Design Example Report

Title	***60 W USB PD 3.0 Power Supply with 3.3 V – 21 V PPS Output Using InnoSwitch™ 3-Pro GaN-based INN3379C-H302 and VIA Labs VP302 Controller***
Specification	90 VAC – 265 VAC Input; 5 V / 3 A; 9 V / 3 A; 15 V / 3 A; 20 V / 3 A; or 3.3 V – 21 V PPS Outputs
Application	Mobile Phone Charger
Author	Applications Engineering Department
Document Number	DER-803
Date	July 24, 2019
Revision	1.0

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
- Compact design with high power density using GaN switch: 12.0 W / inch^3 with enclosure

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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 60 W USB PD power supply with 5 V / 3 A, 9 V / 3 A, 15 V / 3 A, 20 V / 3 A, or 3.3 V – 21 V Programmable Power Supply (PPS) output using InnoSwitch3-Pro INN3379C-H302 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.

The report contains the power supply specification, schematic diagram, printed circuit board layout, bill of materials, magnetics and adapter case specifications, and performance data.

Figure 1 – Populated Circuit Board Photograph, Entire Assembly.

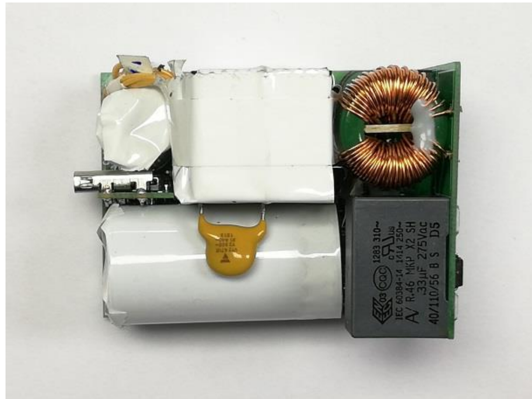

Figure 2 – Populated Circuit Board Photograph - Top.

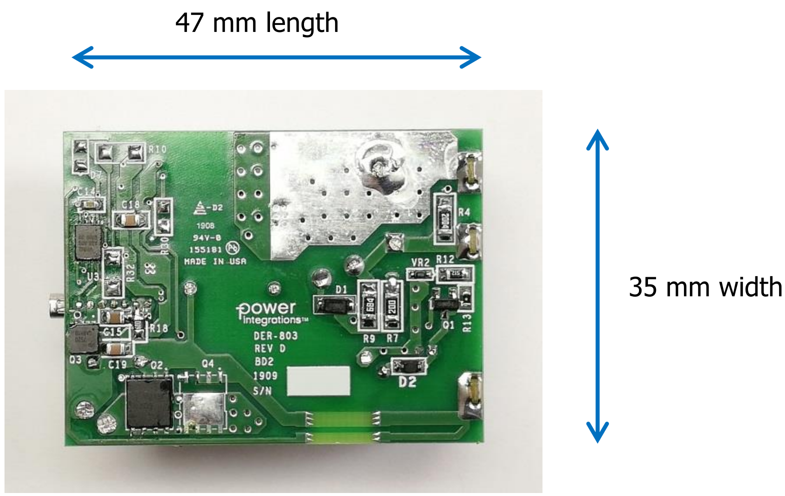

Figure 3 – Populated Circuit Board Photograph - Bottom.

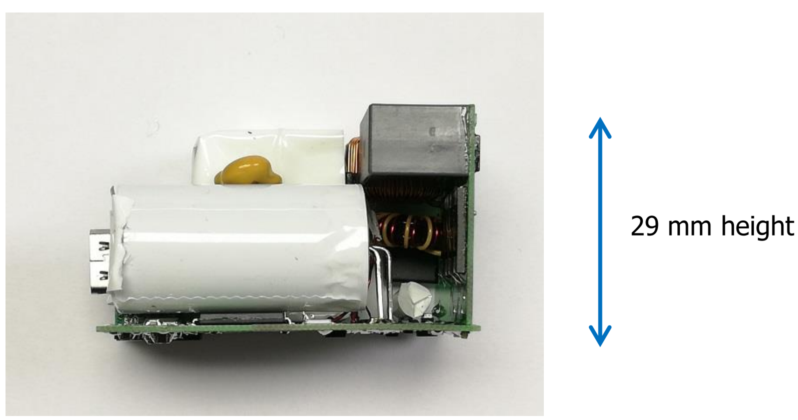

Figure 4 – Populated Circuit Board Photograph - Side.

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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}	90		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power				40	mW	Measured at 230 VAC.
5 V Setting						
Output Voltage	$V_{OUT\ (5\ V)}$		5.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(5\ V)}$			300	mV	Measured at End of 100 mΩ Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(5\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(5\ V)}$		>91		%	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	$V_{RIPPLE(9\ V)}$			250	mV	Measured at End of 100 mΩ Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(9\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(9\ V)}$		>92		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(9\ V)}$			27	W	
15 V Setting						
Output Voltage	$V_{OUT(15\ V)}$		15.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(15\ V)}$			250	mV	Measured at End of 100 mΩ Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(15\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(15\ V)}$		>92		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(15\ V)}$			45	W	
20 V Setting						
Output Voltage	$V_{OUT(20\ V)}$		20.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(20\ V)}$			250	mV	Measured at End of 100 mΩ Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(20\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(20\ V)}$		>92		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(20\ V)}$			60	W	
3.3 – 21 V PPS Setting						
Maximum Programmable Output Voltage	$V_{OUT(MAX)}$			21	V	APDO Maximum Voltage.
Minimum Programmable Output Voltage	$V_{OUT(MIN)}$	3.3			V	APDO Minimum Voltage.
Output Voltage Ripple	$V_{RIPPLE(PPS)}$			400	mV	Measured at End of 100 mΩ Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(PPS)}$			3.0	A	±3%
PPS Voltage Step	$V_{STEP(PPS)}$		20		mV	PPS Voltage Step (USB PD 3.0).
PPS Current Step	$I_{STEP(PPS)}$		50		mA	PPS Current Step (USB PD 3.0).
Continuous Output Power	$P_{OUT(20\ V)}$			60	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.

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3 Schematic

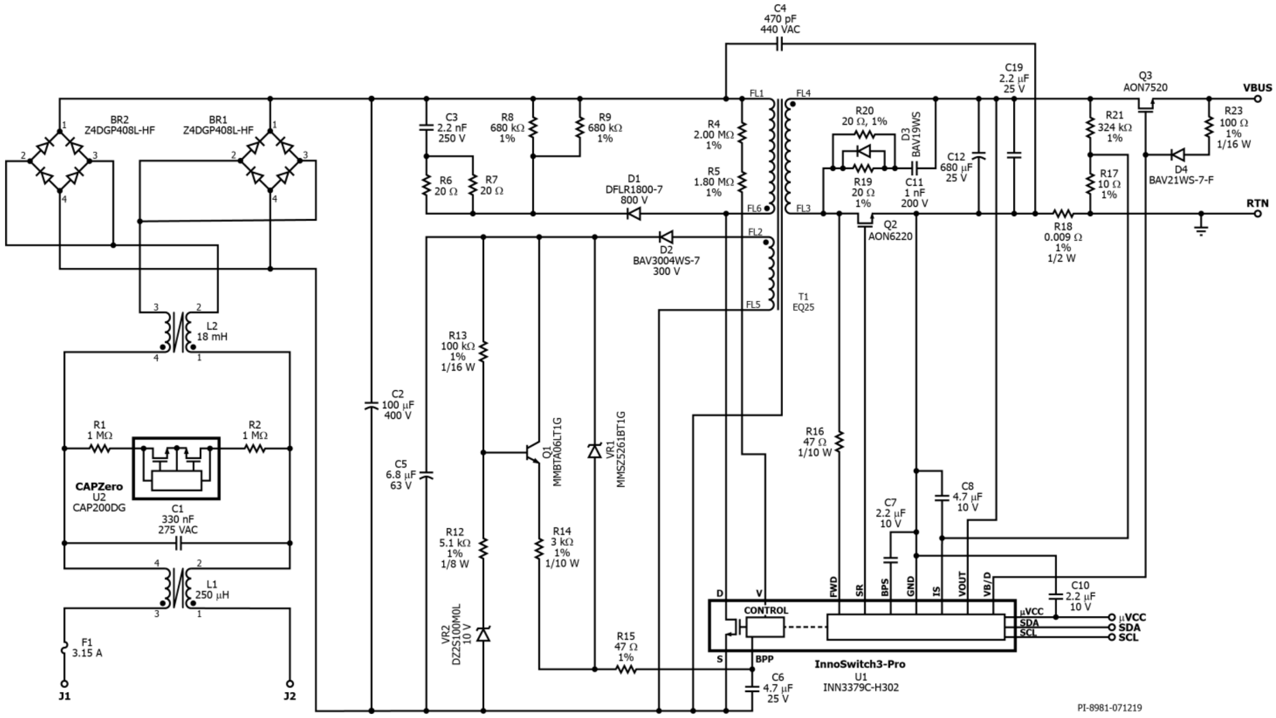

Figure 5 – Schematic, Power Section.

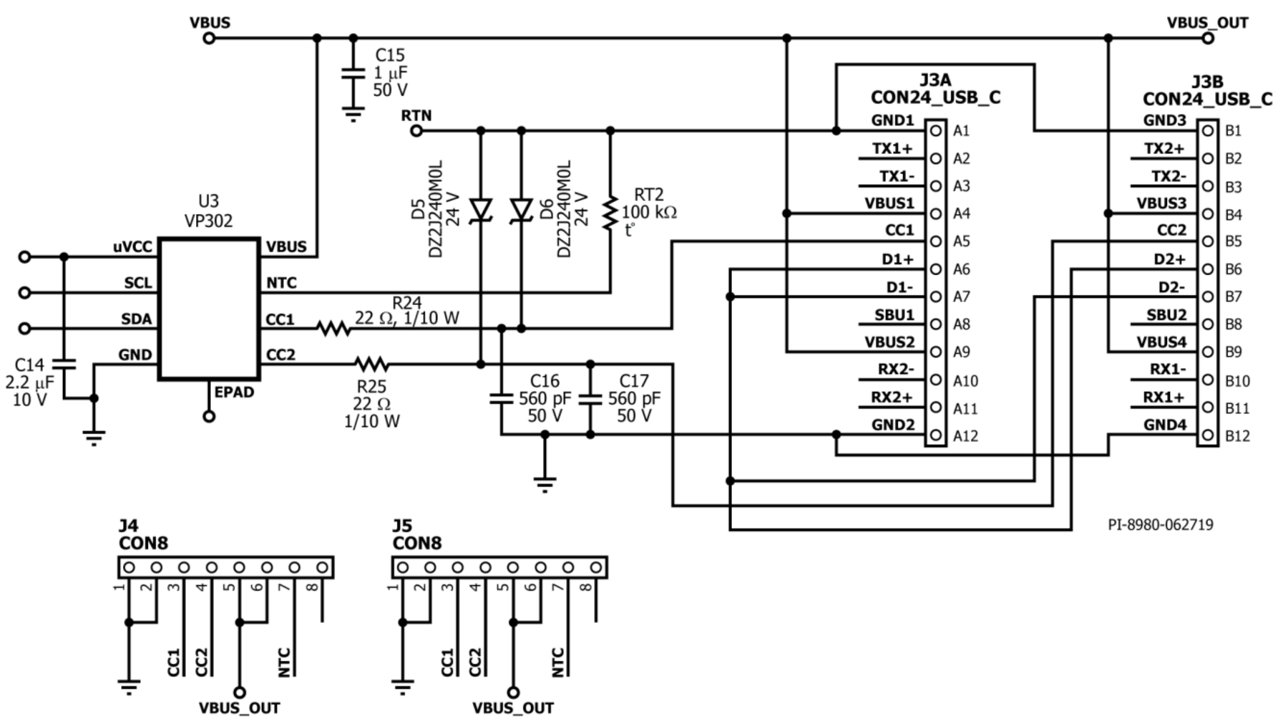

Figure 6 – Schematic, USB PD Controller Section.

4 Circuit Description

4.1 *Input Rectifier and EMI Filter*

Fuse F1 isolates the circuit and provides protection from component failure. Common mode chokes L1 and L2, with capacitors C1 and C4 provide common mode and differential mode noise filtering for EMI attenuation. Bridge rectifier formed by BR1 and BR2 rectifies the AC line voltage and provides a full wave rectified DC across C2.

Resistors R1 and R2 along with CapZero-2 IC U2 discharges capacitor C1 when the power supply is disconnected from AC mains.

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 switch inside the InnoSwitch3-Pro IC U1. Resistors R4 and R5 provide input voltage sensing for protection in case of AC input undervoltage or overvoltage.

A low-cost RCD clamp formed by diode D1, resistors R6, R7, R8, and R9, and capacitor C3 limits the peak drain-source voltage of U1 at the instant the switch 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 C6 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 C5. Resistor R14 limits the current being supplied to the BPP pin of the InnoSwitch3-Pro IC U1. A linear regulator comprising resistor R13, R12, BJT Q1 and Zener diode VR2 ensures sufficient current flows through R14 such that the internal current source of U1 is not required to charge C6 during normal operation.

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 overvoltage 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 U1. 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 R15 limits the current injected to BPP pin during output overvoltage protection event.

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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 FET for synchronous rectification. The voltage across the transformer secondary winding is rectified by the secondary-side FET (or SR FET) Q2 and filtered by capacitor C12. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via a RCD snubber, R19, R20, C11, and D3.

The gate of Q2 is turned on by secondary-side controller inside IC U1, based on the secondary winding voltage sensed via resistor R16 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 switch avoids any possibility of cross conduction of the two switches 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 C7 connected to the BPS pin of InnoSwitch3-Pro IC U1 provides decoupling for the internal circuitry.

The output current is sensed by monitoring the voltage drop across resistor R18. Resistors R17 and R21 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 C8 and monitored across the IS and SECONDARY GROUND pins. An internal current sense threshold which is configured via the I^2C interface up to approximately 32 mV is used to reduce losses. Once the threshold is exceeded, the InnoSwitch3-Pro IC U1 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 U1 will power itself from the secondary winding directly. During the on-time of the primary-side power switch, the forward voltage that appears across the secondary winding is used to charge the SECONDARY BYPASS pin decoupling capacitor C7 via resistor R16 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 IC U1 regulates the output voltage by controlling the number of switch pulses. Capacitor C18 is needed between the VOUT pin and the SECONDARY GROUND pin for ESD protection of the VOUT pin.

N-channel 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 R23 and diode D4 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. Capacitors C15 and C19 are used at the output for ESD protection.

In this design, VP302 (U3) 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.

VP302 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.

Capacitors C10 and C14 provide decoupling to the μVCC of the InnoSwitch3-Pro IC and VCC of the VP302 IC. Capacitors C16 and C17, resistors R24 and R25, and TVS diodes D5, and D6 provide protection from ESD to pins CC1 and CC2.

Thermistor RT2 is connected to 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 C15 when the bus switch Q3 is opened.

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5 PCB Layout

PCB copper thickness is 0.062 inches.

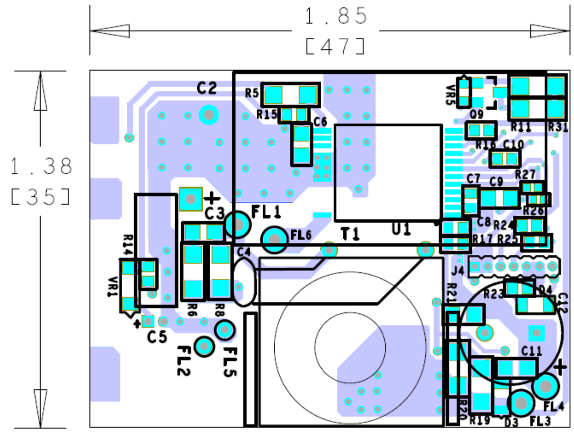

Figure 7 – Motherboard Printed Circuit Layout, Top.

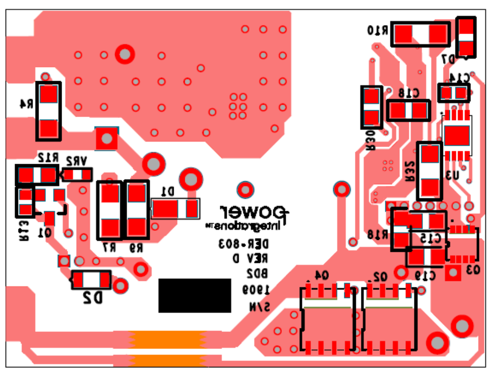

Figure 8 – Motherboard Printed Circuit Layout, Bottom.

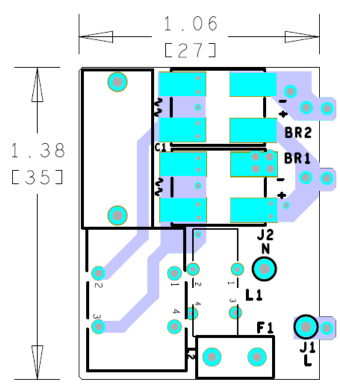

Figure 9 – Input Section Daughterboard Printed Circuit Layout, Top.

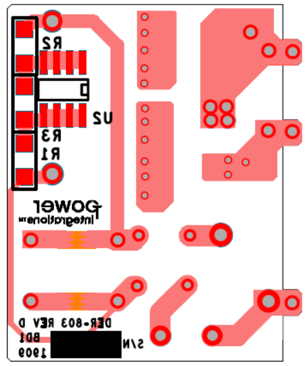

Figure 10 – Input Section Daughterboard Printed Circuit Layout, Bottom.

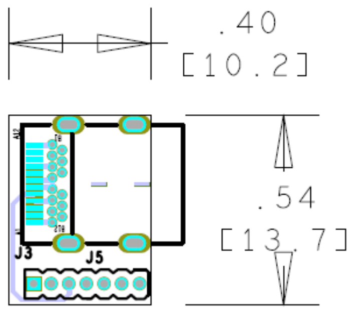

Figure 11 – USB Type-C Daughterboard Printed Circuit Layout, Top.

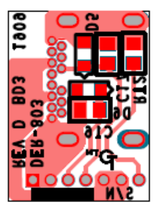

Figure 12 – USB Type-C Daughterboard Printed Circuit Layout, Bottom.

