Title	***Reference Design Report for a 27 W USB PD 3.0 Power Supply with 3.3 V - 11 V PPS Output Using InnoSwitch™ 3-Pro INN3366C-H301 and VIA Labs VP302 Controller***
Specification	85 VAC – 265 VAC Input; 5 V / 3 A; 9 V / 3 A; or 3.3 V – 11 V PPS Outputs
Application	Mobile Phone Charger
Author	Applications Engineering Department
Document Number	RDR-813
Date	October 29, 2019
Revision	1.2

Summary and Features

- InnoSwitch3-Pro - digitally controllable CV/CC QR flyback switcher IC with integrated high-voltage MOSFET, synchronous rectification and FluxLink™ feedback
  - I^2C Interface enables low pin count USB PD Controller (8 pin)
  - Sophisticated telemetry and comprehensive protection features
- USB PD 3.0 with PPS using highly optimized, low pin count USB PD controller VP302
- All the benefits of secondary-side control with the simplicity of primary-side regulation
  - Insensitive to transformer variation
- Meets DOE6 and CoC V5 2016 efficiency requirement (>1% efficiency margin)
- Micro stepping of voltages (20 mV) and CC thresholds (50 mA) in compliance with PPS protocol
- Output overvoltage and overcurrent protection
- Integrated thermal protection
- <30 mW no-load input power

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PATENT INFORMATION

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

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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.

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1 Introduction

This document is an engineering report describing a 27 W USB PD power supply with 5 V / 3 A, 9 V / 3 A, or 3.3 V – 11 V Programmable Power Supply (PPS) output using InnoSwitch3-Pro INN3366C-H301 IC and VIA Labs VP302 USB PD controller. This design shows the high power density and efficiency that is possible due to the high level of integration of the InnoSwitch3-Pro controller providing exceptional performance.

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

Figure 1 – Populated Circuit Board Photograph, Entire Assembly.

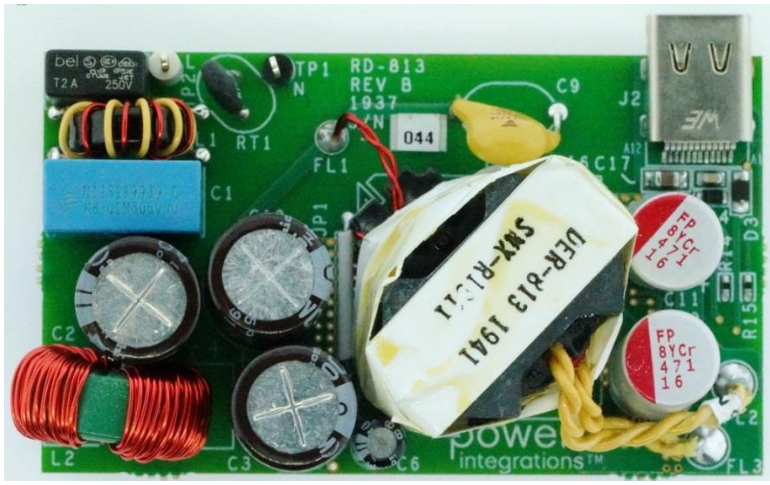

Figure 2 – Populated Circuit Board Photograph - Top.

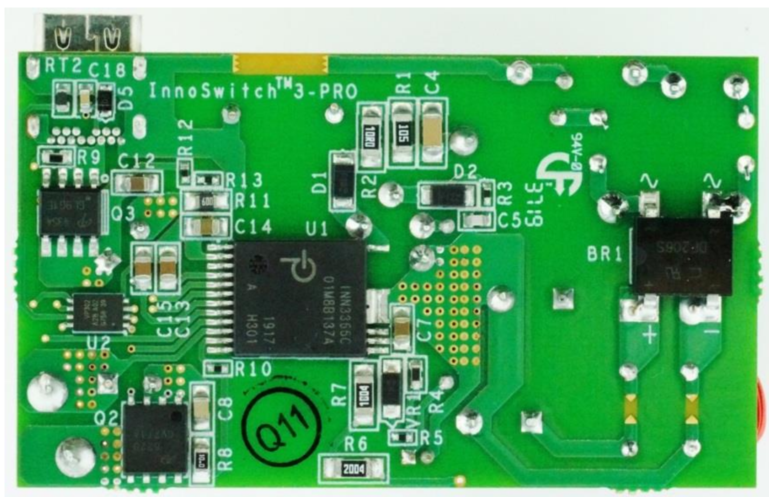

Figure 3 – Populated Circuit Board Photograph - Bottom.

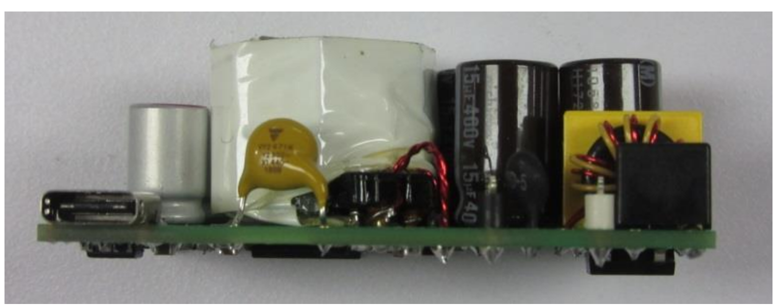

Figure 4 – Populated Circuit Board Photograph (Side View).

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2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power			23.1		mW	Measured at 115 VAC.
5 V Setting						
Output Voltage	$V_{OUT(5 V)}$		5.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(5 V)}$			150	mV	Measured at End of 100 mΩ Cable. (20 MHz Bandwidth).
Output Current	$I_{OUT(5 V)}$			3	A	±3%
Average Efficiency	$\eta_{(5 V)}$		89.5		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(5 V)}$			15	W	
9 V Setting						
Output Voltage	$V_{OUT(9 V)}$		9.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(9 V)}$			150	mV	Measured at End of 100 mΩ Cable. (20 MHz Bandwidth).
Output Current	$I_{OUT(9 V)}$			3	A	±3%
Average Efficiency	$\eta_{(9 V)}$		90.0		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(9 V)}$			27	W	
3.3 V – 11 V PPS Setting						
Output Voltage	$V_{OUT(PPS)}$	3.3		11	V	±3%
Output Voltage Ripple	$V_{RIPPLE(PPS)}$			150	mV	Measured at End of 100 mΩ Cable. (20 MHz Bandwidth).
Output Current	$I_{OUT(PPS)}$			3	A	±3%
PPS Voltage Step	$V_{STEP(PPS)}$		20		mV	PPS Output Voltage Step Size.
PPS Current Step	$I_{STEP(PPS)}$		50		mA	PPS Operating Current Step Size.
Average Efficiency (3.3 V)	$\eta_{(3.3 V)}$		87.3		%	Measured at 230 VAC from AC Receptacle to Type-C Receptacle on the Board.
Average Efficiency (11 V)	$\eta_{(11 V)}$		89.5		%	
Continuous Output Power	$P_{OUT(PPS)}$			27	W	
Conducted EMI		Meets CISPR22B / EN55022B				
Ambient Temperature	T_{AMB}	0		40	ºC	Free Convection, Sea Level.

Note: To use this design for a charger/adapter, circuit board would need to be modified depending on shape and form factor of the housing. ESD and Line surge performance should be evaluated and layout adjusted to meet the target specification.

3 Schematic Diagram

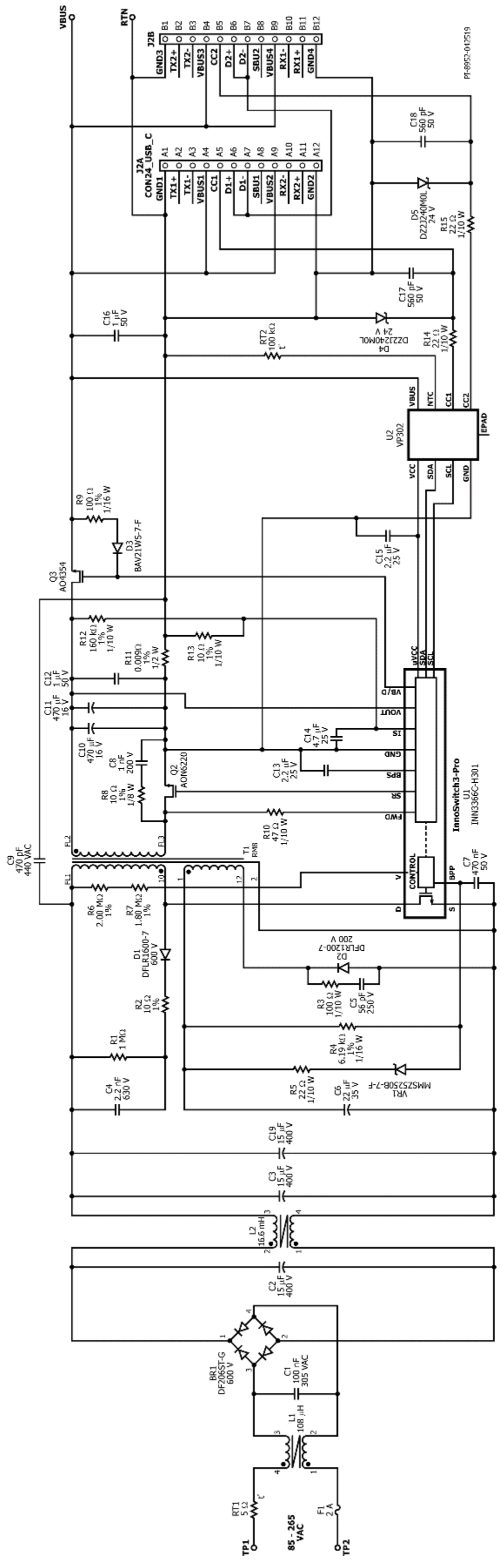

Figure 5 – Schematic Diagram.

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4 Circuit Description

4.1 Input Rectifier and EMI Filter

Fuse F1 isolates the circuit to provide protection from component failure, and the thermistor RT1 limits the inrush current when the unit is connected to the input AC supply. Capacitors C1, C9, and common mode choke L1 provide differential and common mode noise filtering for EMI attenuation. Bridge rectifier BR1 rectifies the AC line voltage to have a full wave rectified DC, which is passed to a filter consisting of C2, L2, C3, and C19. This filter also provides differential and common mode noise filtering to further attenuate EMI.

4.2 InnoSwitch3-Pro IC Primary

One end of the transformer primary is connected to the rectified DC bus and the other end is connected to the drain terminal of the MOSFET inside the InnoSwitch3-Pro IC U1. Resistors R6 and R7 provide input voltage sensing for protection in case of AC input undervoltage or overvoltage.

A low-cost RCD clamp formed by diode D1, resistors R2, R1 and capacitor C4 limits the peak drain-source voltage of U1 at the instant the MOSFET inside U1 turns off. The clamp helps to dissipate the energy stored in the leakage reactance of transformer T1.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor C7 when AC is first applied. During normal operation the primary side block is powered from an auxiliary winding on the transformer T1. The output of the auxiliary (or bias) winding is rectified using diode D2 and filtered using capacitor C6. Resistor R4 limits the current being supplied to the BPP pin of the InnoSwitch3-Pro IC. Capacitor C6 and resistor R4 also ensure sufficient current is provided to the BPP pin such that the internal current source of U1 is not required to charge C7 during normal operation. The RC network comprising of resistor R3 and capacitor C5 offers damping of the high frequency ringing in the voltage across diode D2 to reduce radiated EMI.

Zener diode VR1 offers primary sensed output overvoltage protection. In a flyback converter, output of the auxiliary winding tracks the output voltage of the converter. In case of over voltage at output of the converter, the auxiliary winding voltage increases and causes breakdown of VR1 which then causes excess current to flow into the BPP pin of InnoSwitch3-Pro IC. If the current flowing into the BPP pin increases above the I_{SD} threshold, the InnoSwitch3-Pro controller will latch off and prevent any further increase in output voltage. Resistor R5 limits the current injected to BPP pin when the output overvoltage protection is triggered.

4.3 InnoSwitch3-Pro IC Secondary and USB Power Delivery Controller

The secondary-side of the InnoSwitch3-Pro IC provides output voltage and current sensing and a gate drive to a MOSFET for synchronous rectification. The voltage across the transformer secondary winding is rectified by the secondary-side MOSFET (or SR

FET) Q2 and filtered by capacitors C10 and C11. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via a RC snubber, R8 and C8.

The gate of Q2 is turned on by secondary-side controller inside the InnoSwitch3-Pro IC based on the secondary winding voltage sensed via resistor R10 and fed into the FWD pin of the IC.

In continuous conduction mode of operation, the SR FET is turned off just prior to the secondary-side commanding a new switching cycle from the primary. In discontinuous mode of operation, the SR FET is turned off when the magnitude of the voltage drop across the SR FET falls below a threshold of approximately $V_{SR(TH).}$ Secondary-side control of the primary-side power MOSFET avoids any possibility of cross conduction of the two MOSFETs and provides extremely reliable synchronous rectifier operation.

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. Capacitor C13 connected to the BPS pin of InnoSwitch3-Pro IC provides decoupling for the internal circuitry.

The output current is sensed by monitoring the voltage drop across resistor R11. Resistors R12 and R13 add an offset to the sensed output current to provide a positive slope to the CC characteristic. The resulting current measurement is filtered with decoupling capacitor C14 and monitored across the IS and SECONDARY GROUND pins of the InnoSwitch3-Pro IC. An internal current sense threshold is configured via the I^2C interface up to approximately 32 mV to reduce losses. Once the threshold is exceeded, the InnoSwitch3-Pro IC regulates the number of switch pulses to maintain a fixed output current.

During constant current (CC) operation, when the output voltage falls, the secondary side controller inside InnoSwitch3-Pro IC will power itself from the secondary winding directly. During the on-time of the primary-side power MOSFET, the forward voltage that appears across the secondary winding is used to charge the SECONDARY BYPASS pin decoupling capacitor C13 via resistor R10 and an internal regulator. This allows output current regulation to be maintained down to the minimum UV threshold. Below this level the unit enters auto-restart until the output load is reduced.

When the output current is below the CC threshold, the converter operates in constant voltage mode. The output voltage is monitored by the VOUT pin of the InnoSwitch3-Pro IC. Similar with current regulation, the output voltage is also compared to an internal voltage threshold that is set via the I^2C interface and the controller inside the IC regulates the output voltage by controlling the number of switch pulses. Capacitor C12 is needed between the VOUT pin and the SECONDARY GROUND pin for ESD protection of the VOUT pin.

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N-MOSFET Q3 functions as the bus switch which connects or disconnects the output of the flyback converter from the USB Type-C receptacle. Q3 is controlled by the VB/D pin on the InnoSwitch3-Pro IC. Resistor R9 and diode D3 are connected across the Source and Gate terminals of the Q3 to provide a discharge path for the bus voltage when the Q3 is turned off. Capacitor C16 is needed at the output for ESD protection.

In this design, VP302 (U2) is the USB Power Delivery (USB PD) controller. It is powered by the InnoSwitch3-Pro IC through the µVCC pin. USB PD protocol is communicated over either CC1 or CC2 line depending on the orientation in which Type-C plug is connected.

The VP302 controller communicates with InnoSwitch3-Pro IC through the I^2C interface using the SCL and SDA lines in which it sets the CV, CC, V_{KP}, OVA and UVA parameters. These parameters correspond to the output voltage, constant output current, constant output power voltage threshold, output overvoltage threshold, and output undervoltage threshold registers of the InnoSwitch3-Pro IC, respectively. The status of the InnoSwitch3-Pro IC is read by the VP302 IC from the telemetry registers also using the I^2C interface.

Capacitor C15 provides decoupling to VCC of the VP302 IC. Capacitors C17 and C18, resistors R14, R15, and TVS D4 and D5 provide protection from ESD to pins CC1, CC2.

Thermistor RT2 is connected to the NTC pin of the VP302 IC to provide temperature detection of the USB Type-C receptacle. The VBUS pin of the VP302 IC is used to sense the output voltage at the USB Type-C receptacle, which is the voltage after the bus switch Q3. The VBUS pin is also used for discharging the capacitor C16 when the bus switch Q3 is opened.

5 PCB Layout

PCB copper thickness is 2.0 oz.

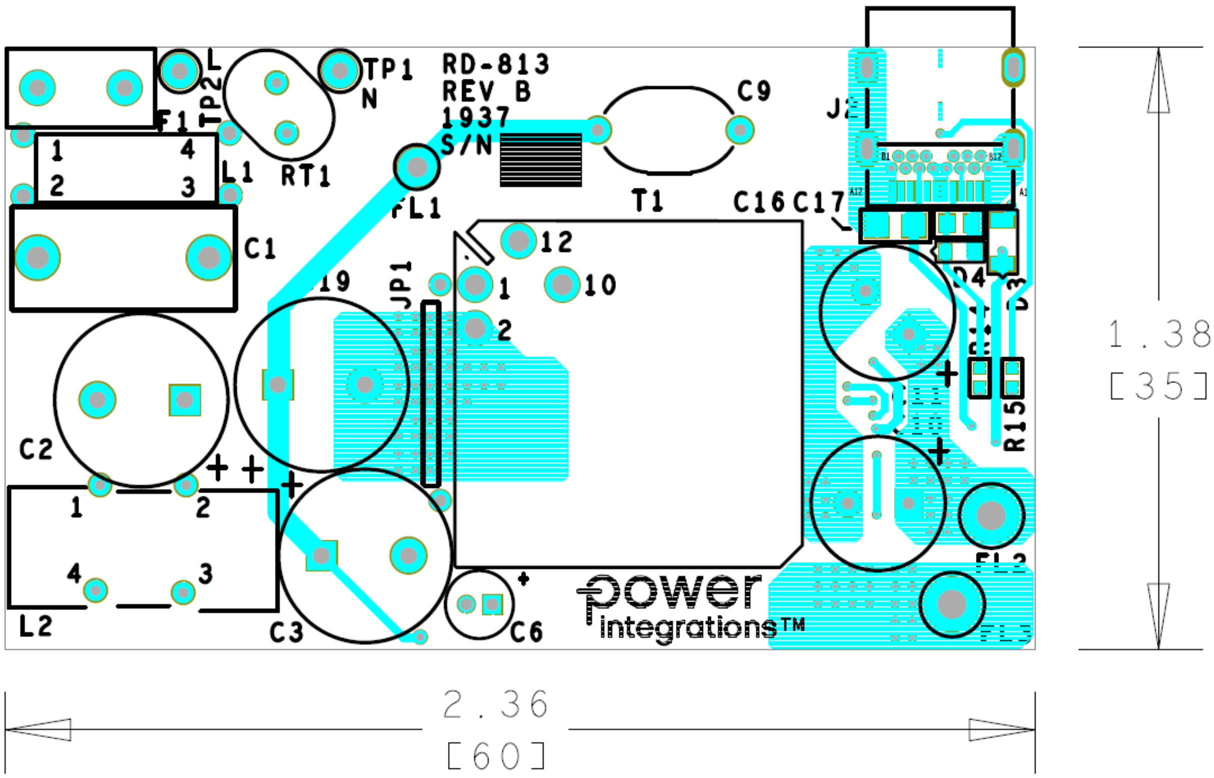

Figure 6 – Printed Circuit Layout, Top.

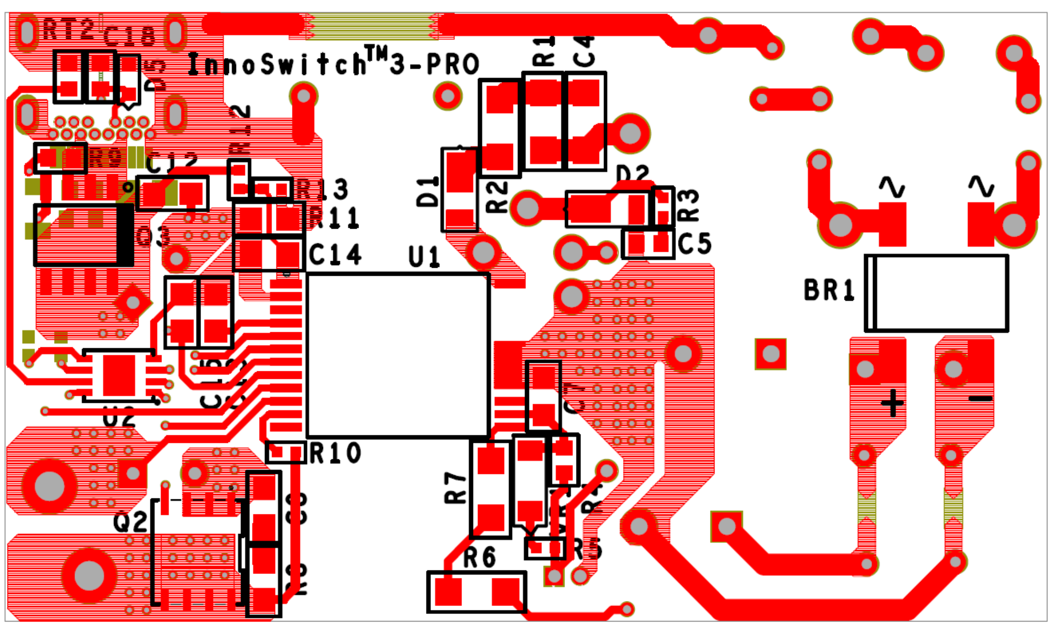

Figure 7 – Printed Circuit Layout, Bottom.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	600 V, 2 A, Bridge Rectifier, SMD, DFS	DF206ST-G	Comchip
2	1	C1	100 nF, 305 VAC, Polypropylene Film, X2	MK61104-P24M B32921C3104M000	Sichuan Zhongxing TDK
3	1	C2	15 μF, 400 V, Electrolytic, (10 x 16)	UVC2G150MPD	Nichicon
4	1	C3	15 μF, 400 V, Electrolytic, (10 x 16)	UVC2G150MPD	Nichicon
5	1	C4	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K C3216X7R2J222K115AA	TDK Corp
6	1	C5	56 pF, 250 V, Ceramic, NP0, 0603	GQM1875C2E560JB12D	Murata
7	1	C6	22 μF, 35 V, Electrolytic, Gen. Purpose, (4 x 12.5)	UVR1V220MDD6TP	Nichicon
8	1	C7	470 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H474KA88L	Murata
9	1	C8	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
10	1	C9	470 pF, ±10%, 440VAC, (X1, Y2) rated, Ceramic, Y5S, Radial, Disc, -40°C ~ 125°C	VY2471K29Y5SS63V7	Vishay
11	1	C10	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
12	1	C11	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
13	1	C12	1 μF, ±20% ,50 V, Ceramic, X7R, AEC-Q200, Automotive, Boardflex Sensitive, 0805	CGA4J3X7R1H105M125AE	TDK
14	1	C13	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M C2012X7R1E225M085AB	TDK
15	1	C14	4.7 μF ±10%, 25V, X7R, 0805,-55°C ~ 125°C	TMK212AB7475KG-T	Taiyo Yuden
16	1	C15	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M C2012X7R1E225M085AB	TDK
17	1	C16	1 μF,±20% ,50 V, Ceramic, X7R, AEC-Q200, Automotive, Boardflex Sensitive, 0805	CGA4J3X7R1H105M125AE	TDK
18	1	C17	560 pF, 50 V, Ceramic, X7R, 0603, 0.063" L x 0.031" W (1.60mm x 0.80mm)	CL10B561KB8NNNC	Samsung
19	1	C18	560 pF, 50 V, Ceramic, X7R, 0603, 0.063" L x 0.031" W (1.60mm x 0.80mm)	CL10B561KB8NNNC	Samsung
20	1	C19	15 μF, 400 V, Electrolytic, (10 x 16)	UVC2G150MPD	Nichicon
21	1	D1	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
22	1	D2	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
23	1	D3	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
24	1	D4	Diode, ZENER, 24 V, 200 mW, SMINI2	DZ2J240M0L	Panasonic
25	1	D5	Diode, ZENER, 24 V, 200 mW, SMINI2	DZ2J240M0L	Panasonic
26	1	F1	2 A, 250V, Slow, Long Time Lag, RST	RST 2	Belfuse
27	1	J2	USB-C USB 3.1 (USB 3.1 Gen 2, Superspeed+) Receptacle Connector 24 Pos SMT, RA, TH	632723300011	Wurth
28	1	JP1	Wire Jumper, Insulated, #24 AWG, 0.8 in	C2003A-12-02	Gen Cable
29	1	L1	Toroidal Common Mode Choke, 108 μH, custom	32-00369-00 SNX-R1912	Power Integrations Santronics
30	1	L2	Toroidal Common Mode Choke, 16.6 mH, custom	32-00368-00 SNX-R1913	Power Integrations Santronics
31	1	Q2	MOSFET, N-CH, 100V, 48A (Tc), 113.5W (Tc), DFN5X6, 8-DFN (5x6)	AON6220	Alpha & Omega Semi
32	1	Q3	MOSFET, N-CH, 30V, 23A (Ta), 3.1W (Ta),3.7 mΩ (@ 20 A, 10 V), 8SOIC	AO4354	Alpha & Omega Semi
33	1	R1	RES, 1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
34	1	R2	RES, 10 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF10R0V	Panasonic
35	1	R3	RES, 100 Ω, 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ101X	Panasonic
36	1	R4	RES, 6.19 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF6191V	Panasonic
37	1	R5	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ220X	Panasonic
38	1	R6	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
39	1	R7	RES, 1.80 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1804V	Panasonic
40	1	R8	RES, 10 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF10R0V	Panasonic
41	1	R9	RES, 100 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1000V	Panasonic

42	1	R10	RES, 47 Ω, 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ470X	Panasonic
43	1	R11	RES, 0.009 Ω, ±1%, 0.5 W, 0805, Automotive AEC-Q200, Current Sense, Moisture Resistant, Metal Element	CRF0805-FZ-R009ELF	Bourns
44	1	R12	RES, 160.0 kΩ, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1603X	Panasonic
45	1	R13	RES, 10 Ω, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF10R0X	Panasonic
46	1	R14	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ220X	Panasonic
47	1	R15	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ220X	Panasonic
48	1	RT1	NTC Thermistor, 5, 1 A	MF72-005D5	Cantherm
49	1	RT2	NTC Thermistor, 100 kΩ, 3%, 0603	NCP18WF104E03RB	Murata
50	1	T1	Flyback Transformer, 570 μH, RM8, PC95 material, custom Bobbin, RM8, Vertical, Circular, 6 pins	SNX-R1911 MCT-RM8-10(V6+0P)	Power Integrations Santronics Mycoiltech
51	1	TP1	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
52	1	TP2	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
53	1	U1	InnoSwitch3-Pro, InSOP24D	INN3366C-H301	Power Integrations
54	1	U2	USB PD Type-C Controller for SMPS	VP302	VIA Labs
55	1	VR1	DIODE ZENER 20 V 500 mW SOD123	MMSZ5250B-7-F	Diodes, Inc.

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7 Transformer Specification

7.1 Electrical Diagram

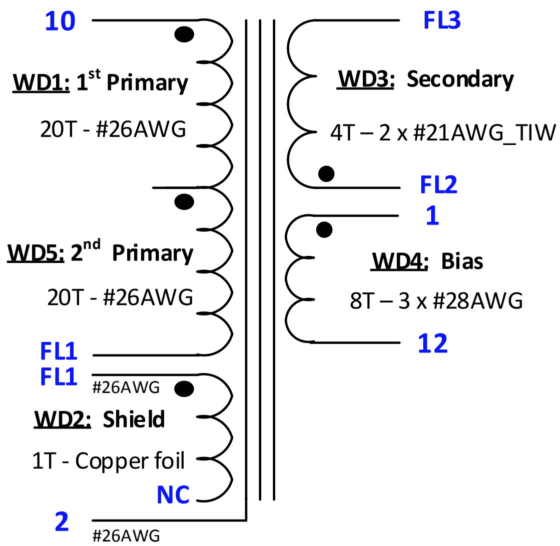

Figure 8 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Electrical Strength	60 seconds, 60 Hz, from pins 1, 2, 10, 12, FL1 to FL2-FL3.	3000 VAC
Primary Inductance	Pin 10 – FL1, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	570 µH ±7%
Resonant Frequency	Pin 10 – FL1, all other windings open.	2000 kHz (Min.)
Primary Leakage Inductance	Pin 10 – FL1, with FL2 - FL3 shorted, measured at 100 kHz, 0.4 V_{RMS}.	8.0 µH (Max.)

7.3 Material List

Item	Description
[1]	Core: RM8, PC95 material; or Equivalent. Gapped ALG: 356nH/T².
[2]	Bobbin: RM8, Vertical, 6 pins, Circular, PI#: 25-01147-00; or Equivalent.
[3]	Clip: RM8, Allstar Magnetic, CLI/P-RM8/I; or Equivalent.
[4]	Magnet Wire: #26 AWG, Double Coated.
[5]	Magnet Wire: #28 AWG, Double Coated.
[6]	Magnet Wire: #21 AWG, Triple Insulated Wire.
[7]	Copper Foil: Copper Tape; 8.6 mm Width x 38.0 mm Length x 1 mil Thick, Soldered with Magnetic Wire #26 AWG at one end.
[8]	Tape: Polyester Film, 3M, 1 mil Thick, 9.3 mm Wide.
[9]	Tape: Polyester Film, 3M, 1 mil Thick, 6.5 mm Wide.
[10]	Tape: Polyester Film, 3M, 1 mil Thick, 16.0 mm Wide.
[11]	Varnish: Dolph BC 359; or Equivalent.

7.4 Transformer Build Diagram

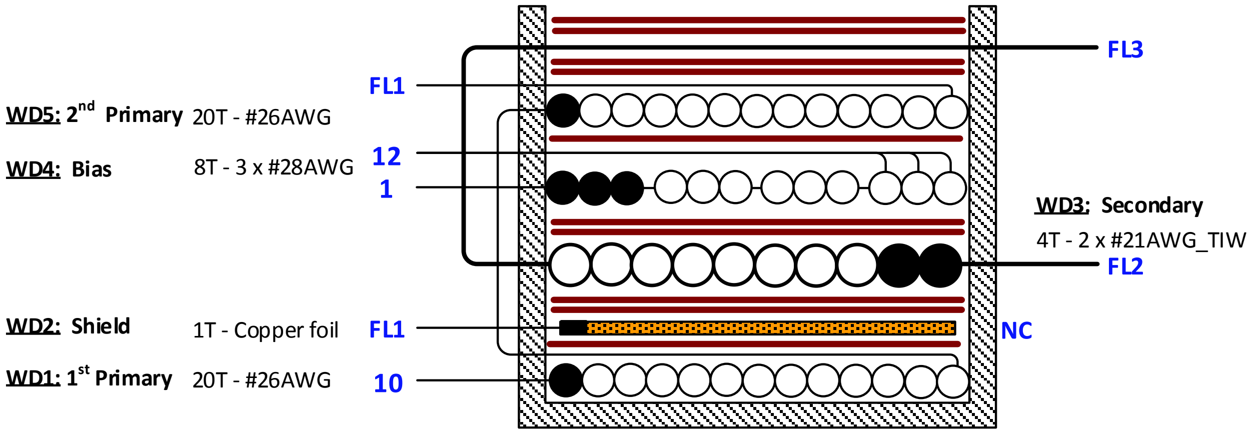

Figure 9 – Transformer Build Diagram.

7.5 Transformer Construction

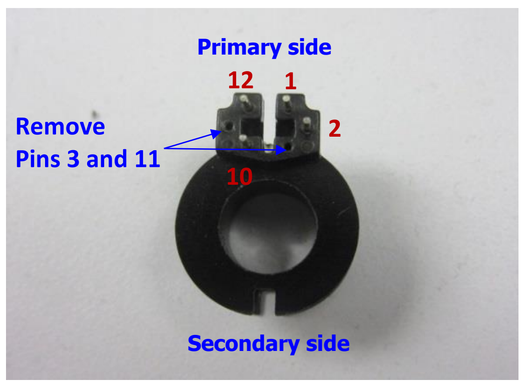

Figure 10 – Bobbin Modification.

Winding Preparation	Trim pins 3 and 11 of bobbin Item [2] as shown in Figure 10. Position the bobbin on the mandrel such that the primary side of the bobbin is on the left side. Winding direction is clock-wise direction for forward direction.
WD1 1st Half Primary	Start from pin 10, wind 20 turns of wire Item [4] in 1 layer, with tight tension, from left to right. At the last turn bring the wire back to the left and leave ~3 ft. long for 2nd half primary winding - WD5.
Insulation	1 layer of tape Item [8].
WD2 Shield	Prepare copper foil Item [7] with one end soldered with wire Item [4] and mark as FL1. Start with the copper foil edge soldered with wire, wind 1 turn overlapped but not shorted. Leave this other end of the copper foil as no-connect.
Insulation	2 layers of tape Item [8].
WD3 Secondary	Use 2 wires Item [6], leave ~2.0" floating, and mark as FL2. Start from top slot of the bobbin secondary side and wind 4 turns from right to left. After the last turn, exit the wires at the left slot of the bobbin secondary side, leave ~2.0" floating and mark as FL3.
Insulation	2 layers of tape Item [8].
WD4 Bias	Start from pin 1, wind 8 tri-filar turns of Item [5] in 1 layer, with tight tension, from left to right. At the last turn bring the wires back to the left and finish at pin 12.
Insulation	1 layer of tape Item [8].

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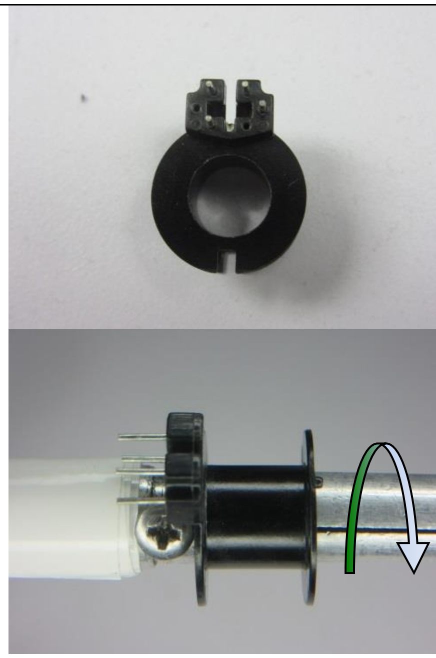
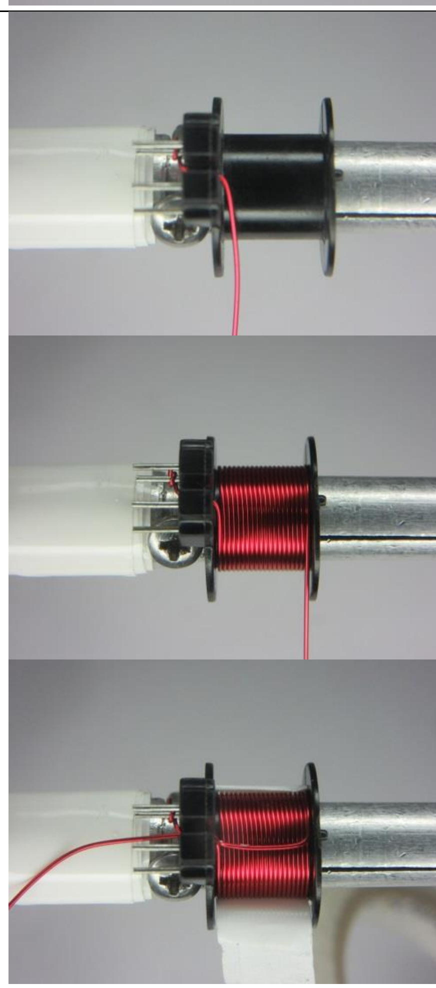
WD5 2nd Half Primary	Use wire floating from WD1 - 1st half Primary; continue winding 20 turns from left to right. At the last turn, bring the wire back to left, leave ~1.0" floating, and mark as FL1.
Insulation	Place 2 layers of tape Item [8], bring the wires FL3 from secondary winding to the right at top slot of the bobbin secondary side, and place another 2 layers of tape Item [8] (total of 4 layers) to secure all windings.
Gap and Ground Core	Gap core halves to 570 μH, secure with clips Item [3] with GND pins on bottom and cut short. Solder Item [4] to the top of one clip then and connect the other end of the wire to pin 2, which is connected to primary ground in the PCB.
Finish	Wrap the core with two turns of tape Item [9]. Cover the bottom of the transformer with tape Item [10], then wrap around the sides of the transformer with tape Item [10]. Ensure that the tape covers the core and bobbin on the secondary side. Varnish with Item [11].

7.6 Winding Illustrations

Winding Preparation		Trim pins 3 and 11 of bobbin Item [2]. Position the bobbin on the mandrel such that the primary side of the bobbin is on the left side. Winding direction is clock-wise direction for forward direction.
WD1 **1st Primary**		Start from pin 10, wind 20 turns of wire Item [4] in 1 layer, with tight tension, from left to right. At the last turn bring the wire back to the left and leave ~3 ft. long for 2nd half primary winding - WD5.

