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|---|---|
| **Title** | ***Reference Design Report for a 26.5 W Isolated Flyback Power Supply Using TOPSwitch™-JX TOP267VG*** |
| **Specification** | 90 VAC – 265 VAC Input; 12.0 V / 2 A, 5 V / 500 mA Outputs |
| **Application** | Appliance |
| **Author** | Applications Engineering Department |
| **Document Number** | RDR-706 |
| **Date** | February 2, 2022 |
| **Revision** | 1.0 |

## Summary and Features

- Dual output flyback topology
- No-load input power < 90 mW @ 230 VAC
- Integrate protection and reliability features
  - Auto recovery output over current (OCP) and short-circuit protection
  - Primary sensed output overvoltage shutdown (OVP) eliminates second optocoupler
  - Over temperature shutdown
  - Line undervoltage lock out (UVLO) and line overvoltage shutdown prevents output glitching and improves reliability
- 132 kHz operation optimizes core size and efficiency performance
- 84% < efficiency full Load @ nominal Lines
- 84.5% < average efficiency



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

# 1 Introduction

This engineering report describes a flyback converter designed to provide an isolated nominal output voltage of 12 V at 2.0 A load and a second output of 5 V at 200 mA load from a wide input voltage range of 90 VAC to 265 VAC. This power supply utilizes the TOP267VG from the TOPSwitch-JX family of ICs.

This document contains the complete power supply specifications, bill of materials, transformer construction, circuit schematic and printed circuit board layout, along with performance data and electrical waveforms.

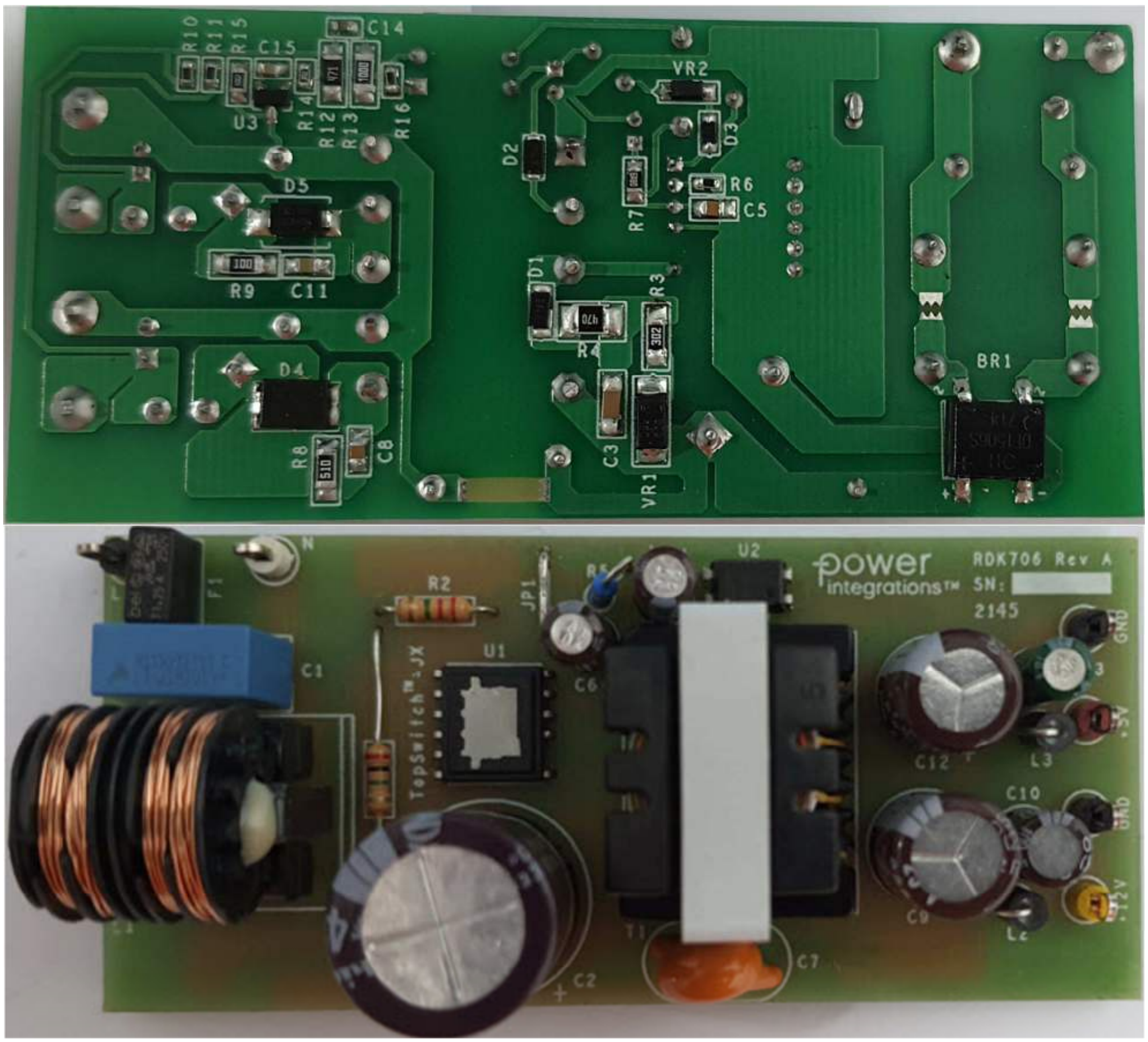


**Figure 1 –** Populated Circuit Board.

## 2 Power Supply Specification

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

| Description | Symbol | Min | Typ | Max | Units | Comment |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| Voltage | $V_{IN}$ | 90 | | 265 | VAC | 2 Wire – no P.E. |
| Frequency | $f_{LINE}$ | 47 | 50/60 | 64 | Hz | |
| No-load Input Power (230 VAC) | | | | 100 | mW | |
| **Output1** | | | | | | |
| Output Voltage | $V_{OUT1}$ | 10.8 | 12 | 13.2 | V | ± 10% |
| Output Ripple Voltage | $V_{RIPPLE1}$ | | | 120 | mV | 20 MHz Bandwidth. |
| Output Current | $I_{OUT1}$ | 200 | | 2000 | mA | |
| **Output2** | | | | | | |
| Output Voltage2 | $V_{OUT2}$ | 4.75 | 5 | 5.25 | V | ± 5% |
| Output Ripple Voltage2 | $V_{RIPPLE2}$ | | | 50 | mV | 20 MHz Bandwidth. |
| Output Curren2 | $I_{OUT2}$ | 50 | | 500 | mA | |
| **Total Output Power** | | | | | | |
| Continuous Output Power | $P_{OUT}$ | | | 26.5 | W | |
| **Efficiency** | | | | | | |
| Full Load Nominal Input | $\eta$ | 84 | | | % | Measured at $P_{OUT}$ 25 °C. |
| Required average efficiency at 25, 50, 75 and 100 % of $P_{OUT}$ | $\eta_{DOE}$ | 84.5 | | | % | Measured at Nominal Input 115 VAC and 230 VAC. |
| **Environmental** | | | | | | |
| Conducted EMI | | Meets CISPR22B / EN55022B | | | | |
| Surge (Differential) | | | | 1 | kV | 1.2/50 µs Surge, IEC 61000-4-5, Series Impedance: Differential Mode: 2 Ω. |
| Surge (Common Mode) | | | | 2 | kV | Common Mode: 12 Ω. |
| Ambient Temperature | $T_{AMB}$ | 0 | | 40 | °C | Free Convection, Sea Level. |

# 3 Schematic

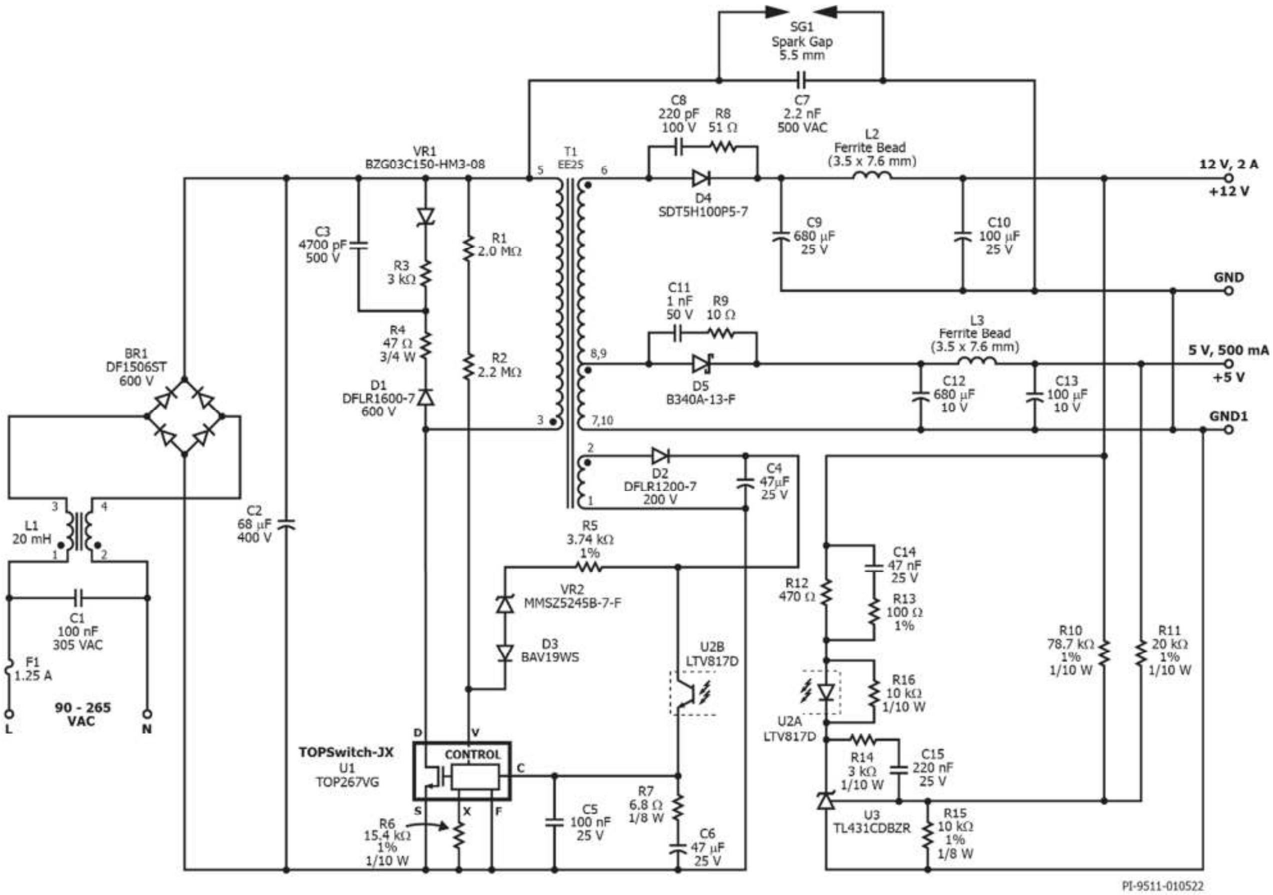



**Figure 2 –** Schematic.

# 4 Circuit Description

This power supply employs a TOP267VG off-line switcher, (U1), in a flyback configuration. IC U1 has an integrated 725 V power MOSFET and a multi-mode controller. It regulates the output by adjusting the power MOSFET duty cycle, based on the current fed into its CONTROL pin.

## 4.1 *Input EMI Filtering and Rectification*

Fuse F1 isolates the circuit and provides protection from component failure. X capacitor C1 together with common mode choke L1 forms an EMI filter that attenuates both common mode and differential mode conducted EMI. BR1 converts the AC line voltage into the DC voltage seen across capacitors C2.

## 4.2 *TopSwitch-JX Primary*

The TOP267VG device (U1) integrates an oscillator, a switch controller, start-up and protection circuitry, and a power MOSFET, all on one monolithic IC. One side of the power transformer (T1) primary winding is connected to the positive side of the bulk capacitors C2, and the other side are connected to the DRAIN pin of U1. When the MOSFET turns off, the leakage inductance of the transformer induces a voltage spike on the drain node. The spike amplitude is limited by a RZCD clamp network that consists of D1, R4, VR1, R3 and C3. The RZCD arrangement prevents the voltage across the capacitor C3 discharging below a minimum value (defined by the voltage rating of VR1) and therefore minimizing clamp dissipation under light and no-load conditions. Resistor R4 is used together with capacitor C3 to damp out high frequency ringing and improve EMI. This arrangement was selected to reduce clamp losses under light and no-load conditions.

The TOP267VG regulates the output by adjusting the duty cycle based on the current into its CONTROL pin. The power supply output voltage is sensed on the secondary-side by shunt regulator U3 and provides a feedback signal to the primary side through optocoupler U2.

The line undervoltage is determine by the current supplied from resistors R1 and R2 to the V pin. R5, VR2, and D3 are used for output overvoltage protection. An increase in output voltage causes an increase in the bias winding on the primary-side, sensed by VR2. Once VR2 is activated, it will inject current to the V pin causing the IC to shut down and undergo auto-restart.

Capacitor C6 provides the auto-restart timing for U1, start-up and loop compensation. At start-up, this capacitor is charged through the DRAIN (D) pin. Once it is charged, U1 begins to switch. Capacitor C6 stores enough energy to ensure the power supply output reaches regulation. After start-up, the bias winding powers the controller via the current through the optocoupler into the CONTROL pin. Bypass capacitor C5 is placed as physically close as possible to U1. Resistor R7 provides additional compensation to the feedback loop.

X pin resistor R6 was used to reduce the current limit to a value close to the operating peak current. This allows the supply to limit the output power at high line and deliver the rated output at low line.

## 4.3 *Output Rectification*

Schottky diodes D4 rectify the 12 V secondary winding output of T1. The output voltage is filtered by C9, L2, and C10. Resistor R8 and capacitor C8 snubs the voltage spike caused by the commutation of D4. Schottky diode D5 rectifies the 5 V secondary winding output of T1. The output voltage is filtered by C12, L3, and C13. Resistor R9 and capacitor C11 absorb the noise caused by the commutation of D5.

A low voltage rating diode was achievable for D4 and D5 due to the flexibility of a higher turns ratio (higher VOR). This is realized due to the 725 V rating of the MOSFET in U1. This also further improves efficiency due to the low forward voltage drop ($V_F$) of the low voltage diode.

## 4.4 *Output Feedback*

The reference IC, U3 or TL431 is used to set the two output voltages programmed via the resistor divider R10, R11 and R15. A portion of both 12 V and the 5 V outputs are fed into the shunt regulator U3 or TL431. The TL431 varies its cathode voltage to keep its input voltage constant (equal to 2.495 V, ±2.2%). As the cathode voltage changes, the current through the LED and transistor within U3 change. A high CTR opto-coupler was selected for U2 to minimize the secondary-side feedback (opto) current and thereby reduce no-load and standby input power. Capacitor C15 and R14 provide compensation for the feedback control loop. Capacitor C14 and R13 is a phase boost network to improve the phase margin of the unit. Resistor R12 limits the gain of the feedback system to ensure power supply stability throughout the range of operation.

Good cross-regulation on 12 V and 5 V outputs are achieved by AC-stacked the secondary windings 12 V and 5 V and sensing feedback from both outputs.

# 5 PCB Layout

1 Layer PCB, 1.6 mm Board Thickness, FR4 Material, 2 oz Copper Thickness

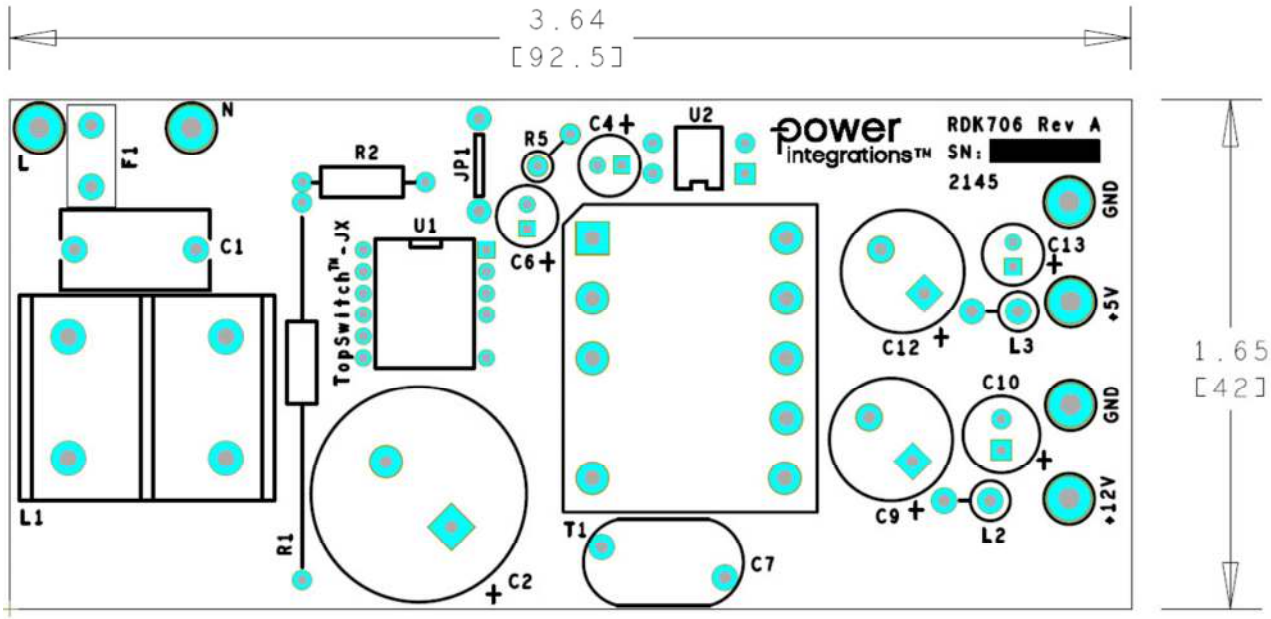



**Figure 3 –** Printed Circuit Board, Top View.

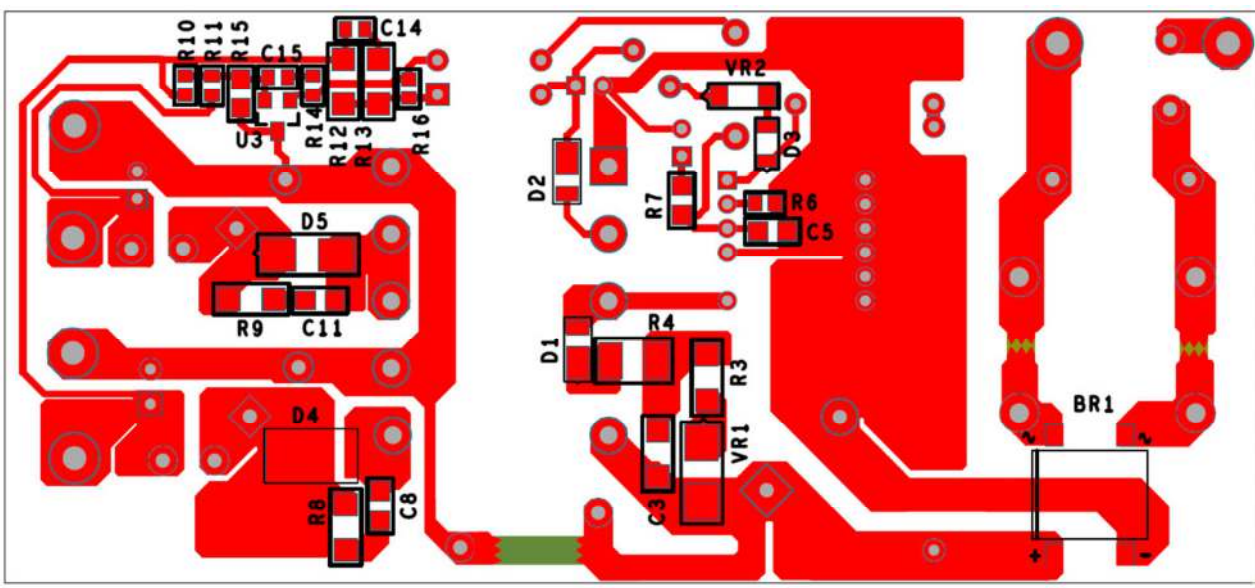



**Figure 4 –** Printed Circuit Board, Bottom View.

# 6 Bill of Materials

## 6.1 *Electrical BOM*

| Item | Qty | Ref Des | Description | Mfg Part Number | Mfg |
|---|---|---|---|---|---|
| 1 | 1 | BR1 | BRIDGE RECT, 1PH, 1.5 A, 600 V, Vf = 1.1 V @ 1.5 A, -65 °C ~ 150 °C (TJ), DF-S,4-SMD | DF1506S-T | Diodes, Inc. |
| 2 | 1 | C1 | 100 nF, 305 VAC, Film, X2 | B32921C3104M | Epcos |
| 3 | 1 | C2 | 68 μF, 400 V, Electrolytic, Low ESR, 530 mΩ, (18 x 25) | EKMX401ELL680MM25S | Nippon Chemi-Con |
| 4 | 1 | C3 | 4700 pF ±5% 500 V Ceramic C0G, NP0 1206 | C1206C472JCGACAUTO | Kemet |
| 5 | 2 | C4 C6 | 47 μF, 25 V, Electrolytic, Very Low ESR, 300 mΩ, (5 x 11) | EKZE250ELL470ME11D | Nippon Chemi-Con |
| 6 | 1 | C5 | 100 nF, 25 V, Ceramic, X7R, 0805 | 08053C104KAT2A | AVX |
| 7 | 1 | C7 | 2200 pF, ±20%, 500 VAC (Y1),760 VAC (X1), Ceramic, Y5U €, RADIAL | 440LD22-R | Vishay |
| 8 | 1 | C8 | 220 pF, 100 V, Ceramic, X7R, 0805 | 08051C221KAT2A | AVX |
| 9 | 1 | C9 | 680 μF, 25 V, Electrolytic, Very Low ESR, 32 mΩ, (10 x 16) | EKZH250EC3681MJ16S | Nippon Chemi-Con |
| 10 | 1 | C10 | 100 μF, 25 V, Electrolytic, Very Low ESR, 130 mΩ, (6.3 x 11) | EKZE250ELL101MF11D | Nippon Chemi-Con |
| 11 | 1 | C11 | 1 nF, 50 V, Ceramic, X7R, 0805 | 08055C102KAT2A | AVX |
| 12 | 1 | C12 | 680 μF, 10 V, Electrolytic, Very Low ESR, 53 mΩ, (10 x 12.5) | EKZE100ELL681MJC5S | Nippon Chemi-Con |
| 13 | 1 | C13 | 100 μF, 10 V, Electrolytic, Very Low ESR, 300 mΩ, (5 x 11) | EKZE100ELL101ME11D | Nippon Chemi-Con |
| 14 | 1 | C14 | 47 nF 25 V, Ceramic, X7R, 0603 | CC0603KRX7R8BB473 | Yago |
| 15 | 1 | C15 | 220 nF, 25 V, Ceramic, X7R, 0603 | 06033D224KAT2A | AVX |
| 16 | 1 | D1 | 600 V, 1 A, Rectifier, Glass Passivated, POWERDI123 | DFLR1600-7 | Diodes, Inc. |
| 17 | 1 | D2 | 200 V, 1 A, Rectifier, Glass Passivated, POWERDI123 | DFLR1200-7 | Diodes, Inc. |
| 18 | 1 | D3 | 100 V, 0.2 A, Fast Switching, 50 ns, SOD-323 | BAV19WS-7-F | Diodes, Inc. |
| 19 | 1 | D4 | 100 V, 5 A, Schottky, SMD, POWERD15, PowerDI™ 5 | SDT5H100P5-7 | Diodes, Inc. |
| 20 | 1 | D5 | Diode, SCHOTTKY, 40 V, 3 A, SMA, DO-214AA | B340A-13-F | Diodes, Inc. |
| 21 | 1 | F1 | FUSE, 1.25 A 250 VAC, Slow, 8.35 mm x 4.0 mm x 7.7 mm | RST 1.25-BULK | Bel Fuse |
| 22 | 1 | L1 | 20 mH, 0.8 A, Common Mode Choke | SS21V-R080200 | KEMET |
| 23 | 2 | L2 L3 | 3.5 mm x 7.6 mm, 75 Ω at 25 MHz, #22 AWG hole, Ferrite Bead | 2743004112 | Fair-Rite |
| 24 | 1 | R1 | RES, 2.0 MΩ, 5%, 1/4 W, Carbon Film | CFR-25JB-2M0 | Yageo |
| 25 | 1 | R2 | RES, 2.2 MΩ, 5%, 1/4 W, Carbon Film | CFR-25JB-2M2 | Yageo |
| 26 | 1 | R3 | RES, 3.0 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ302V | Panasonic |
| 27 | 1 | R4 | RES, 47 Ω, ±5%, 0.75 W, 1210, Pulse Withstanding, Thick Film | CRCW121047R0JNEAHP | Vishay |
| 28 | 1 | R5 | RES, 3.74 kΩ, 1%, 1/4 W, Metal Film | MFR-25FBF-3K74 | Yageo |
| 29 | 1 | R6 | RES, 15.4 kΩ, 1%, 1/10 W, Thick Film, 0603 | ERJ-3EKF1542V | Panasonic |
| 30 | 1 | R7 | RES, 6.8 Ω, 5%, 1/8 W, Thick Film, 0805 | ERJ-6GEYJ6R8V | Panasonic |
| 31 | 1 | R8 | RES, 51 Ω, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ510V | Panasonic |
| 32 | 1 | R9 | RES, 10 Ω, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ100V | Panasonic |
| 33 | 1 | R10 | RES, 78.7 kΩ, 1%, 1/10 W, Thick Film, 0603 | ERJ-3EKF7872V | Panasonic |
| 34 | 1 | R11 | RES, 20 kΩ, 1%, 1/10 W, Thick Film, 0603 | ERJ-3EKF2002V | Panasonic |
| 35 | 1 | R12 | RES, 470 Ω, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ471V | Panasonic |
| 36 | 1 | R13 | RES, 100 Ω, 1%, 1/4 W, Thick Film, 1206 | ERJ-8ENF1000V | Panasonic |
| 37 | 1 | R14 | RES, 3 kΩ, 5%, 1/10 W, Thick Film, 0603 | ERJ-3GEYJ302V | Panasonic |
| 38 | 1 | R15 | RES, 10.0 kΩ, 1%, 1/8 W, Thick Film, 0805 | ERJ-6ENF1002V | Panasonic |
| 39 | 1 | R16 | RES, 10 kΩ, 5%, 1/10 W, Thick Film, 0603 | ERJ-3GEYJ103V | Panasonic |
| 40 | 1 | T1 | Bobbin, EE25, Vertical, 10 pins<br>Transformer | YW-360-02B<br>POL-JX042 | Yih-Hwa Enterprises<br>Premier Magnetics |
| 41 | 1 | U1 | TopSwitch-JX, eDIP-12P | TOP267VG | Power Integrations |
| 42 | 1 | U2 | Optocoupler, 35 V, CTR 300-600%, 4-DIP | LTV-817D | Liteon |
| 43 | 1 | U3 | IC, Shunt Regulator Adj., 2.495 V, 2.2%, 100 mA, 0 °C ~ 70 °C (TA), SOT23-3, TO-236-3, SC-59, SOT-23-3 | TL431CDBZR | Texas Instruments |
| 44 | 1 | VR1 | Zener Diode, 150 V, 1.25 W, ±6%, SMT, DO-214AC (SMA) | BZG03C150-HM3-08 | Vishay |
| 45 | 1 | VR2 | Diode Zener 15 V 500 mW SOD123 | MMSZ5245B-7-F | Diodes, Inc. |

## 6.2 *Mechanical BOM*

| Item | Qty | Ref Des | Description | Mfg Part Number | Mfg |
|---|---|---|---|---|---|
| 1 | 1 | +12 V | Test Point, YEL, THRU-HOLE MOUNT | 5014 | Keystone |
| 2 | 1 | +5 V | Test Point, RED, THRU-HOLE MOUNT | 5010 | Keystone |
| 3 | 3 | GND1, GND, L | Test Point, BLK, THRU-HOLE MOUNT | 5011 | Keystone |
| 4 | 1 | JP1 | Wire Jumper, Non-insulated, #26 AWG, 0.3 in | 299/1 SV001 | Alpha Wire |
| 5 | 1 | N | Test Point, WHT, THRU-HOLE MOUNT | 5012 | Keystone |

# 7 Transformer Specification

## 7.1 *Electrical Diagram*

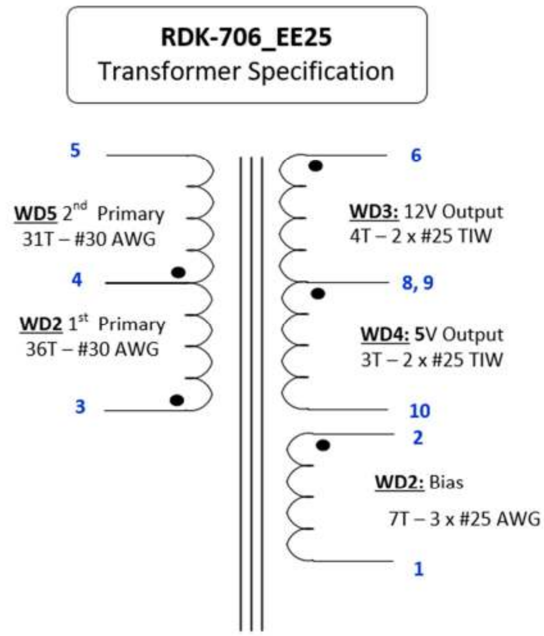



**Figure 5 –** Transformer Electrical Diagram.

## 7.2 *Electrical Specifications*

| Parameter | Condition | Spec. |
|---|---|---|
| Nominal Primary Inductance | Measured at 1 $V_{PK-PK}$, 100 kHz switching frequency, between pin 1 and pin 3 with all other windings open. | 535 μH |
| Tolerance | Tolerance of primary inductance. | ±5% |
| Leakage Inductance | Measured across primary winding with all other windings shorted. | <8 μH |

## 7.3 *Material List*

| Item | Description |
|---|---|
| **[1]** | Core: EE25 TDK PC40 |
| **[2]** | Bobbin: EE2, Vertical, 10 pins (Mfg PN: YW-360-02B, Mfg: Yih-Hwa Enterprises) |
| **[3]** | Magnet Wire: #30 AWG. |
| **[4]** | Magnet Wire: #25 AWG. |
| **[5]** | TIW Wire: #25 AWG. |
| **[6]** | Polyester Tape: 10.7 mm. |
| **[7]** | Polyester Tape: 7 mm. |
| **[8]** | Varnish: Dolph BC 359 or Equivalent. |

## 7.4 *Transformer Build Diagram*

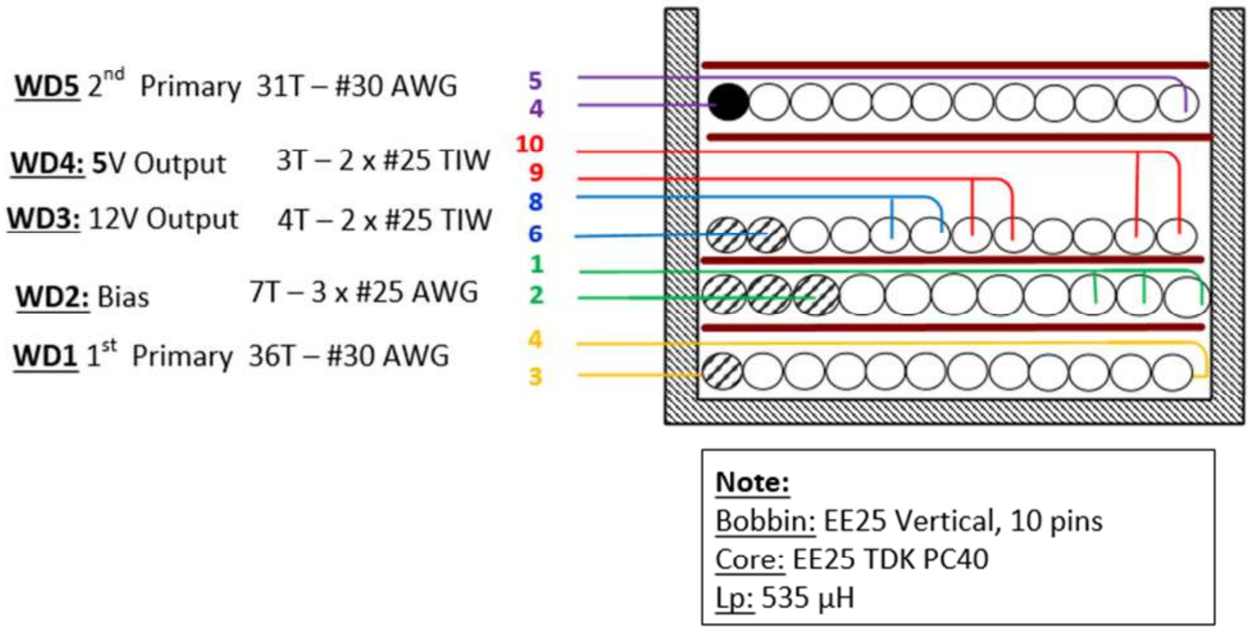
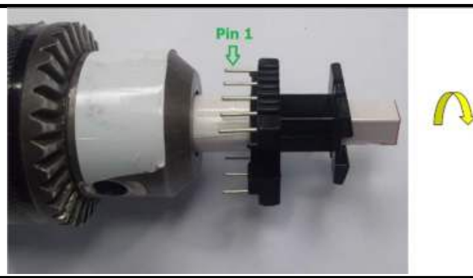
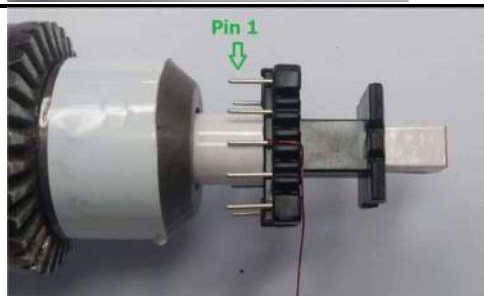
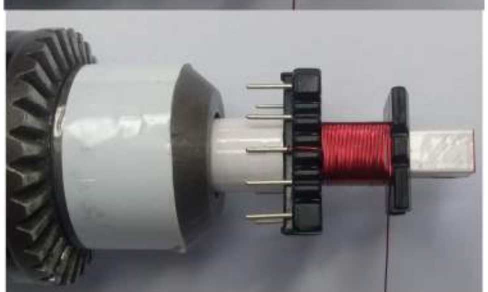
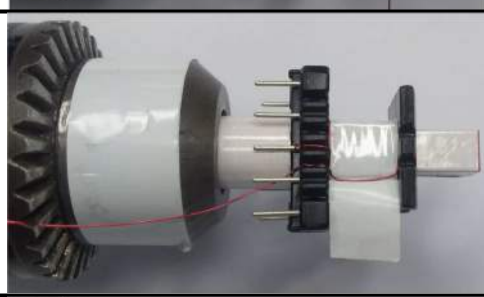
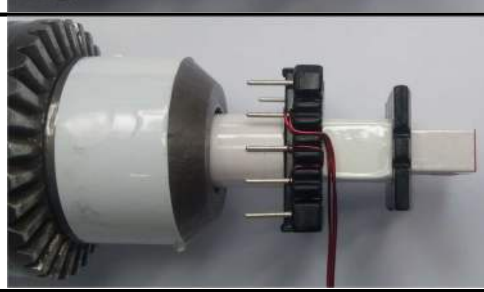