Note:
Component references R3, R10, R11, R26, R27, R30, R31, R32, C9, D7, Q4, Q9, VR5, and J4, although present in the layout, should not be populated.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	2	BR1 BR2	RECT BRIDGE, GP, 800V, 4A, Z4-D	Z4DGP408L-HF	Comchip
2	1	C1	330 nF, 275 VAC, Film, X2	R46KI333000N1M	Kemet
3	1	C2	100 μF, 400 V, Electrolytic, Low ESR, (16 x 30)	EPAG401ELL101ML30S	Nippon Chemi-Con
4	1	C3	2.2 nF, 250 V, Ceramic, X7R, 0805	C2012X7R2E222K085AA	TDK
5	1	C4	470 pF, ±10%, 440VAC, (X1, Y2) rated, Ceramic Capacitor, Y5S, Radial, Disc, -40°C ~ 125°C	VY2471K29Y5SS63V7	Vishay
6	1	C5	6.8 μF, ±20%, 63 V, Electrolytic, Gen Purpose, (4 mm x 11 mm)	UPW1J6R8MDD6	Nichicon
7	1	C6	4.7 μF, ±10%, 25 V, Ceramic, X7R, -55°C ~ 125°C, 0805	TMK212AB7475KG-T	Taiyo Yuden
8	3	C7 C10 C14	2.2 μF, 10 V, Ceramic, X7R, 0603	GRM188R71A225KE15D	Murata
9	1	C8	4.7 μF, 10 V, Ceramic, X5R, 0603	C1608X5R1A475M/0.50	TDK
10	1	C19	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
11	1	C11	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
12	1	C12	680 μF, ±20%, 25V, Aluminum Polymer Capacitor Radial, Can, 292.56 mΩ, 1500 Hrs @ 125°C, (10 x 13.5)	687AVG025MGBJ	Illinois Capacitor
13	1	C15	1 μF, 50 V, Ceramic, X5R, 0805	08055D105KAT2A	AVX
14	2	C16 C17	560 pF, 50V, Ceramic, X7R, 0603, 0.063" L x 0.031" W (1.60 mm x 0.80 mm)	CL10B561KB8NNNC	Samsung
15	1	D1	800 V, 1 A, Fast Recovery Rectifier, POWERDI123	DFLF1800-7	Diodes, Inc.
16	1	D2	DIODE, GEN PURP, FAST RECOVERY, 300 V, 225 mA, SOD323	BAV3004WS-7	Diodes, Inc.
17	1	D3	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
18	1	D4	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
19	2	D5 D6	DIODE, ZENER, 24V, 200 mW, SC-90, SOD-323F, SMini2-F5-B	DZ2J240M0L	Panasonic
20	1	F1	3.15 A, 250 V, Slow, RST	507-1181	Belfuse
21	1	J3	Connector, "Certified", USB - C, USB 3.1, For 0.062" PCB Material, Superspeed+, Receptacle Connector, 24 Position, SMT, Right Angle, TH	632723300011	Wurth
22	2	J5	8 Position (1 x 8) header, 0.050" (1.27 mm) pitch, Gold, R/A	M50-3930842	Harwin Inc.
23	1	L1	250 μH, Toroidal Common Mode Choke, custom, DER-538, wound on 32-00275-00 core.	32-00367-00	Power Integrations
24	1	L2	Custom, CMC, 18 mH @ 10 kHz, Toroidal, 17.5 mm OD x 11.0 mm thick. 40 turns x 2, 0.40 mm wire 190 mΩ max	04291-T231	Sumida
25	1	Q1	NPN, Small Signal BJT, 80 V, 0.5 A, SOT-23	MMBTA06LT1G	On Semi
26	1	Q2	MOSFET, N-CH, 100V, 48A (Tc), 113.5W (Tc), DFN5X6, 8-DFN (5x6)	AON6220	Alpha & Omega Semi
27	1	Q3	MOSFET, N-CH, 30V, 21A, 8-DFN-EP (3.3x3.3),8-PowerWDFN	AON7520	Alpha & Omega Semi
28	2	R1-R2	RES, 1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
29	1	R4	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
30	1	R5	RES, 1.80 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1804V	Panasonic
31	2	R6 R7	RES, 20 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ200V	Panasonic
32	2	R8 R9	RES, 680 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ684V	Panasonic
33	1	R12	RES, 5.1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ512V	Panasonic
34	1	R13	RES, 100 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
35	1	R14	RES, 3 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ302V	Panasonic
36	2	R15 R16	RES, 47 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470V	Panasonic
37	1	R17	RES, 10 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF10R0V	Panasonic
38	1	R18	RES, 0.009 Ω, ±1%, 0.5 W, 0805, Automotive AEC-Q200, Current Sense, Moisture Resistant, Metal	CRF0805-FZ-R009ELF	Bourns

			Element		
39	2	R19 R20	RES, 20 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF20R0V	Panasonic
40	1	R21	RES, 324 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF3243V	Panasonic
41	1	R23	RES, 100 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1000V	Panasonic
42	2	R24 R25	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
43	1	RT2	NTC Thermistor, 100 kΩ, 3%, 0603	NCP18WF104E03RB	Murata
44	1	T1	Bobbin, EQ25, 4 pins, 4pri, 0sec	TBI-235-01091.1206	TBI Transformer Bobbin Industrial Co, LTD tbi-tw.com
45	1	U1	InnoSwitch3-Pro, InSOP24D	INN3379C-H302	Power Integrations
46	1	U2	CAPZero-2, SO-8C	CAP200DG	Power Integrations
47	1	U3	IC, USB PD Type-C Controller for SMPS, DFN-8	VP302	VIA Labs
48	1	VR1	DIODE ZENER 47 V 500 mW SOD123	MMSZ5261BT1G	ON Semi
49	1	VR2	10 V, 5%, 150 mW, SSMINI-2	DZ2S100M0L	Panasonic

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7 Transformer Specification

7.1 *Electrical Diagram*

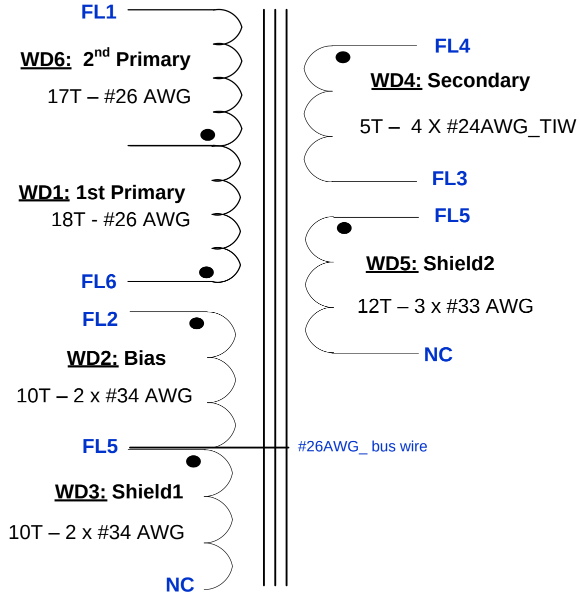

Figure 13 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between FL1 and FL6, with all other windings open.	515 μH± 5%
Resonant Frequency	Between pin FL1 and FL6, other windings open.	1,500 kHz (min.)
Primary Leakage Inductance	Between pin FL1 and FL6, with shorted FL3 and FL4.	4.5 μH (max.)

7.3 *Material List*

Item	Description
[1]	Core: EQ25-3C95, Ferroxcube.
[2]	Bobbin: EQ25-Vertical, 4pins (4/0), PI custom, P/N: 25-01141-00.
[3]	Magnet wire: **#**26 AWG, double coated.
[4]	Magnet wire: **#**34 AWG, double coated.
[5]	Magnet wire: **#**33 AWG, double coated.
[6]	Magnet wire: #24 AWG, Triple Insulated Wire.
[7]	Bus wire: #26AWG, Alpha wire, tinned copper.
[8]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 8.2mm width.
[9]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 30 mm x 55mm.
[10]	Glue: Loctite, 409, Gel, Mf #:40904; or equivalent.
[11]	Epoxy: Devcon, 5 mins Epoxy, Mfr#: 14270; or equivalent.
[12]	Varnish: Dolph BC-359.

7.4 *Transformer Build Diagram*

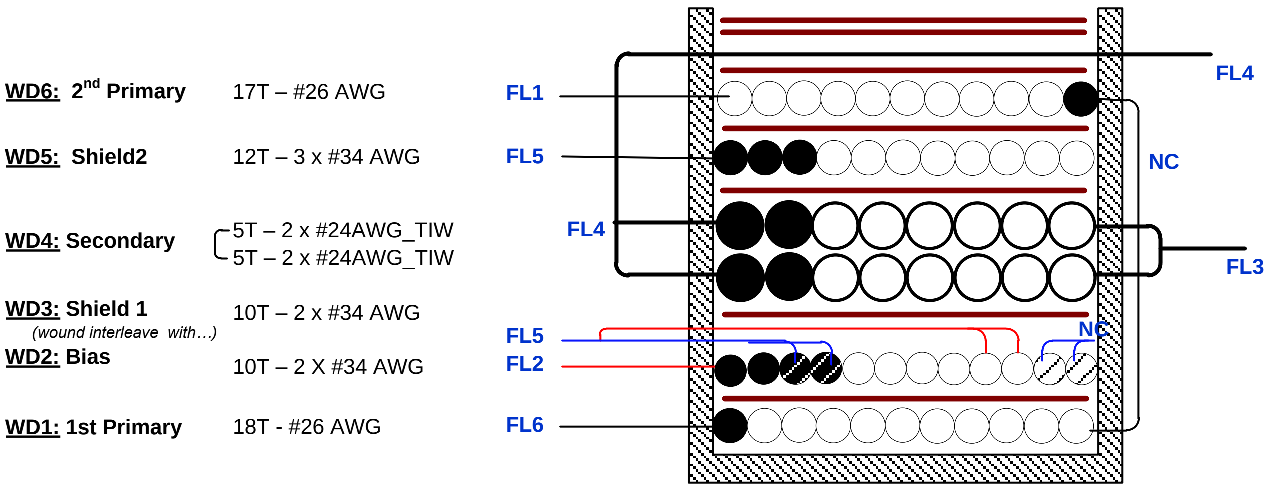

Figure 14 – Transformer Build Diagram.

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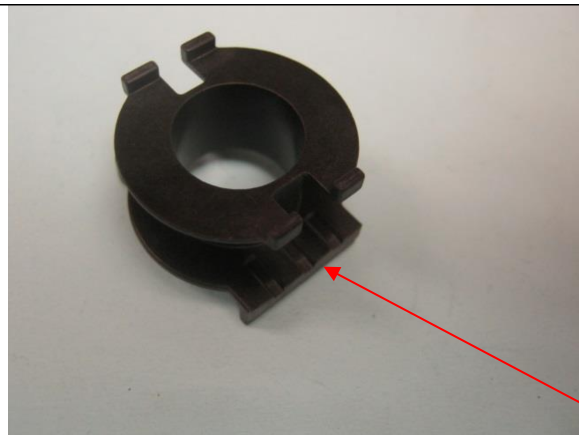
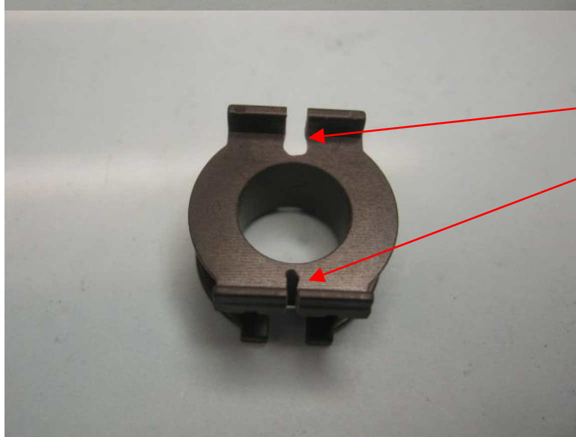
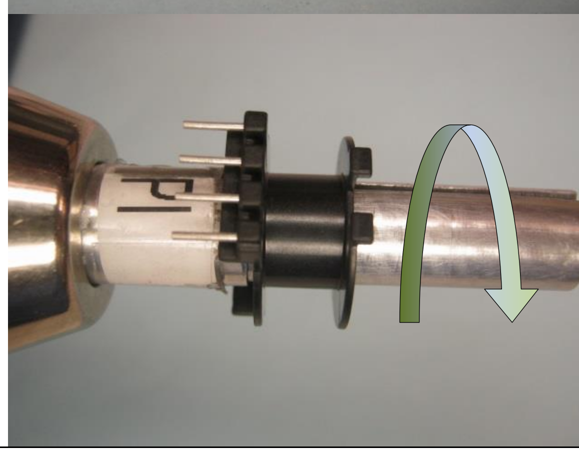
7.5 *Transformer Construction*

Winding Preparation	Remove all 4 primary pins and cut the flange to match top flange. Make slot with 3.0 mm width on bottom secondary flange and slot 1.0mm width on bottom primary flange of the bobbin Item [2]. Position the bobbin Item [2] 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 as FL6, leave ~1" floating, wind 18 turns of wire Item [3] in 1 layer, with tight tension, from left to right. At the last turn, leave on the right of bobbin enough length of wire-floating for WD6-2nd Primary.
Insulation	1 layer of tape Item [8].
WD2: Bias & WD3: Shield1	Use 2 wires Item [4] start at as FL2, leave ~1" floating for Bias winding, also use 2 wires same Item [4] start as FL5, leave ~1" floating for Shield1 winding. Wind all 4 wires in parallel, at the 10th turn: - bring 2 wires for Bias winding to the left and end as FL5 and leave 1" floating, - cut short 2 wires for Shield1 Winding as No-Connect.
Insulation	1 layer of tape Item [8].
WD4 Secondary	Start at left slot of secondary side, use 2 wires Item [6], leaving ~40.0 mm floating, and mark as FL4.Wind 5 bifilar turns in 1 layer, from left to right, at the last turn exit the wires at right slot, also leaving ~30.0 mm floating, and mark FL3. Repeat the same winding above on top previous winding, also mark start and finish ends as FL4 and FL3.
Insulation	1 layer of tape Item [8].
WD5 Shield2	Start as FL5, use of wire Item [5], leave ~1" floating, wind 12 tri-filar turns, from left to right. At the last turn, cut short to leave as No-Connect.
Insulation	1 layer of tape Item [8].
WD6 2nd Primary	Use floating wire from WD1-1st Primary, wind 17 turns from right to left and finish at pin FL1.
Insulation	1 layer of tape Item [8]. Bring 4 wires marked as FL4 to the right and secure with 2 layers of` tape Item [8].
Finish Assembly	Gap cores to get 515 μH. Apply glue Item [10] at center legs of cores. Place bus wire Item [7] along the cores which also is FL5 and secure with tape. Apply epoxy Item [11] between cores to body of the transformer. Varnish with Item [12]. Place 2 layers of tape Item [9] at the bottom then wrap up to the body of transformer. Wrap 2 layers of tape Item [9] with 35 mm long at the right side of transformer and tape around 1turn of tape Item [7]. (*See pictures below).*

7.6 *Winding Illustrations*

Winding Preparation	  	Make slot with 3.0mm width on bottom secondary flange of the bobbin Item [2]. Remove all 4 primary pins and cut the flange to match top flange, (see picture beside. This step can be done in finish assembly). Position the bobbin Item [2] 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.

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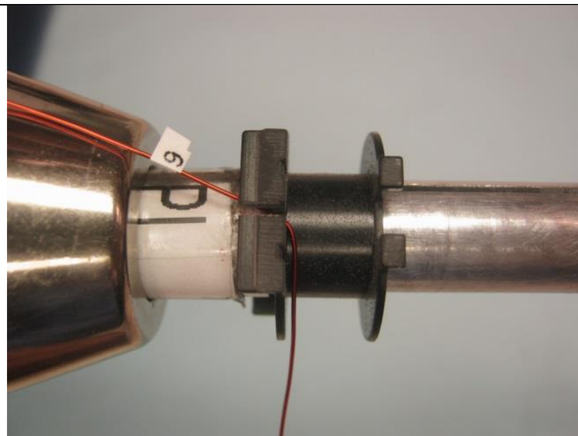
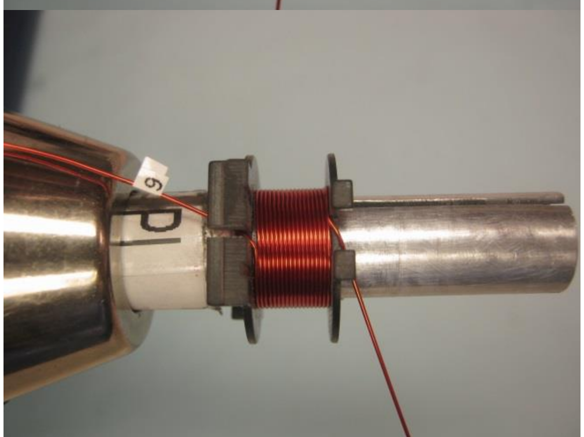
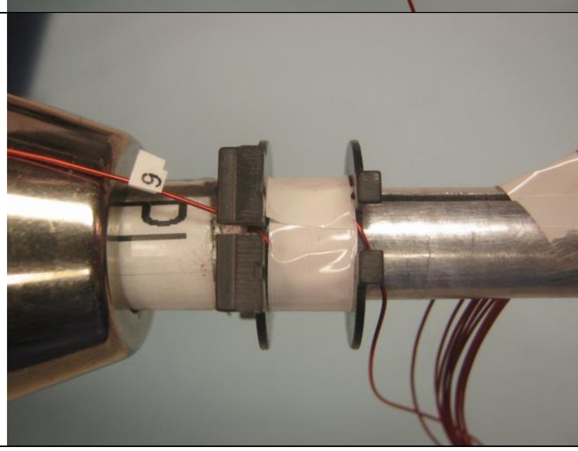
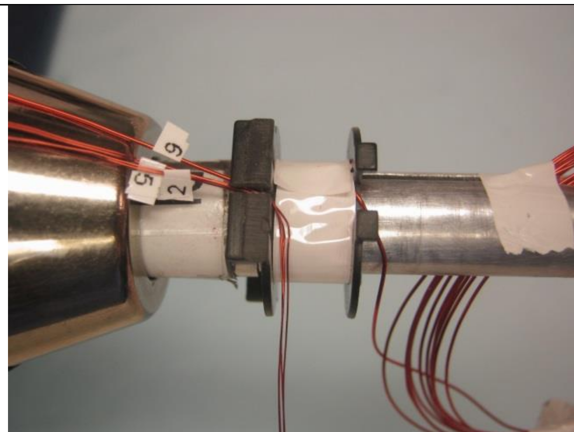
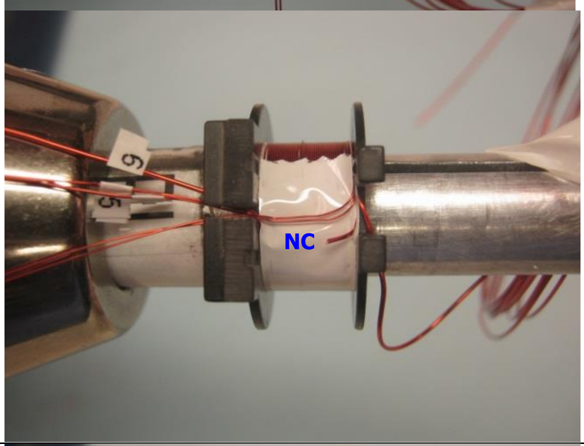
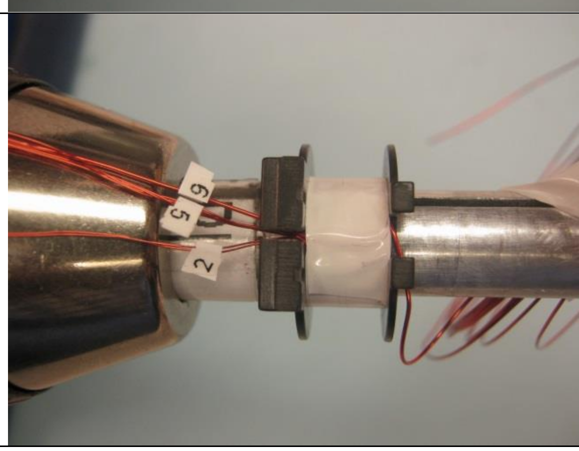
WD1 **1st Primary**	 	Start as FL6, leave ~1" floating, wind 18 turns of wire Item [3] in 1 layer, with tight tension, from left to right. At the last turn, leave on the right of bobbin enough length of wire-floating for WD6-2nd Primary.
Insulation		1 layer of tape Item [7].

