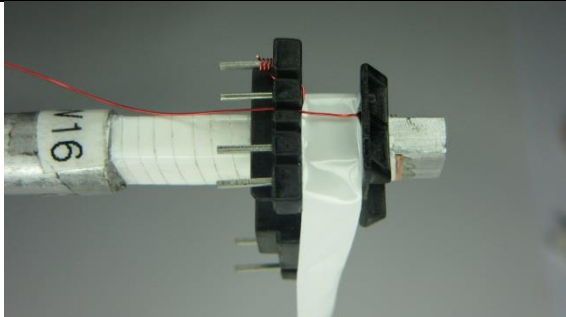
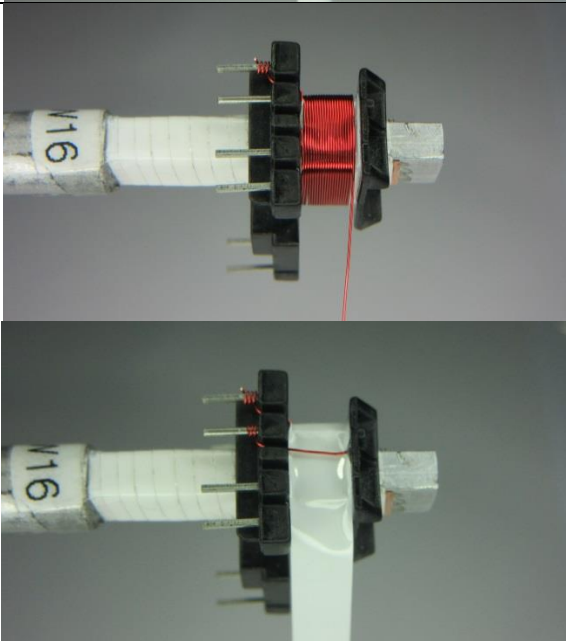
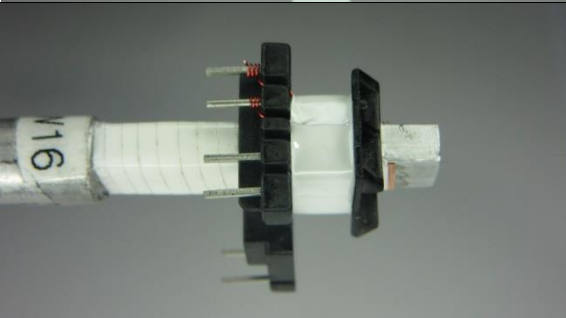
Figure 7 – Transformer Electrical Diagram.

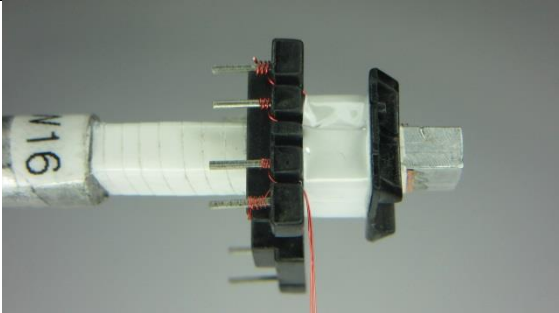
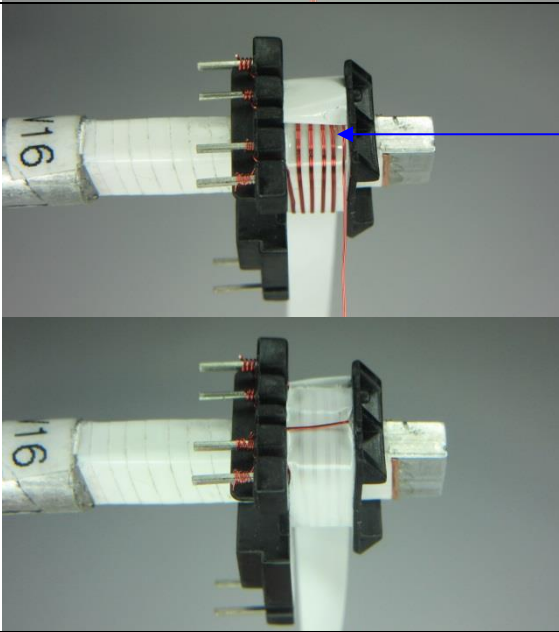
## 7.5 Winding Instructions

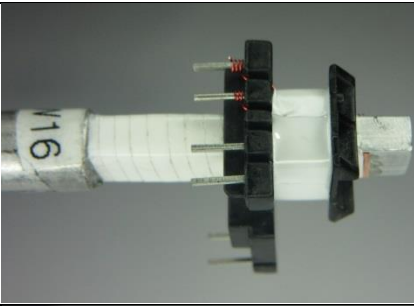
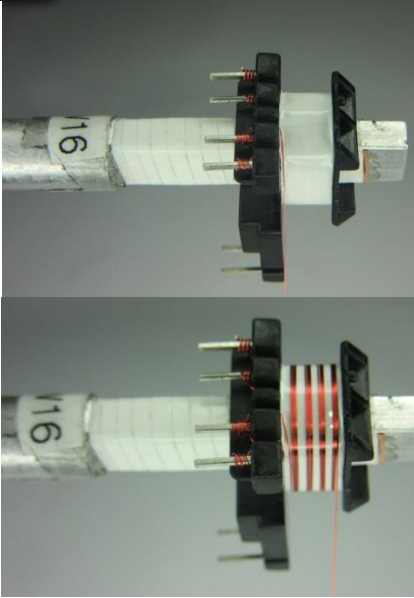
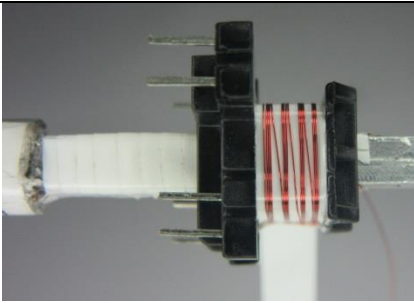
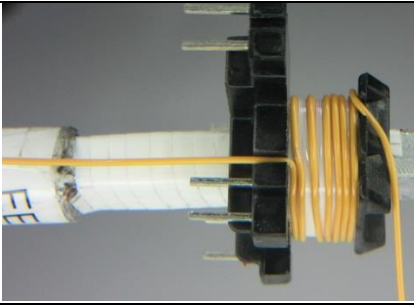
|                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| <b>WD1 Primary</b>                                                       | Start at pin 1, wind 22 turns of wire Item [3] from left to right and bring it back to the left and turn 2 layers of tape Item [7] for insulation. Continue to wind 22 turns on the second layer using the same wire from left to right and bring it back to the left and turn 2 layers of tape Item [7] for insulation. Continue to wind 20 turns on the third layer using the same wire from left to right and bring it back to the left and terminate the wire on pin 2.                                                                                                                                       |
| <b>Insulation</b>                                                        | 2 layer of tape Item [7] for insulation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>WD2A Bias &amp; WD2B Shield</b>                                       | Take 3 wires Item [4], start at pin 4 for 2 wires (Bias), start at pin 3 for 1 wire(Shield),wind 5 turns for all 3 wires from left to right, cut 1 wire (Shield)and leave no-connection for WD2B-Shield. Bring other 2 wires (Bias)to the left and terminate to pin 3.                                                                                                                                                                                                                                                                                                                                            |
| <b>Insulation</b>                                                        | 2 layer of tape Item [7] for insulation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>WD3 Shield</b>                                                        | Take 1 wire Item [4], start at pin 3 wind 16 turns from left to right, leave no-connection for WD3-Shield. Shield should be wind equally spaced and by 4 turns (Please see illustration).                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Insulation</b>                                                        | 1 layer of tape Item [7] for insulation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>WD4A 1<sup>st</sup> Secondary &amp; WD4B 2<sup>nd</sup> Secondary</b> | Take 1 wire Item [5], designate start leads FL1 for WD4A. Wind 7 turns for WD4A and designate the finish lead to FL2. Take 1 wire Item [6] and start at pin6, wind first turn for WD4B beginning right after the first turn of WD4A and 2 <sup>nd</sup> turn right after the 2 <sup>nd</sup> turn of WD4A and 3 <sup>rd</sup> turn right after the 3 <sup>rd</sup> turn of WD4A. Please see illustration. Turn 1 layer of tape and bring two wire to the left and turn another 1 layer of tape for insulation. Terminate finish of WD4B to pin 5.<br>2 layers of tape Item [7] for secure windings and insulation |
| <b>Finish</b>                                                            | Cut short FL1 to ~22.0 mm and FL2 to ~19.0 mm.<br>Gap the core halves to get 1180 $\mu$ H.<br>Prepare copper foil Item [8], solder wire Item [3] at the middle to connect to pin 3, and then place on top core halves. Then secure 2 core halves with 2 layers of tape Item [9].<br>Remove pins: 7 and 8.<br>Varnish with Item [10].                                                                                                                                                                                                                                                                              |

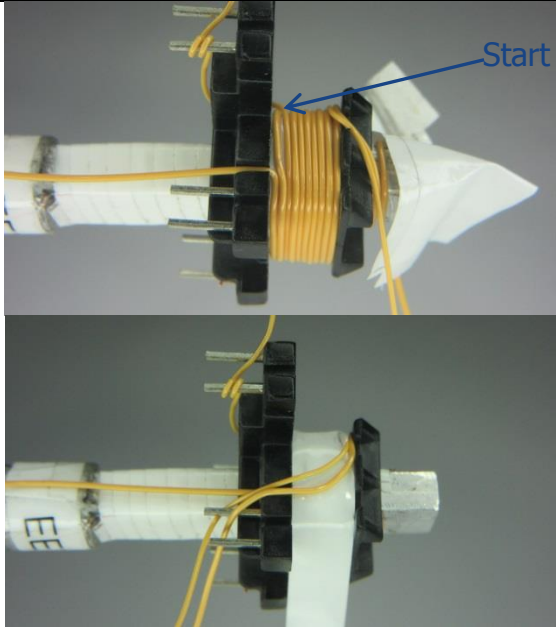
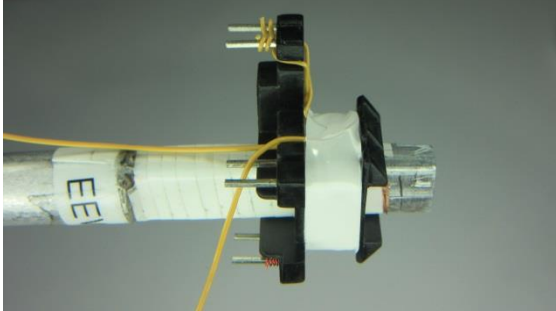
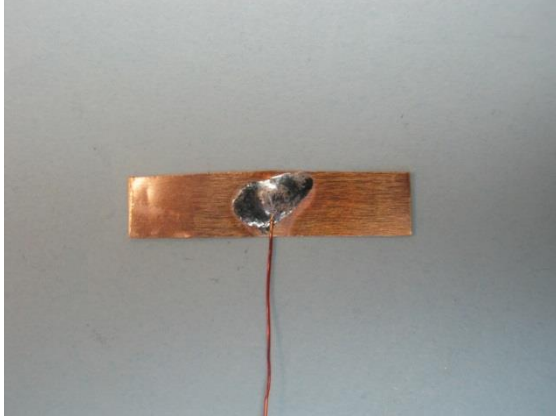
## 7.6 Winding Illustrations

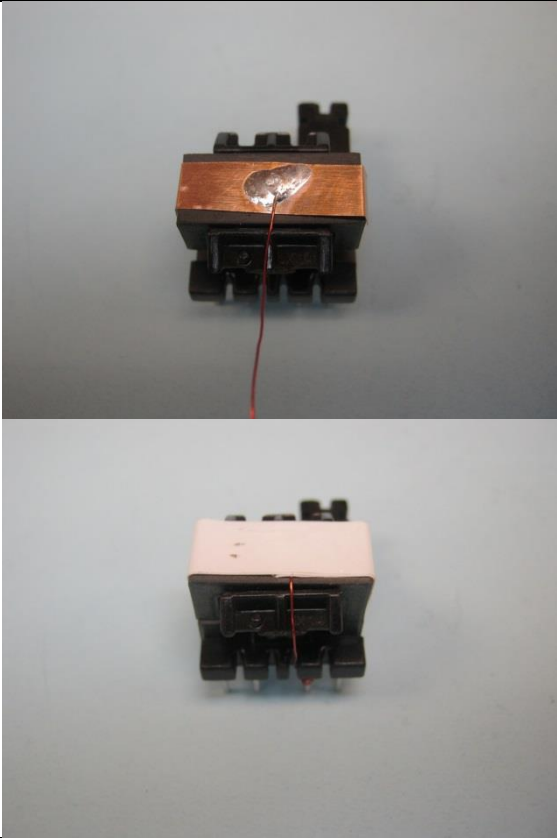
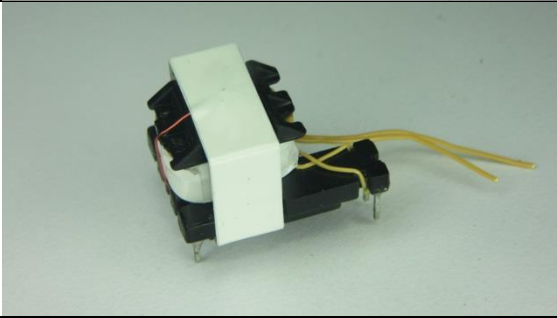
|                                                   |                                                                                     |                                                                                                                                                           |
|---------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Winding Preparation</b>                        |   | <p>For the purpose of these instructions, bobbin Item [1] is oriented on winder such that pin side is on the left side.</p>                               |
| <b>WD1<br/>Primary<br/>(1<sup>st</sup> Layer)</b> |  | <p>Start at pin 1, wind 22 turns of wire Item [3] from left to right and bring it back to the left and turn 2 layers of tape Item [7] for insulation.</p> |

|                                        |                                                                                      |                                                                                                                                                                       |
|----------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WD1<br/>Primary<br/>(2nd Layer)</b> |    | Continue to wind 22 turns on the second layer using the same wire from left to right and bring it back to the left and turn 2 layers of tape Item [7] for insulation. |
| <b>WD1<br/>Primary<br/>(3rd Layer)</b> |   | Continue to wind 20 turns on the third layer using the same wire from left to right and bring it back to the left and terminate the wire on pin 2.                    |
|                                        |  | 2 layer of tape Item [7] for insulation.                                                                                                                              |

|                                        |                                                                                     |                                                                                                                                                                      |
|----------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                        |   | Start at pin 3 (for 1 wire shield),wind 5 turns for all 3 wires from left to right.                                                                                  |
| <b>WD2A Bias &amp;<br/>WD2B Shield</b> |  | <p>Cut wire and leave no connection for WD2B shield</p> <p>Bring other 2 wire (Bias) to the left and terminate to pin3. 2 layer of tape Item [7] for insulation.</p> |

|                                                                        |                                                                                      |                                                                                                                                    |
|------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| <b>Insulation</b>                                                      |    | 2 layer of tape Item [8] for insulation.                                                                                           |
| <b>WD3 Shield</b>                                                      |   | Take 1 wire Item [4], start at pin 3 wind 16 turns from left to right.<br><br>Shield should be wind equally spaced and by 4 turns. |
| <b>Insulation</b>                                                      |  | Back view (secondary side). 1 layer of tape Item [7] for insulation.                                                               |
| <b>WD4A 1<sup>st</sup> Secondary and WD4B 2<sup>nd</sup> Secondary</b> |  | Take 1 wire Item [5], designate start leads FL1 for WD4A. Wind 7 turns for WD4A and designate the finish lead to FL2.              |

|                   |                                                                                      |                                                                                                                                                                                                                                                                                                                                                          |
|-------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                   |    | <p>Take 1 wire Item [6] and start at pin 6, wind first turn for WD4B beginning right after the first turn of WD4A and 2<sup>nd</sup> turn right after the 2<sup>nd</sup> turn of WD4A and 3<sup>rd</sup> turn right after the 3<sup>rd</sup> turn of WD4A.</p> <p>1 layer of tape Item [8] for insulation.</p>                                           |
| <b>Insulation</b> |   | <p>Bring two wires to the left and turn another 1 layer of tape for insulation. Terminate finish of WD4B to pin 5.</p>                                                                                                                                                                                                                                   |
| <b>Finish</b>     |  | <p>Cut short FL1 to ~22.0 mm, and FL2 to ~19.0 mm.</p> <p>Gap the core halves to get 1180 <math>\mu</math>H.</p> <p>Prepare copper foil Item [8], solder wire Item [3] at the middle to connect to pin 3, and then place on top core halves. Then secure 2 core halves with 2 layers of tape Item [9]. Remove pins: 7 and 8. Varnish with Item [10].</p> |

|                   |                                                                                      |                                                                                                                                          |
|-------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
|                   |   |                                                                                                                                          |
| <b>Insulation</b> |  | <p>Wrap 2 layers of tape Item [9] around the transformer for insulation.</p> <p>Remove pins: 7 and 8.</p> <p>Varnish with Item [10].</p> |