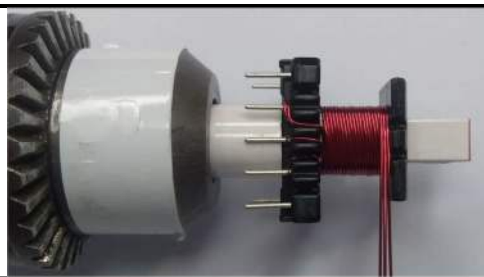
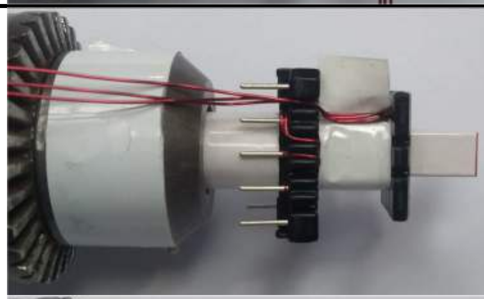
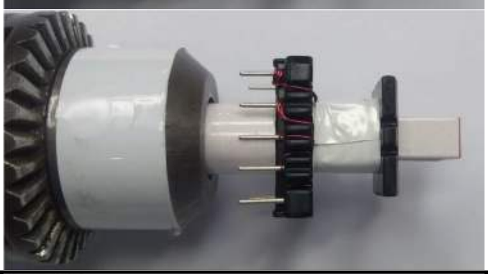
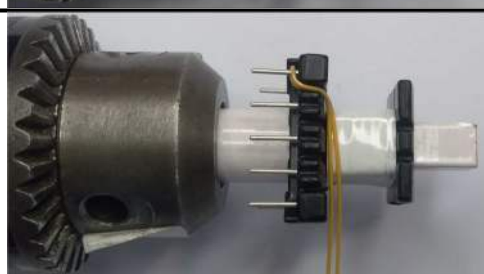
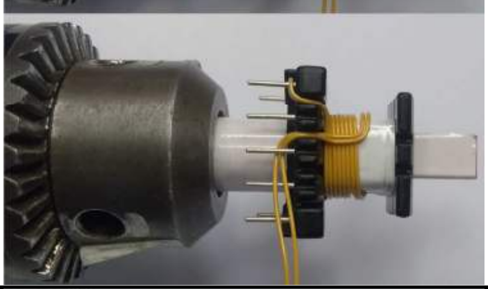
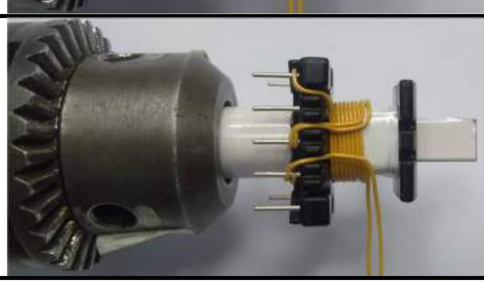

**Figure 6 –** Transformer Build Diagram.

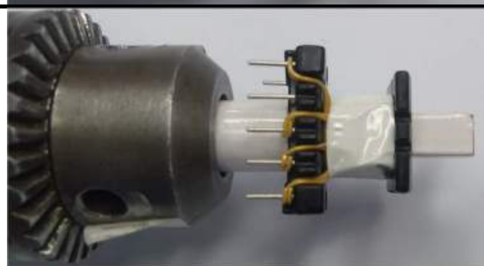
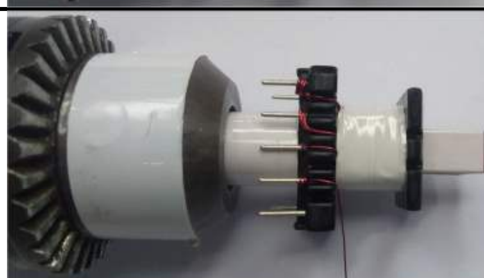
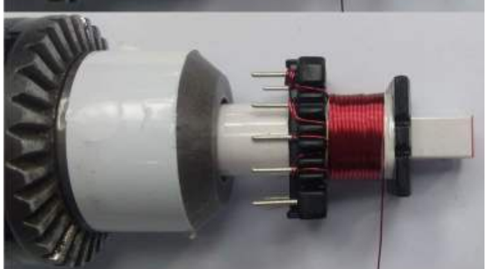
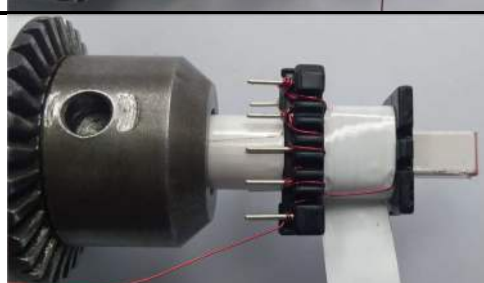
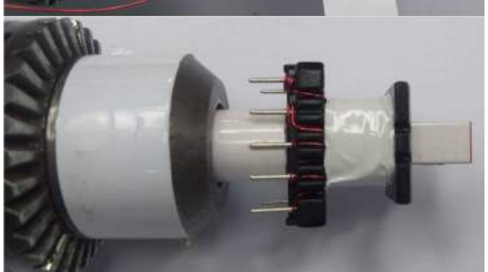
## 7.5 *Transformer Instructions*

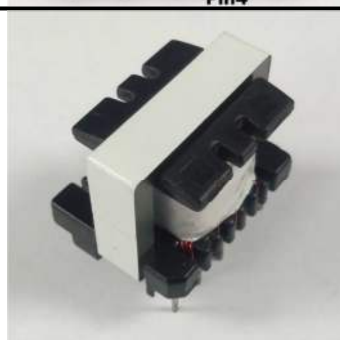
| | |
|---|---|
| **Bobbin Preparation** | For the purposes of these instructions, bobbin is oriented on winder such that pin 1 to 5 is located on the top side. Winding direction is clockwise. |
| **WD1 1st Primary** | Start at pin 3, wind 36 turns of wire Item [3] in 1 layers. |
| **Insulation** | Finish WD1 at pin 4. Use 1 layer of tape Item [6] for insulation. |
| **WD2 Bias** | Prepare 3 strands of wire Item [4]. Start 3 strands of wire Item [4] at pin 2, wind 3 wires 7 turns in parallel in 1 layer. |
| **Insulation** | Finish WD2 at pin 1. Use 1 layer of tape Item [6] for insulation. |
| **WD3 12 V Output** | Prepare 2 strands of wire Item [5]. Start 2 strands of wire Item [5] at pin 6, wind 2 wires 4 turns in parallel in 1 layer. Finish at pin 8. |
| **WD4 5 V Output** | Prepare 2 strands of wire Item [5]. Start 2 strands of wire Item [5] at pin 9, wind 2 wires 3 turns in parallel in 1 layer. Finish at pin 10. |
| **Insulation** | Use 1 layer of tape Item [6] for insulation. |
| **WD5 2nd Primary** | Start at pin 4, wind 31 turns of wire Item [3] in 1 layer. |
| **Insulation** | Finish WD5 at pin 5. Use 1 layer of tape Item [6] for insulation. |
| **Solder and Cut Pin** | Solder the wires to the leads of the bobbin and cut Pin 4 |
| **Finish** | Gap cores to get 535 µH. Wrap the body of transformer with 3 layers of tape Item [7]. Varnish using Item [8]. |

## 7.6 *Transformer Winding Illustrations*

| | | |
|---|---|---|
| **Bobbin Preparation** |   | For the purposes of these instructions, bobbin is oriented on winder such that pin 1 to 5 is located on the top side. Winding direction is clockwise. |
| **WD1**<br>**1st Primary** |    | Start at pin 3, wind 36 turns of wire Item [3] in 1 layers. |
| **Insulation** |  | Finish WD1 at pin 4<br>Use 1 layer of tape Item [6] for insulation. |
| **WD2**<br>**Bias** |  | Prepare 3 strands of wire Item [4]. Start 3 strands of wire Item [4] at pin 2, wind 3 wires 7 turns in parallel in 1 layer. |

| | | |
|---|---|---|
| |  | |
| **Insulation** |   | Finish WD2 at pin 1<br>Use 1 layer of tape Item [6] for insulation. |
| **WD3**<br>**12 V**<br>**Output** |   | Prepare 2 strands of wire Item [5]. Start 2 strands of wire Item [5] at pin 6, wind 2 wires 4 turns in parallel in 1 layer. Finish at pin 8. |
| **WD4**<br>**5 V Output** |  | Prepare 2 strands of wire Item [5]. Start 2 strands of wire Item [5] at pin 9, wind 2 wires 3 turns in parallel in 1 layer. Finish at pin 10. |

| | | |
|---|---|---|
| |  | |
| **Insulation** |  | Use 1 layer of tape Item [6] for insulation. |
| **WD5**<br>**2nd Primary** | <br> | Start at pin 4, wind 31 turns of wire Item [3] in 1 layers. |
| **Insulation** | <br> | Finish WD5 at pin 5.<br>Use 1 layer of tape Item [6] for insulation. |

| | | |
|---|---|---|
| **Solder and Cut Pin** |  | Solder the wires to the leads of the bobbin and cut Pin 4 |
| **Finish** |  | Gap cores to get 535 uH. Wrap the body of transformer with 3 layers of tape Item [7]. Varnish using Item [8]. |

# 9 Transformer Design Spreadsheet

| 1 | ACDC_TOPSwitchJX_062521; Rev.2.1; Copyright Power Integrations 2021 | INPUT | INFO | OUTPUT | UNITS | TOPSwitch-JX Flyback Design Spreadsheet |
|---|---|---|---|---|---|---|
| **2** | **Application Variables** | | | | | |
| 3 | VAC_RANGE | | | Universal | | Input voltage range |
| 4 | VAC_MIN | 90 | | 90 | V | Minimum input RMS voltage |
| 5 | VAC_MAX | 265 | | 265 | V | Maximum input RMS voltage |
| 6 | FL | | | 50 | Hz | Line frequency |
| 7 | VOUT | 12.00 | | 12.00 | V | Output voltage |
| 8 | IOUT | | | 2.21 | A | Output current |
| 9 | POUT | 26.5 | | 26.5 | W | Output power |
| 10 | POUT_PEAK | | | 26.5 | W | Peak output power |
| 11 | EFFICIENCY_ACDC | | | 0.86 | | AC-DC efficiency |
| 12 | FACTOR_Z | | | 0.50 | | Z-factor |
| **15** | **Input Side Components** | | | | | |
| **16** | **Input Capacitor** | | | | | |
| 17 | CIN | 68.0 | | 68.0 | uF | Input capacitance |
| 18 | VF_BRIDGEDIODE | | | 0.70 | V | Input bridge diode forward voltage |
| 19 | VAC_MIN_VLY | | | 96.2 | V | Valley of the rectified minimum input AC voltage when delivering POUT. During peak power delivery, the valley of the rectified minimum input AC voltage is 96.2V |
| **21** | **V-Pin** | | | | | |
| 22 | UVOV TYPE | UVOV | | UVOV | | Standard under-voltage and over-voltage. Refer to page.13 of the TopSwitch-JX spreadsheet |
| 23 | UNDERVOLTAGE | | | 65.6 - 82.5 | V | Actual RMS under-voltage range |
| 24 | OVERVOLTAGE | | | 316.7 - 353.7 | V | Actual RMS over-voltage range |
| 25 | RLS1 | | | 4.22 | MΩ | 1% resistor connected from the rectified line voltage to the V-pin |
| 26 | RLS2 | | | NA | kΩ | Not required |
| **28** | **X-Pin** | | | | | |
| 29 | KI | | | 0.37 - 0.56 | | Typical current limit reduction factor target |
| 30 | ILIMIT_KI_RANGE | | | 1.036 - 1.804 | A | Minimum current limit based on KI |
| 31 | RIL | | | 15.40 | kΩ | Current limit programming resistor (1%) connected to the X-pin. Refer to page.31 of the TOPSwitch-JX datasheet |
| 32 | RPL | | | NA | MΩ | Power limiting resistor (1%) connected from the rectified input voltage to the X-pin. Refer to page.14 of the TOPSwitch-JX datasheet |
| **34** | **Bias Winding** | | | | | |
| 35 | VBIAS | | | 12.00 | V | Target rectified bias winding voltage at low-load |
| 36 | VF_BIAS | | | 0.70 | V | Bias winding rectifier diode on-time voltage drop |
| 37 | VBIAS_OVP | | | 18.00 | V | Target rectified bias winding voltage to trigger output over-voltage |
| 38 | VZ_OVP | | | 16.00 | V | Zener voltage (1%) required for bias winding sensed output over-voltage. Refer to fig.15 in the TOPSwitch-JX datasheet |
| 39 | R_OVP | | | 3.74 | kΩ | Resistor (1%) required for bias winding sensed output over-voltage. Refer to fig.15 in the TOPSwitch-JX datasheet |
| **42** | **TOPSwitch-JX** | | | | | |
| 43 | PACKAGE | eDIP- | | eDIP-12B | | TOPSwitch Package |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 12B | | | | |
| 44 | HEATSINK | PCB | | PCB | | TOPSwitch Heatsink |
| 45 | ENCLOSURE | Open Frame | | Open Frame | | Power supply enclosure |
| 46 | MODE_FREQUENCY | F | | F | | Frequency operation mode (F=132kHz, H=66kHz) |
| 47 | DEVICE | TOP267 | | TOP267VG | | TOPSwitch device |
| 48 | PMAX | | | 32 | W | TOPSwitch device maximum power capability |
| 49 | ILIMIT_MIN | | | 2.800 | A | Minimum TOPSwitch current limit |
| 50 | ILIMIT_MAX | | | 3.222 | A | Maximum TOPSwitch current limit |
| 51 | VDSON | | | 1.085 | V | TOPSwitch on-time drain to source voltage |
| 52 | VDSOFF | | | 543.4 | V | TOPSwitch off-time drain to source voltage |
| **55** | **Electrical Parameters (Worst Case)** | | | | | |
| 56 | KP | | | 0.752 | | Measure of continuous/discontinuous mode of operation. The actual KP calculated based on tolerance may be lower than the value entered |
| 57 | DUTY | | | 0.558 | | Primary switch duty cycle |
| 58 | IAVG_PRI | | | 0.301 | A | Primary switch average current |
| 59 | IPK_PRI | | | 0.979 | A | Primary switch peak current |
| 60 | IRMS_PRI | | | 0.446 | A | Primary Switch RMS current |
| 61 | IRIPPLE_PRI | | | 0.974 | A | Primary Switch ripple current |
| 62 | IPK_SEC | | | 9.371 | A | Secondary rectifier peak current |
| 63 | IRMS_SEC | | | 3.797 | A | Secondary winding RMS current |
| **66** | **Transformer** | | | | | |
| 67 | LP_TYP | | | 534.6 | uH | Typical primary magnetizing inductance |
| 68 | LP_RANGE | | | 507.9 - 561.3 | uH | Range of primary magnetizing inductance to ensure power delivery |
| 69 | LP_TOL | | | 5.0 | % | Magnetizing inductance tolerance |
| 70 | VOR | | | 120.0 | V | Secondary winding voltage reflected to the primary winding |
| **72** | **Core/Bobbin Selection** | | | | | |
| 73 | CORE | Custom | | Custom | | Transformer core selection - refer to the Transformer Parameters tab to verify fit |
| 74 | CORE CODE | B-EE25-H | | B-EE25-H | | Core code |
| 75 | AE | 41.0 | | 41.0 | mm^2 | Core cross sectional area |
| 76 | LE | 47.0 | | 47.0 | mm | Core magnetic path length |
| 77 | AL | 2140 | | 2140 | nH/turns^2 | Ungapped core effective inductance |
| 78 | VE | 0 | | 0 | mm^3 | Core volume |
| 79 | BOBBIN | B-EE25-H | | B-EE25-H | | Bobbin |
| 80 | AW | 60.67 | | 60.67 | mm^2 | Window area of the bobbin |
| 81 | BW | 10.72 | | 10.72 | mm | Bobbin width |
| 82 | MARGIN | 0.00 | | 0.00 | mm | Safety margin width (Half the primary to secondary creepage distance) |
| **84** | **Winding Parameters** | | | | | |
| 85 | NP | | | 67 | | Primary winding number of turns |
| 86 | NB | | | 7 | | Bias winding number of turns |
| 87 | NS | | | 7 | | Secondary winding number of turns |
| 88 | BPEAK | | | 0.3687 | T | Transformer core's peak flux density |
| 89 | BMAX | | | 0.1915 | T | Transformer core's operating flux density |
| 90 | BAC | | | 0.0811 | T | Transformer core AC flux density (0.5 x Peak-Peak) |
| 91 | ALG | | | 119.1 | nH/turns^2 | Gapped core effective inductance (Typical) |
| 92 | LG | | | 0.41 | mm | Core gap length |
| **95** | **Output Stage** | | | | | |
| **96** | **Output 1** | | | | | |
| 97 | VOUT1 | | | 12.00 | | Output voltage |

| | | | | | | |
|---|---|---|---|---|---|---|
| 98 | IOUT1 | 2.00 | | 2.00 | | Output current |
| 99 | POUT1 | | | 24.00 | | Output power |
| 100 | IRMS_SEC1 | | | 3.439 | | Secondary winding RMS current |
| 101 | IRIPPLE_COUT1 | | | 2.798 | | Output capacitor ripple current |
| 102 | NS1 | | | 7 | | Secondary winding number of turns |
| 103 | VDSOFF_DIODE1 | | | 51.0 | | Output rectifier off-time voltage stress (not incl. the parasitic ring) |
| 104 | PN_DIODE1 | | | SB380 | | Suggested output rectifier schottky diode |
| 105 | VRRM_DIODE1 | | | 80 | | Output rectifier rated reverse repetitive voltage |
| 106 | VF_DIODE1 | | | 0.85 | | Output rectifier rated on-time voltage drop |
| 107 | IF_DIODE1 | | | 3.0 | | Output rectifier rated average forward current |
| **109** | **Output 2** | | | | | |
| 110 | VOUT2 | 5.00 | | 5.00 | | Output voltage |
| 111 | IOUT2 | 0.50 | | 0.50 | | Output current |
| 112 | POUT2 | | | 2.50 | | Output power |
| 113 | IRMS_SEC2 | | | 0.860 | | Secondary winding RMS current |
| 114 | IRIPPLE_COUT2 | | | 0.699 | | Output capacitor ripple current |
| 115 | NS2 | | | 3 | | Secondary winding number of turns |
| 116 | VDSOFF_DIODE2 | | | 21.7 | | Output rectifier off-time voltage stress (not incl. the parasitic ring) |
| 117 | PN_DIODE2 | | | SB240 | | Suggested output rectifier schottky diode |
| 118 | VRRM_DIODE2 | | | 40 | | Output rectifier rated reverse repetitive voltage |
| 119 | VF_DIODE2 | | | 0.5 | | Output rectifier rated on-time voltage drop |
| 120 | IF_DIODE2 | | | 2 | | Output rectifier rated average forward current |
| 135 | POUT_TOTAL | | | 26.5 | | Total output power |
| 136 | NEGATIVE OUTPUT | N/A | | N/A | | Select the negative output voltage index (Eg. Select 3 if you want the 3rd output to be negative) |

# 10 Performance Data

## 10.1 *Average Efficiency*

### 10.1.1 Average Efficiency, 115 VAC

| Load | $V_{IN}$ | $I_{IN}$ | $P_{IN}$ | $V_{OUT1}$ at PCB | $I_{OUT1}$ | $P_{OUT1}$ | $V_{OUT2}$ at PCB | $I_{OUT2}$ | $P_{OUT2}$ | Efficiency at PCB |
|---|---|---|---|---|---|---|---|---|---|---|
| (A) | ($V_{RMS}$) | ($mA_{RMS}$) | (W) | ($V_{DC}$) | ($mA_{DC}$) | (W) | ($V_{DC}$) | ($mA_{DC}$) | (W) | (%) |
| 100% | 114.97 | 546.10 | 31.25 | 12.06 | 1998.50 | 24.11 | 5.02 | 499.58 | 2.51 | 85.18 |
| 75% | 114.98 | 435.50 | 23.27 | 12.07 | 1498.30 | 18.08 | 5.02 | 374.54 | 1.88 | 85.79 |
| 50% | 114.99 | 321.60 | 15.50 | 12.08 | 998.60 | 12.06 | 5.02 | 249.54 | 1.25 | 85.88 |
| 25% | 115.00 | 193.92 | 7.76 | 12.08 | 498.50 | 6.02 | 5.02 | 124.64 | 0.63 | 85.71 |
| | | | | | | | | | **Average** | **85.64** |

### 10.1.2 Average Efficiency, 230 VAC

| Load | $V_{IN}$ | $I_{IN}$ | $P_{IN}$ | $V_{OUT1}$ at PCB | $I_{OUT1}$ | $P_{OUT1}$ | $V_{OUT2}$ at PCB | $I_{OUT2}$ | $P_{OUT2}$ | Efficiency at PCB |
|---|---|---|---|---|---|---|---|---|---|---|
| (A) | ($V_{RMS}$) | ($mA_{RMS}$) | (W) | ($V_{DC}$) | ($mA_{DC}$) | (W) | ($V_{DC}$) | ($mA_{DC}$) | (W) | (%) |
| 100% | 229.90 | 359.20 | 30.84 | 12.04 | 1998.50 | 24.07 | 5.03 | 499.56 | 2.51 | 86.17 |
| 75% | 229.91 | 286.30 | 23.11 | 12.05 | 1498.30 | 18.05 | 5.03 | 374.53 | 1.88 | 86.25 |
| 50% | 229.91 | 270.60 | 21.53 | 12.05 | 1398.30 | 16.85 | 5.03 | 349.53 | 1.76 | 86.41 |
| 25% | 229.91 | 208.30 | 15.40 | 12.05 | 998.60 | 12.04 | 5.03 | 249.52 | 1.25 | 86.30 |
| | | | | | | | | | **Average** | **86.19** |

### 10.2 ***Full Load Efficiency vs. Line***

Test Condition: Soak for 15 minutes for each line.

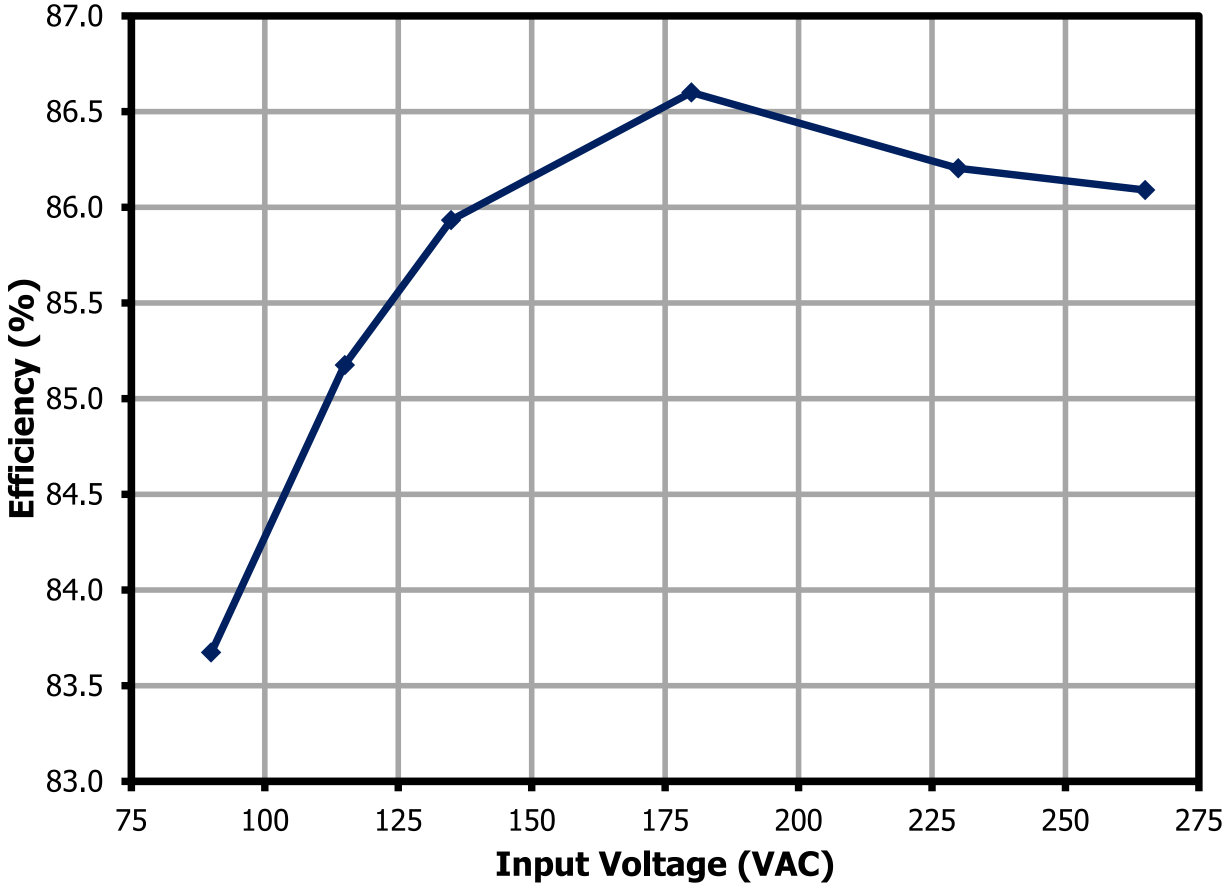



**Figure 7 –** Efficiency vs. Input Voltage.

## 10.3 *Efficiency vs. Load*

Test Condition: Soak for 15 minutes each line, and 5 minutes for each load.

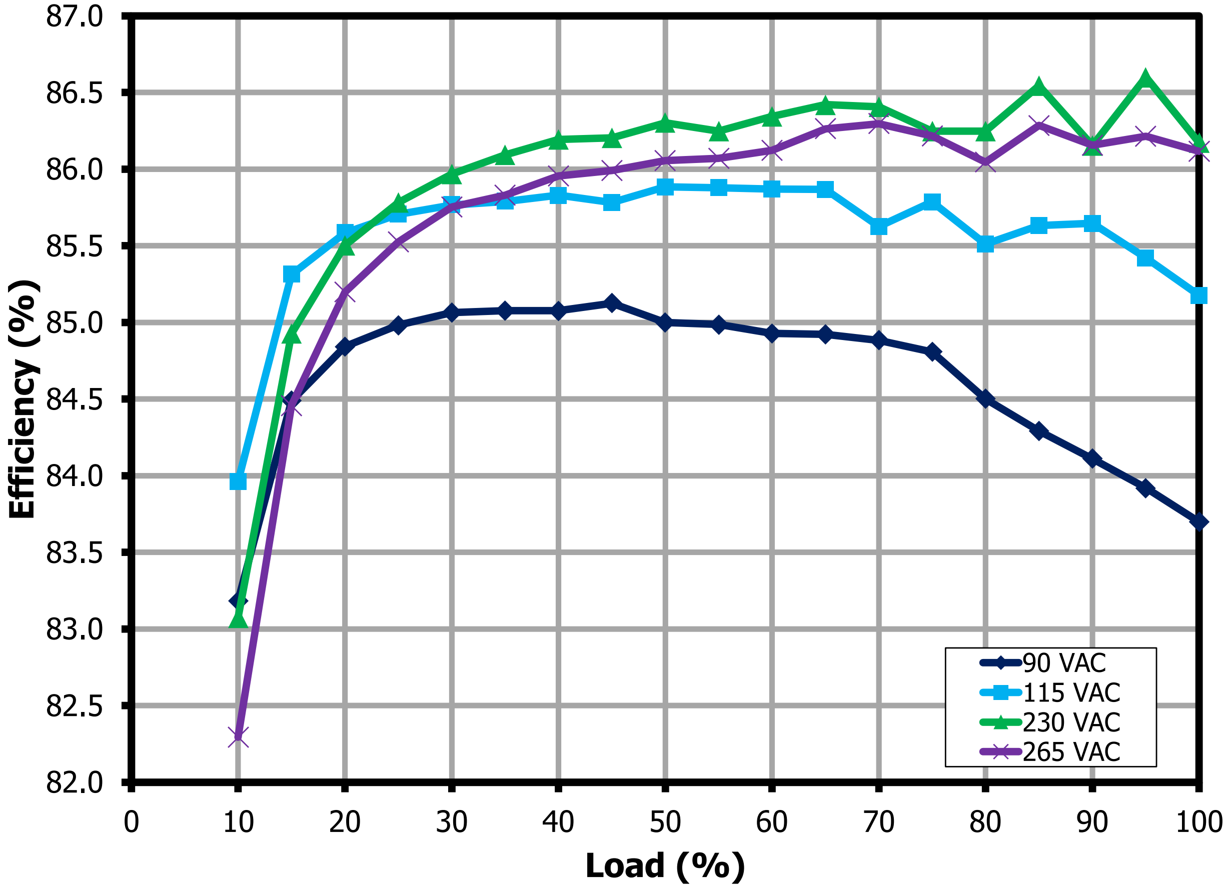



**Figure 8 –** Efficiency vs. Percentage Load.

### 10.4 *No-Load Input Power*

Test Condition: Soak for 15 minutes each line and 1 minute integration time.

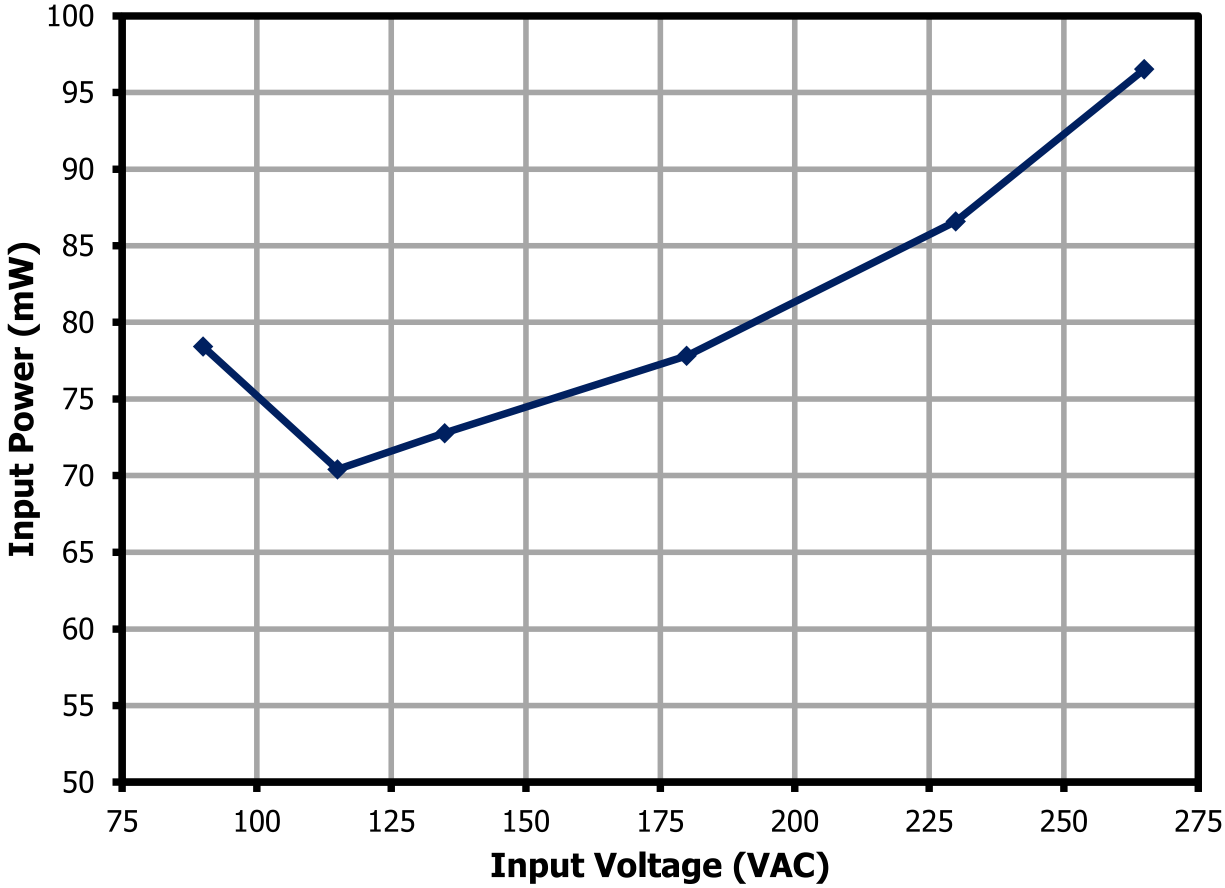



**Figure 9 –** No-Load Input Power vs. Line at Room Temperature.

### 10.5 *Line Regulation*

Test Condition: Soak for 15 minutes for each line.