WD2: Bias & WD3: Shield 1	 	Use 2 wires Item [4] start at as FL2, leave ~1" floating for Bias winding, also use 2 wires same Item [4] start as FL5, leave ~1" floating for Shield1 winding. Wind all 4 wires in parallel, at the 10th turn: - bring 2 wires for Bias winding to the left and end as FL5 and leave 1" floating, - cut short 2 wires for Shield1 Winding as No-Connect.
Insulation		1 layer of tape Item [7].

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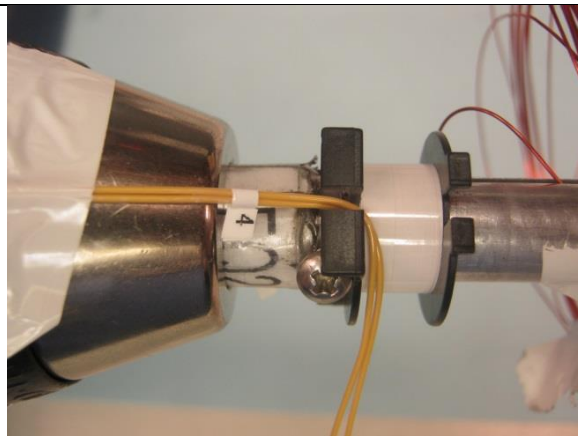
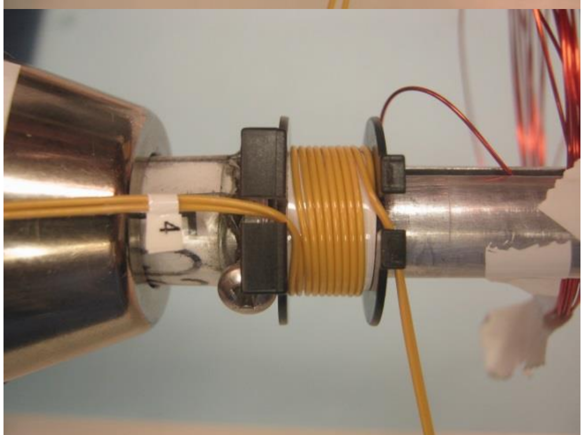
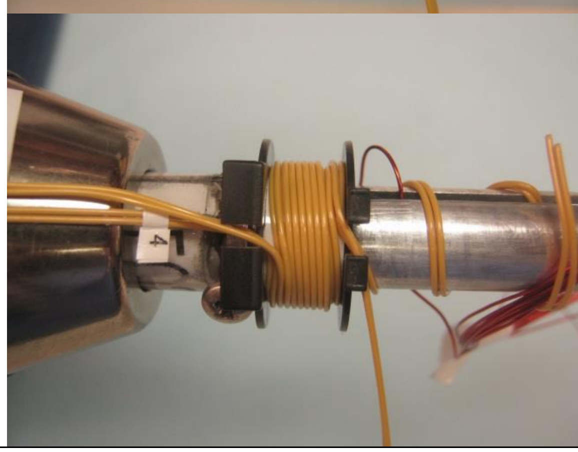
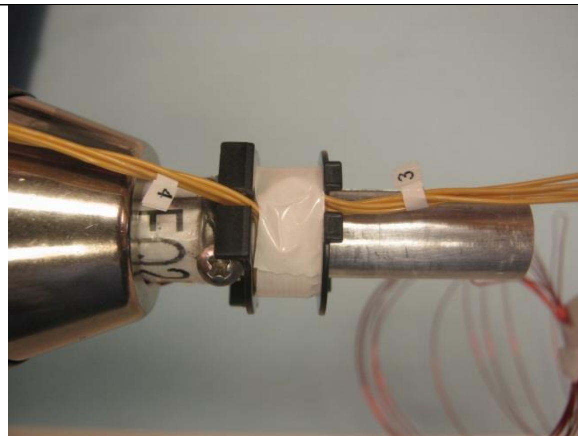
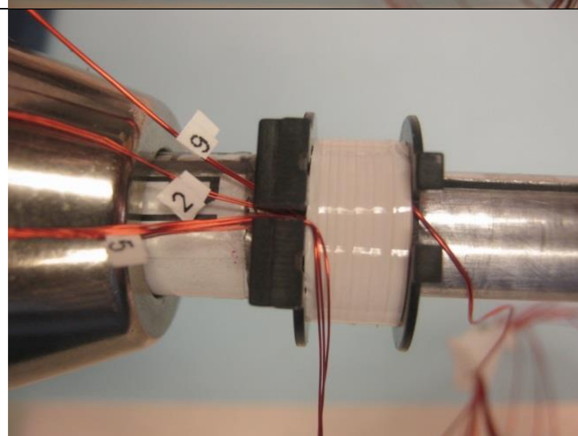
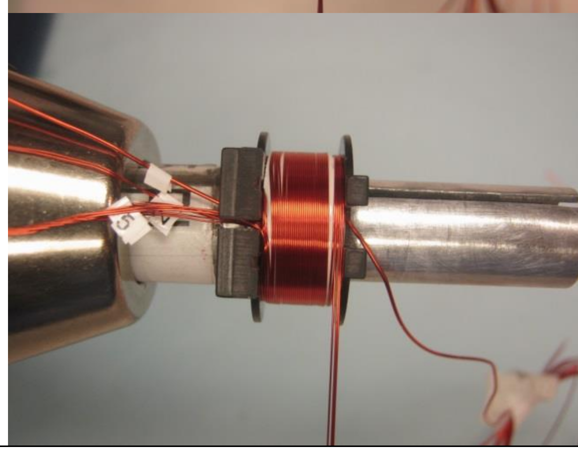
WD4 **Secondary**	  	Start at left slot of secondary side, use 2 wires Item [5], leaving ~40.0 mm floating, and mark as FL4.Wind 5 bifilar turns in 1 layer, from left to right, at the last turn exit the wires at right slot, also leaving ~30.0 mm floating, and mark FL3. Repeat the same winding above on top previous winding, also mark start and finish ends as FL4 and FL3.

Insulation		1 layer of tape Item [7].
WD5 Shield2	 	Start as FL5, use of wire Item [4], leave ~1" floating, wind 14 tri-filar turns, from left to right. At the last turn, cut short to leave as No-Connect.

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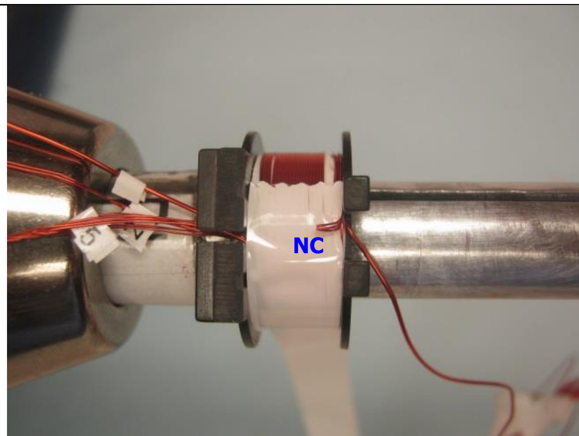
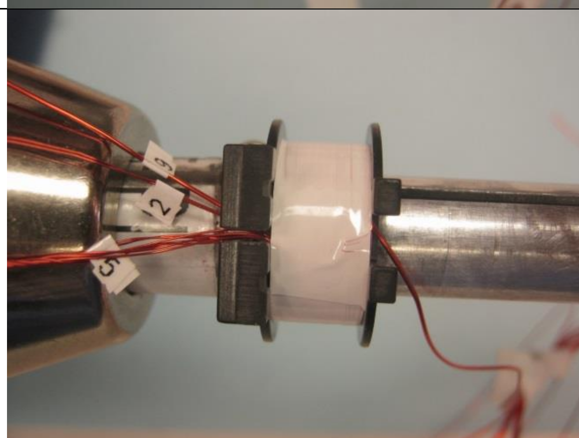
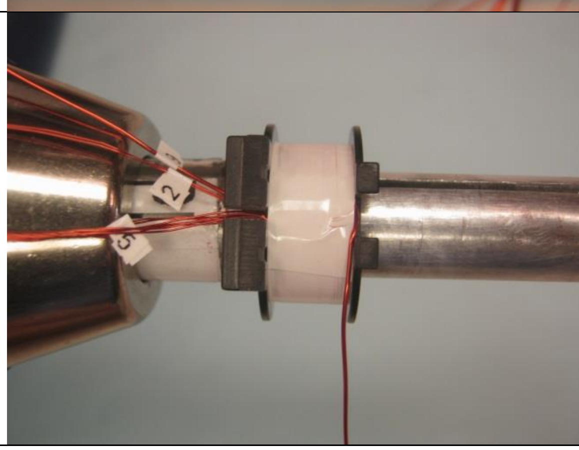
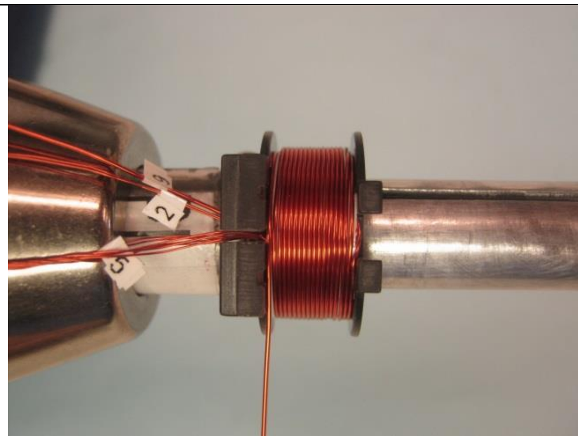
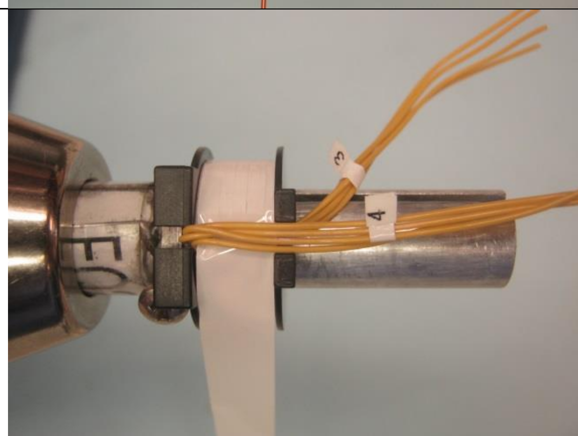
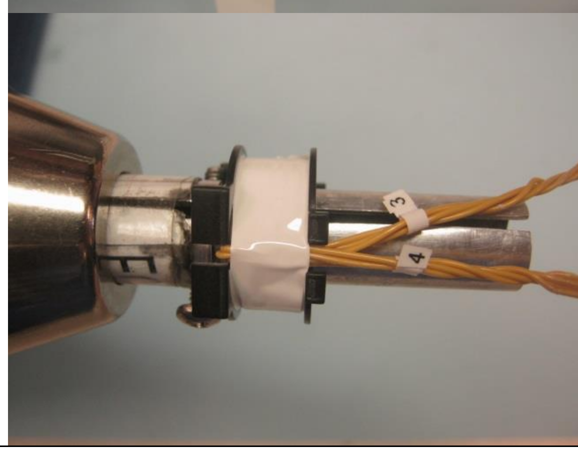
		
Insulation		1 layer of tape Item [7].
WD6 **2nd Primary**		Use floating wire from WD1-1st Primary, wind 17 turns from right to left and finish at pin FL1.

		
Insulation	 	1 layer of tape Item [7]. Bring 4 wires marked as FL4 to the right and secure with 2 layers of tape Item [7], and twist.

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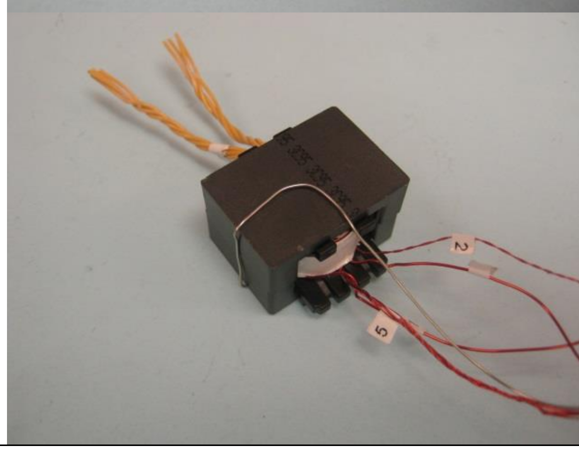
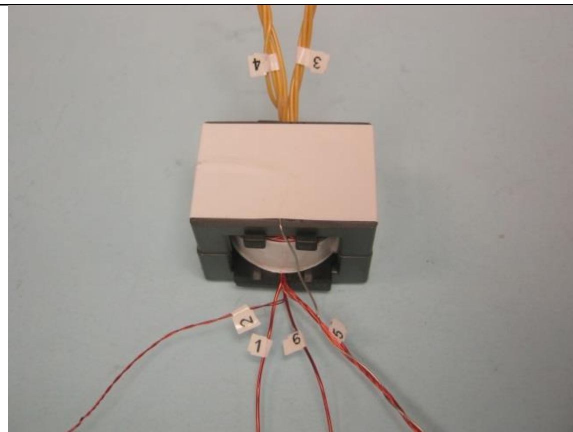
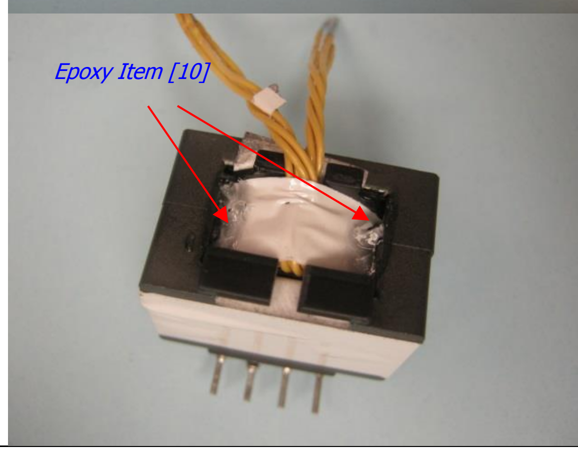
<table>
<tr>
<td>Finish Assembly</td>
<td>



</td>
<td>Gap cores to get 515 μH.
Apply glue Item [9] at center legs of cores.
Place bus wire Item [6] along the cores which also is FL5 and secure with tape.
Apply epoxy Item [10] between cores to body of the transformer.
Varnish with Item [11].</td>
</tr>
</table>





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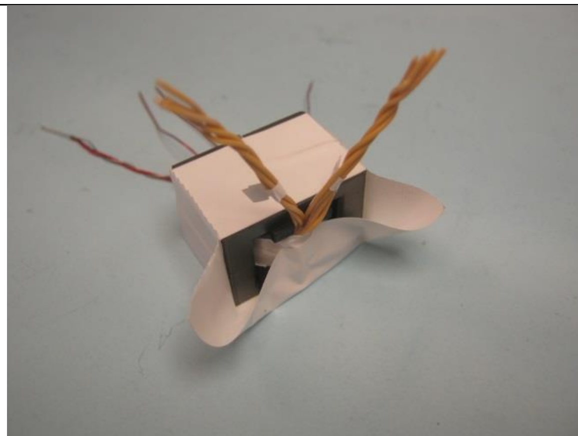
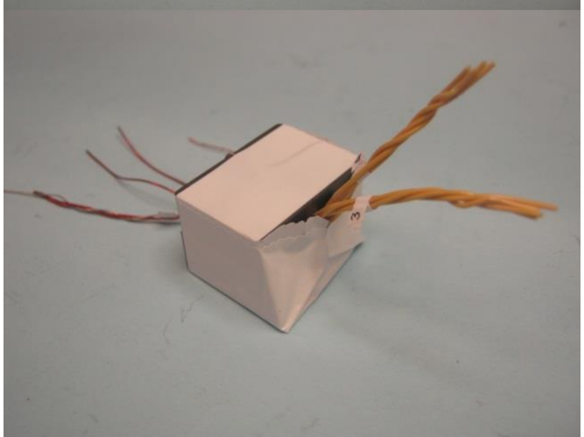
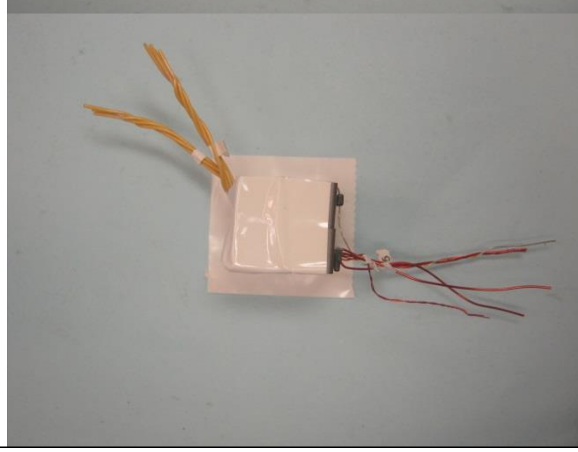
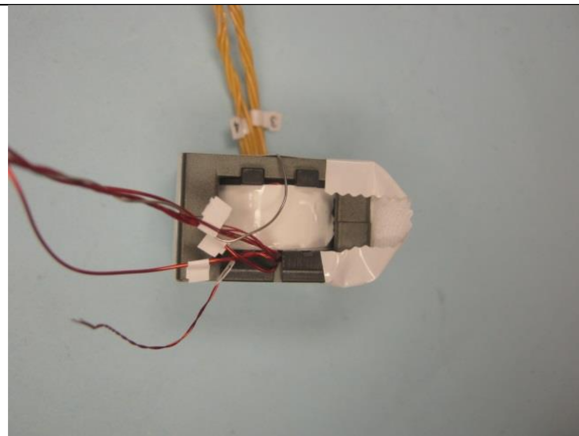
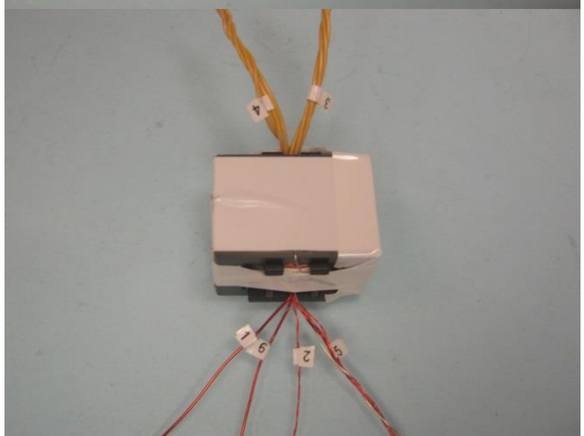
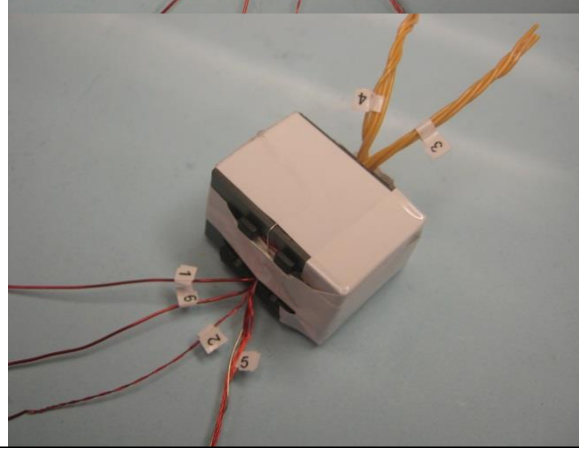
	  	Place 2 layers of tape Item [8] at the bottom then wrap up to the body of transformer. Wrap another 2 layers of tape Item [8] with 35 mm long at the right side of transformer and tape around 1turn of tape Item [7]. (*See pictures beside).*







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8 Common Mode Choke Specifications

8.1 *250 uH Common Mode Choke (L1)*

8.1.1 Electrical Diagram

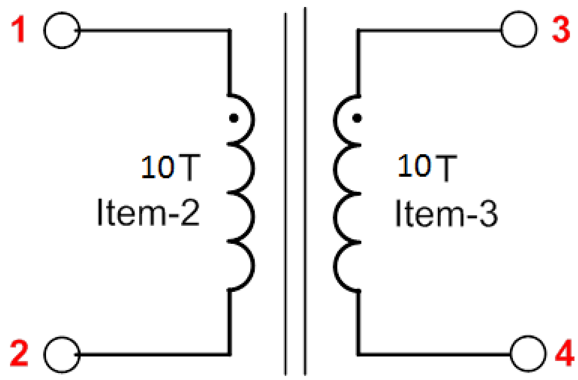


Figure 15 – Inductor Electrical Diagram.