## 8 Transformer Design Spreadsheet

| ACDC_InnoSwitch3-EP_Flyback_083017; Rev.1.0; Copyright Power Integrations 2017 | INPUT      | INFO | OUTPUT     | UNITS | InnoSwitch3 EP Flyback Design Spreadsheet                                                                                            |
|--------------------------------------------------------------------------------|------------|------|------------|-------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>APPLICATION VARIABLES</b>                                                   |            |      |            |       |                                                                                                                                      |
| VIN_MIN                                                                        | 90         |      | 90         | V     | Minimum AC input voltage                                                                                                             |
| VIN_MAX                                                                        |            |      | 265        | V     | Maximum AC input voltage                                                                                                             |
| VIN_RANGE                                                                      |            |      | UNIVERSAL  |       | Range of AC input voltage                                                                                                            |
| LINEFREQ                                                                       |            |      | 60         | Hz    | AC Input voltage frequency                                                                                                           |
| CAP_INPUT                                                                      | 20.0       |      | 20.0       | uF    | Input capacitor                                                                                                                      |
| VOUT                                                                           | 12.00      |      | 12.00      | V     | Output voltage at the board                                                                                                          |
| PERCENT_CDC                                                                    |            |      | 0%         |       | Cable drop compensation required                                                                                                     |
| IOUT                                                                           | 0.83       |      | 0.83       | A     | Output current                                                                                                                       |
| POUT                                                                           |            |      | 9.96       | W     | Output power                                                                                                                         |
| EFFICIENCY                                                                     | 0.85       |      | 0.85       |       | AC-DC efficiency estimate at full load given that the converter is switching at the valley of the rectified minimum input AC voltage |
| FACTOR_Z                                                                       |            |      | 0.50       |       | Z-factor estimate                                                                                                                    |
| ENCLOSURE                                                                      | OPEN FRAME |      | OPEN FRAME |       | Power supply enclosure                                                                                                               |
| <b>PRIMARY CONTROLLER SELECTION</b>                                            |            |      |            |       |                                                                                                                                      |
| ILIMIT_MODE                                                                    | INCREASED  |      | INCREASED  |       | Device current limit mode                                                                                                            |
| DEVICE_GENERIC                                                                 | INN36X2    |      | INN36X2    |       | Generic device code                                                                                                                  |
| DEVICE_CODE                                                                    |            |      | INN3672C   |       | Actual device code                                                                                                                   |
| POUT_MAX                                                                       |            |      | 10         | W     | Power capability of the device based on thermal performance                                                                          |
| RDSON_100DEG                                                                   |            |      | 10.41      | Ω     | Primary MOSFET on time drain resistance at 100 degC                                                                                  |
| ILIMIT_MIN                                                                     |            |      | 0.50       | A     | Minimum current limit of the primary MOSFET                                                                                          |
| ILIMIT_TYP                                                                     |            |      | 0.55       | A     | Typical current limit of the primary MOSFET                                                                                          |
| ILIMIT_MAX                                                                     |            |      | 0.60       | A     | Maximum current limit of the primary MOSFET                                                                                          |
| VBREAKDOWN_MOSFET                                                              |            |      | 725        | V     | Device breakdown voltage                                                                                                             |
| VDRAIN_ON_MOSFET                                                               |            |      | 1.22       | V     | Primary MOSFET on time drain voltage                                                                                                 |
| VDRAIN_OFF_MOSFET                                                              |            |      | 553.4      | V     | Peak drain voltage on the primary MOSFET during turn-off                                                                             |
| <b>WORST CASE ELECTRICAL PARAMETERS</b>                                        |            |      |            |       |                                                                                                                                      |
| FSWITCHING_MAX                                                                 | 82000      |      | 82000      | Hz    | Maximum switching frequency at full load and valley of the rectified minimum AC input voltage                                        |
| VOR                                                                            | 110.0      |      | 110.0      | V     | Secondary voltage reflected to the primary when the primary MOSFET turns off                                                         |
| VMIN                                                                           |            |      | 93.59      | V     | Valley of the rectified minimum AC input voltage at full power                                                                       |
| KP                                                                             |            |      | 1.26       |       | Measure of continuous/discontinuous mode of operation                                                                                |
| MODE_OPERATION                                                                 |            |      | DCM        |       | Mode of operation                                                                                                                    |
| DUTYCYCLE                                                                      |            |      | 0.486      |       | Primary MOSFET duty cycle                                                                                                            |
| TIME_ON                                                                        |            |      | 7.61       | us    | Primary MOSFET on-time                                                                                                               |
| TIME_OFF                                                                       |            |      | 6.35       | us    | Primary MOSFET off-time                                                                                                              |
| LPRIMARY_MIN                                                                   |            |      | 1102.6     | uH    | Minimum primary inductance                                                                                                           |
| LPRIMARY_TYP                                                                   |            |      | 1185.5     | uH    | Typical primary inductance                                                                                                           |
| LPRIMARY_TOL                                                                   | 7.0        |      | 7.0        | %     | Primary inductance tolerance                                                                                                         |
| LPRIMARY_MAX                                                                   |            |      | 1268.5     | uH    | Maximum primary inductance                                                                                                           |
| <b>PRIMARY CURRENT</b>                                                         |            |      |            |       |                                                                                                                                      |
| IPEAK_PRIMARY                                                                  |            |      | 0.56       | A     | Primary MOSFET peak current                                                                                                          |
| IPEDESTAL_PRIMARY                                                              |            |      | 0.00       | A     | Primary MOSFET current pedestal                                                                                                      |



|                                            |        |      |        |                       |                                                                                                                                     |
|--------------------------------------------|--------|------|--------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| IAVG_PRIMARY                               |        |      | 0.12   | A                     | Primary MOSFET average current                                                                                                      |
| IRIPPLE_PRIMARY                            |        |      | 0.56   | A                     | Primary MOSFET ripple current                                                                                                       |
| IRMS_PRIMARY                               |        |      | 0.21   | A                     | Primary MOSFET RMS current                                                                                                          |
| <b>SECONDARY CURRENT</b>                   |        |      |        |                       |                                                                                                                                     |
| IPEAK_SECONDARY                            |        |      | 5.16   | A                     | Secondary winding peak current                                                                                                      |
| IPEDESTAL_SECONDARY                        |        |      | 0.00   | A                     | Secondary winding current pedestal                                                                                                  |
| IRMS_SECONDARY                             |        |      | 1.90   | A                     | Secondary winding RMS current                                                                                                       |
| <b>TRANSFORMER CONSTRUCTION PARAMETERS</b> |        |      |        |                       |                                                                                                                                     |
| <b>CORE SELECTION</b>                      |        |      |        |                       |                                                                                                                                     |
| CORE                                       | Custom | Info | Custom |                       | The transformer windings may not fit: pick a bigger core or bobbin and refer to the Transformer Parameters tab for fit calculations |
| CORE CODE                                  | EE1621 |      | EE1621 |                       | Core code                                                                                                                           |
| AE                                         | 32.50  |      | 32.50  | mm <sup>2</sup>       | Core cross sectional area                                                                                                           |
| LE                                         | 39.30  |      | 39.30  | mm                    | Core magnetic path length                                                                                                           |
| AL                                         | 2800   |      | 2800   | nH/turns <sup>2</sup> | Ungapped core effective inductance                                                                                                  |
| VE                                         | 980.0  |      | 980.0  | mm <sup>3</sup>       | Core volume                                                                                                                         |
| BOBBIN                                     | EE1621 |      | EE1621 |                       | Bobbin                                                                                                                              |
| AW                                         | 12.33  |      | 12.33  | mm <sup>2</sup>       | Window area of the bobbin                                                                                                           |
| BW                                         | 5.40   |      | 5.40   | mm                    | Bobbin width                                                                                                                        |
| MARGIN                                     | 0.0    |      | 0.0    | mm                    | Safety margin width (Half the primary to secondary creepage distance)                                                               |
| <b>PRIMARY WINDING</b>                     |        |      |        |                       |                                                                                                                                     |
| NPRIMARY                                   |        |      | 64     |                       | Primary turns                                                                                                                       |
| BPEAK                                      |        |      | 3745   | Gauss                 | Peak flux density                                                                                                                   |
| BMAX                                       |        |      | 3381   | Gauss                 | Maximum flux density                                                                                                                |
| BAC                                        |        |      | 1690   | Gauss                 | AC flux density                                                                                                                     |
| ALG                                        |        |      | 289    | nH/turns <sup>2</sup> | Typical gapped core effective inductance                                                                                            |
| LG                                         |        |      | 0.127  | mm                    | Core gap length                                                                                                                     |
| LAYERS_PRIMARY                             |        |      | 3      |                       | Number of primary layers                                                                                                            |
| AWG_PRIMARY                                |        |      | 32     | AWG                   | Primary winding wire AWG                                                                                                            |
| OD_PRIMARY_INSULATED                       |        |      | 0.244  | mm                    | Primary winding wire outer diameter with insulation                                                                                 |
| OD_PRIMARY_BARE                            |        |      | 0.202  | mm                    | Primary winding wire outer diameter without insulation                                                                              |
| CMA_PRIMARY                                |        |      | 301    | Cmil/A                | Primary winding wire CMA                                                                                                            |
| <b>SECONDARY WINDING</b>                   |        |      |        |                       |                                                                                                                                     |
| NSECONDARY                                 |        |      | 7      |                       | Secondary turns                                                                                                                     |
| AWG_SECONDARY                              |        |      | 24     | AWG                   | Secondary winding wire AWG                                                                                                          |
| OD_SECONDARY_INSULATED                     |        |      | 0.815  | mm                    | Secondary winding wire outer diameter with insulation                                                                               |
| OD_SECONDARY_BARE                          |        |      | 0.511  | mm                    | Secondary winding wire outer diameter without insulation                                                                            |
| CMA_SECONDARY                              |        |      | 229    | Cmil/A                | Secondary winding wire CMA                                                                                                          |
| <b>BIAS WINDING</b>                        |        |      |        |                       |                                                                                                                                     |
| NBIAS                                      |        |      | 8      |                       | Bias turns                                                                                                                          |
| <b>PRIMARY COMPONENTS SELECTION</b>        |        |      |        |                       |                                                                                                                                     |
| <b>Line undervoltage</b>                   |        |      |        |                       |                                                                                                                                     |
| BROWN-IN REQUIRED                          |        |      | 76.5   | V                     | Required AC RMS line voltage brown-in threshold                                                                                     |
| RLS                                        |        |      | 4.52   | MΩ                    | Connect two 2.26 MOhm resistors to the V-pin for the required UV/OV threshold                                                       |
| BROWN-IN ACTUAL                            |        |      | 77.0   | V                     | Actual AC RMS brown-in threshold                                                                                                    |
| BROWN-OUT ACTUAL                           |        |      | 70.6   | V                     | Actual AC RMS brown-out threshold                                                                                                   |
| <b>Line overvoltage</b>                    |        |      |        |                       |                                                                                                                                     |
| OVERVOLTAGE_LINE                           |        |      | 339.2  | V                     | Actual AC RMS line over-voltage threshold                                                                                           |
| Bias diode                                 |        |      |        |                       |                                                                                                                                     |
| VBIAS                                      |        |      | 12.0   | V                     | Rectified bias voltage                                                                                                              |
| VF_BIAS                                    |        |      | 0.70   | V                     | Bias winding diode forward drop                                                                                                     |
| VREVERSE_BIASDIODE                         |        |      | 58.67  | V                     | Bias diode reverse voltage (not accounting                                                                                          |

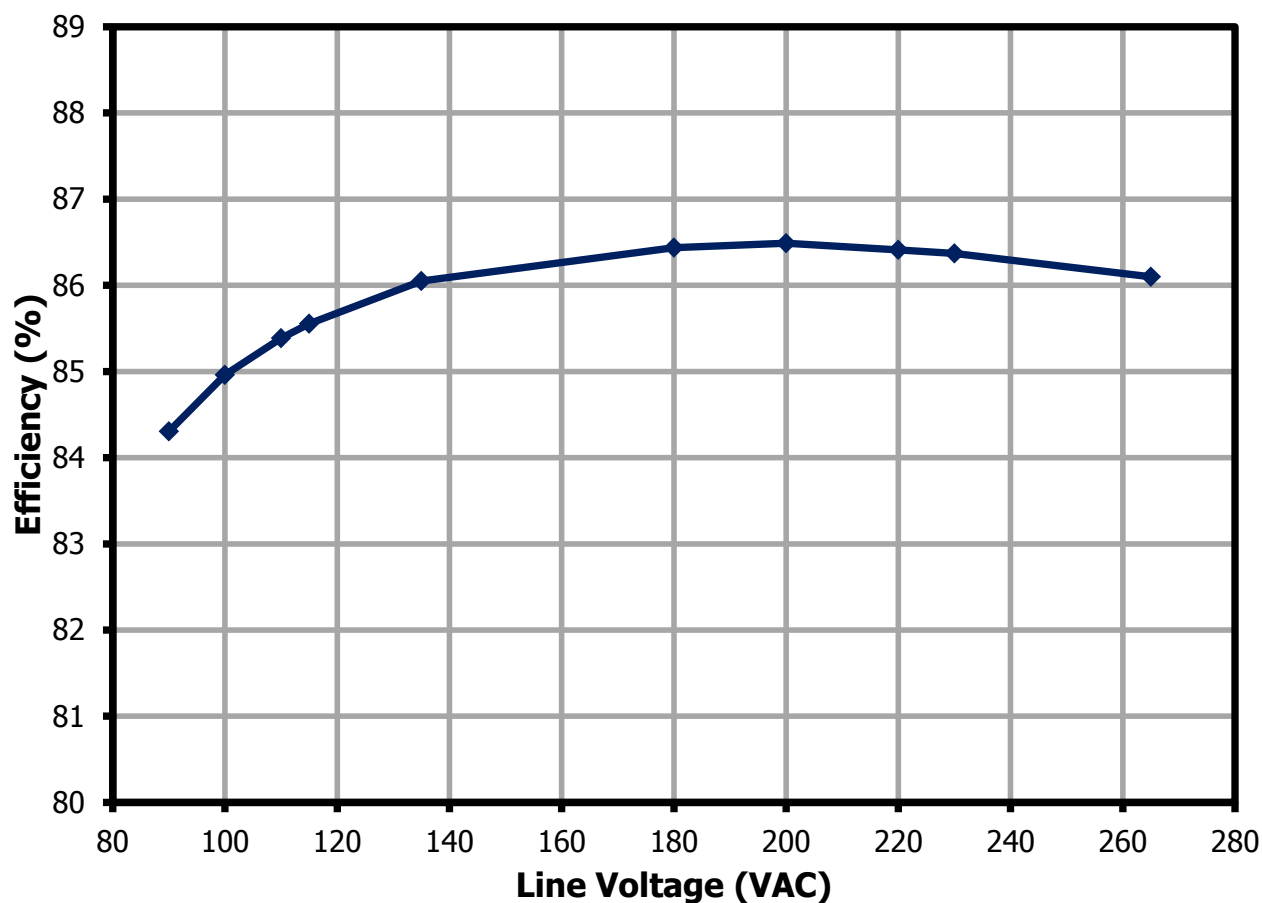
|                                   |      |  |         |       |                                                                            |
|-----------------------------------|------|--|---------|-------|----------------------------------------------------------------------------|
|                                   |      |  |         |       | parasitic voltage ring)                                                    |
| CBIAS                             |      |  | 22      | uF    | Bias winding rectification capacitor                                       |
| CBPP                              |      |  | 4.70    | uF    | BPP pin capacitor                                                          |
| <b>SECONDARY COMPONENTS</b>       |      |  |         |       |                                                                            |
| RFB_UPPER                         |      |  | 100.00  | kΩ    | Upper feedback resistor (connected to the first output voltage)            |
| RFB_LOWER                         |      |  | 11.80   | kΩ    | Lower feedback resistor                                                    |
| CFB_LOWER                         |      |  | 330     | pF    | Lower feedback resistor decoupling capacitor                               |
| <b>MULTIPLE OUTPUT PARAMETERS</b> |      |  |         |       |                                                                            |
| <b>OUTPUT 1</b>                   |      |  |         |       |                                                                            |
| VOUT1                             |      |  | 12.00   | V     | Output 1 voltage                                                           |
| IOUT1                             | 0.70 |  | 0.70    | A     | Output 1 current                                                           |
| POUT1                             |      |  | 8.40    | W     | Output 1 power                                                             |
| IRMS_SECONDARY1                   |      |  | 1.48    | A     | Root mean squared value of the secondary current for output 1              |
| IRIPPLE_CAP_OUTPUT1               |      |  | 1.31    | A     | Current ripple on the secondary waveform for output 1                      |
| AWG_SECONDARY1                    |      |  | 25      | AWG   | Wire size for output 1                                                     |
| OD_SECONDARY1_INSULATED           |      |  | 0.760   | mm    | Secondary winding wire outer diameter with insulation for output 1         |
| OD_SECONDARY1_BARE                |      |  | 0.455   | mm    | Secondary winding wire outer diameter without insulation for output 1      |
| CM_SECONDARY1                     |      |  | 297     | Cmils | Bare conductor effective area in circular mils for output 1                |
| NSECONDARY1                       |      |  | 7       |       | Number of turns for output 1                                               |
| VREVERSE_RECTIFIER1               |      |  | 52.84   | V     | SRFET reverse voltage (not accounting parasitic voltage ring) for output 1 |
| SRFET1                            | Auto |  | AOD2816 |       | SRFET selection for output 1                                               |
| VF_SRFET1                         |      |  | 0.020   | V     | SRFET on-time drain voltage for output 1                                   |
| VBREAKDOWN_SRFET1                 |      |  | 80      | V     | SRFET breakdown voltage for output 1                                       |
| RDSON_SRFET1                      |      |  | 29.0    | mΩ    | SRFET on-time drain resistance at 25degC and VGS=4.4V for output 1         |
| <b>OUTPUT 2</b>                   |      |  |         |       |                                                                            |
| VOUT2                             | 5.00 |  | 5.00    | V     | Output 2 voltage                                                           |
| IOUT2                             | 0.30 |  | 0.30    | A     | Output 2 current                                                           |
| POUT2                             |      |  | 1.50    | W     | Output 2 power                                                             |
| IRMS_SECONDARY2                   |      |  | 0.64    | A     | Root mean squared value of the secondary current for output 2              |
| IRIPPLE_CAP_OUTPUT2               |      |  | 0.56    | A     | Current ripple on the secondary waveform for output 2                      |
| AWG_SECONDARY2                    |      |  | 28      | AWG   | Wire size for output 2                                                     |
| OD_SECONDARY2_INSULATED           |      |  | 0.625   | mm    | Secondary winding wire outer diameter with insulation for output 2         |
| OD_SECONDARY2_BARE                |      |  | 0.321   | mm    | Secondary winding wire outer diameter without insulation for output 2      |
| CM_SECONDARY2                     |      |  | 127     | Cmils | Bare conductor effective area in circular mils for output 2                |
| NSECONDARY2                       |      |  | 3       |       | Number of turns for output 2                                               |
| VREVERSE_RECTIFIER2               |      |  | 22.50   | V     | SRFET reverse voltage (not accounting parasitic voltage ring) for output 2 |
| SRFET2                            | Auto |  | AON7534 |       | SRFET selection for output 2                                               |
| VF_SRFET2                         |      |  | 0.003   | V     | SRFET on-time drain voltage for output 2                                   |
| VBREAKDOWN_SRFET2                 |      |  | 30      | V     | SRFET breakdown voltage for output 2                                       |
| RDSON_SRFET2                      |      |  | 8.5     | mΩ    | SRFET on-time drain resistance at 25degC and VGS=4.4V for output 2         |
| <b>OUTPUT 3</b>                   |      |  |         |       |                                                                            |
| VOUT3                             |      |  | 0.00    | V     | Output 3 voltage                                                           |
| IOUT3                             |      |  | 0.00    | A     | Output 3 current                                                           |
| POUT3                             |      |  | 0.00    | W     | Output 3 power                                                             |
| IRMS_SECONDARY3                   |      |  | 0.00    | A     | Root mean squared value of the secondary                                   |