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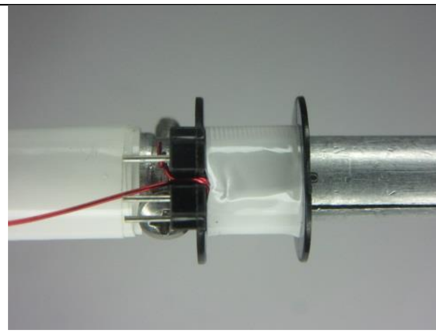
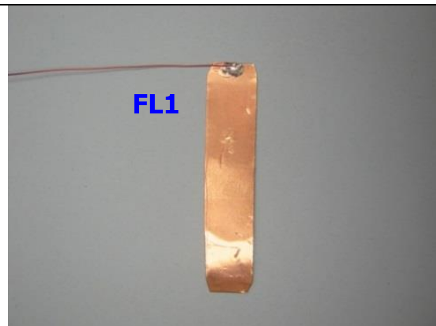
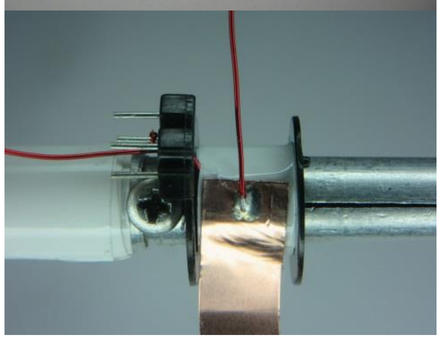
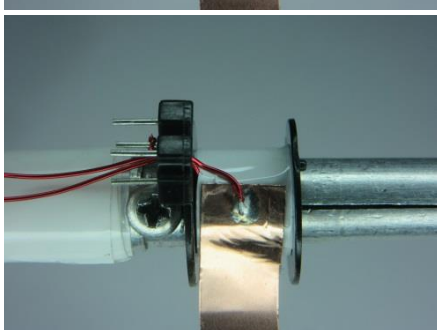
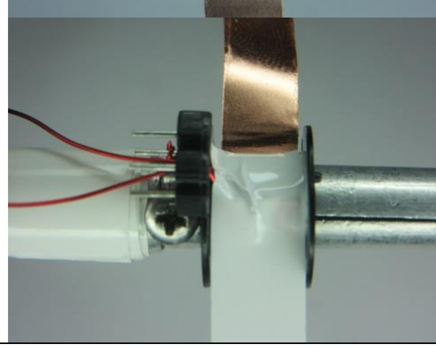
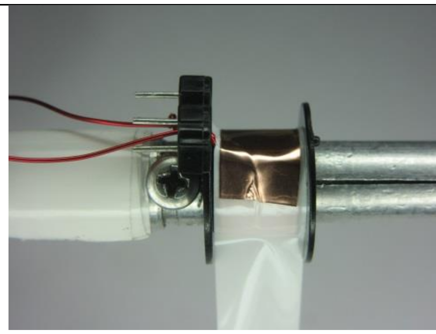
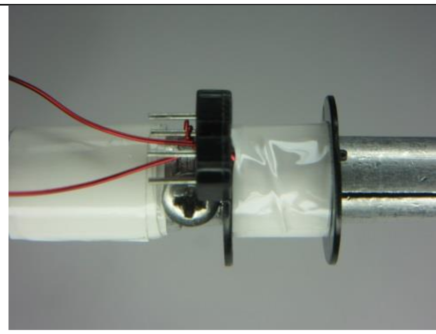
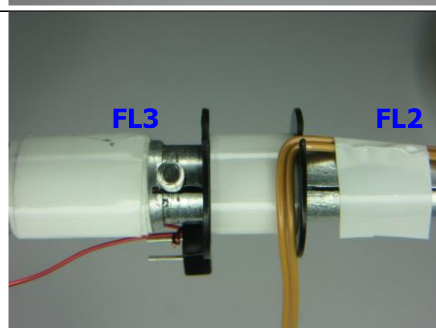
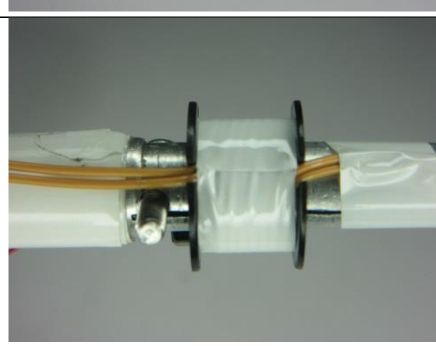
Insulation		1 layer of tape Item [8].
WD2 Shield		Prepare copper foil Item [7] with one end soldered with wire Item [4] and mark as FL1. Start with the copper foil edge soldered with wire, wind 1 turn overlapped but not shorted. Leave this other end of the copper foil as no-connect.

		
Insulation		2 layers of tape Item [8].
WD3 Secondary	 	Use 2 wires Item [6], leave ~2.0” floating, and mark as FL2. Start from top slot of the bobbin secondary side and wind 4 turns from right to left. After the last turn, exit the wires at the left slot of the bobbin secondary side, leave ~2.0” floating and mark as FL3.
Insulation		2 layers of tape Item [8].

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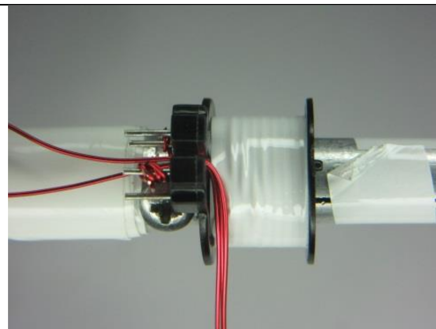
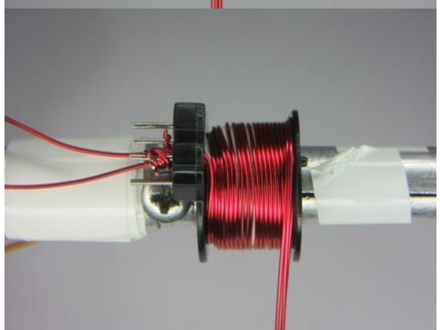
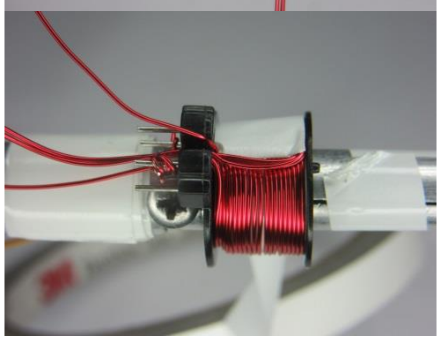
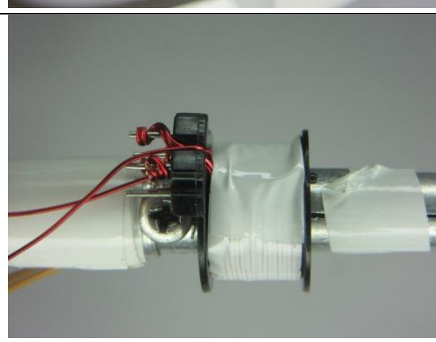
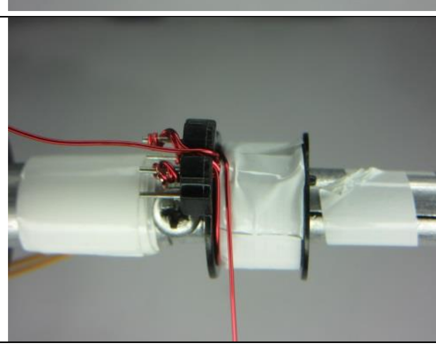
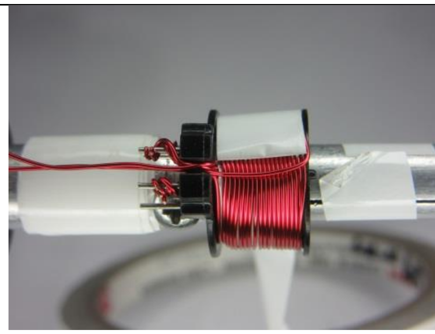
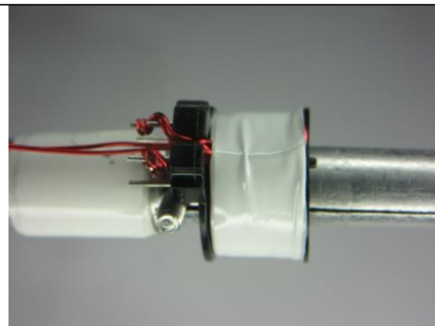
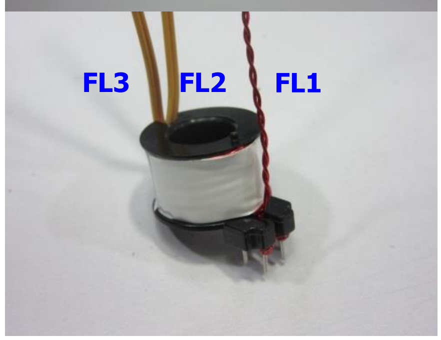
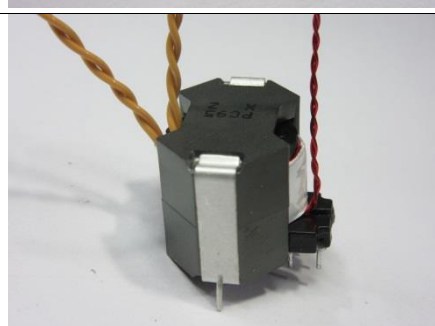
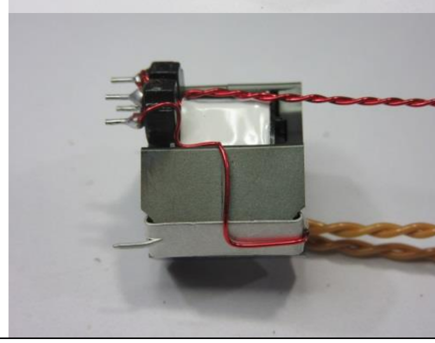
WD4 **Bias**		Start from pin 1, wind 8 tri-filar turns of Item [4] in 1 layer, with tight tension, from left to right. At the last turn bring the wires back to the left and finish at pin 12.
Insulation		1 layer of tape Item [8].
WD5 **2nd Primary**		Use wire floating from WD1 - 1st half Primary; continue winding 20 turns from left to right. At the last turn, bring the wire back to left, leave ~1.0" floating, and mark as FL1.

		
Insulation	 	Place 2 layers of tape Item [8], bring the wires FL3 from secondary winding to the right at top slot of the bobbin secondary side, and place another 2 layers of tape Item [8] (total of 4 layers) to secure all windings.
Gap and Ground Core	 	Gap core halves to 570 μH, secure with clips Item [3] with GND pins on bottom and cut short. Solder Item [4] to the top of one clip then and connect the other end of the wire to pin 2, which is connected to primary ground in the PCB.

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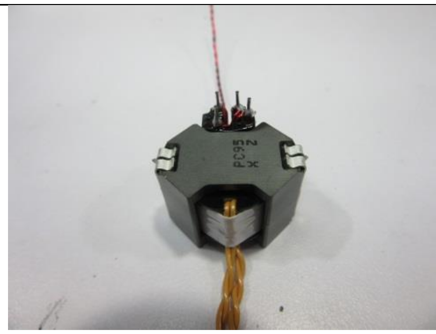
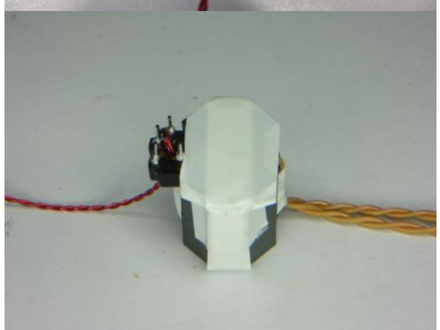
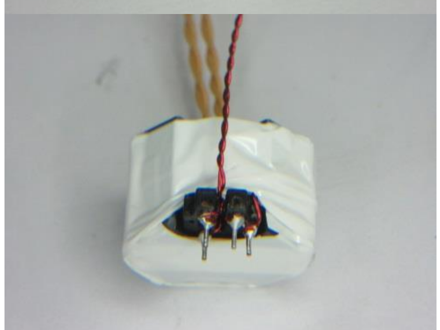
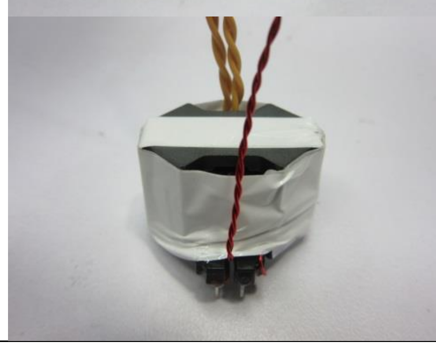
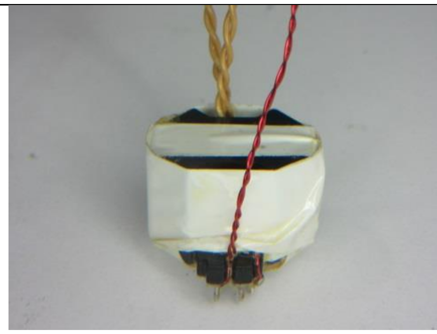
		
Finish	   	Wrap the core with two turns of tape Item [9]. Cover the bottom of the transformer with tape Item [10], then wrap around the sides of the transformer with tape Item [10]. Ensure that the tape covers the core and bobbin on the secondary side. Varnish with Item [11].

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8 Common Mode Choke Specifications

8.1 108 µH Common Mode Choke (L1)

8.1.1 *Electrical Diagram*

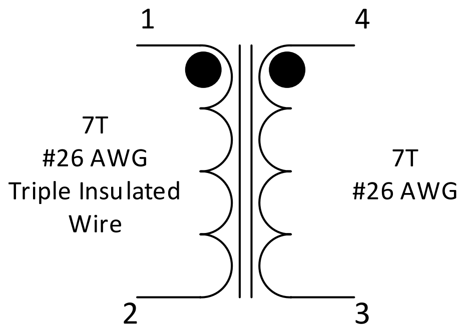

Figure 11 – Inductor Electrical Diagram.

8.1.2 *Electrical Specifications*

Inductance	Pins 1-2 measured at 100 kHz, 0.4 RMS.	108 µH ±20%
Leakage Inductance	Pins 1-2, with 3-4 shorted.	0.5 µH ±10%

8.1.3 *Material List*

Item	Description
[1]	Toroid: Ferrite Inductor Toroid. 415" OD; Mfg Part Number: 35T0375-10H. Dim: 9.53 mm, O.D. x 4.75 mm, I.D. x 3.18 mm L.
[2]	Magnet Wire: #26 AWG, Double Coated.
[3]	Magnet Wire: #26 AWG, Triple Insulated Wire.

8.1.4 *Winding Illustration*

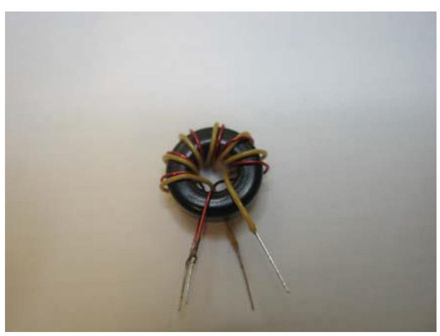

Figure 12 – 108 µH CMC L1 Front View.

8.2 16.6 mH Common Mode Choke (L2)

8.2.1 *Electrical Diagram*

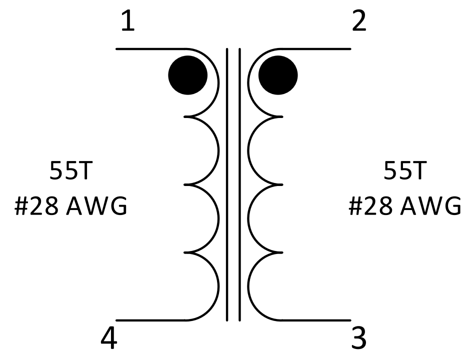

Figure 13 – Inductor Electrical Diagram.

8.2.2 *Electrical Specifications*

Inductance	Pins 1-4 and pins 2-3 measured at 100 kHz, 0.4 RMS.	16.6 mH ±25%
Core effective Inductance Index		5500 nH/N^2
Leakage Inductance	Pins 1-4, with 2-3 shorted.	80 μH ±10%

8.2.3 *Materials List*

Item	Description
[1]	Toroid: Ferrite Inductor Toroid T14 x 8 x 5.5, PI#: 32-00286-00.
[2]	Divider - Fish Paper, Insulating Cotton Rag, 0.010" thick, PI #: 66-00042-00.
[3]	Magnet Wire: #28 AWG Heavy Nyleze.
[4]	Epoxy: Devcon, 5 mins Epoxy; or equivalent.

8.2.4 *Winding Instructions*

- Place fish paper Item [2] onto toroid core Item [1] to divide the core into two equal sections. Use Epoxy Item [4] to fix the position of the fish paper divider.
- Use 4 ft of wire Item [3], start as pin 1, wind 55 turns in 2 layers in one toroid half, and end as pin 4.
- Do the same for another half of the toroid, starting as pin 2 and ending as pin 3.

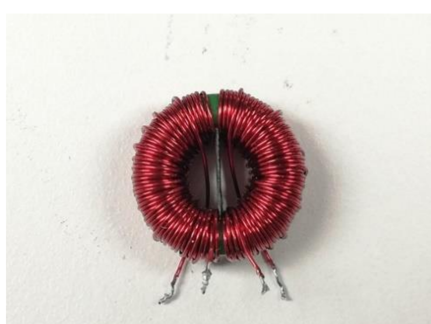

Figure 14 – 16.6 mH CMC L2 Front View.

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9 Transformer Design Spreadsheet

1	ACDC_InnoSwitch3-Pro_Flyback_042018; Rev.1.0; Copyright Power Integrations 2018	INPUT	INFO	OUTPUT	UNITS	InnoSwitch3-Pro Flyback Design Spreadsheet
2	APPLICATION VARIABLES					
3	VAC_MIN			85	V	Minimum AC line voltage
4	VAC_MAX			265	V	Maximum AC input voltage
5	VAC_RANGE			UNIVERSAL		AC line voltage range
6	FLINE			60	Hz	AC line voltage frequency
7	CAP_INPUT	45.0		45.0	uF	Input capacitance
9	SETPOINT 1					
10	VOUT1	11.00		11.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	2.450		2.450	A	Output current 1
12	POUT1			26.95	W	Output power 1
13	EFFICIENCY1	0.89		0.89		Converter efficiency for output 1
14	Z_FACTOR1	0.50		0.50		Z-factor for output 1
16	SETPOINT 2					
17	VOUT2	9.00		9.00	V	Output voltage 2
18	IOUT2	3.000		3.000	A	Output current 2
19	POUT2			27.00	W	Output power 2
20	EFFICIENCY2	0.89		0.89		Converter efficiency for output 2
21	Z_FACTOR2	0.50		0.50		Z-factor for output 2
23	SETPOINT 3					
24	VOUT3	5.00		5.00	V	Output voltage 3
25	IOUT3	3.000		3.000	A	Output current 3
26	POUT3			15.00	W	Output power 3
27	EFFICIENCY3	0.89		0.89		Converter efficiency for output 3
28	Z_FACTOR3	0.50		0.50		Z-factor for output 3
30	SETPOINT 4					
31	VOUT4	3.30		3.30	V	Output voltage 4
32	IOUT4	3.000		3.000	A	Output current 4
33	POUT4			9.90	W	Output power 4
34	EFFICIENCY4	0.89		0.89		Converter efficiency for output 4
35	Z_FACTOR4	0.50		0.50		Z-factor for output 4
37	SETPOINT 5					
38	VOUT5			0.00	V	Output voltage 5
39	IOUT5			0.000	A	Output current 5
40	POUT5			0.00	W	Output power 5
41	EFFICIENCY5			0.00		Converter efficiency for output 5
42	Z_FACTOR5			0.00		Z-factor for output 5
44	SETPOINT 6					
45	VOUT6			0.00	V	Output voltage 6
46	IOUT6			0.000	A	Output current 6
47	POUT6			0.00	W	Output power 6
48	EFFICIENCY6			0.00		Converter efficiency for output 6
49	Z_FACTOR6			0.00		Z-factor for output 6
51	SETPOINT 7					
52	VOUT7			0.00	V	Output voltage 7
53	IOUT7			0.000	A	Output current 7
54	POUT7			0.00	W	Output power 7
55	EFFICIENCY7			0.00		Converter efficiency for output 7
56	Z_FACTOR7			0.00		Z-factor for output 7
58	SETPOINT 8					
59	VOUT8			0.00	V	Output voltage 8
60	IOUT8			0.000	A	Output current 8
61	POUT8			0.00	W	Output power 8
62	EFFICIENCY8			0.00		Converter efficiency for output 8

63	Z_FACTOR8			0.00		Z-factor for output 8
65	**SETPOINT 9**					
66	VOUT9			0.00	V	Output voltage 9
67	IOUT9			0.000	A	Output current 9
68	POUT9			0.00	W	Output power 9
69	EFFICIENCY9			0.00		Converter efficiency for output 9
70	Z_FACTOR9			0.00		Z-factor for output 9
72	VOLTAGE_CDC	0.000		0.000		Percentage (of output voltage) cable drop compensation desired at full load
76	**PRIMARY CONTROLLER SELECTION**					
77	ENCLOSURE	ADAPTER		ADAPTER		Power supply enclosure
78	ILIMIT_MODE	STANDARD		STANDARD		Device current limit mode
79	VDRAIN_BREAKDOWN	650		650	V	Device breakdown voltage
80	DEVICE_GENERIC	INN33X6		INN33X6		Device selection
81	DEVICE_CODE			INN3366C		Device code
82	PDEVICE_MAX			27	W	Device maximum power capability
83	RDSON_25DEG			1.50	Ω	Primary switch on-time resistance at 25°C
84	RDSON_100DEG			2.32	Ω	Primary switch on-time resistance at 100°C
85	ILIMIT_MIN			1.162	A	Primary switch minimum current limit
86	ILIMIT_TYP			1.250	A	Primary switch typical current limit
87	ILIMIT_MAX			1.338	A	Primary switch maximum current limit
88	VDRAIN_ON_PRSW			0.85	V	Primary switch on-time voltage drop
89	VDRAIN_OFF_PRSW			553.31	V	Peak drain voltage on the primary switch during turn-off
93	**WORST CASE ELECTRICAL PARAMETERS**					
94	FSWITCHING_MAX	86000		86000	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
95	VOR	110.0		110.0	V	Voltage reflected to the primary winding (corresponding to setpoint 1) when the primary switch turns off
96	VMIN			79.20	V	Valley of the rectified minimum input AC voltage at full load
97	KP			0.789		Measure of continuous/discontinuous mode of operation
98	MODE_OPERATION			CCM		Mode of operation
99	DUTYCYCLE			0.584		Primary switch duty cycle
100	TIME_ON			9.73	us	Primary switch on-time
101	TIME_OFF			4.97	us	Primary switch off-time
102	LPRIMARY_MIN			529.3	uH	Minimum primary magnetizing inductance
103	LPRIMARY_TYP			569.2	uH	Typical primary magnetizing inductance
104	LPRIMARY_TOL	7.0		7.0	%	Primary magnetizing inductance tolerance
105	LPRIMARY_MAX			609.0	uH	Maximum primary magnetizing inductance
107	**PRIMARY CURRENT**					
108	IAVG_PRIMARY			0.366	A	Primary switch average current
109	IPEAK_PRIMARY			1.275	A	Primary switch peak current
110	IPEDESTAL_PRIMARY			0.238	A	Primary switchT current pedestal
111	IRIPPLE_PRIMARY			1.274	A	Primary switch ripple current
112	IRMS_PRIMARY			0.559	A	Primary switch RMS current
114	**SECONDARY CURRENT**					
115	IPEAK_SECONDARY			12.753	A	Secondary MOSFET peak current
116	IPEDESTAL_SECONDARY			2.380	A	Secondary MOSFET pedestal current
117	IRMS_SECONDARY			5.211	A	Secondary MOSFET RMS current
118	IRIPPLE_CAP_OUT			4.261	A	Output capacitor ripple current
122	**TRANSFORMER CONSTRUCTION PARAMETERS**					
123	**CORE SELECTION**					

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124	CORE	RM8	Info	RM8		The transformer windings may not fit: pick a bigger core or bobbin and refer to the Transformer Parameters tab for fit calculations
125	CORE NAME			B65811J0000R095		Core code
126	AE			64.0	mm^2	Core cross sectional area
127	LE			38.0	mm	Core magnetic path length
128	AL			4100	nH/N^2	Ungapped core effective inductance per turns squared
129	VE			2430	mm^3	Core volume
130	BOBBIN NAME			B65812N1012D001		Bobbin name
131	AW			30.0	mm^2	Bobbin window area
132	BW			10.03	mm	Bobbin width
133	MARGIN			0.0	mm	Bobbin safety margin
135	**PRIMARY WINDING**					
136	NPRIMARY			40		Primary winding number of turns
137	BPEAK			3258	Gauss	Peak flux density
138	BMAX			2984	Gauss	Maximum flux density
139	BAC			1490	Gauss	AC flux density (0.5 x Peak to Peak)
140	ALG			356	nH/N^2	Typical gapped core effective inductance per turns squared
141	LG			0.206	mm	Core gap length
142	LAYERS_PRIMARY			2		Primary winding number of layers
143	AWG_PRIMARY			26		Primary wire gauge
144	OD_PRIMARY_INSULATED			0.465	mm	Primary wire insulated outer diameter
145	OD_PRIMARY_BARE			0.405	mm	Primary wire bare outer diameter
146	CMA_PRIMARY			454.5	Cmils/A	Primary winding wire CMA
148	**SECONDARY WINDING**					
149	NSECONDARY	4		4		Secondary winding number of turns
150	AWG_SECONDARY			19		Secondary wire gauge
151	OD_SECONDARY_INSULATED			1.217	mm	Secondary wire insulated outer diameter
152	OD_SECONDARY_BARE			0.912	mm	Secondary wire bare outer diameter
153	CMA_SECONDARY			247.2	Cmils/A	Secondary winding wire CMA
155	**BIAS WINDING**					
156	NBIAS			7		Bias winding number of turns
160	**PRIMARY COMPONENTS SELECTION**					
161	**LINE UNDERVOLTAGE**					
162	BROWN-IN REQURED	76.00		76.00	V	Required line brown-in threshold
163	RLS			3.82	MΩ	Connect two 1.91 MOhm resistors to the V-pin for the required UV/OV threshold
164	BROWN-IN ACTUAL			76.58	V	Actual brown-in threshold using standard resistors
165	BROWN-OUT ACTUAL			69.26	V	Actual brown-out threshold using standard resistors
167	**LINE OVERVOLTAGE**					
168	OVERVOLTAGE_LINE		Warning	319.20	V	The device voltage stress will be higher than 585V when overvoltage is triggered
170	**BIAS WINDING**					
171	VBIAS	5.00	Info	5.00	V	The rectified bias voltage maybe too low to supply the BP pin: Increase the rectified bias voltage to a value higher than 9V
172	VF_BIAS			0.70	V	Bias winding diode forward drop
173	VREVERSE_BIASDIODE			70.33	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
174	CBIAS			22	uF	Bias winding rectification capacitor
175	CBPP			0.47	uF	BPP pin capacitor
179	**SECONDARY COMPONENTS SELECTION**					

180	**RECTIFIER**					
181	VDRAIN_OFF_SRFET			48.33	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
182	SRFET	SiR876ADP		SiR876ADP		Secondary rectifier (Logic MOSFET)
183	VBREAKDOWN_SRFET			100	V	Secondary rectifier breakdown voltage
184	RDSON_SRFET			14.5	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
188	**VARIABLE OUTPUTS ANALYSIS**					
189	**TOLERANCE CORNER**					
190	USER_VAC	115		115	V	Input AC RMS voltage corner to be evaluated
191	USER_ILIMIT	TYP		1.250	A	Current limit corner to be evaluated
192	USER_LPRIMARY	TYP		569.2	uH	Primary inductance corner to be evaluated
194	**SETPOINT SELECTION**					
195	SETPOINT	1		1		Select the setpoint which needs to be evaluated
196	FSWITCHING			69941.6	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
197	VOR			110.0	V	Voltage reflected to the primary winding when the primary switch turns off
198	VMIN			132.74	V	Valley of the minimum input AC voltage
199	KP			1.473		Measure of continuous/discontinuous mode of operation
200	MODE_OPERATION			DCM		Mode of operation
201	DUTYCYCLE			0.361		Primary switch duty cycle
202	TIME_ON			5.16	us	Primary switch on-time
203	TIME_OFF			9.14	us	Primary switch off-time
205	**PRIMARY CURRENT**					
206	IAVG_PRIMARY			0.216	A	Primary switch average current
207	IPEAK_PRIMARY			1.199	A	Primary switch peak current
208	IPEDESTAL_PRIMARY			0.000	A	Primary switch current pedestal
209	IRIPPLE_PRIMARY			1.199	A	Primary switch ripple current
210	IRMS_PRIMARY			0.416	A	Primary switch RMS current
212	**SECONDARY CURRENT**					
213	IPEAK_SECONDARY			11.990	A	Secondary MOSFET peak current
214	IPEDESTAL_SECONDARY			0.000	A	Secondary MOSFET pedestal current
215	IRMS_SECONDARY			4.560	A	Secondary MOSFET RMS current
216	IRIPPLE_CAP_OUT			3.846	A	Output capacitor ripple current
218	**MAGNETIC FLUX DENSITY**					
219	BPEAK			2845	Gauss	Peak flux density
220	BMAX			2666	Gauss	Maximum flux density
221	BAC			1333	Gauss	AC flux density (0.5 x Peak to Peak)

Note: Although the spreadsheet shows a warning indicating that device voltage stress likely exceeding 90% of the device rating, this voltage will still be safely below the specified voltage breakdown rating of the device and is acceptable since line OV is an abnormal operating condition and hence not expected to be a continuous operating condition.

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10 Enclosure Drawings

10.1 Enclosure Bottom

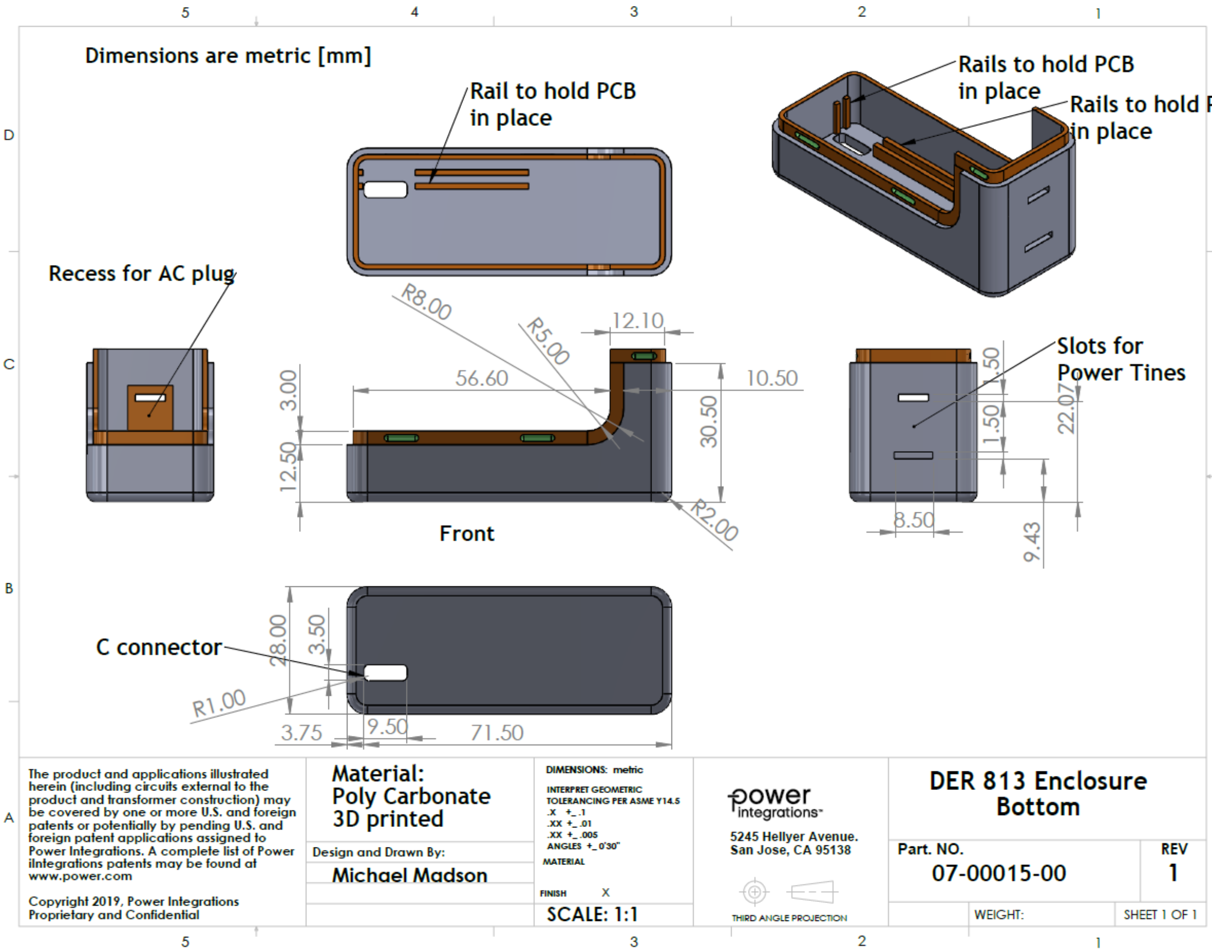

Figure 15 – RD-813 Enclosure, Bottom.

10.2 Enclosure Top

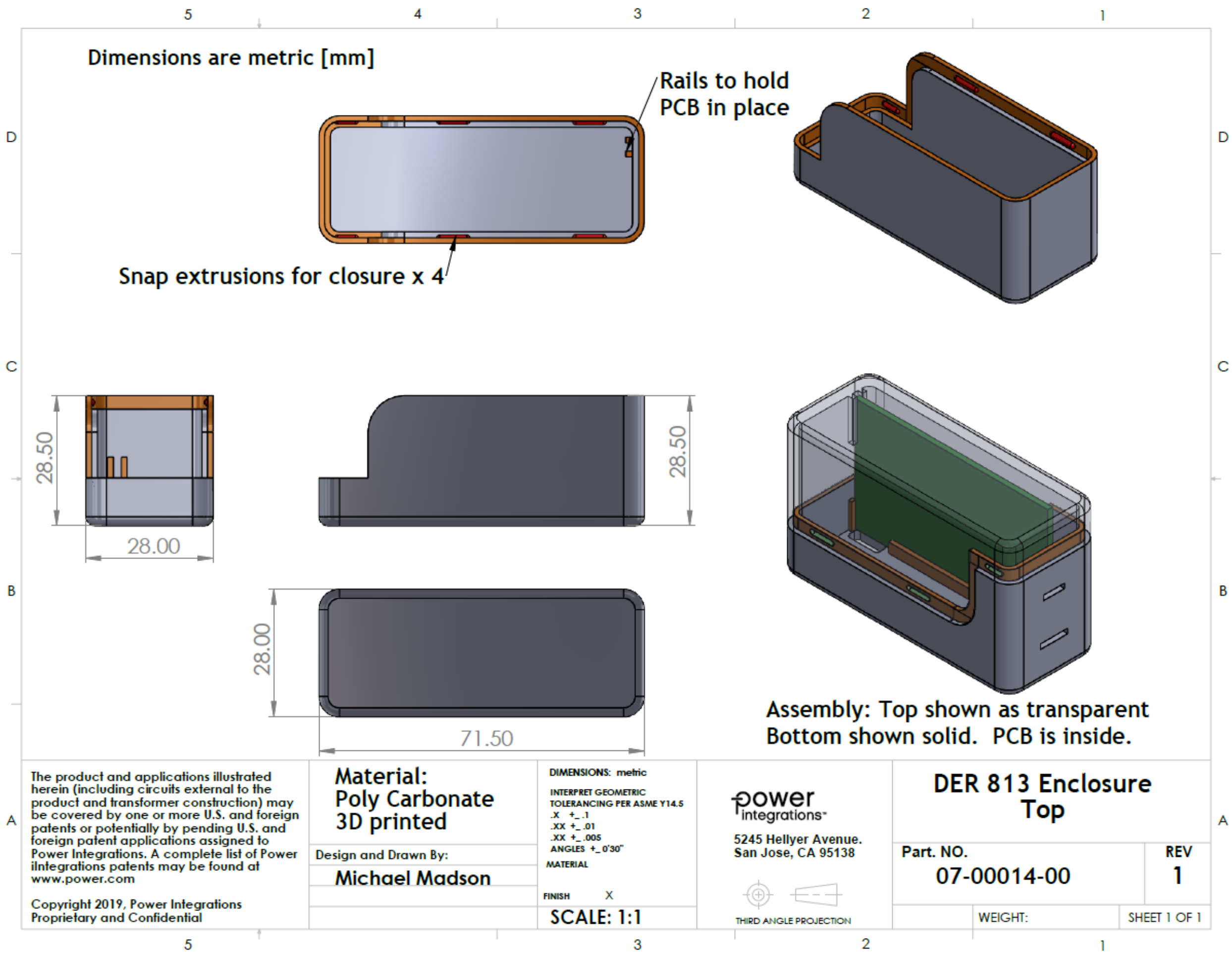

Figure 16 – RD-813 Enclosure, Bottom.