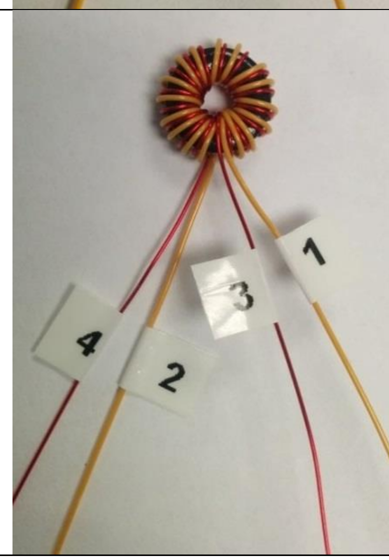
8.1.2 Electrical Specifications

Winding Inductance	Pin 1 – pin 2 (pin 3 – pin 4), all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	250 μH ±20%

8.1.3 Material List

Item	Description
[1]	Toroidal Core: 35T0375-10H, PI#: 32-00275-00.
[2]	Triple Insulated Wire: #26 AWG, Triple Coated.
[3]	Magnet Wire: #26 AWG, Double Coated.

8.1.4 Winding Instructions

Mark the start end of the winding as 1 and wind 10 turns of Item [2] on Item [1]. Mark the end of this winding as 2	
Repeat the same procedure as above for the other winding using Item [3], making sure that the start/end and the direction of winding is the same as the first winding. Varnish using Item [4]. Mark the start of this winding as 3 and the end as 4.	

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8.2 *18 mH Common Mode Choke (L2)*

8.2.1 Electrical Diagram

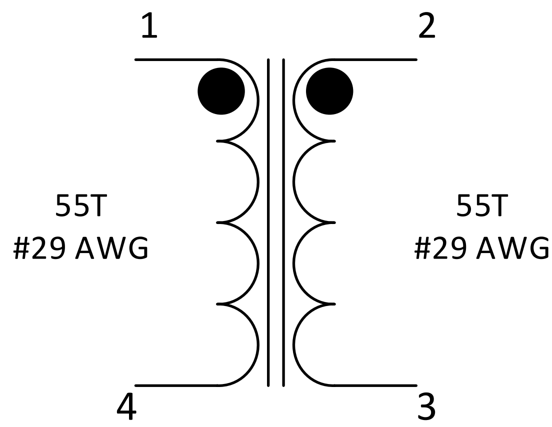

Figure 16 – Inductor Electrical Diagram.

8.2.2 Electrical Specifications

Inductance	Pins 1 - 4 and pins 2 - 3 measured at 100 kHz, 0.4 RMS.	18 mH ±25%
Core effective Inductance Index		5950 nH/N^2
Leakage Inductance	Pins 1 - 4, with pins 2 - 3 shorted.	80 μH ±10%

8.2.3 Material List

Item	Description
[1]	Toroid: FERRITE INDUCTOR TOROID T14 x 8 x 5.5, PI#: 32-00286-00.
[2]	Divider: Cable Tie, Panduit - Fish Paper, Insulating Cotton Rag, 0.010” Thick, PI#: 66-00042-00.
[3]	Magnet Wire: #29 AWG Heavy Nyleze.
[4]	Epoxy: Devon, 5mins Epoxy; or Equivalent.

8.2.4 Winding Instructions

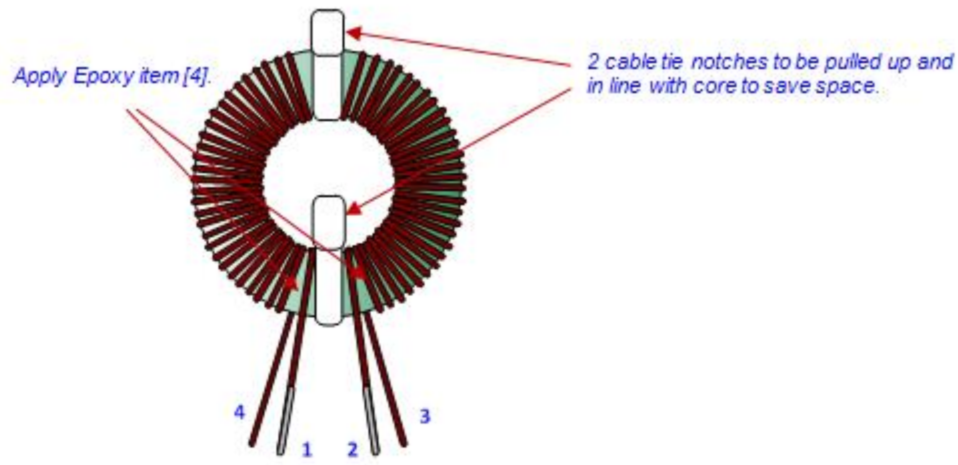

Figure 17 – 18 mH CMC Illustration Image.

- Place 2 pieces of cable tie Item [2] on to toroid Item [1] to divide 2 equal sections.
- Use 4 ft of wire Item [3], start as 1, wind 55 turns in 2 layers in a half section of toroid, and end as 4.
- Do the same for another half of Toroid, start as 2 and end as 3.
- Pull up 2 notches of cable ties to be in line with toroid body (to save space), and apply Epoxy Item [4] where leads floating.

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9 Transformer Design Spreadsheet

1	ACDC_Flyback_061319; Rev.0.1; Copyright Power Integrations 2019	INPUT	INFO	OUTPUT	UNITS	Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**					
3	VAC_MIN	90		90	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	100.0		100.0	uF	Input capacitance
9	**SET-POINT 1**					
10	VOUT1	21.00		21.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	3.000		3.000	A	Output current 1
12	POUT1			63.00	W	Output power 1
13	EFFICIENCY1	0.92		0.92		Converter efficiency for output 1
14	Z_FACTOR1	0.50		0.50		Z-factor for output 1
16	**SET-POINT 2**					
17	VOUT2	15.00		15.00	V	Output voltage 2
18	IOUT2	3.000		3.000	A	Output current 2
19	POUT2			45.00	W	Output power 2
20	EFFICIENCY2	0.92		0.92		Converter efficiency for output 2
21	Z_FACTOR2	0.50		0.50		Z-factor for output 2
23	**SET-POINT 3**					
24	VOUT3	9.00		9.00	V	Output voltage 3
25	IOUT3	3.000		3.000	A	Output current 3
26	POUT3			27.00	W	Output power 3
27	EFFICIENCY3	0.92		0.92		Converter efficiency for output 3
28	Z_FACTOR3	0.50		0.50		Z-factor for output 3
30	**SET-POINT 4**					
31	VOUT4	5.00		5.00	V	Output voltage 4
32	IOUT4	3.000		3.000	A	Output current 4
33	POUT4			15.00	W	Output power 4
34	EFFICIENCY4	0.91		0.91		Converter efficiency for output 4
35	Z_FACTOR4	0.50		0.50		Z-factor for output 4
37	**SET-POINT 5**					
38	VOUT5	3.30		3.30	V	Output voltage 5
39	IOUT5	3.000		3.000	A	Output current 5
40	POUT5			9.90	W	Output power 5
41	EFFICIENCY5	0.90		0.90		Converter efficiency for output 5
42	Z_FACTOR5	0.50		0.50		Z-factor for output 5
44	**SET-POINT 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	**SET-POINT 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	**SET-POINT 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	**SET-POINT 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
71						
72	VOLTAGE_CDC	0.000		0.000	V	Cable drop compensation desired at full load
76	**PRIMARY CONTROLLER SELECTION**					
77	ENCLOSURE	ADAPTER		ADAPTER		Power supply enclosure
78	ILIMIT_MODE	INCREASED		INCREASED		Device current limit mode
79	VDRAIN_BREAKDOWN	750		750	V	Device breakdown voltage
80	DEVICE_GENERIC	AUTO		INN3379		Device selection
81	DEVICE_CODE			INN3379C		Device code
82	PDEVICE_MAX			65	W	Device maximum power capability
83	RDSON_25DEG			0.44	Ω	Primary switch on-time resistance at 25°C
84	RDSON_100DEG			0.62	Ω	Primary switch on-time resistance at 100°C
85	ILIMIT_MIN			1.980	A	Primary switch minimum current limit
86	ILIMIT_TYP			2.130	A	Primary switch typical current limit
87	ILIMIT_MAX			2.279	A	Primary switch maximum current limit
88	VDRAIN_ON_PRSW			0.47	V	Primary switch on-time voltage drop
89	VDRAIN_OFF_PRSW			588.31	V	Peak drain voltage on the primary switch during turn-off
93	**WORST CASE ELECTRICAL PARAMETERS**					
94	FSWITCHING_MAX	77350	Info	77350	Hz	The worst case minimum operating frequency is less than 25kHz: may result in audible noise
95	VOR	145.0		145.0	V	Voltage reflected to the primary winding (corresponding to set-point 1) when the primary switch turns off
96	VMIN			88.10	V	Valley of the rectified minimum input AC voltage at full load
97	KP			0.737		Measure of continuous/discontinuous mode of operation
98	MODE_OPERATION			CCM		Mode of operation
99	DUTYCYCLE			0.623		Primary switch duty cycle
100	TIME_ON			12.10	us	Primary switch on-time
101	TIME_OFF			4.87	us	Primary switch off-time
102	LPRIMARY_MIN			489.3	uH	Minimum primary magnetizing inductance
103	LPRIMARY_TYP			515.0	uH	Typical primary magnetizing inductance

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104	LPRIMARY_TOL			5.0	%	Primary magnetizing inductance tolerance
105	LPRIMARY_MAX			540.8	uH	Maximum primary magnetizing inductance
107	**PRIMARY CURRENT**					
108	IAVG_PRIMARY			0.750	A	Primary switch average current
109	IPEAK_PRIMARY			2.134	A	Primary switch peak current
110	IPEDESTAL_PRIMARY			0.501	A	Primary switch current pedestal
111	IRIPPLE_PRIMARY			2.030	A	Primary switch ripple current
112	IRMS_PRIMARY			1.041	A	Primary switch RMS current
113						
114	SECONDARY CURRENT					
115	IPEAK_SECONDARY			14.940	A	Secondary winding peak current
116	IPEDESTAL_SECONDARY			3.504	A	Secondary winding pedestal current
117	IRMS_SECONDARY			5.663	A	Secondary winding RMS current
118	IRIPPLE_CAP_OUT			4.803	A	Output capacitor ripple current
122	**TRANSFORMER CONSTRUCTION PARAMETERS**					
123	**CORE SELECTION**					
124	CORE	EQ25		EQ25		Core selection
125	CORE NAME			EQ25-3C95		Core code
126	AE			100.0	mm^2	Core cross sectional area
127	LE			41.4	mm	Core magnetic path length
128	AL			5710	nH	Ungapped core effective inductance per turns squared
129	VE			4145	mm^3	Core volume
130	BOBBIN NAME			TBI-235-01091.1206		Bobbin name
131	AW			34.8	mm^2	Bobbin window area
132	BW			8.10	mm	Bobbin width
133	MARGIN			0.0	mm	Bobbin safety margin
135	**PRIMARY WINDING**					
136	NPRIMARY			35		Primary winding number of turns
137	BPEAK			3604	Gauss	Peak flux density
138	BMAX			3256	Gauss	Maximum flux density
139	BAC			1543	Gauss	AC flux density (0.5 x Peak to Peak)
140	ALG			420	nH	Typical gapped core effective inductance per turns squared
141	LG			0.277	mm	Core gap length
142	LAYERS_PRIMARY	2		2		Primary winding number of layers
143	AWG_PRIMARY	26		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			244.2	Cmils/A	Primary winding wire CMA
148	**SECONDARY WINDING**					
149	NSECONDARY	5		5		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			227.5	Cmils/A	Secondary winding wire CMA
155	**BIAS WINDING**					
156	NBIAS			10		Bias winding number of turns
160	**PRIMARY COMPONENTS SELECTION**					
161	**LINE UNDERVOLTAGE**					
162	BROWN-IN REQURED	77.00		77.00	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 600V when overvoltage is trigerred
170	**BIAS WINDING**					
171	VBIAS	6.00	Info	6.00	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			112.66	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
174	CBIAS			22	uF	Bias winding rectification capacitor
175	CBPP			4.70	uF	BPP pin capacitor
179	**SECONDARY COMPONENTS SELECTION**					
180	**RECTIFIER**					
181	VDRAIN_OFF_SRFET			74.33	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
182	SRFET	AUTO		AO4294		Secondary rectifier (Logic MOSFET)
183	VBREAKDOWN_SRFET			100	V	Secondary rectifier breakdown voltage
184	RDSON_SRFET			15.5	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
188	**SET-POINTS ANALYSIS**					
189	**TOLERANCE CORNER**					
190	USER_VAC	115		115	V	Input AC RMS voltage corner to be evaluated
191	USER_ILIMIT	TYP		2.130	A	Current limit corner to be evaluated
192	USER_LPRIMARY	TYP		515.0	uH	Primary inductance corner to be evaluated
194	**SET-POINT SELECTION**					
195	SET-POINT	1		1		Select the set-point which needs to be evaluated
196	FSWITCHING			63094.0	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
197	VOR			145.0	V	Voltage reflected to the primary winding when the primary switch turns off
198	VMIN			132.23	V	Valley of the minimum input AC voltage

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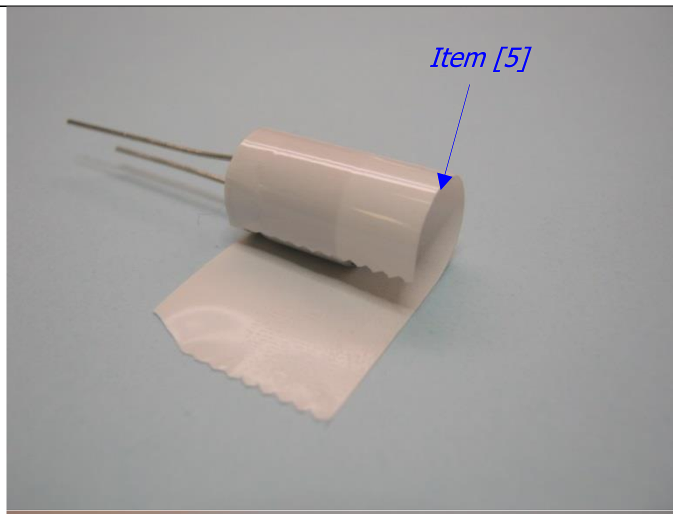
199	KP			1.119		Measure of continuous/discontinuous mode of operation
200	MODE_OPERATION			DCM		Mode of operation
201	DUTYCYCLE			0.495		Primary switch duty cycle
202	TIME_ON			7.85	us	Primary switch on-time
203	TIME_OFF			8.00	us	Primary switch off-time
205	**PRIMARY CURRENT**					
206	IAVG_PRIMARY			0.498	A	Primary switch average current
207	IPEAK_PRIMARY			2.012	A	Primary switch peak current
208	IPEDESTAL_PRIMARY			0.000	A	Primary switch current pedestal
209	IRIPPLE_PRIMARY			2.012	A	Primary switch ripple current
210	IRMS_PRIMARY			0.817	A	Primary switch RMS current
212	**SECONDARY CURRENT**					
213	IPEAK_SECONDARY			14.081	A	Secondary winding peak current
214	IPEDESTAL_SECONDARY			0.000	A	Secondary winding pedestal current
215	IRMS_SECONDARY			5.458	A	Secondary winding RMS current
216	IRIPPLE_CAP_OUT			4.560	A	Output capacitor ripple current
217						
218	MAGNETIC FLUX DENSITY					
219	BPEAK			3208	Gauss	Peak flux density
220	BMAX			2960	Gauss	Maximum flux density
221	BAC			1480	Gauss	AC flux density (0.5 x Peak to Peak)

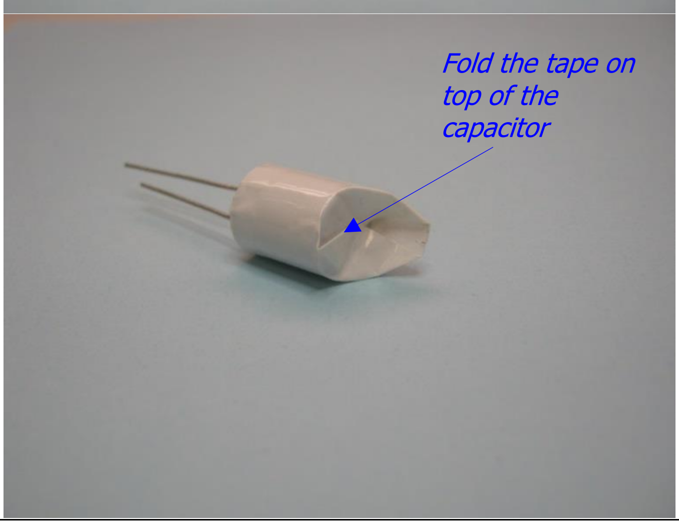
10 PCB Assembly Instructions

10.1 *Materials*

Item	Description
[1]	Output Capacitor C12 on DER-803 Schematic.
[2]	Bulk Capacitor C2 on DER-803 Schematic.
[3]	Bias Capacitor C5 on DER_803 Schematic.
[4]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 16.4 mm Wide, 25 mm Long.
[5]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 18.2 mm Wide, 15 mm Long.
[6]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 36 mm Wide, 15 mm Long.
[7]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 20.4 mm Wide, 40 mm Long.
[8]	Teflon Tubing #22.

10.2 *Capacitors Assembly Taping Instructions*





Wrap Output capacitor C12 with tape Item [5] to insulate the capacitor form transformer core.