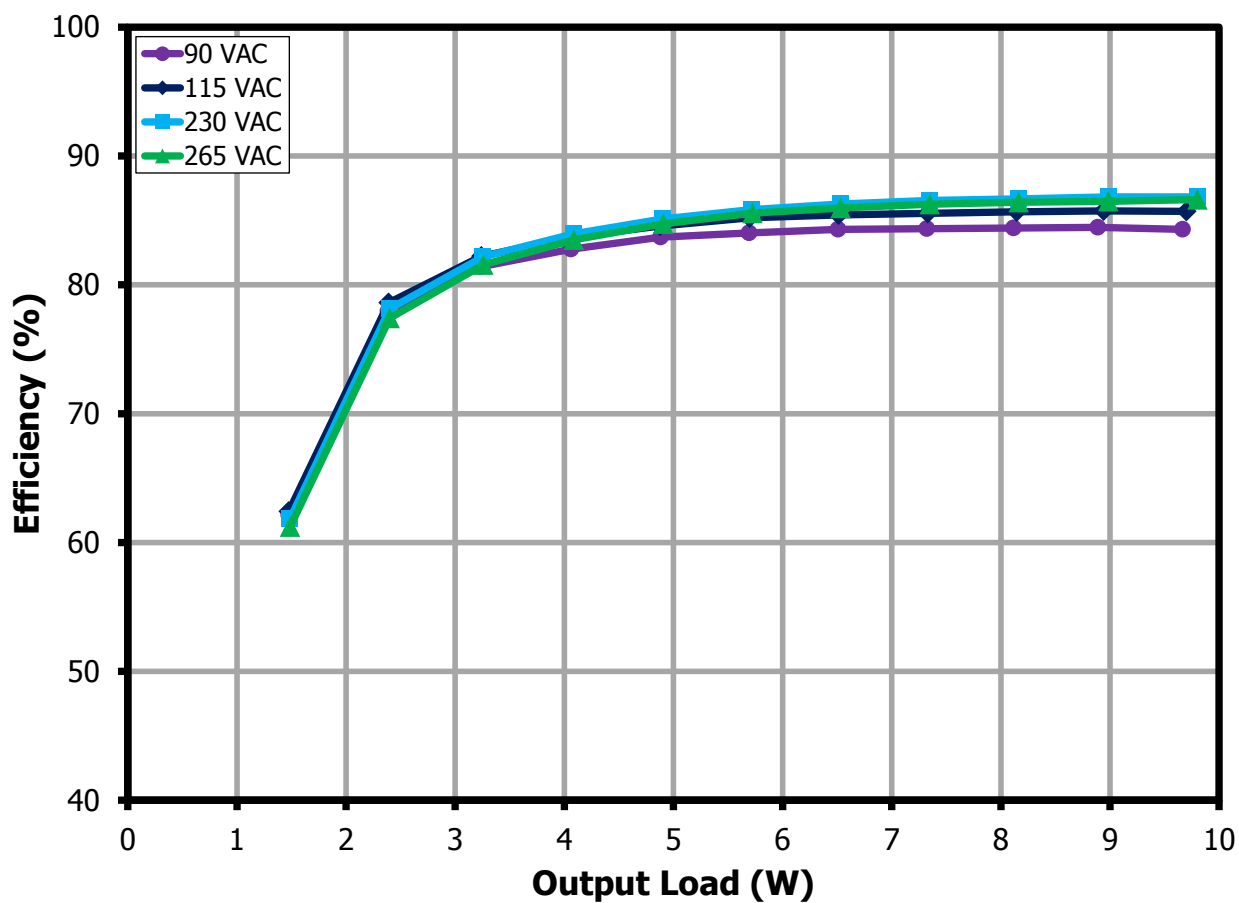
|                           |      |  |        |        |                                                                                              |
|---------------------------|------|--|--------|--------|----------------------------------------------------------------------------------------------|
|                           |      |  |        |        | current for output 3                                                                         |
| IRIPPLE_CAP_OUTPUT3       |      |  | 0.00   | A      | Current ripple on the secondary waveform for output 3                                        |
| AWG_SECONDARY3            |      |  | 0      | AWG    | Wire size for output 3                                                                       |
| OD_SECONDARY3_INSULATED   |      |  | 0.000  | mm     | Secondary winding wire outer diameter with insulation for output 3                           |
| OD_SECONDARY3_BARE        |      |  | 0.000  | mm     | Secondary winding wire outer diameter without insulation for output 3                        |
| CM_SECONDARY3             |      |  | 0      | Cmils  | Bare conductor effective area in circular mils for output 3                                  |
| NSECONDARY3               |      |  | 0      |        | Number of turns for output 3                                                                 |
| VREVERSE_RECTIFIER3       |      |  | 0.00   | V      | SRFET reverse voltage (not accounting parasitic voltage ring) for output 3                   |
| SRFET3                    | Auto |  | NA     |        | SRFET selection for output 3                                                                 |
| VF_SRFET3                 |      |  | NA     | V      | SRFET on-time drain voltage for output 3                                                     |
| VBREAKDOWN_SRFET3         |      |  | NA     | V      | SRFET breakdown voltage for output 3                                                         |
| RDSON_SRFET3              |      |  | NA     | mΩ     | SRFET on-time drain resistance at 25degC and VGS=4.4V for output 3                           |
| PO_TOTAL                  |      |  | 9.90   | W      | Total power of all outputs                                                                   |
| NEGATIVE OUTPUT           | N/A  |  | N/A    |        | If negative output exists, enter the output number; e.g. If VO2 is negative output, select 2 |
| <b>TOLERANCE ANALYSIS</b> |      |  |        |        |                                                                                              |
| CORNER_VAC                |      |  | 90     | V      | Input AC RMS voltage corner to be evaluated                                                  |
| CORNER_ILIMIT             | TYP  |  | 0.55   | A      | Current limit corner to be evaluated                                                         |
| CORNER_LPRIMARY           | TYP  |  | 1185.5 | uH     | Primary inductance corner to be evaluated                                                    |
| MODE_OPERATION            |      |  | DCM    |        | Mode of operation                                                                            |
| KP                        |      |  | 1.467  |        | Measure of continuous/discontinuous mode of operation                                        |
| FSWITCHING                |      |  | 66635  | Hz     | Switching frequency at full load and valley of the rectified minimum AC input voltage        |
| DUTYCYCLE                 |      |  | 0.448  |        | Steady state duty cycle                                                                      |
| TIME_ON                   |      |  | 6.72   | us     | Primary MOSFET on-time                                                                       |
| TIME_OFF                  |      |  | 8.28   | us     | Primary MOSFET off-time                                                                      |
| IPEAK_PRIMARY             |      |  | 0.52   | A      | Primary MOSFET peak current                                                                  |
| IPEDESTAL_PRIMARY         |      |  | 0.00   | A      | Primary MOSFET current pedestal                                                              |
| IAVERAGE_PRIMARY          |      |  | 0.12   | A      | Primary MOSFET average current                                                               |
| IRIPPLE_PRIMARY           |      |  | 0.52   | A      | Primary MOSFET ripple current                                                                |
| IRMS_PRIMARY              |      |  | 0.20   | A      | Primary MOSFET RMS current                                                                   |
| CMA_PRIMARY               |      |  | 312    | Cmil/A | Primary winding wire CMA                                                                     |
| BPEAK                     |      |  | 3209   | Gauss  | Peak fux density                                                                             |
| BMAX                      |      |  | 2986   | Gauss  | Maximum flux density                                                                         |

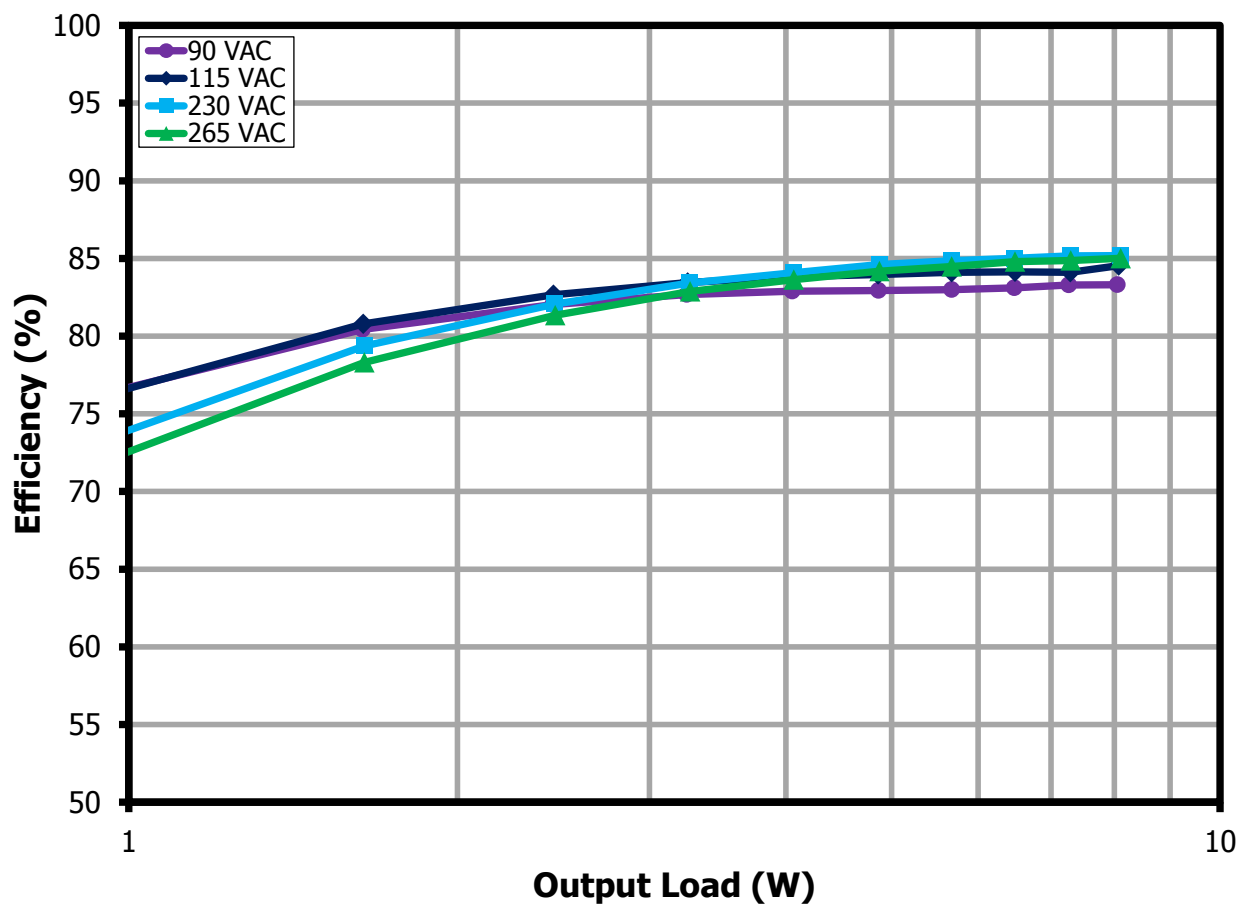
## 9 Performance Data

### 9.1 Full Load Efficiency vs. Line

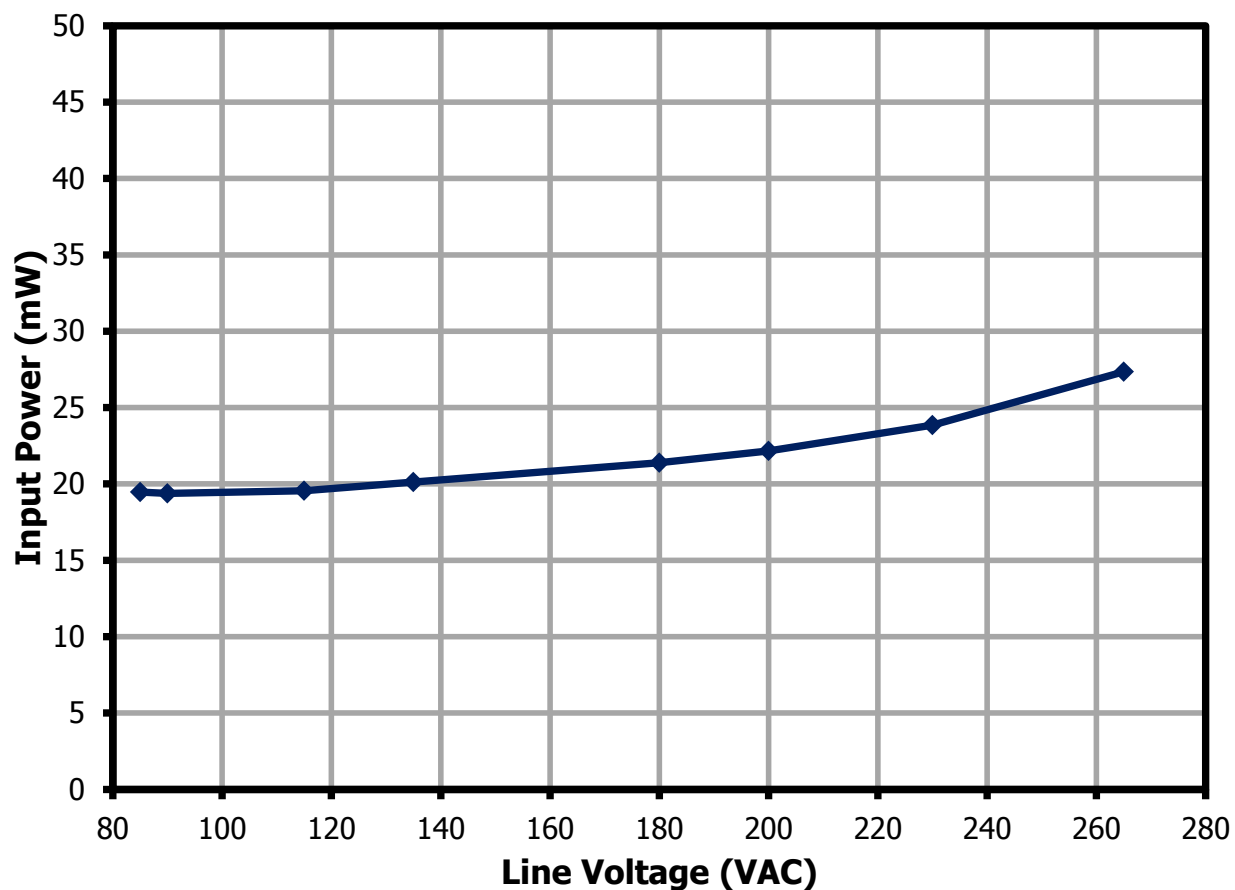


**Figure 8** – Full load Efficiency vs. Line Voltage, Room Temperature.

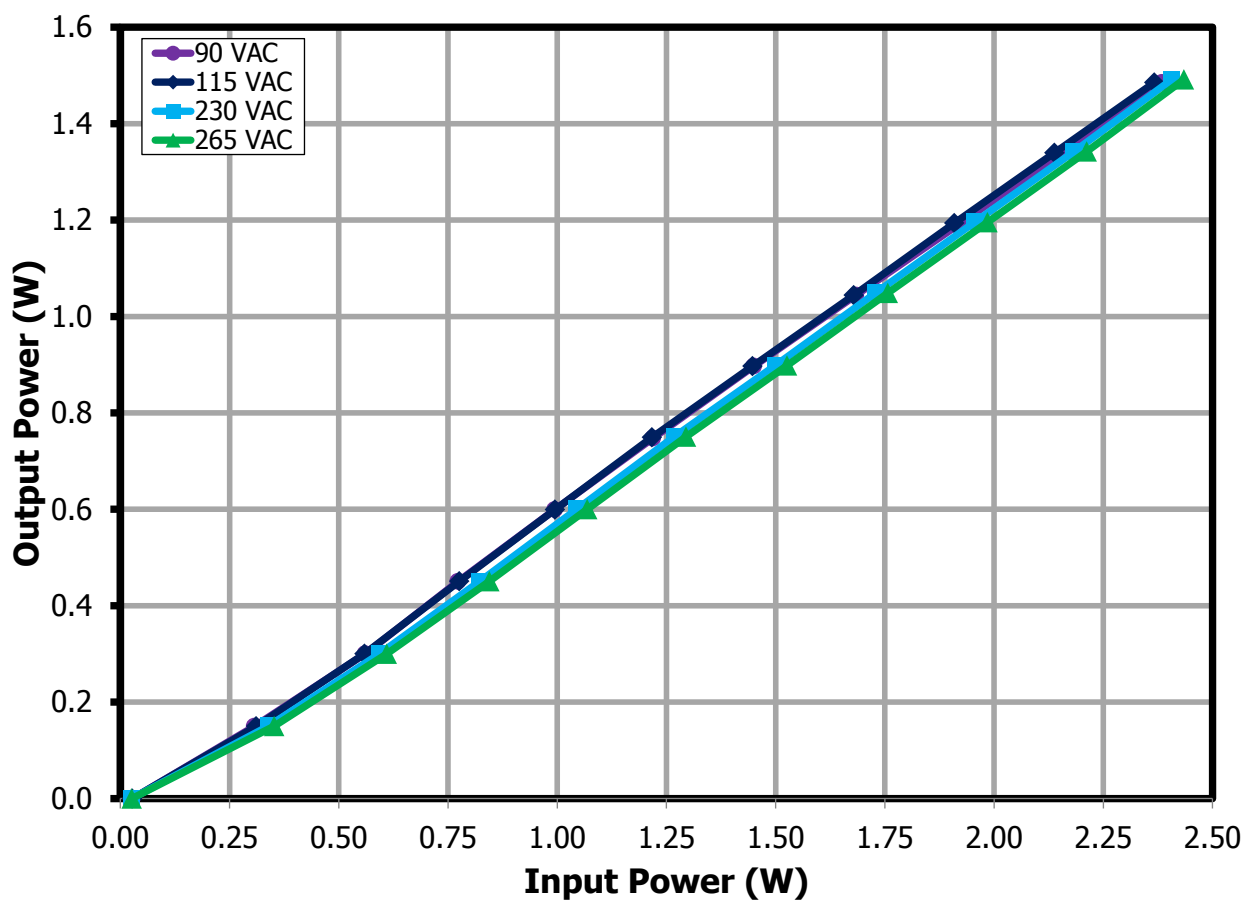
**9.2 Efficiency vs. Load (0 A – 0.7 A on 12 V, Full Load on 5 V)****Figure 9** – Efficiency vs. Load, Room Ambient.