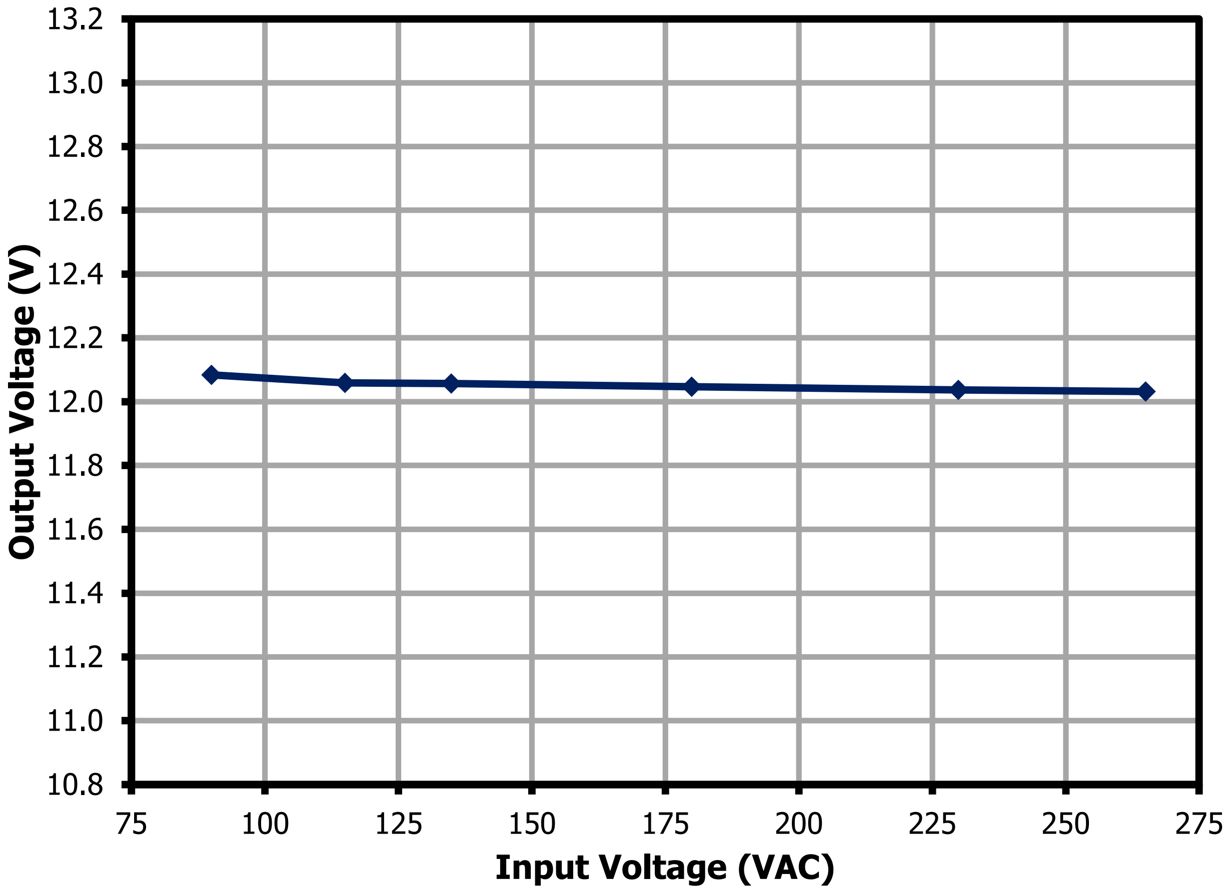



**Figure 10 –** 12 V Output Voltage vs. Line Voltage.

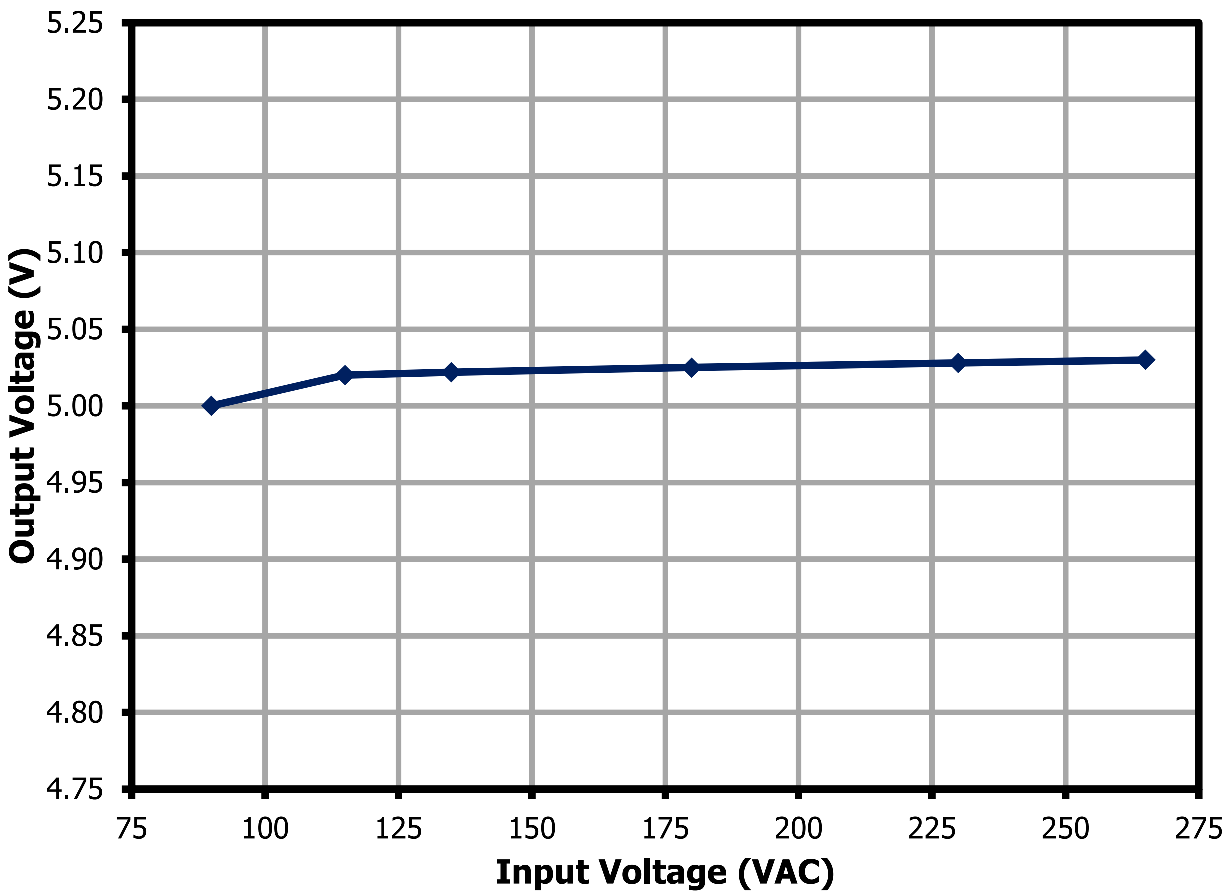



**Figure 11 –** 5 V Output Voltage vs. Line Voltage.

## 10.6 *Load Regulation*

Test Condition: Soak for 15 minutes each line, and 5 minutes for each load.