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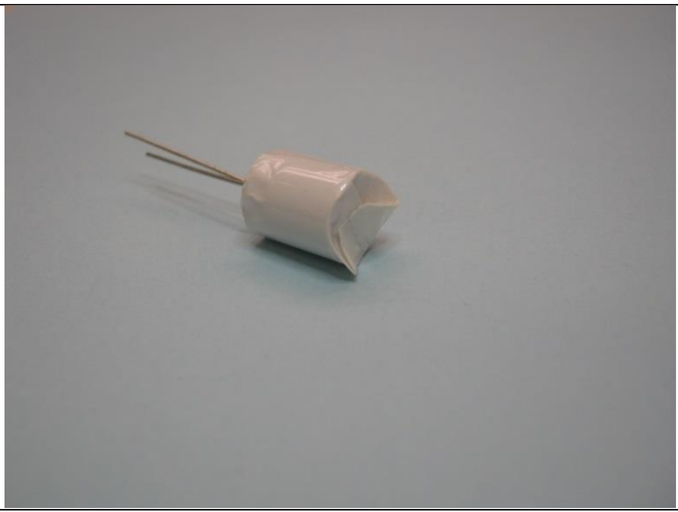
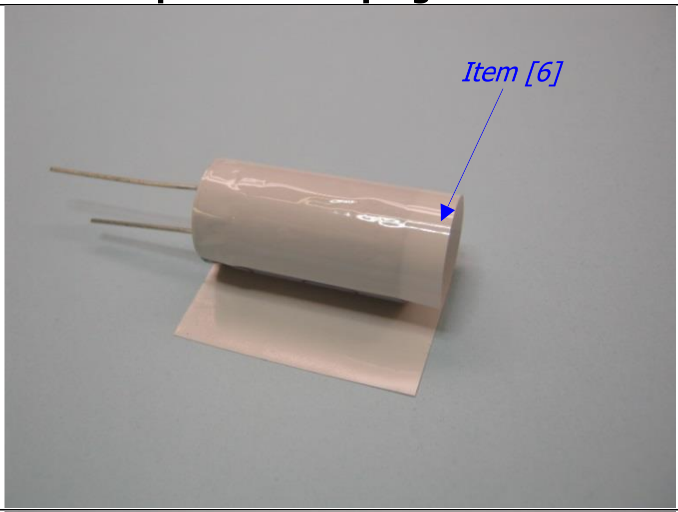
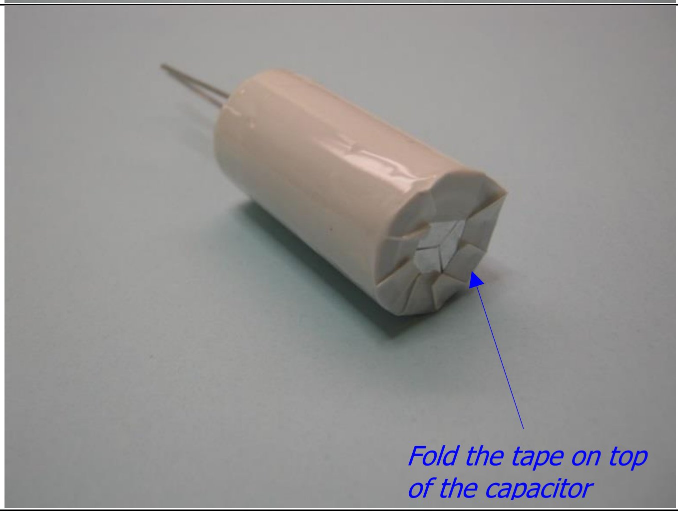
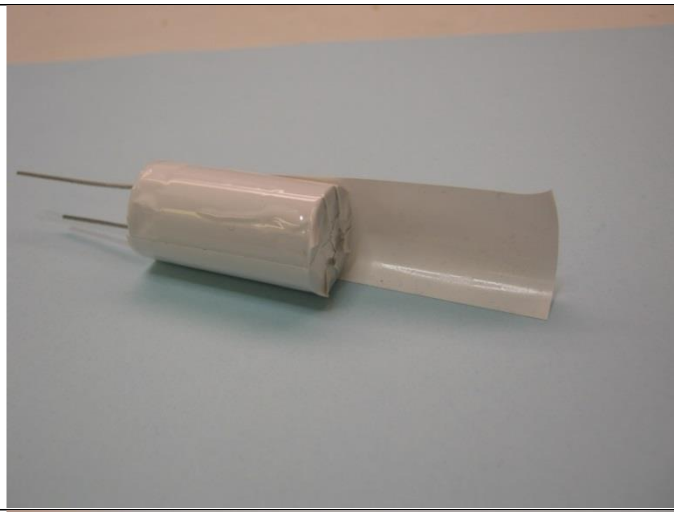
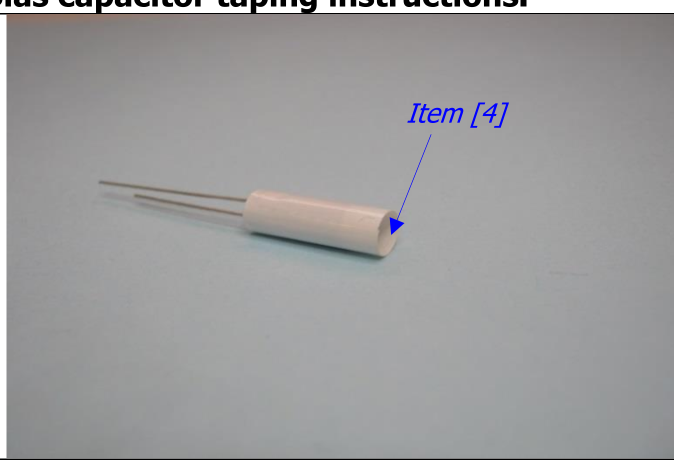
	Completed C12 Capacitor.
Bulk capacitor C2 taping instructions.	
	Wrap Bulk capacitor C2 with tape Item [6] to insulate the capacitor form transformer core
	

	Tape Item [7]
	Completed tape C2 capacitor.
Bias capacitor taping instructions.	
	Wrap Bias capacitor C5 with tape Item [4] to insulate the capacitor form transformer core.

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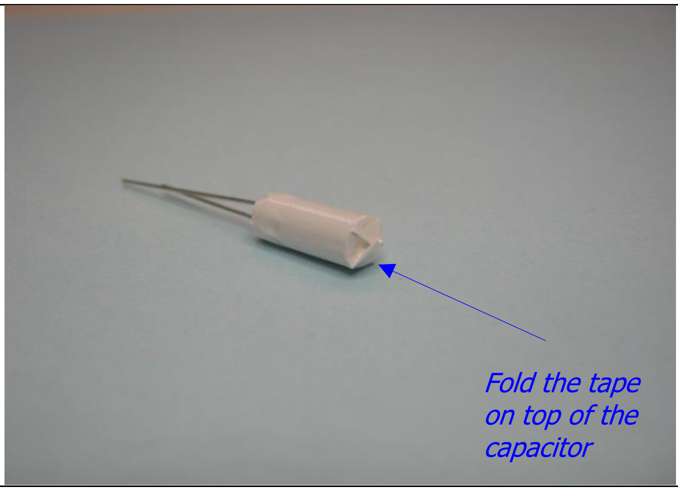
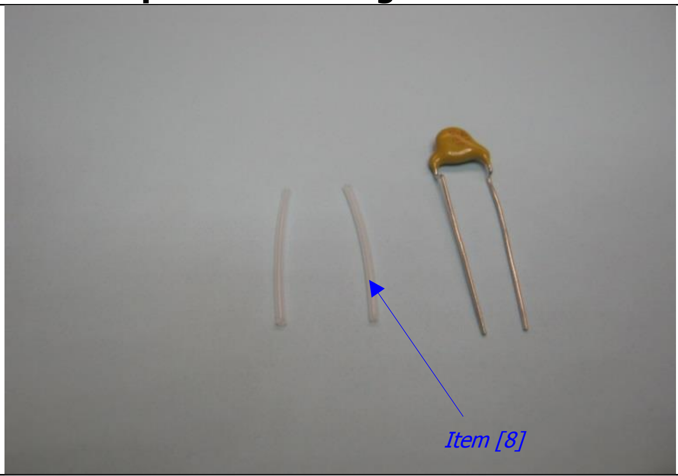
	Completed tape C5 capacitor.
Y capacitor sleeving instructions.	
	Cut 2 pcs Item [8] 24mm long.
	Insert Item [8] into Y capacitor.

11 Adapter Case and Heat Spreader Assembly

11.1 *Materials*

Item	Description
[1]	Heat Spreader: PI#: 61-00250-00, (Material: Aluminum, 3003, 25 mil Thick).
[2]	Insulator: PI#: 61-00249-00, (Use Mylar Teijin, Clear, 3 mil Thick, PI#: 66-00230-00).
[3]	Thermal Pad #1, use 3M, Pad5549S, PI#: 66-00231-00 cut into Dimension: 1.75” x 1.35”.
[4]	Thermal Pad #2, use Bergquist. 0.5mm Thick, PI#: 66-00075-00 cut into Dimension: 1.0” x 0.8”.
[5]	Thermal Pad #3, use 3M, Pad5549S, PI#: 66-00231-00 cut into dimension: 0.9” x 0.5”.
[6]	Thermal Pad #4, use Bergquist. 0.5 mm Thick, PI#: 66-00075-00 cut into dimension: 0.40” x 0.25”.
[7]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 8.0 mm Wide.
[8]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 18.0 mm Wide.
[9]	AC plug, 2 Prongs (L/N), PI#: 35-00476-00.
[10]	Epoxy, 5 min Gel, Devon #: 14265; or equivalent.
[11]	Enclosure: Body: PI#: 07-00009-00, cap: 07-00008-00

11.2 *Adapter Case Dimensions*

Note: Dimensions are in millimeters.

11.2.1 Case Body

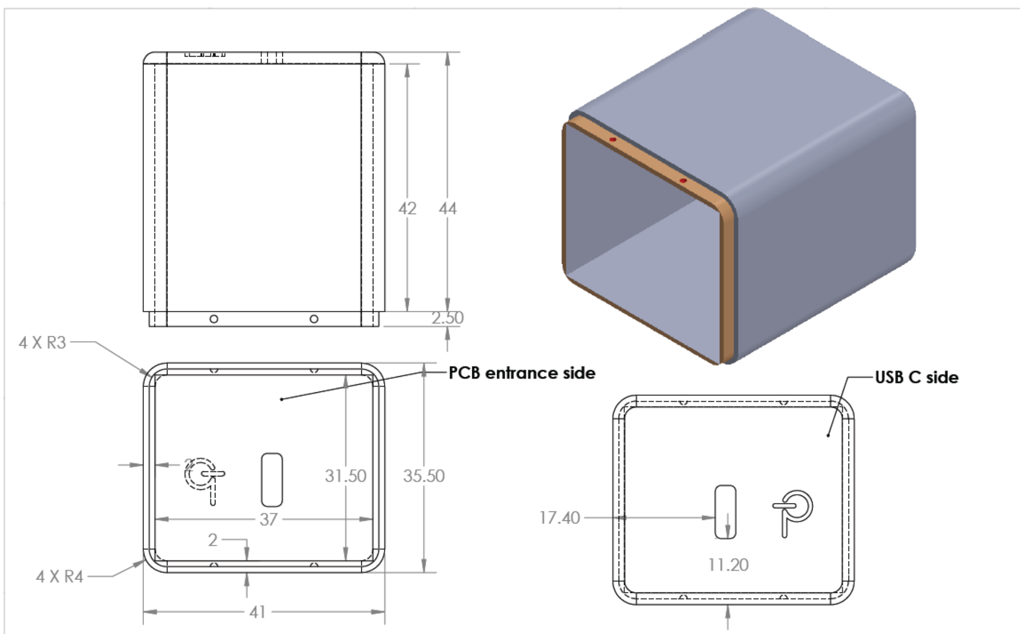


Figure 18 – Adapter Case Body Dimensions.

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11.2.2 Case Cap

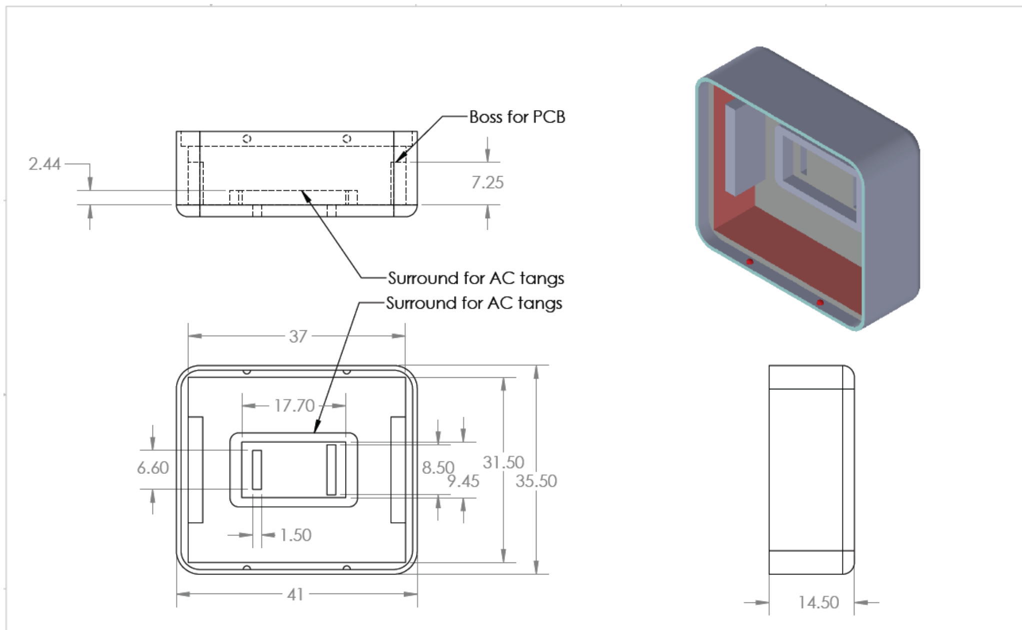

Figure 19 – Adapter Case Cap Dimensions.

11.3 *Heat Spreader Dimensions*

Note: Dimensions are in inches.

11.3.1 Aluminum Sheet

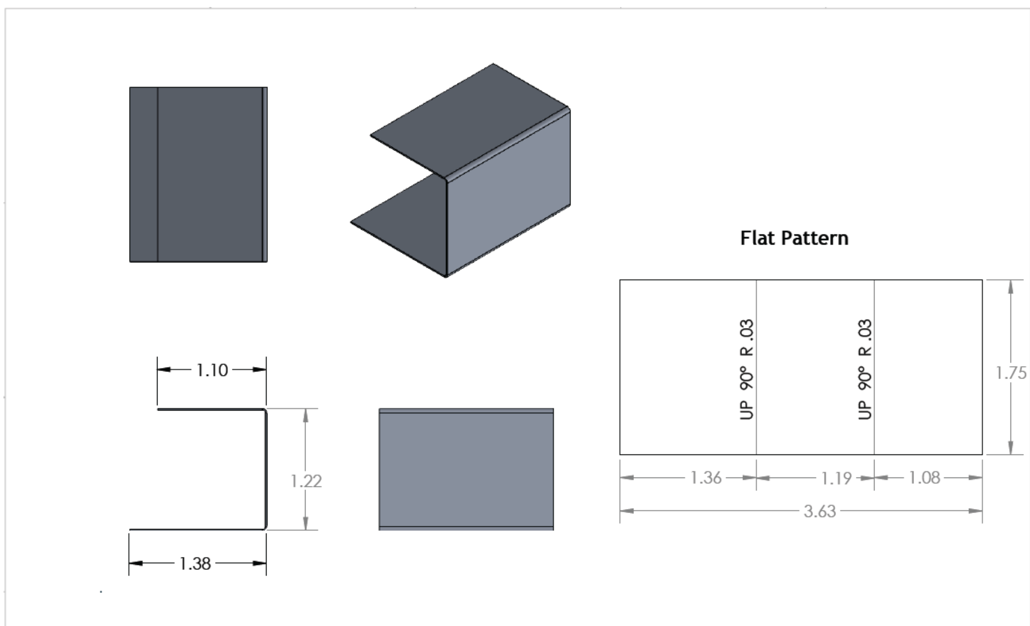

Figure 20 – Aluminum Sheet (25 mils thick) Dimensions.

11.3.2 Thermal Pad

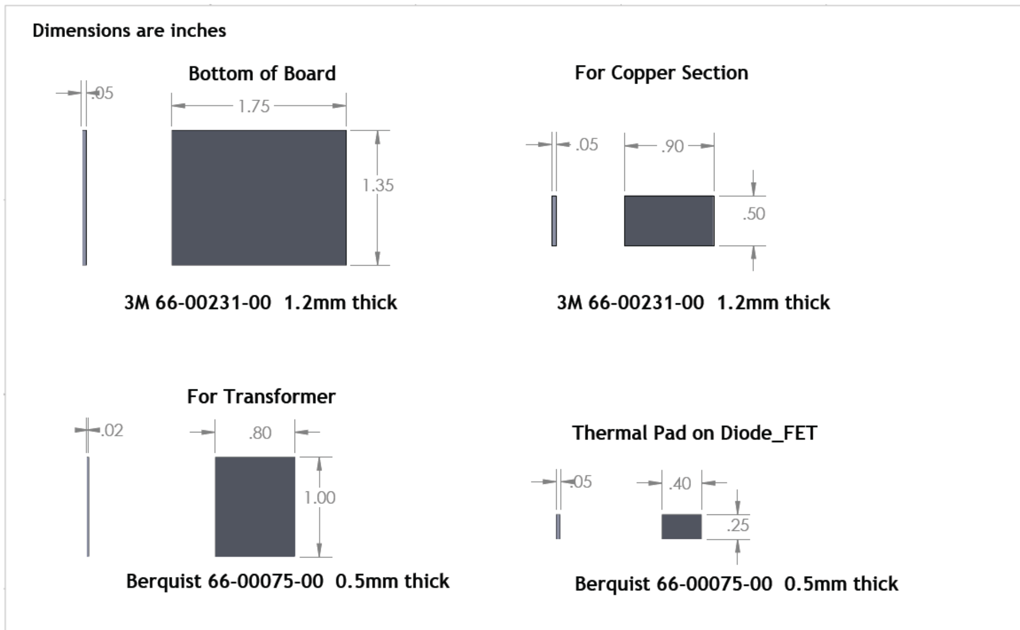

Figure 21 – Thermal Pad Dimensions.