**9.3 Efficiency vs. Load (0 A – 0.7 A on 12 V, No-Load on 5 V)****Figure 10** – Efficiency vs. Load (Log Scale to Demonstrate Light Load Performance).

#### 9.4 No-Load Input Power

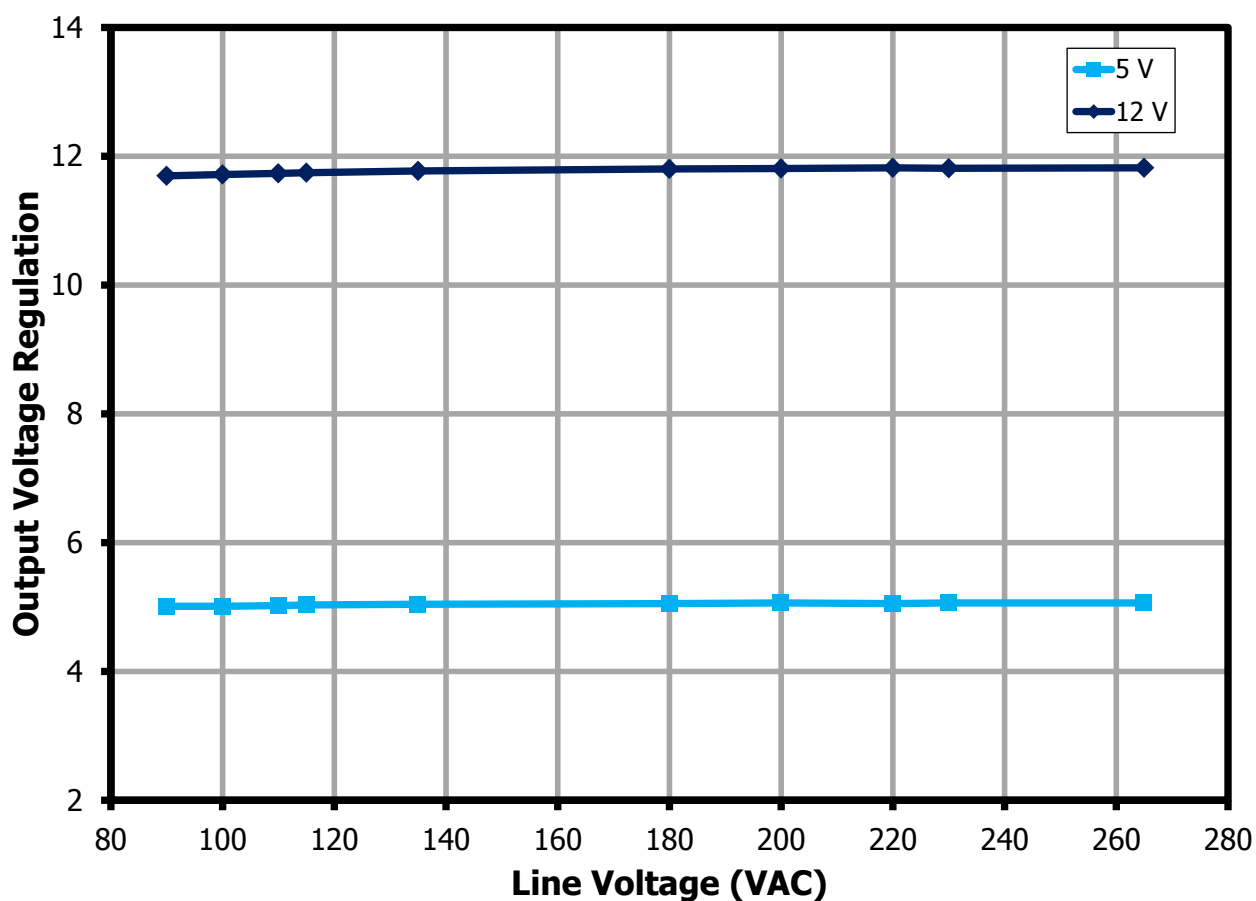


**Figure 11** – No-Load Input Power vs. Input Line Voltage, Room Temperature.

**9.5 5 V Output Power with Low Input Power (No-Load on 12 V)****Figure 12** – 5 V Output Power vs. Input Power (12 V No-Load).

## 9.6 Line and Load Regulation

### 9.6.1 Line Regulation (Full load)



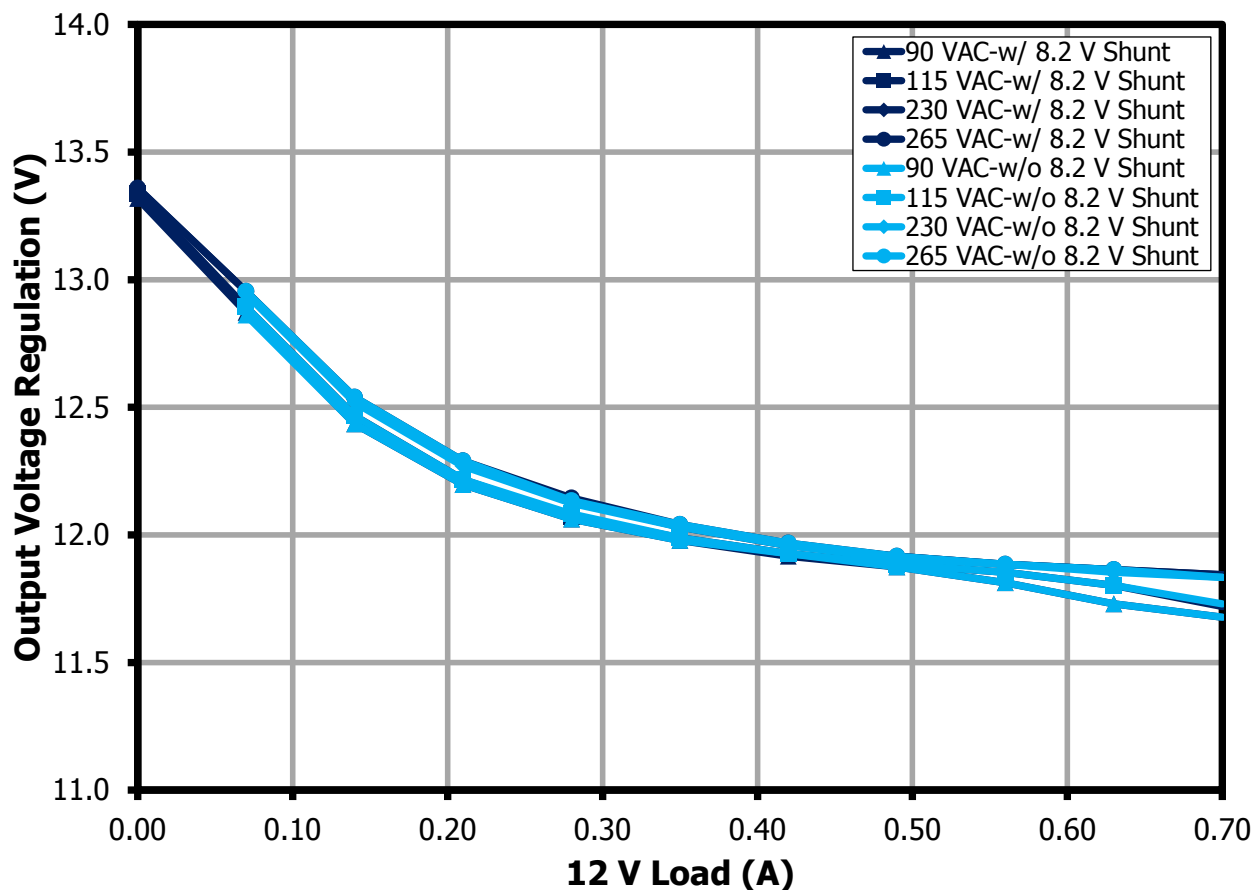
**Figure 13** – Output Voltage vs. Input Line Voltage, Room Temperature.

|      | 5 V    | 12 V    |
|------|--------|---------|
| Min. | 5.01 V | 11.69 V |
| Max. | 5.06 V | 11.81 V |

## 9.6.2 Cross Load Regulation

### 9.6.2.1 12 V Load Change with Full Load on 5 V

Zener diode (8.2 V) across 12 V output to 5 V output (minimum load = 0 A) vs. removing the shunt with 10% minimum to either load.



**Figure 14** – 12 V Output Voltage vs. Output Load, Room Temperature.

|            | With Shunt |         | Without Shunt |          |
|------------|------------|---------|---------------|----------|
|            | 5 V        | 12 V    | 5 V           | 12 V     |
| <b>Min</b> | 4.95 V     | 11.68 V | *4.97 V       | *11.68 V |
| <b>Max</b> | 5.07 V     | 13.36 V | *5.06 V       | *12.95 V |

**\*Note:** Minimum load current without shunt to either load is 10% of the nominal load (30 mA in 5 V and 70 mA to 12 V).

## 9.6.2.2 12 V Load Change with No Load on 5 V

Zener diode (8.2 V) across 12 V output to 5 V output (minimum load = 0 A) vs. removing the shunt with 10% minimum to either load.

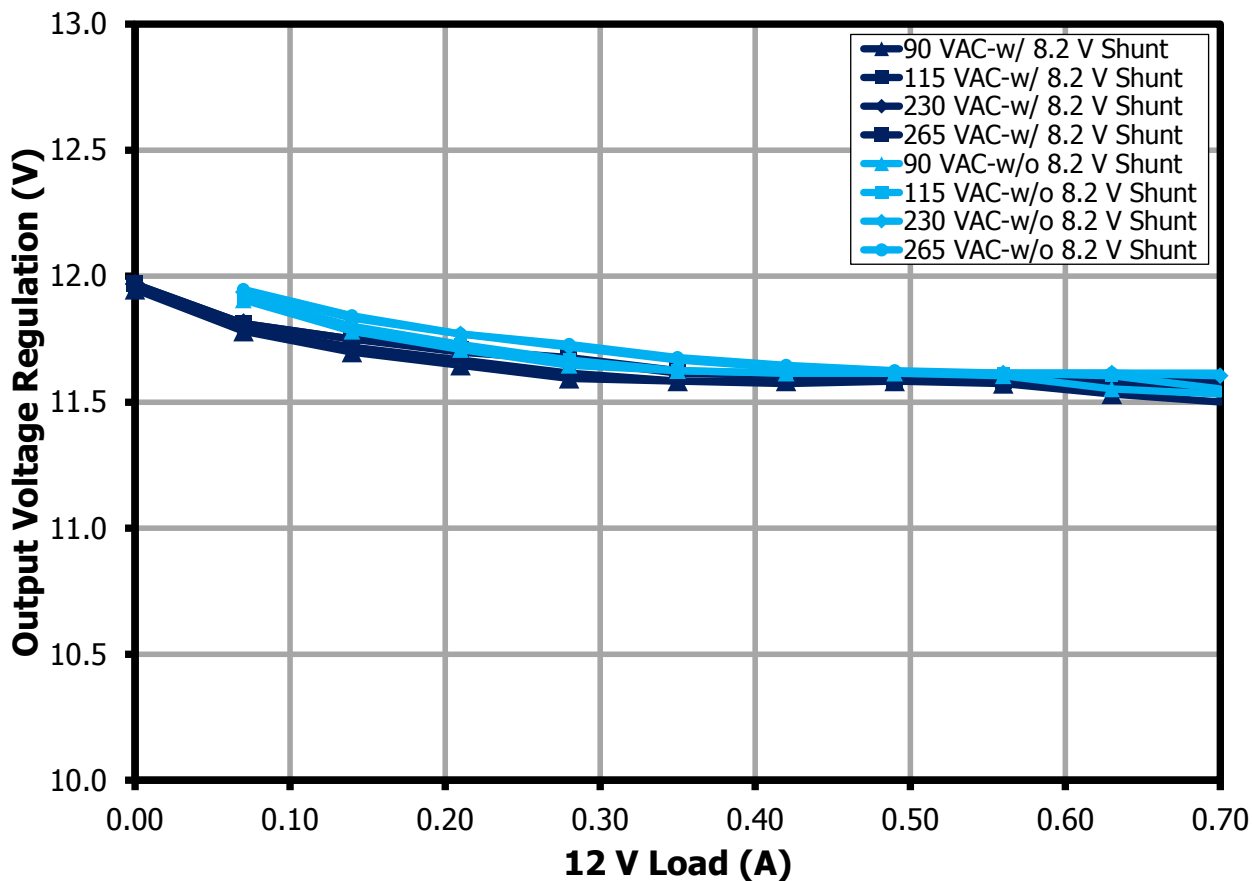


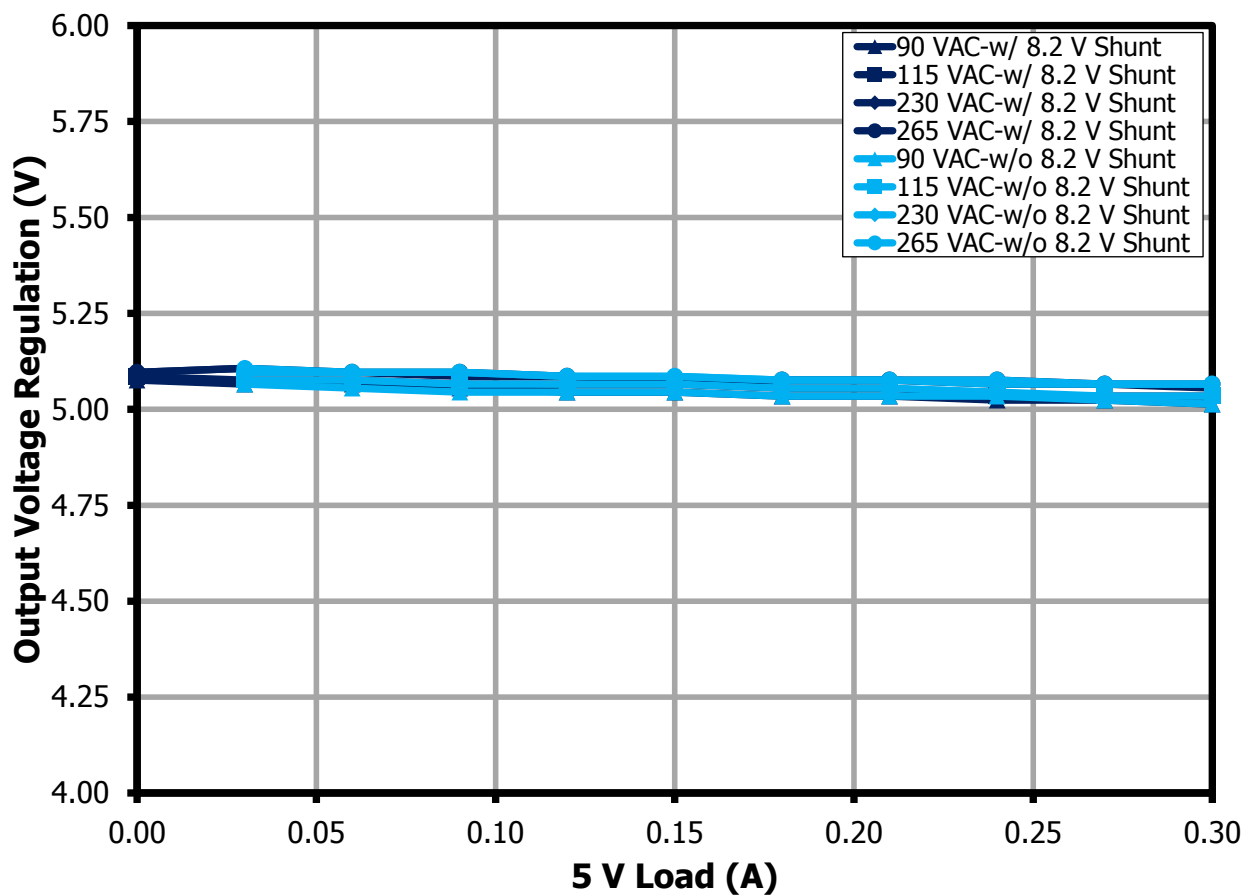
Figure 15 – 12 V Output Voltage vs. Output Load, Room Temperature.

|     | With Shunt |         | Without Shunt |          |
|-----|------------|---------|---------------|----------|
|     | 5V         | 12V     | 5 V           | 12 V     |
| Min | 5.07 V     | 11.50 V | *5.06 V       | *11.53 V |
| Max | 5.17 V     | 11.97 V | *5.15 V       | *11.95 V |

**\*Note:** Minimum load current without shunt to either load is 10% of the nominal load (30 mA in 5 V and 70 mA to 12 V).