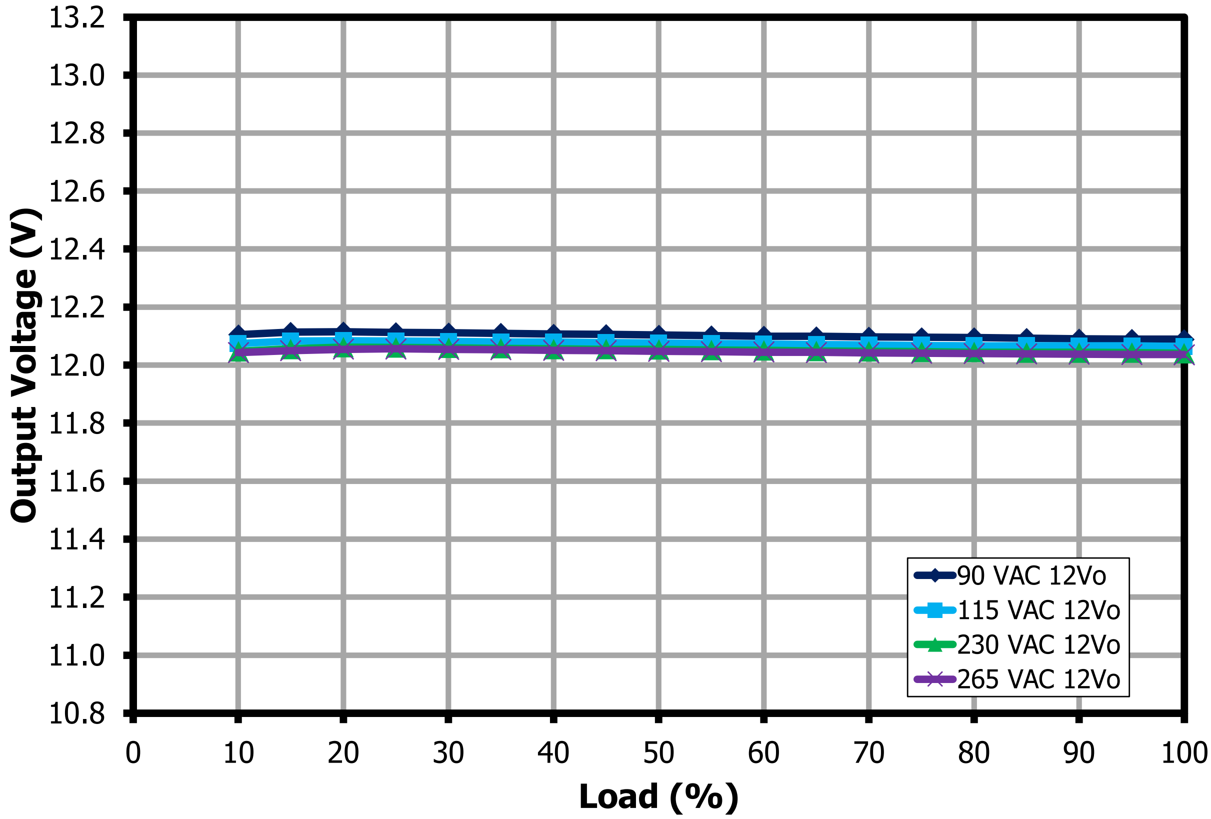



**Figure 12 –** 12 V Output Voltage vs. Percent Load.

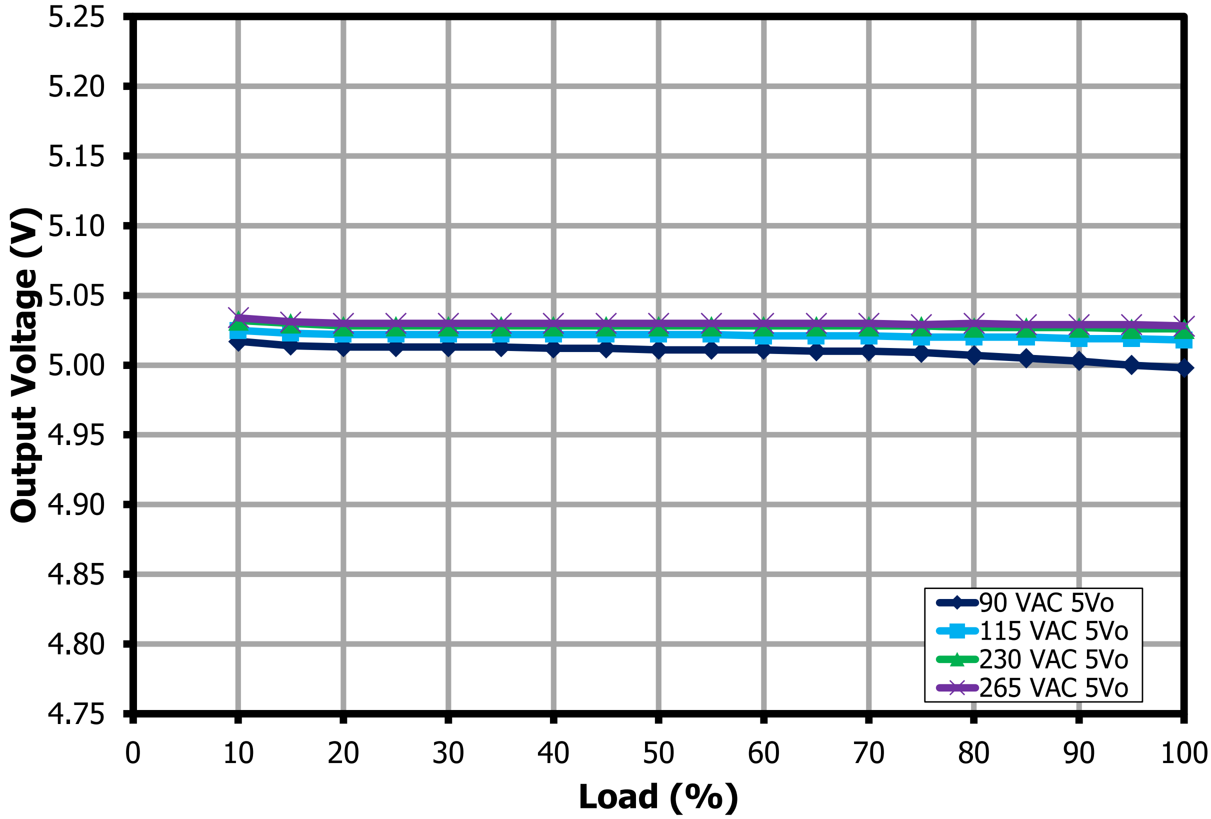



**Figure 13 –** 5 V Output Voltage vs. Percent Load.

## 10.7 *Cross Regulation*

### 10.7.1 Cross Regulation with 12 V at Minimum Load and Varying 5 V Load

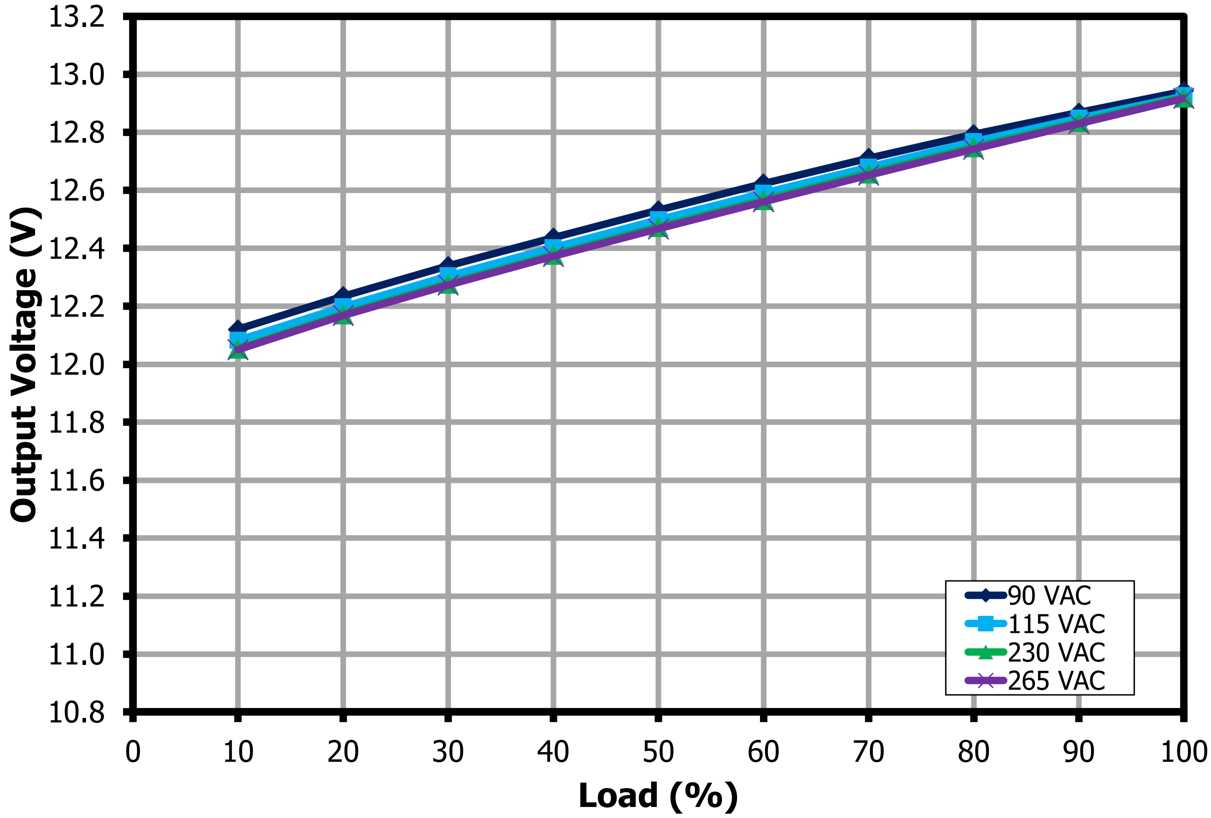



**Figure 14 –** 12 V Output Voltage vs. Percent Load.

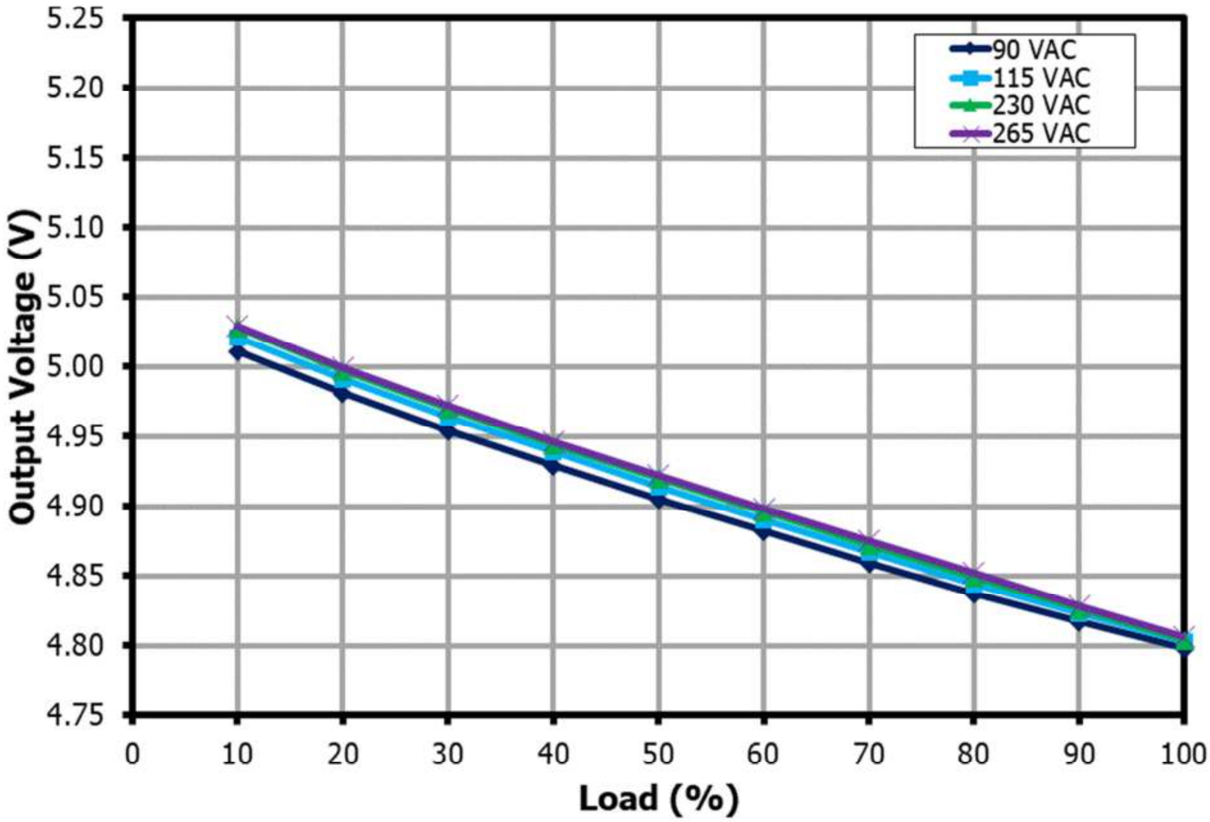



**Figure 15 –** 5 V Output Voltage vs. Percent Load.

### 10.7.2 Cross Regulation with 12 V at Full Load and Varying 5 V Load

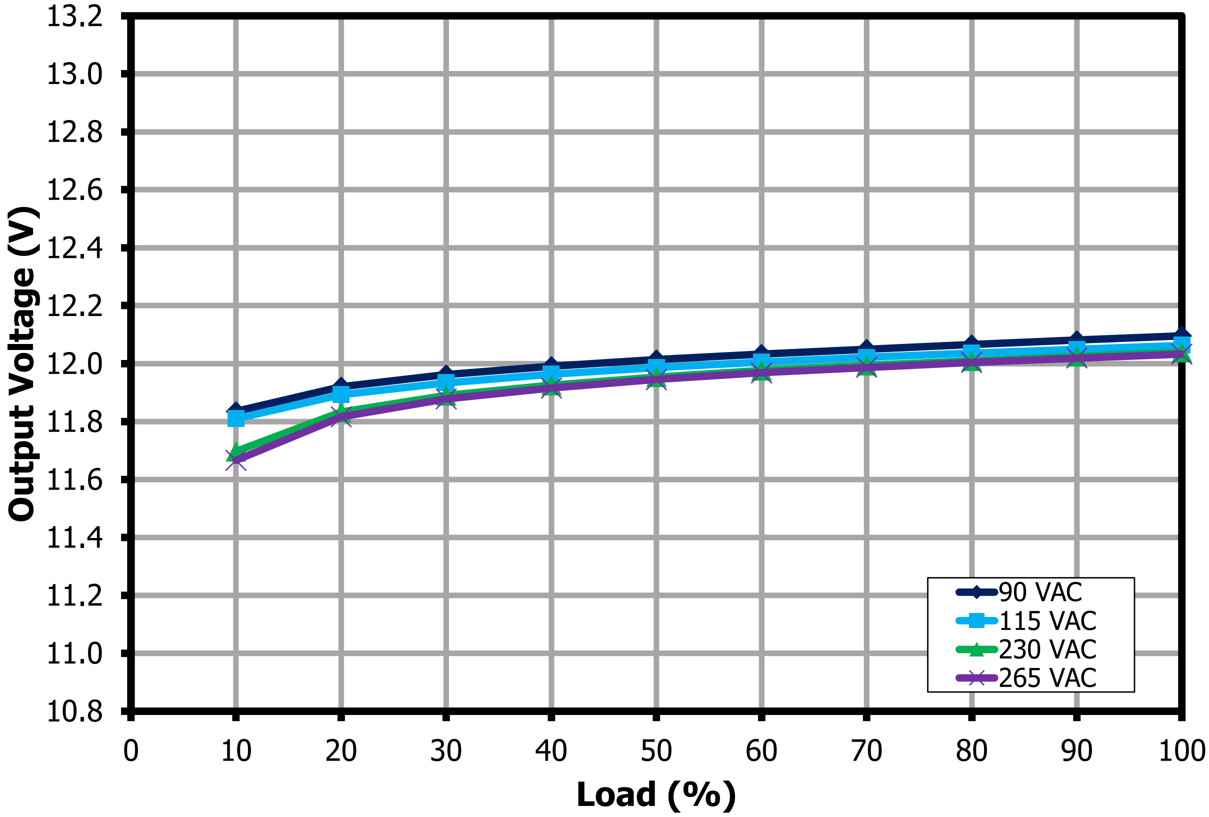



**Figure 16 –** 12 V Output Voltage vs. Percent Load.

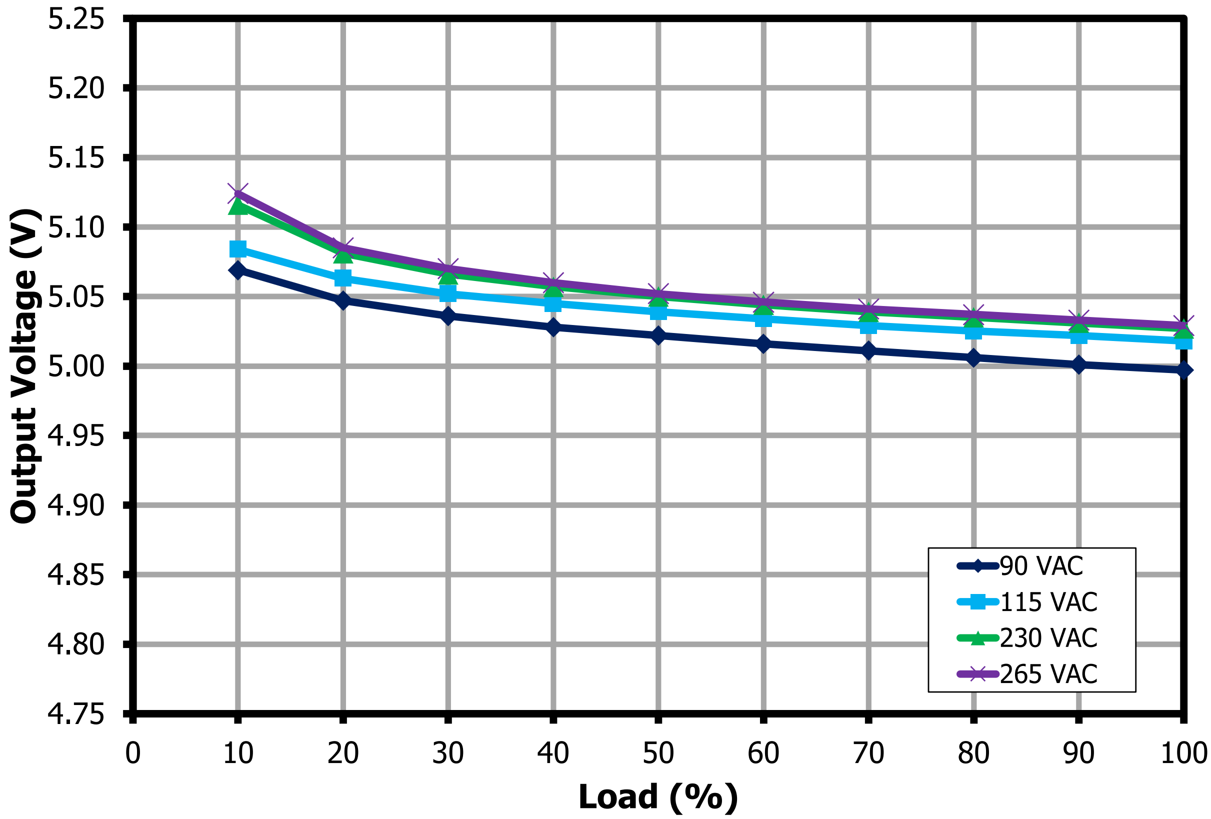



**Figure 17 –** 5 V Output Voltage vs. Percent Load.

### 10.7.3 Cross Regulation with 5 V at Minimum Load and Varying 12 V Load

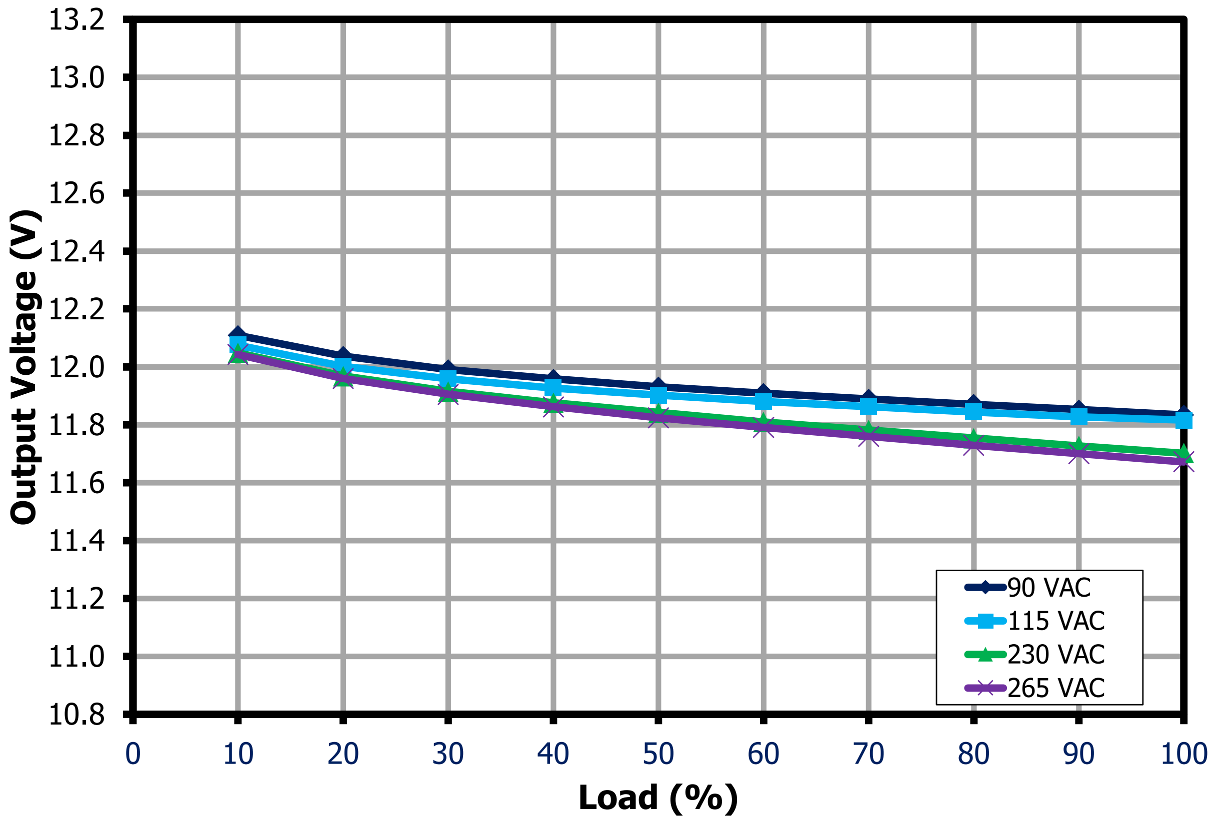



**Figure 18 –** 12 V Output Voltage vs. Percent Load.

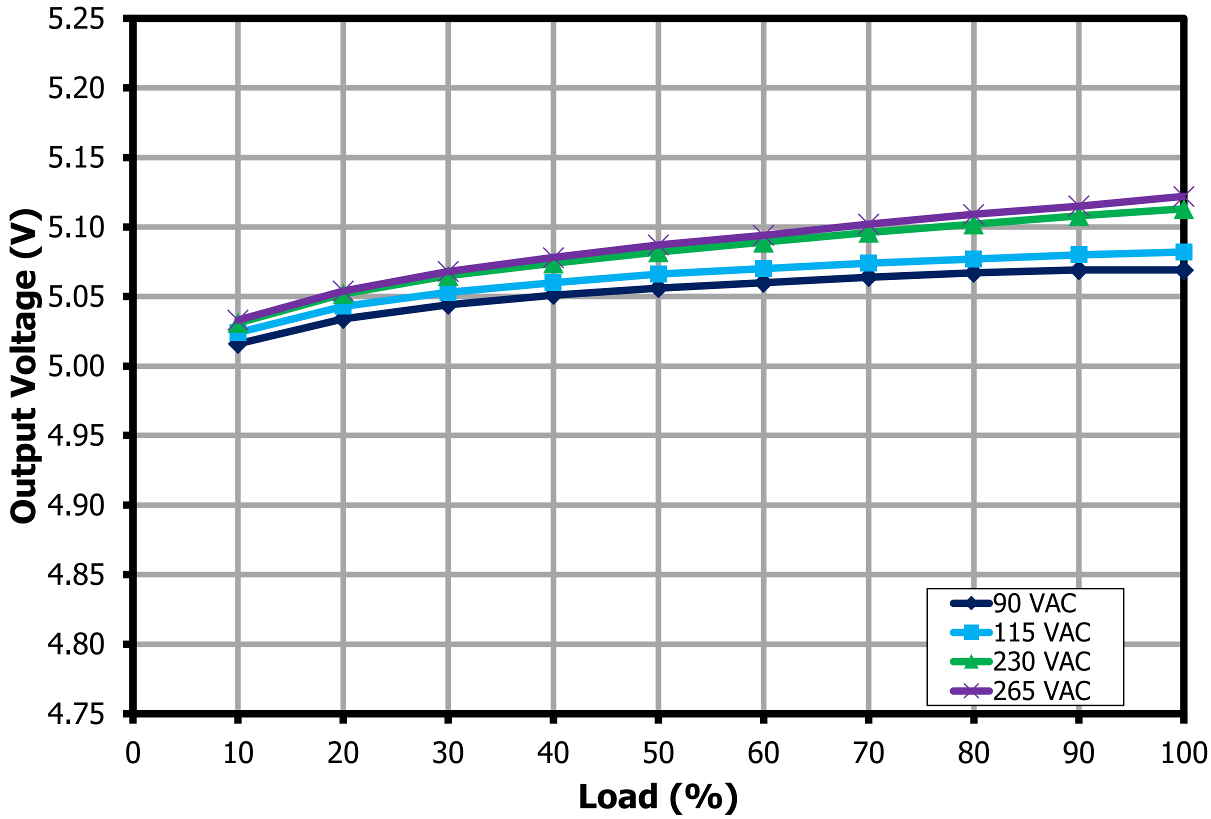



**Figure 19 –** 5 V Output Voltage vs. Percent Load.

### 10.7.4 Cross Regulation with 5 V at Full Load and Varying 12 V Load

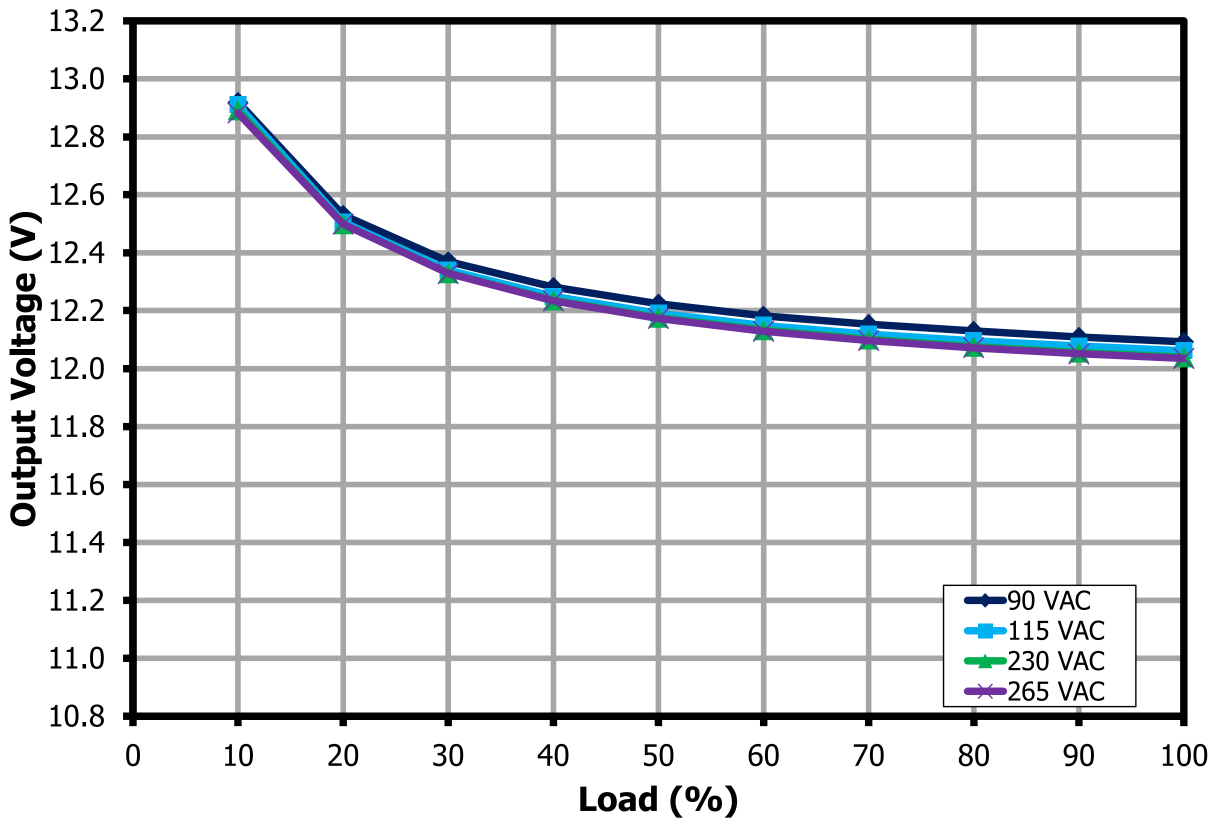



**Figure 20 –** 12 V Output Voltage vs. Percent Load.

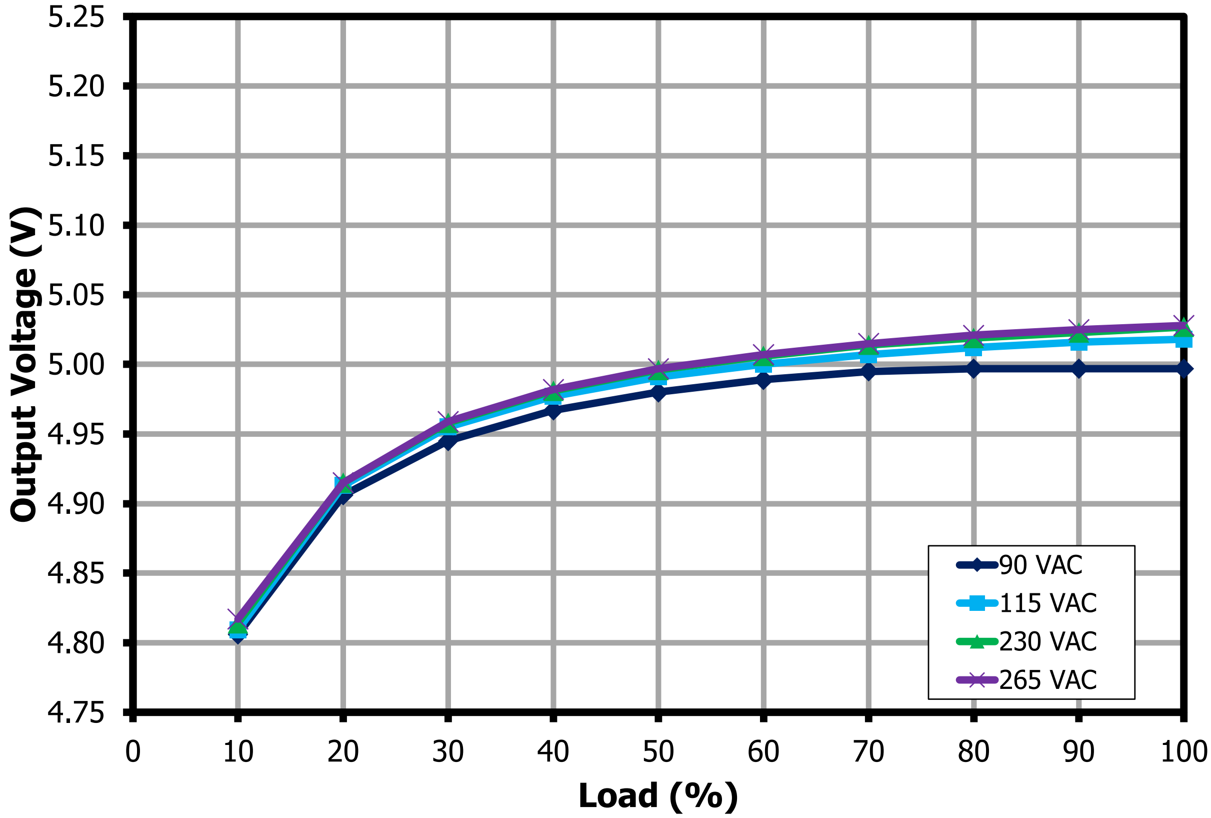



**Figure 21 –** 5 V Output Voltage vs. Percent Load.

# 11 Waveforms

## 11.1 *Load Transient Response*

Test Condition: Dynamic load frequency = 100 Hz, Duty cycle = 50 %
Slew Rate = 0.8 A / µs

### 11.1.1 12 V Transient 10% - 100% Load Change (5 V, 100% Load)

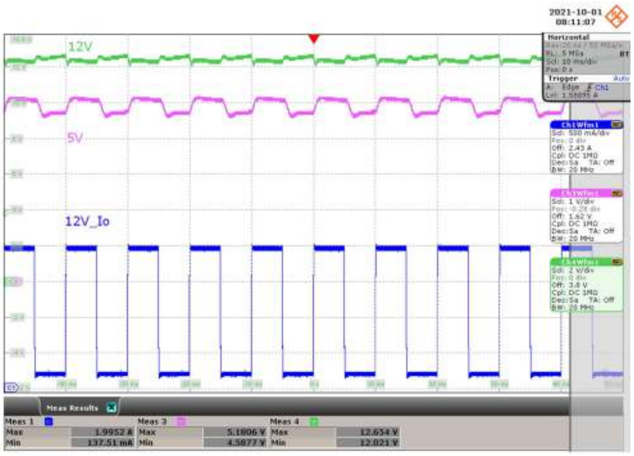



**Figure 22 –** 90 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.654 V, $V_{MIN}$: 12.021 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1806 V, $V_{MIN}$: 4.5877 V.

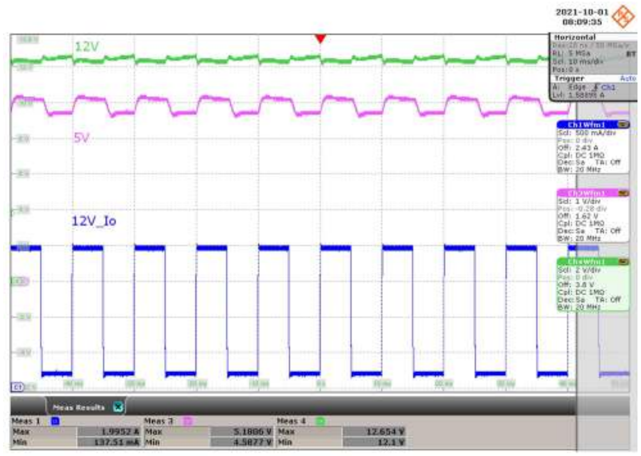



**Figure 23 –** 115 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.654 V, $V_{MIN}$: 12.1 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1806 V, $V_{MIN}$: 4.5877 V.

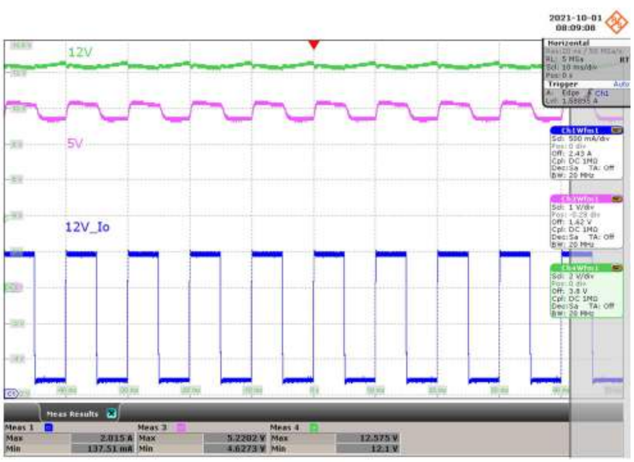



**Figure 24 –** 230 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.575 V, $V_{MIN}$: 12.1 V.
5 $V_{OUT}$: $V_{MAX}$: 5.2202 V, $V_{MIN}$: 4.6273 V.

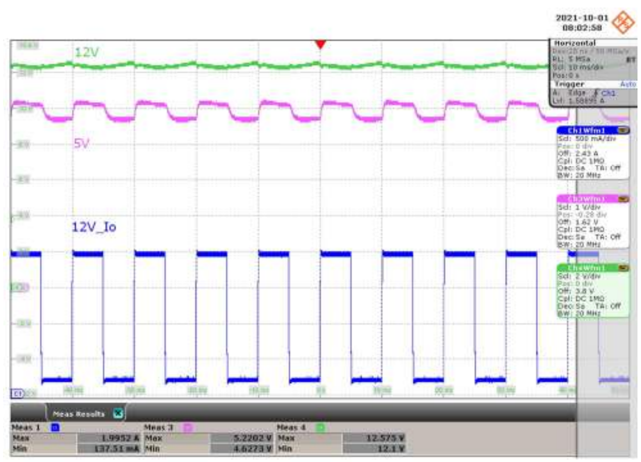



**Figure 25 –** 265 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.575 V, $V_{MIN}$: 12.1 V.
5 $V_{OUT}$: $V_{MAX}$: 5.2202 V, $V_{MIN}$: 4.6273 V.

### 11.1.2 12 V Transient 50% - 100% Load Change (5 V, 100% Load)

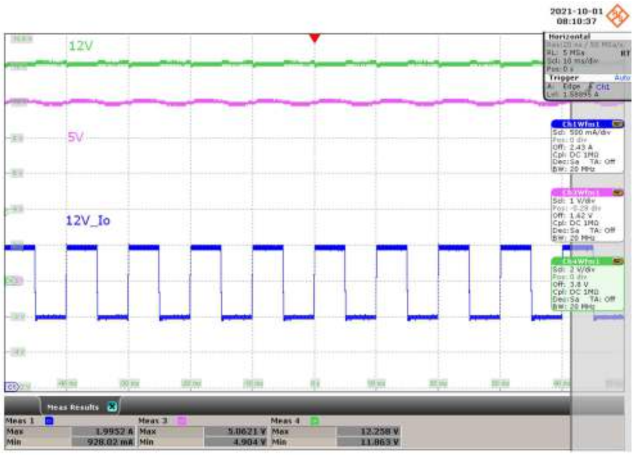



**Figure 26 –** 90 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.258 V, $V_{MIN}$: 11.863 V.
5 $V_{OUT}$: $V_{MAX}$: 5.0621 V, $V_{MIN}$: 4.904 V.

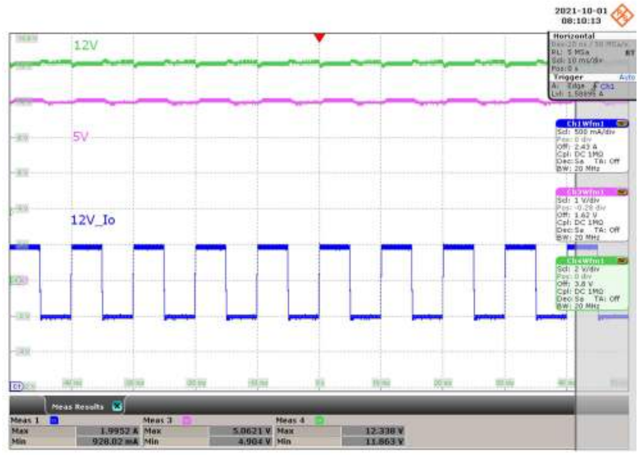



**Figure 27 –** 115 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.338 V, $V_{MIN}$: 11.863 V.
5 $V_{OUT}$: $V_{MAX}$: 5.0621 V, $V_{MIN}$: 4.904 V.

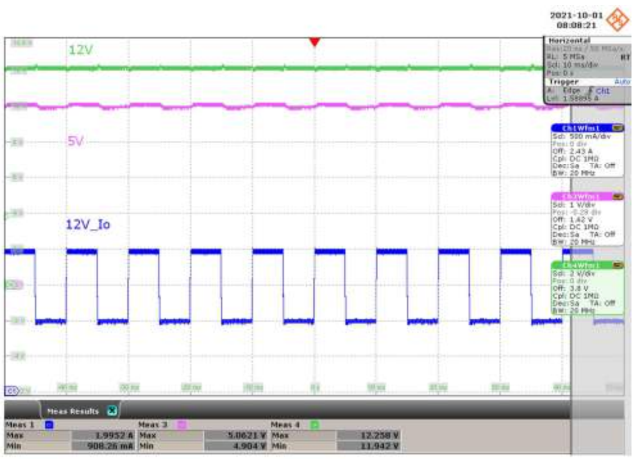



**Figure 28 –** 230 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.258 V, $V_{MIN}$: 11.942 V.
5 $V_{OUT}$: $V_{MAX}$: 5.0621 V, $V_{MIN}$: 4.904 V.

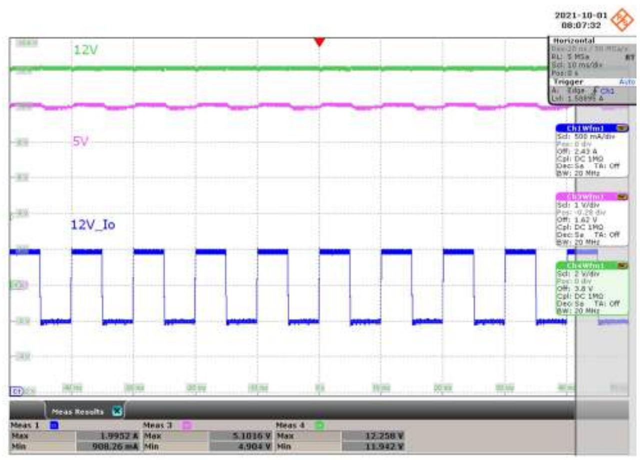



**Figure 29 –** 265 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.258 V, $V_{MIN}$: 11.942 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1016 V, $V_{MIN}$: 4.904 V.

### 11.1.3 12 V Transient 10% - 100% Load Change (5 V, 10% Load)

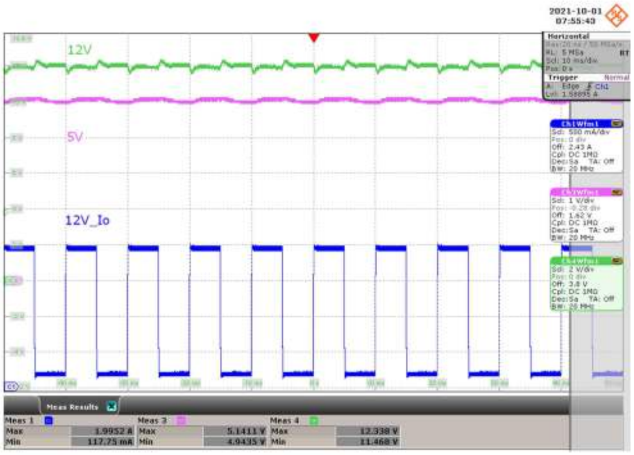



**Figure 30 –** 90 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.338 V, $V_{MIN}$: 11.468 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1411 V, $V_{MIN}$: 4.9435 V.

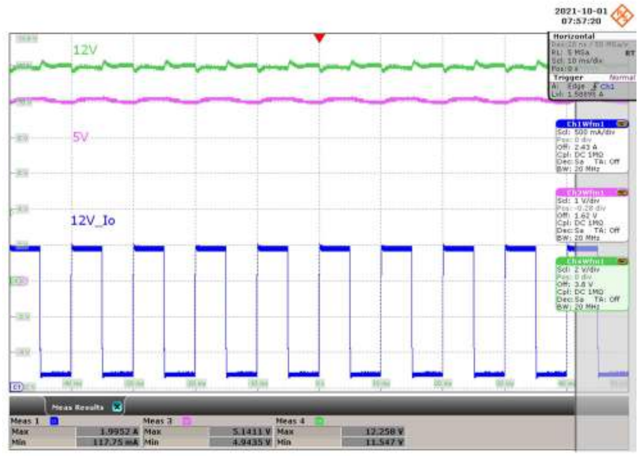



**Figure 31 –** 115 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.258 V, $V_{MIN}$: 11.547 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1411 V, $V_{MIN}$: 4.9435 V.

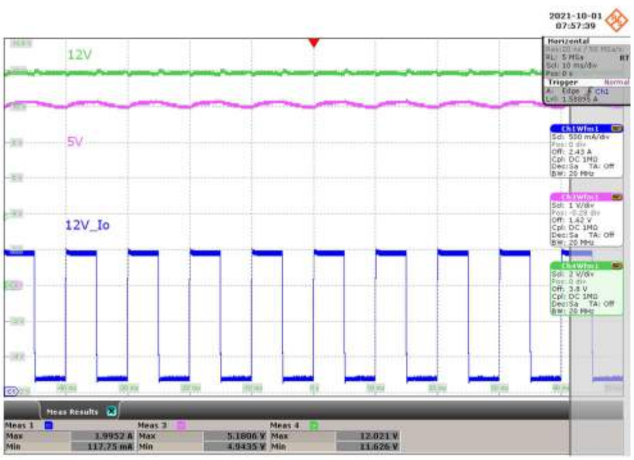



**Figure 32 –** 230 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.021 V, $V_{MIN}$: 11.626 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1806 V, $V_{MIN}$: 4.9435 V.

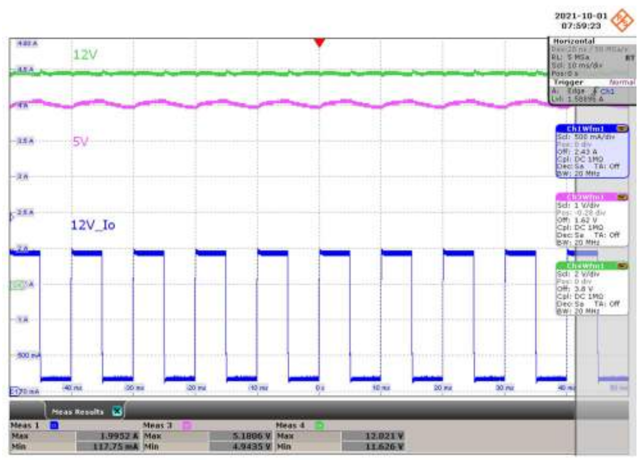



**Figure 33 –** 265 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.021 V, $V_{MIN}$: 11.626 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1806 V, $V_{MIN}$: 4.9435 V.

#### 11.1.4 12 V Transient 50% - 100% Load Change (5 V, 10% Load)

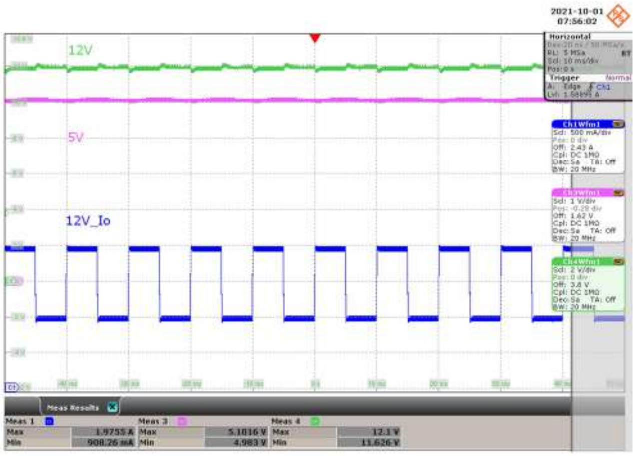



**Figure 34 –** 90 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.1 V, $V_{MIN}$: 11.626 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1016 V, $V_{MIN}$: 4.983 V.

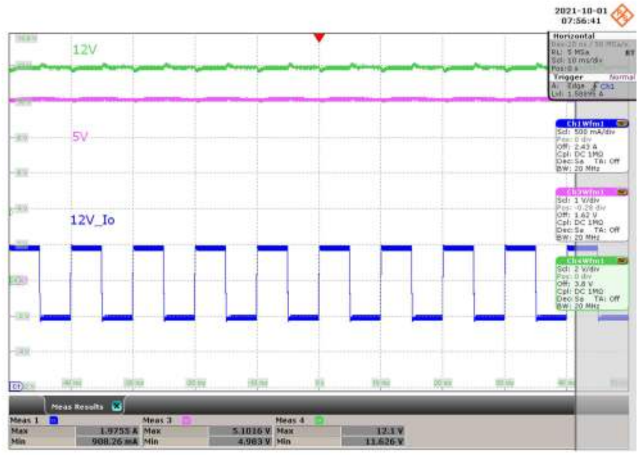



**Figure 35 –** 115 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.1 V, $V_{MIN}$: 11.626 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1016 V, $V_{MIN}$: 4.983 V.

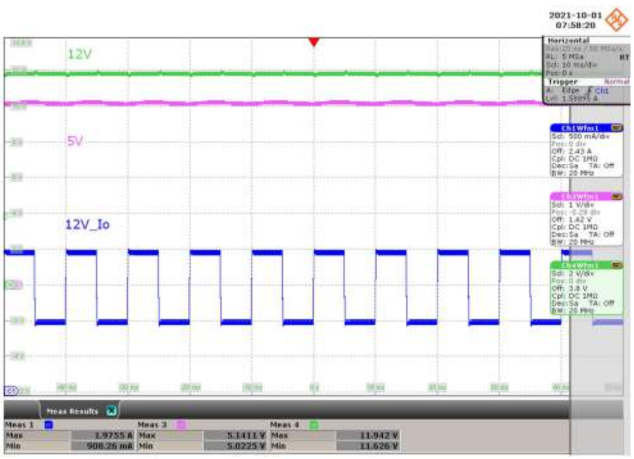



**Figure 36 –** 230 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 11.942 V, $V_{MIN}$: 11.626 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1411 V, $V_{MIN}$: 5.0225 V.

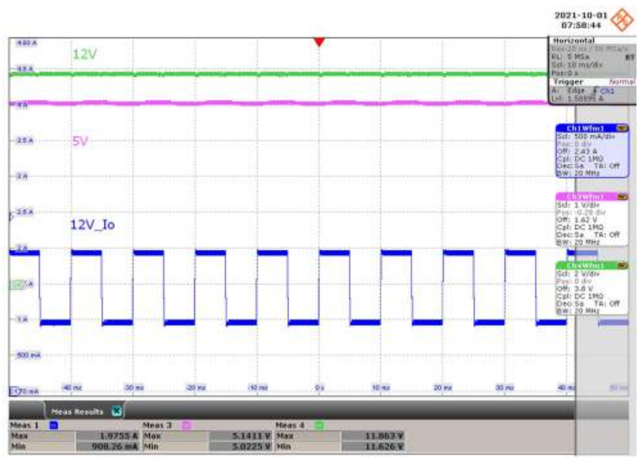



**Figure 37 –** 265 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 500 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 11.863 V, $V_{MIN}$: 11.626 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1411 V, $V_{MIN}$: 5.0225 V.

### 11.1.5 5 V Transient 10% - 100% Load Change (12 V, 100% Load)

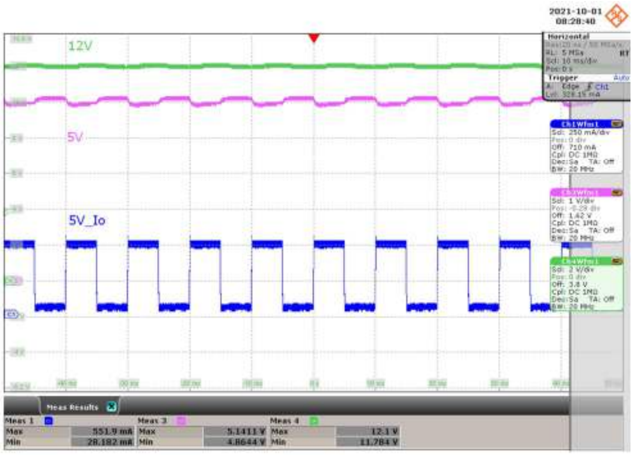



**Figure 38 –** 90 VAC 60 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.1 V, $V_{MIN}$: 11.784 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1411 V, $V_{MIN}$: 4.8644 V.

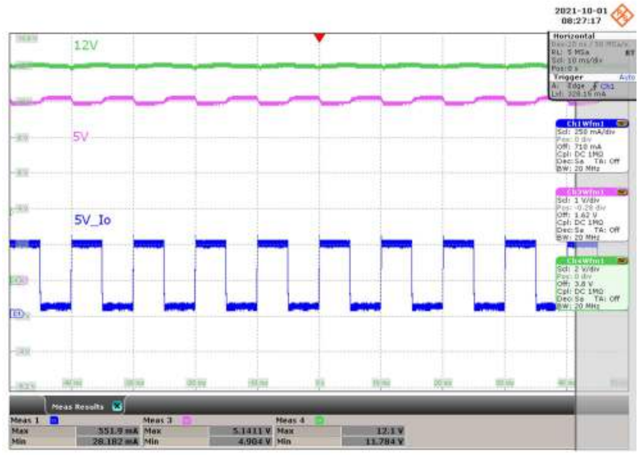



**Figure 39 –** 115 VAC 60 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.1 V, $V_{MIN}$: 11.784 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1411 V, $V_{MIN}$: 4.904 V.

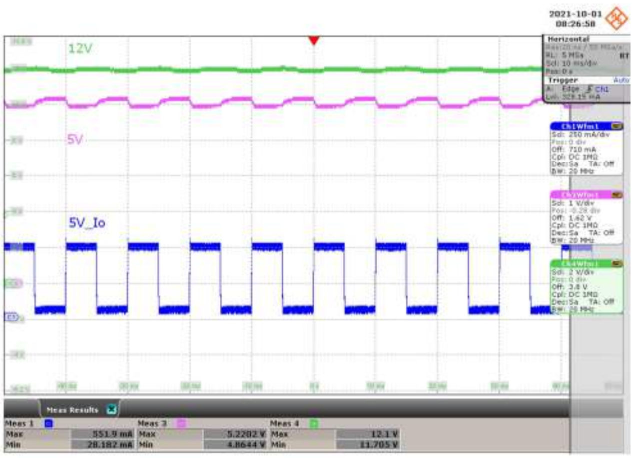



**Figure 40 –** 230 VAC 50 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.1 V, $V_{MIN}$: 11.705 V.
5 $V_{OUT}$: $V_{MAX}$: 5.2202 V, $V_{MIN}$: 4.8644 V.

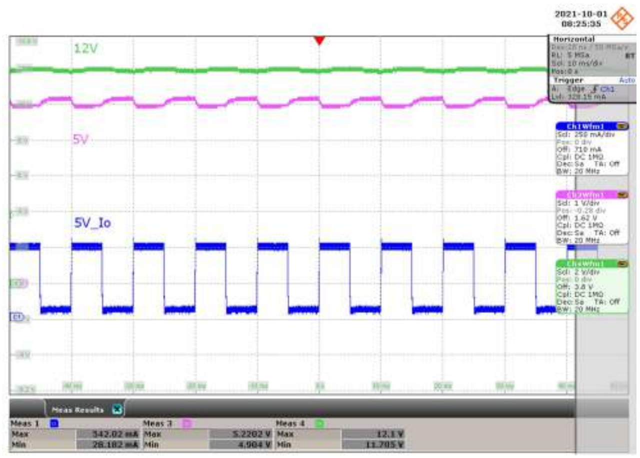



**Figure 41 –** 265 VAC 50 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.1 V, $V_{MIN}$: 11.705 V.
5 $V_{OUT}$: $V_{MAX}$: 5.2202 V, $V_{MIN}$: 4.904 V.

### 11.1.6 5 V Transient 50% - 100% Load Change (12 V, 100% Load)

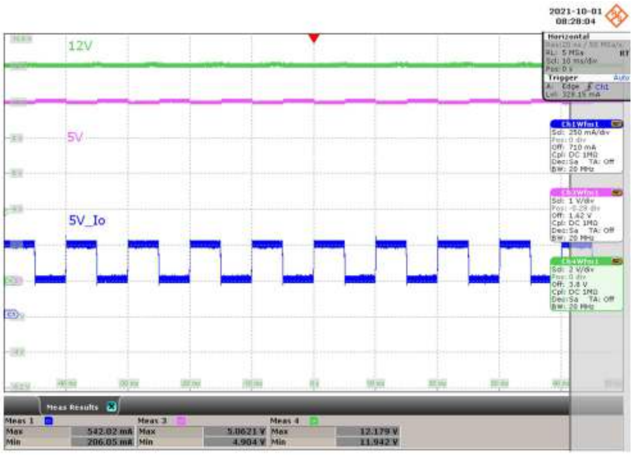



**Figure 42 –** 90 VAC 60 Hz.
CH1: $I_{5V\_OUT,}$ 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT,}$ 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.179 V, $V_{MIN}$: 11.942 V.
5 $V_{OUT}$: $V_{MAX}$: 5.0621 V, $V_{MIN}$: 4.904 V.

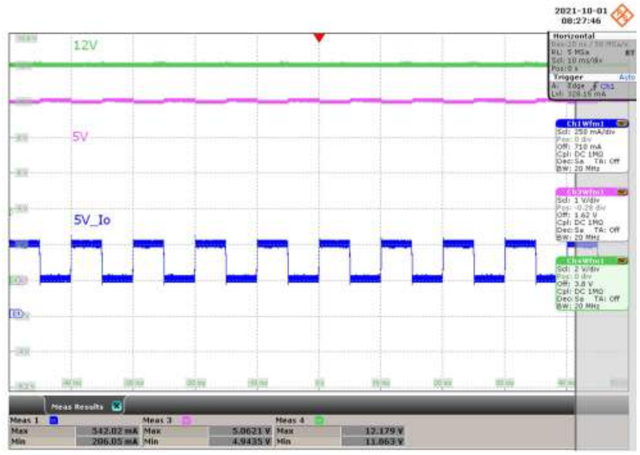



**Figure 43 –** 115 VAC 60 Hz.
CH1: $I_{5V\_OUT,}$ 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT,}$ 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.179 V, $V_{MIN}$: 11.863 V.
5 $V_{OUT}$: $V_{MAX}$: 5.0621 V, $V_{MIN}$: 4.9435 V.

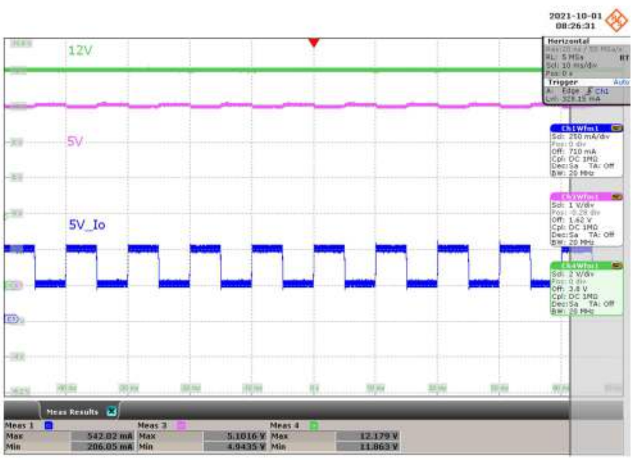



**Figure 44 –** 230 VAC 50 Hz.
CH1: $I_{5V\_OUT,}$ 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT,}$ 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.179 V, $V_{MIN}$: 11.863 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1016 V, $V_{MIN}$: 4.9435 V.

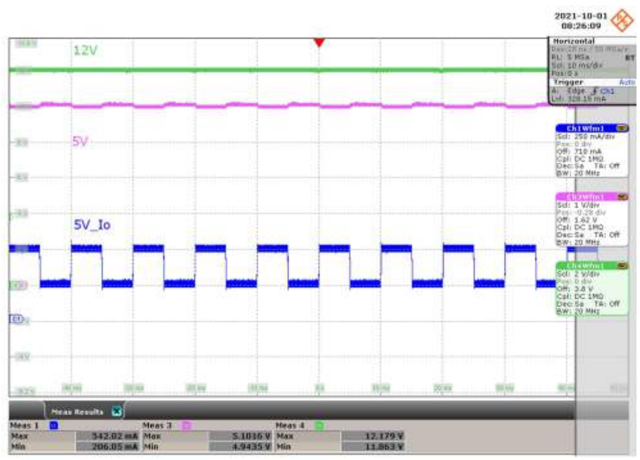



**Figure 45 –** 265 VAC 50 Hz.
CH1: $I_{5V\_OUT,}$ 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT,}$ 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.179 V, $V_{MIN}$: 11.863 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1016 V, $V_{MIN}$: 4.9435 V.