11.3.3 Mylar Insulator

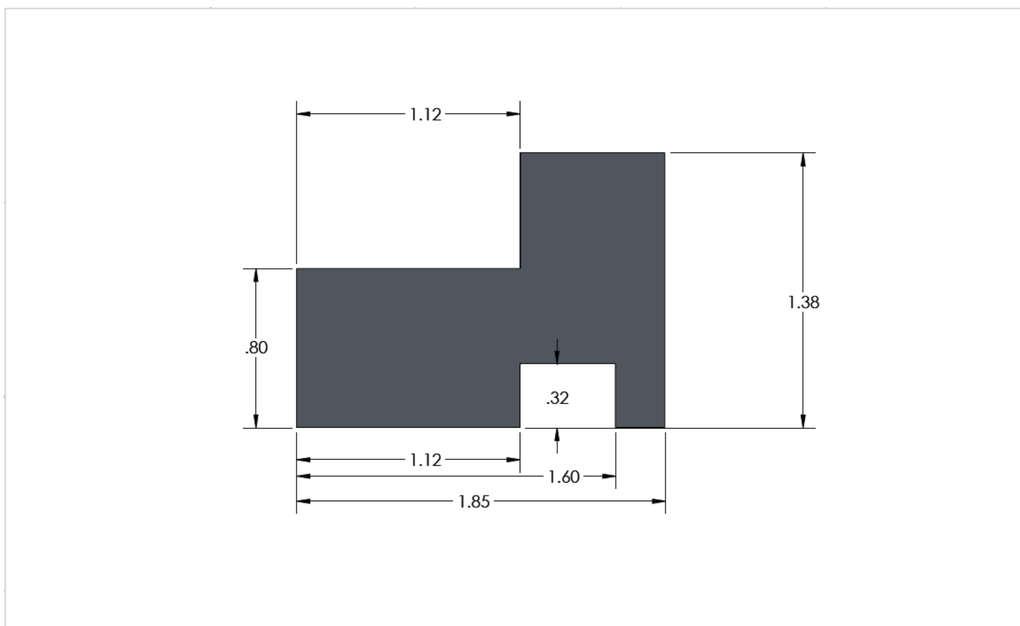

Figure 22 – Mylar Insulator Dimensions.

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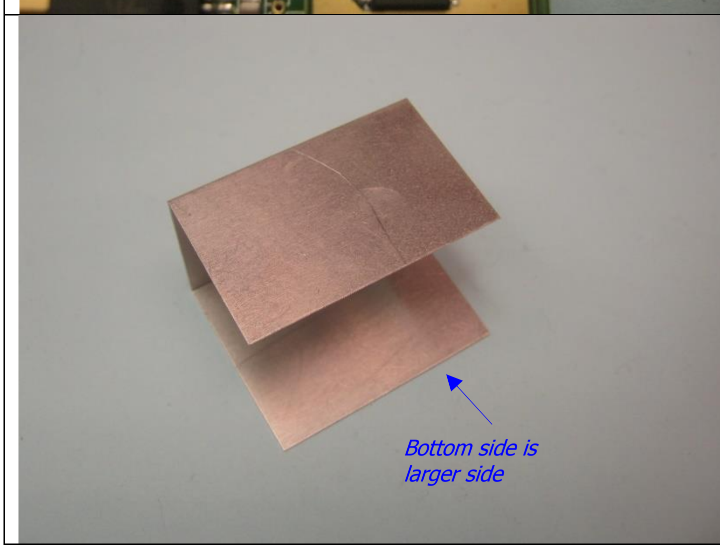
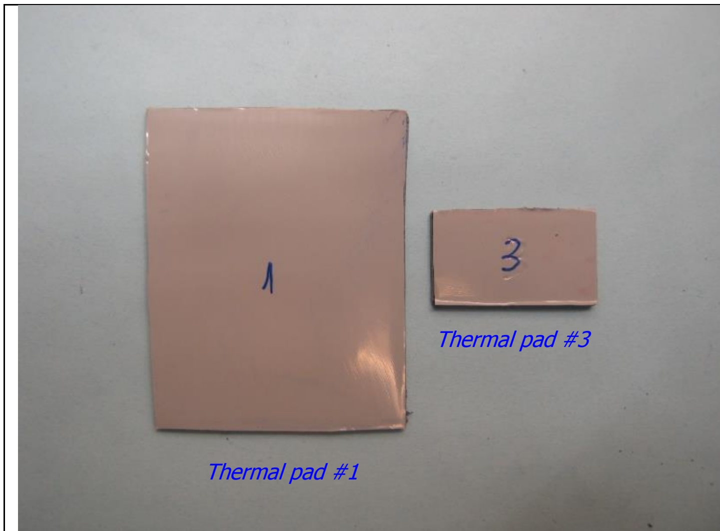
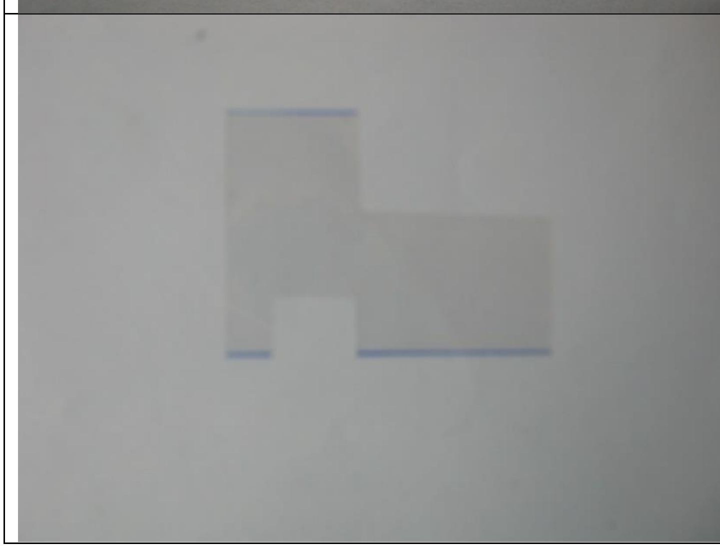
11.4 ***Assembly Illustrations***

Use proper flush cutters such as shown in this picture to have all pin of PCB to be flush cut in order to avoid any pins poking into the thermal pads. *(see illustration beside for reference).*



Heat spreader Item [1].

	Prepare thermal pad #1 and #3.
	Prepare thermal pad #2 and #4.
	Insulator Item [2].

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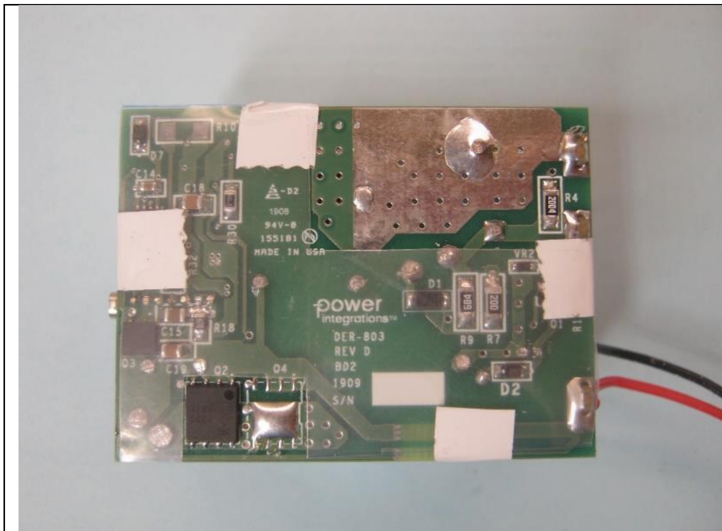
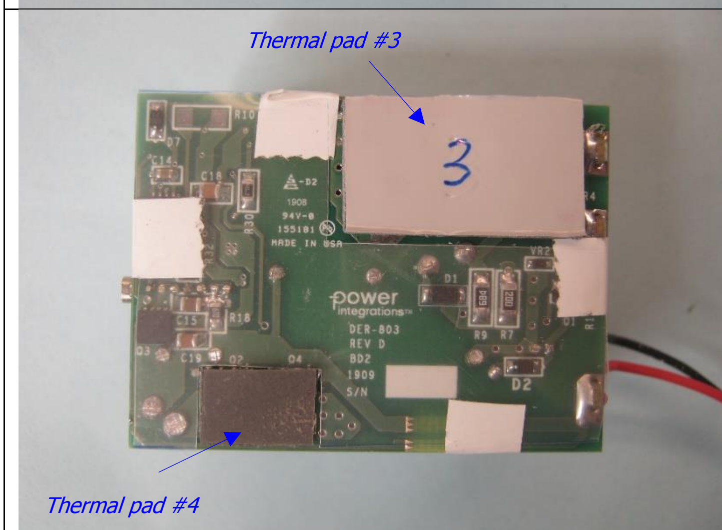
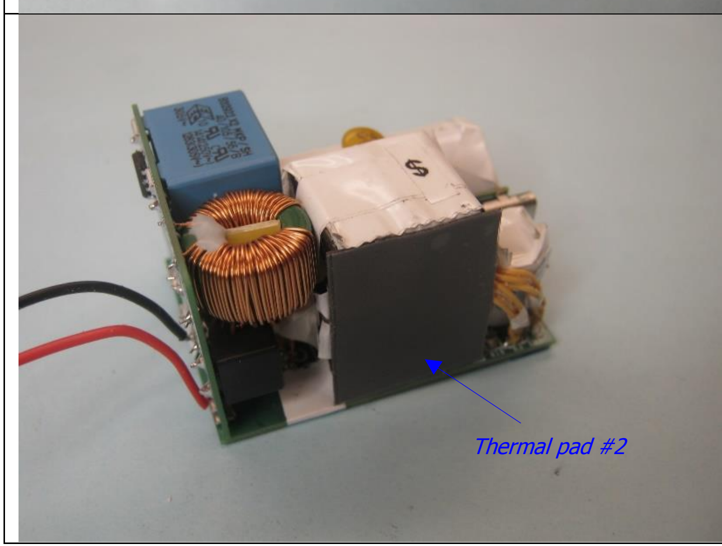
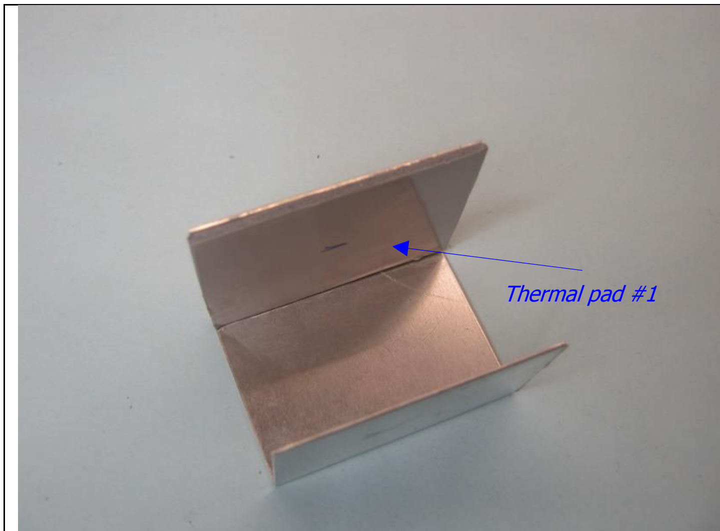
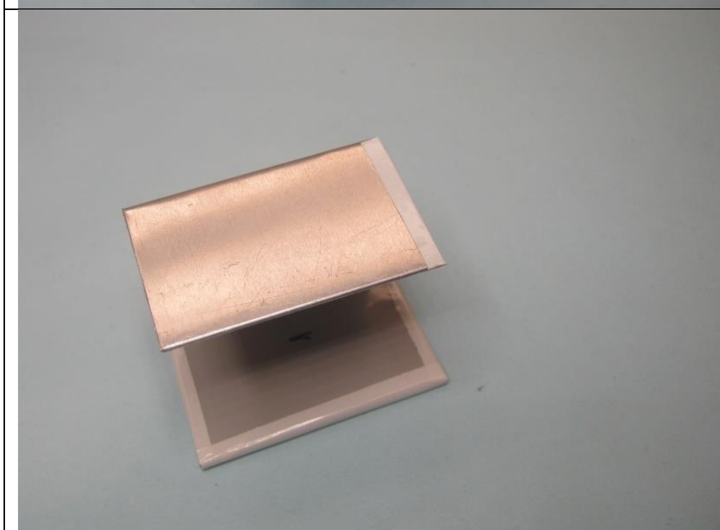
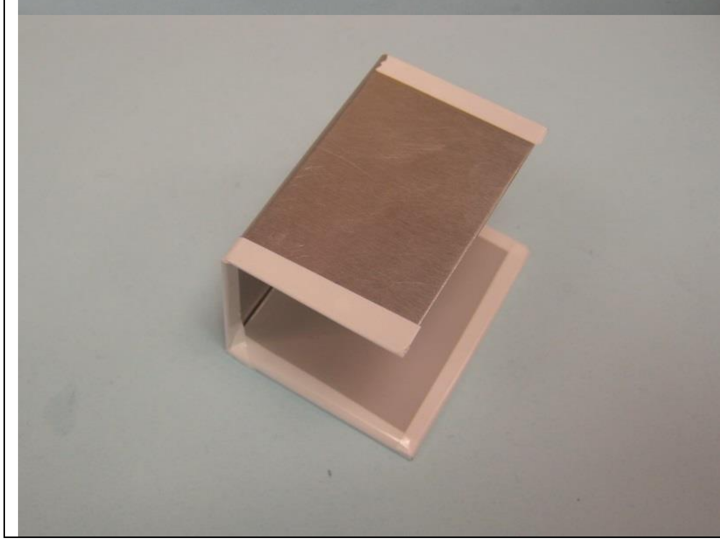
	Place; align insulator Item [2] onto bottom of PCB, then use tape Item [7] to tape it with PCB as shown in this picture.
	Remove plastic cover of thermal pad #3 and place onto copper section of PCB. Also remove both side plastic covers of thermal pad #4, place on top of diode. See picture beside.
	Remove both side plastic covers of thermal pad #2 and attach to the transformer.

<table>
<tr>
<td>
</td>
<td>Remove the plastic cover of thermal pad Item [1], attach the sticky side to bottom of heat spreader.</td>
</tr>
<tr>
<td>
</td>
<td>Then use tape Item [7] to tape along 3 sides of thermal pad, right side and left side of top heat spreader.</td>
</tr>
</table>

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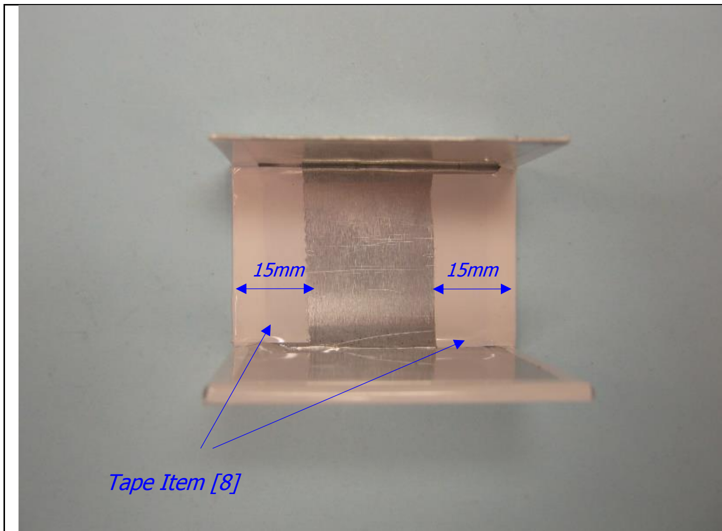
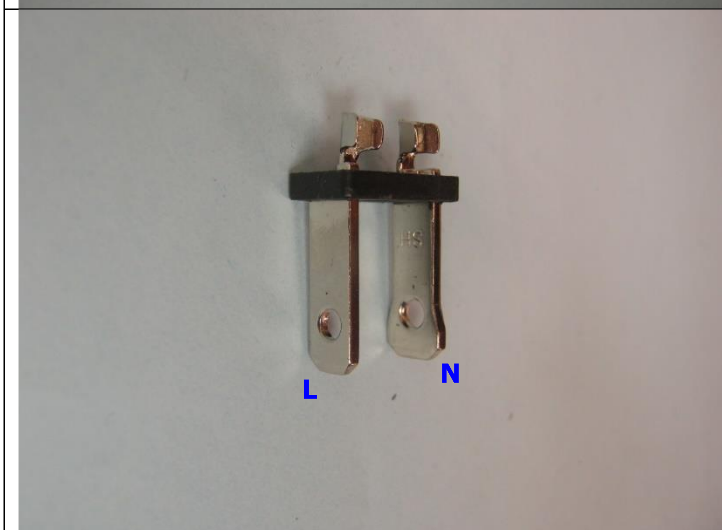
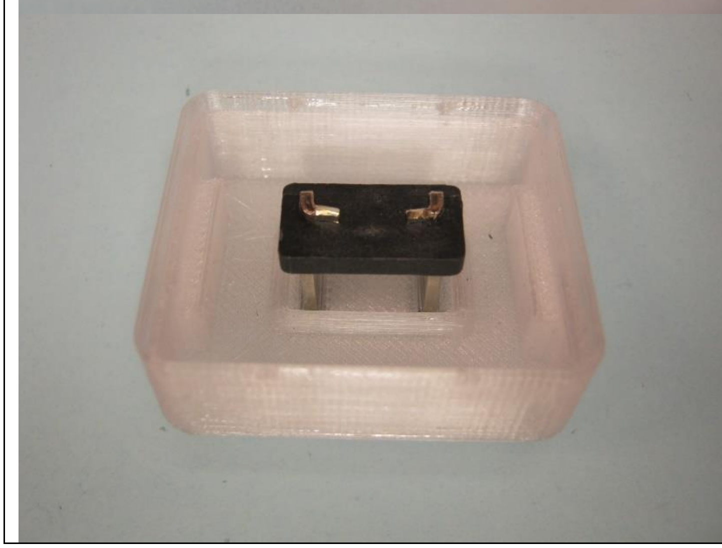
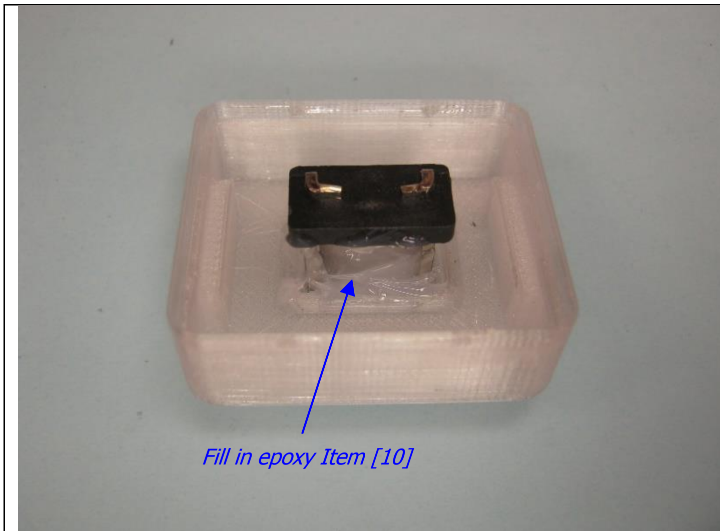
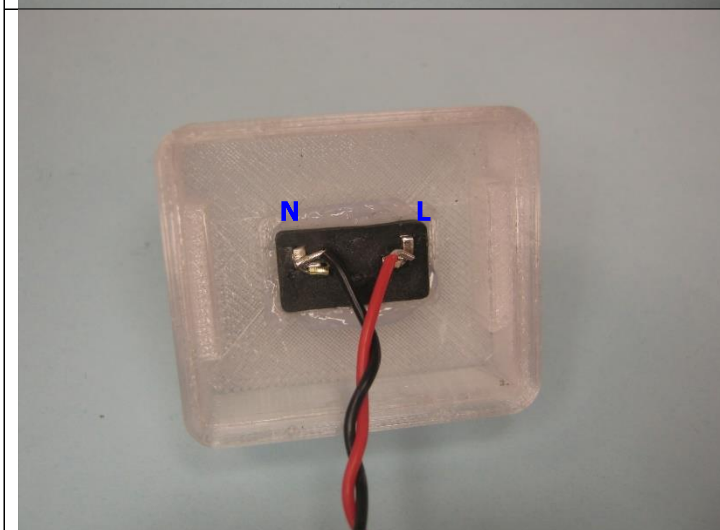
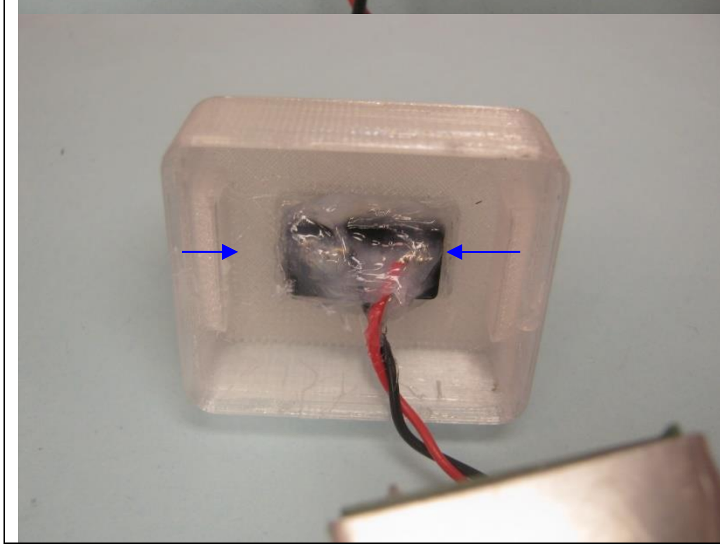


Place tape Item [8] on both sides into inner side of heat spreader as shown in this picture.