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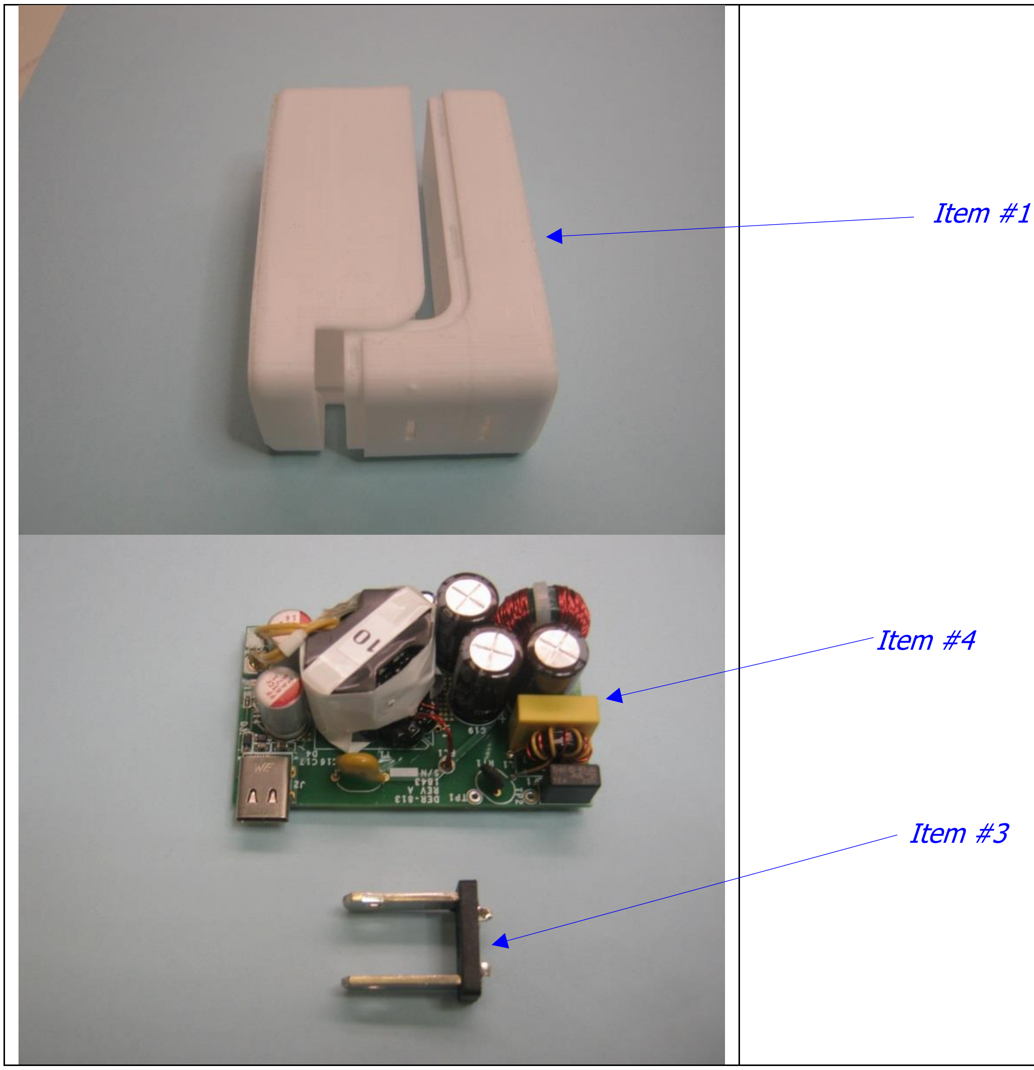
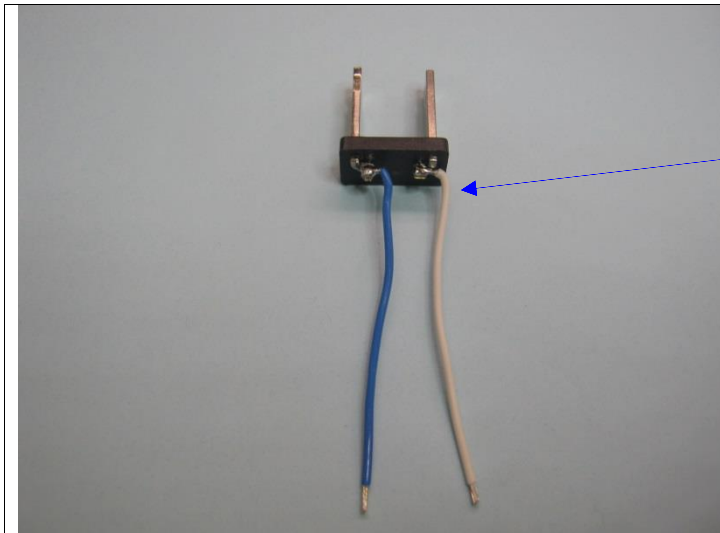
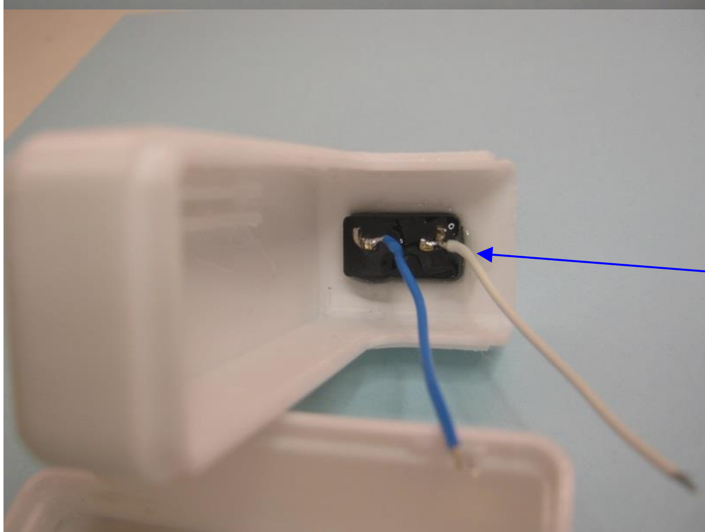
11 Enclosure Assembly

Item	Description
[1]	DER_813 Enclosure PI-07-00014-00 and PI-07-00015-00
[2]	Devcon 5 Minute Epoxy. Stock# 14270
[3]	AC_input Connector PI# 35-00476-00.
[4]	DER_813 PCB.
[5]	White Wire #24 AWG.
[6]	Blue Wire # 24 AWG.

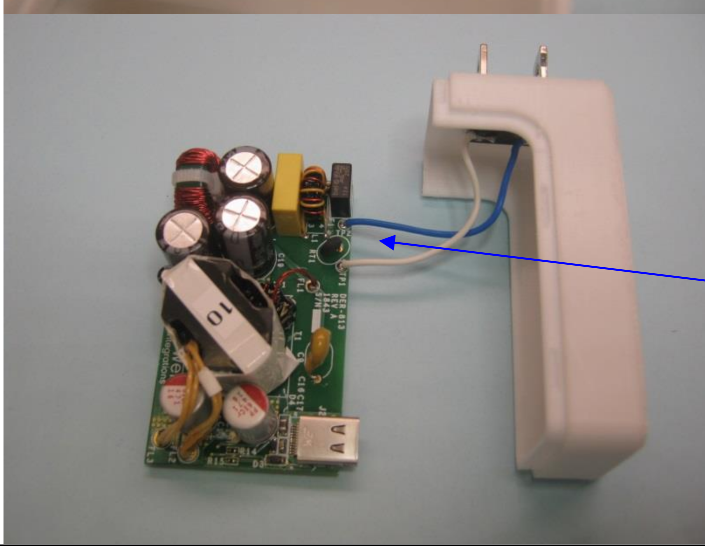




Solder 2 wires Item #5 and Item #6 into item #3



Insert item [3] into slot .make sure to put Epoxy item [2] between connector and enclosure and around outside of connector.



Solder 2wires White and Blue into PCB as shown.

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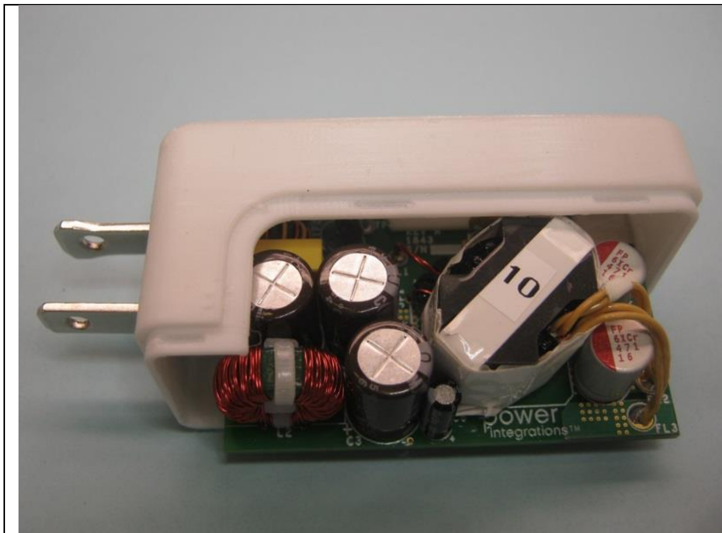
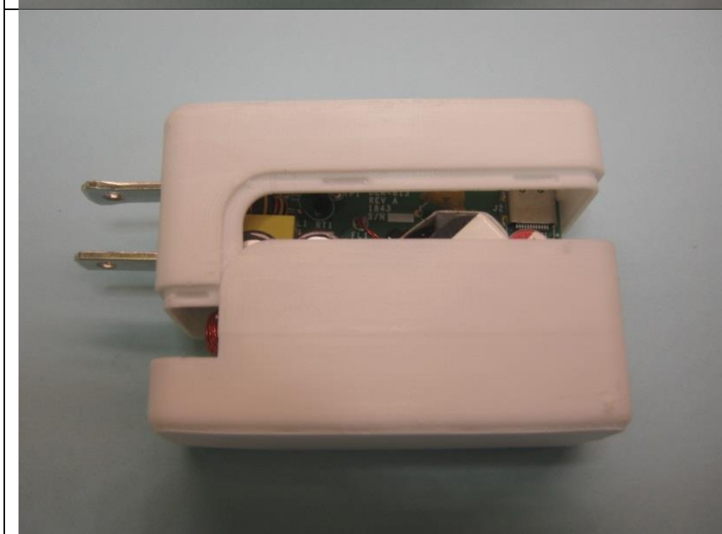
	Slide The PCB into Enclosure.
	Close the Enclosure.
	Complete Assembly RD-813 Enclosure.

12 Performance Data

Note 1: Output voltages measured on the board.
2: Measurements taken at room temperature.

12.1 Efficiency vs. Load

12.1.1 *Output: 3.3 V / 3 A*

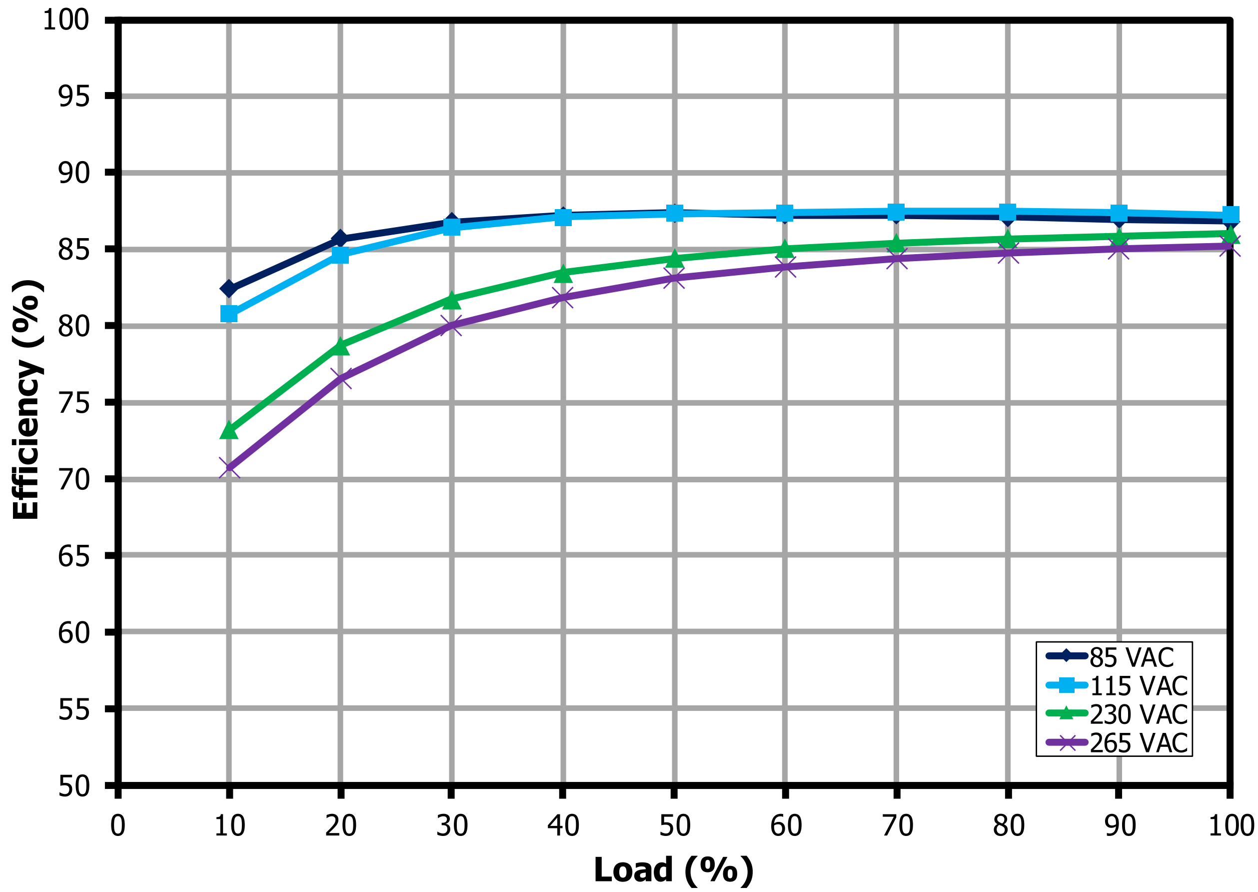


Figure 17 – 3.3 V Output Efficiency vs. Load.

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12.1.2 *Output: 5 V / 3 A*

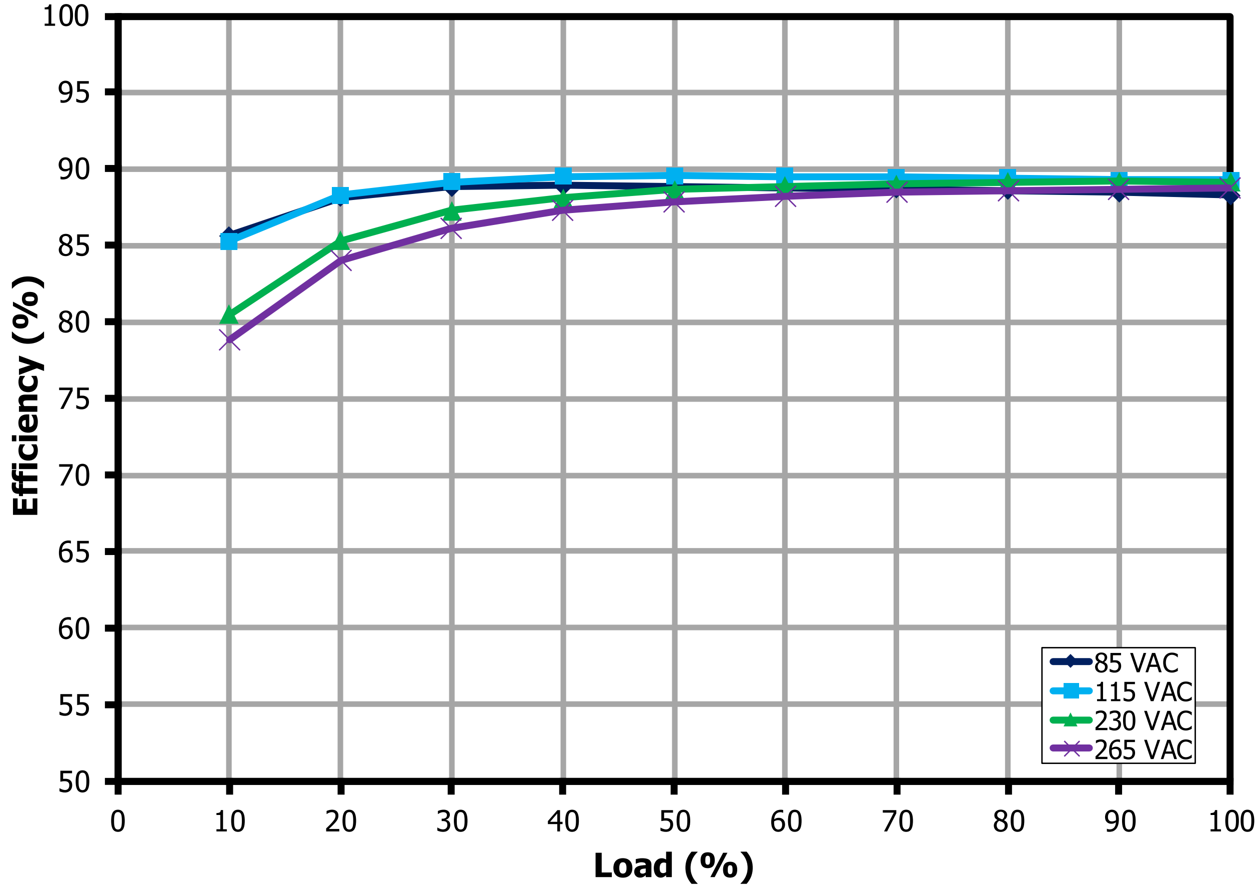

Figure 18 – 5 V Output Efficiency vs. Load.

12.1.3 *Output: 9 V / 3 A*

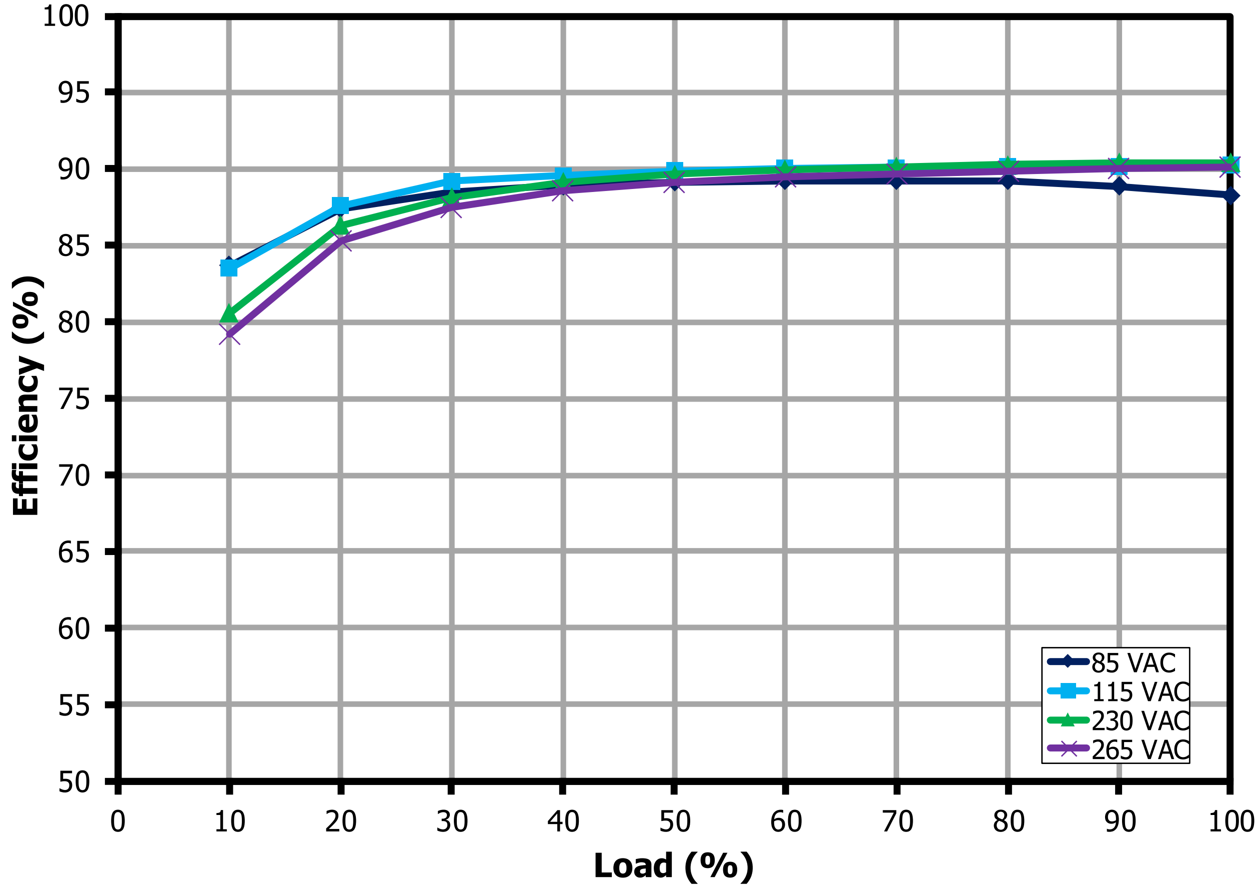

Figure 19 – 9 V Output Efficiency vs. Load.

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12.1.4 *Output: 11 V / 2.45 A*

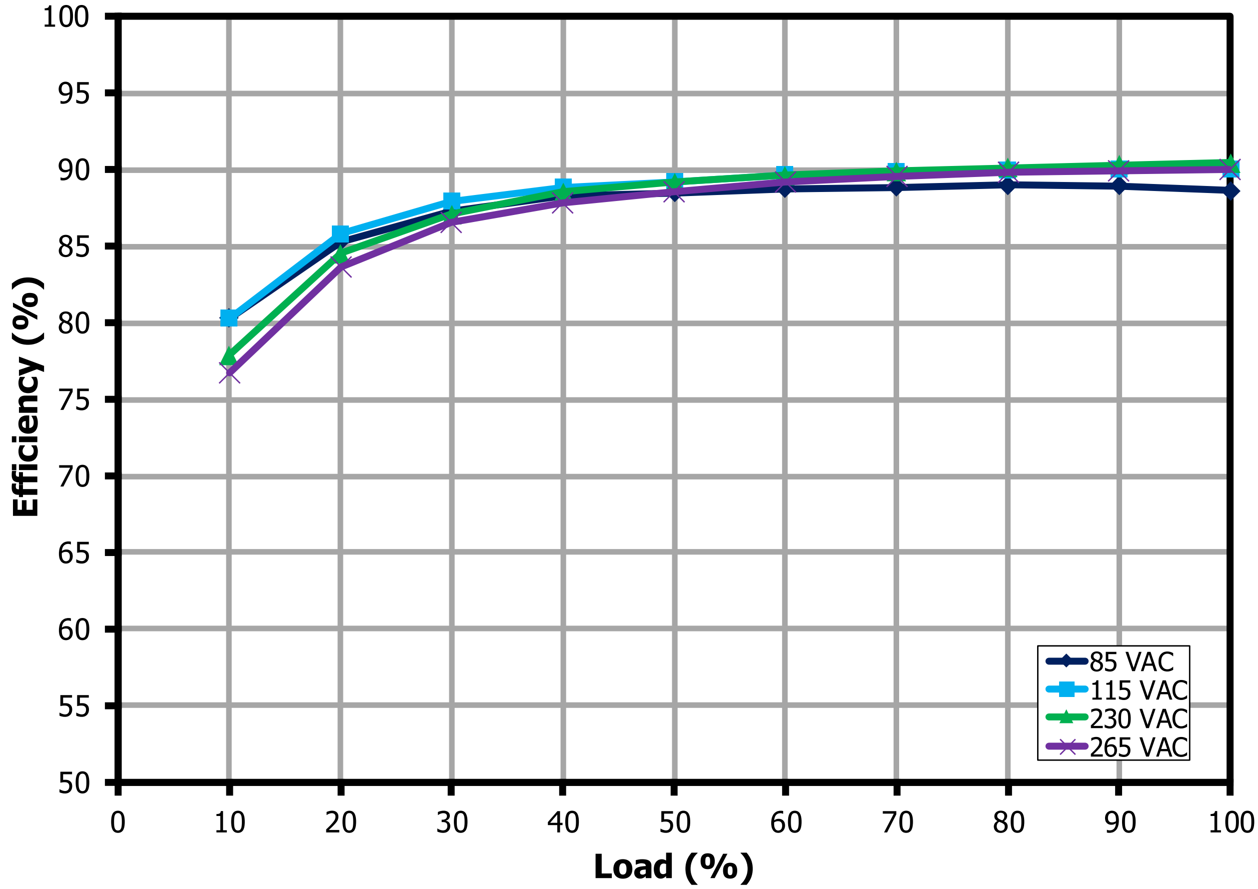

Figure 20 – 11 V Output Efficiency vs. Load.

12.2 Efficiency vs. Line

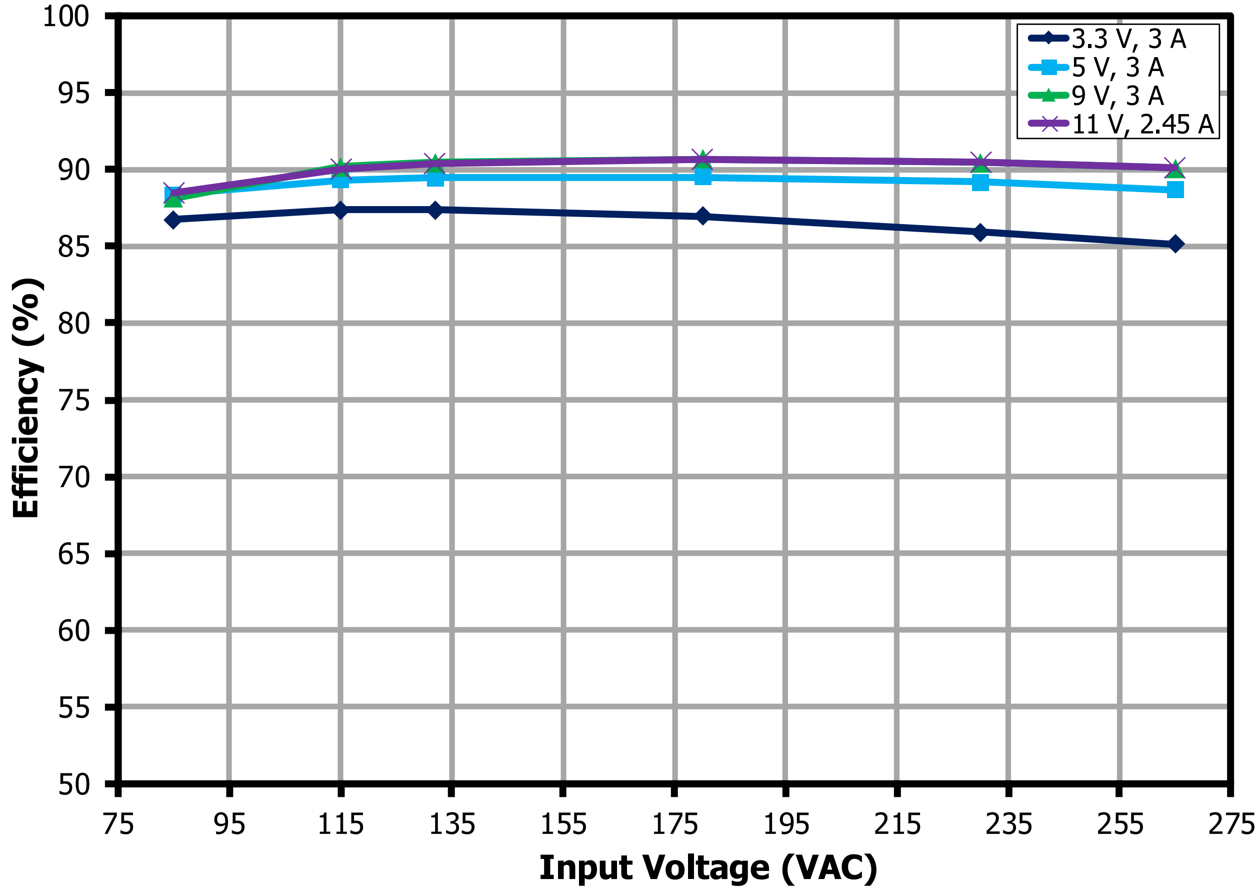

Figure 21 – Efficiency vs. Line.

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12.3 Load Regulation

12.3.1 *Output: 3.3 V / 3 A*

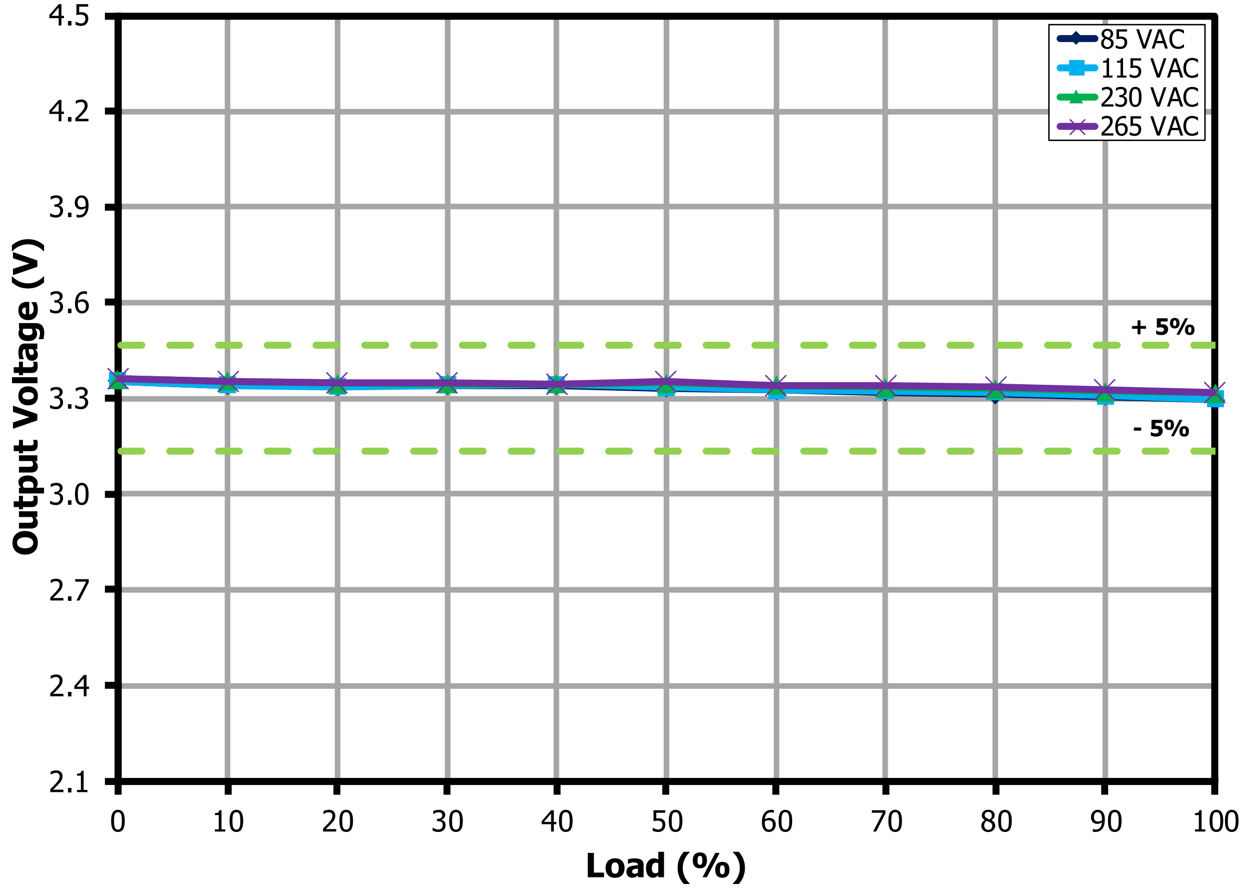

Figure 22 – 3.3 V Output Regulation vs. Percent Load.

12.3.2 *Output: 5 V / 3 A*

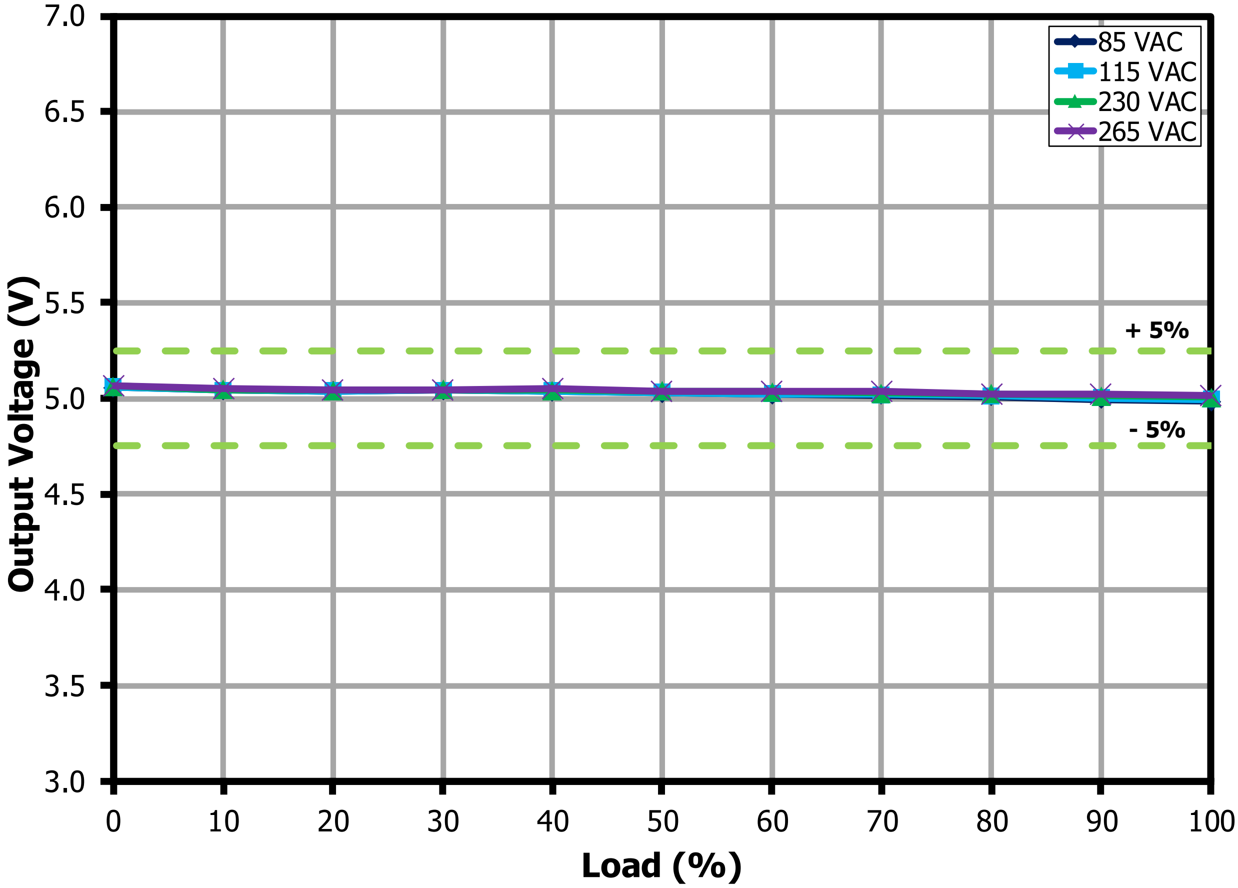

Figure 23 – 5 V Output Regulation vs. Percent Load.

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12.3.3 *Output: 9 V / 3 A*

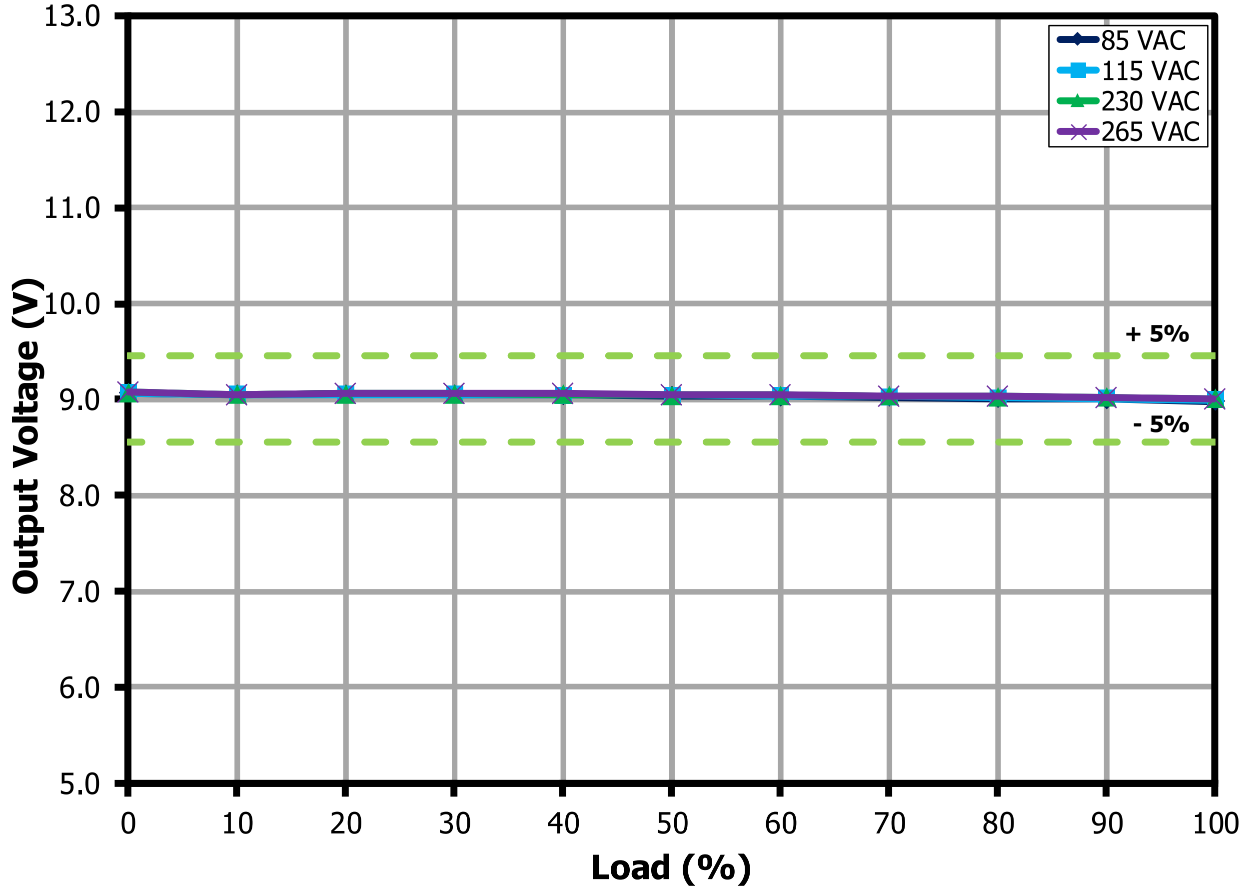

Figure 24 – 9 V Output Regulation vs. Percent Load.