## 9.6.2.3 5 V Load Change with Full Load on 12 V

Zener diode (8.2 V) across 12 V output to 5 V output (minimum load = 0 A) vs. removing the shunt with 10% minimum to either load.



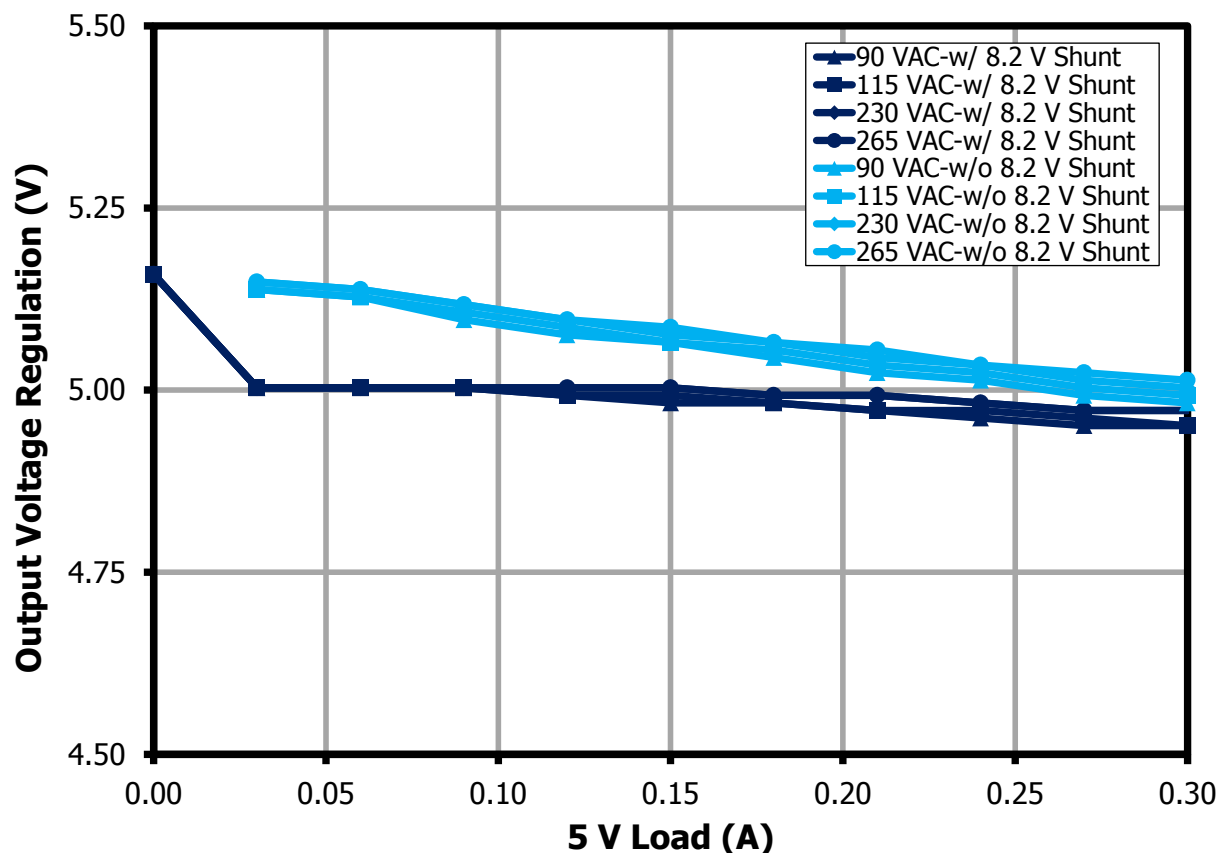
**Figure 16** – 5 V Output Voltage vs. Output Load, Room Temperature.

|            | With Shunt |         | Without Shunt |          |
|------------|------------|---------|---------------|----------|
|            | 5 V        | 12 V    | 5 V           | 12 V     |
| <b>Min</b> | 5.01 V     | 11.50 V | *5.01 V       | *11.51 V |
| <b>Max</b> | 5.11 V     | 11.82 V | *5.10 V       | *11.81 V |

**\*Note:** Minimum Load current without shunt to either load is 10% of the nominal load (30 mA in 5 V and 70 mA to 12 V).

## 9.6.2.4 5 V Load Change with No Load on 12 V

Zener diode (8.2 V) across 12 V output to 5 V output (minimum load = 0 A) vs. removing the shunt with 10% minimum to either load.



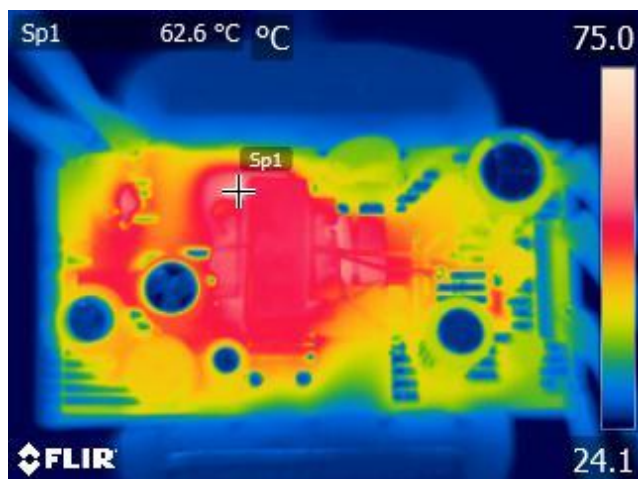
**Figure 17** – 5 V Output Voltage vs. Output Load, Room Temperature.

|            | With Shunt |         | Without Shunt |          |
|------------|------------|---------|---------------|----------|
|            | 5 V        | 12 V    | 5 V           | 12 V     |
| <b>Min</b> | 4.95 V     | 11.86 V | *4.98 V       | *11.89 V |
| <b>Max</b> | 5.00 V     | 13.36 V | *5.15 V       | *12.95 V |

**\*Note:** Minimum Load current without shunt to either load is 10% of the nominal load (30 mA in 5 V and 70 mA to 12 V).

## 10 Thermal Performance

### 10.1 90 VAC



**Figure 18** – Transformer Side. 90 VAC, Full Load.

|                    | Reference | °C   |
|--------------------|-----------|------|
| <b>Ambient</b>     |           | 24.9 |
| <b>Transformer</b> | T1        | 62.6 |
| <b>Thermistor</b>  | RT1       | 59.4 |

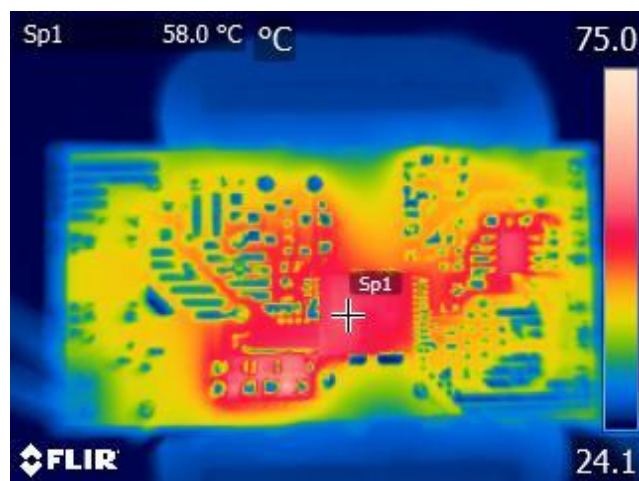


**Figure 19** – InnoSwitch3-EP Side. 90 VAC, Full Load.

|                       | Reference | °C   |
|-----------------------|-----------|------|
| <b>Ambient</b>        |           | 25.2 |
| <b>InnoSwitch3-EP</b> | U1        | 65.5 |
| <b>SR FET Q1</b>      | Q1        | 44.7 |
| <b>SR FET Q2</b>      | Q2        | 53.8 |
| <b>Clamp Resistor</b> | R22       | 74.6 |
| <b>Snubber Diode</b>  | D1        | 69.3 |
| <b>Bridge Diode</b>   | BR1       | 55.6 |

**10.2 265 VAC****Figure 20** – Transformer Side. 265 VAC, Full Load.

|                    | Reference | °C   |
|--------------------|-----------|------|
| <b>Ambient</b>     |           | 24.8 |
| <b>Transformer</b> | T1        | 57.3 |
| <b>Thermistor</b>  | RT1       | 42.5 |

**Figure 21** – InnoSwitch3-EP Side. 265 VAC, Full Load.

|                       | Reference | °C   |
|-----------------------|-----------|------|
| <b>Ambient</b>        |           | 25.3 |
| <b>InnoSwitch3-EP</b> | U1        | 58.0 |
| <b>SR FET Q1</b>      | Q1        | 46.5 |
| <b>SR FET Q2</b>      | Q2        | 56.7 |
| <b>Clamp Resistor</b> | R22       | 65.8 |
| <b>Snubber Diode</b>  | D1        | 60.4 |
| <b>Bridge Diode</b>   | BR1       | 44.3 |

## 11 Over Temperature Protection (OTP)

### 11.1 90 VAC

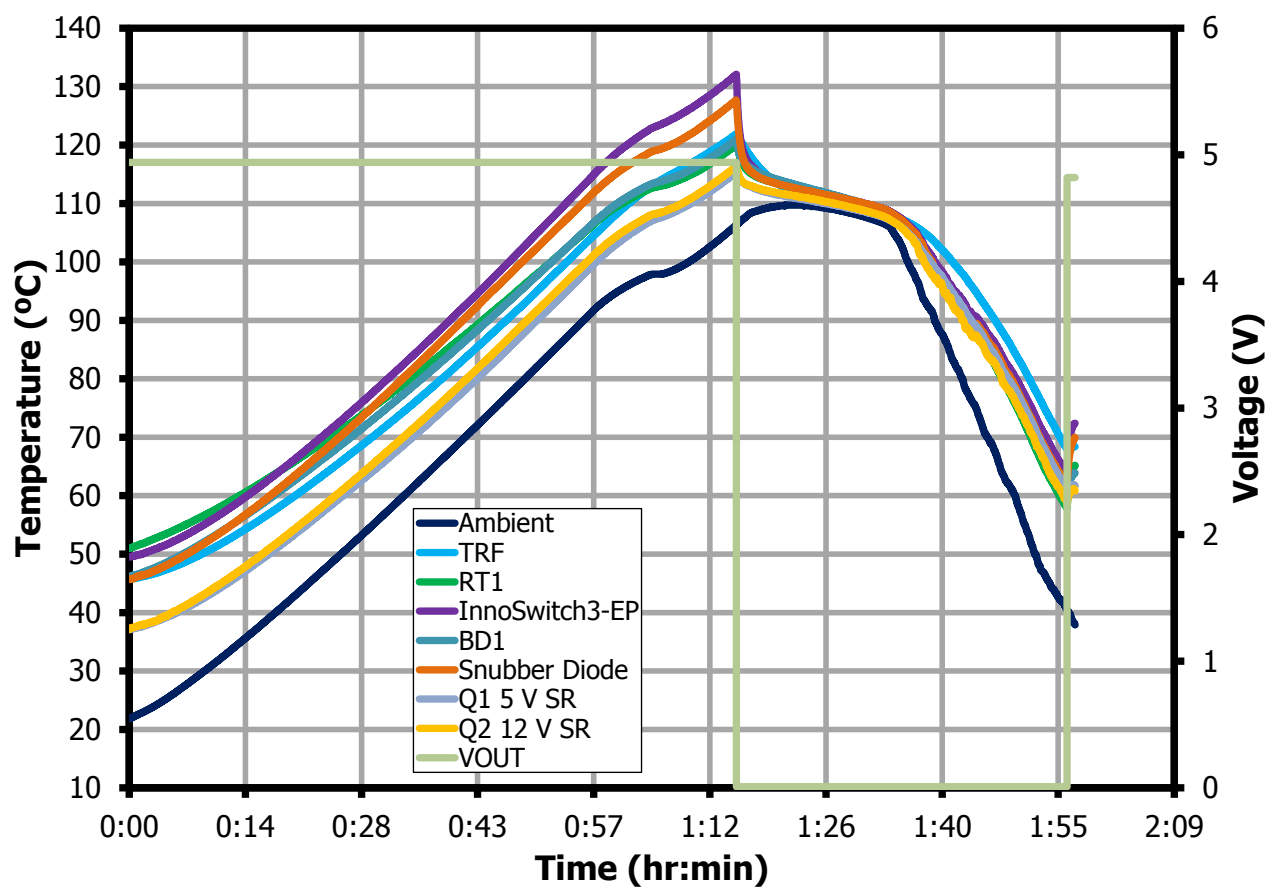
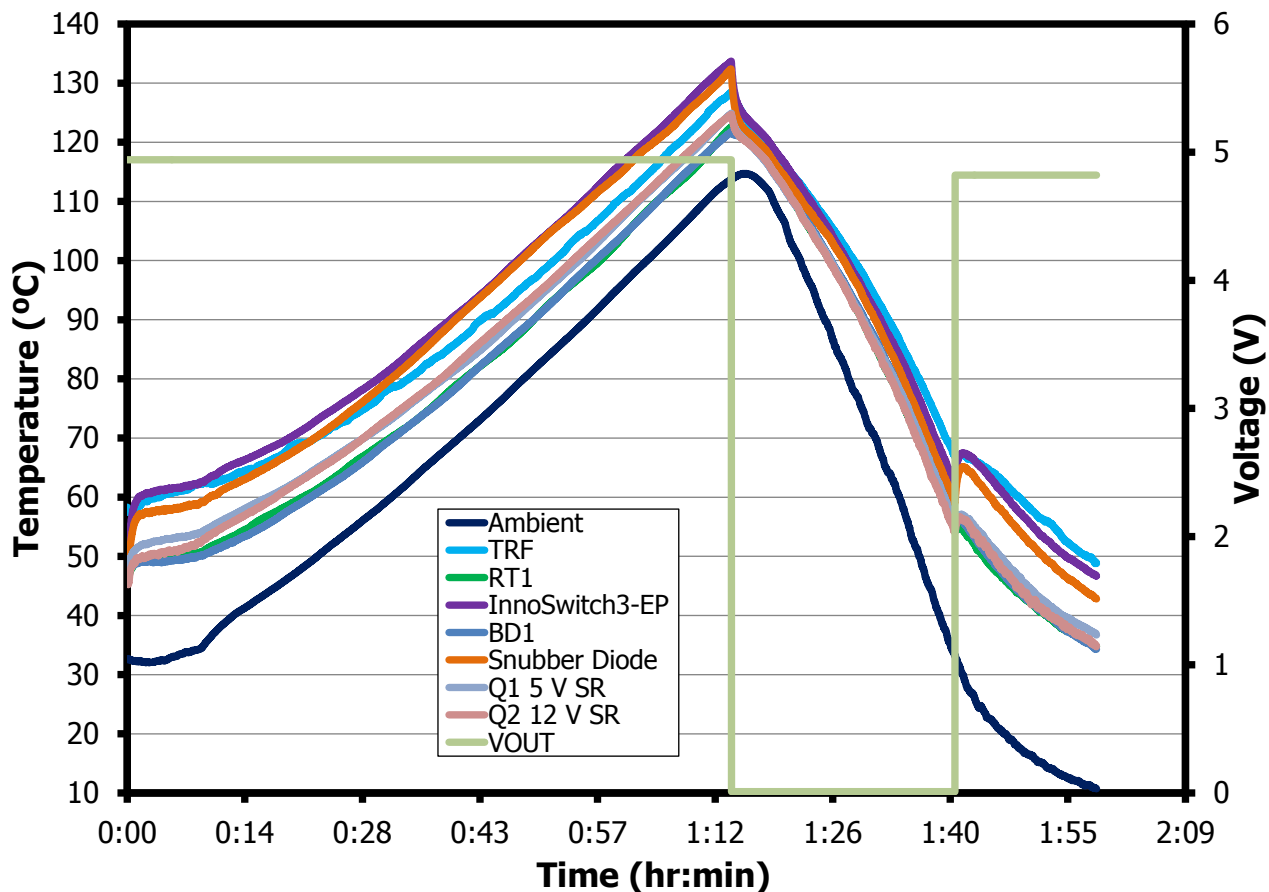


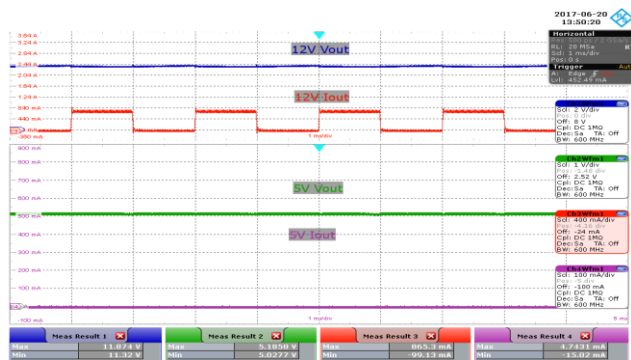
Figure 22 – Temperature vs. Time, 90 VAC.