Cut short 2 prong ends of AC plug Item [9], insert half way to the cap of the case Item [11], which N prong goes into wider slot.
Then fill in with epoxy Item [10] and insert the AC plug completely.

	
 	Solder red wire to L prong and black wire to N prong. Again, cover it with epoxy Item [10].

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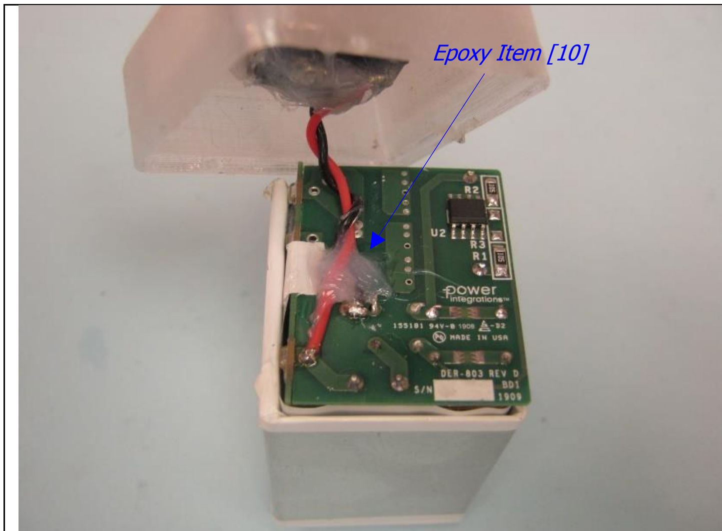
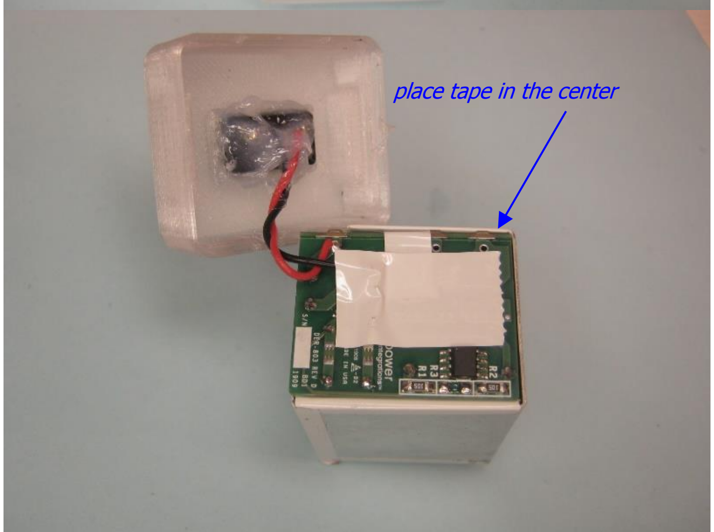
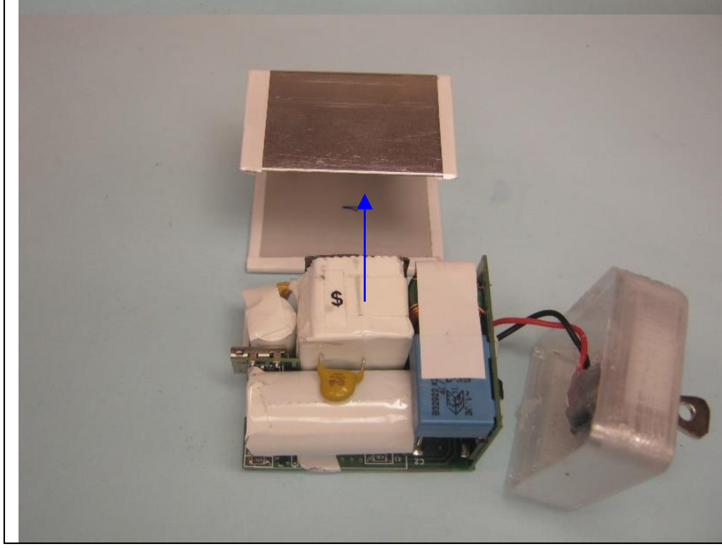
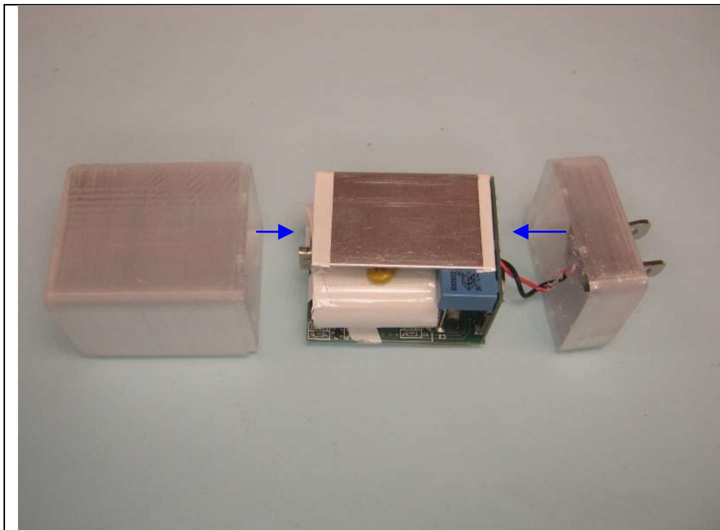
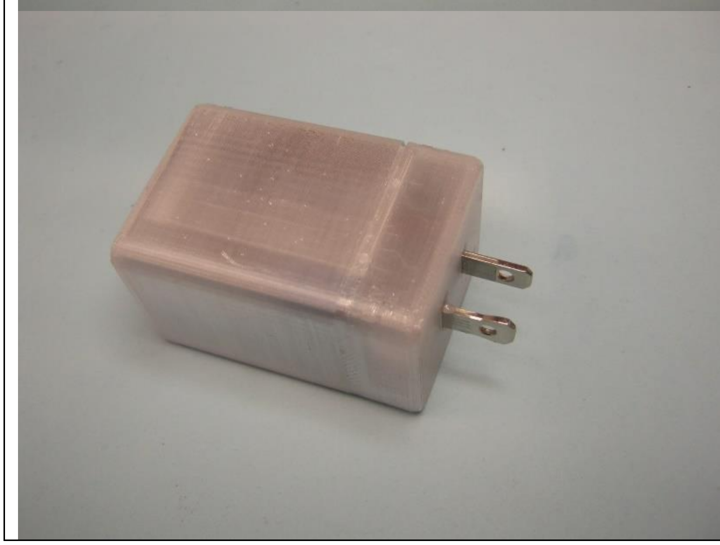






Apply epoxy Item [10] to secure wires with PCB. Place tape in the center of PCB. Insert whole assembly of PCB into heat spreader and to enclosure body Item [11] then snap with the cap of Item [11]. (see pics beside).





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12 Performance Data

Note 1: Output voltages measured on the PCB end.
2: Measurements taken at room temperature (approximately 24 °C).

12.1 *No-Load Input Power at 5 V_{OUT}*

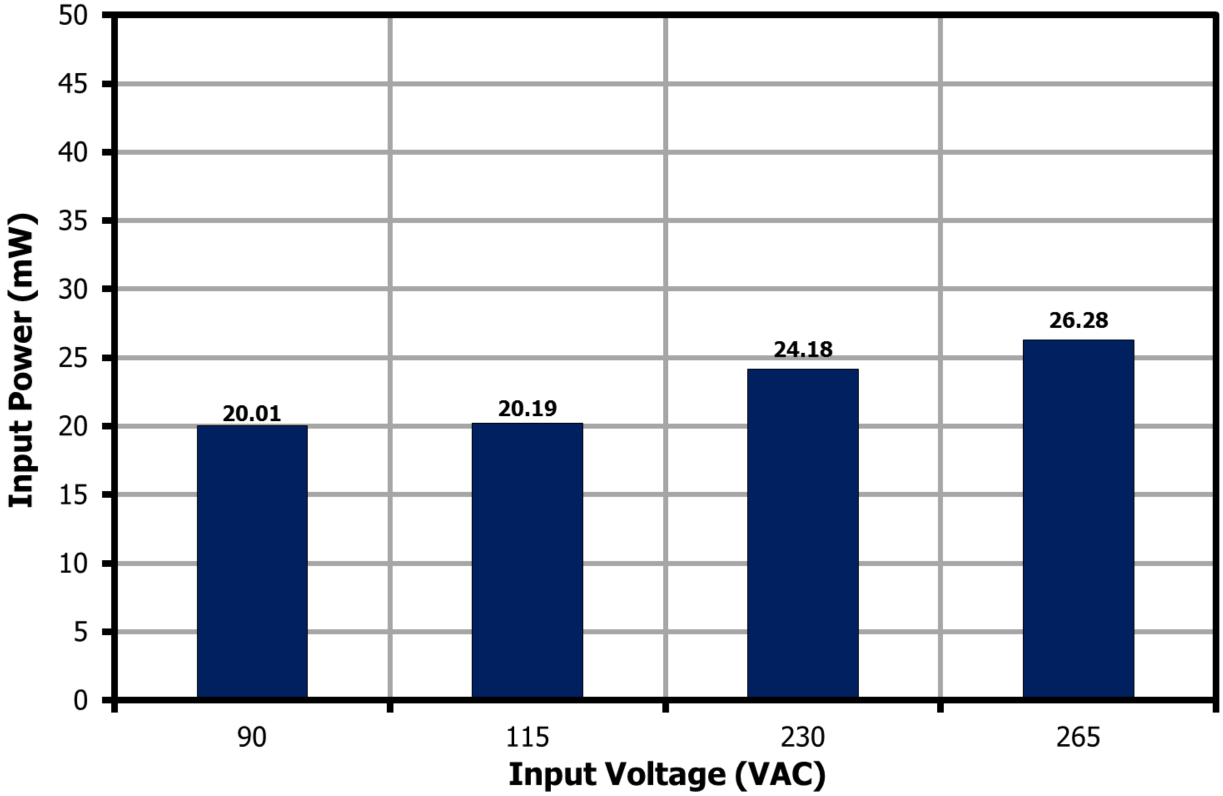

Figure 23 – No-Load Input Power vs. Input Line Voltage.

12.2 *Average and 10% Load Efficiency*

12.2.1 Efficiency Requirements

		Test Effective Power (W)	Average 2016 New EISA2007	Average Jan-16 CoC v5 Tier 2	10% Load Jan-16 CoC v5 Tier 2
V_{OUT} (V)	Model				
5	<6 V	15	81.4%	81.8%	72.5%
9	>6 V	27	86.6%	87.3%	77.3%
15	>6 V	45	88.0%	88.9%	78.9%
20	>6 V	60	88.0%	89.0%	79.0%

12.2.2 Efficiency Performance Summary (On Board)

V_{OUT} (V)	Power (W)	Average Efficiency (%)		10% Load Efficiency (%)	
		115 VAC	230 VAC	115 VAC	230 VAC
5	15	91.71	90.31	87.94	84.01
9	27	92.51	91.86	88.35	85.71
15	45	92.73	92.64	87.28	86.21
20	60	92.66	92.83	86.94	85.82

12.2.3 Average and 10% Load Efficiency at 115 VAC

12.2.3.1 Output: 5 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	15.13	91.94	**91.71**
75	11.37	92.00	
50	7.59	91.92	
25	3.79	90.99	
10	1.51	**87.94**	

12.2.3.2 Output: 9 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	27.13	92.83	**92.51**
75	20.38	92.84	
50	13.60	92.69	
25	6.79	91.67	
10	2.71	**88.35**	

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12.2.3.3 Output: 15 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	45.08	93.16	**92.73**
75	33.88	93.11	
50	22.60	92.91	
25	11.29	91.74	
10	4.51	**87.28**	

12.2.3.4 Output: 20 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	60.00	93.20	**92.66**
75	45.11	93.09	
50	30.07	92.79	
25	15.03	91.55	
10	6.00	**86.94**	

12.2.4 Average and 10% Load Efficiency at 230 VAC

12.2.4.1 Output: 5 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	15.18	91.41	**90.31**
75	11.40	91.12	
50	7.60	90.34	
25	3.80	88.36	
10	1.51	**84.01**	

12.2.4.2 Output: 9 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	27.19	92.81	**91.86**
75	20.42	92.59	
50	13.62	92.01	
25	6.80	90.03	
10	2.71	**85.71**	

12.2.4.3 Output: 15 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	45.19	93.56	**92.64**
75	33.91	93.32	
50	22.62	92.72	
25	11.30	90.97	
10	4.51	**86.21**	

12.2.4.4 Output: 20 V / 3 A

Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	60.16	93.81	**92.83**
75	45.14	93.52	
50	30.10	92.92	
25	15.04	91.08	
10	6.00	**85.82**	

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12.3 ***Efficiency Across Load (On Board)***

12.3.1 Output: 5 V / 3 A

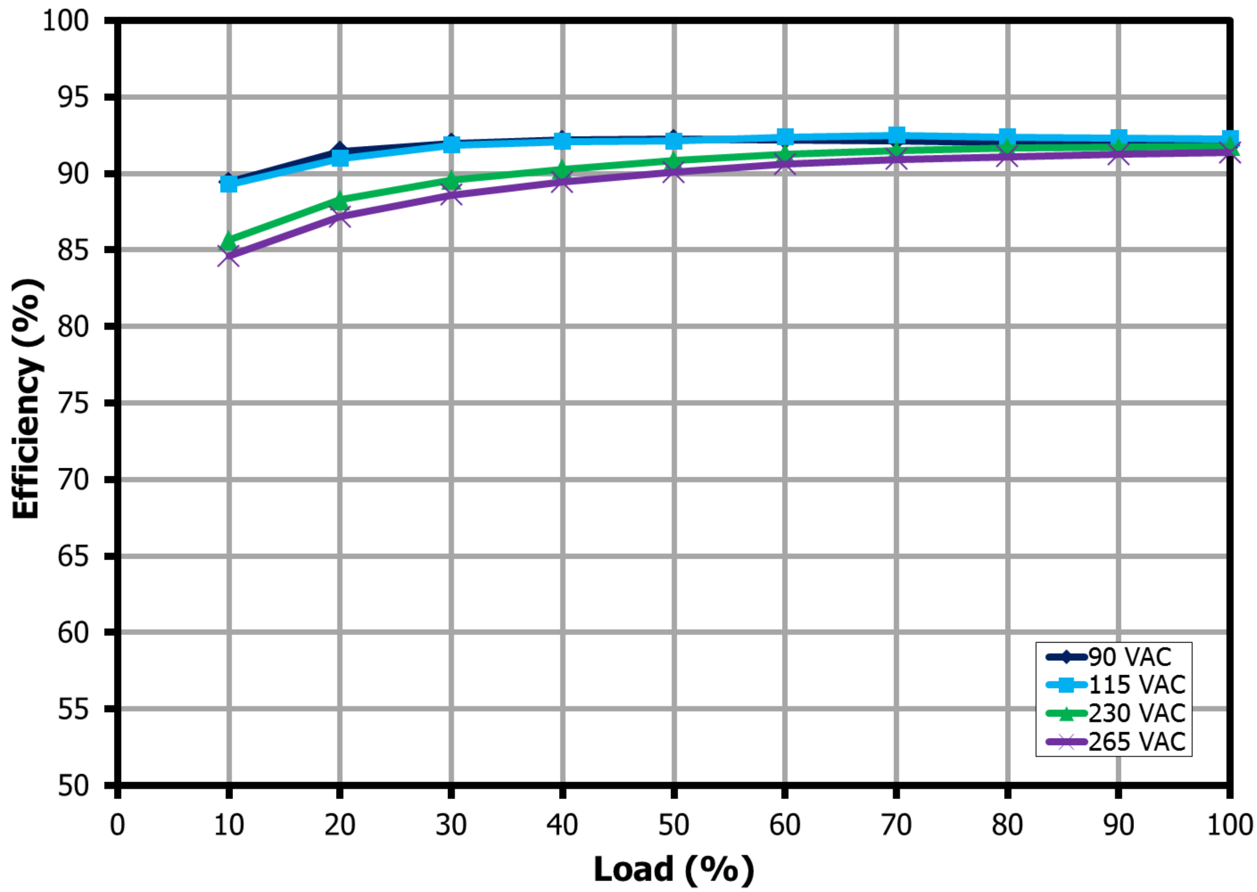

Figure 24 – Efficiency vs. Load for 5 V Output, Room Temperature.