12.3.4 *Output: 11 V / 2.45 A*

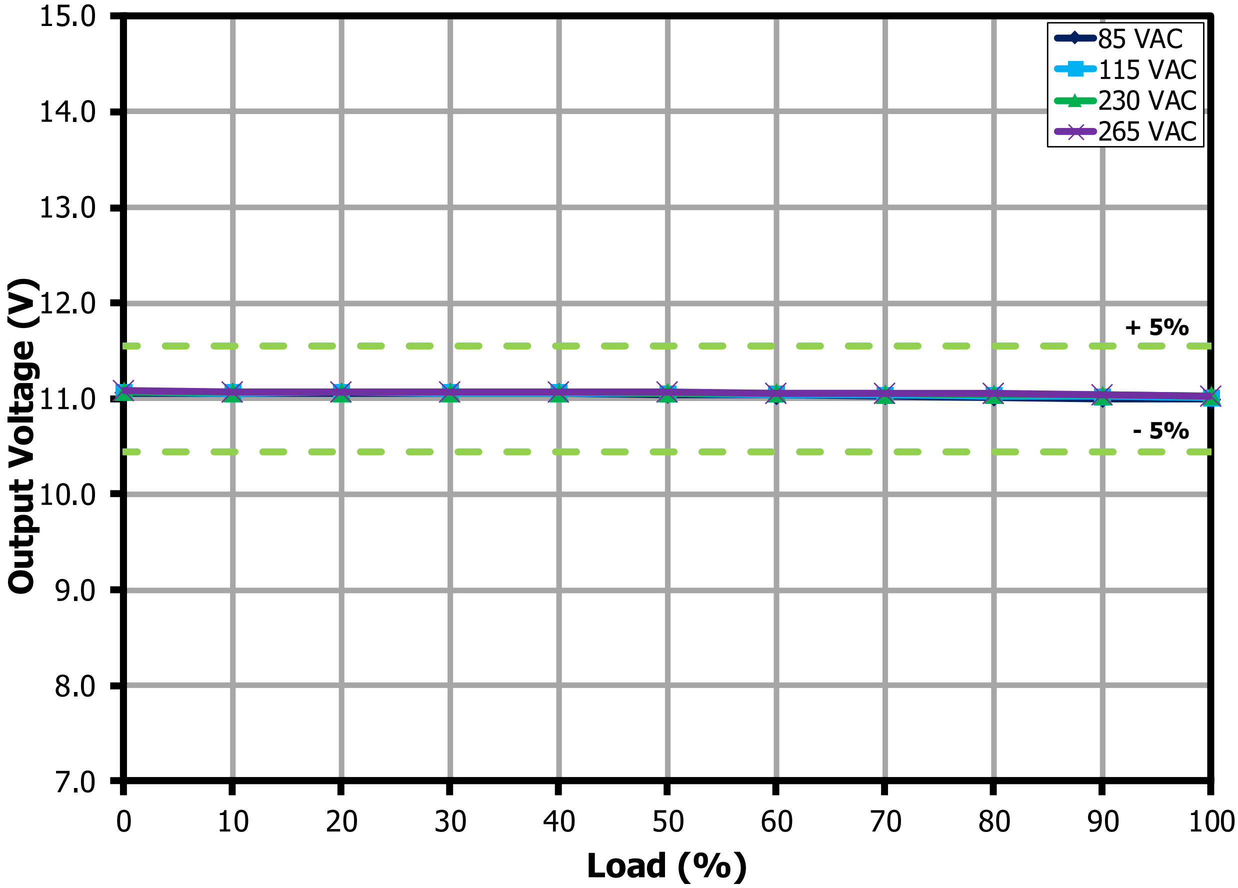

Figure 25 – 11 V Output Regulation vs. Percent Load.

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12.4 Line Regulation

12.4.1 *Output: 3.3 V / 3 A*

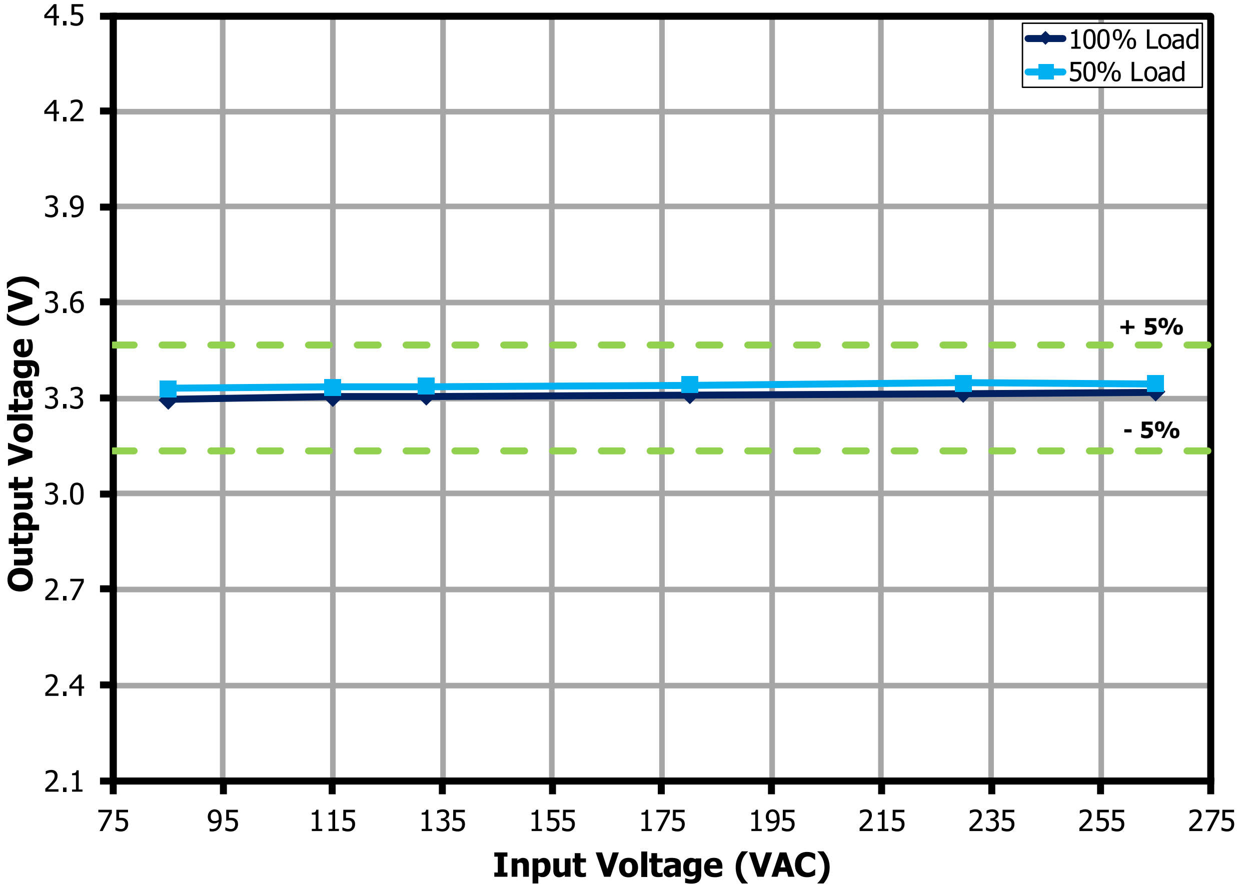

Figure 26 – 3.3 V Output Regulation vs. Input Line Voltage at 50% and 100% Load.

12.4.2 *Output: 5 V / 3 A*

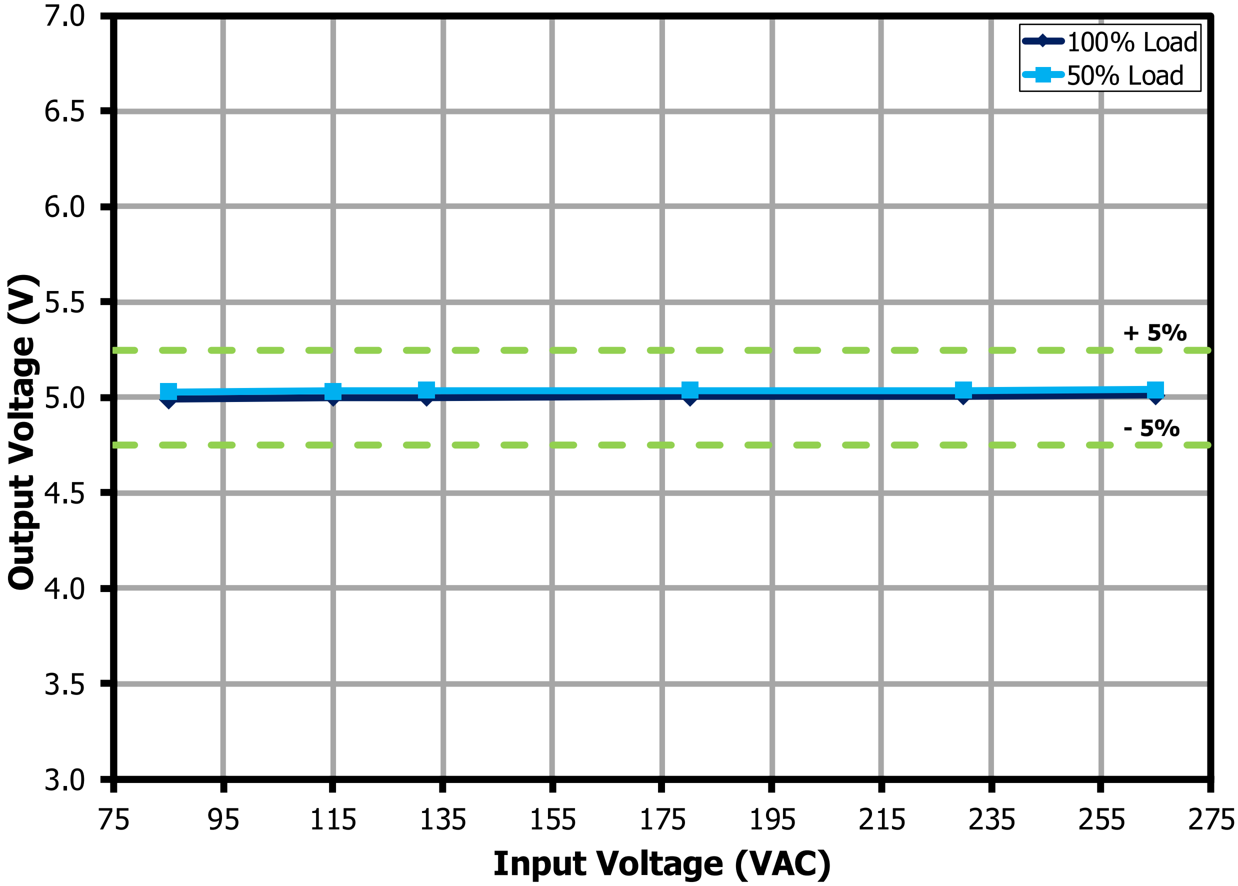

Figure 27 – 5 V Output Regulation vs. Input Line Voltage at 50% and 100% Load.

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12.4.3 *Output: 9 V / 3 A*

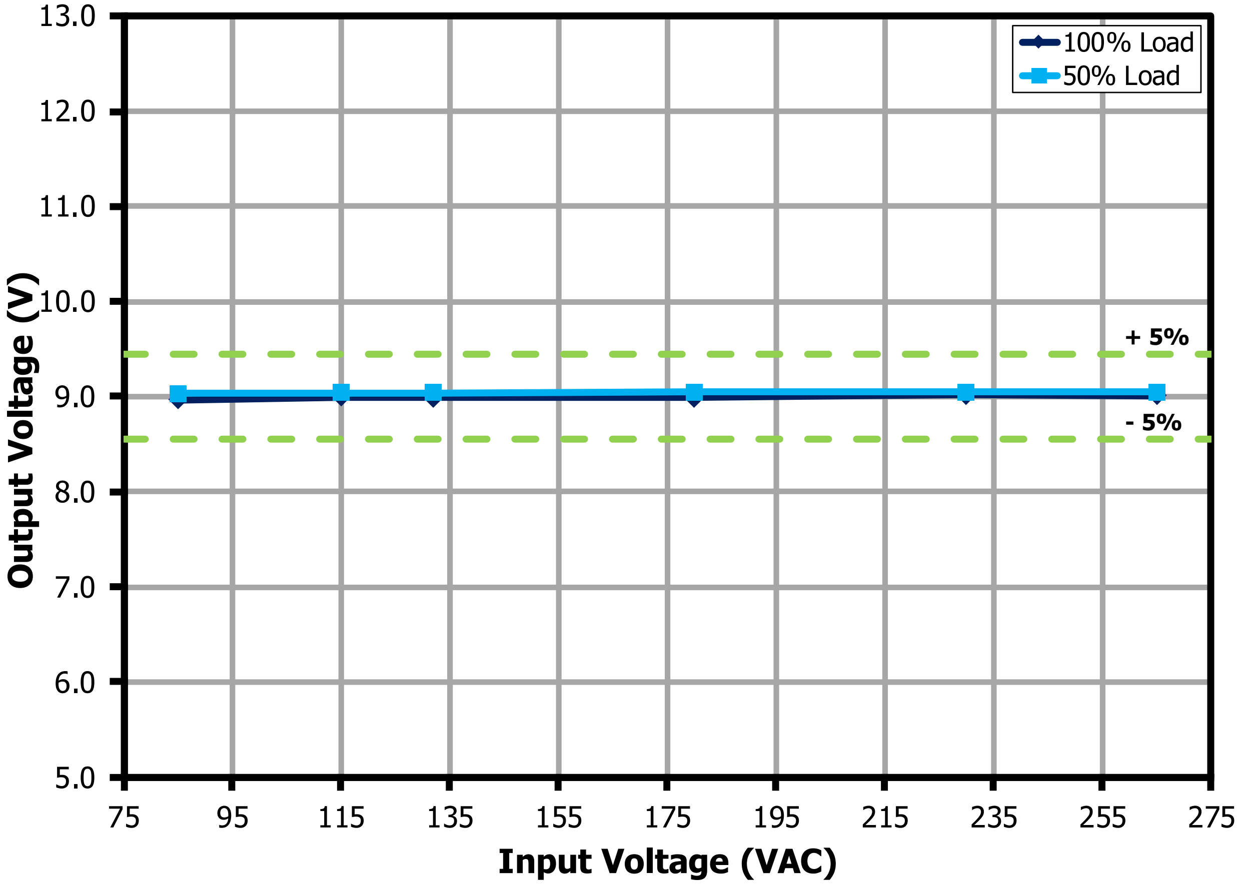

Figure 28 – 9 V Output Regulation vs. Input Line Voltage at 50% and 100% Load.

12.4.4 *Output: 11 V / 2.45 A*

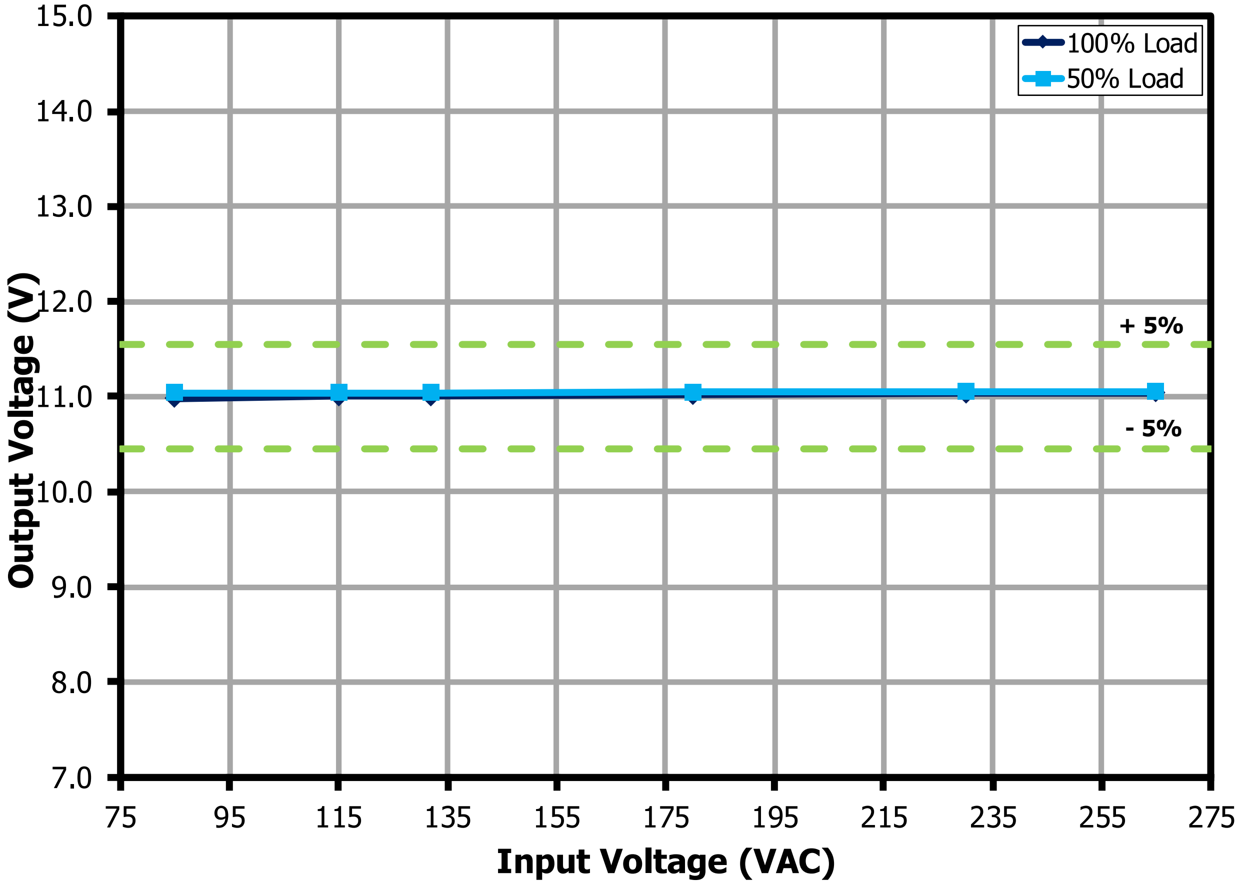

Figure 29 – 11 V Output Regulation vs. Input Line Voltage at 50% and 100% Load.

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12.5 No-Load Input Power at 5 V Output

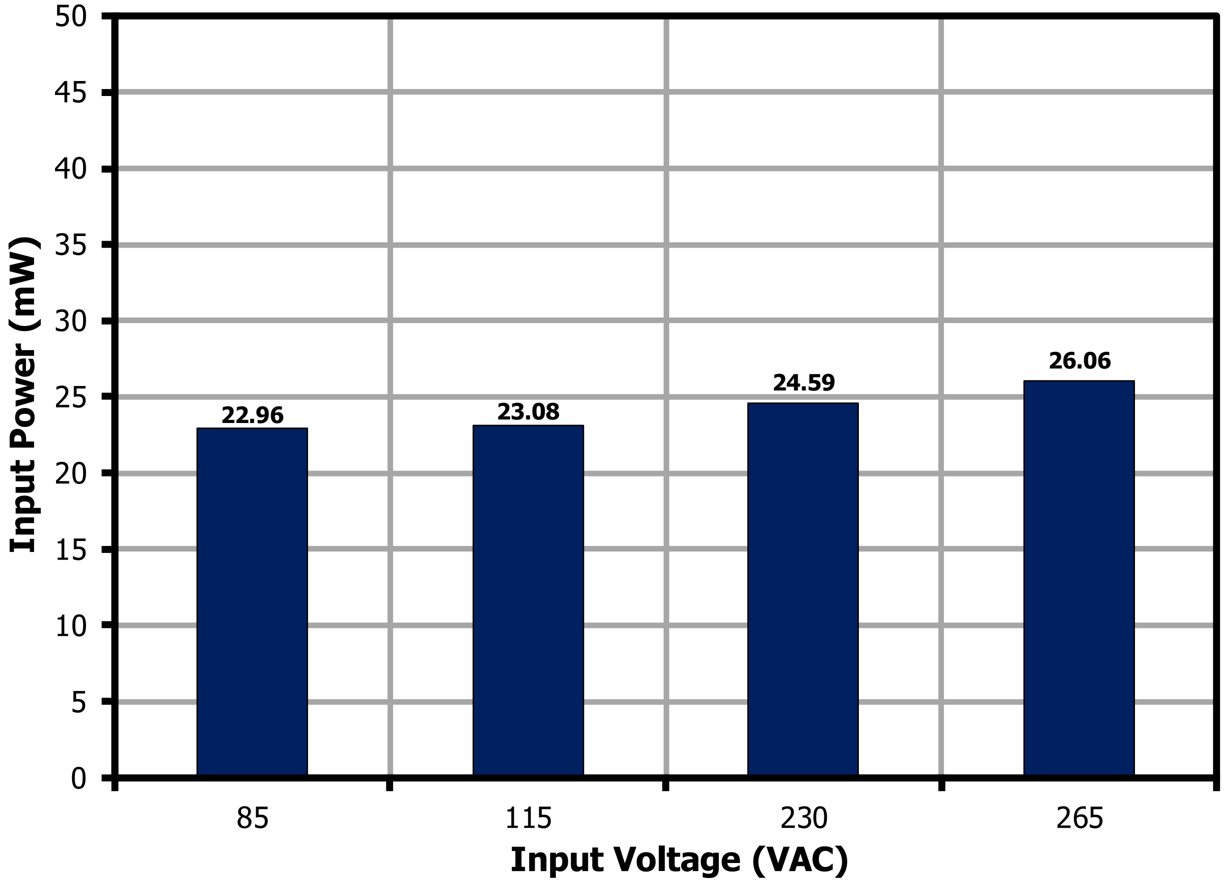

Figure 30 – No-Load Input Power vs. Input Line Voltage.

12.6 Average and 10% Load Efficiency

12.6.1 *Efficiency Requirements*

		Test Effective	Average 2016	Average Jan-16	10% Load Jan-16
Output Voltage (V)	Model (V)	Power (W)	New EISA2007 (%)	CoC v5 Tier 2 (%)	CoC v5 Tier 2 (%)
3.3	<6	9.9	78.6	78.9	69.7
5	<6	15	81.4	81.8	72.5
9	>6	27	86.6	87.3	77.3
11	>6	27	86.6	87.3	77.3

12.6.2 *Average and 10% Load Efficiency (On the Board)*

12.6.2.1 Output: 3.3 V / 3 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	CoC v5 Tier 2	
					Requirement (%)	Margin (%)
115	100	9.90	87.62	87.34	78.93	8.41
	75	7.46	87.81			
	50	5.00	87.71			
	25	2.50	86.21			
	10	1.00	81.37		69.66	11.7
230	100	9.94	86.54	84.70	78.93	5.77
	75	7.49	86.17			
	50	5.01	84.99			
	25	2.50	81.11			
	10	1.00	74.01		69.66	4.34

12.6.2.2 Output: 5 V / 3 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	CoC v5 Tier 2	
					Requirement (%)	Margin (%)
115	100	14.97	89.46	89.57	81.84	7.73
	75	11.28	89.69			
	50	7.54	89.84			
	25	3.78	89.29			
	10	1.51	85.96		72.48	13.48
230	100	15.01	89.68	88.94	81.84	7.11
	75	11.29	89.63			
	50	7.55	89.21			
	25	3.78	87.25			
	10	1.51	81.73		72.48	9.25

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12.6.2.3 Output: 9 V / 3 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	CoC v5 Tier 2	
					Requirement (%)	Margin (%)
115	100	26.97	90.49	90.11	87.30	2.81
	75	20.29	90.48			
	50	13.56	90.30			
	25	6.79	89.16			
	10	2.71	84.30		77.30	7.01
230	100	27.01	90.94	90.04	87.30	2.75
	75	20.31	90.76			
	50	13.57	90.27			
	25	6.80	88.20			
	10	2.71	81.74		77.30	4.44

12.6.2.4 Output: 11 V / 2.45 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	CoC v5 Tier 2	
					Requirement (%)	Margin (%)
115	100	26.95	90.38	89.56	87.29	2.27
	75	20.25	90.26			
	50	13.53	89.82			
	25	6.77	87.77			
	10	2.70	81.13		77.29	3.84
230	100	27.00	90.93	89.57	87.29	2.28
	75	20.28	90.60			
	50	13.54	89.81			
	25	6.77	86.94			
	10	2.70	78.78		77.29	1.49

12.7 CV/CC Operation

Note: Positive slope in CC region is per the guidelines of USB PD 3.0 PPS specification.

12.7.1 *Output: 5 V / 3 A*

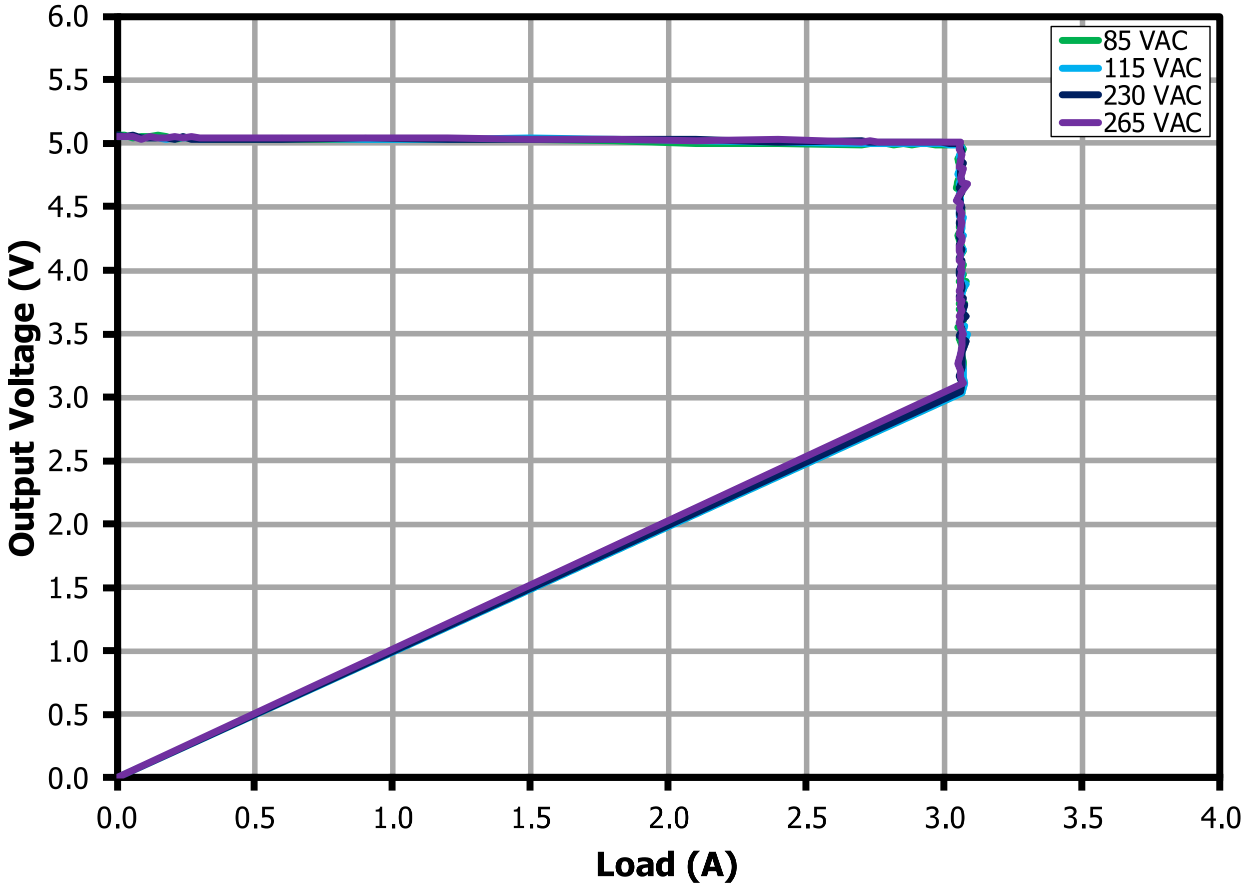

Figure 31 – Output Voltage vs. Output Current, Room Temperature.

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12.7.2 *Output: 9 V / 3 A*

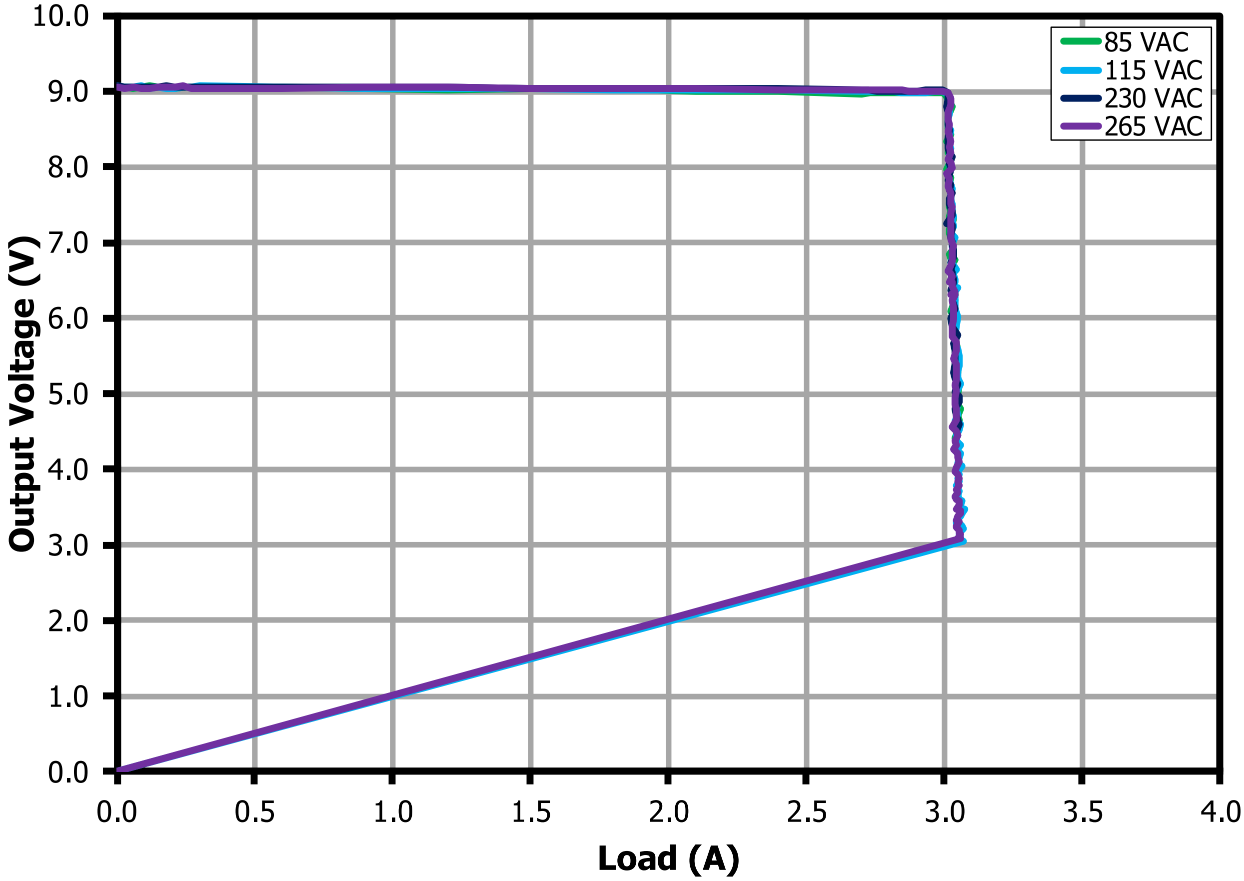

Figure 32 – Output Voltage vs. Output Current, Room Temperature.

12.7.3 *Output: 11 V / 2.45 A*

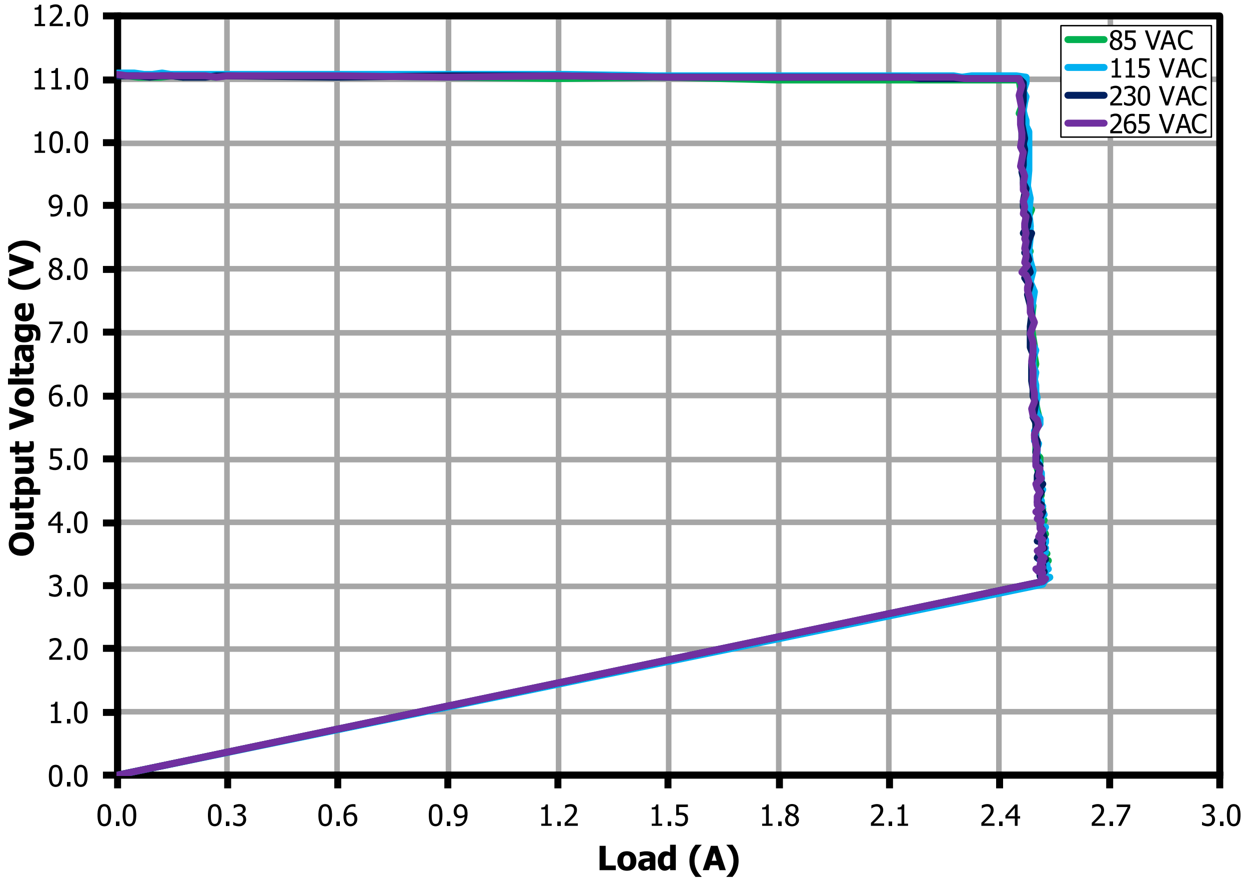

Figure 33 – Output Voltage vs. Output Current, Room Temperature.

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13 Thermal Performance in Open Case

Note 1: For plastic enclosed adapters, this design requires use of a metallic heat spreader and suitable thermally conductive insulator to ensure sufficiently low temperature of the InnoSwitch3-Pro IC and transformer. The performance data below is for open case operation and does not use the heat spreader for cooling.
Note 2: Measurements taken at approximately 27 ºC room temperature.

13.1 85 VAC Input 5 V / 3 A

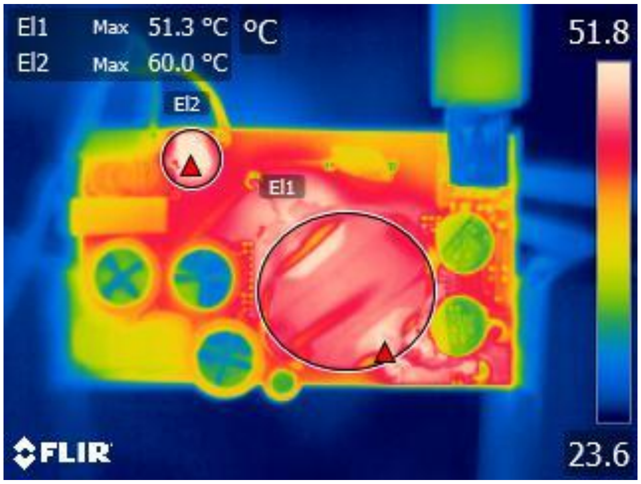

Figure 34 – Top Side Thermal Image.
El1: Transformer = 51.3 ºC.
El2: Thermistor RT1 = 60.0 ºC.