### 11.1.7 5 V Transient 10% - 100% Load Change (12 V, 10% Load)

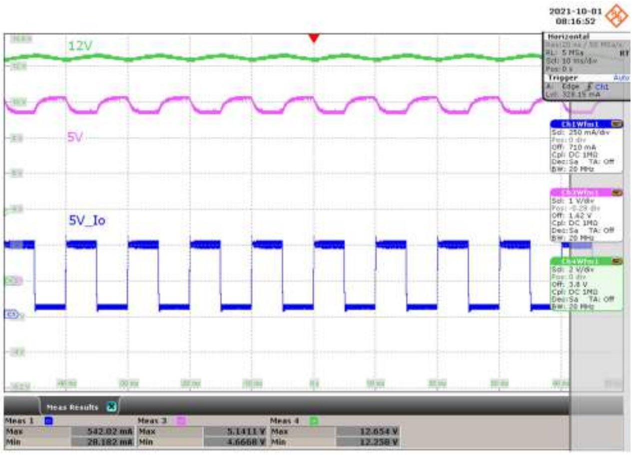



**Figure 46 –** 90 VAC 60 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.654 V, $V_{MIN}$: 12.258 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1411 V, $V_{MIN}$: 4.6668 V.

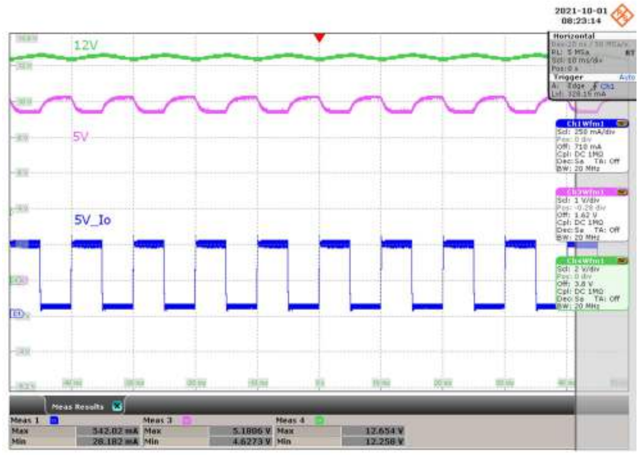



**Figure 47 –** 115 VAC 60 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.654 V, $V_{MIN}$: 12.258 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1806 V, $V_{MIN}$: 4.6273 V.

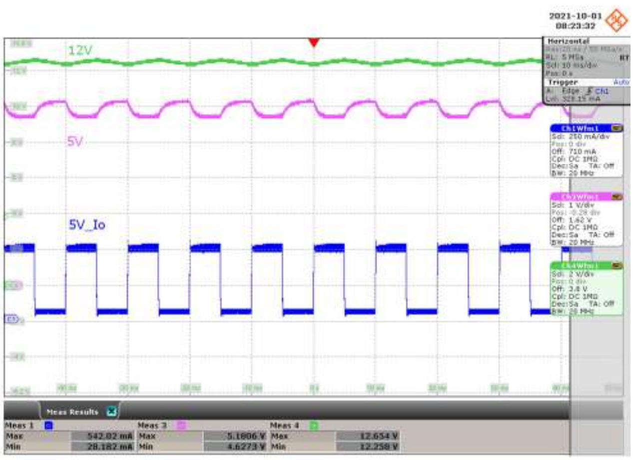



**Figure 48 –** 230 VAC 50 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.654 V, $V_{MIN}$: 12.258 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1806 V, $V_{MIN}$: 4.6273 V.

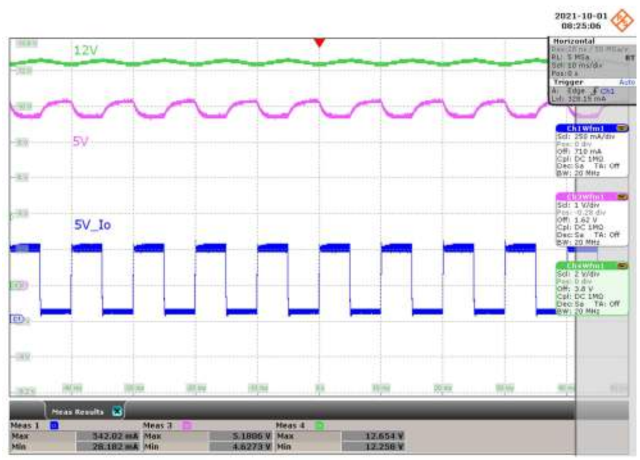



**Figure 49 –** 265 VAC 50 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.654 V, $V_{MIN}$: 12.258 V.
5 $V_{OUT}$: $V_{MAX}$: 5.1806 V, $V_{MIN}$: 4.6273 V.

### 11.1.8 5 V Transient 50% - 100% Load Change (12 V, 10% Load)

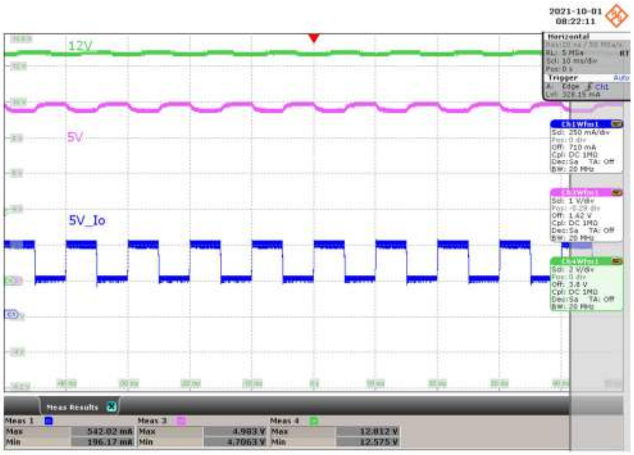



**Figure 50 –** 90 VAC 60 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.812 V, $V_{MIN}$: 12.575 V.
5 $V_{OUT}$: $V_{MAX}$: 4.983 V, $V_{MIN}$: 4.7063 V.

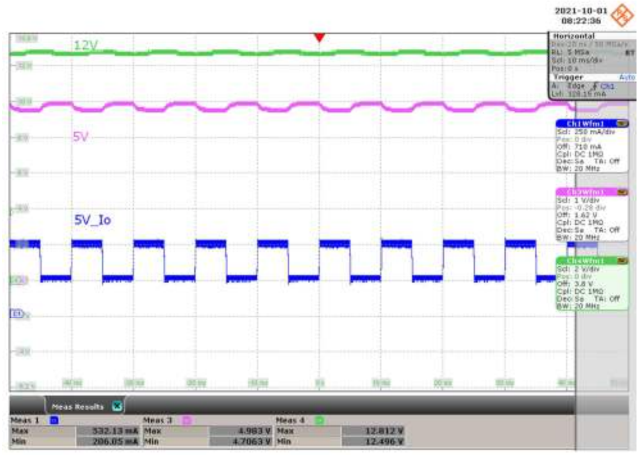



**Figure 51 –** 115 VAC 60 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.812 V, $V_{MIN}$: 12.496 V.
5 $V_{OUT}$: $V_{MAX}$: 4.983 V, $V_{MIN}$: 4.7063 V.

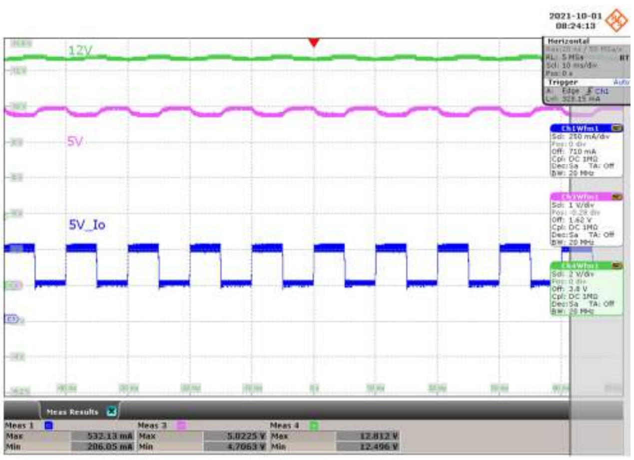



**Figure 52 –** 230 VAC 50 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.812 V, $V_{MIN}$: 12.496 V.
5 $V_{OUT}$: $V_{MAX}$: 5.0225 V, $V_{MIN}$: 4.7063 V.

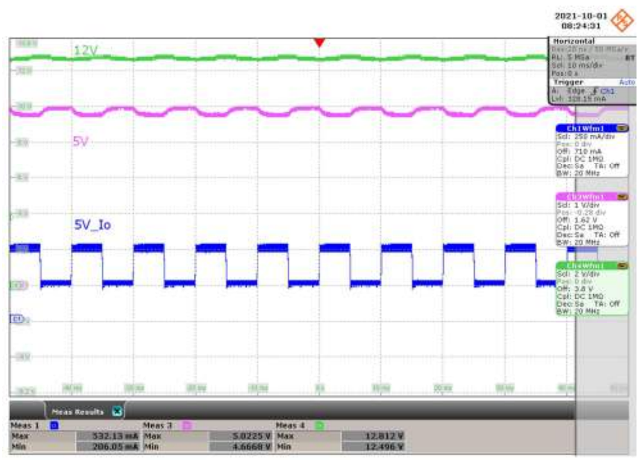



**Figure 53 –** 265 VAC 50 Hz.
CH1: $I_{5V\_OUT}$, 250 mA / div., 10 ms / div.
CH3: $V_{5V\_OUT}$, 1 V / div., 10 ms / div.
CH4: $V_{12V\_OUT}$, 2 V / div., 10 ms / div.
12 $V_{OUT}$: $V_{MAX}$: 12.812 V, $V_{MIN}$: 12.496 V.
5 $V_{OUT}$: $V_{MAX}$: 5.0225 V, $V_{MIN}$: 4.6668 V.

## 11.2 ***Output Start-up***

### 11.2.1 Full Load CC Mode

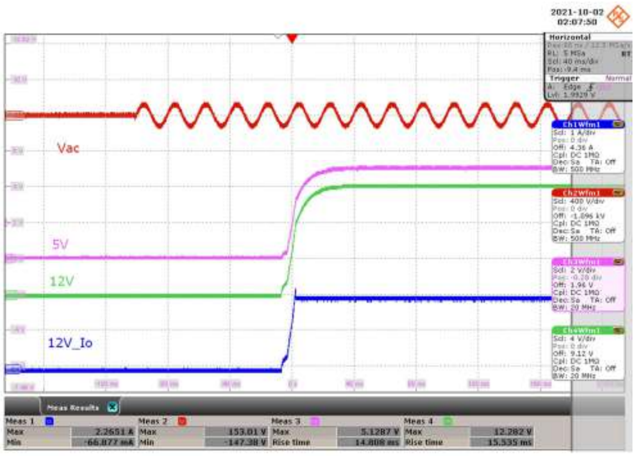



**Figure 54 –** 90 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 15.53 ms., $V_{5V}$= 14.80 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

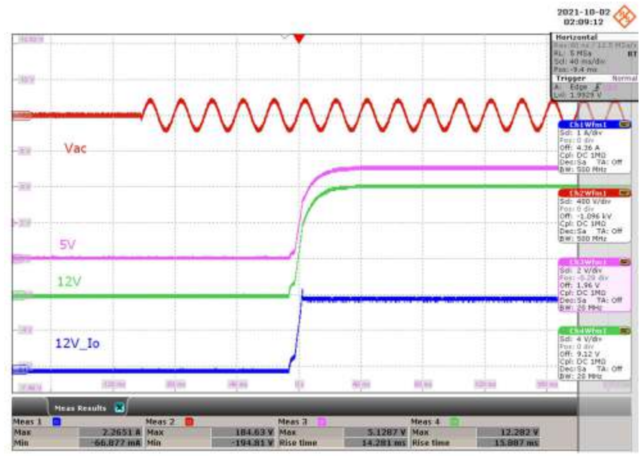



**Figure 55 –** 115 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 15.88 ms., $V_{5V}$= 14.28 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.128 V.

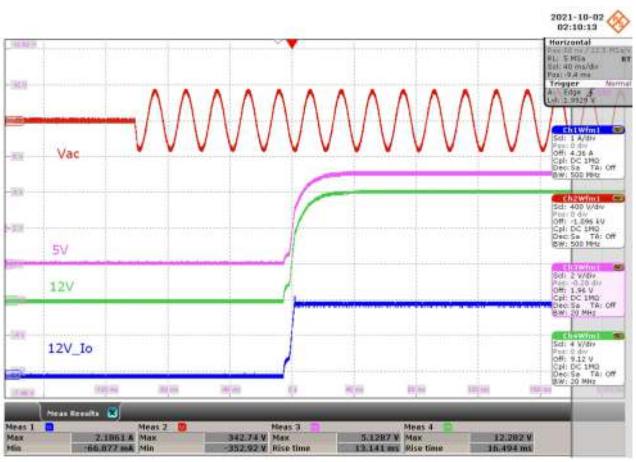



**Figure 56 –** 230 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 16.49 ms., $V_{5V}$= 13.14 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

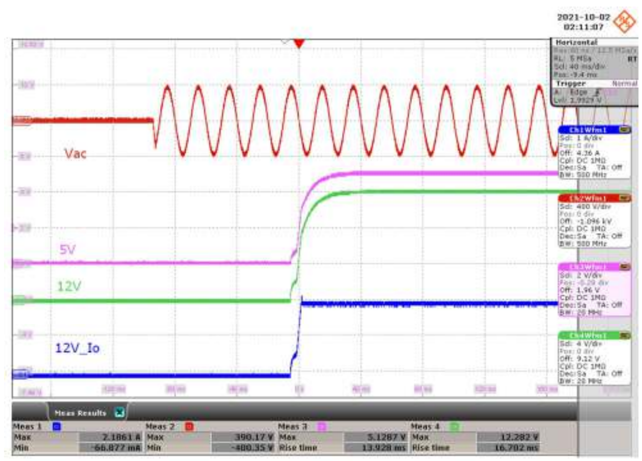



**Figure 57 –** 265 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 16.70 ms., $V_{5V}$= 13.92 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

### 11.2.2 Full Load CR Mode

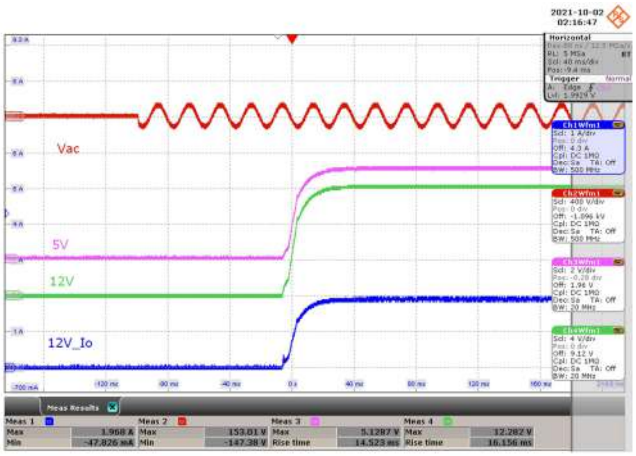



**Figure 58 –** 90 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 16.15 ms., $V_{5V}$= 14.52 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

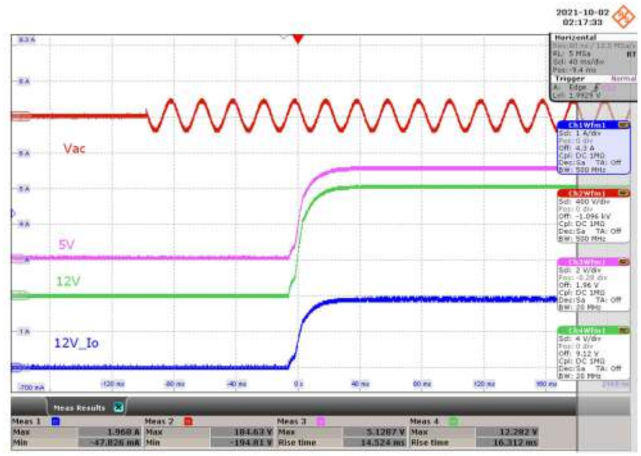



**Figure 59 –** 115 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 16.31 ms., $V_{5V}$= 14.52 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

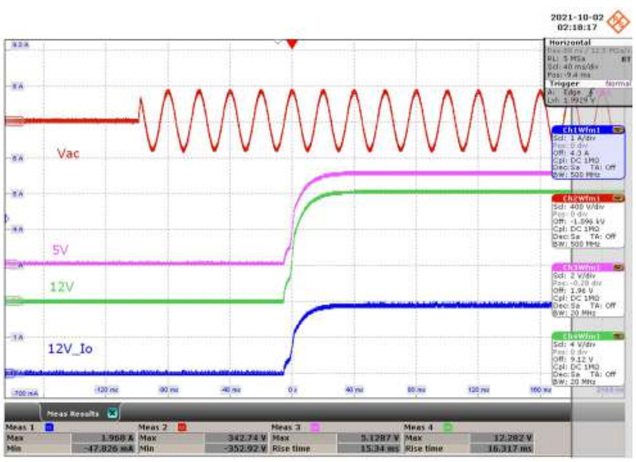



**Figure 60 –** 230 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 16.31 ms., $V_{5V}$= 15.34 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

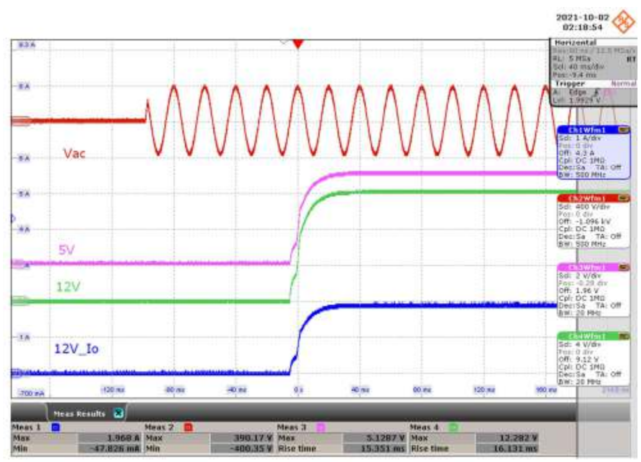



**Figure 61 –** 265 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 16.13 ms., $V_{5V}$= 15.35 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

### 11.2.3 0% Load

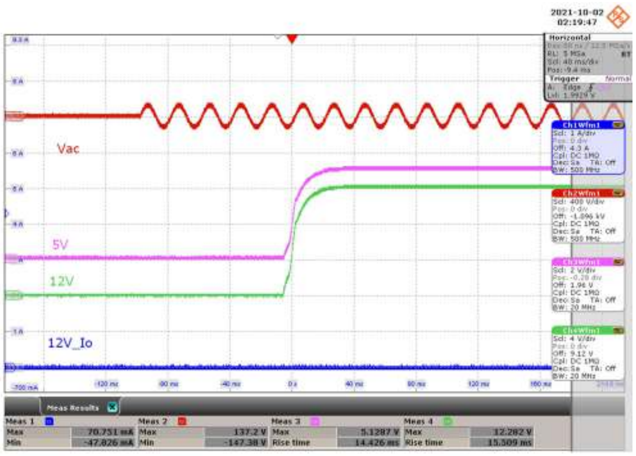



**Figure 62 –** 90 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 15.50 ms., $V_{5V}$= 14.42 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

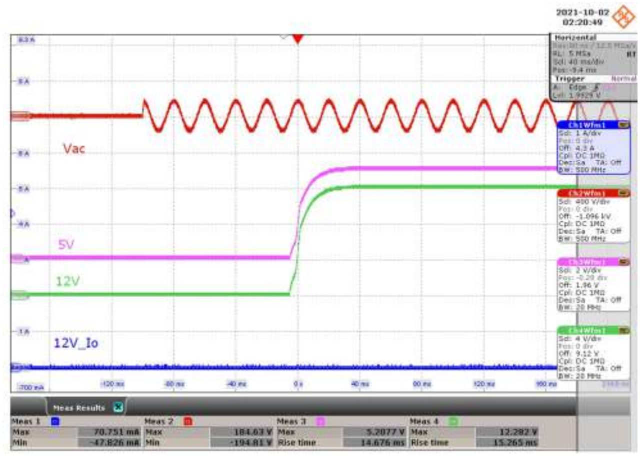



**Figure 63 –** 115 VAC 60 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 15.26 ms., $V_{5V}$= 14.67 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.2077 V.

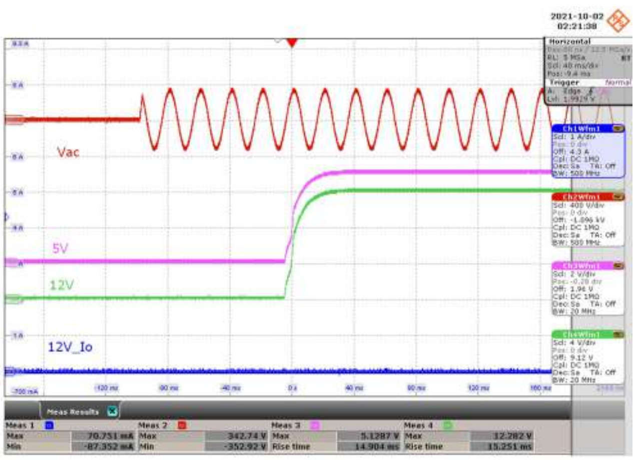



**Figure 64 –** 230 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 15.25 ms., $V_{5V}$= 14.90 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.1287 V.

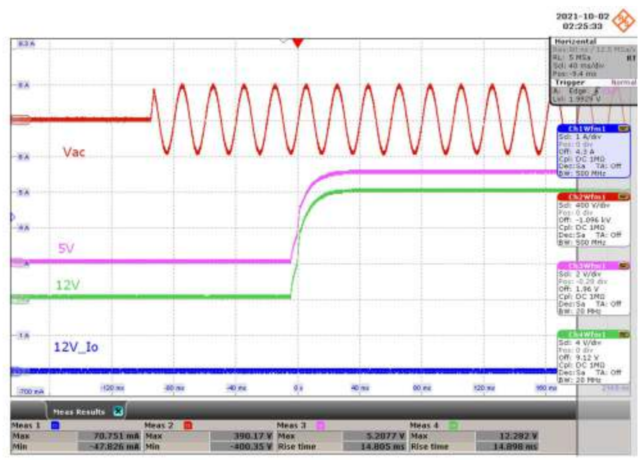



**Figure 65 –** 265 VAC 50 Hz.
CH1: $I_{12V\_OUT}$, 1 A / div., 40 ms / div.
CH2: $V_{IN}$, 400 V / div., 40 ms / div.
CH3: $V_{5V\_OUT}$, 2 V / div., 40 ms / div.
CH4: $V_{12V\_OUT}$, 4 V / div., 40 ms / div.
Rise Time: $V_{12V}$= 14.89 ms., $V_{5V}$= 14.80 ms.
$V_{MAX}$: $V_{12V}$= 12.282 V, $V_{5V}$= 5.2077 V.

## 11.3 *Switching Waveforms*

### 11.3.1 Primary MOSFET Drain-Source Voltage and Current at Normal Operation

#### 11.3.1.1 100% Load

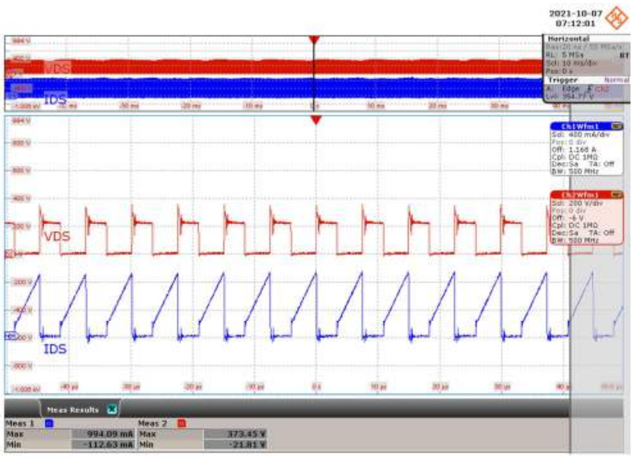



**Figure 66 –** 90 VAC 60 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 373.45 V, $I_{DS(MAX)}$ = 0.994 A.

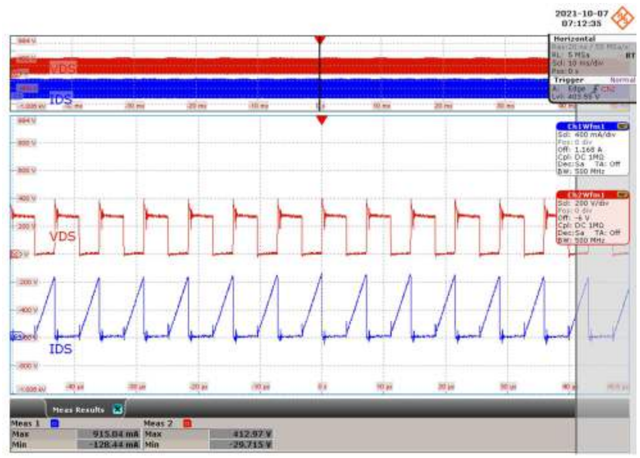



**Figure 67 –** 115 VAC 60 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 412.97 V, $I_{DS(MAX)}$ = 0.915 A.

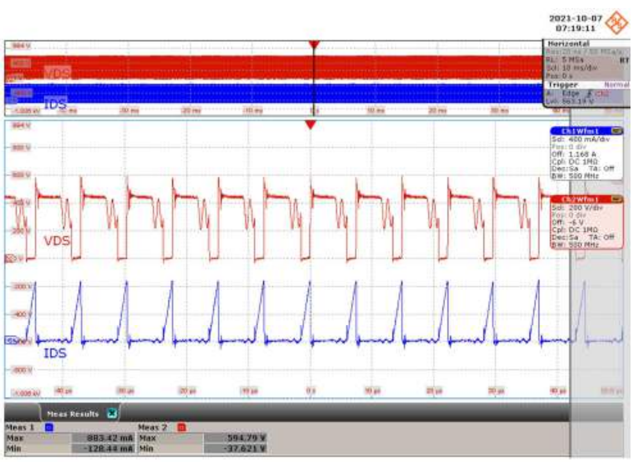



**Figure 68 –** 230 VAC 50 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 594.79 V, $I_{DS(MAX)}$ = 0.883 A.

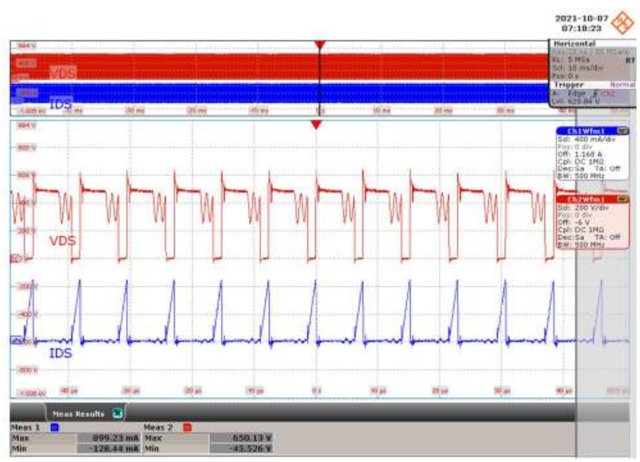



**Figure 69 –** 265 VAC 50 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 650.13 V, $I_{DS(MAX)}$ = 0.899 A.

### 11.3.1.2 10% Load

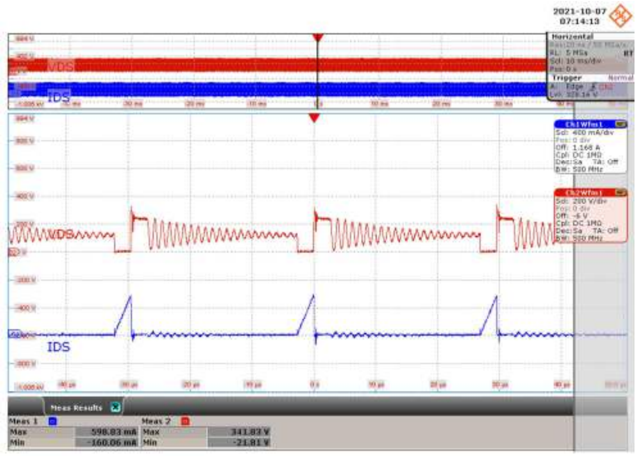



**Figure 70 –** 90 VAC 60 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 341.83 V, $I_{DS(MAX)}$ = 0.598 A.

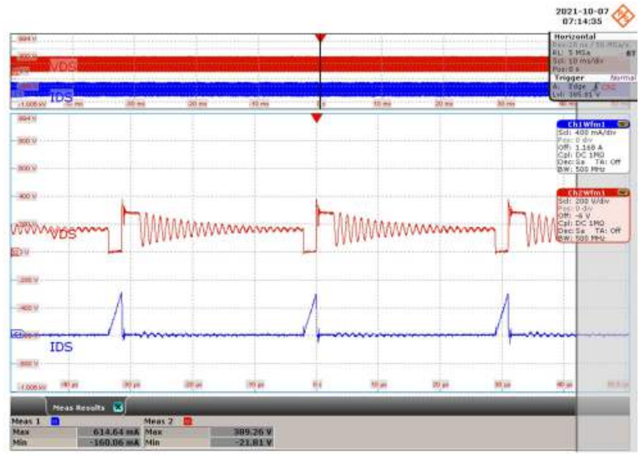



**Figure 71 –** 115 VAC 60 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 389.26 V, $I_{DS(MAX)}$ = 0.614 A.

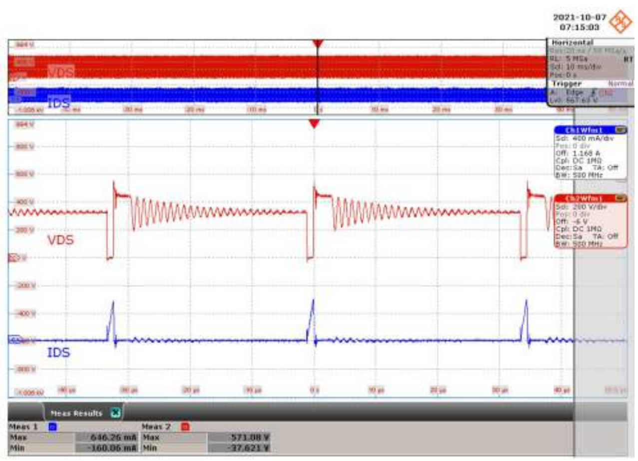



**Figure 72 –** 230 VAC 50 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 571.08 V, $I_{DS(MAX)}$ = 0.646 A.

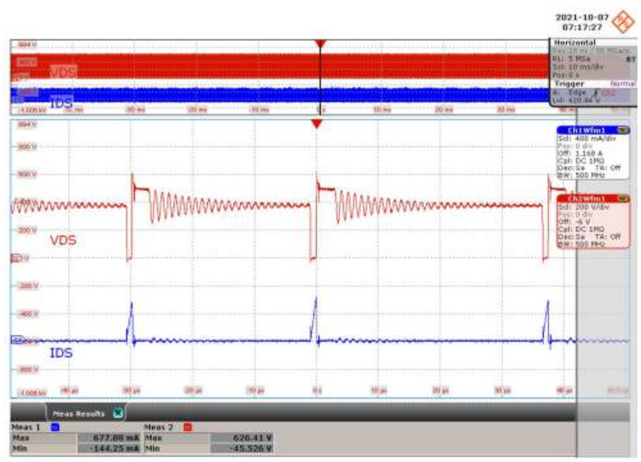



**Figure 73 –** 265 VAC 50 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 626.41 V, $I_{DS(MAX)}$ = 0.677 A.

### 11.3.2 Primary MOSFET Drain-Source Voltage and Current at Start-up Operation

#### 11.3.2.1 100% Load


**Figure 74 –** 90 VAC 60 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 373.45 V, $I_{DS(MAX)}$ = 1.1048 A.


**Figure 75 –** 115 VAC 60 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 412.97 V, $I_{DS(MAX)}$ = 1.0415 A.

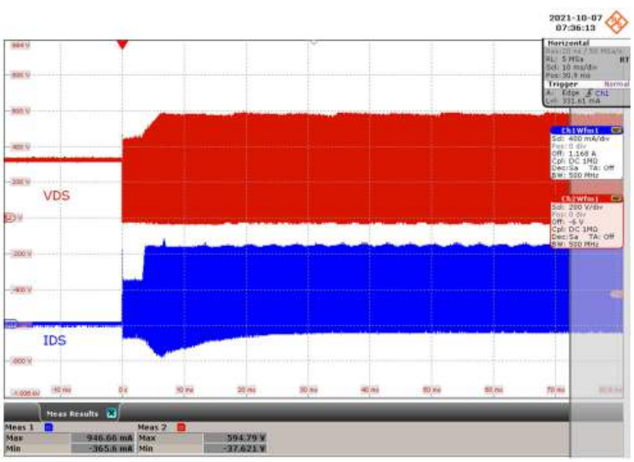



**Figure 76 –** 230 VAC 50 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 594.79 V, $I_{DS(MAX)}$ =0.946 A.

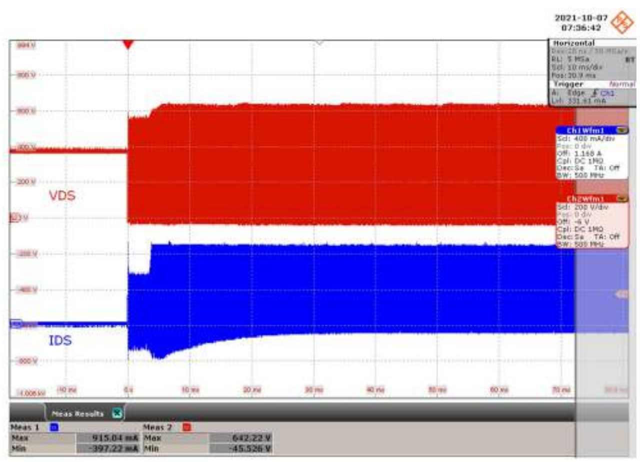



**Figure 77 –** 265 VAC 50 Hz.
CH1: $I_{DS,}$ 400 mA / div., 10 ms / div.
CH2: $V_{DS,}$ 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 642.22 V, $I_{DS(MAX)}$ = 0.915 A.