**11.2 265 VAC****Figure 23** – Temperature vs. Time, 265 VAC.

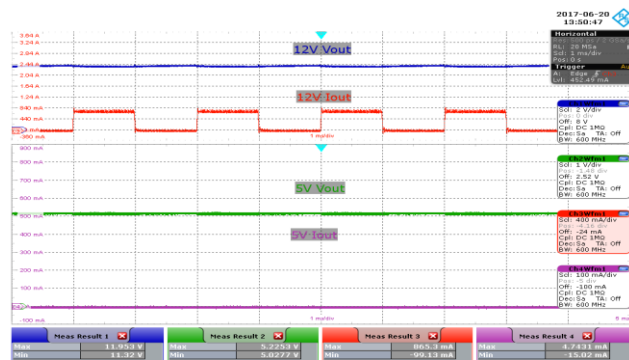
## 12 Waveforms

### 12.1 Load Transient Response

#### 12.1.1 12 V Load Transient – No-Load at 5 V Output

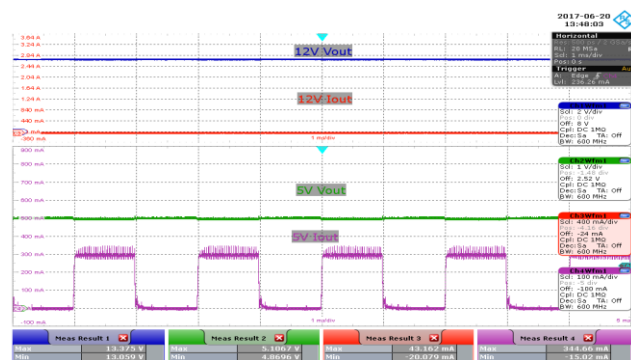


**Figure 24** – 0 A – 0.7 A, 12 V Load Step Transient Response, 90 VAC.  
 $5 V_{MIN}$ : 5.02 V.;  $5 V_{MAX}$ : 5.18 V.  
 $12 V_{MIN}$ : 11.32 V.  $12 V_{MAX}$ : 11.87 V.  
 Upper: 12 V<sub>OUT</sub>, 2 V / div.  
 Upper Middle: 12 V I<sub>OUT</sub>. 400 mA / div.  
 Upper Middle: 5 V<sub>OUT</sub>, 1 V / div.  
 Lower: 5 V I<sub>OUT</sub>, 100 mA / div., 1 ms / div.

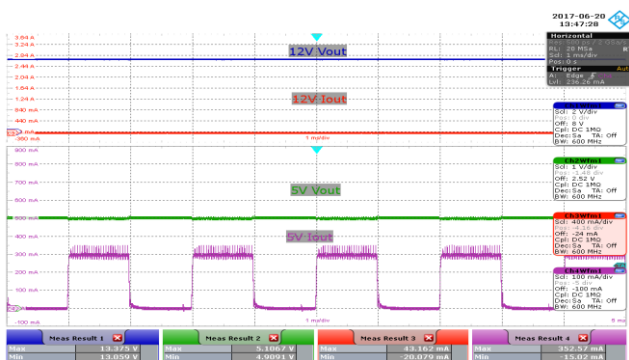


**Figure 25** – 0 A – 0.7 A, 12 V Load Step Transient Response. 265 VAC.  
 $5 V_{MIN}$ : 5.02 V.;  $5 V_{MAX}$ : 5.22 V.  
 $12 V_{MIN}$ : 11.32 V.;  $12 V_{MAX}$ : 11.95 V.  
 Upper: 12 V<sub>OUT</sub>, 2 V / div.  
 Upper Middle: 12 V I<sub>OUT</sub>. 400 mA / div.  
 Upper Middle: 5 V<sub>OUT</sub>, 1 V / div.  
 Lower: 5 V I<sub>OUT</sub>, 100 mA / div., 1 ms / div.

#### 12.1.2 5 V Load Transient – No-Load at 12 V Output



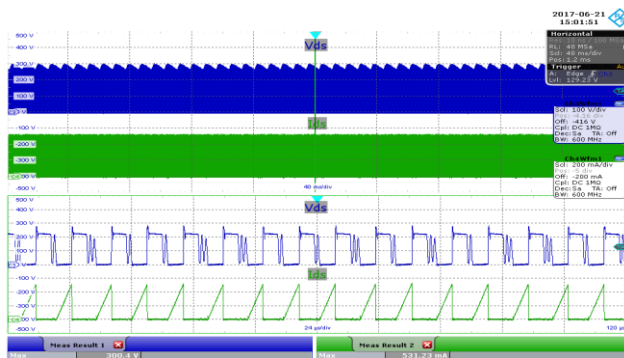
**Figure 26** – 0 A – 0.3 A, 5 V Load Step Transient Response, 90 VAC.  
 $5 V_{MIN}$ : 4.86 V.;  $5 V_{MAX}$ : 5.10 V.  
 $12 V_{MIN}$ : 13.05 V.  $12 V_{MAX}$ : 13.37 V.  
 Upper: 12 V<sub>OUT</sub>, 2 V / div.  
 Upper Middle: 12 V I<sub>OUT</sub>. 400 mA / div.  
 Upper Middle: 5 V<sub>OUT</sub>, 1 V / div.  
 Lower: 5 V I<sub>OUT</sub>, 100 mA / div., 1 ms / div.



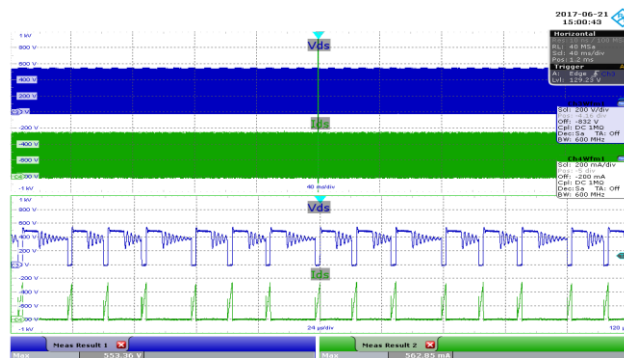
**Figure 27** – 0 A – 0.3 A, 5 V Load Step Transient Response. 265 VAC.  
 $5 V_{MIN}$ : 4.90 V.;  $5 V_{MAX}$ : 5.10 V.  
 $12 V_{MIN}$ : 13.05 V.  $12 V_{MAX}$ : 13.37 V.  
 Upper: 12 V<sub>OUT</sub>, 2 V / div.  
 Upper Middle: 12 V I<sub>OUT</sub>. 400 mA / div.  
 Upper Middle: 5 V<sub>OUT</sub>, 1 V / div.  
 Lower: 5 V I<sub>OUT</sub>, 100 mA / div., 1 ms / div.

## 12.2 Switching Waveforms

### 12.2.1 InnoSwitch3-EP Waveforms

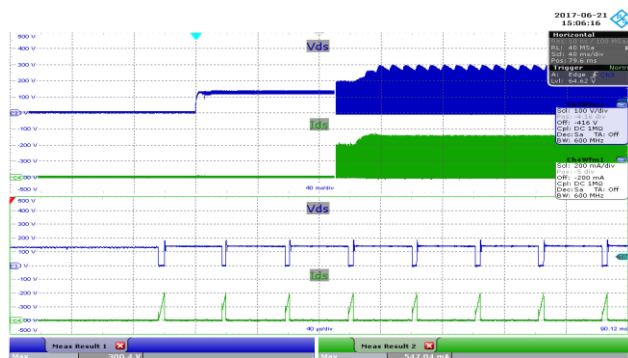


**Figure 28** – Drain Voltage and Current Waveforms.  
90 VAC Input, Full Load.  
Upper:  $V_{DRAIN}$ , 100 V, 40 ms, 24  $\mu$ s / div.  
Lower:  $I_{DRAIN}$ , 200 mA / div.

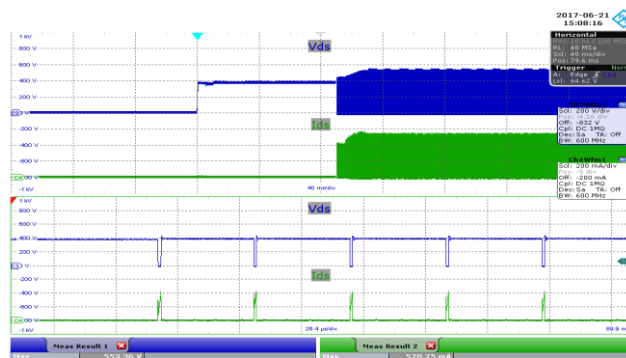


**Figure 29** – Drain Voltage and Current Waveforms.  
265 VAC Input, Full Load, (553  $V_{MAX}$ ).  
Upper:  $V_{DRAIN}$ , 200 V, 40 ms, 24  $\mu$ s / div.  
Lower:  $I_{DRAIN}$ , 200 mA / div.

### 12.2.2 InnoSwitch3-EP Drain Voltage and Current Waveforms During Start-up

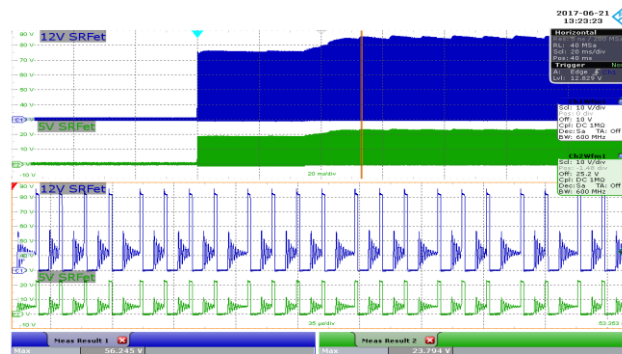
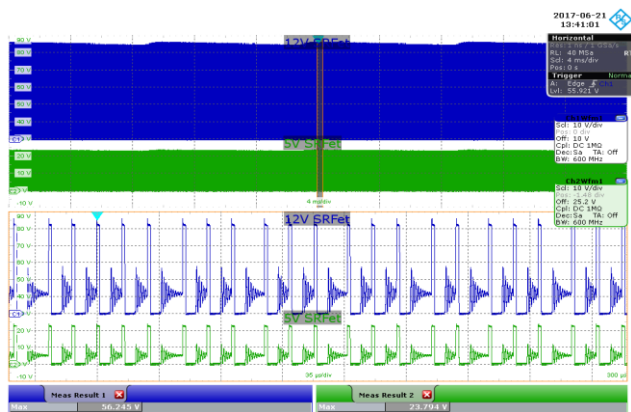


**Figure 30** – Drain Voltage and Current Waveforms.  
90 VAC Input, Full Load.  
Upper:  $V_{DRAIN}$ , 100 V, 40 ms, 40  $\mu$ s / div.  
Lower:  $I_{DRAIN}$ , 200 mA / div.



**Figure 31** – Drain Voltage and Current Waveforms.  
265 VAC Input, Full Load, (553  $V_{MAX}$ ).  
Upper:  $V_{DRAIN}$ , 200 V, 40 ms, 26.4  $\mu$ s / div.  
Lower:  $I_{DRAIN}$ , 200 mA / div.

## 12.2.3 SR FET Waveforms

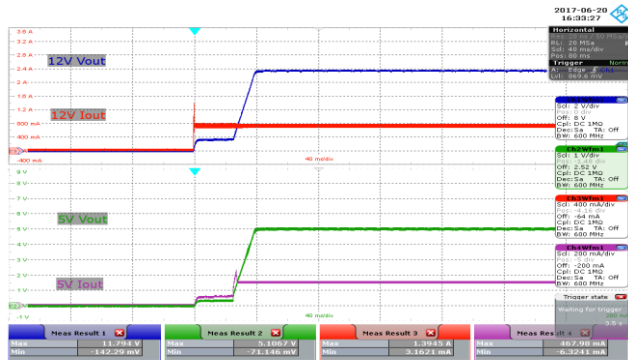


**Figure 32** – SR FET Voltage Waveforms.  
 265 VAC Input, Full Load.  
 (57 V<sub>MAX</sub> for 12 V, 24 V<sub>MAX</sub> for 5 V.)  
 Upper: 12 V, 10 V / div.  
 Lower: 5 V, 10 V / , 4 ms, 35  $\mu$ s / div.

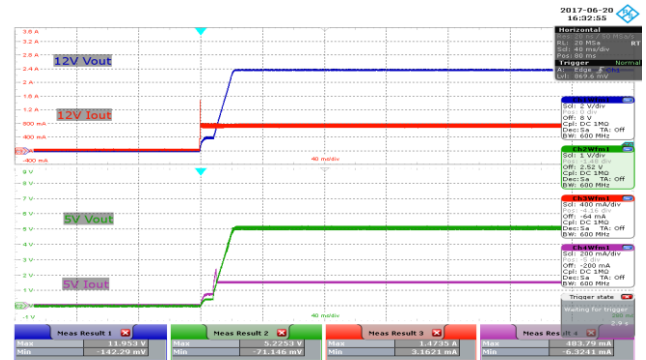
**Figure 33** – SR FET Voltage Waveforms During Start-Up.  
 265 VAC Input, Full Load.  
 (57 V<sub>MAX</sub> for 12 V, 24 V<sub>MAX</sub> for 5 V.)  
 Upper: 12 V, 10 V / div.  
 Lower: 5 V, 10 V / , 10 ms, 35  $\mu$ s / div.

## 12.2.4 Output Voltage and Current Waveforms During Start-Up

## 12.2.4.1 Full load

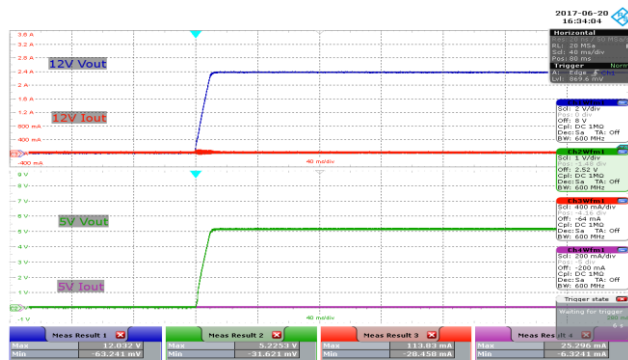


**Figure 34** – Output Voltage and Current Waveforms.  
90 VAC Input.  
Upper: 12 V, 2 V / div.  
Lower: 5 V, 1 V, 10 ms / div.

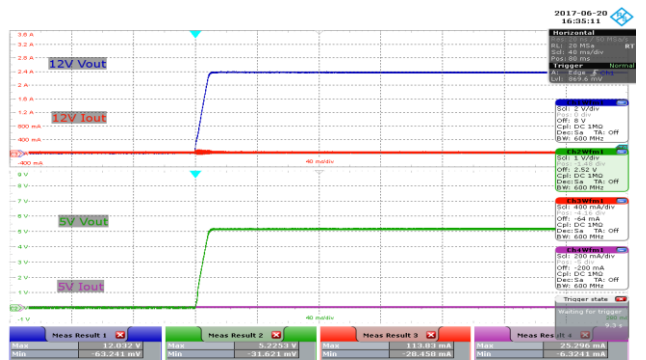


**Figure 35** – Output Voltage and Current Waveforms.  
265 VAC Input.  
Upper: 12 V, 2 V / div.  
Lower: 5 V, 1 V, 10 ms / div.

## 12.2.4.2 No-Load

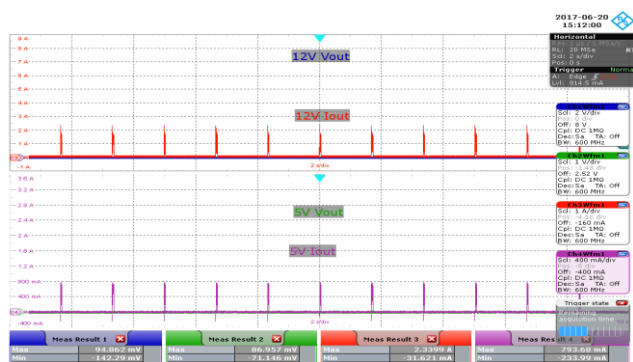


**Figure 36** – Output Voltage and Current Waveforms.  
90 VAC Input.  
Upper: 12 V, 2 V / div.  
Lower: 5 V, 1 V, 10 ms / div.



**Figure 37** – Output Voltage and Current Waveforms.  
265 VAC Input.  
Upper: 12 V, 2 V / div.  
Lower: 5 V, 1 V, 10 ms / div.

## 12.2.5 Output Voltage and Current Waveform with Shorted Output (12 V)



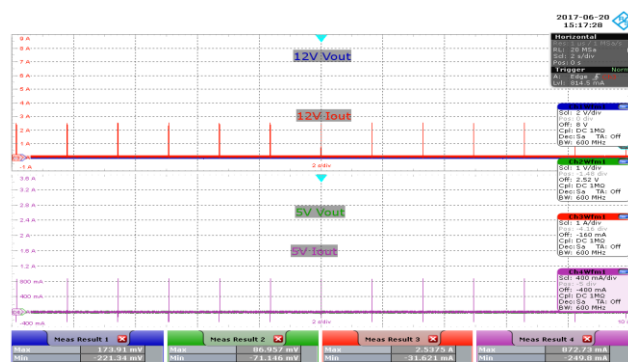
**Figure 38** – Output Voltage and Current Waveforms.  
90 VAC Input.

Upper: 12 V<sub>OUT</sub>, 2 V / div.

Upper: 12 V I<sub>OUT</sub>, 1 A / div.

Lower: 5 V<sub>OUT</sub>, 1 V / div.

Lower: 5 V I<sub>OUT</sub>, 400 mA / div., 2 s / div.



**Figure 39** – Output Voltage and Current Waveforms.  
265 VAC Input.

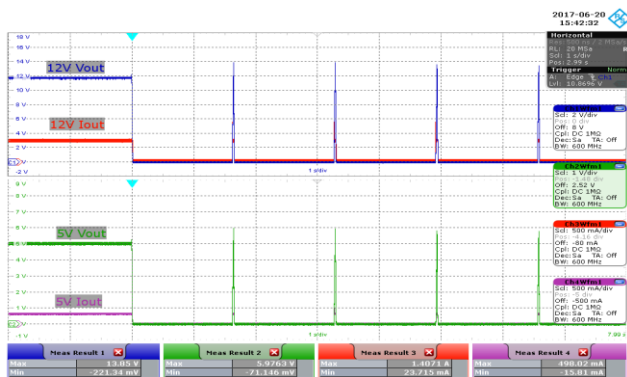
Upper: 12 V<sub>OUT</sub>, 2 V / div.

Upper: 12 V I<sub>OUT</sub>, 1 A / div.