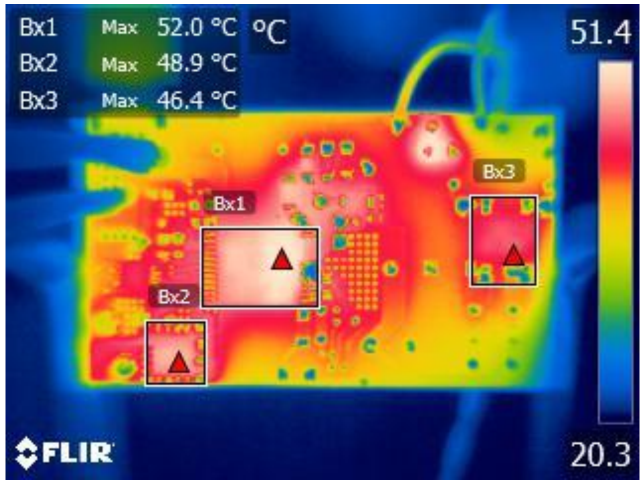

Figure 35 – Bottom Side Thermal Image.
Bx1: InnoSwitch3-Pro = 52.0 ºC.
Bx2: SR FET = 48.9 ºC.
Bx3: Bridge Rectifier BR1 = 46.4 ºC.

13.2 265 VAC Input 5 V / 3 A

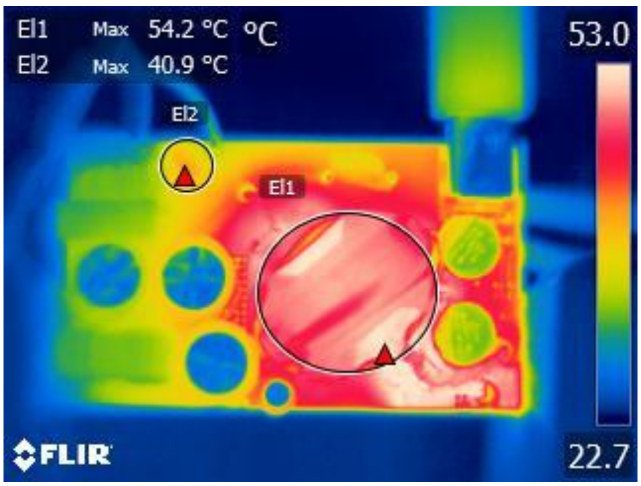

Figure 36 – Top Layer Thermal Image.
El1: Transformer = 54.2 ºC.
El2: Thermistor RT1 = 40.9 ºC.

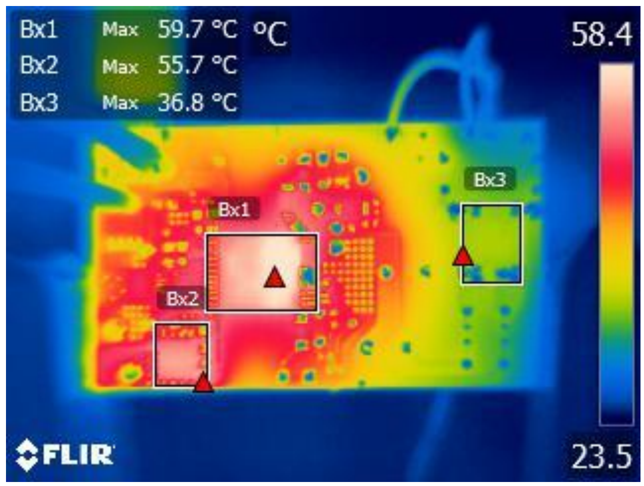

Figure 37 – Bottom Side Thermal Image.
Bx1: InnoSwitch3-Pro = 59.7 ºC.
Bx2: SR FET = 55.7 ºC.
Bx3: Bridge Rectifier BR1 = 36.8 ºC.

13.3 85 VAC Input 9 V / 3 A

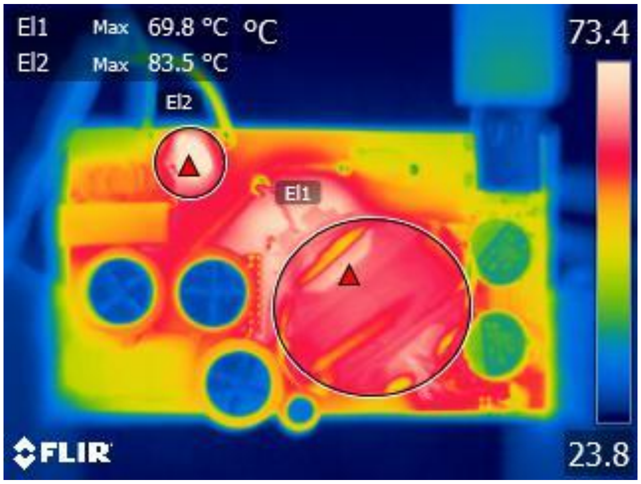

Figure 38 – Top Side Thermal Image.
El1: Transformer = 69.8 ºC.
El2: Thermistor RT1 = 83.5 ºC.

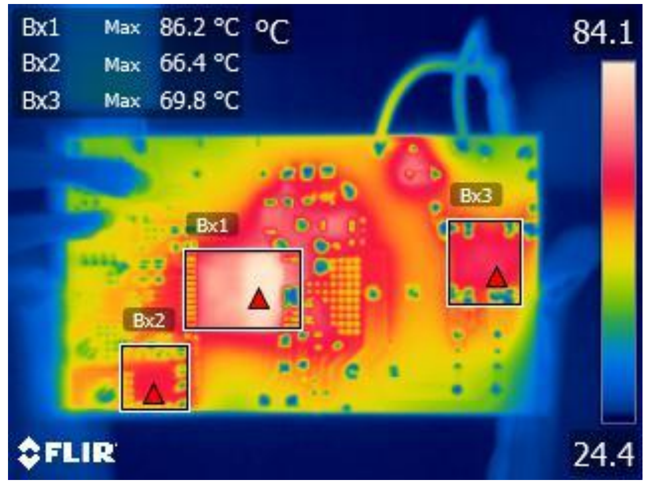

Figure 39 – Bottom Side Thermal Image.
Bx1: InnoSwitch3-Pro = 86.2 ºC.
Bx2: SR FET = 66.4 ºC.
Bx3: Bridge Rectifier BR1 = 69.8 ºC.

13.4 265 VAC Input 9 V / 3 A

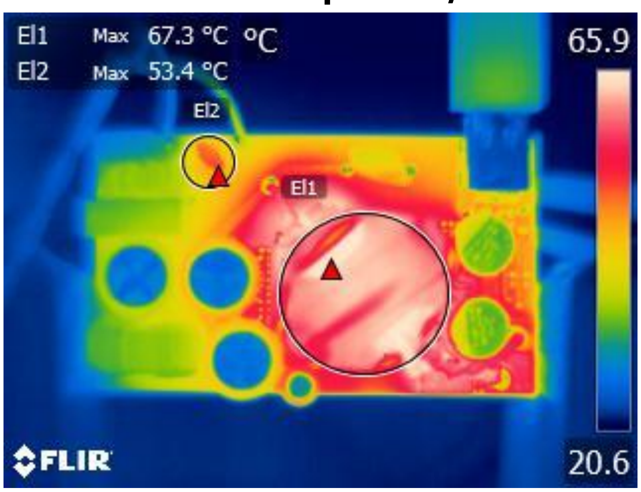

Figure 40 – Top Layer Thermal Image.
El1: Transformer = 67.3 ºC.
El2: Thermistor RT1 = 53.4 ºC.

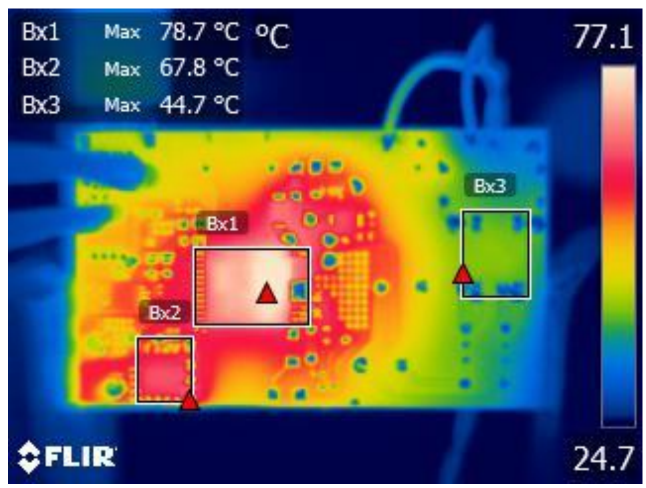

Figure 41 – Bottom Side Thermal Image.
Bx1: InnoSwitch3-Pro = 78.7 ºC.
Bx2: SR FET = 67.8 ºC.
Bx3: Bridge Rectifier BR1 = 44.7 ºC.

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13.5 85 VAC Input 11 V / 2.45 A

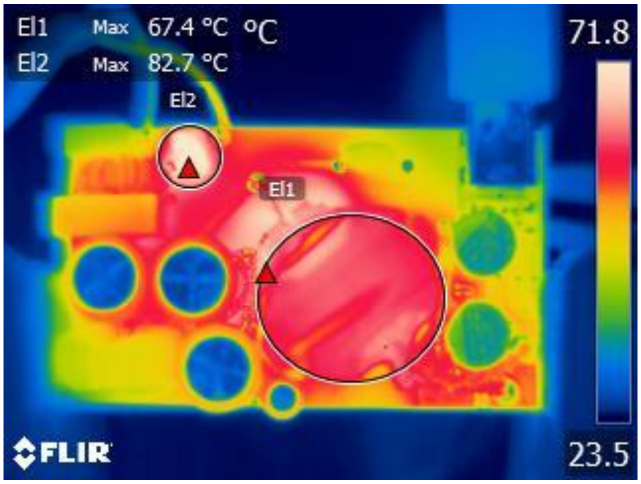

Figure 42 – Top Side Thermal Image.
El1: Transformer = 67.4 ºC.
El2: Thermistor RT1 = 82.7 ºC.

Figure 43 – Bottom Side Thermal Image.
Bx1: InnoSwitch3-Pro = 81.1 ºC.
Bx2: SR FET = 61.8 ºC.
Bx3: Bridge Rectifier BR1 = 68.8 ºC.

13.6 265 VAC Input 11 V / 2.45 A

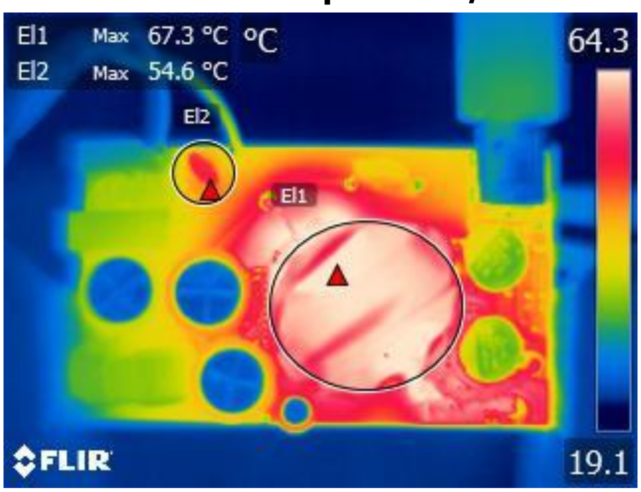

Figure 44 – Top Layer Thermal Image.
El1: Transformer = 67.3 ºC.
El2: Thermistor RT1 = 54.6 ºC.

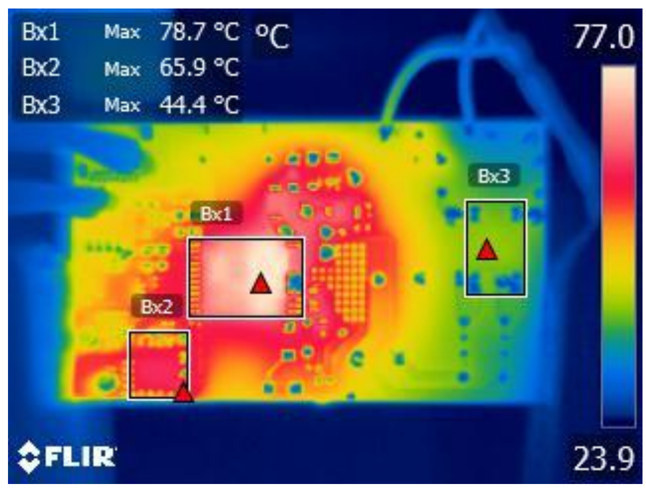

Figure 45 – Bottom Side Thermal Image.
Bx1: InnoSwitch3-Pro = 78.7 ºC.
Bx2: SR FET = 65.9 ºC.
Bx3: Bridge Rectifier BR1 = 44.4 ºC.

14 Output Voltage Ripple Measurements

14.1 Ripple Measurement Technique

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

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

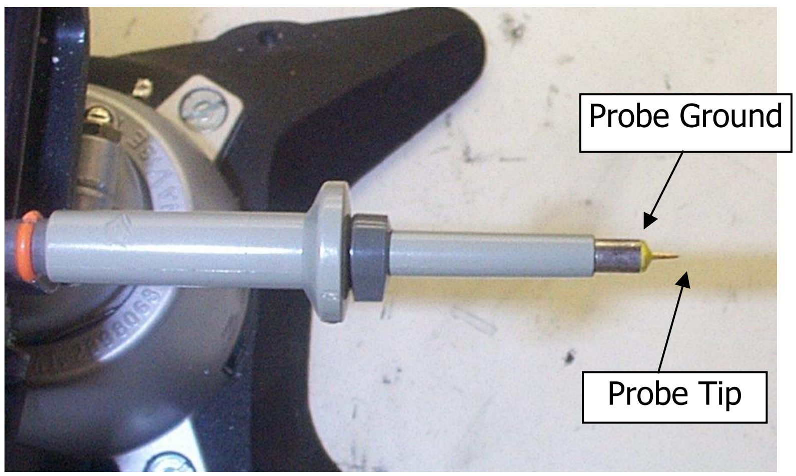

Figure 46 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)

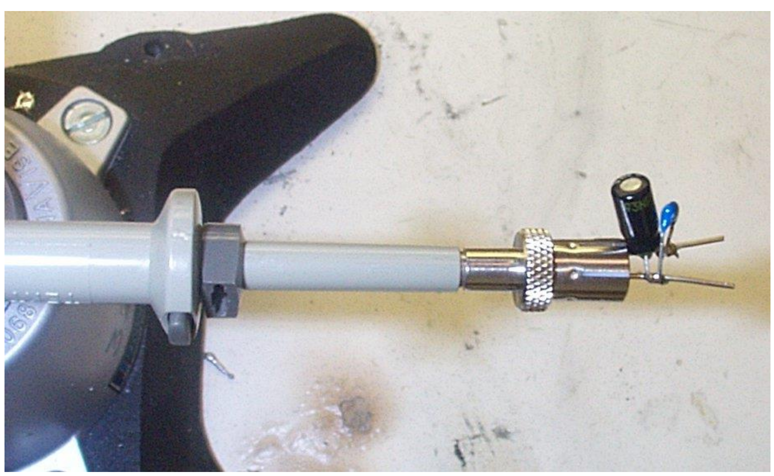

Figure 47 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

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14.2 Output Voltage Ripple Waveforms

Note: Measurements are taken at the end of 60 mΩ cable.

14.2.1 *Output: 3.3 V / 3 A*

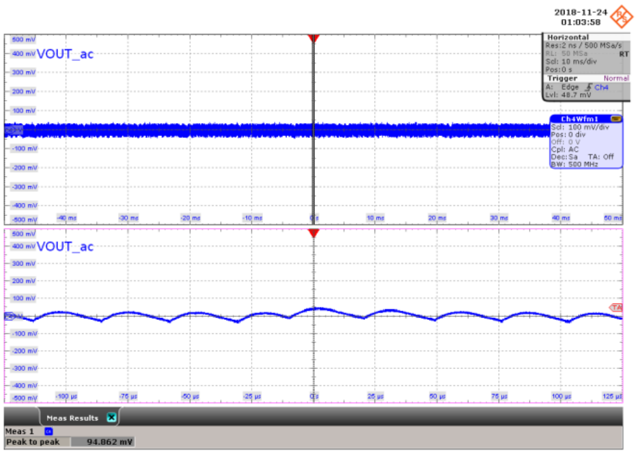

Figure 48 – Output Ripple (94 mV_{PK-PK}).
85 VAC, 3.3 V, 3 A Load.
CH1: V_{OUT}, 100 mV / div., 10 ms / div.

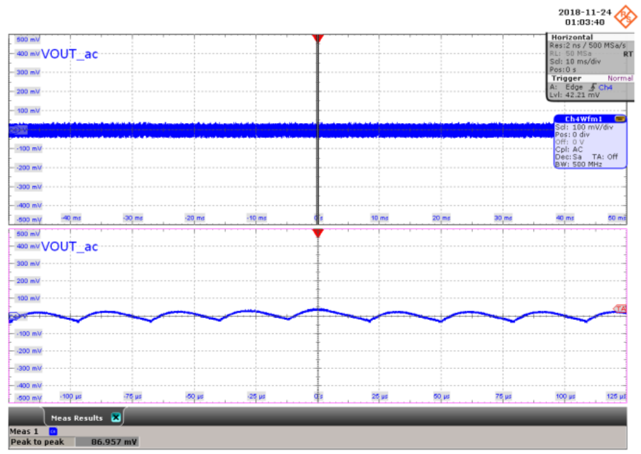

Figure 49 – Output Ripple (86 mV_{PK-PK}).
265 VAC, 3.3 V, 3 A Load.
CH1: V_{OUT}, 100 mV / div., 10 ms / div.

14.2.2 *Output: 5 V / 3 A*

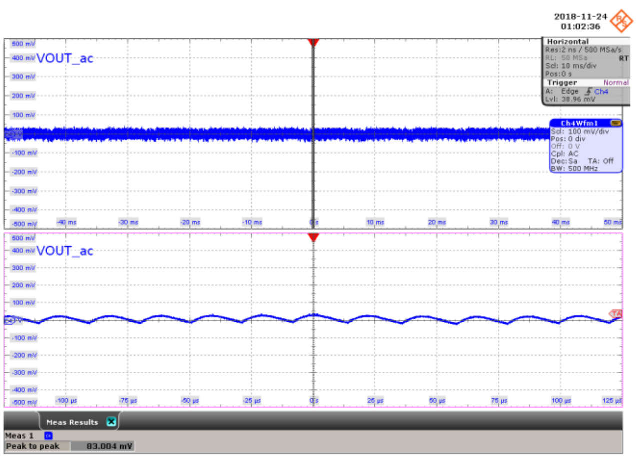

Figure 50 – Output Ripple (83 mV_{PK-PK}).
85 VAC, 5.0 V, 3 A Load.
CH1: V_{OUT}, 100 mV / div., 10 ms / div.

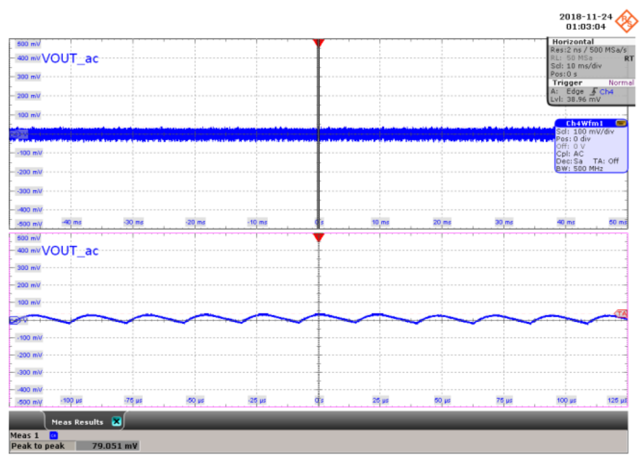

Figure 51 – Output Ripple (79 mV_{PK-PK}).
265 VAC, 5.0 V, 3 A Load.
CH1: V_{OUT}, 100 mV / div., 10 ms / div.

14.2.3 *Output: 9 V / 3 A*

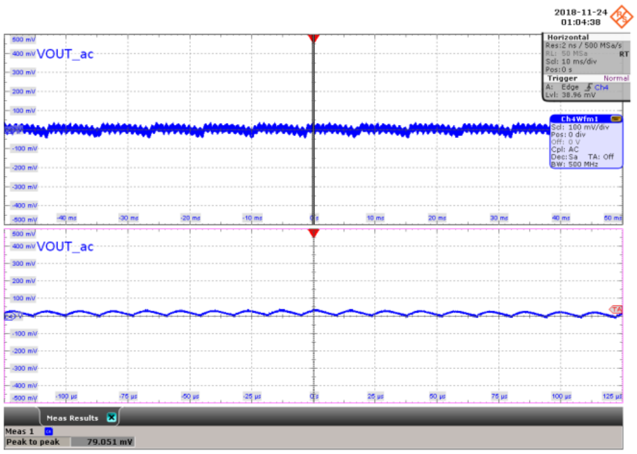

Figure 52 – Output Ripple (79 mV_{PK-PK}).
85 VAC, 9.0 V, 3 A Load.
V_{OUT}, 100 mV / div., 10 ms / div.

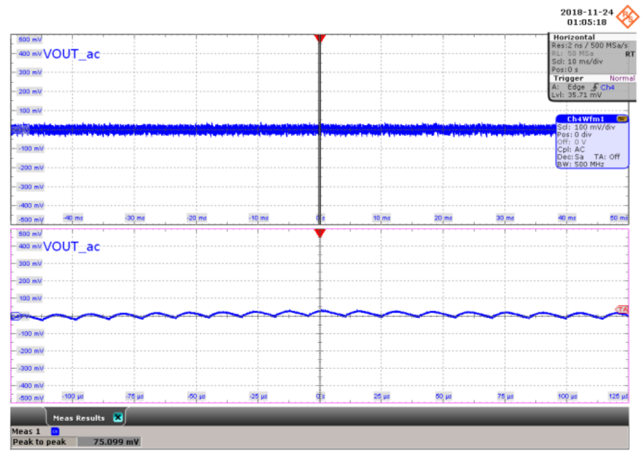

Figure 53 – Output Ripple (75 mV_{PK-PK}).
265 VAC, 9.0 V, 3 A Load.
V_{OUT}, 100 mV / div., 10 ms / div.

14.2.4 *Output: 11 V / 2.45 A*

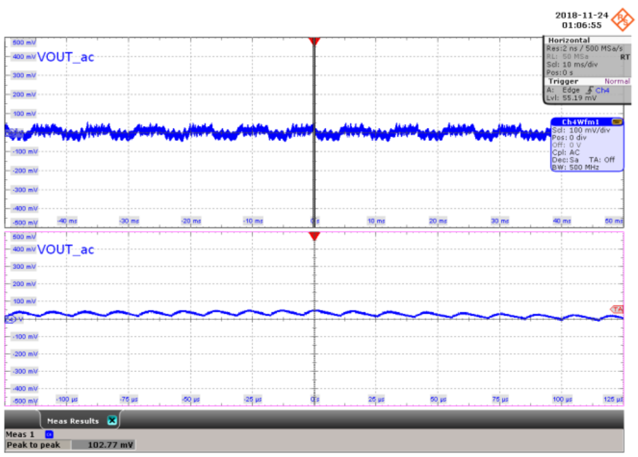

Figure 54 – Output Ripple (102 mV_{PK-PK}).
85 VAC, 11.0 V, 2.45 A Load.
CH1: V_{OUT}, 100 mV / div., 10 ms / div.

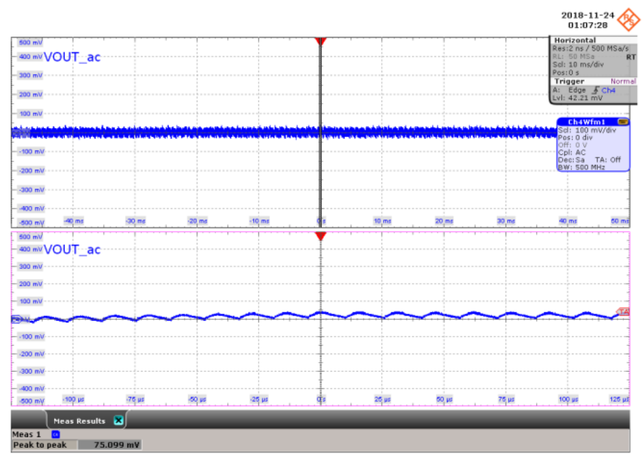

Figure 55 – Output Ripple (75 mV_{PK-PK}).
265 VAC, 11.0 V, 2.45 A Load.
CH1: V_{OUT}, 100 mV / div., 10 ms / div.

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14.3 Output Voltage Ripple Amplitude vs. Load

14.3.1 *Output: 3.3 V / 3 A*

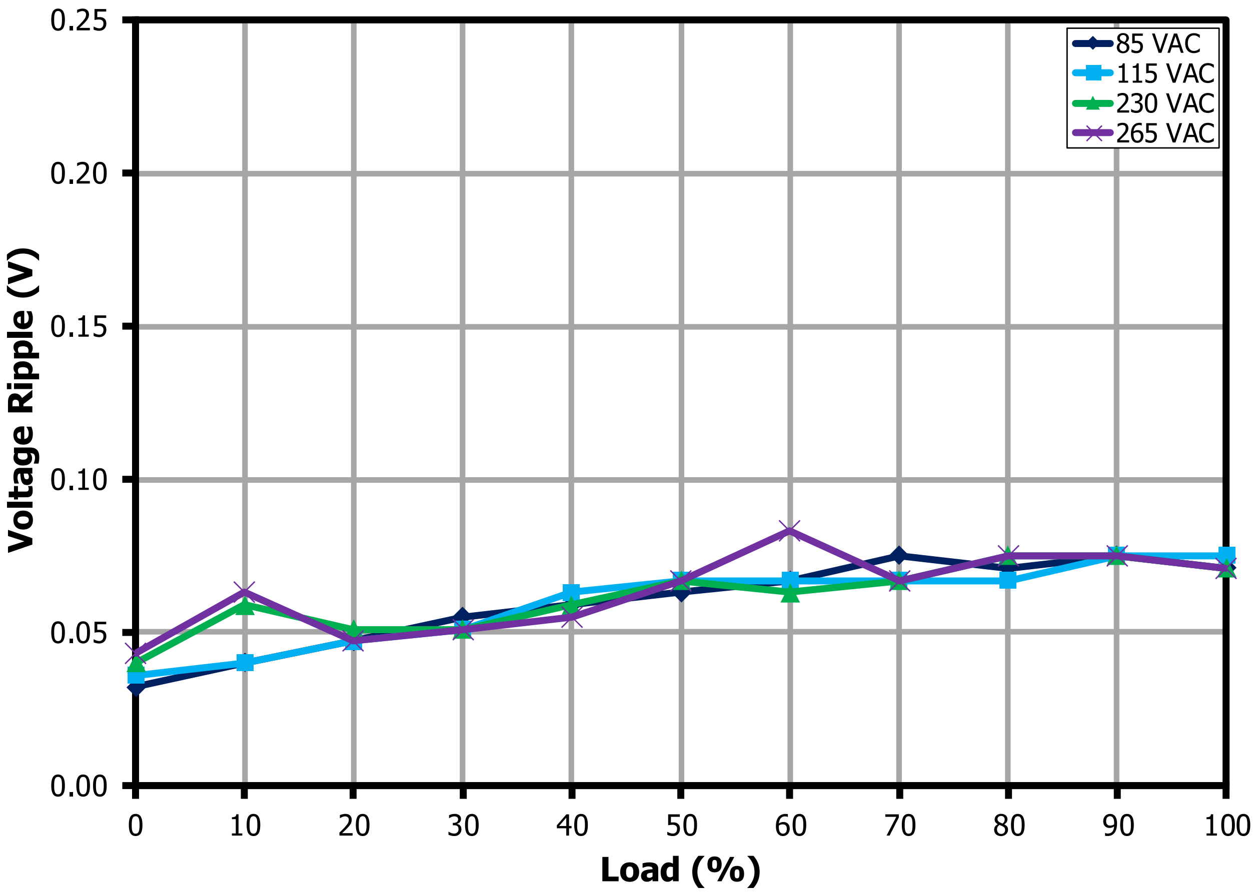

Figure 56 – 3.3 V Output Peak-to-Peak Ripple Amplitude vs. Percent Load.

14.3.2 *Output: 5 V / 3 A*

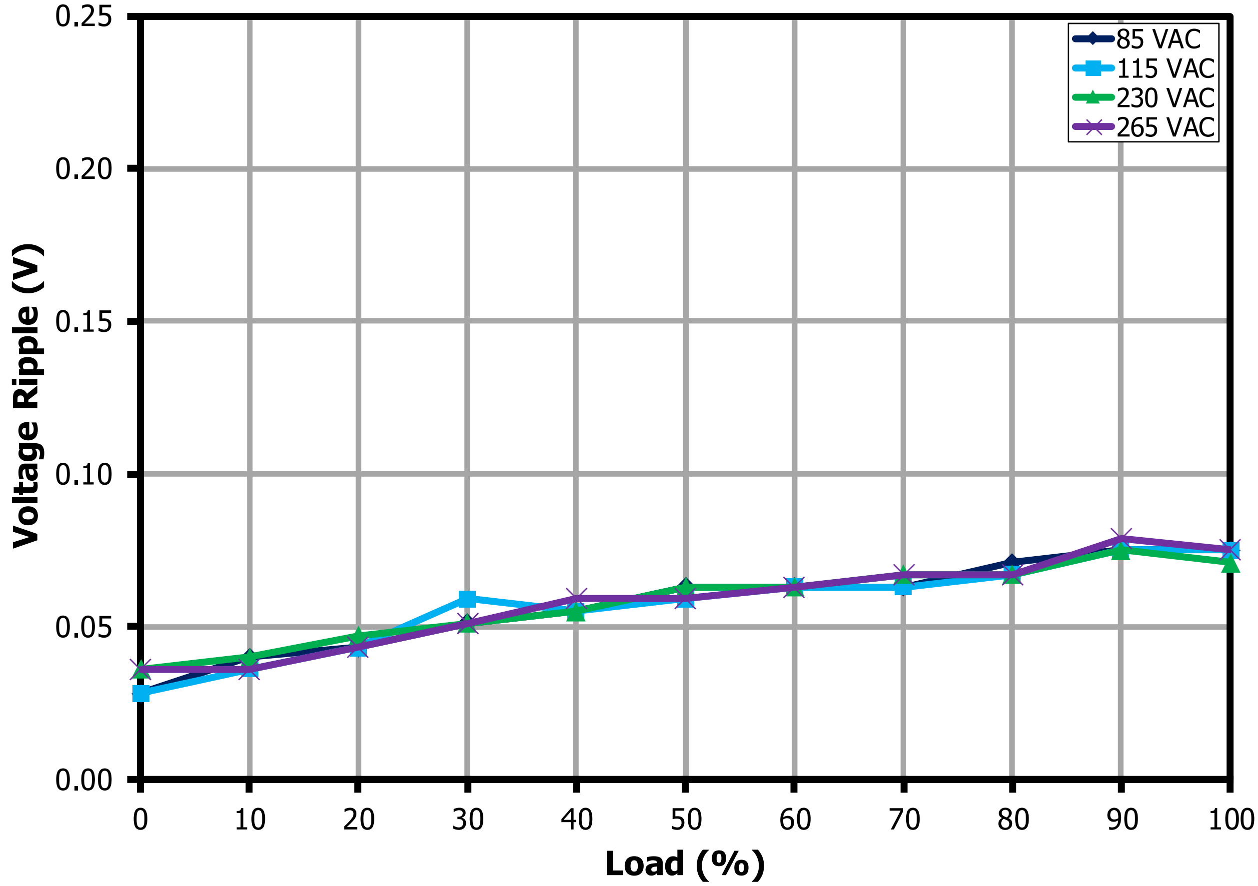

Figure 57 – 5 V Output Peak-to-Peak Ripple Amplitude vs. Percent Load.

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14.3.3 *Output: 9 V / 3 A*

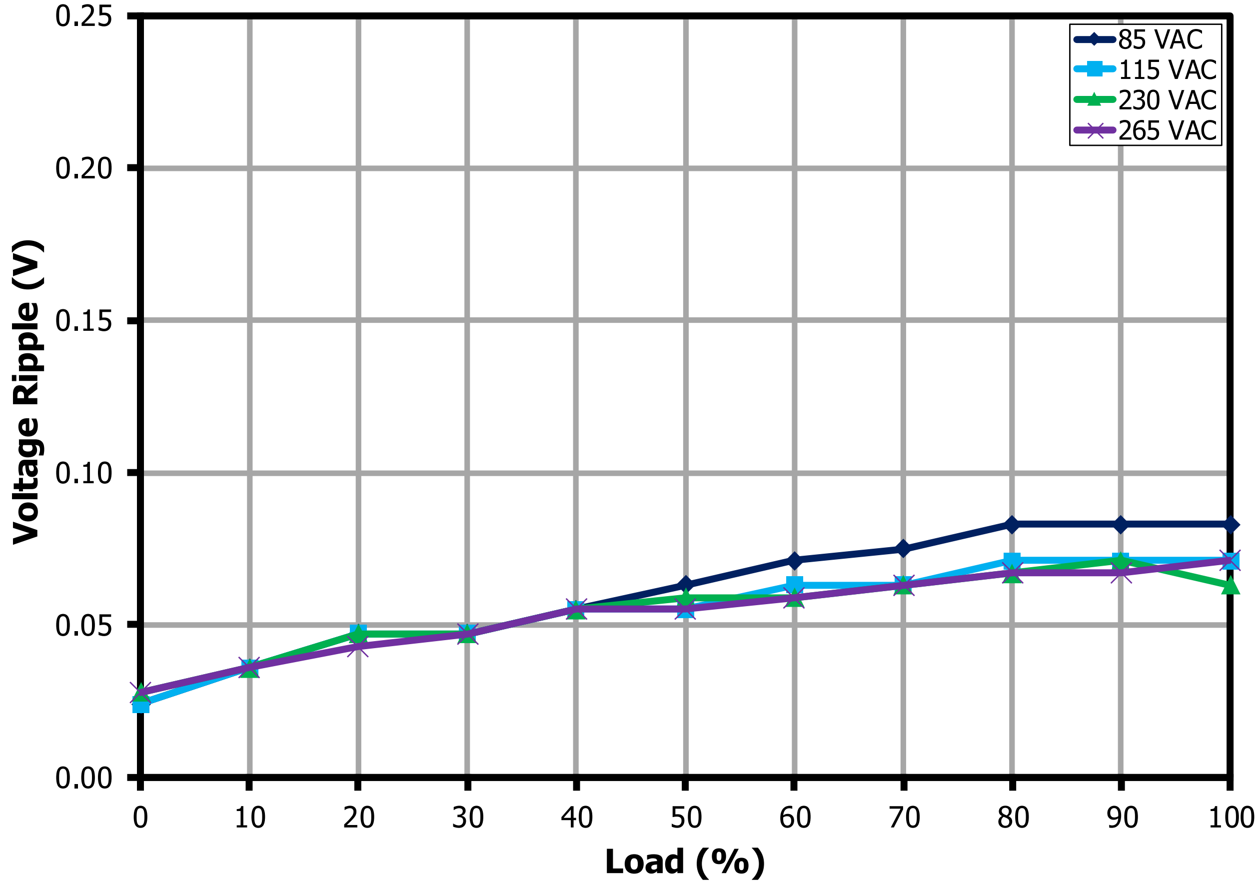

Figure 58 – 9 V Output Peak-to-Peak Ripple Amplitude vs. Percent Load.