### 11.3.2.2 10% Load


**Figure 78 –** 90 VAC 60 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 349.73 V, $I_{DS(MAX)}$ = 0.756 A.

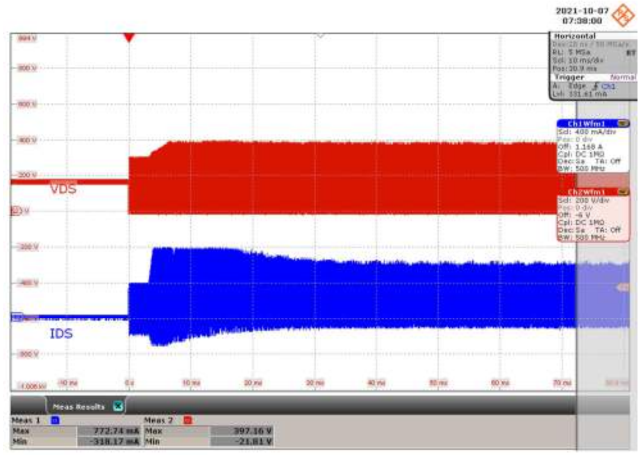



**Figure 79 –** 115 VAC 60 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 397.16 V, $I_{DS(MAX)}$ = 0.772 A.

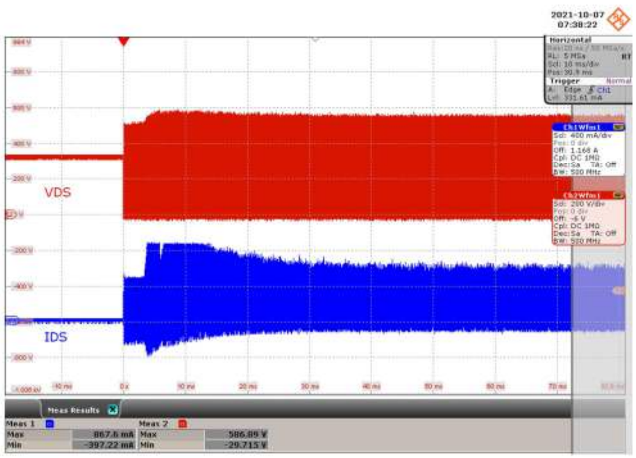



**Figure 80 –** 230 VAC 50 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 586.89 V, $I_{DS(MAX)}$ = 0.867 A.

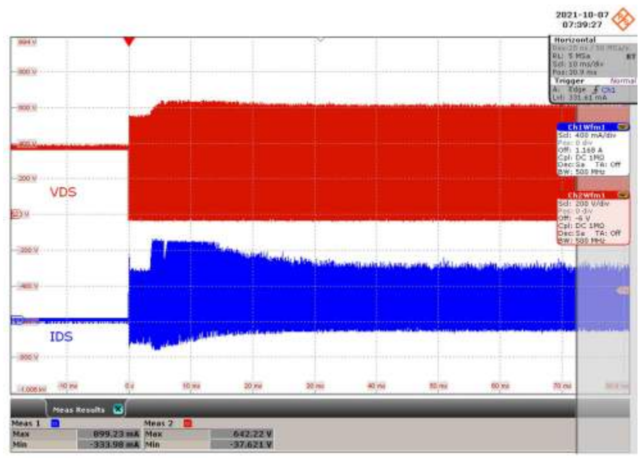



**Figure 81 –** 265 VAC 50 Hz.
CH1: $I_{DS}$, 400 mA / div., 10 ms / div.
CH2: $V_{DS}$, 200 V / div., 10 ms / div.
$V_{DS(MAX)}$ = 642.22 V, $I_{DS(MAX)}$ = 0.899 A.

### 11.3.3 12 V Freewheeling Diode Voltage and Current at Normal Operation

#### 11.3.3.1 100% Load


**Figure 82 –** 90 VAC 60 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 40.313 V, $I_{D(MEAN)}$ = 2.272 A.


**Figure 83 –** 115 VAC 60 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 41.104 V, $I_{D(MEAN)}$ = 2.2819 A.


**Figure 84 –** 230 VAC 50 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 46.637 V, $I_{D(MEAN)}$ = 2.278 A.

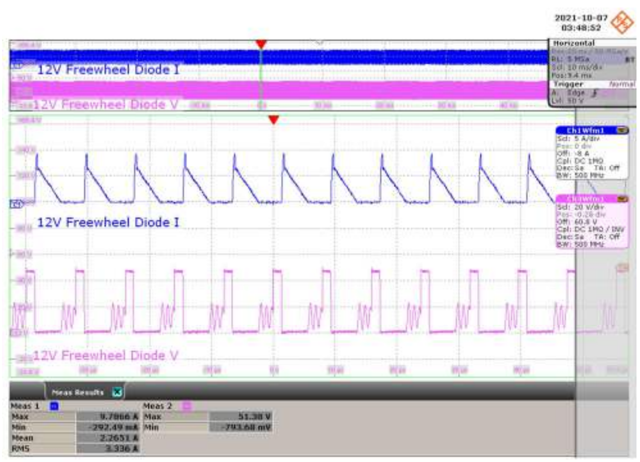



**Figure 85 –** 265 VAC 50 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 51.38 V, $I_{D(MEAN)}$ = 2.2651 A.

#### 11.3.3.2 10% Load


**Figure 86 –** 90 VAC 60 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 26.874 V, $I_{D(MEAN)}$ = 0.489 A.

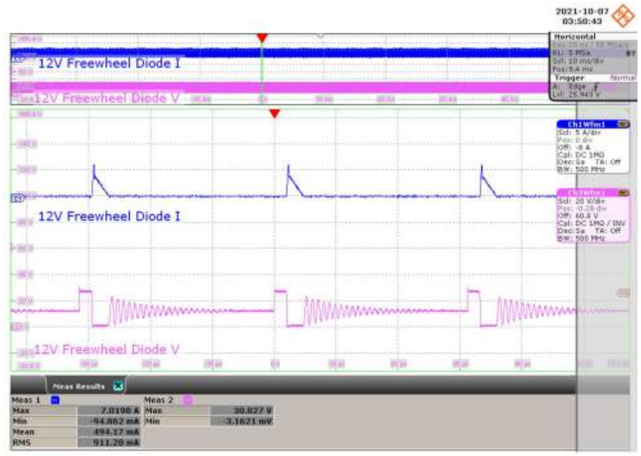



**Figure 87 –** 115 VAC 60 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 30.827 V, $I_{D(MEAN)}$ = 0.494 A.

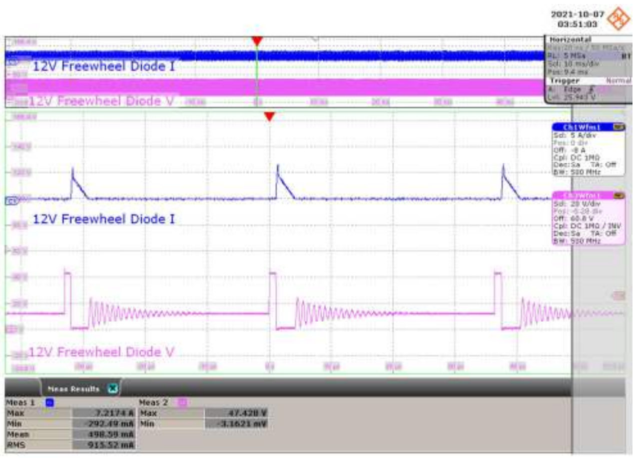



**Figure 88 –** 230 VAC 50 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 47.428 V, $I_{D(MEAN)}$ = 0.498 A.

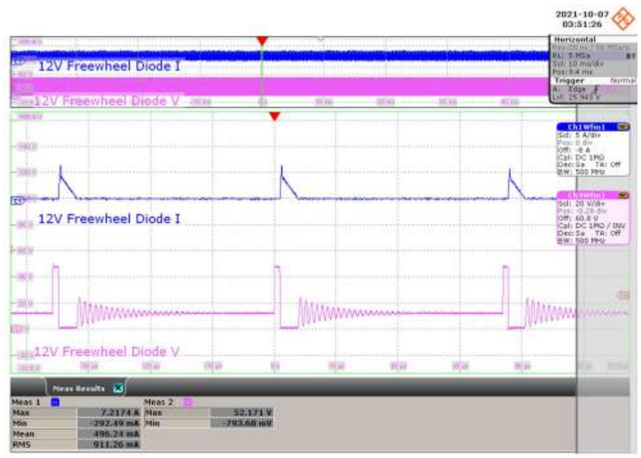



**Figure 89 –** 265 VAC 50 Hz.
CH1: $I_{12V\_Diode}$, 5 A / div., 10 ms / div.
CH3: $V_{12V\_Diode}$, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 52.171 V, $I_{D(MEAN)}$ = 0.496 A.

## 11.3.4 5 V Freewheeling Diode Voltage and Current at Normal Operation

### 11.3.4.1 100% Load


**Figure 90 –** 90 VAC 60 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 15.818 V, $I_{D(MEAN)}$ = 0.451 A.


**Figure 91 –** 115 VAC 60 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 17.399 V, $I_{D(MEAN)}$ = 0.453 A.


**Figure 92 –** 230 VAC 50 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 21.747 V, $I_{D(MEAN)}$ = 0.452 A.


**Figure 93 –** 265 VAC 50 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 24.119 V, $I_{D(MEAN)}$ = 0.454 A.

#### 11.3.4.2 10% Load

**Figure 94 –** 90 VAC 60 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 12.261 V, $I_{D(MEAN)}$ = 0.011 A.

**Figure 95 –** 115 VAC 60 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 15.028 V, $I_{D(MEAN)}$ = 0.011 A.

**Figure 96 –** 230 VAC 50 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 22.538 V, $I_{D(MEAN)}$ = 0.012 A.

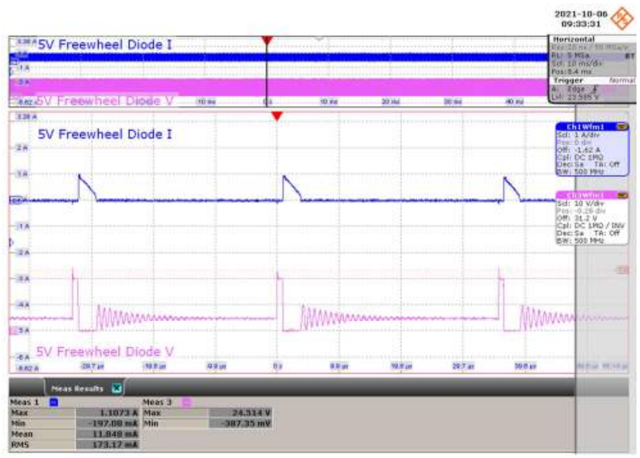


**Figure 97 –** 265 VAC 50 Hz.
CH1: $I_{5V\_Diode}$, 1 A / div., 10 ms / div.
CH3: $V_{5V\_Diode}$, 10 V / div., 10 ms / div.
Zoom: 10 µs / div.
PIV = 24.514 V, $I_{D(MEAN)}$ = 0.011 A.

## 11.4 ***Brown-In and Brown-Out***

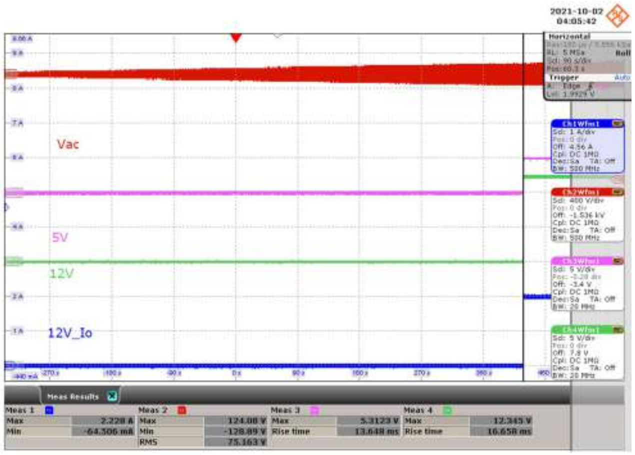



**Figure 98 –** Brown-In Full Load.
CH1: $I_{12V\_OUT}$, 1 A / div., 90 s / div.
CH2: $V_{IN}$, 400 V / div., 90 s / div.
CH3: $V_{5V\_OUT}$, 5 V / div., 90 s / div.
CH4: $V_{12V\_OUT}$, 5 V / div., 90 s / div.
$V_{IN(UV)}$ = 75.163 $V_{RMS}$.

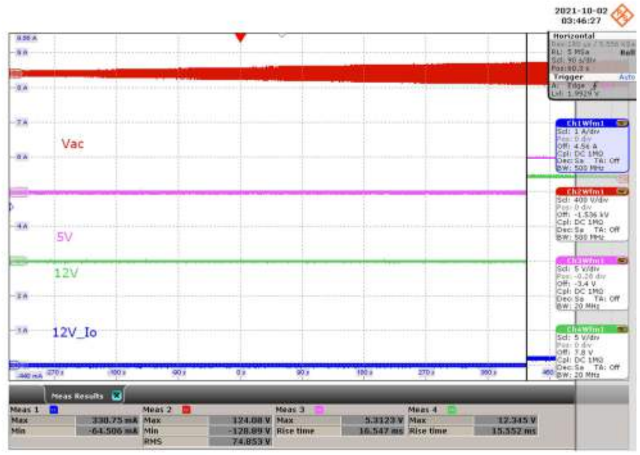



**Figure 99 –** Brown-In Minimum Load.
CH1: $I_{12V\_OUT}$, 1 A / div., 90 s / div.
CH2: $V_{IN}$, 400 V / div., 90 s / div.
CH3: $V_{5V\_OUT}$, 5 V / div., 90 s / div.
CH4: $V_{12V\_OUT}$, 5 V / div., 90 s / div.
$V_{IN(UV)}$ 74.853 $V_{RMS}$.

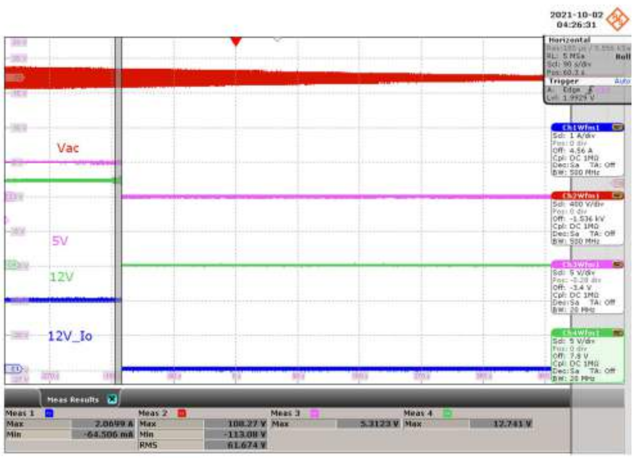



**Figure 100 –** Brown-Out Full Load.
CH1: $I_{12V\_OUT}$, 1 A / div., 90 s / div.
CH2: $V_{IN}$, 400 V / div., 90 s / div.
CH3: $V_{5V\_OUT}$, 5 V / div., 90 s / div.
CH4: $V_{12V\_OUT}$, 5 V / div., 90 s / div.
$V_{IN(UV)}$ = 61.674 $V_{RMS}$.

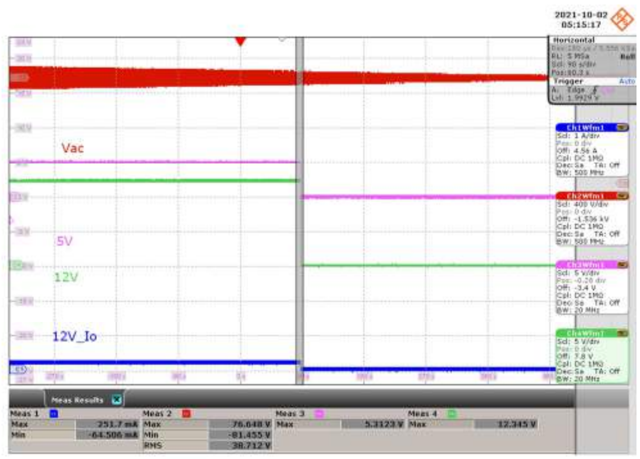



**Figure 101 –** Brown-Out Minimum Load.
CH1: $I_{12V\_OUT}$, 1 A / div., 90 s / div.
CH2: $V_{IN}$, 400 V / div., 90 s / div.
CH3: $V_{5V\_OUT}$, 5 V / div., 90 s / div.
CH4: $V_{12V\_OUT}$, 5 V / div., 90 s / div.
$V_{IN(UV)}$ = 38.712 $V_{RMS}$.

## 11.5 ***Output Voltage Ripple***

### 11.5.1 Ripple Measurement Technique

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

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF / 50 V ceramic type and one (1) 47 μF / 50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

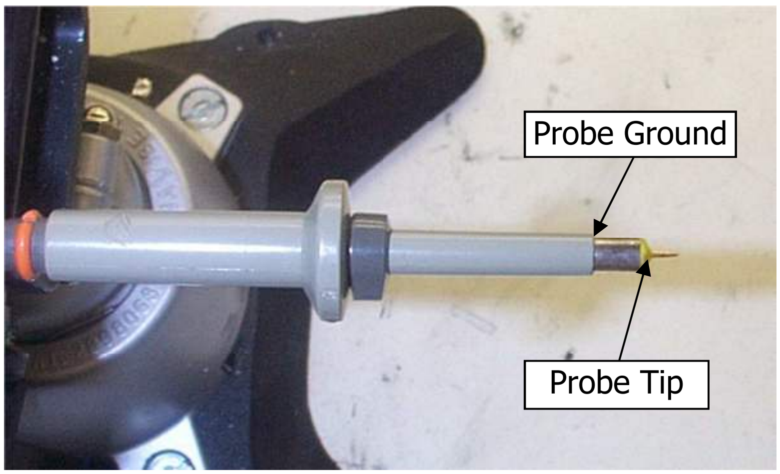



**Figure 102 –** Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)

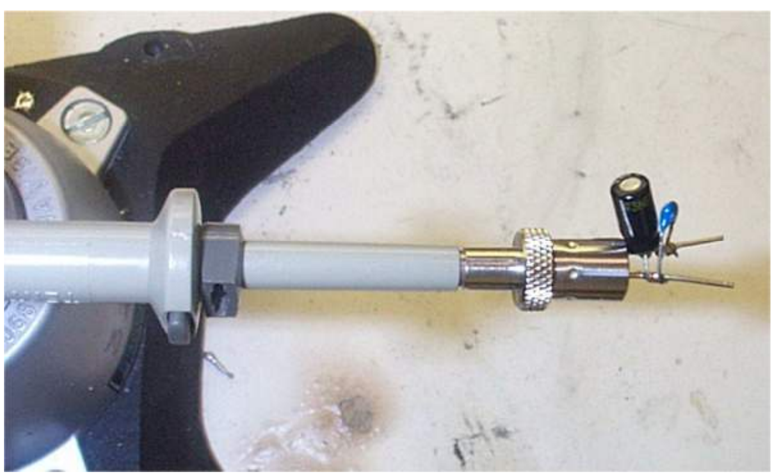


**Figure 103 –** Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

### 11.5.2 Measurement Results

Note: All ripple measurements were taken at PCB end.

#### 11.5.2.1 100% Load Condition

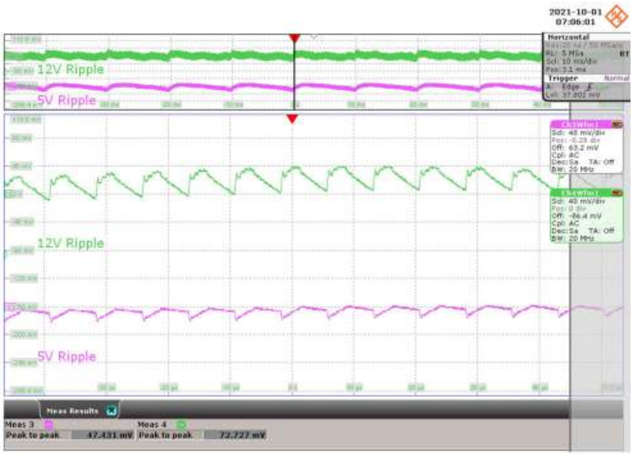



**Figure 104 –** 90 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 47.431 mV.
12 V Output Ripple = 72.727 mV.

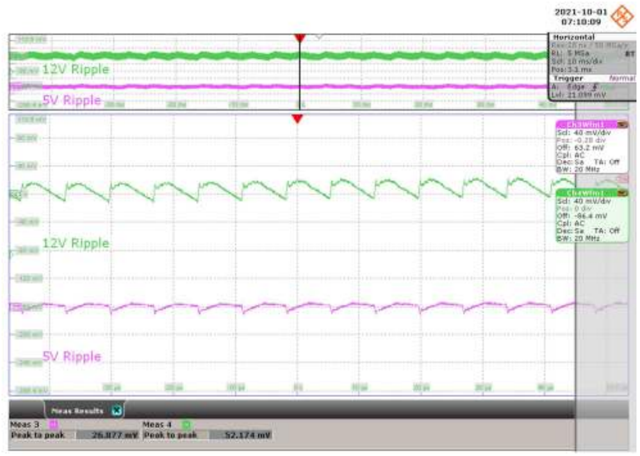



**Figure 105 –** 115 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 26.877 mV.
12 V Output Ripple = 52.174 mV.

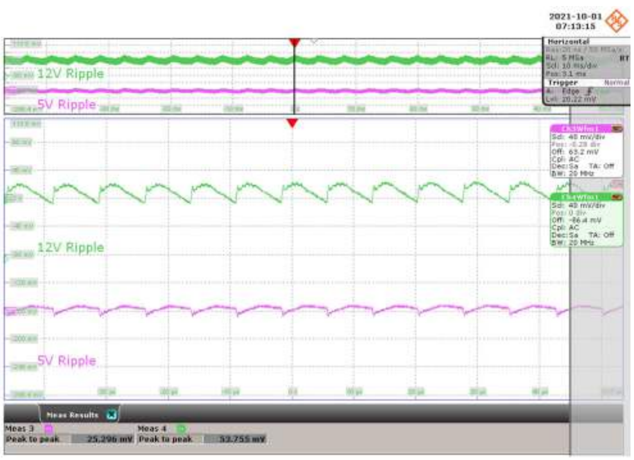



**Figure 106 –** 230 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 25.296 mV.
12 V Output Ripple = 53.755 mV.

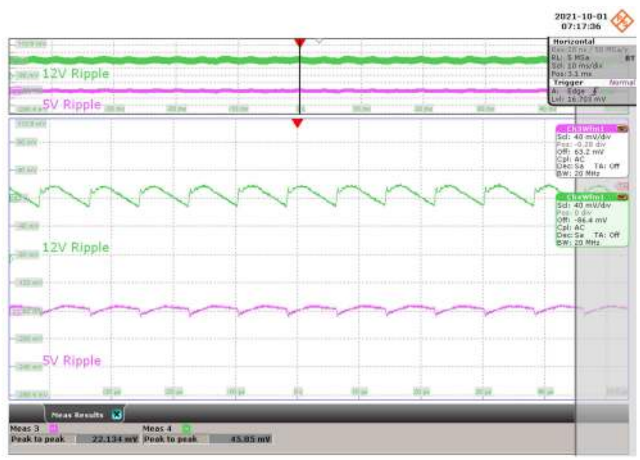



**Figure 107 –** 265 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 22.134 mV.
12 V Output Ripple = 45.85 mV.

#### 11.5.2.2 75% Load Condition


**Figure 108 –** 90 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple =31.621 mV.
12 V Output Ripple = 47.431 mV.

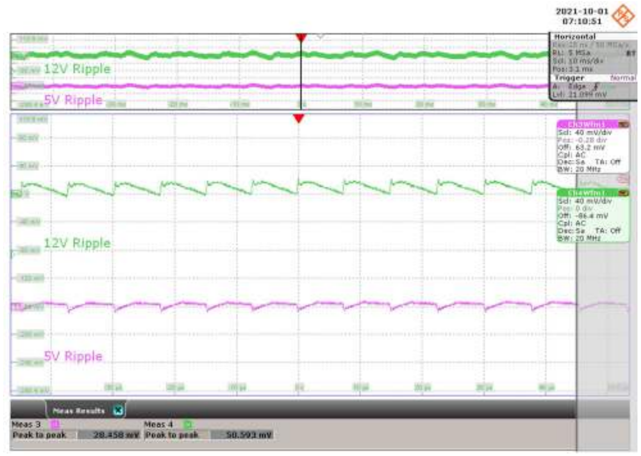



**Figure 109 –** 115 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple =28.458 mV.
12 V Output Ripple = 50.593 mV.

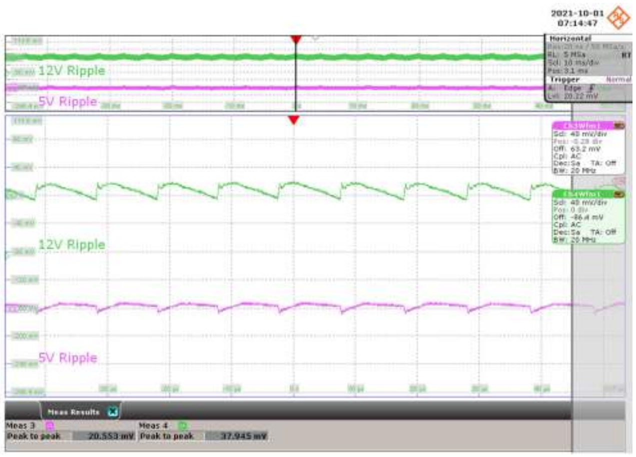



**Figure 110 –** 230 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 20.553 mV.
12 V Output Ripple = 37.945 mV.


**Figure 111 –** 265 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 22.134 mV.
12 V Output Ripple = 39.526 mV.

#### 11.5.2.3 50% Load Condition


**Figure 112 –** 90 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 26.877 mV.
12 V Output Ripple = 45.85 mV.

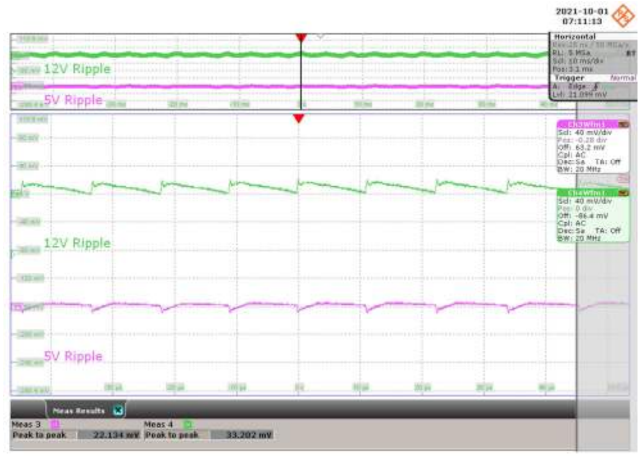



**Figure 113 –** 115 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 22.134 mV.
12 V Output Ripple = 33.202 mV.

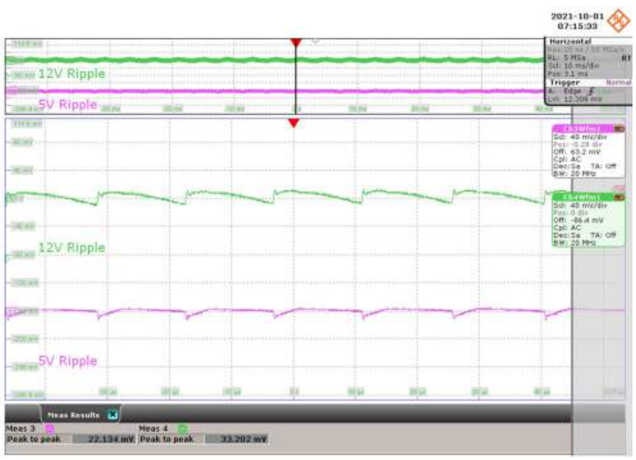



**Figure 114 –** 230 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 22.134 mV.
12 V Output Ripple = 33.202 mV.

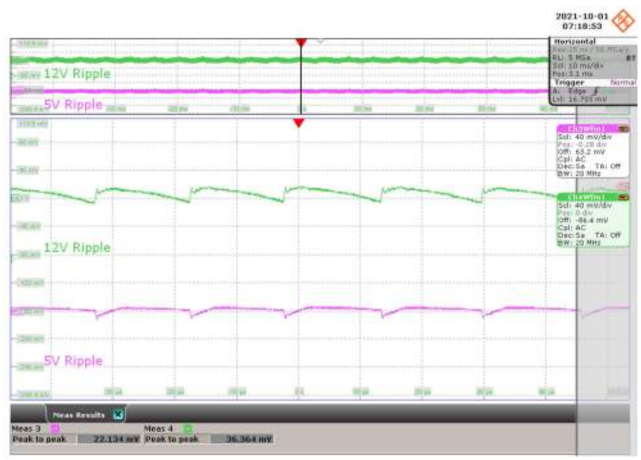



**Figure 115 –** 265 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 22.134 mV.
12 V Output Ripple = 36.364 mV.

### 11.5.2.4 25% Load Condition

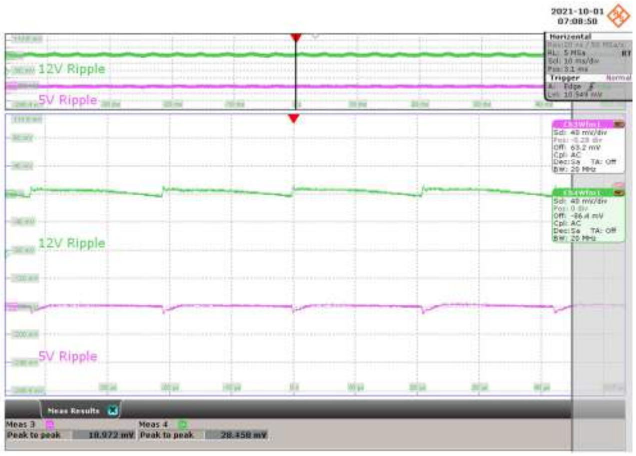



**Figure 116 –** 90 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 18.972 mV.
12 V Output Ripple = 28.458 mV.

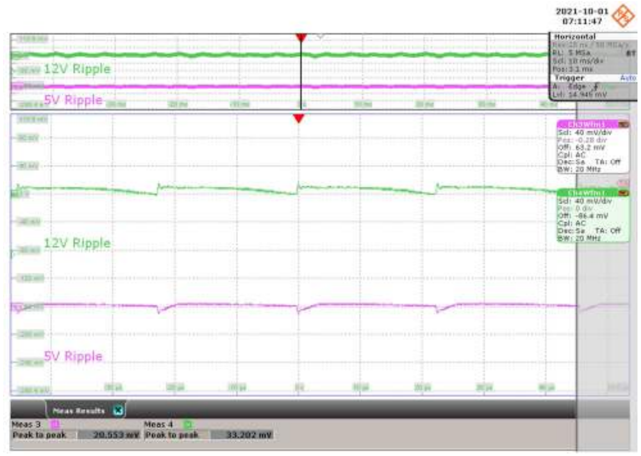



**Figure 117 –** 115 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 20.553 mV.
12 V Output Ripple = 33.202 mV.

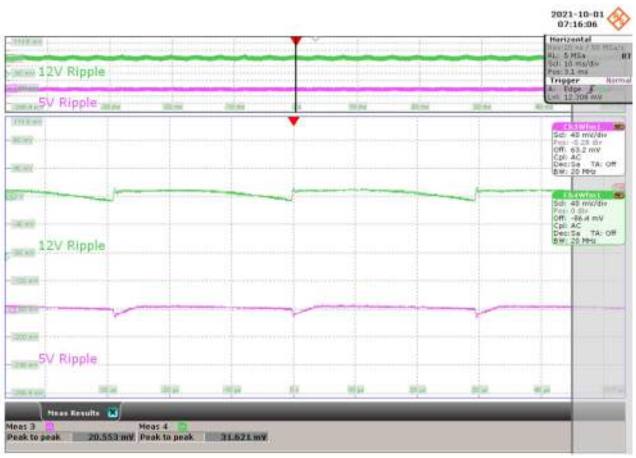



**Figure 118 –** 230 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 20.553 mV.
12 V Output Ripple = 31.621 mV.

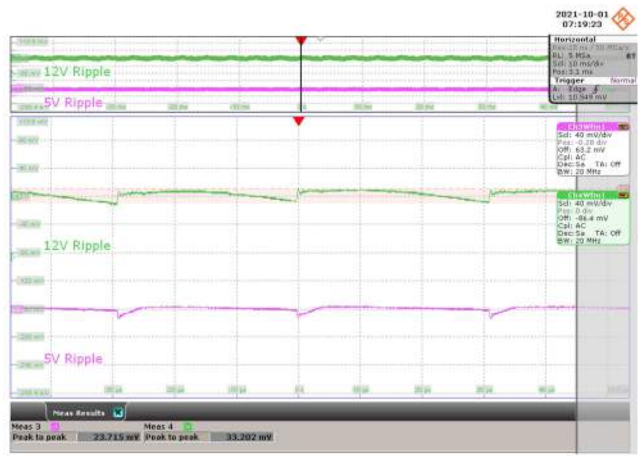



**Figure 119 –** 265 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 23.715 mV.
12 V Output Ripple = 33.202 mV.

### 11.5.2.5 10% Load Condition


**Figure 120 –** 90 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 15.81 mV.
12 V Output Ripple = 23.715 mV.


**Figure 121 –** 115 VAC 60 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 15.81 mV.
12 V Output Ripple = 23.715 mV.