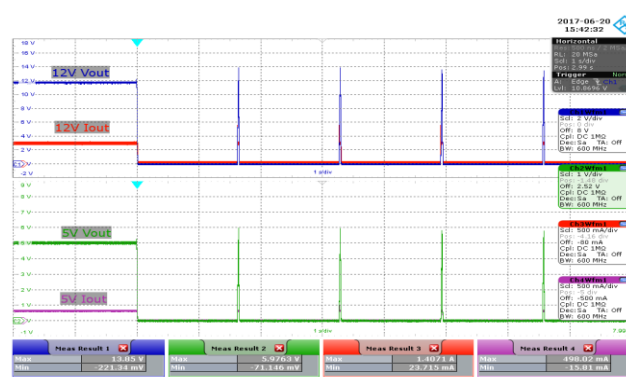
Lower: 5 V<sub>OUT</sub>, 1 V / div.

Lower: 5 V I<sub>OUT</sub>, 400 mA / div., 2 s / div.

### 12.2.6 Overvoltage Protection (OVP while power supply was in operation.)



**Figure 40** – Output Voltage Waveform.  
90 VAC Input.  
Upper: 12 V<sub>OUT</sub>, 2 V / div.  
Upper: 12 V I<sub>OUT</sub>, 500 mA / div.  
Lower: 5 V<sub>OUT</sub>, 1 V / div.  
Lower: 5 V I<sub>OUT</sub>, 500 mA / div., 1 s / div.



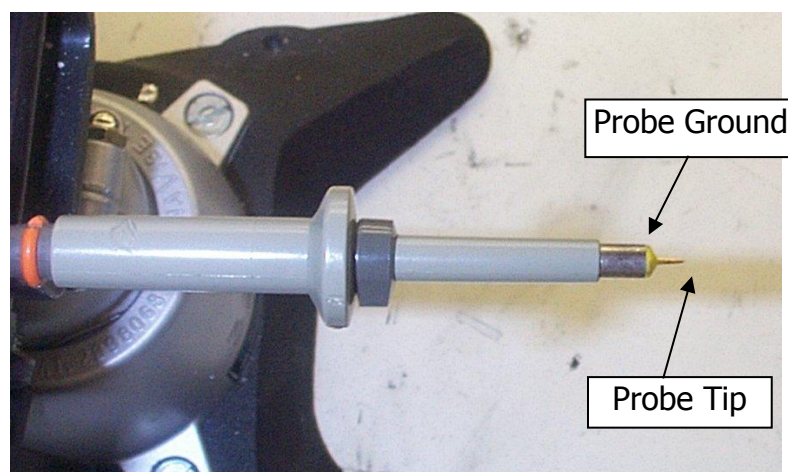
**Figure 41** – Output Voltage Waveform.  
265 VAC Input.  
Upper: 12 V<sub>OUT</sub>, 2 V / div.  
Upper: 12 V I<sub>OUT</sub>, 1 A / div.  
Lower: 5 V<sub>OUT</sub>, 1 V / div.  
Lower: 5 V I<sub>OUT</sub>, 500 mA / div., 1 s / div.

## 12.3 Output Ripple Measurements

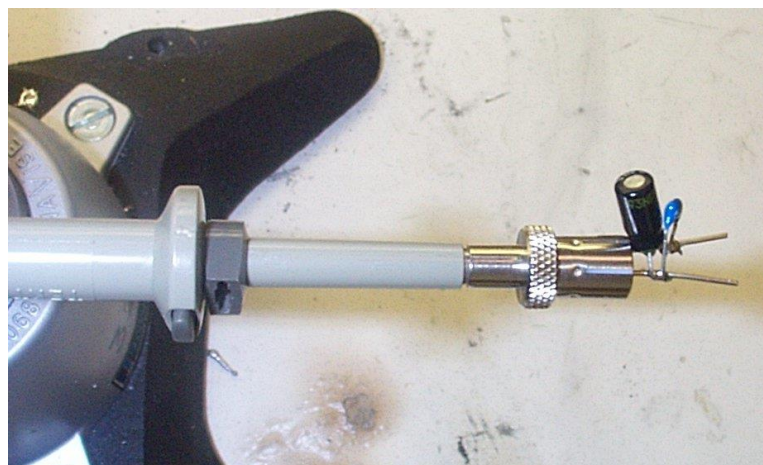
### 12.3.1 Ripple Measurement Technique

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).



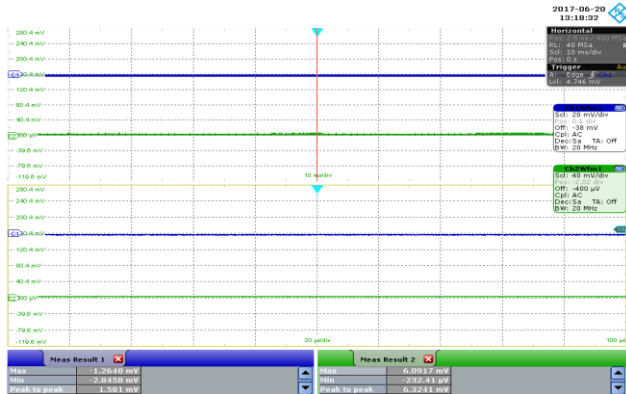
**Figure 42** – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)



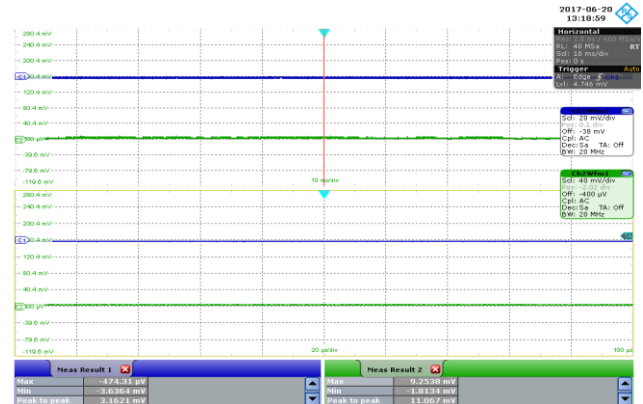
**Figure 43** – Oscilloscope Probe with Probe Master ([www.probemaster.com](http://www.probemaster.com)) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

## 12.3.2 Ripple Voltage Waveforms

### 12.3.2.1 0% Load

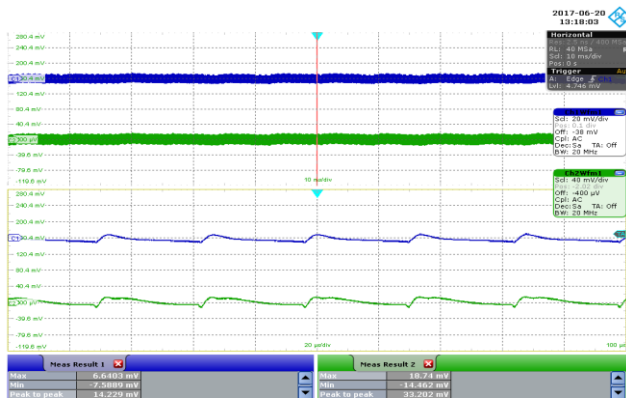


**Figure 44** – Output Voltage ripple Waveforms.  
90 VAC Input.  
5  $V_{PK}$ : 2 mV, 12  $V_{PK}$ : 7 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

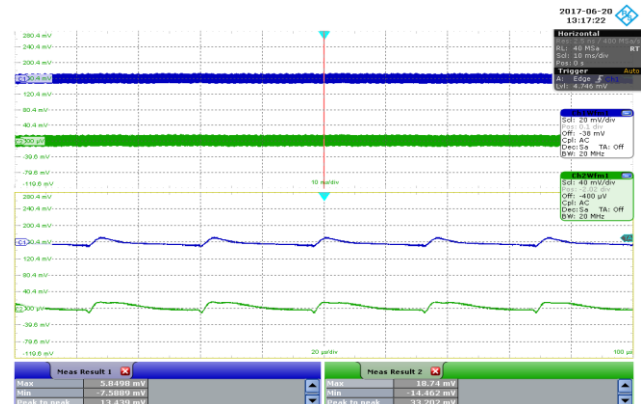


**Figure 45** – Output Ripple Voltage Waveforms.  
265 VAC Input.  
5  $V_{PK}$ : 4 mV, 12  $V_{PK}$ : 12 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

### 12.3.2.2 25% Load

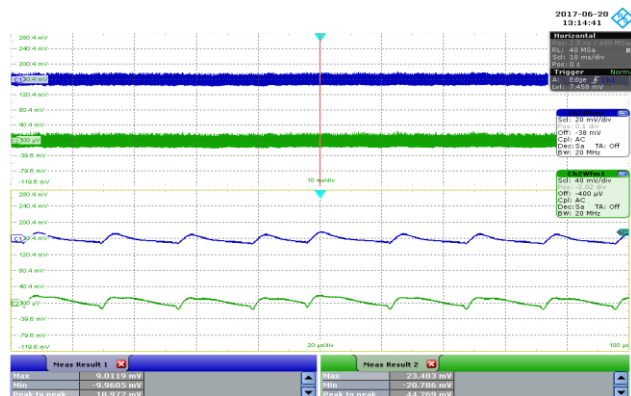


**Figure 46** – Output Voltage ripple Waveforms.  
90 VAC Input.  
5  $V_{PK}$ : 15 mV, 12  $V_{PK}$ : 34 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

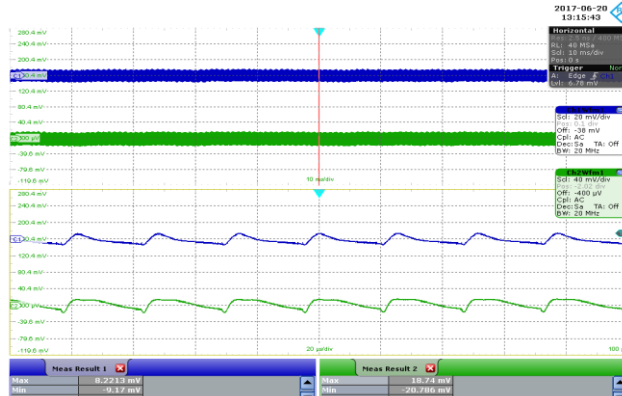


**Figure 47** – Output Ripple Voltage Waveforms.  
265 VAC Input.  
5  $V_{PK}$ : 14 mV, 12  $V_{PK}$ : 34 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

## 12.3.2.3 50% Load

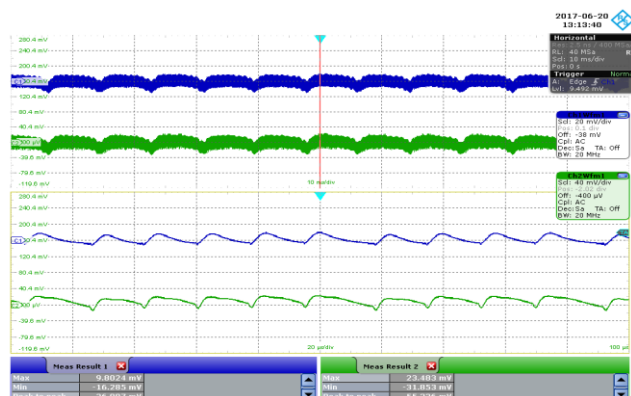


**Figure 48** – Output Voltage ripple Waveforms.  
90 VAC Input.  
5  $V_{PK}$ : 19 mV, 12  $V_{PK}$ : 45 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

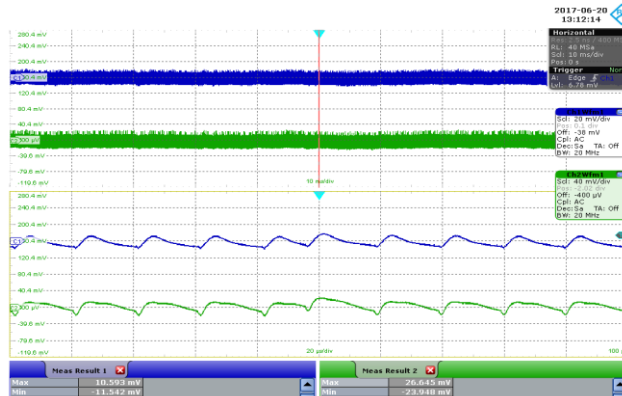


**Figure 49** – Output Ripple Voltage Waveforms.  
265 VAC Input.  
5  $V_{PK}$ : 18 mV, 12  $V_{PK}$ : 40 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

## 12.3.2.4 75% Load

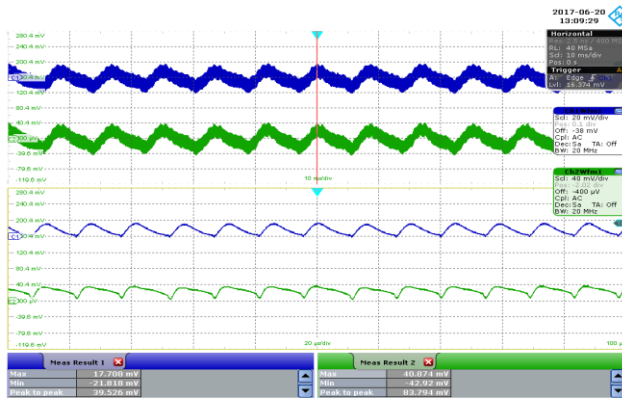


**Figure 50** – Output Voltage ripple Waveforms.  
90 VAC Input.  
5  $V_{PK}$ : 27 mV, 12  $V_{PK}$ : 56 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

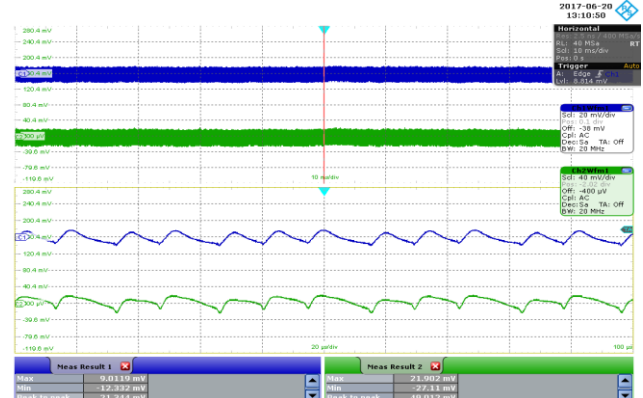


**Figure 51** – Output Ripple Voltage Waveforms.  
265 VAC Input.  
5  $V_{PK}$ : 23 mV, 12  $V_{PK}$ : 51 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

## 12.3.2.5 100% Load

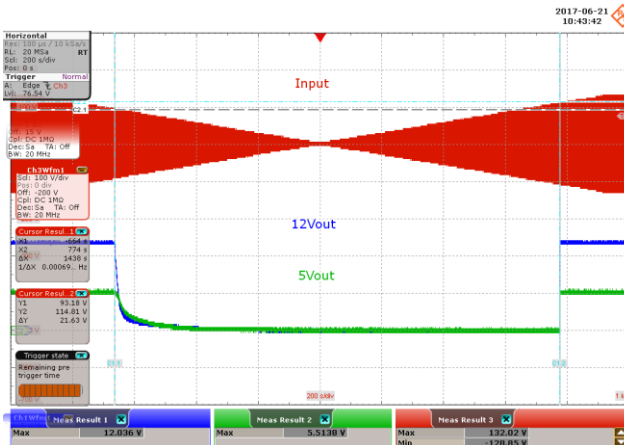


**Figure 52** – Output Voltage ripple Waveforms.  
90 VAC Input.  
5 V<sub>PK</sub>: 40 mV, 12 V<sub>PK</sub>: 84 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

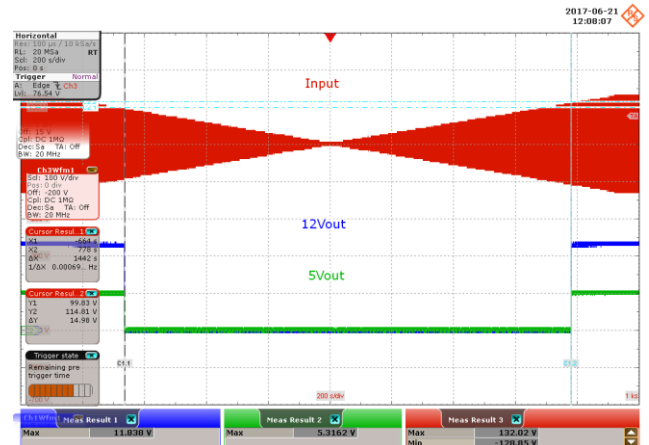


**Figure 53** – Output Voltage ripple Waveforms.  
265 VAC Input.  
5 V<sub>PK</sub>: 22 mV, 12 V<sub>PK</sub>: 50 mV.  
Upper: 5 V, 20 mV / div.  
Lower: 12 V, 40 mV / , 10 ms, 20  $\mu$ s / div.

## 12.4 Brown-in and Brown out



**Figure 54** – Line Undervoltage.  
AC Input, No-Load.  
 $V_{UV+}$ : 114 V,  $V_{UV-}$ : 93 V  
Upper: Input, 100 V / div.  
Middle: 12 V, 5 V / div.  
Lower: 5 V, 5 V / , 200 s / div.