14.3.4 *Output: 11 V / 2.45 A*

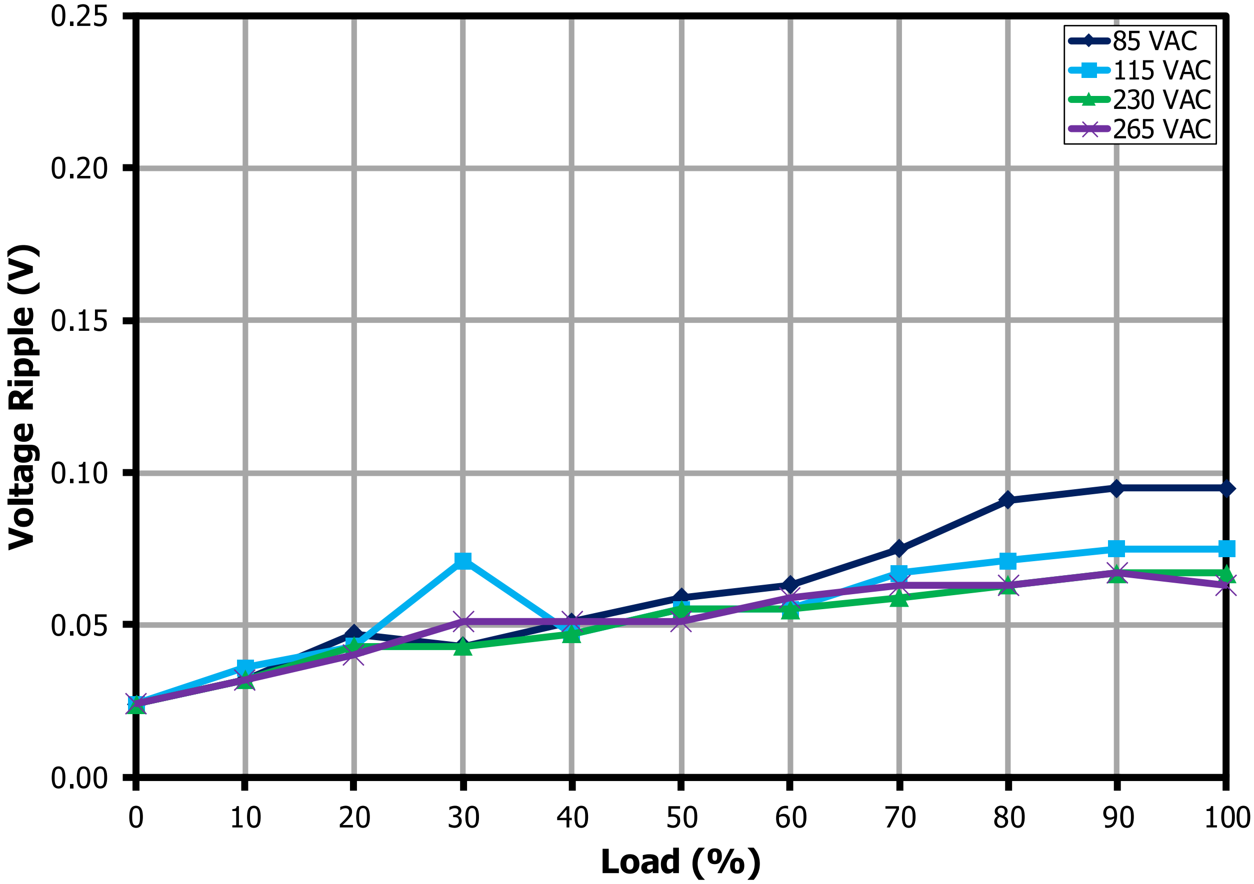

Figure 59 – 11 V Output Peak-to-Peak Ripple Amplitude vs. Percent Load.

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15 Waveforms

15.1 Output Voltage and Current at Start-up (On the Board)

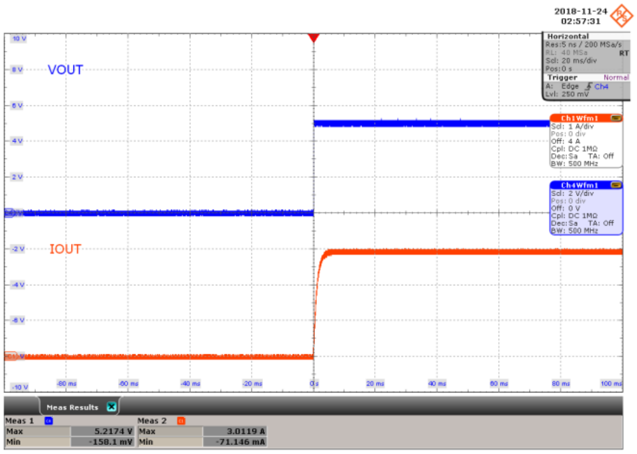

Figure 60 – Output Voltage and Current Waveforms.
85 VAC, 5 V, 3 A Load.
CH1: I_{OUT}, 1 A / div., 20 ms / div.
CH4: V_{OUT}, 2 V / div., 20 ms / div.

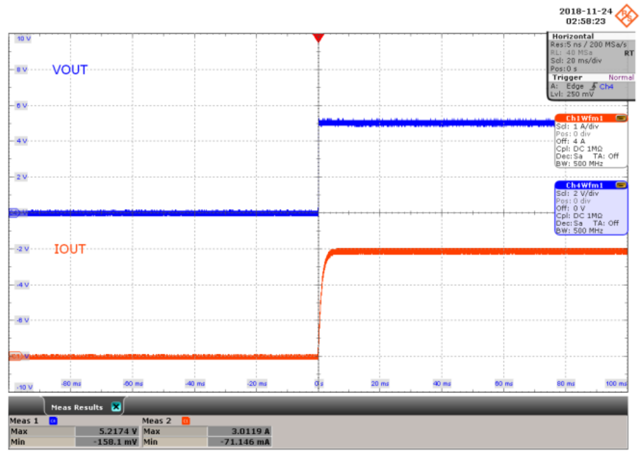

Figure 61 – Output Voltage and Current Waveforms.
265 VAC, 5 V, 3 A Load.
CH1: I_{OUT}, 1 A / div., 20 ms / div.
CH4: V_{OUT}, 2 V / div., 20 ms / div.

15.2 Load Transient Response (On the Board)

15.2.1 *Load Step Response*

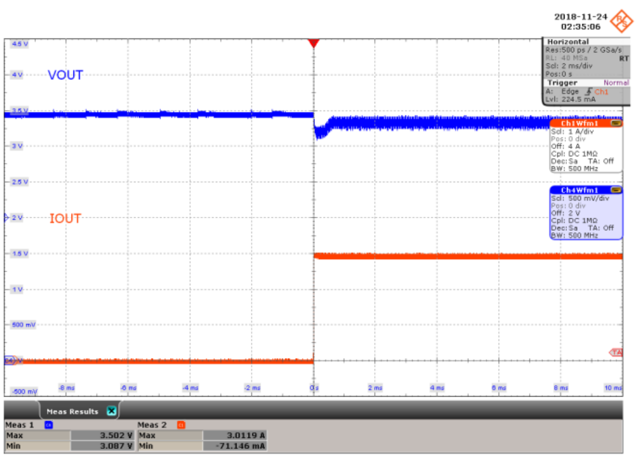

Figure 62 – Load Step Response (Rising).
85 VAC, 3.3 V, 0 – 3 A Load Step.
V_{MIN}: 3.08 V, V_{MAX}: 3.50 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 500 mV / div., 2 ms / div.

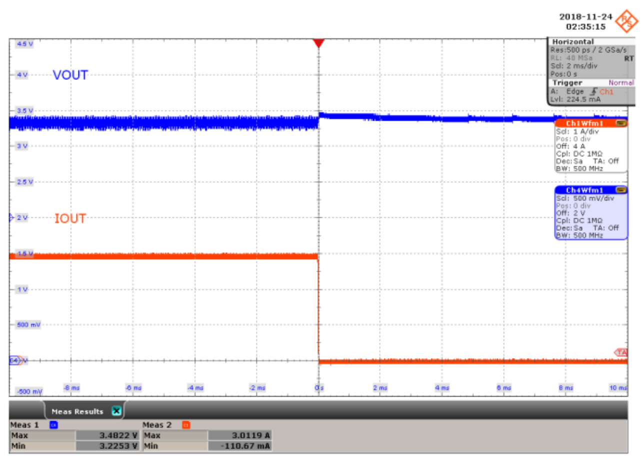

Figure 63 – Load Step Response (Falling).
85 VAC, 3.3 V, 3 – 0 A Load Step.
V_{MIN}: 3.22 V, V_{MAX}: 3.48 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 500 mV / div., 2 ms / div.

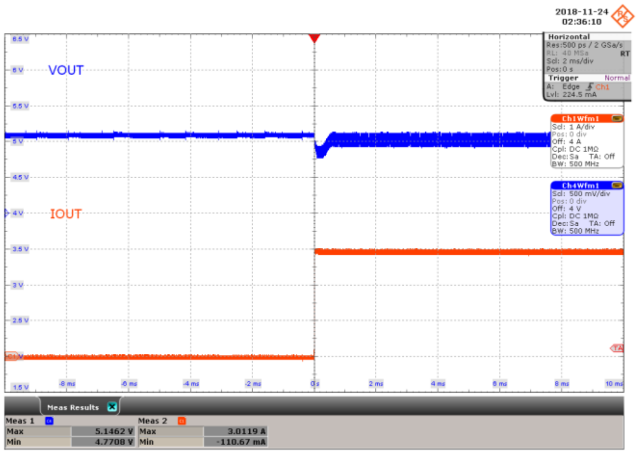

Figure 64 – Load Step Response (Rising).
85 VAC, 5.0 V, 0 – 3 A Load Step.
V_{MIN}: 4.77 V, V_{MAX}: 5.14 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 500 mV / div., 2 ms / div.

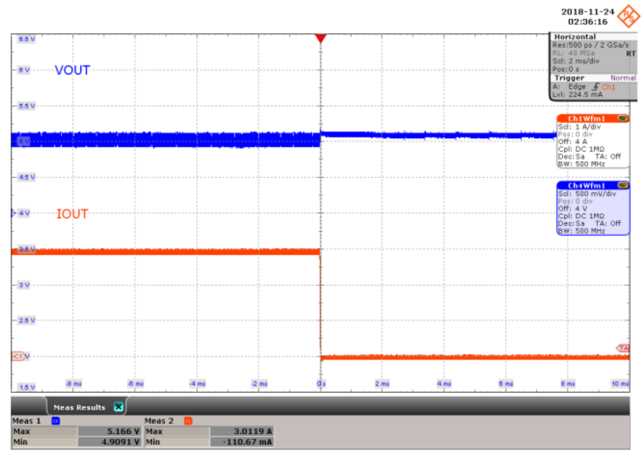

Figure 65 – Load Step Response (Falling).
85 VAC, 5.0 V, 3 – 0 A Load Step.
V_{MIN}: 4.90 V, V_{MAX}: 5.16 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 500 mV / div., 2 ms / div.

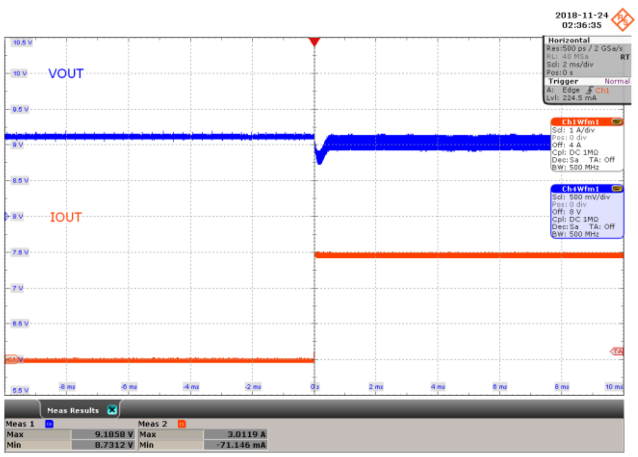

Figure 66 – Load Step Response (Rising).
85 VAC, 9.0 V, 0 – 3 A Load Step.
V_{MIN}: 8.73 V, V_{MAX}: 9.18 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 500 mV / div., 2 ms / div.

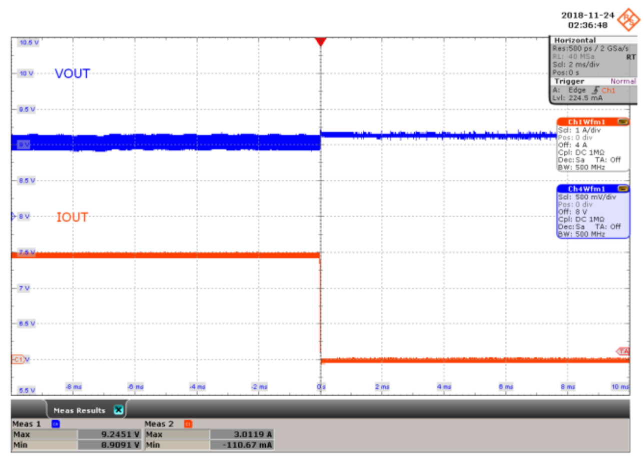

Figure 67 – Load Step Response (Falling).
85 VAC, 9.0 V, 3 – 0 A Load Step.
V_{MIN}: 8.90 V, V_{MAX}: 9.24 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 500 mV / div., 2 ms / div.

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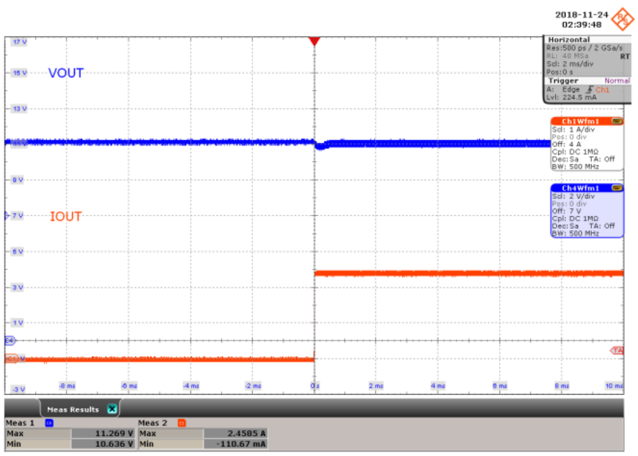

Figure 68 – Load Step Response (Rising).
85 VAC, 11.0 V, 0 – 2.45 A Load Step.
V_{MIN}: 10.63 V, V_{MAX}: 11.26 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 2 V / div., 2 ms / div.

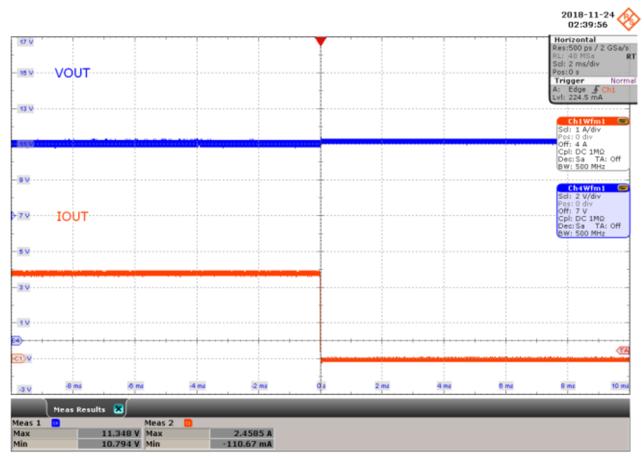

Figure 69 – Load Step Response (Falling).
85 VAC, 11.0 V, 2.45 – 0 A Load Step.
V_{MIN}: 10.79 V, V_{MAX}: 11.34 V.
CH1: I_{OUT}, 1 A / div., 2 ms / div.
CH4: V_{OUT}, 2 V / div., 2 ms / div.

15.2.2 *Dynamic Load Response*

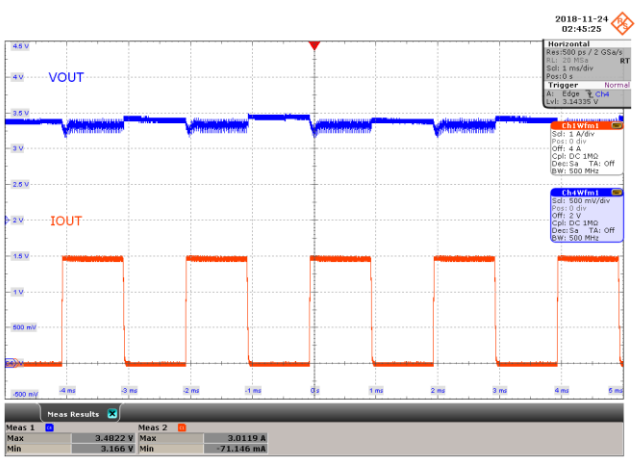

Figure 70 – Dynamic Load Response.
85 VAC, 3.3 V, 0 - 3 A Load.
V_{MIN}: 3.16 V, V_{MAX}: 3.48 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 500 mV / div., 1 ms / div.

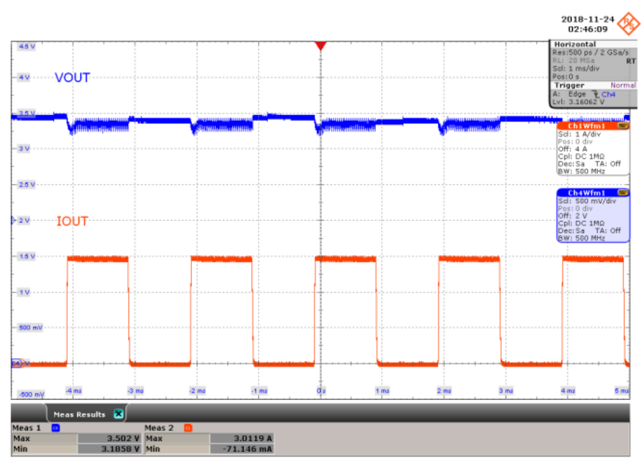

Figure 71 – Dynamic Load Response.
265 VAC, 3.3 V, 0 - 3 A Load.
V_{MIN}: 3.18 V, V_{MAX}: 3.50 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 500 mV / div., 1 ms / div.

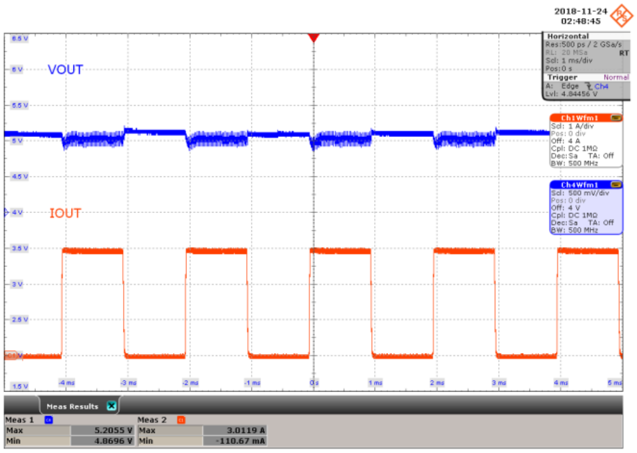

Figure 72 – Dynamic Load Response.
85 VAC, 5.0 V, 0 - 3 A Load.
V_{MIN}: 4.86 V, V_{MAX}: 5.20 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 500 mV / div., 1 ms / div.

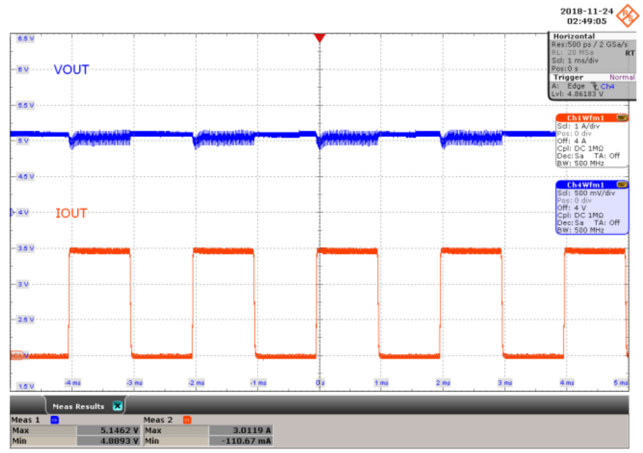

Figure 73 – Dynamic Load Response.
265 VAC, 5.0 V, 0 - 3 A Load.
V_{MIN}: 4.88 V, V_{MAX}: 5.14 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 500 mV / div., 1 ms / div.

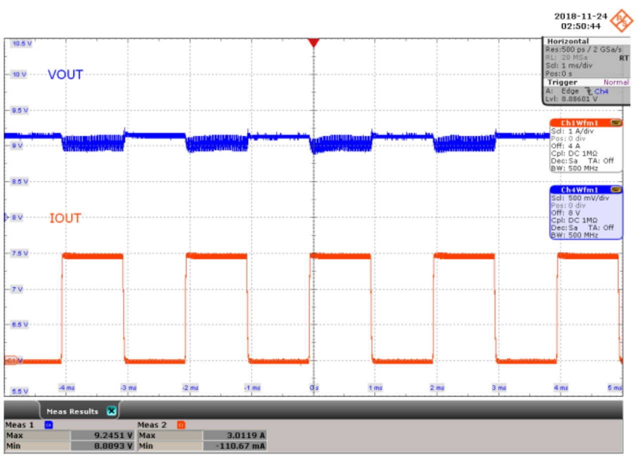

Figure 74 – Dynamic Load Response.
85 VAC, 9.0 V, 0 - 3 A Load.
V_{MIN}: 8.88 V, V_{MAX}: 9.24 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 500 mV / div., 1 ms / div.

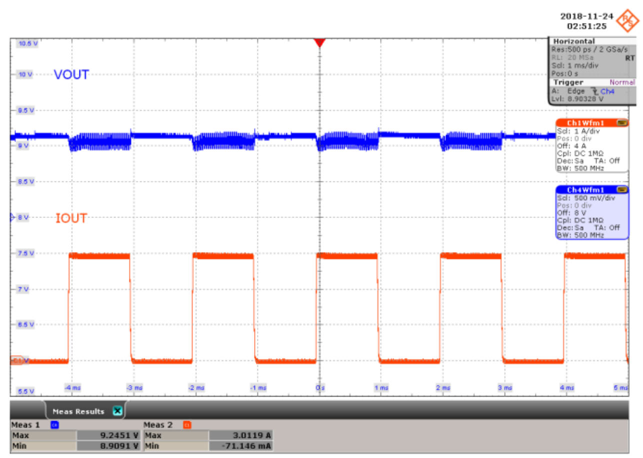

Figure 75 – Dynamic Load Response.
265 VAC, 9.0 V, 0 - 3 A Load.
V_{MIN}: 8.90 V, V_{MAX}: 9.24 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 500 mV / div., 1 ms / div.

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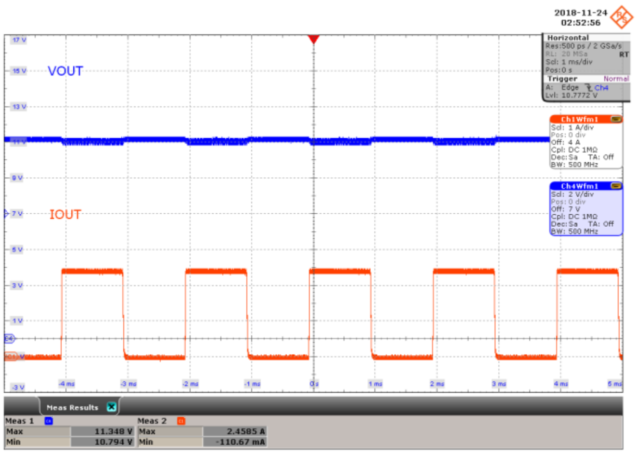

Figure 76 – Dynamic Load Response.
85 VAC, 11.0 V, 0 - 2.45 A Load.
V_{MIN}: 10.79 V, V_{MAX}: 11.34 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 2 V / div., 1 ms / div.

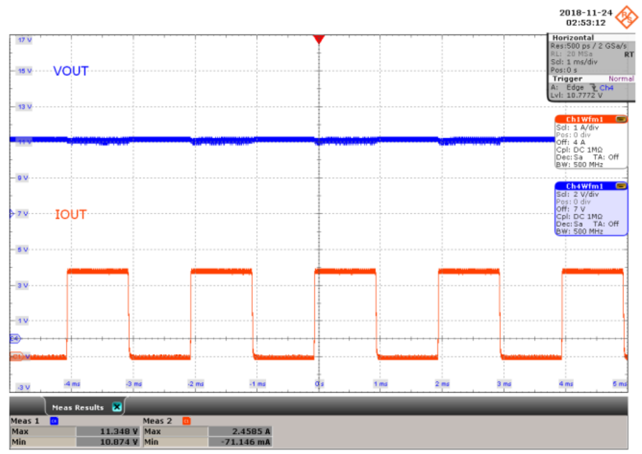

Figure 77 – Dynamic Load Response.
265 VAC, 11.0 V, 0 - 2.45 A Load.
V_{MIN}: 10.87 V, V_{MAX}: 11.34 V.
CH1: I_{OUT}, 1 A / div., 1 ms / div.
CH4: V_{OUT}, 2 V / div., 1 ms / div.

15.3 Switching Waveforms

15.3.1 *Drain Voltage and Current*

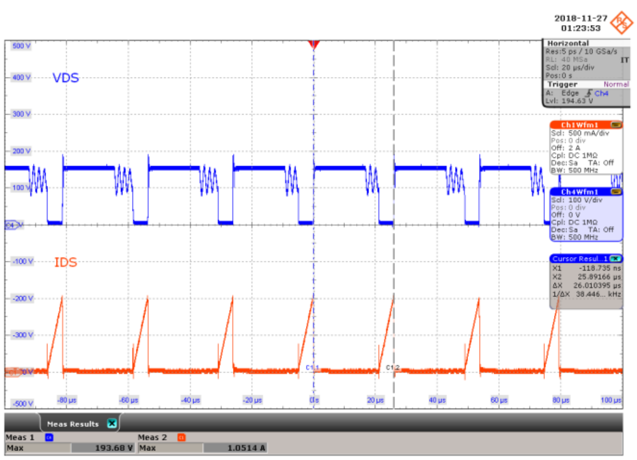

Figure 78 – Drain Voltage and Current Waveforms.
85 VAC, 3.3 V, 3 A Load (193 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 100 V / div., 20 µs / div.

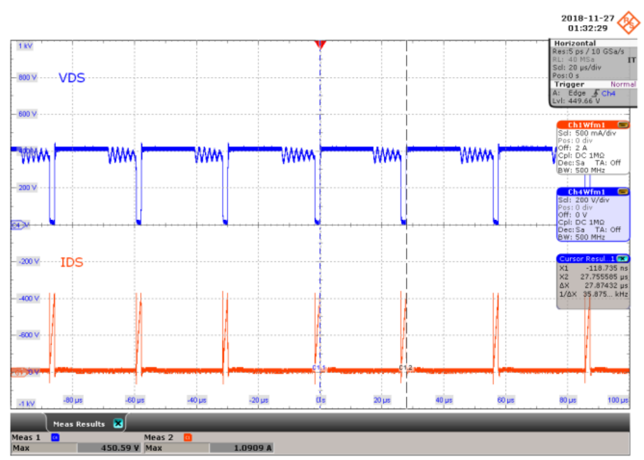

Figure 79 – Drain Voltage and Current Waveforms.
265 VAC, 3.3 V, 3 A Load (450 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 200 V / div., 20 µs / div.

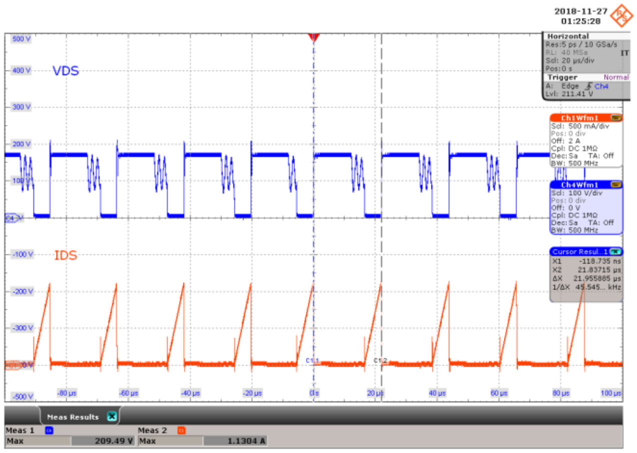

Figure 80 – Drain Voltage and Current Waveforms.
85 VAC, 5.0 V, 3 A Load (209 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 100 V / div., 20 µs / div.

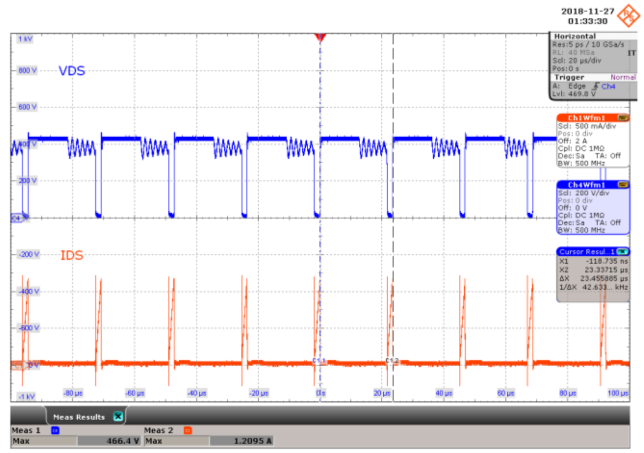

Figure 81 – Drain Voltage and Current Waveforms.
265 VAC, 5.0 V, 3 A Load (466 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 200 V / div., 20 µs / div.

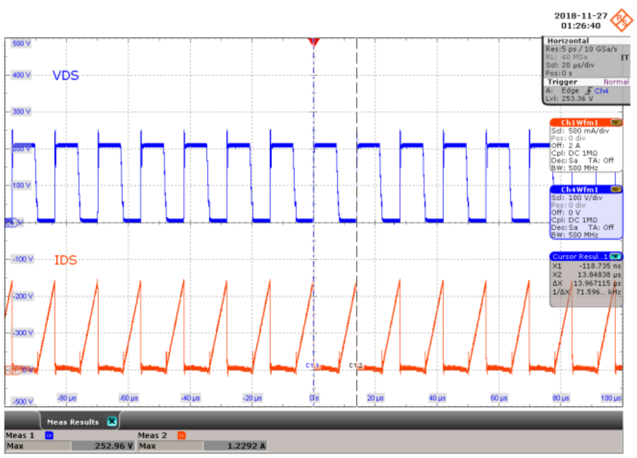

Figure 82 – Drain Voltage and Current Waveforms.
85 VAC, 9.0 V, 3 A Load (252 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 100 V / div., 20 µs / div.

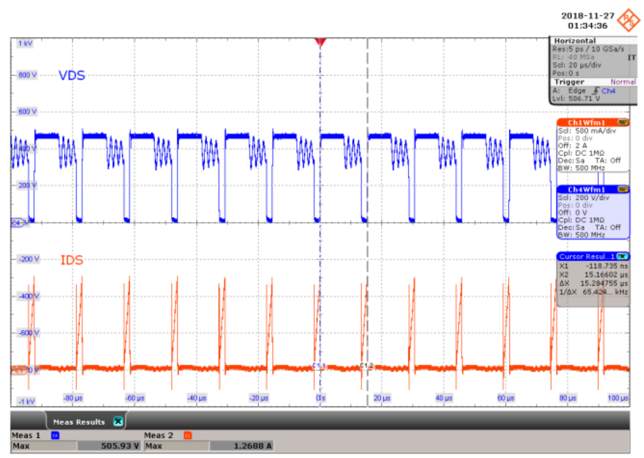

Figure 83 – Drain Voltage and Current Waveforms.
265 VAC, 9.0 V, 3 A Load (505 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 200 V / div., 20 µs / div.

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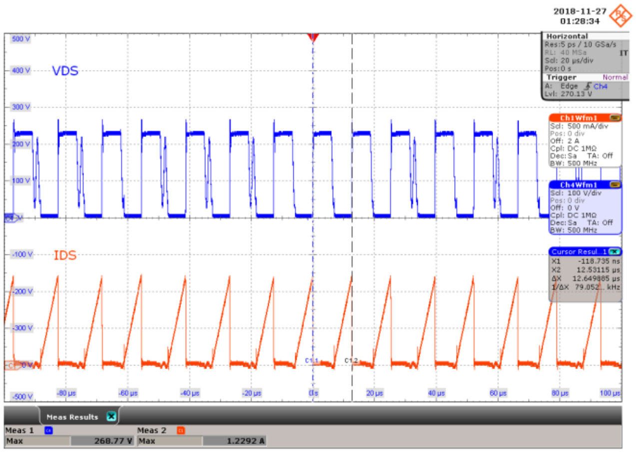

Figure 84 – Drain Voltage and Current Waveforms.
85 VAC, 11.0 V, 2.45 A Load (268 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 100 V / div., 20 µs / div.

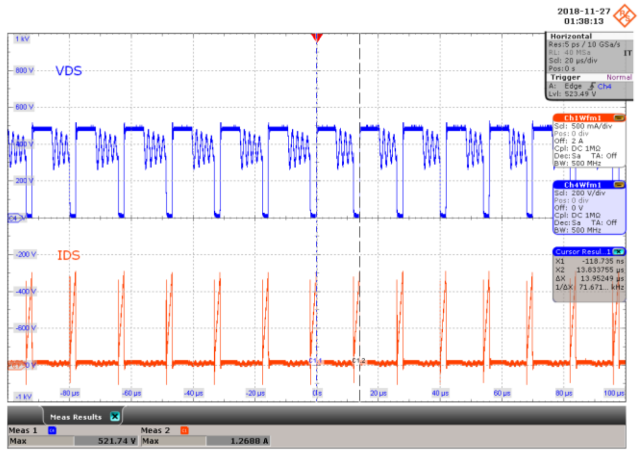

Figure 85 – Drain Voltage and Current Waveforms.
265 VAC, 11.0 V, 2.45 A Load (521 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 µs / div.
CH4: V_{DRAIN}, 200 V / div., 20 µs / div.

15.3.2 *Drain Voltage and Current During Output Voltage Transition*

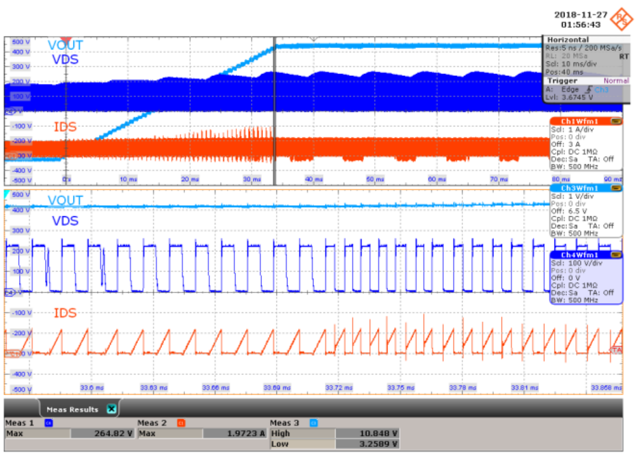

Figure 86 – Drain Voltage, Current, and Output Voltage Waveforms.
85 VAC, 3.3 V – 11.0 V, 2.45 A Load (264 V_{MAX}).
CH1: I_{DRAIN}, 1 A / div., 10 ms / div.
CH3: V_{OUT}, 1 V / div., 10 ms / div.
CH4: V_{DRAIN}, 100 V / div., 10 ms / div.

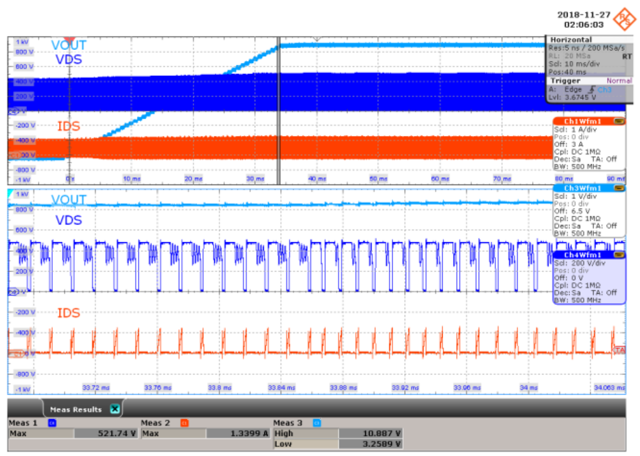

Figure 87 – Drain Voltage, Current, and Output Voltage Waveforms.
265 VAC, 3.3 V – 11.0 V, 2.45 A Load (521 V_{MAX}).
CH1: I_{DRAIN}, 1 A / div., 10 ms / div.
CH3: V_{OUT}, 1 V / div., 10 ms / div.
CH4: V_{DRAIN}, 200 V / div., 10 ms / div.

15.3.3 *Drain Voltage and Current at Start-up*

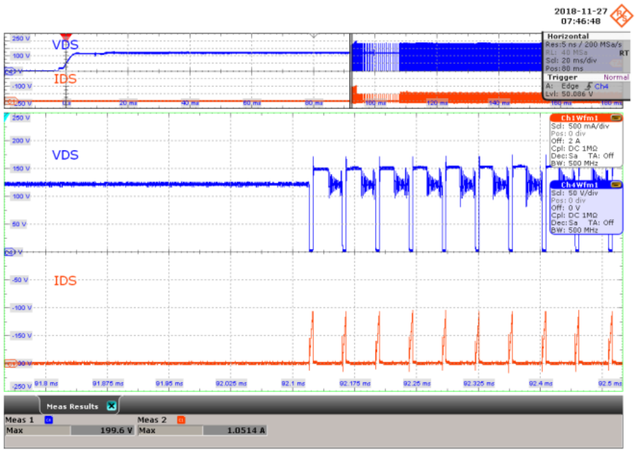

Figure 88 – Drain Voltage and Current Waveforms.
85 VAC, 5.0 V, 3.0 A Load (199 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 ms / div.
CH4: V_{DRAIN}, 50 V / div., 20 ms / div.

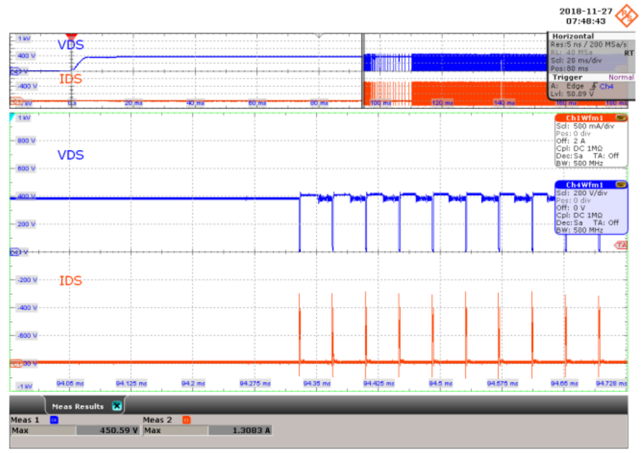

Figure 89 – Drain Voltage and Current Waveforms.
265 VAC, 5.0 V, 3.0 A Load (450 V_{MAX}).
CH1: I_{DRAIN}, 500 mA / div., 20 ms / div.
CH4: V_{DRAIN}, 200 V / div., 20 ms / div.