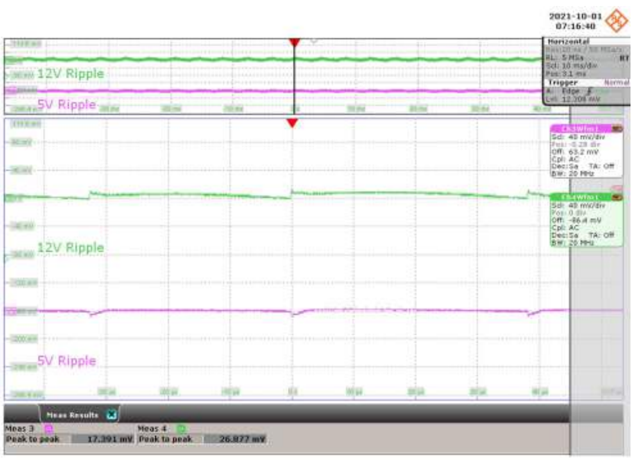



**Figure 122 –** 230 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 17.391 mV.
12 V Output Ripple = 26.877 mV.

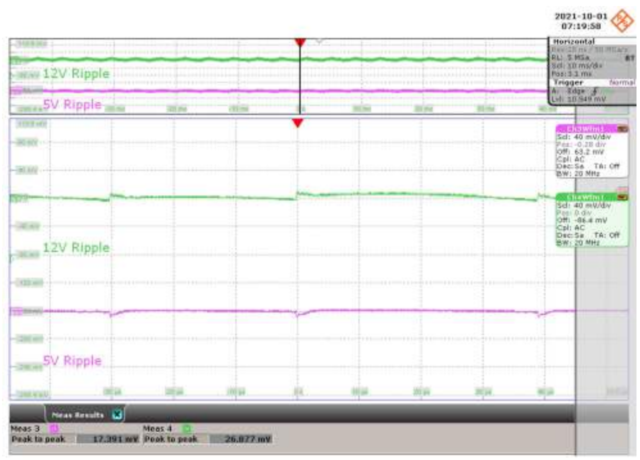



**Figure 123 –** 265 VAC 50 Hz.
CH3: $V_{5V\_Ripple}$, 40 mV / div., 10 ms / div.
CH4: $V_{12V\_Ripple}$, 40 mV / div., 10 ms / div.
Zoom: 10 µs / div.
5 V Output Ripple = 17.391 mV.
12 V Output Ripple = 26.877 mV.

### 11.5.3 12 V Output Ripple Voltage Graph from 10% - 100%

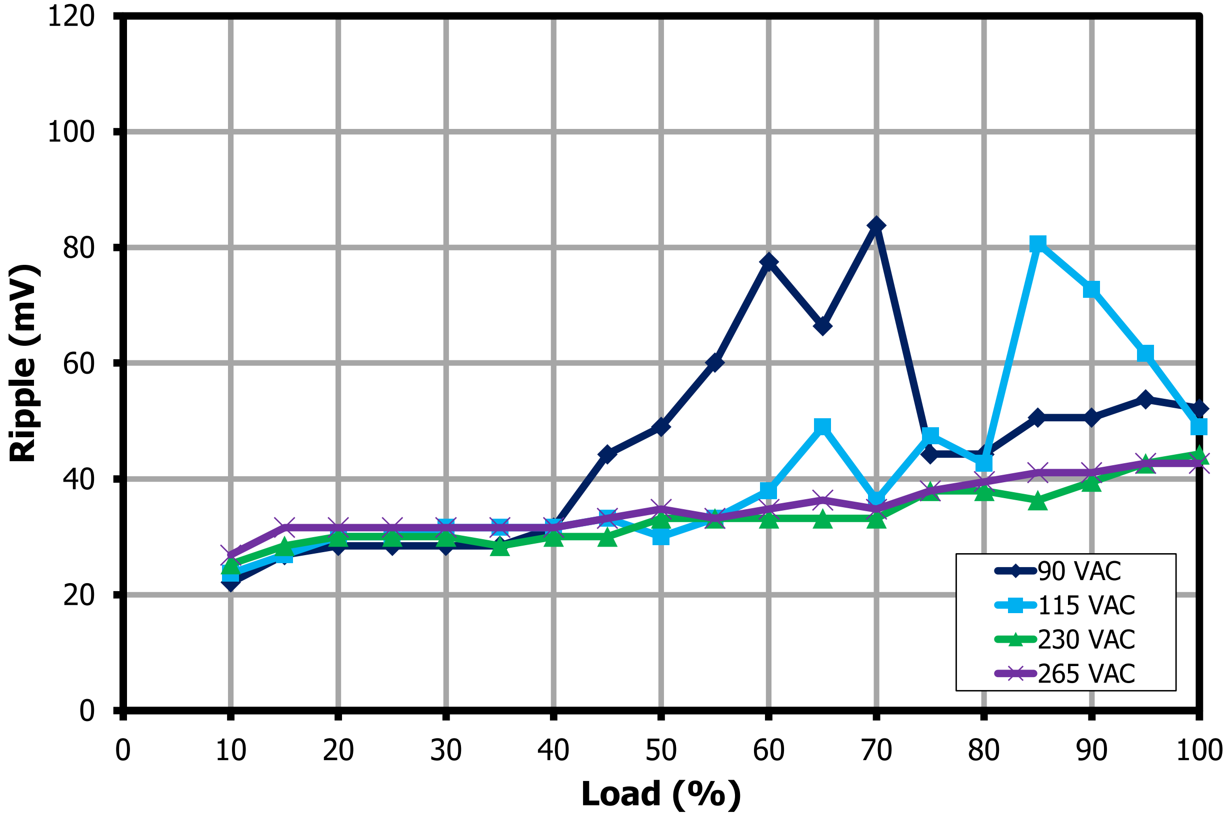



**Figure 124 –** 12 V Voltage Ripple (Measured at PCB End at Room Temperature).

### 11.5.4 5 V Output Ripple Voltage Graph from 10% - 100%

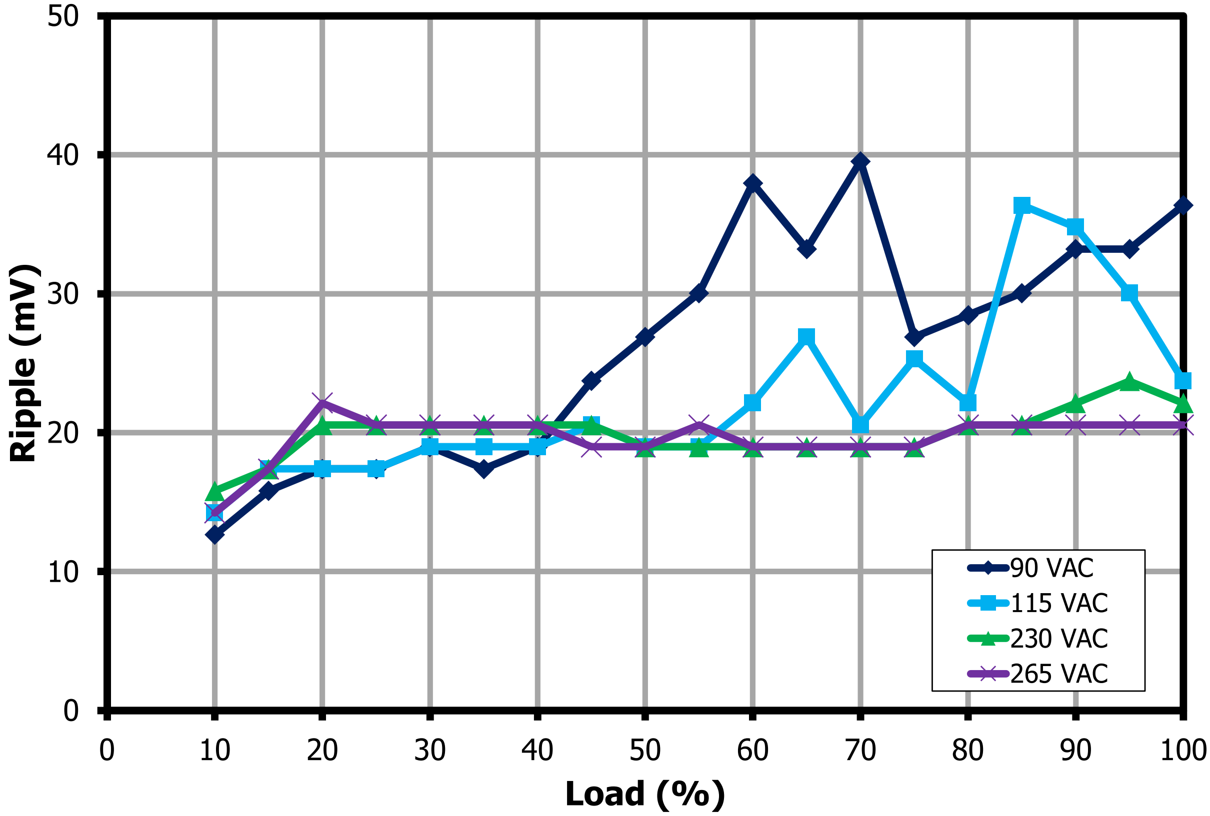



**Figure 125 –** 5 V Voltage Ripple (Measured at PCB End at Room Temperature).

# 12 Thermal Performance

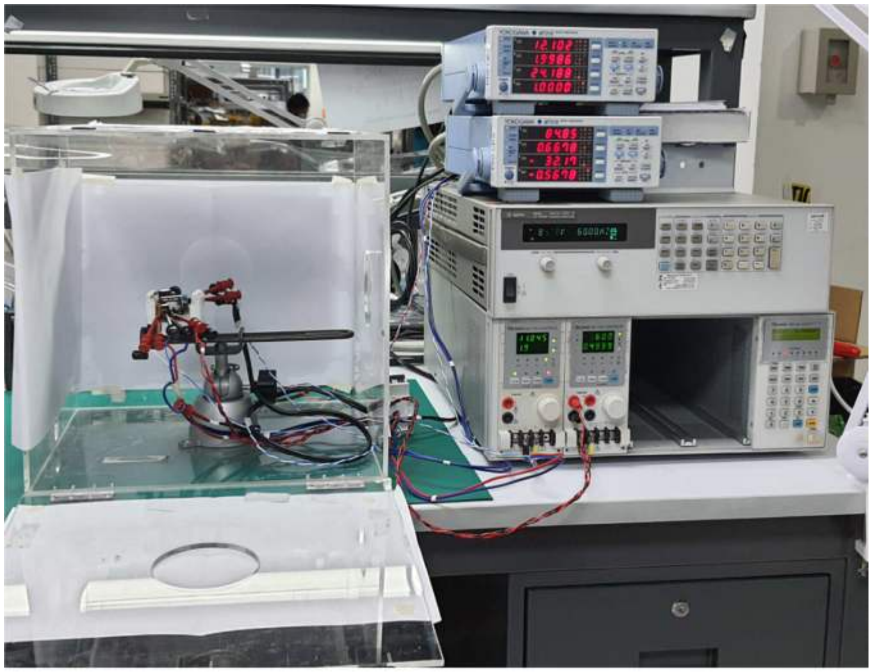


**Figure 126 –** Thermal Performance Set-up Using an Acrylic Box at Room Temperature.

**Figure 127 –** Thermal Performance Set-up Using Thermal Chamber.

### 12.1.1 90 VAC Full Load at Room Temperature

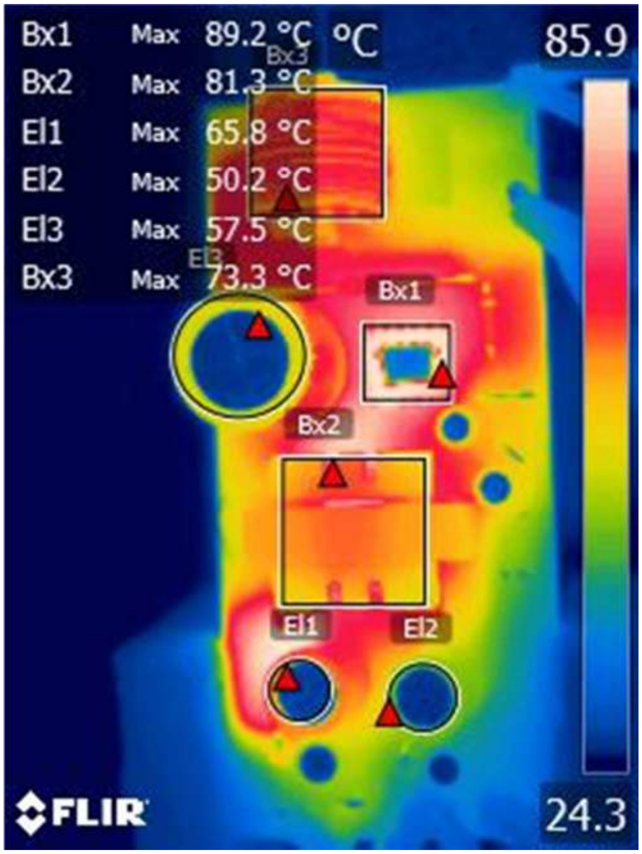



**Figure 128 –** 90 VAC 60 Hz. Thermals Top.

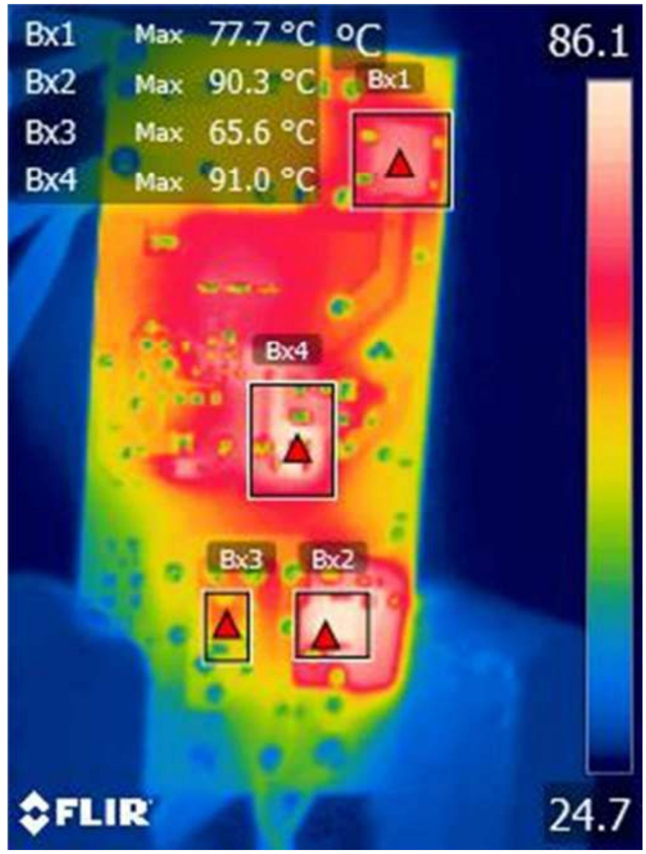



**Figure 129 –** 90 VAC 60 Hz. Thermals Bottom.

| Component | Temperature (°C) |
|---|---|
| Ambient | 24.3 |
| TOP267VG (U1) | 89.2 |
| Transformer (T1) | 81.3 |
| 12 V Output Capacitor (C9) | 65.8 |
| 5 V Output Capacitor (C12) | 50.2 |
| Input Capacitor (C2) | 57.5 |
| CMC (L1) | 73.3 |
| Bridge (BR1) | 77.7 |
| 12 V FreeWheeling Diode (D4) | 90.3 |
| 5 V FreeWheeling Diode (D5) | 65.6 |
| Snubber Resistor (R4) | 91 |

### 12.1.2 265 VAC Full Load at Room Temperature

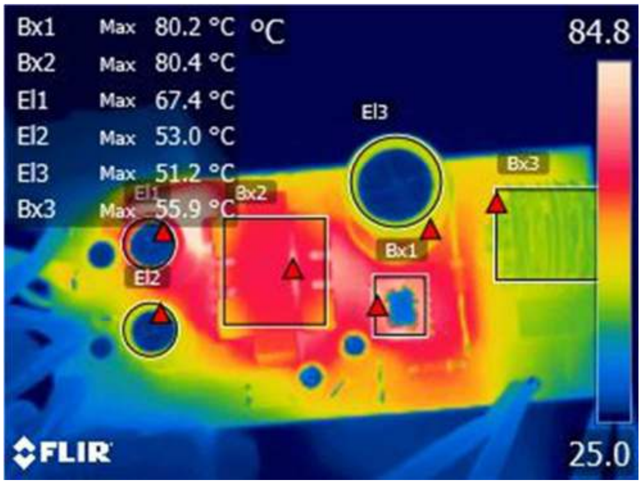



**Figure 130 –** 265 VAC 60 Hz. Thermals Top.

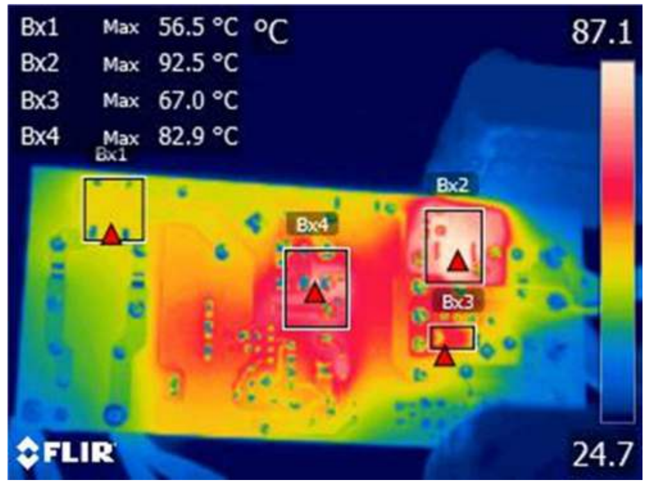



**Figure 131 –** 265 VAC 60 Hz. Thermals Bottom.

| Component | Temperature (°C) |
|---|---|
| Ambient | 25 |
| TOP267VG (U1) | 80.2 |
| Transformer (T1) | 80.4 |
| 12 V Output Capacitor (C9) | 67.4 |
| 5 V Output Capacitor (C12) | 53 |
| Input Capacitor (C2) | 51.2 |
| CMC (L1) | 55.9 |
| Bridge (BR1) | 56.5 |
| 12 V FreeWheeling Diode (D4) | 92.5 |
| 5 V FreeWheeling Diode (D5) | 67 |
| Snubber Resistor (R4) | 82.9 |

### 12.1.3 90 VAC Full Load at 40 ºC Ambient (Thermal Chamber)

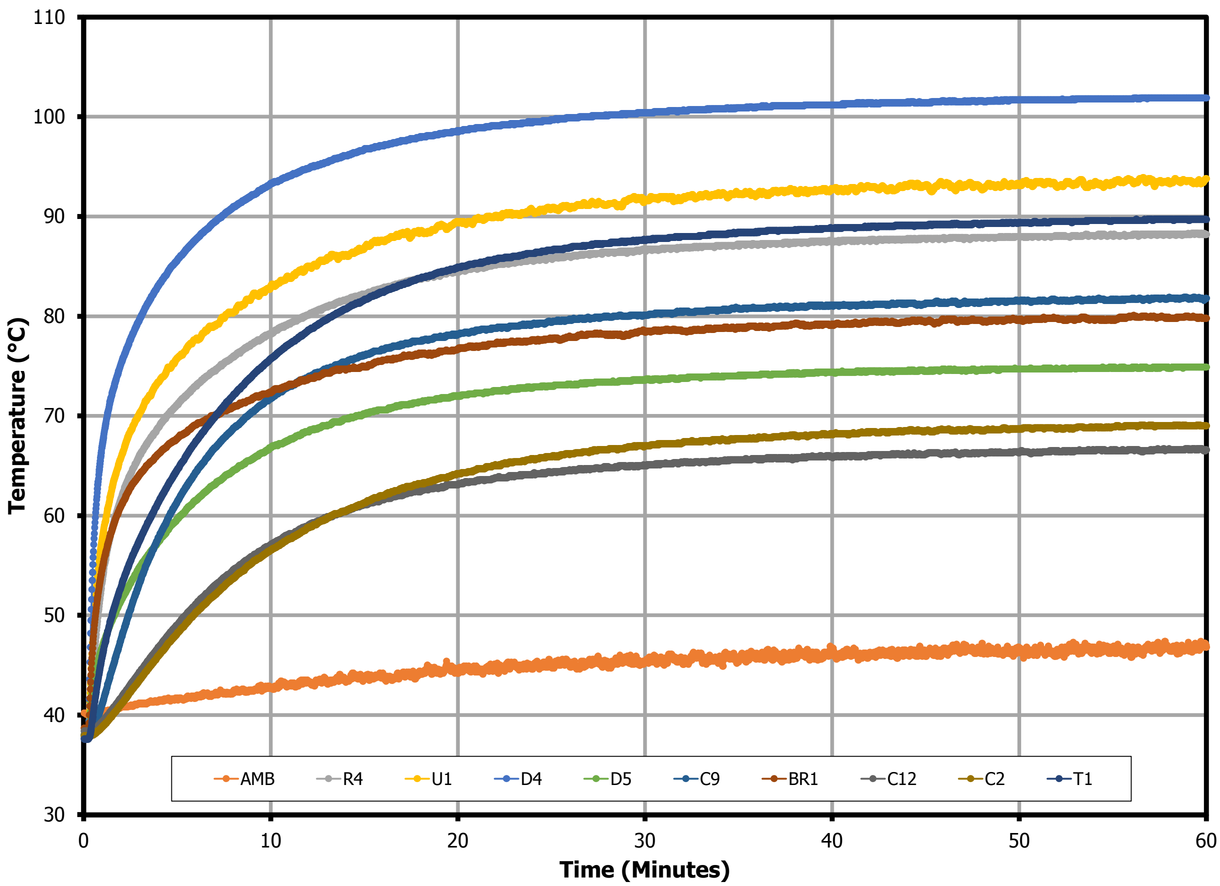



**Figure 132 –** 90 VAC 60 Hz. Thermals at 40 ºC Ambient.

| Component | Temperature (°C) |
|---|---|
| Ambient | 46.9 |
| TOP267VG (U1) | 93.5 |
| Transformer (T1) | 89.8 |
| 12 V Output Capacitor (C9) | 82 |
| 5 V Output Capacitor (C12) | 66.8 |
| Input Capacitor (C2) | 69 |
| Bridge (BR1) | 80 |
| 12 V FreeWheeling Diode (D4) | 102 |
| 5 V FreeWheeling Diode (D5) | 74.9 |
| Snubber Resistor (R4) | 88.4 |

### 12.1.4 265 VAC Full Load at 40 ºC Ambient (Thermal Chamber)

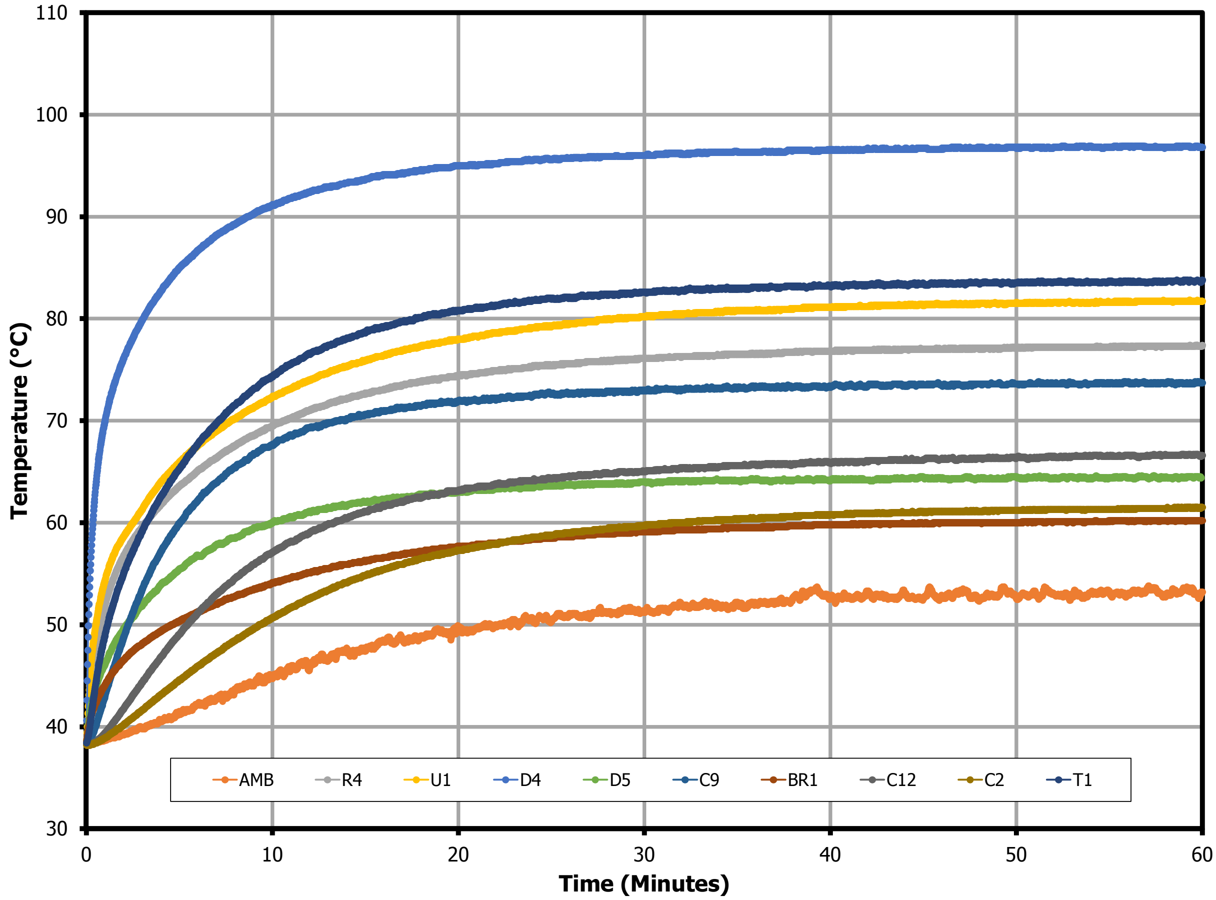



**Figure 133 –** 265 VAC 60 Hz. Thermals at 40 ºC Ambient.

| Component | Temperature (°C) |
|---|---|
| Ambient | 53.2 |
| TOP267VG (U1) | 81.7 |
| Transformer (T1) | 83.8 |
| 12 V Output Capacitor (C9) | 73.7 |
| 5 V Output Capacitor (C12) | 66.8 |
| Input Capacitor (C2) | 61.5 |
| Bridge (BR1) | 60.2 |
| 12 V FreeWheeling Diode (D4) | 96.8 |
| 5 V FreeWheeling Diode (D5) | 64.4 |
| Snubber Resistor (R4) | 77.4 |

# 13 Fault Condition

## 13.1 *Output Short-Circuit Protection*

5 V and 12 V output were shorted to 0 V simultaneously


**Figure 134 –** 90 VAC 60 Hz. Output Short.
CH1: $I_{DS}$, 400 mA / div., 1 s / div.
CH2: $V_{DS}$, 200 V / div., 1 s / div.
$V_{DS(MAX)}$ = 412.97 V.
$I_{DS(MAX)}$ = 1.4842 A.
$t_{AR\_ON}$ = 50 ms, $t_{AR\_OFF}$ = 1.79 s.

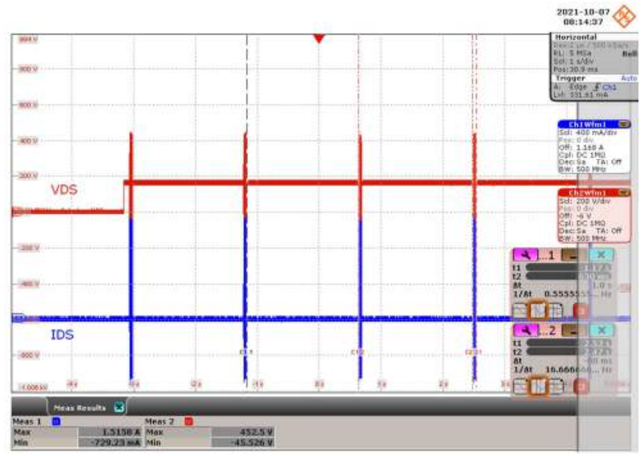



**Figure 135 –** 115 VAC 60 Hz Output Short.
CH1: $I_{DS}$, 400 mA / div., 1 s / div.
CH2: $V_{DS}$, 200 V / div., 1 s / div.
$V_{DS(MAX)}$ = 452.5 V.
$I_{DS(MAX)}$ = 1.5158 A.
$t_{AR\_ON}$ = 60 ms, $t_{AR\_OFF}$ = 1.8 s.


**Figure 136 –** 230 VAC 60 Hz. Output Short.
CH1: $I_{DS}$, 400 mA / div., 1 s / div.
CH2: $V_{DS}$, 200 V / div., 1 s / div.
$V_{DS(MAX)}$ = 642.22 V.
$I_{DS(MAX)}$ = 1.7055 A.
$t_{AR\_ON}$ = 60 ms, $t_{AR\_OFF}$ = 1.77 s.

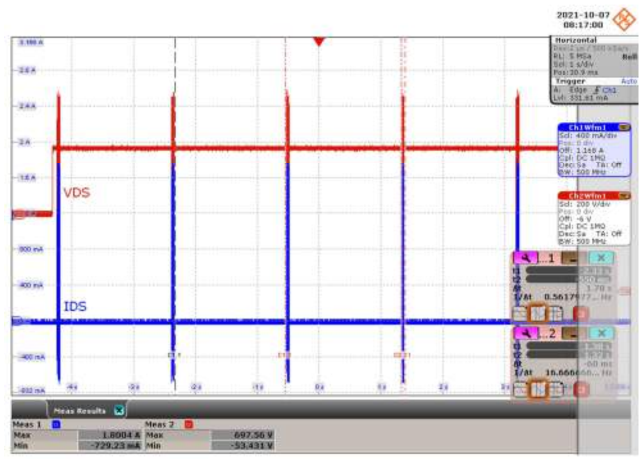



**Figure 137 –**265 VAC 60 Hz. Output Short.
CH1: $I_{DS}$, 400 mA / div., 1 s / div.
CH2: $V_{DS}$, 200 V / div., 1 s / div.
$V_{DS(MAX)}$ = 697.56 V.
$I_{DS(MAX)}$ = 1.8004 A.
$t_{AR\_ON}$ = 60 ms, $t_{AR\_OFF}$ = 1.78 s.