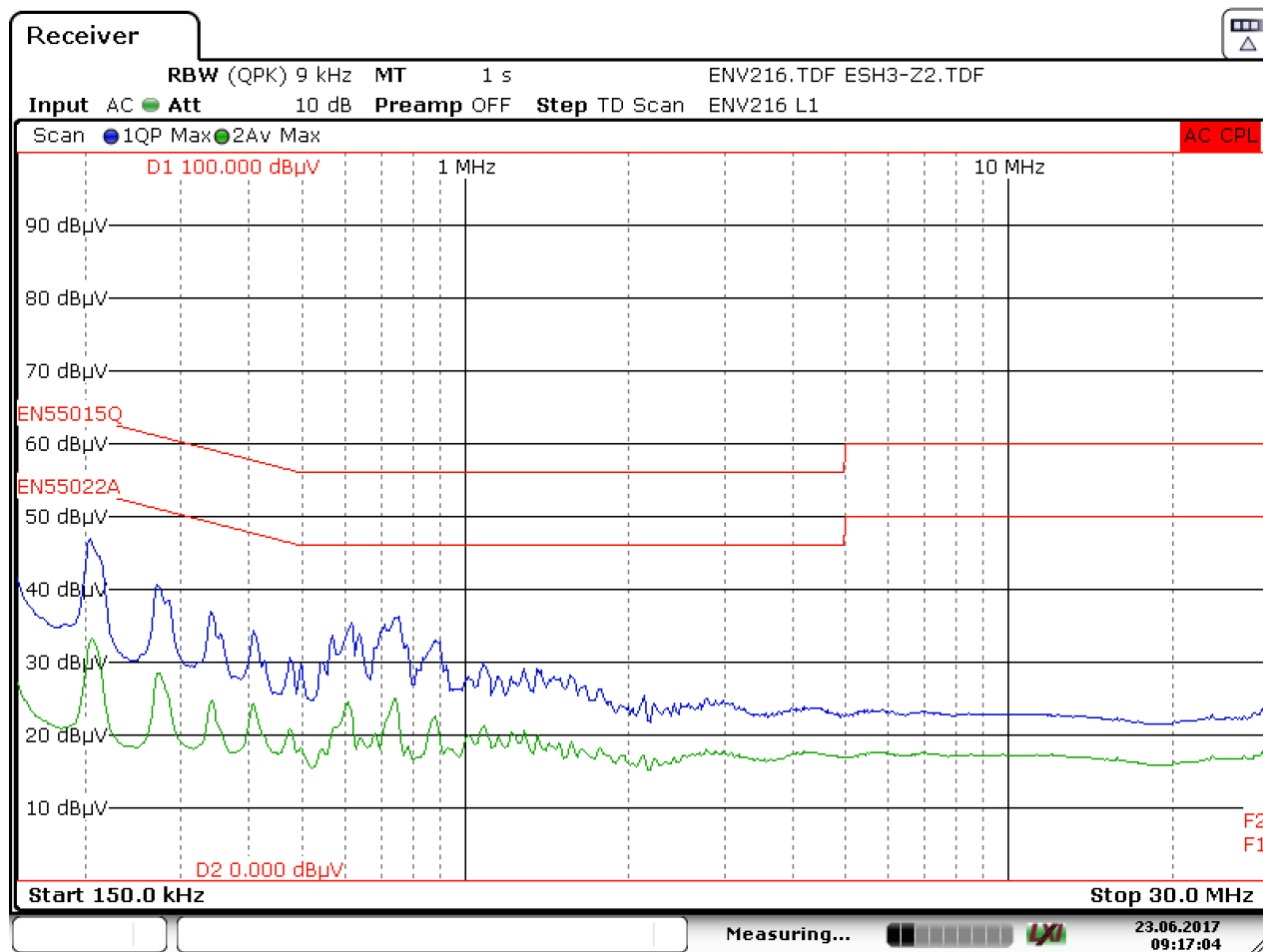
**Figure 55** – Line Overvoltage.  
AC Input, Full-Load.  
 $V_{UV+}$ : 114 V,  $V_{UV-}$ : 99 V  
Upper: Input, 100 V / div.  
Middle: 12 V, 5 V / div.  
Lower: 5 V, 5 V / , 200 s / div.

## 13 EMI

### 13.1 Conductive EMI

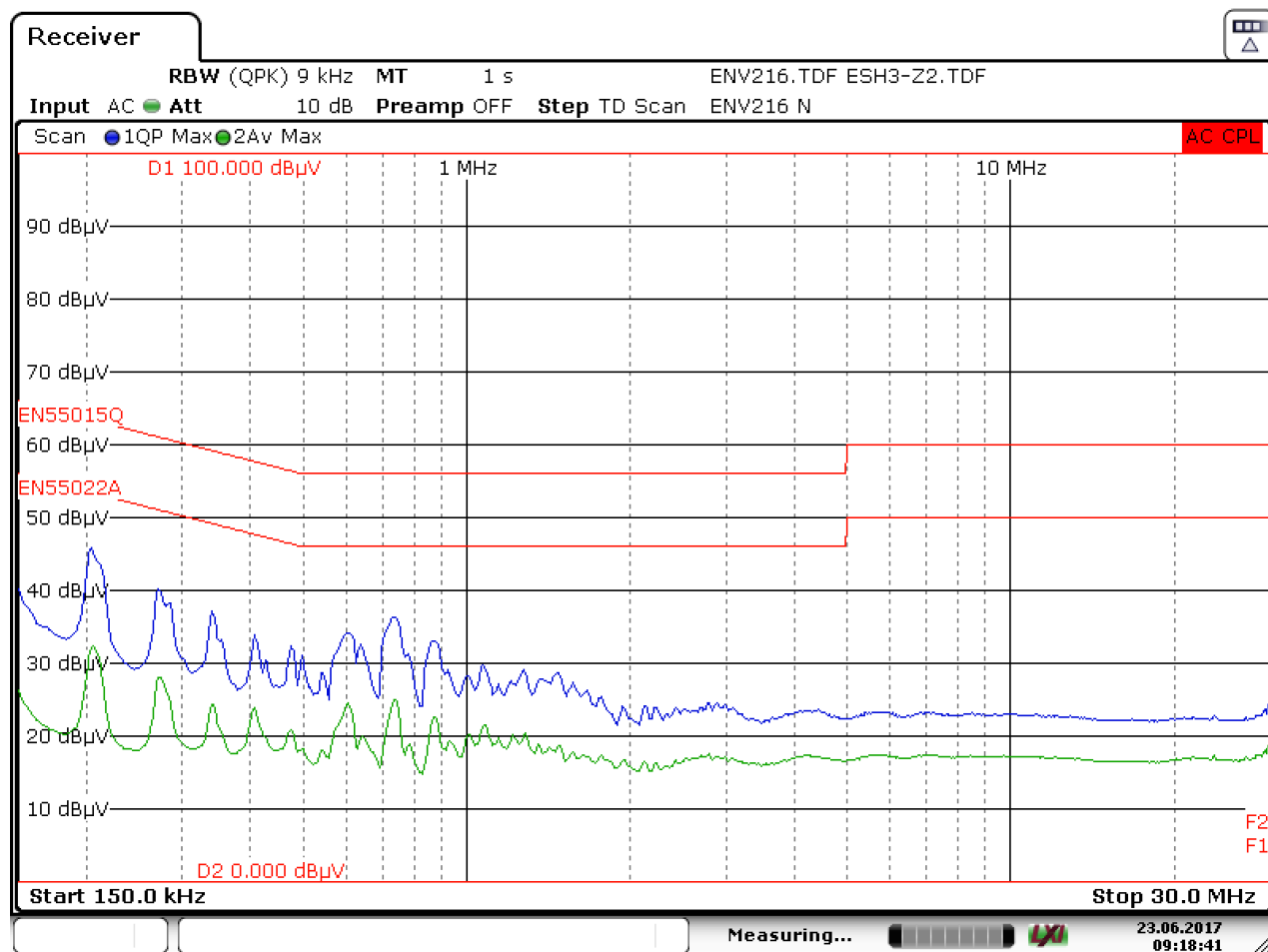
#### 13.1.1 Floating Output (QP / AV)

##### 13.1.1.1 110 VAC Input



Date: 23.JUN.2017 09:17:04

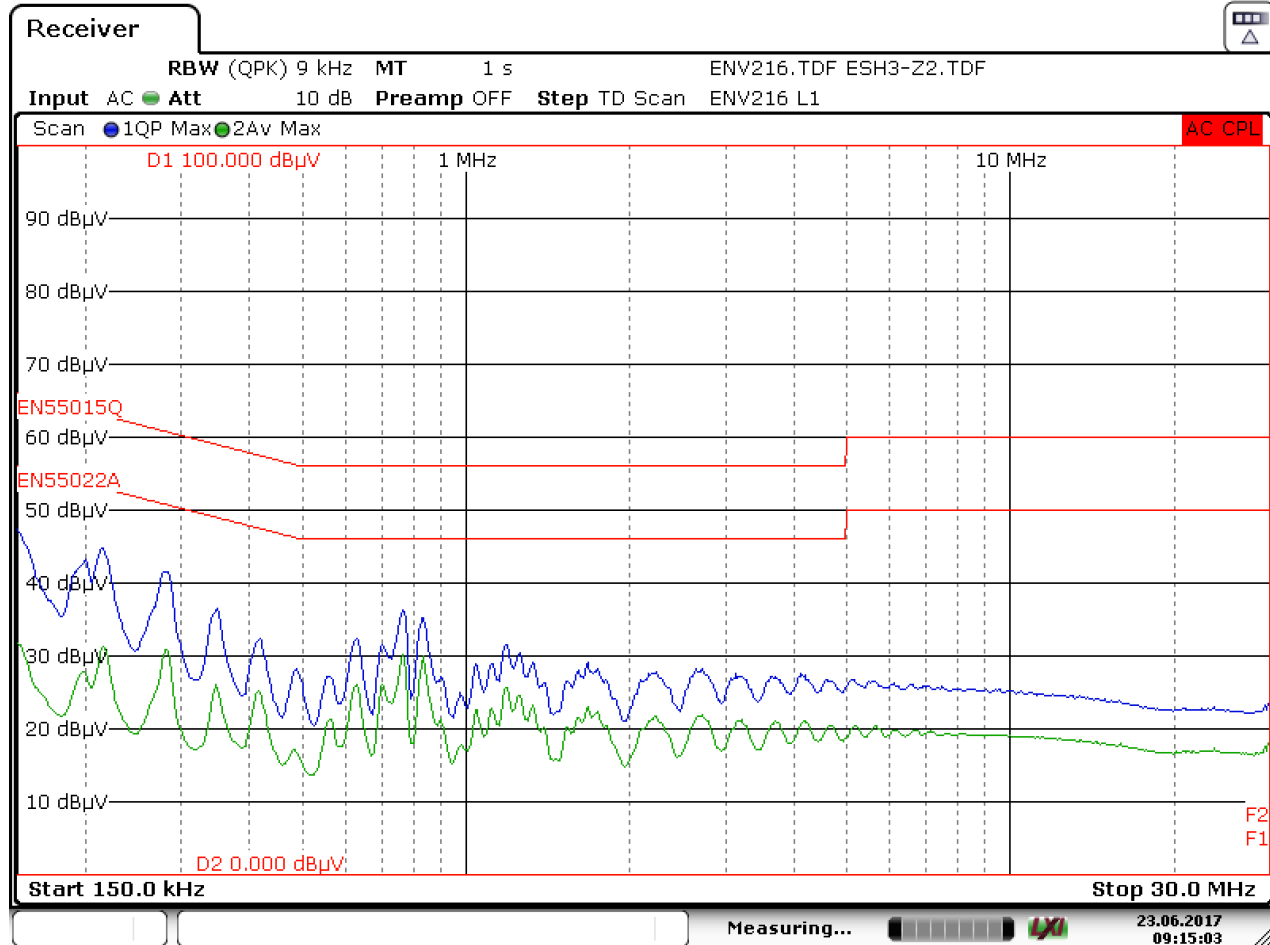
**Figure 56** – Floating Ground - 110 VAC Line.



Date: 23.JUN.2017 09:18:41

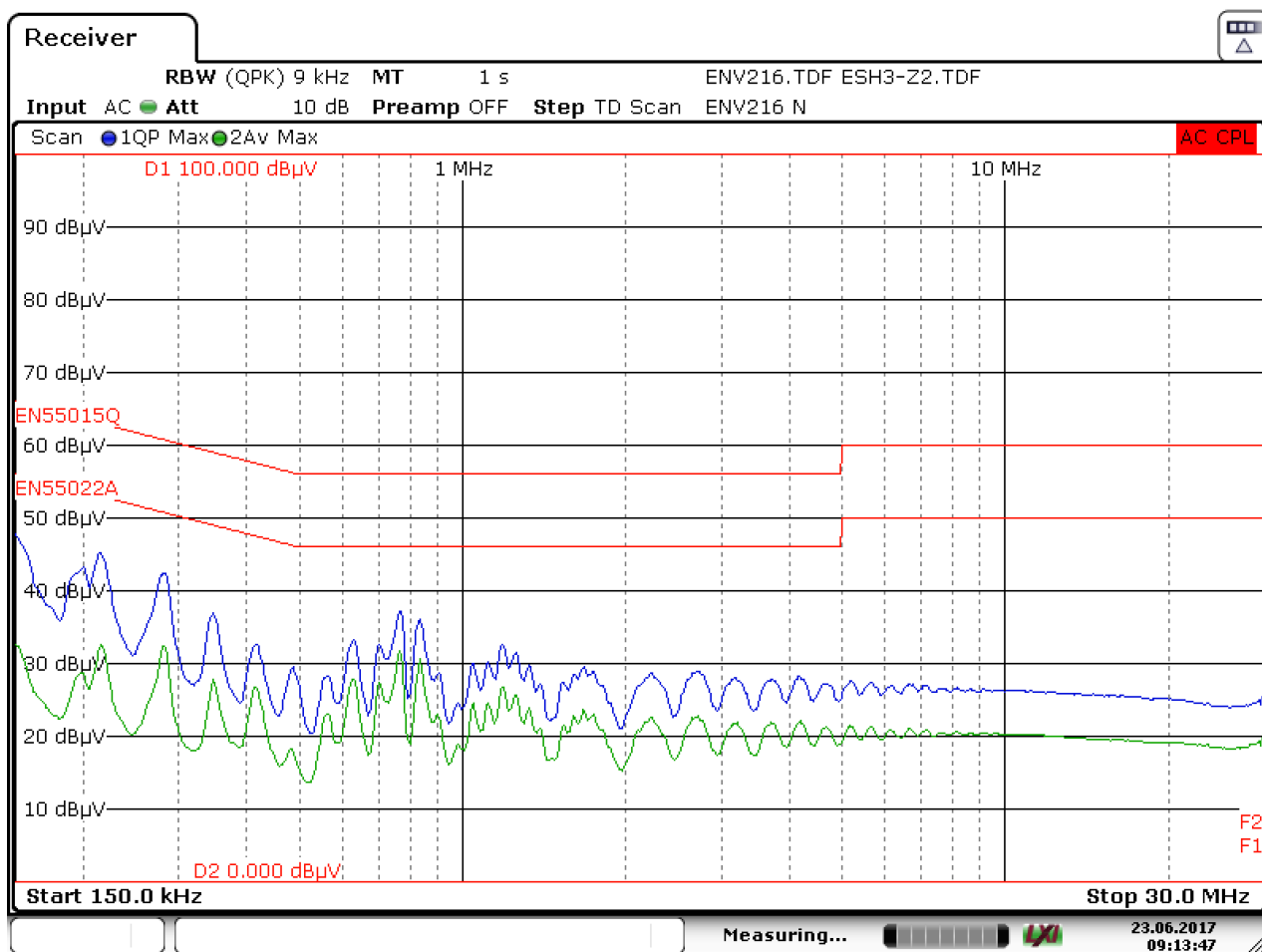
Figure 57 – Floating Ground - 110 VAC Neutral.

## 13.1.1.2 230 VAC Input



Date: 23.JUN.2017 09:15:03

**Figure 58** – Floating Ground - 230 VAC Line.



Date: 23.JUN.2017 09:13:47

**Figure 59** – Floating Ground - 230 VAC Neutral.

## 14 Lighting Surge Test

### 14.1 Differential Mode Test

Passed  $\pm 1$  kV, 500 A surge test.

| Surge Voltage (kV) | Phase Angle (°) | Generator Impedance ( $\Omega$ ) | Number of Strikes | Test Result |
|--------------------|-----------------|----------------------------------|-------------------|-------------|
| 1                  | 0               | 2                                | 10                | PASS        |
| -1                 | 0               | 2                                | 10                | PASS        |
| 1                  | 90              | 2                                | 10                | PASS        |
| -1                 | 90              | 2                                | 10                | PASS        |
| 1                  | 180             | 2                                | 10                | PASS        |
| -1                 | 180             | 2                                | 10                | PASS        |
| 1                  | 270             | 2                                | 10                | PASS        |
| -1                 | 270             | 2                                | 10                | PASS        |

### 14.2 Common Mode Test

Passed  $\pm 2$  kV, ring wave test.

| Ring Wave Voltage (kV) | Phase Angle (°) | Generator Impedance ( $\Omega$ ) | Number of Strikes | Test Result |
|------------------------|-----------------|----------------------------------|-------------------|-------------|
| 2                      | 0               | 12                               | 10                | PASS        |
| -2                     | 0               | 12                               | 10                | PASS        |
| 2                      | 90              | 12                               | 10                | PASS        |
| -2                     | 90              | 12                               | 10                | PASS        |
| 2                      | 180             | 12                               | 10                | PASS        |
| -2                     | 180             | 12                               | 10                | PASS        |
| 2                      | 270             | 12                               | 10                | PASS        |
| -2                     | 270             | 12                               | 10                | PASS        |

## 15 ESD Test

Passed  $\pm 8$  kV contact discharge.

| Contact Voltage (kV) | Applied to    | Number of Strikes | Test Result |
|----------------------|---------------|-------------------|-------------|
| 8                    | 5 V Positive  | 10                | PASS        |
| -8                   | 5 V Negative  | 10                | PASS        |
| 8                    | 12 V Positive | 10                | PASS        |
| -8                   | 12 V Negative | 10                | PASS        |

Passed  $\pm 16$  kV air discharge.

| Differential Voltage (kV) | Applied to    | Number of Strikes | Test Result |
|---------------------------|---------------|-------------------|-------------|
| 16                        | 5 V Positive  | 10                | PASS        |
| -16                       | 5 V Negative  | 10                | PASS        |
| 16                        | 12 V Positive | 10                | PASS        |
| -16                       | 12 V Negative | 10                | PASS        |

## 16 Revision History

| Date      | Author   | Revision | Description & Changes             | Reviewed    |
|-----------|----------|----------|-----------------------------------|-------------|
| 07-Sep-17 | JRV / DK | 1.0      | Initial Release.                  | Apps & Mktg |
| 21-Sep-17 | KM       | 1.1      | Added Test Points to the BOM.     |             |
| 02-May-18 | KM       | 1.2      | Added Transformer Supplier for T1 |             |
|           |          |          |                                   |             |

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