15.3.4 *SR FET Voltage*

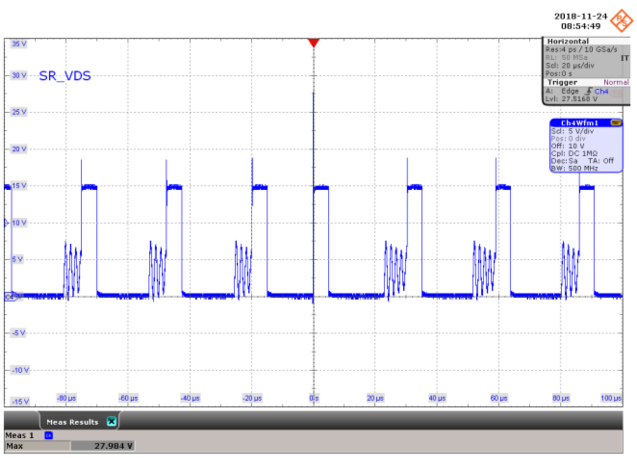

Figure 90 – SR FET Voltage Waveform.
85 VAC, 3.3 V, 3 A Load (27.98 V_{MAX}).
CH4: SR_V_{DRAIN}, 5 V / div., 20 μs / div.

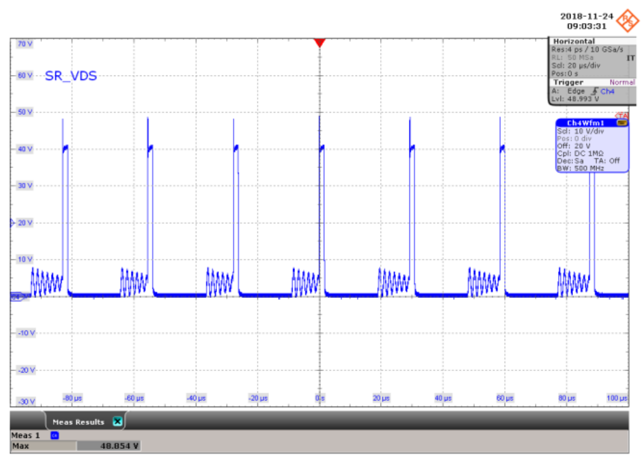

Figure 91 – SR FET Voltage Waveform.
265 VAC, 3.3 V, 3 A Load (48.85 V_{MAX}).
CH4: SR_V_{DRAIN}, 10 V / div., 20 μs / div.

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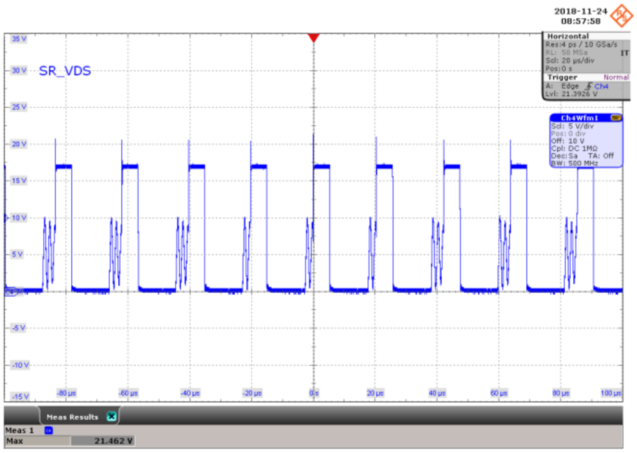

Figure 92 – SR FET Voltage Waveform.
85 VAC, 5.0 V, 3 A Load (21.46 V_{MAX}).
CH4: SR_V_{DRAIN}, 5 V / div., 20 µs / div.

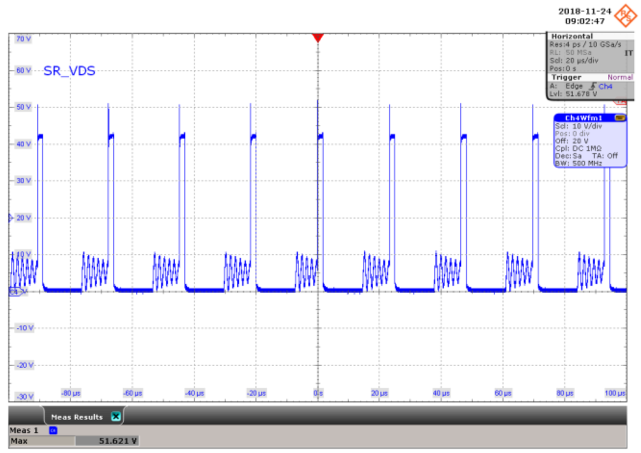

Figure 93 – SR FET Voltage Waveform.
265 VAC, 5.0 V, 3 A Load (51.62 V_{MAX}).
CH4: SR_V_{DRAIN}, 10 V / div., 20 µs / div.

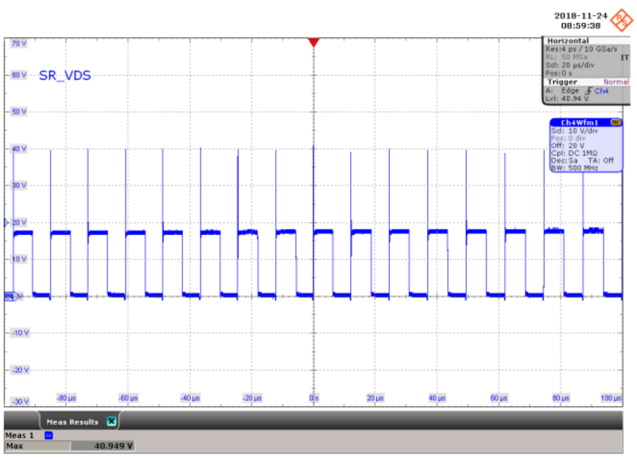

Figure 94 – SR FET Voltage Waveform.
85 VAC, 9.0 V, 3 A Load (40.94 V_{MAX}).
CH4: SR_V_{DRAIN}, 5 V / div., 20 µs / div.

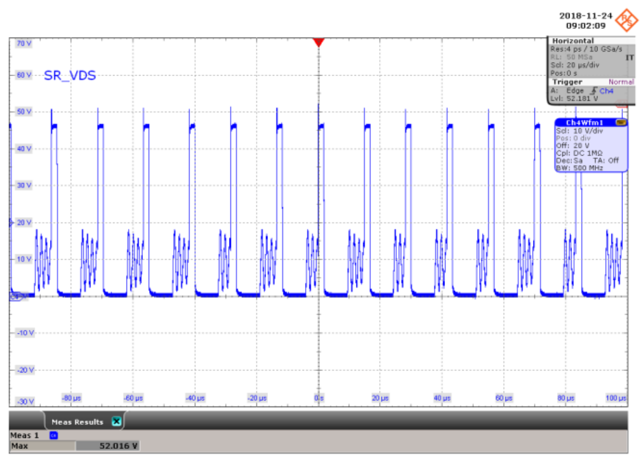

Figure 95 – SR FET Voltage Waveform.
265 VAC, 9.0 V, 3 A Load (52.01 V_{MAX}).
CH4: SR_V_{DRAIN}, 10 V / div., 20 µs / div.

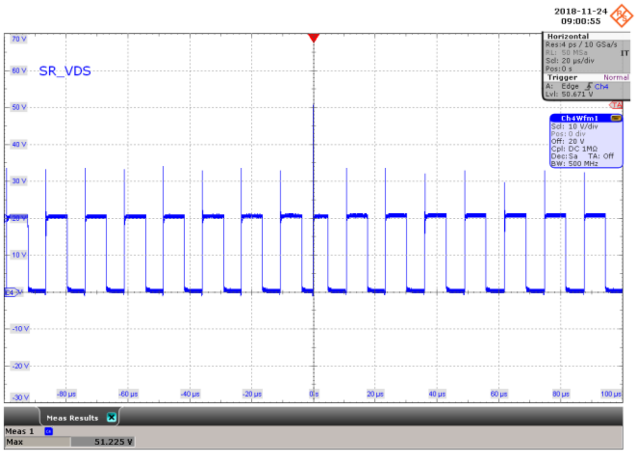

Figure 96 – SR FET Voltage Waveform.
85 VAC, 11.0 V, 2.45 A Load (51.22 V_{MAX}).
CH4: SR_V_{DRAIN}, 10 V / div., 20 µs / div.

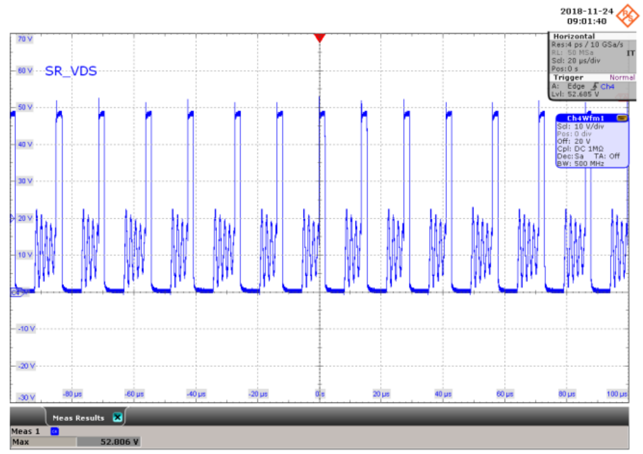

Figure 97 – SR FET Voltage Waveform.
265 VAC, 11.0 V, 2.45 A Load (52.80 V_{MAX}).
CH4: SR_V_{DRAIN}, 10 V / div., 20 µs / div.

15.3.5 *SR FET Voltage During Output Voltage Transition*

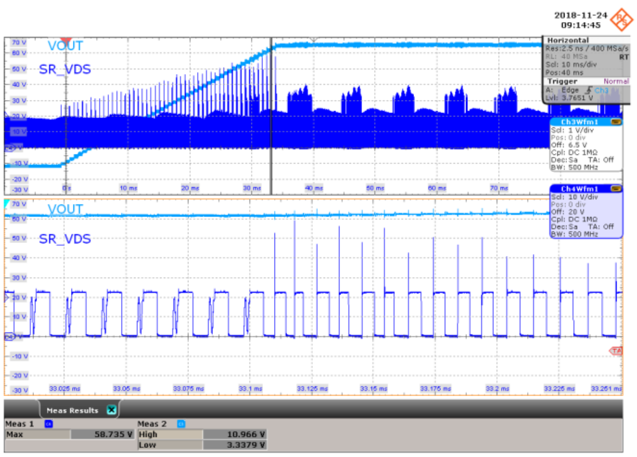

Figure 98 – SR FET and Output Voltage Waveforms.
85 VAC, 3.3 V – 11.0 V, 2.45 A Load
(58.73 V_{MAX}).
CH3: V_{OUT}, 1 V / div., 10 ms / div.
CH4: SR_V_{DRAIN}, 10 V / div., 10 ms / div.

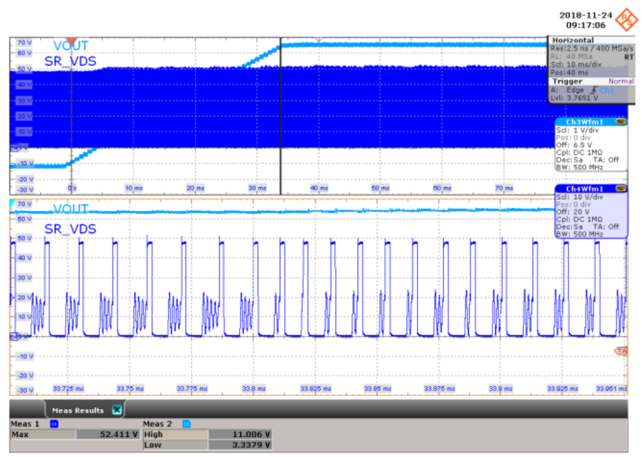

Figure 99 – SR FET and Output Voltage Waveforms.
265 VAC, 3.3 V – 11.0 V, 2.45 A Load
(52.41 V_{MAX}).
CH3: V_{OUT}, 1 V / div., 10 ms / div.
CH4: SR_V_{DRAIN}, 10 V / div., 10 ms / div.

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16 Voltage and Current Step Test using Quadramax and Total Phase Analyzer

16.1 Voltage Step Test (VST)

Figure 100 – Plot of SPT.6 VST from Total Phase Analyzer.

16.2 Current Limit Test (CLT)

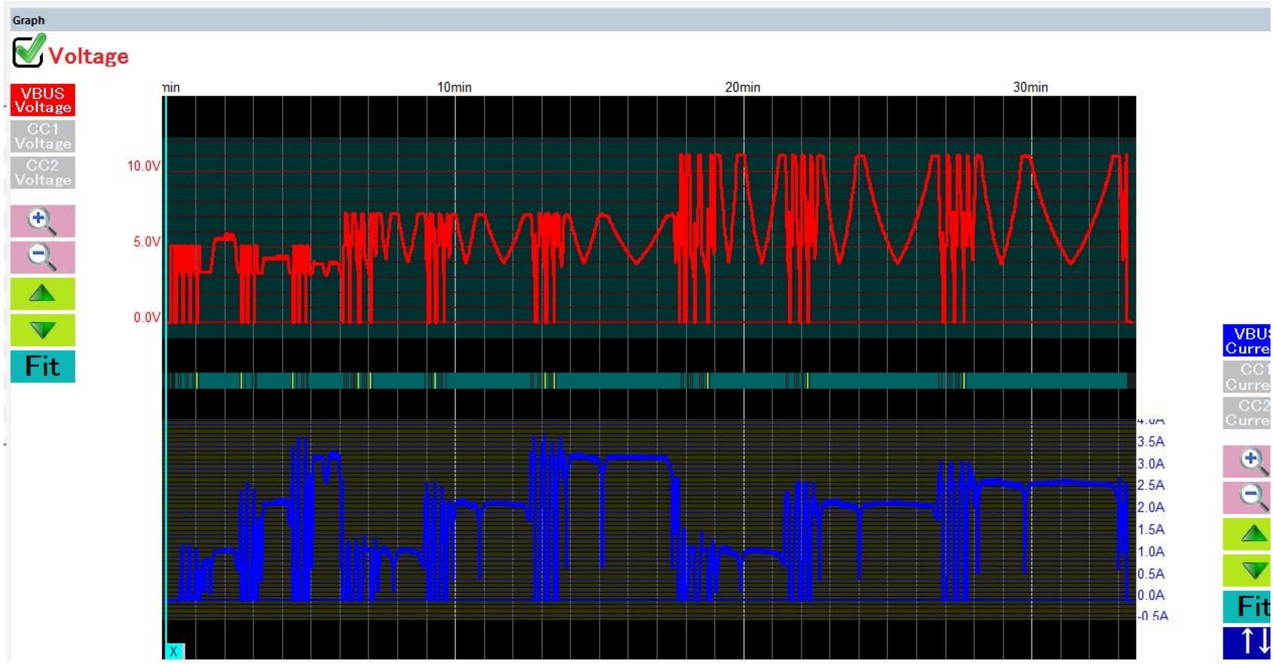

Figure 101 – Plot of SPT.7 CLT from Total Phase Analyzer.

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17 Conducted EMI

17.1 Floating Output

17.1.1 *Output: 5 V / 3 A*

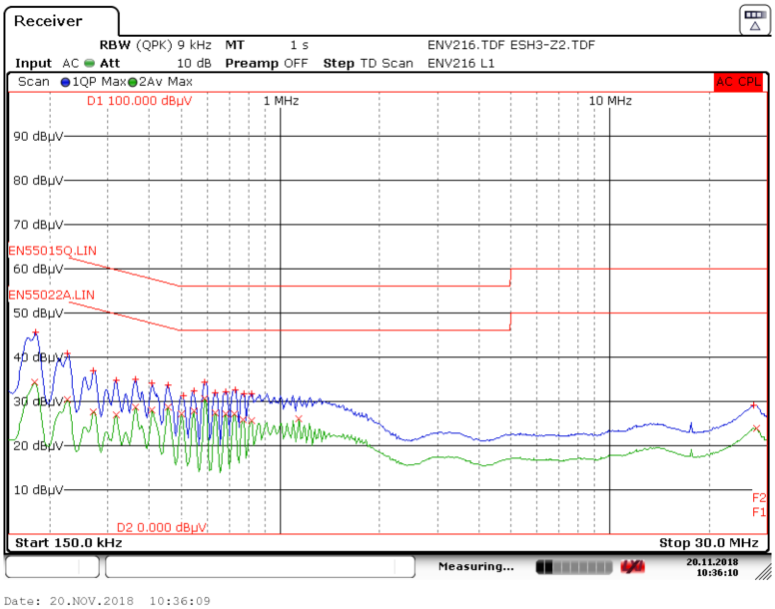

Figure 102 – Floating Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

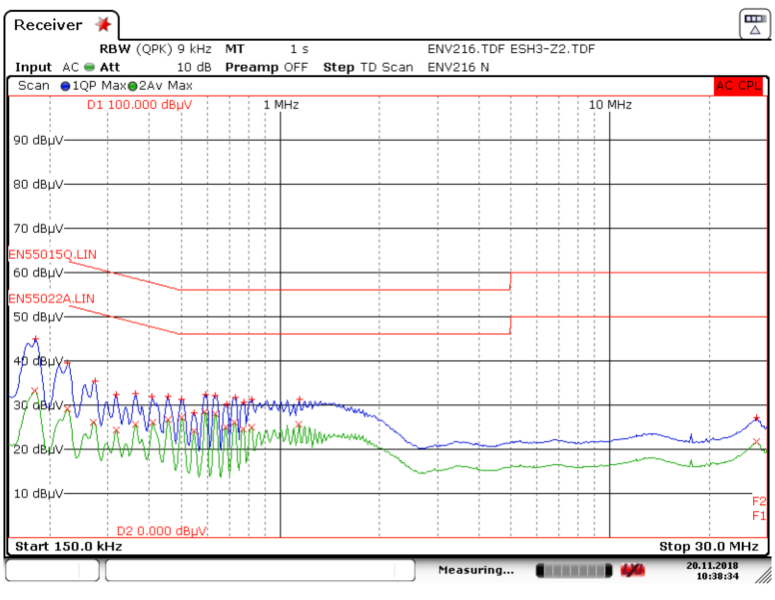

Figure 103 – Floating Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

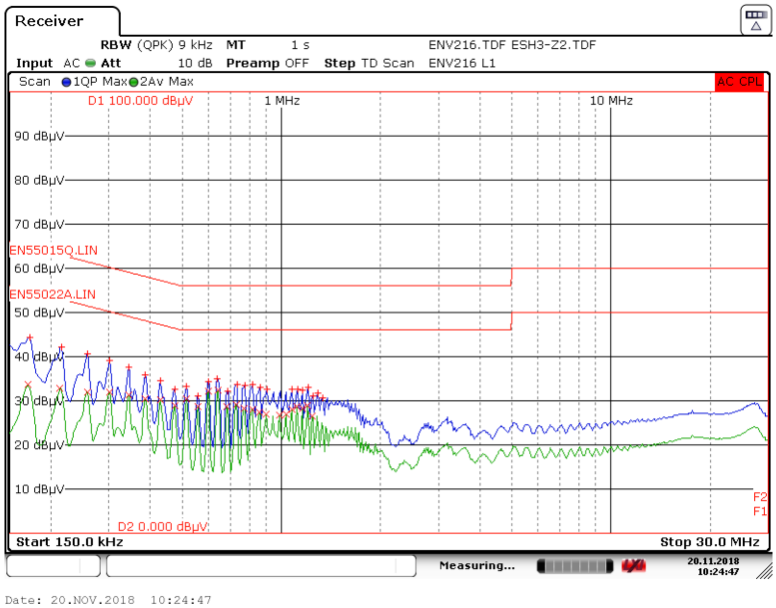

Figure 104 – Floating Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

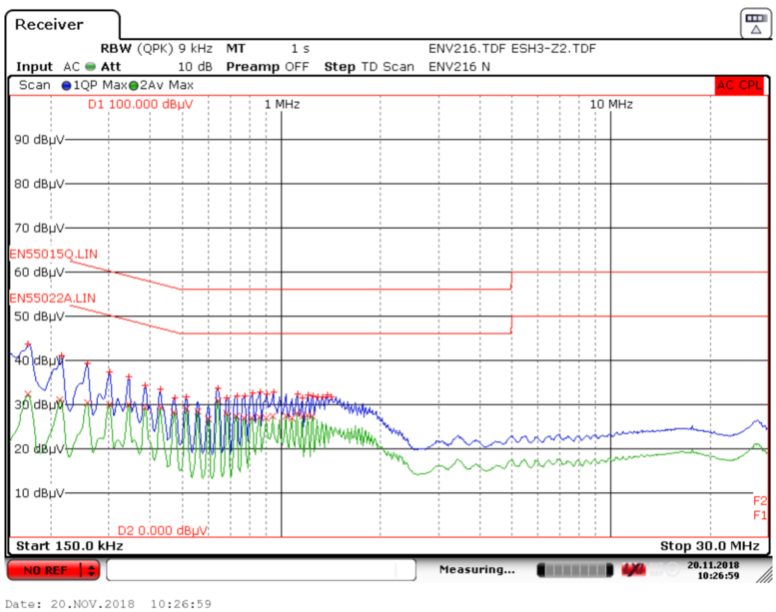

Figure 105 – Floating Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.1.2 *Output: 9 V / 3 A*

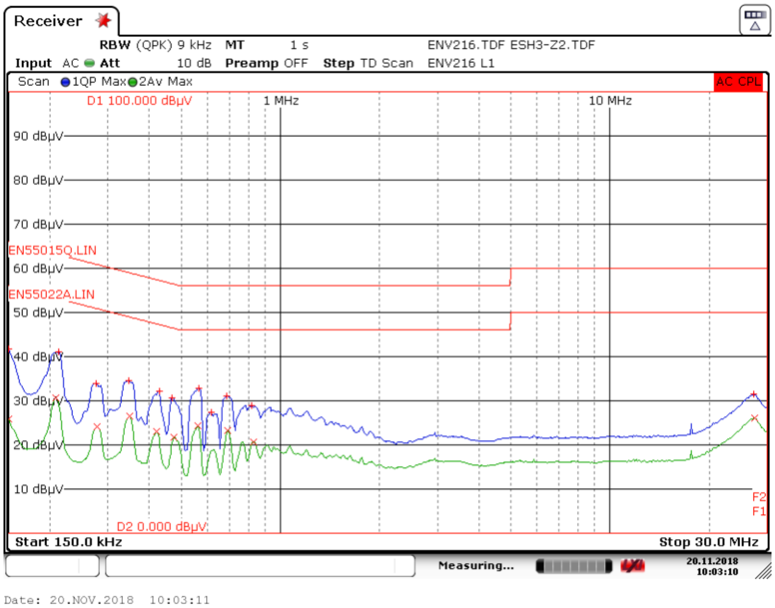


Figure 106 – Floating Ground EMI, 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

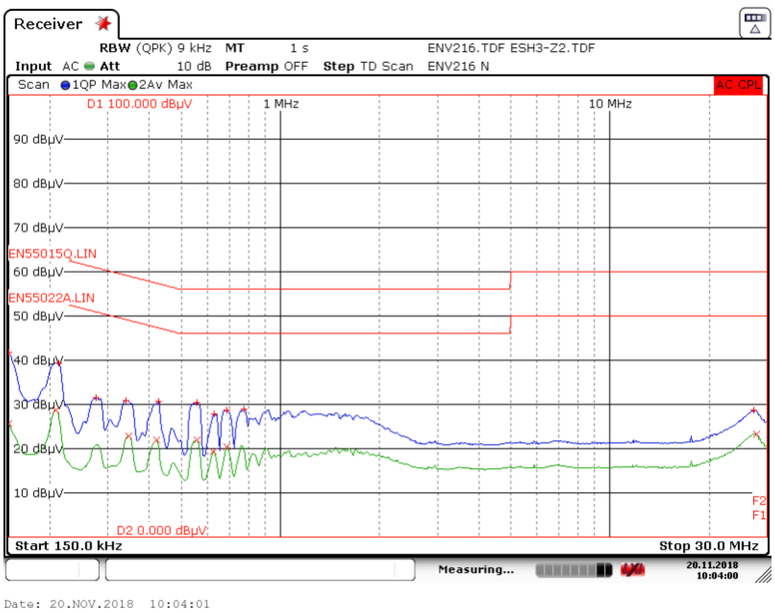
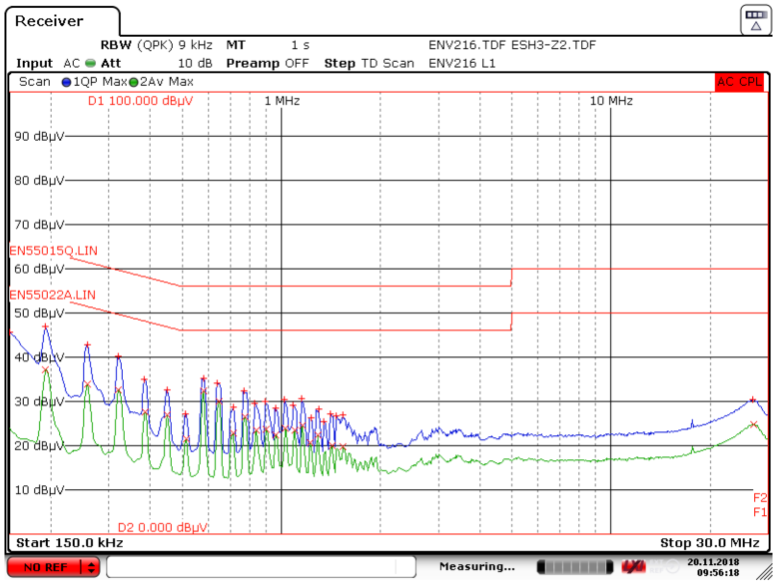
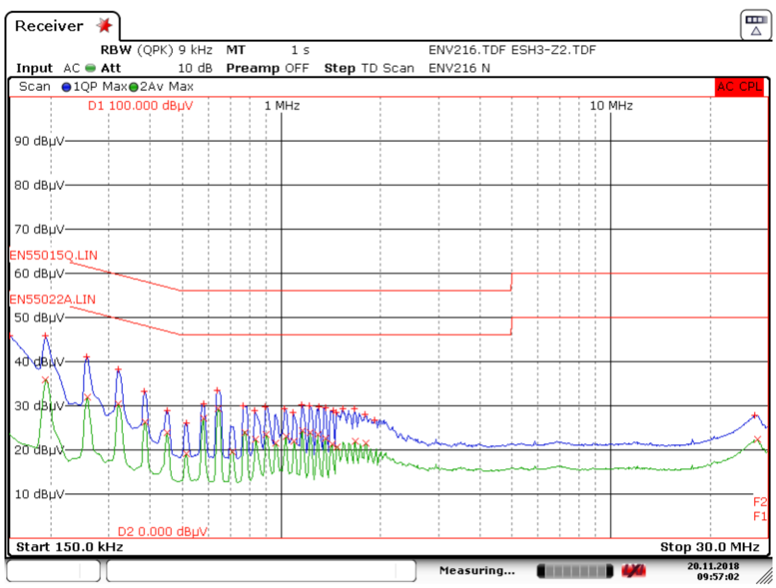


Figure 107 – Floating Ground EMI, 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).



Date: 20.NOV.2018 09:56:18

Figure 108 – Floating Ground EMI, 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).



Date: 20.NOV.2018 09:57:02

Figure 109 – Floating Ground EMI, 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.1.3 *Output: 11 V / 2.45 A*

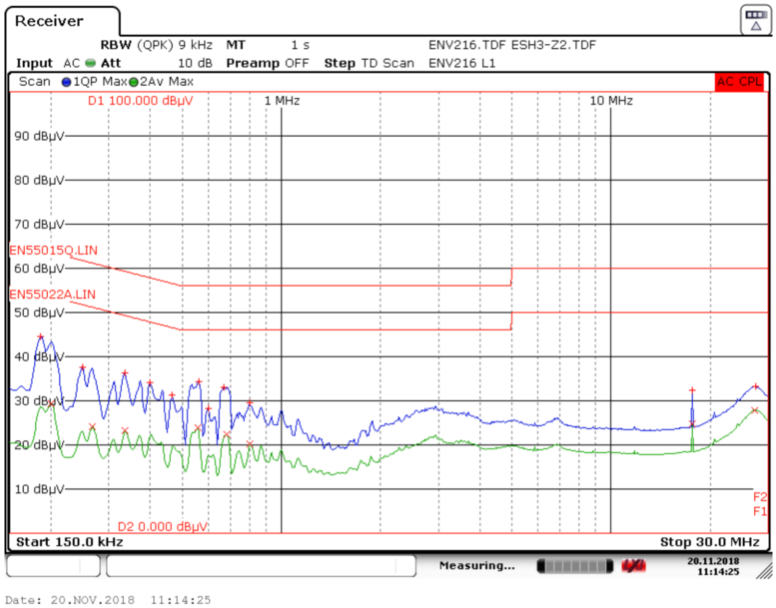

Figure 110 – Floating Ground EMI, 11 V / 2.45 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

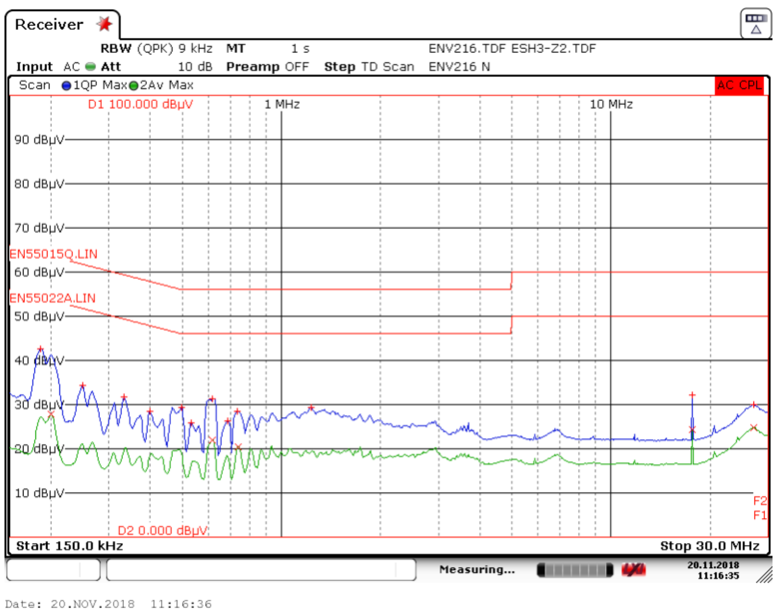

Figure 111 – Floating Ground EMI, 11 V / 2.45 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

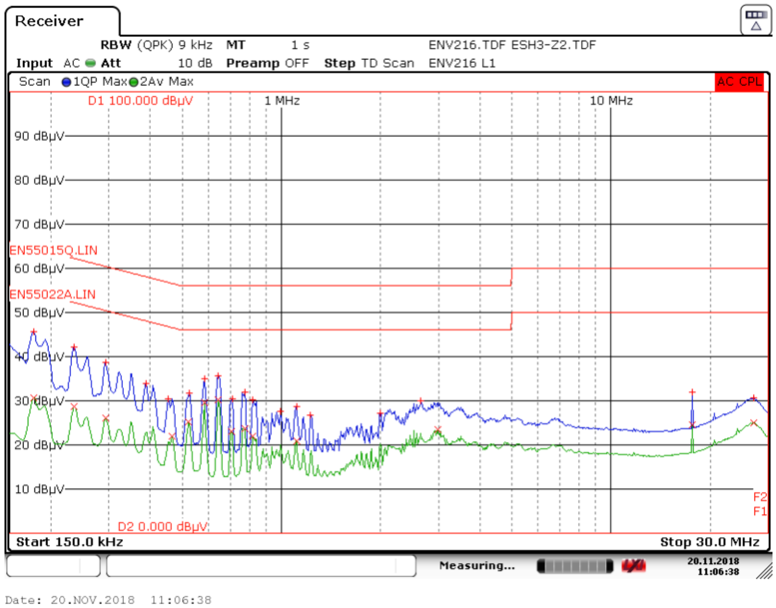

Figure 112 – Floating Ground EMI, 11 V / 2.45 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

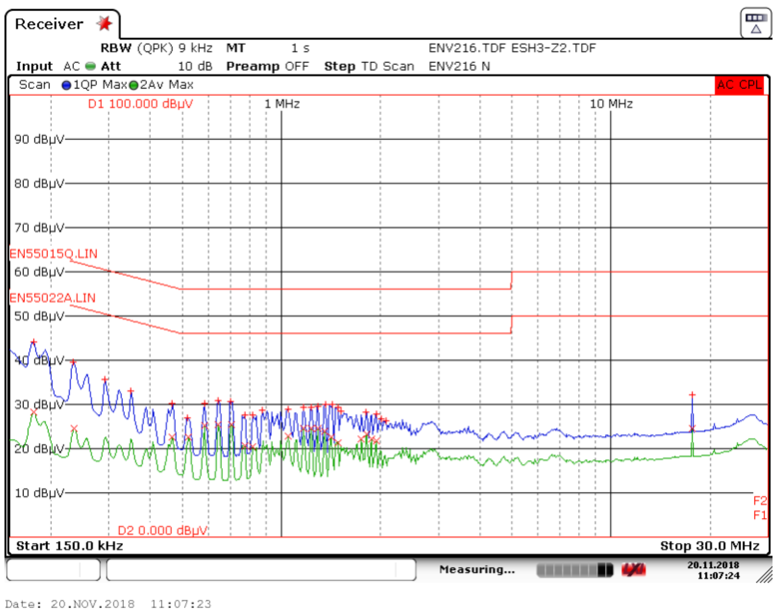

Figure 113 – Floating Ground EMI, 11 V / 2.45 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.2 **Artificial Hand**

17.2.1 *Output: 5 V / 3 A*

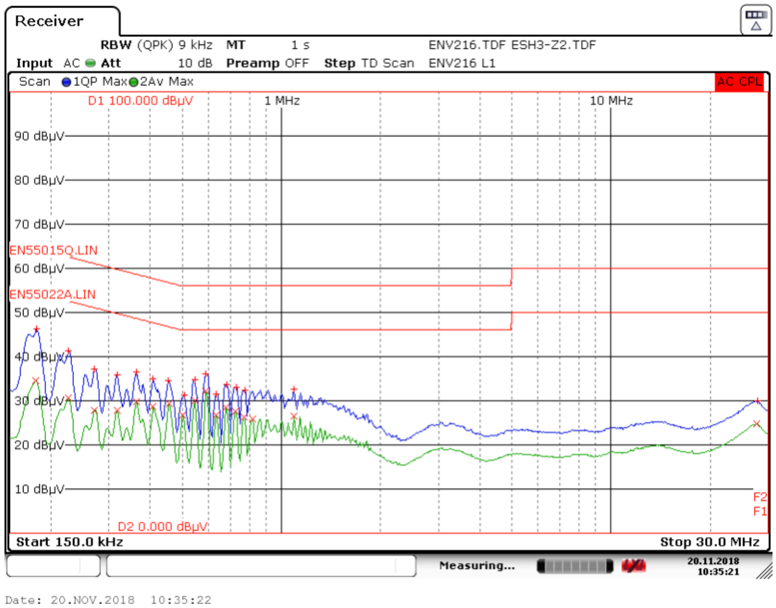

Figure 114 – Artificial Hand EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

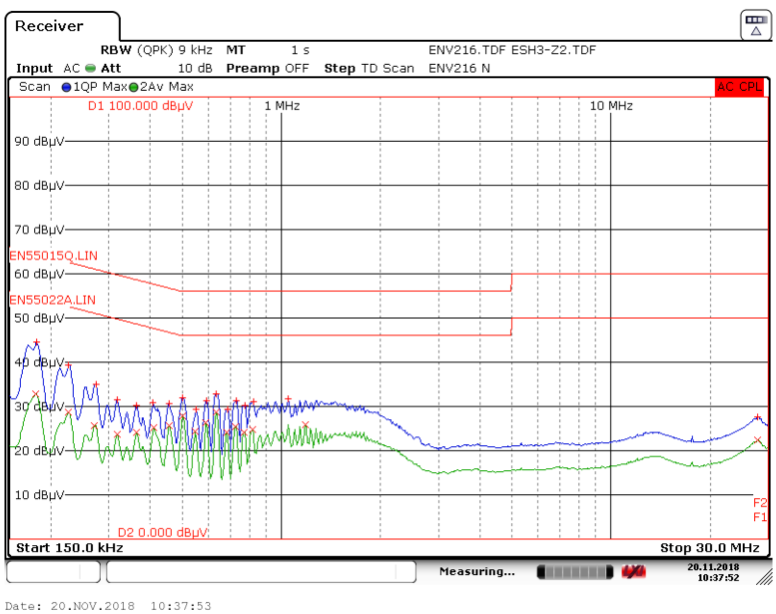

Figure 115 – Artificial Hand EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