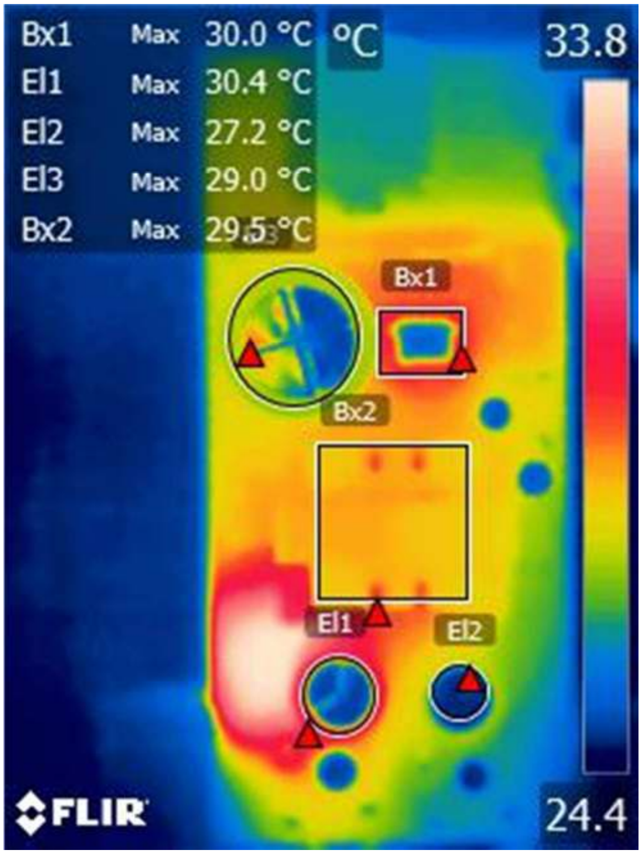



**Figure 138 –** 90 VAC 60 Hz. Output Short Thermals Top.

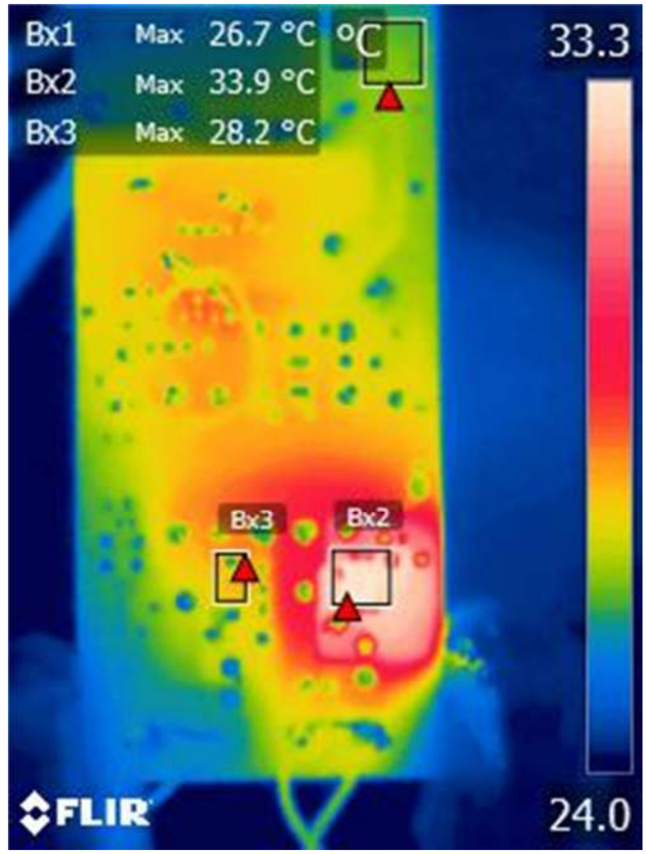



**Figure 139 –** 90 VAC 60 Hz. Output Short Thermals Bottom.

| Component | Temperature (°C) |
|---|---|
| Ambient | 24.4 |
| TOP267VG (U1) | 30 |
| Transformer (T1) | 29.5 |
| 12 V Output Capacitor (C9) | 30.4 |
| 5 V Output Capacitor (C12) | 27.2 |
| Input Capacitor (C2) | 29 |
| Bridge (BR1) | 26.7 |
| 12 V Freewheeling Diode (D4) | 33.9 |
| 5 V Freewheeling Diode (D5) | 28.2 |

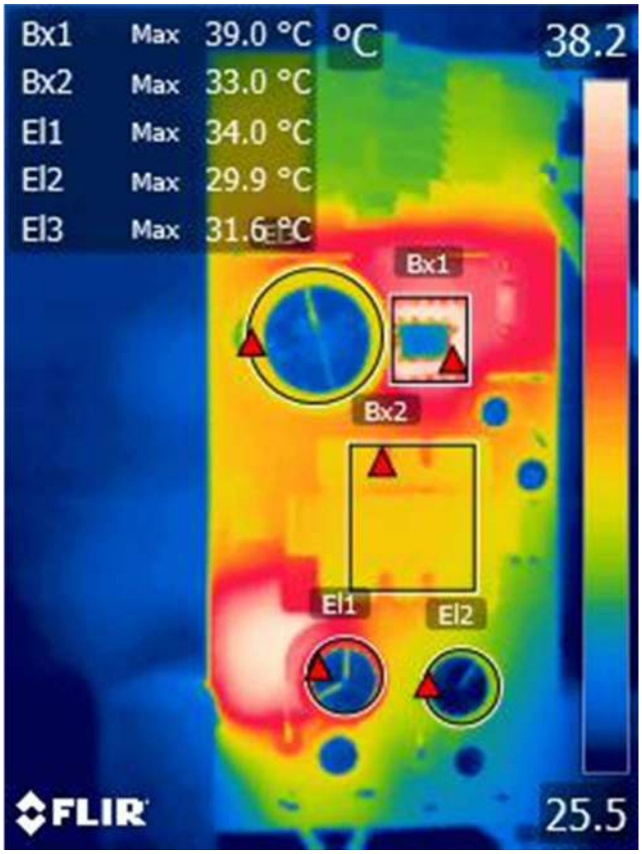



**Figure 140 –** 265 VAC 60 Hz. Output Short Thermals Top.

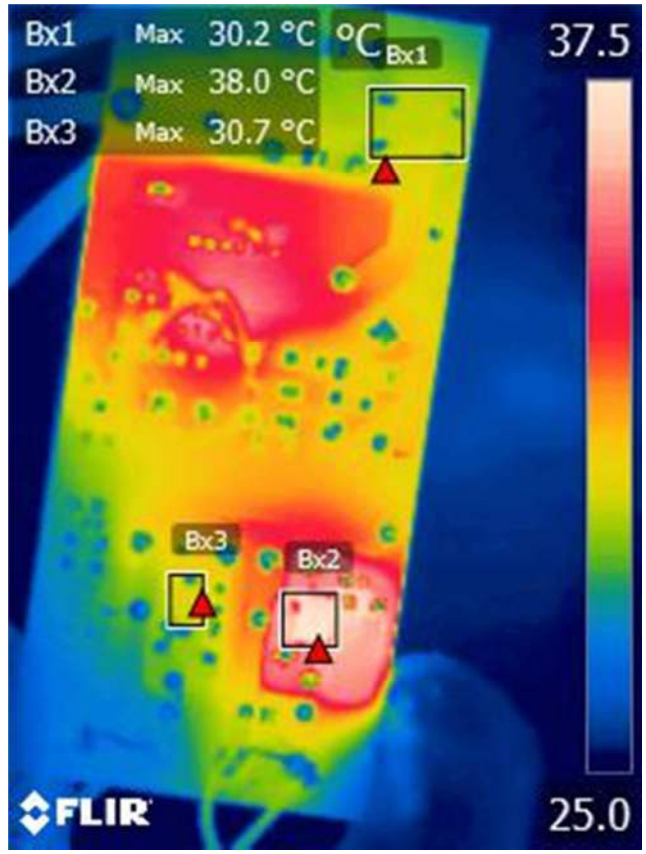



**Figure 141 –** 265 VAC 60 Hz. Output Short Thermals Bottom.

| Component | Temperature (°C) |
|---|---|
| Ambient | 25.5 |
| TOP267VG (U1) | 39 |
| Transformer (T1) | 33 |
| 12 V Output Capacitor (C9) | 34 |
| 5 V Output Capacitor (C12) | 29.9 |
| Input Capacitor (C2) | 31.6 |
| Bridge (BR1) | 30.2 |
| 12 V Freewheeling Diode (D4) | 38 |
| 5 V Freewheeling Diode (D5) | 30.7 |

### 13.2 *Output Overvoltage Protection*

Output overvoltage condition was simulated by shorting LED of the optocoupler (U2) with output at full load and minimum load. Overvoltage protection was implemented by primary-side output overvoltage circuit VR2, D3, and R5.

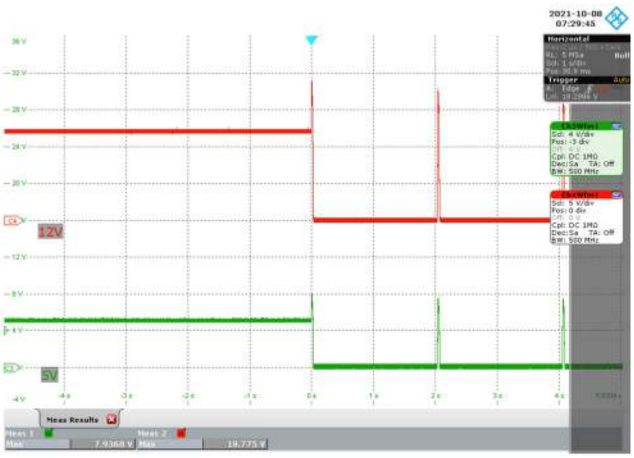


**Figure 142 –** 90 VAC 60 Hz. Full Load.
CH3: $V_{5V}$, 4 V / div., 1 s / div.
CH4: $V_{12V}$, 5 V / div., 1 s / div.
12 $V_{OUT}$: $V_{MAX}$: 18.775 V.
5 $V_{OUT}$: $V_{MAX}$: 7.9368 V.

**Figure 143 –** 90 VAC 60 Hz Min Load.
CH3: $V_{5V}$, 4 V / div., 1 s / div.
CH4: $V_{12V}$, 5 V / div., 1 s / div.
12 $V_{OUT}$: $V_{MAX}$: 19.96 V.
5 $V_{OUT}$: $V_{MAX}$: 8.5692 V.

**Figure 144 –** 265 VAC 60 Hz. Full Load.
CH3: $V_{5V}$, 4 V / div., 1 s / div.
CH4: $V_{12V}$, 5 V / div., 1 s / div.
12 $V_{OUT}$: $V_{MAX}$: 18.972 V.
5 $V_{OUT}$: $V_{MAX}$: 7.9447 V.

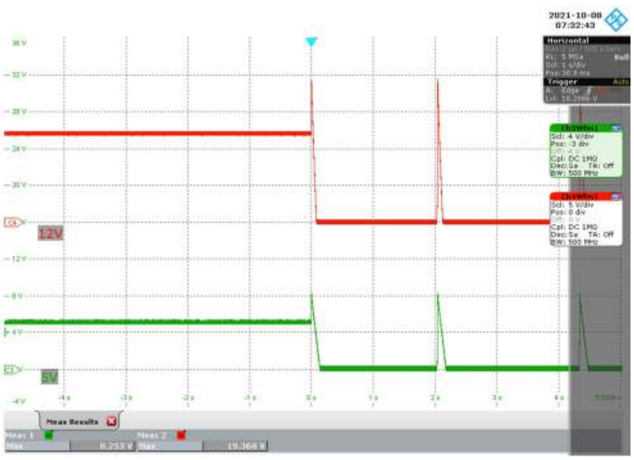


**Figure 145 –** 265 VAC 60 Hz. Min Load.
CH3: $V_{5V}$, 4 V / div., 1 s / div.
CH4: $V_{12V}$, 5 V / div., 1 s / div.
12 $V_{OUT}$: $V_{MAX}$: 19.368 V.
5 $V_{OUT}$: $V_{MAX}$: 8.253 V.

## 13.3 *Over Temperature Protection*

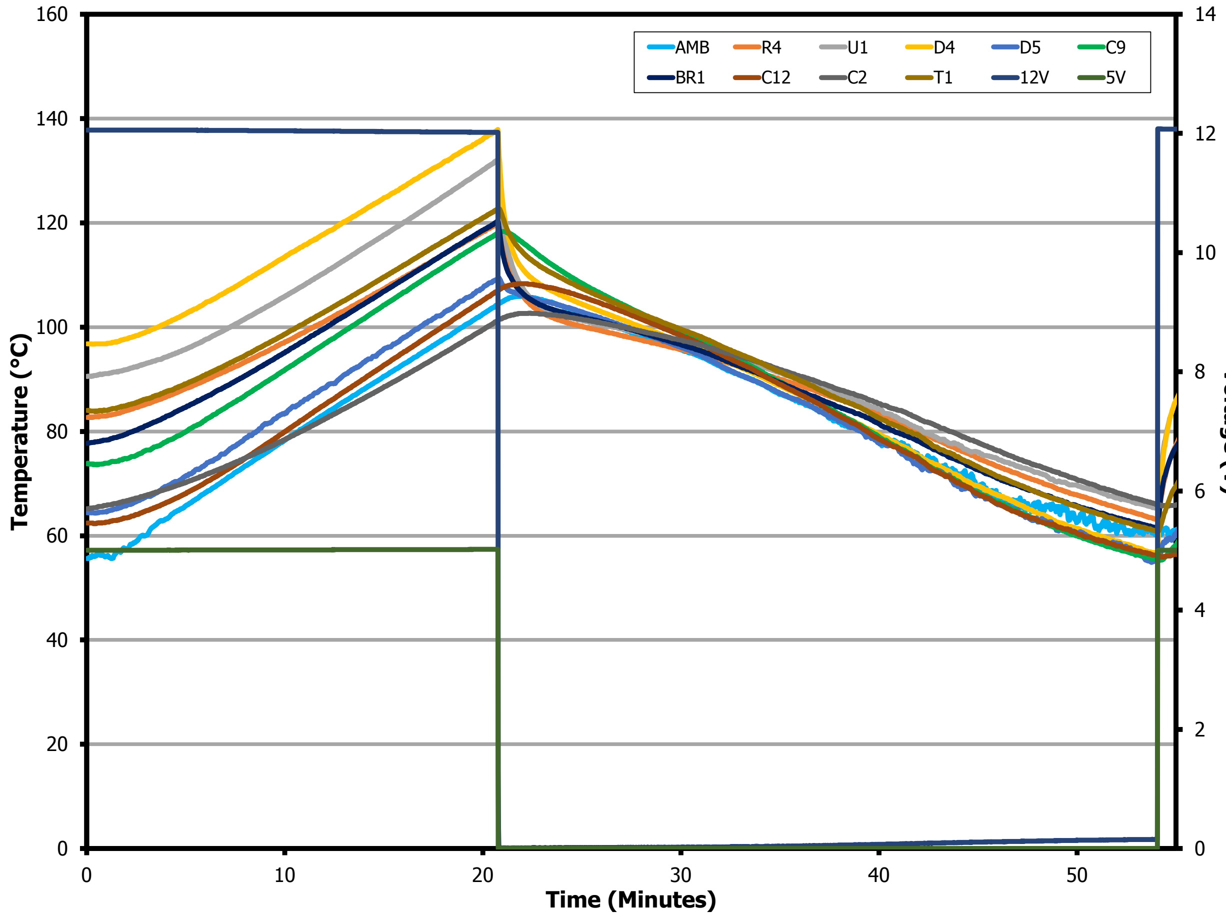



**Figure 146 –** 90 VAC 60 Hz. Full Load OTP.

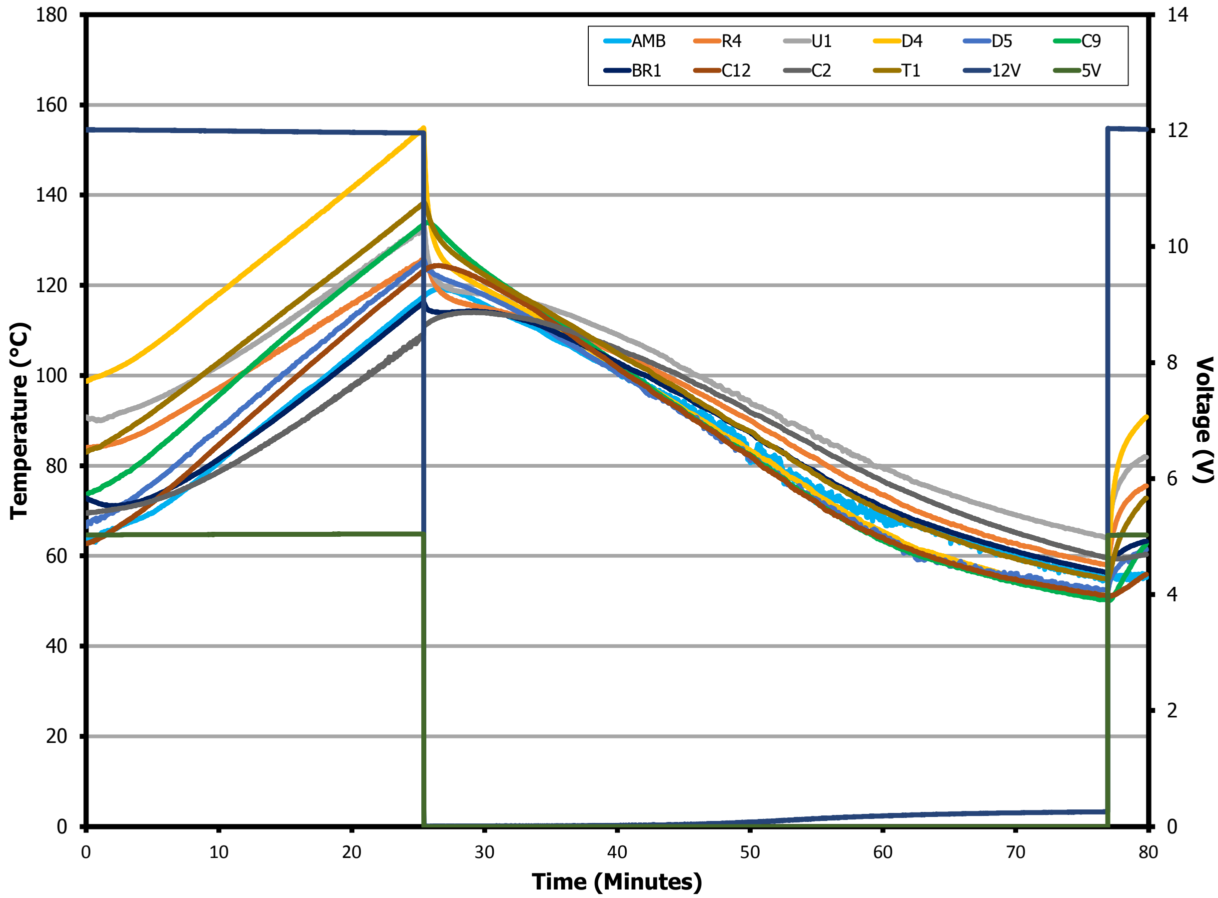



**Figure 147 –** 265 VAC 60 Hz. Full Load OTP.

| Input (VAC) | IC Temperature (°C) | |
|---|---|---|
| | OTP Shutdown | Recover |
| 90 | 132.1 | 65.3 |
| 265 | 134.3 | 64.1 |

# 14 Conducted EMI

Conducted emissions tests were performed at 115 VAC and 230 VAC at full load (12 V 2 A, 5 V 0.5 A). Measurements were taken with floating ground and grounded output.

## 14.1 *Test Set-up Equipment*

### 14.1.1 Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Yokogawa WT310E digital power meter.
4. Chroma measurement test fixture A662003.
5. Input voltage set at 115 VAC and 230 VAC.
6. 12 V RLOAD resistance is 6 ohms.
7. 5 V RLOAD resistance is 10 ohms.

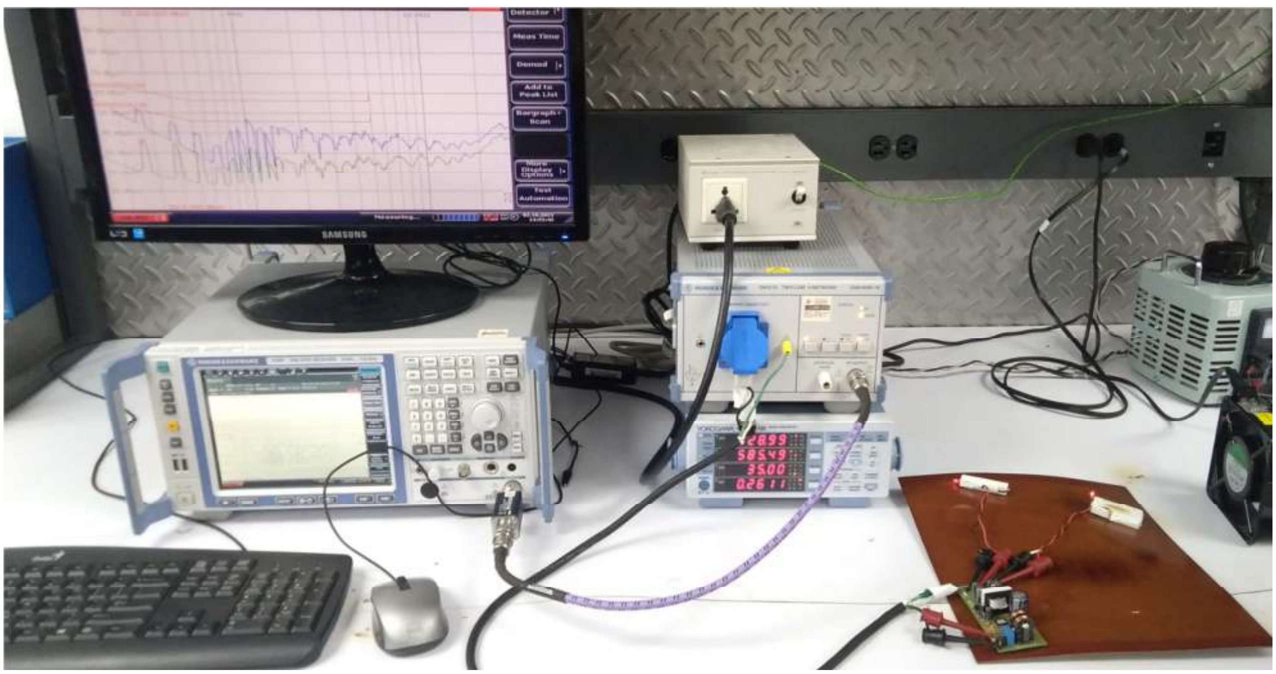


**Figure 148 –** EMI Test Set-up.

## 14.2 *Output Float*

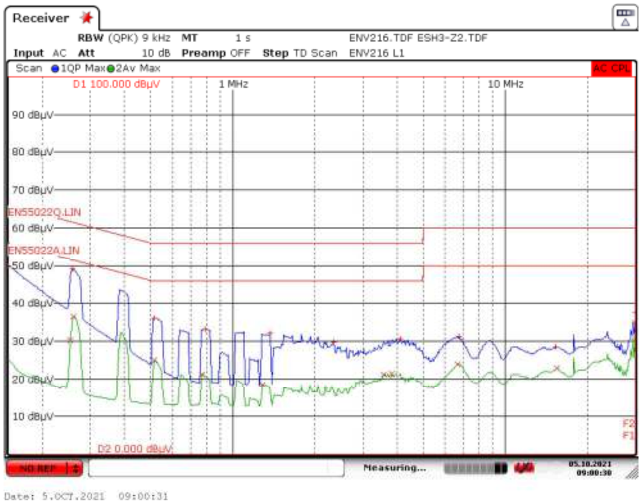



**Figure 149 –** 115 VAC 60 Hz.
Line with Floating Ground.

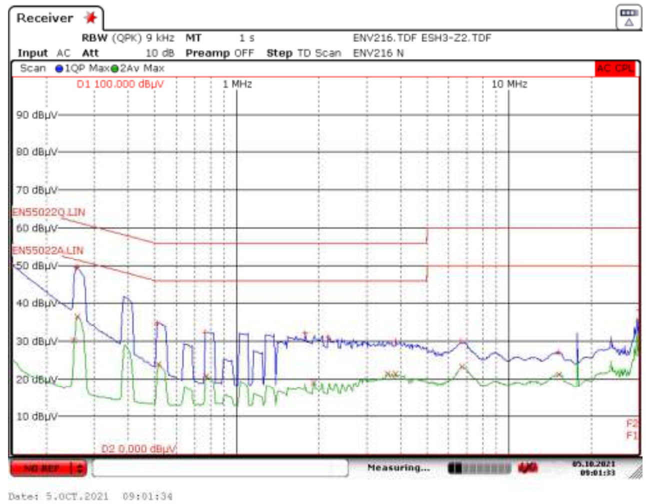



**Figure 150 –** 115 VAC 60 Hz.
Neutral with Floating Ground.

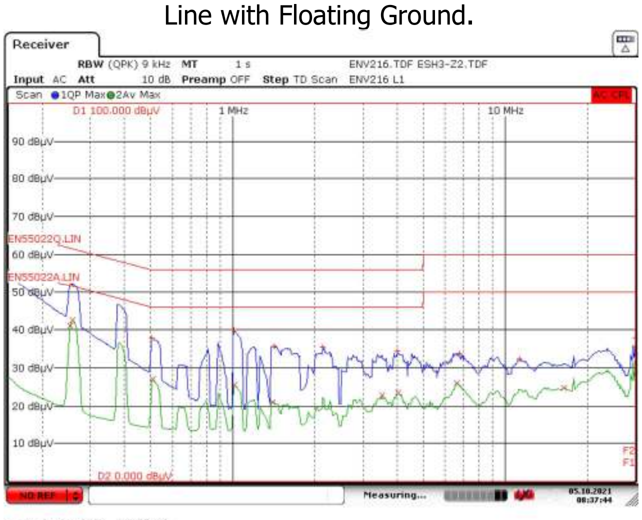



**Figure 151 –** 230 VAC 60 Hz.
Line with Floating Ground.

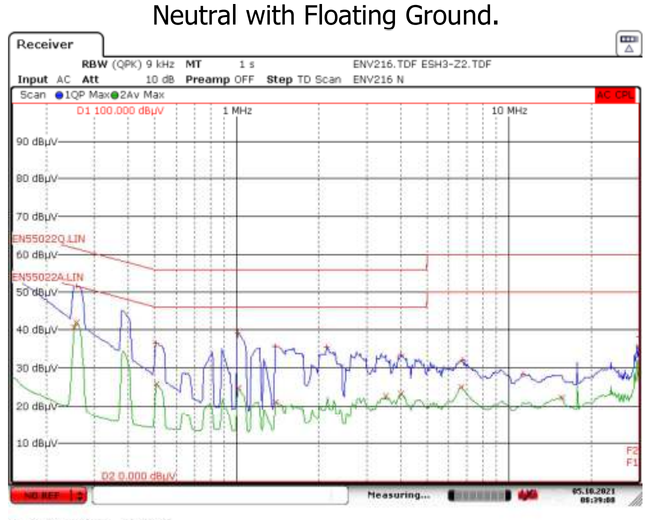



**Figure 152 –** 230 VAC 60 Hz.
Neutral with Floating Ground.

## 14.3 *Output Grounded*

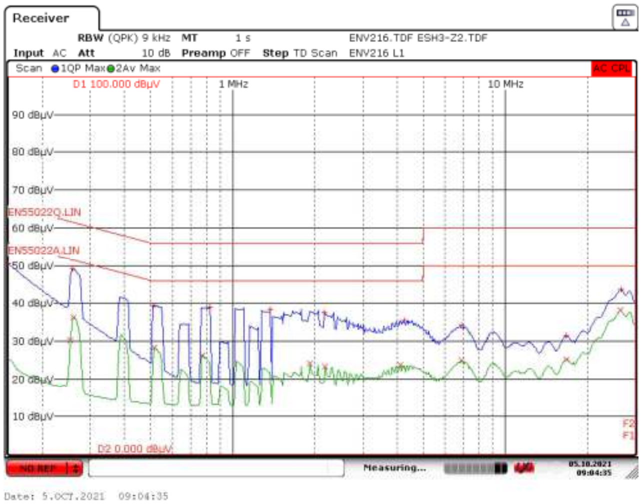



**Figure 153 –** 115 VAC 60 Hz.
Line with Output Grounded.

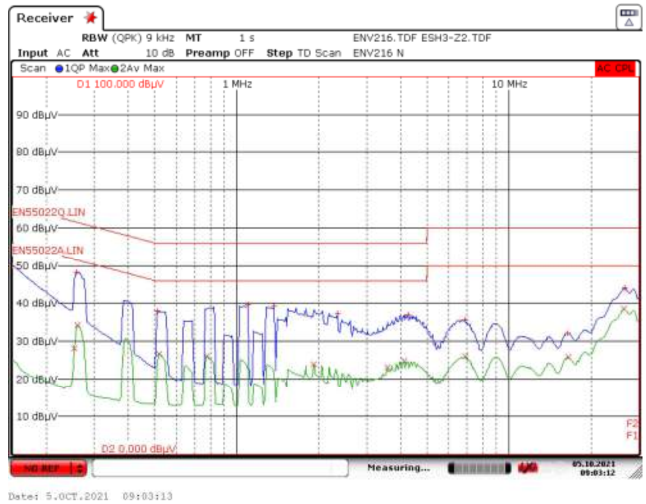



**Figure 154 –** 115 VAC 60 Hz.
Neutral with Output Grounded.

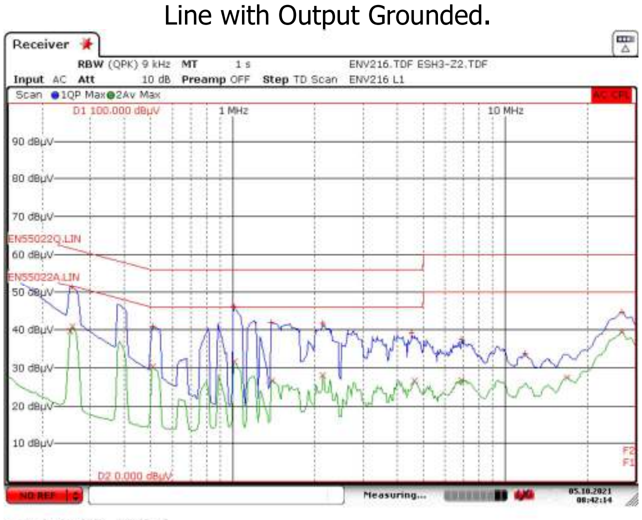



**Figure 155 –** 230 VAC 60 Hz.
Line with Output Grounded.

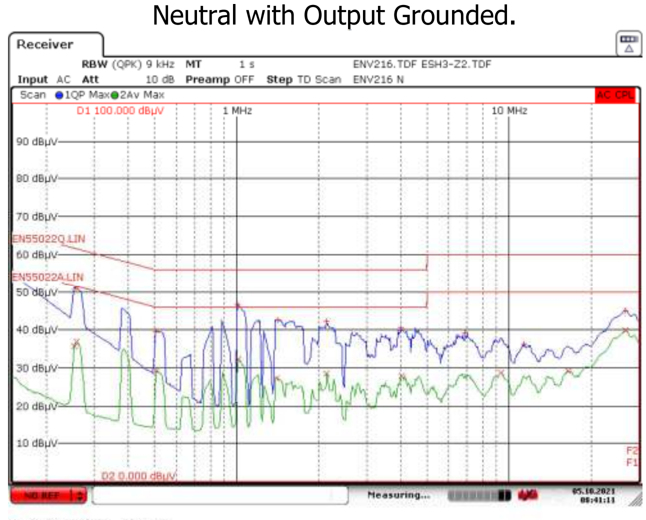



**Figure 156 –** 230 VAC 60 Hz.
Neutral with Output Grounded.

# 15 Line Surge

IEC61000-4-5 differential mode and common mode input line surge testing was completed on a single test unit. Input voltage was set at 230 VAC / 60 Hz. Output was loaded at full load and operation was verified following each surge event.

## 15.1 *Differential Mode Surge*

| DM Surge Level (V) | Input Voltage (VAC) | Injection Location | Injection Phase (º) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| +1000 | 230 | L to N | 0 | Pass |
| -1000 | 230 | L to N | 0 | Pass |
| +1000 | 230 | L to N | 90 | Pass |
| -1000 | 230 | L to N | 90 | Pass |
| +1000 | 230 | L to N | 180 | Pass |
| -1000 | 230 | L to N | 180 | Pass |
| +1000 | 230 | L to N | 270 | Pass |
| -1000 | 230 | L to N | 270 | Pass |

**Note:** In all PASS results, power supply is still functional after the test.

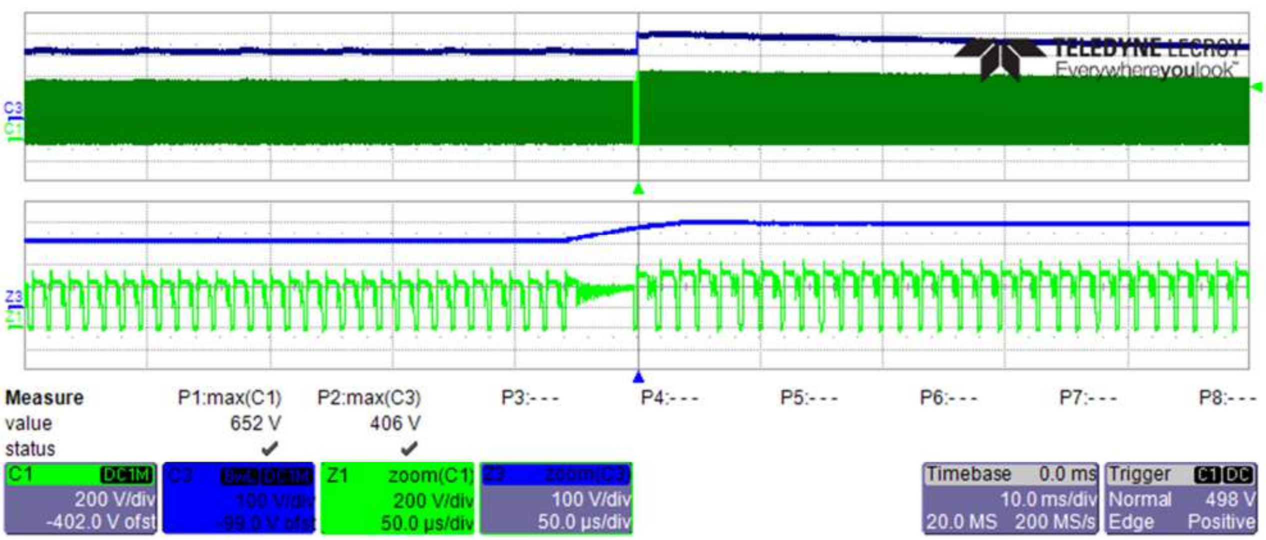



**Figure 157 –** Differential Mode Surge Input AC and $V_{DS}$ Waveform.

Ch1: $V_{DS}$ 200 V / div., 10 ms /div.

Ch2: Bulk Voltage 100 V / div., 10 ms / div.

Zoom: 50 µs / div.

$V_{DS(MAX)}$: 652 V.

### 15.2 *Common Mode Surge*

| Surge Voltage (kV) | Phase Angle (°) | IEC Coupling | Generator Impedance (Ω) | Number of Strikes | Result |
|---|---|---|---|---|---|
| +2 | 0 | L, N - PE | 12 | 10 | PASS |
| -2 | 0 | L, N - PE | 12 | 10 | PASS |
| +2 | 90 | L, N - PE | 12 | 10 | PASS |
| -2 | 90 | L, N - PE | 12 | 10 | PASS |
| +2 | 270 | L, N - PE | 12 | 10 | PASS |
| -2 | 270 | L, N - PE | 12 | 10 | PASS |

**Note:** In all PASS results, power supply is still functional after the test.

# 16 ESD

All ESD strikes were applied at end of cable with 230 VAC input voltage and full load.

Passed ±8 kV contact discharge

| Contact Discharge Voltage (kV) | Applied to | Number of Strikes | Test Result |
|---|---|---|---|
| +8.0 | 12 V | 10 | PASS |
| -8.0 | 12 V | 10 | PASS |
| +8.0 | GND | 10 | PASS |
| -8.0 | GND | 10 | PASS |

**Note:** In all PASS results, power supply is still functional after the test.

Passed ±15 kV air discharge

| Air Discharge Voltage (kV) | Applied to | Number of Strikes | Test Result |
|---|---|---|---|
| +15 | 12 V | 10 | PASS |
| -15 | 12 V | 10 | PASS |
| +15 | GND | 10 | PASS |
| -15 | GND | 10 | PASS |

**Note:** In all PASS results, power supply is still functional after the test.

# 17 Revision History

| Date | Author | Revision | Description and Changes | Reviewed |
|---|---|---|---|---|
| 02-Feb-22 | RPA/RPL | 1.0 | Initial Release. | Apps & Mktg |
| | | | | |
| | | | | |
| | | | | |

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