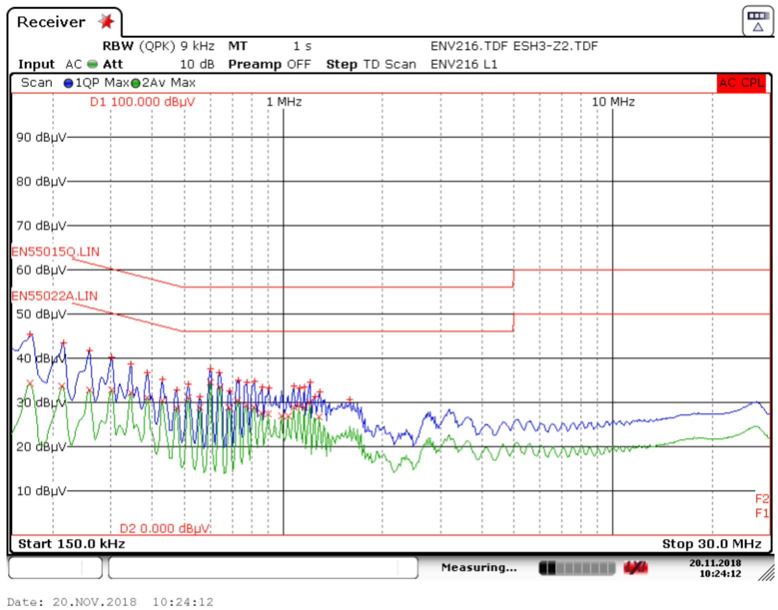

Figure 116 – Artificial Hand EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

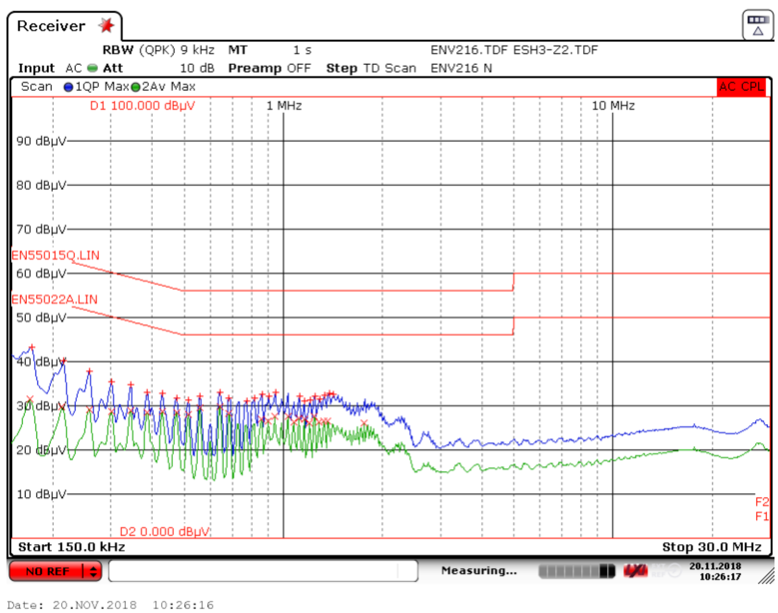

Figure 117 – Artificial Hand EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.2.2 *Output: 9 V / 3 A*

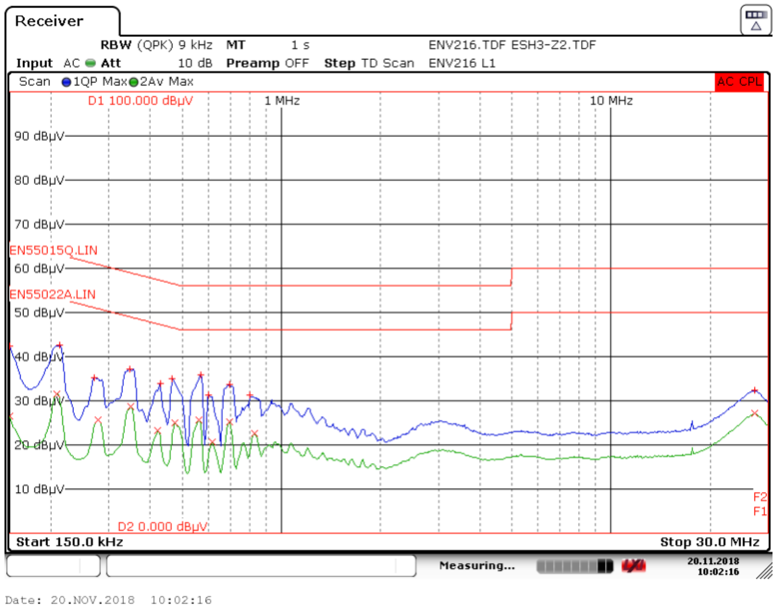

Figure 118 – Artificial Hand EMI, 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

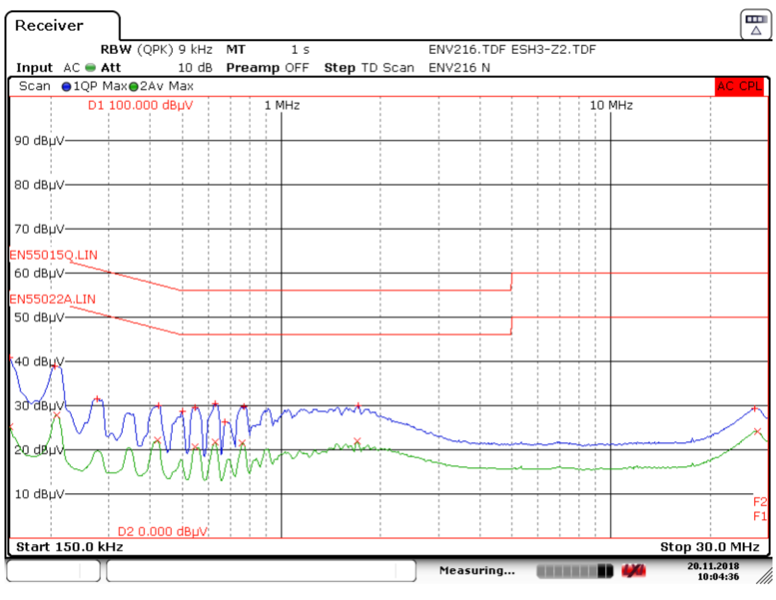

Figure 119 – Artificial Hand EMI, 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

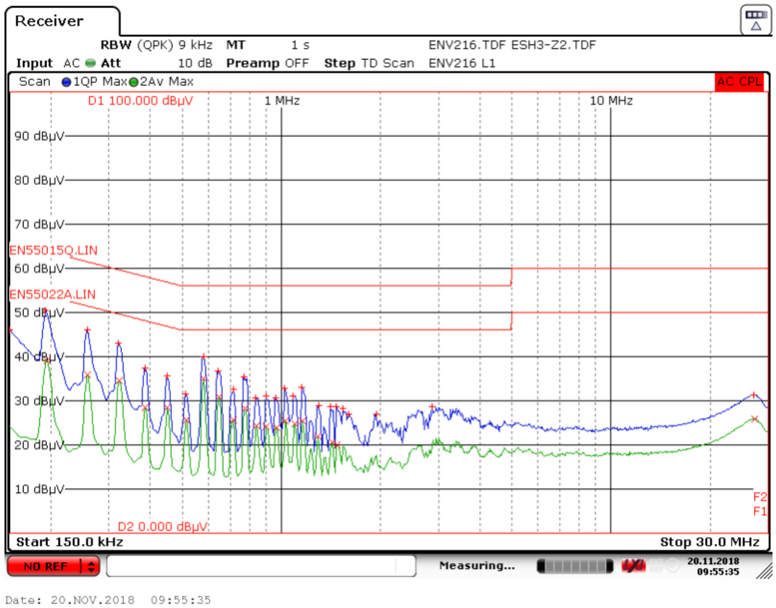

Figure 120 – Artificial Hand EMI, 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

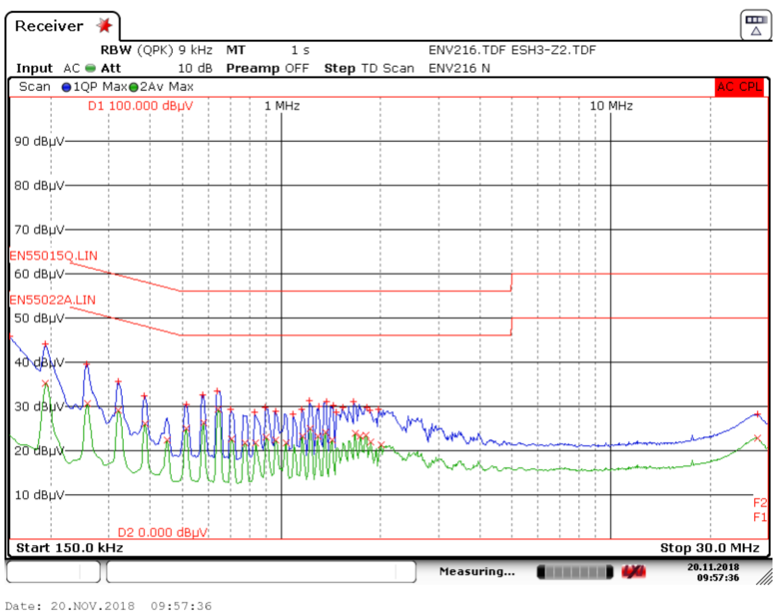

Figure 121 – Artificial Hand EMI, 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.2.3 *Output: 11 V / 2.45 A*

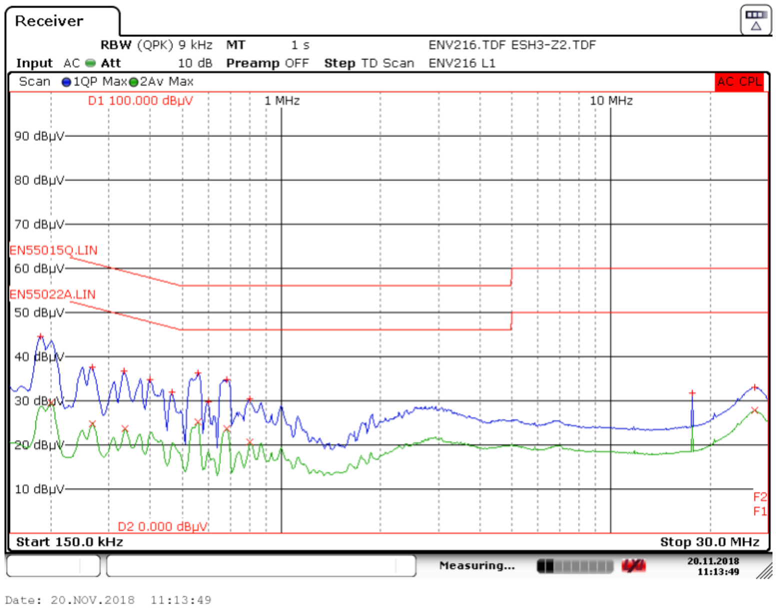

Figure 122 – Artificial Hand EMI, 11 V / 2.45 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

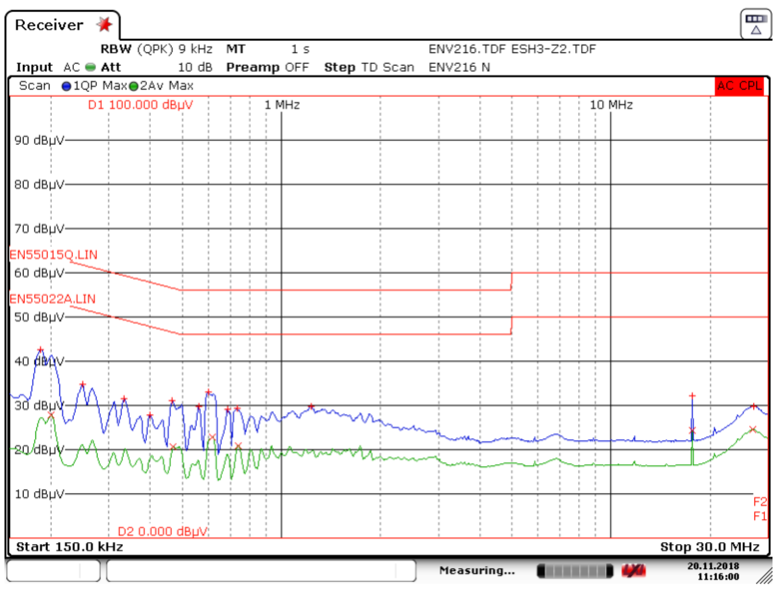

Figure 123 – Artificial Hand EMI, 11 V / 2.45 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

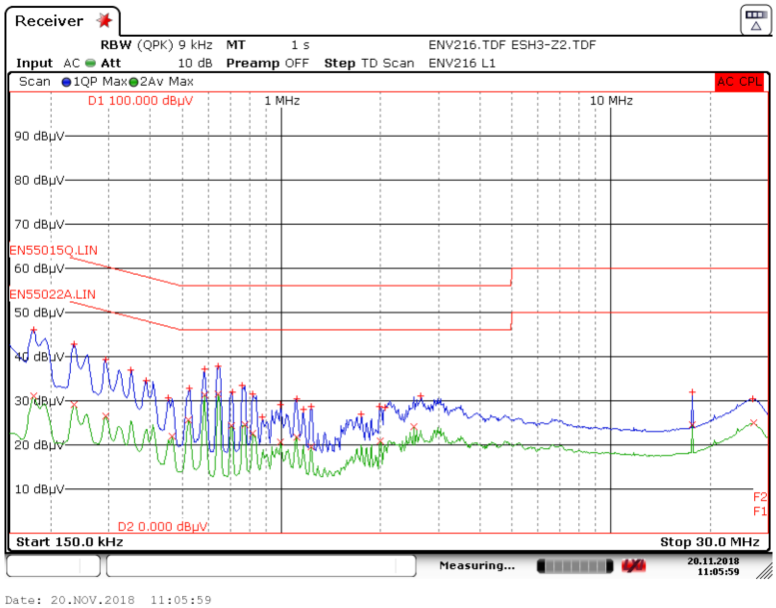

Figure 124 – Artificial Hand EMI, 11 V / 2.45 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

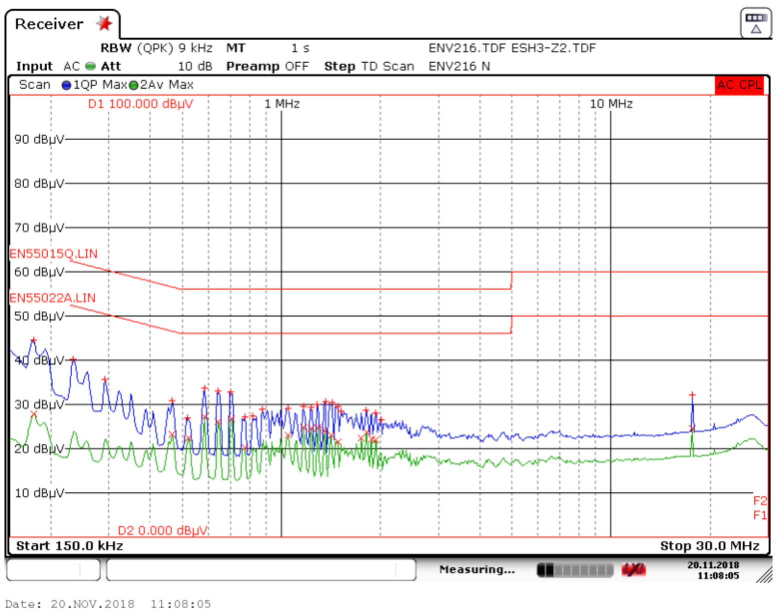

Figure 125 – Artificial Hand EMI, 11 V / 2.45 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.3 **Earth Ground**

17.3.1 *Output: 5 V / 3 A*

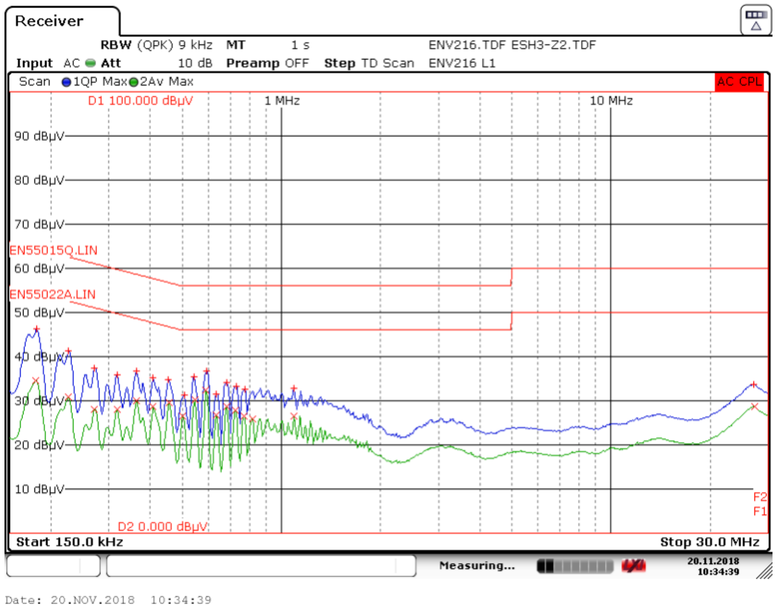

Figure 126 – Earth Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

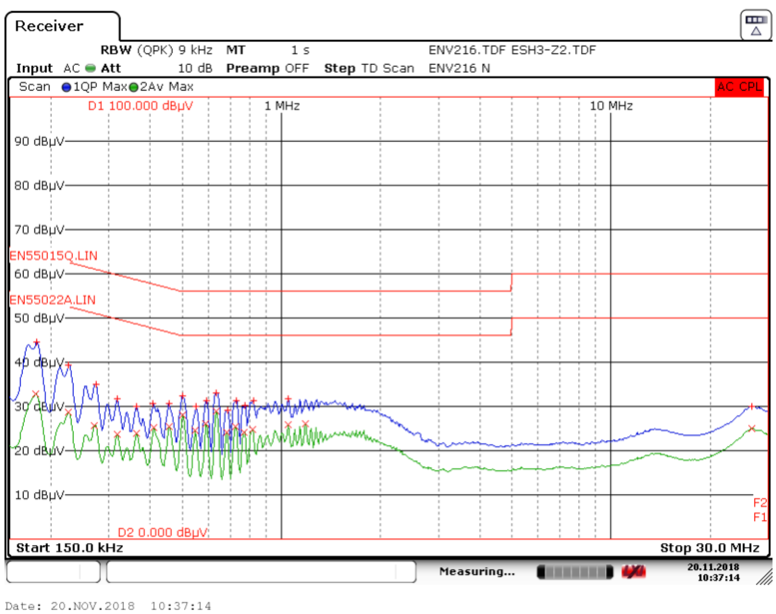

Figure 127 – Earth Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

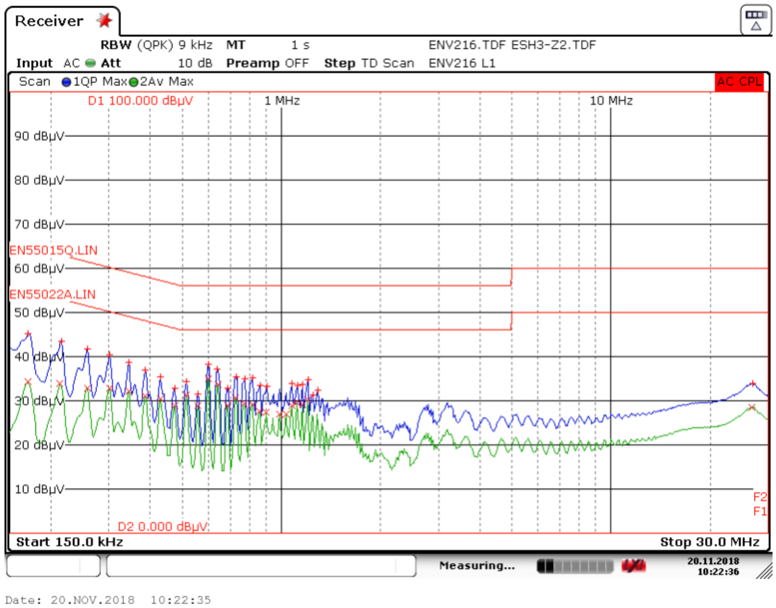

Figure 128 – Earth Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

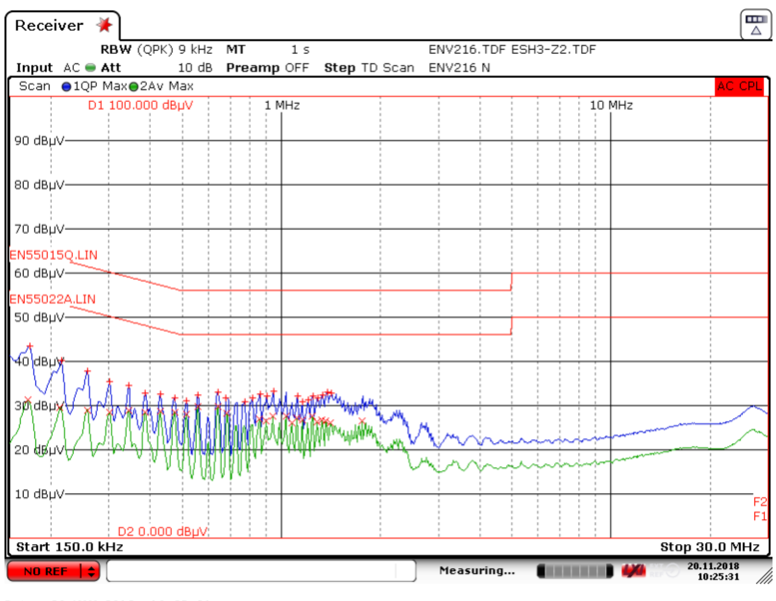

Figure 129 – Earth Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.3.2 *Output: 9 V / 3 A*

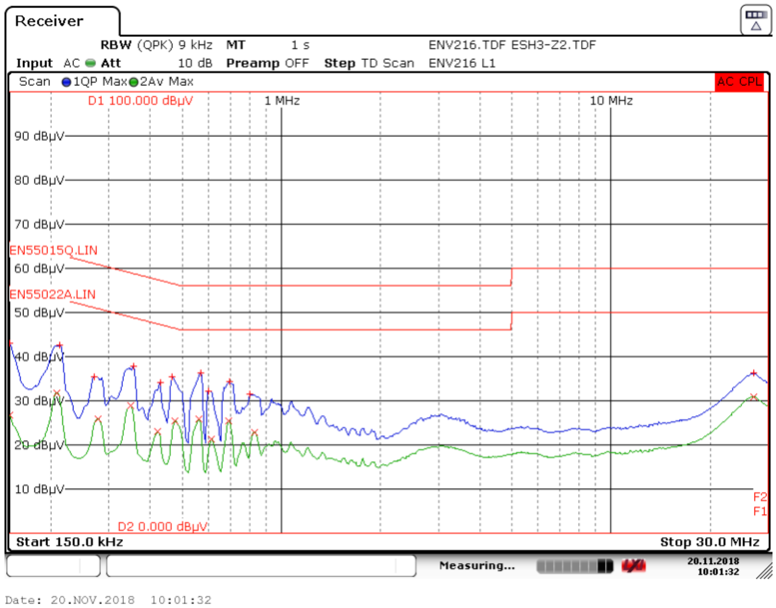

Figure 130 – Earth Ground EMI, 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

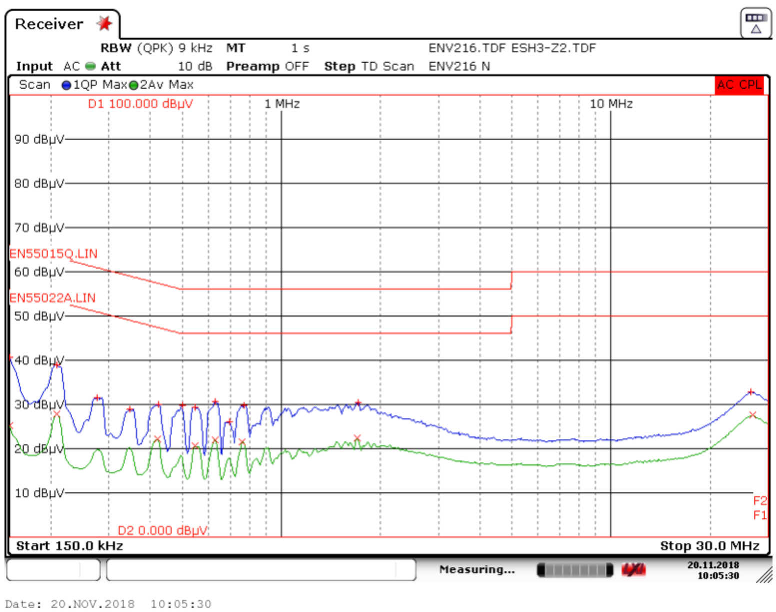

Figure 131 – Earth Ground EMI, 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

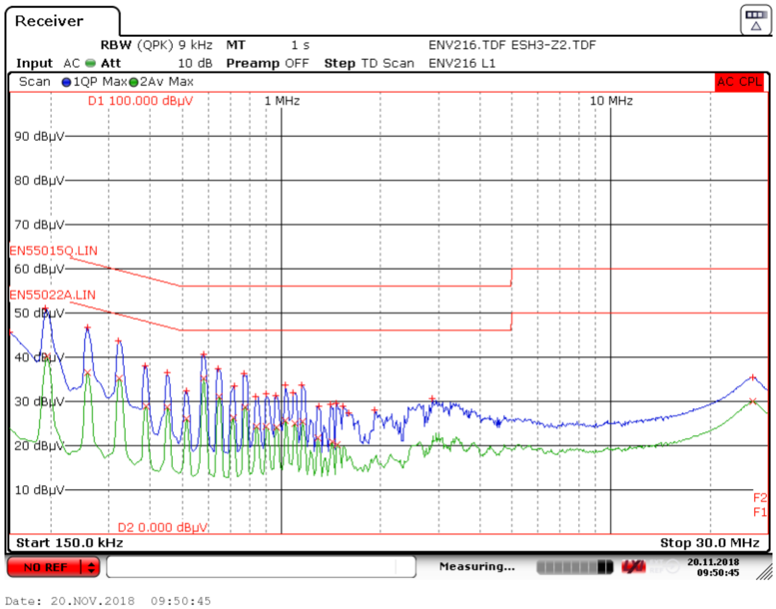

Figure 132 – Earth Ground EMI, 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

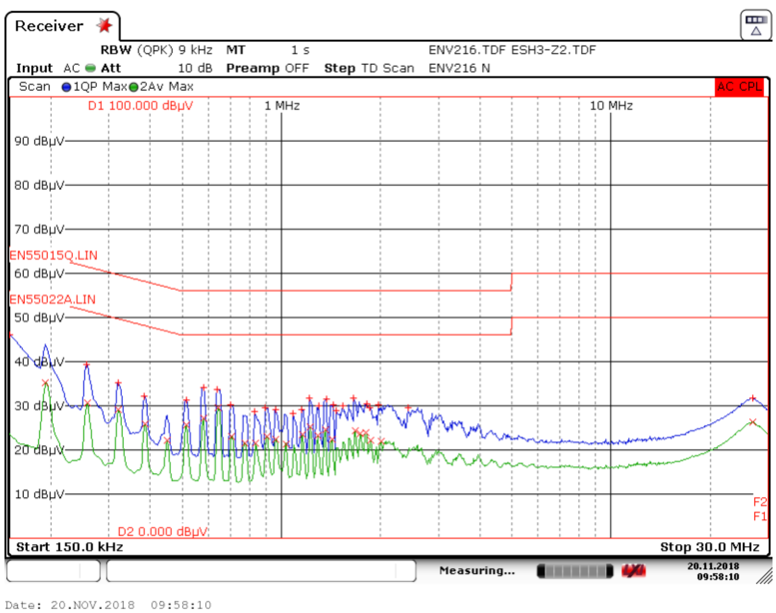

Figure 133 – Earth Ground EMI, 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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17.3.3 *Output: 11 V / 2.45 A*

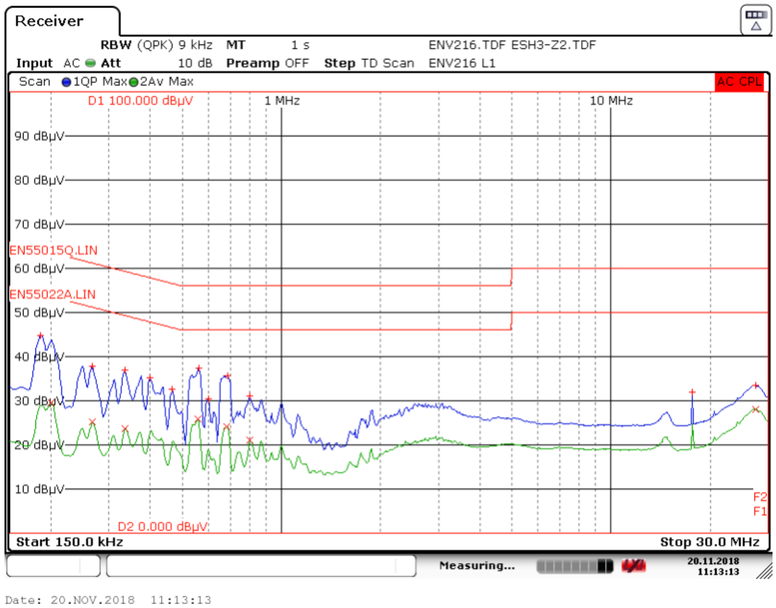

Figure 134 – Earth Ground EMI, 11 V / 2.45 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

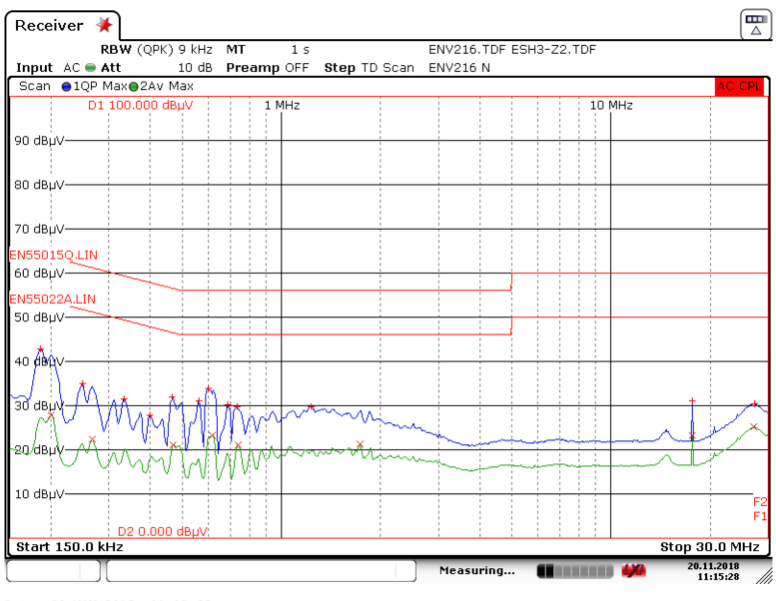

Figure 135 – Earth Ground EMI, 11 V / 2.45 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

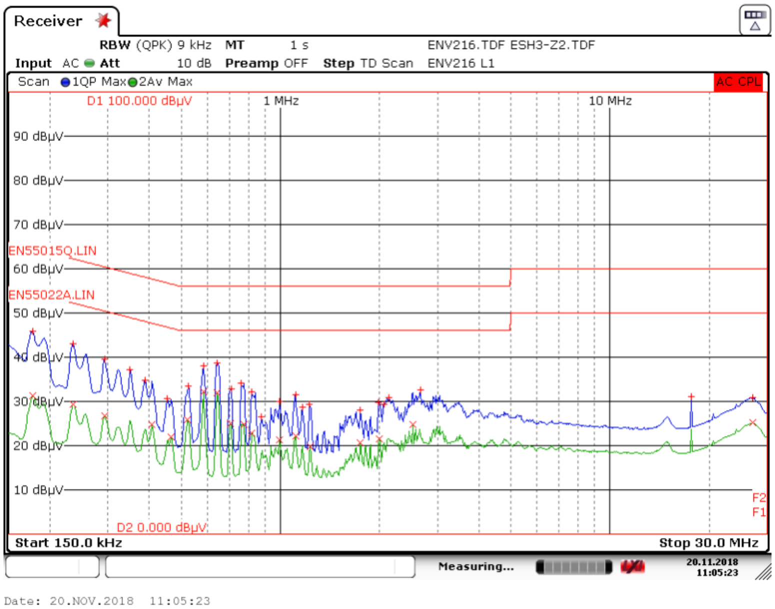

Figure 136 – Earth Ground EMI, 11 V / 2.45 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

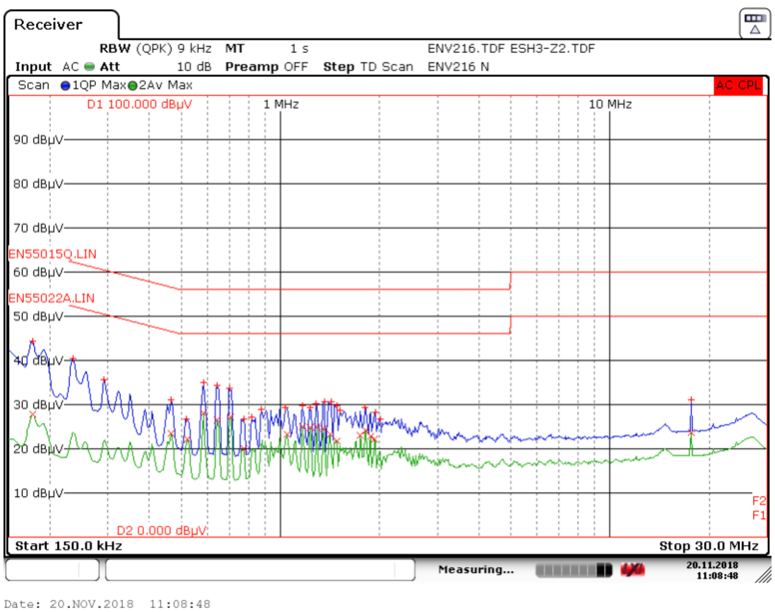

Figure 137 – Earth Ground EMI, 11 V / 2.45 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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18 Combination Wave Surge

The unit was subjected to ±1000 V differential mode and ±2000 V common mode combination wave surge at several line phase angles with 10 strikes for each condition.

A test failure was defined as a temporary interruption of output, even if it is self-recoverable or needs operator intervention to recover, or a complete loss of function which is not recoverable.

18.1 Differential Mode Surge (L1 to L2), 230 VAC Input

Surge Level (V)	Injection Phase (°)	Test Result 5 V / 3 A	Test Result 9 V / 3 A
+1000	0	Pass	Pass
-1000	0	Pass	Pass
+1000	90	(Auto-Restart)	Pass
-1000	90	Pass	Pass
+1000	180	Pass	Pass
-1000	180	Pass	Pass
+1000	270	Pass	Pass
-1000	270	(Auto-Restart)	Pass

Note: Auto-Restart (AR) is one of the safety features of InnoSwitch3-Pro which protects the converter during fault conditions such as increased voltage across the input bulk capacitor due to surge. For applications that require completely no output interruption, a varistor must be added at the input stage of the design.

18.2 Common Mode Surge (L1 to PE), 230 VAC input

Surge Level (V)	Injection Phase (°)	Test Result 5 V / 3 A	Test Result 9 V / 3 A
+2000	0	Pass	Pass
-2000	0	Pass	Pass
+2000	90	Pass	Pass
-2000	90	Pass	Pass
+2000	180	Pass	Pass
-2000	180	Pass	Pass
+2000	270	Pass	Pass
-2000	270	Pass	Pass

18.3 Common Mode Surge (L2 to PE), 230 VAC Input

Surge Level (V)	Injection Phase (°)	Test Result 5 V / 3 A	Test Result 9 V / 3 A
+2000	0	Pass	Pass
-2000	0	Pass	Pass
+2000	90	Pass	Pass
-2000	90	Pass	Pass
+2000	180	Pass	Pass
-2000	180	Pass	Pass
+2000	270	Pass	Pass
-2000	270	Pass	Pass

18.4 Common Mode Surge (L1, L2 to PE), 230 VAC Input

Surge Level (V)	Injection Phase (°)	Test Result 5 V / 3 A	Test Result 9 V / 3 A
+2000	0	Pass	Pass
-2000	0	Pass	Pass
+2000	90	Pass	Pass
-2000	90	Pass	Pass
+2000	180	Pass	Pass
-2000	180	Pass	Pass
+2000	270	Pass	Pass
-2000	270	Pass	Pass

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19 Electrostatic Discharge

The unit was tested with ±8.8 kV contact discharge and ±8 kV to ±16.5 kV air discharge to the USB receptacle on the board with 10 strikes for each condition. After each strike, the discharge location is discharged to Earth with two 470 kΩ resistors in series.

A test failure was defined as a temporary interruption of output, even if it is self-recoverable or needs operator intervention to recover, or a complete loss of function which is not recoverable.

19.1 Contact Discharge: On-board USB Receptacle, 230 VAC Input

Discharge Voltage (kV)	Number of Strikes	Test Result 5 V / 3 A	Test Result 9 V / 3 A
+8.8	10	Pass	Pass
-8.8	10	Pass	Pass

19.2 Air Discharge: On-board USB Receptacle, 230 VAC Input

Discharge Voltage (kV)	Number of Strikes	Test Result 5 V / 3 A	Test Result 9 V / 3 A
+8	10	Pass	Pass
-8	10	Pass	Pass
+10	10	Pass	Pass
-10	10	Pass	Pass
+12	10	Pass	Pass
-12	10	Pass	Pass
+14	10	Pass	Pass
-14	10	Pass	Pass
+16.5	10	Pass	Pass
-16.5	10	Pass	Pass

20 Revision History

Date	Author	Revision	Description & Changes	Reviewed
29-Apr-19	DB	1.0	Initial Release.	Apps & Mktg
17-Sep-19	KM	1.1	Updated BOM and Added Case Details.	Apps & Mktg
29-Oct-19	KM	1.2	Converted to RDR.	Apps & Mktg

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