12.3.2 Output: 9 V / 3 A

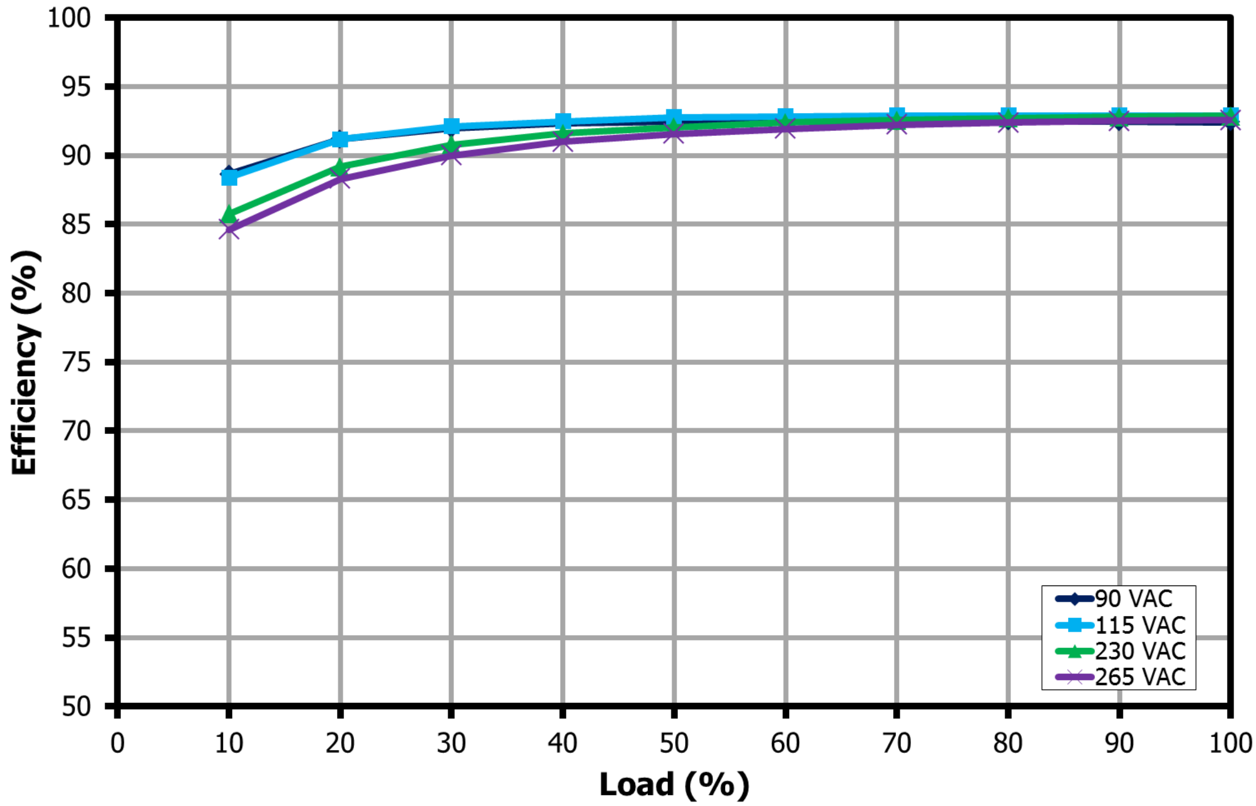

Figure 25 – Efficiency vs. Load for 9 V Output, Room Temperature.

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12.3.3 Output: 15 V / 3 A

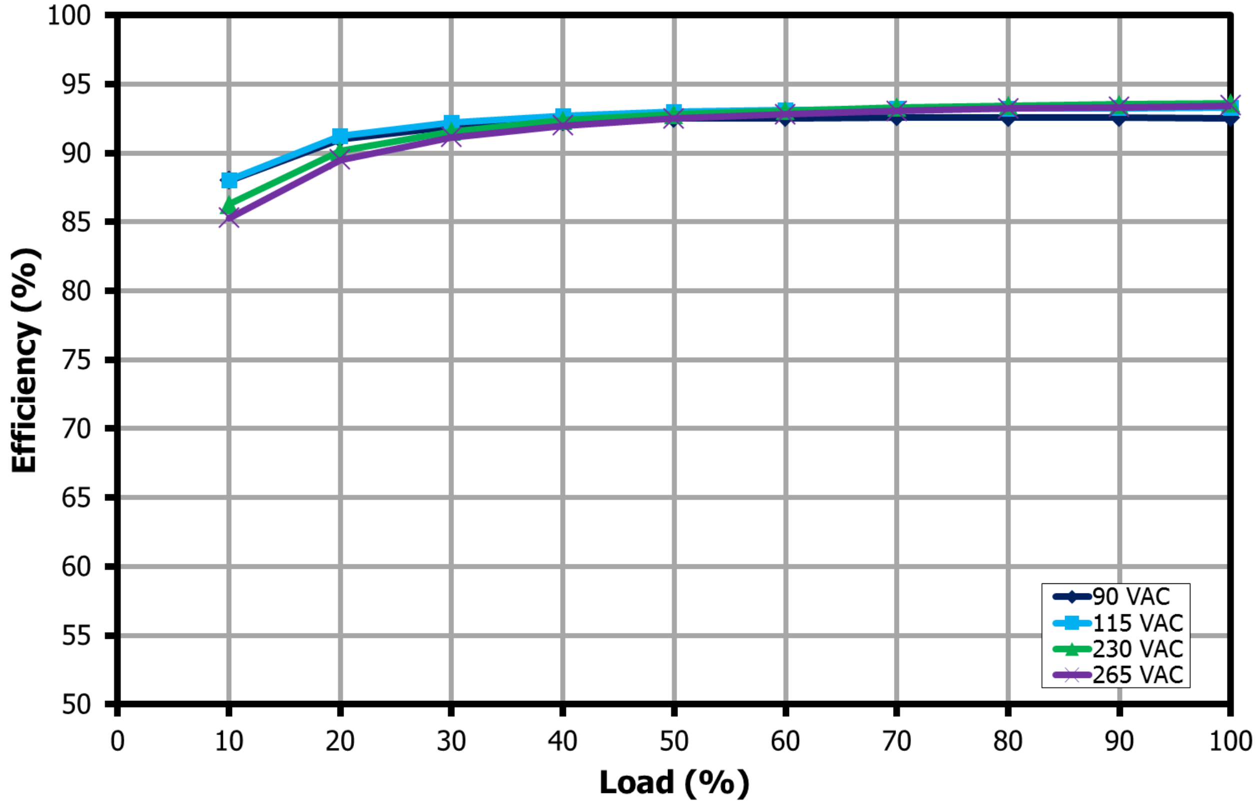

Figure 26 – Efficiency vs. Load for 15 V Output, Room Temperature.

12.3.4 Output: 20 V / 3 A

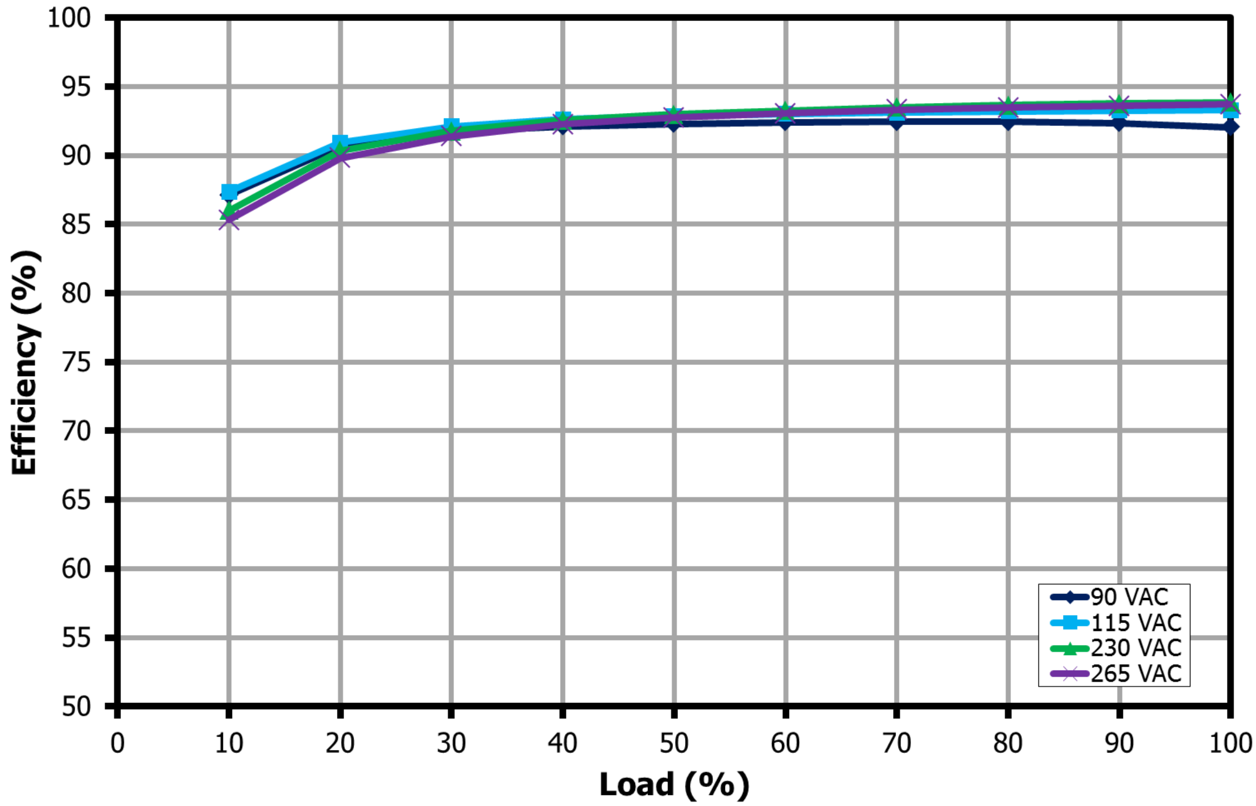

Figure 27 – Efficiency vs. Load for 20 V Output, Room Temperature.

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12.4 *Efficiency Across Line (On Board)*

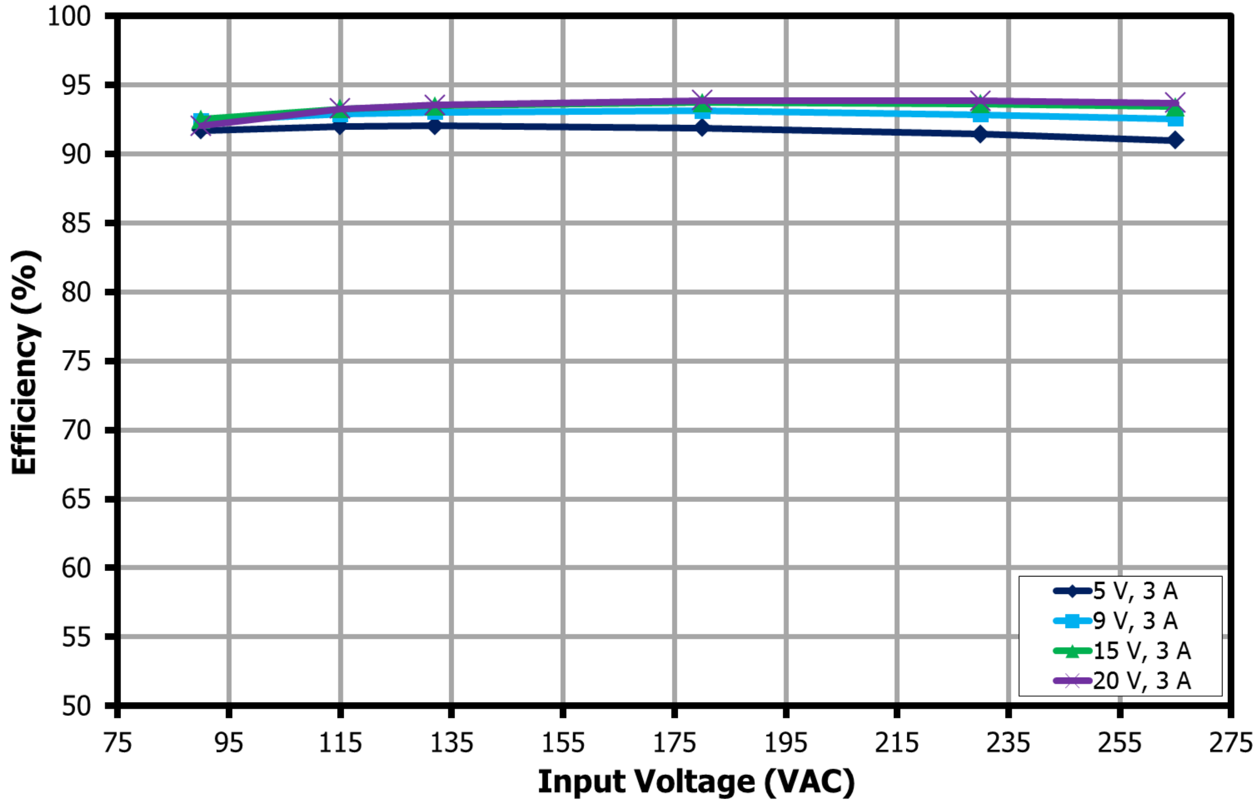

Figure 28 – Full Load Efficiency vs. Input Line for 5 V, 9 V, 15 V, and 20 V Output, Room Temperature.

12.5 *Load Regulation (On Board)*

12.5.1 Output: 5 V / 3 A

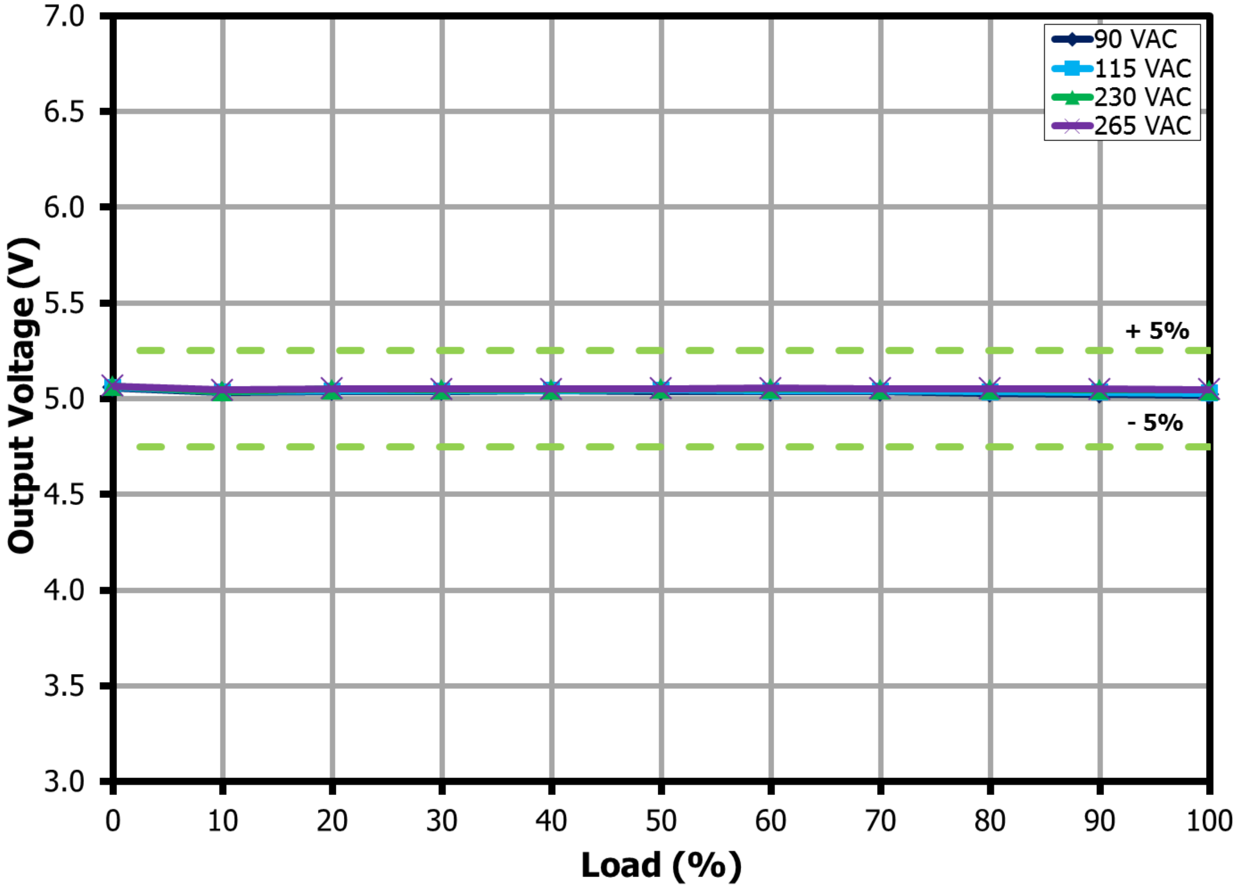

Figure 29 – Output Voltage vs. Output Load for 5 V Output, Room Temperature.

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12.5.2 Output: 9 V / 3 A

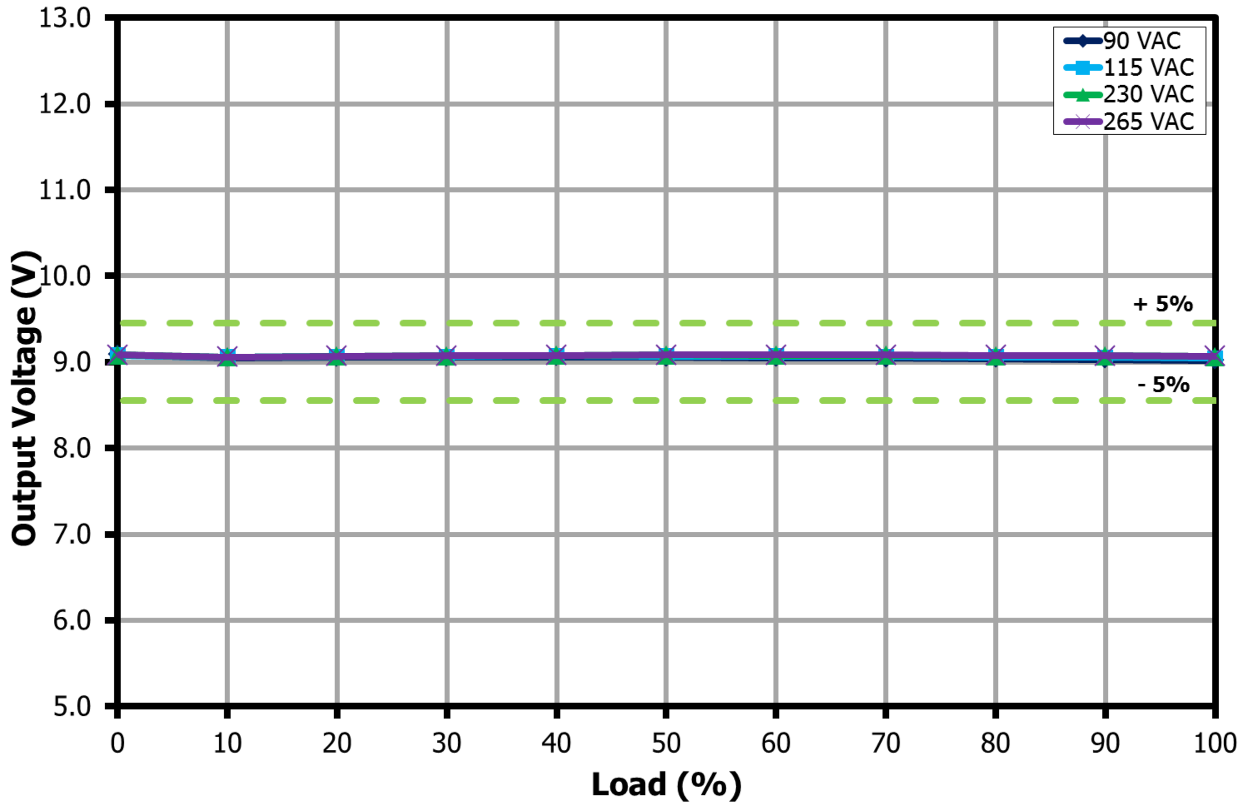

Figure 30 – Output Voltage vs. Output Load for 9 V Output, Room Temperature.

12.5.3 Output: 15 V / 3 A

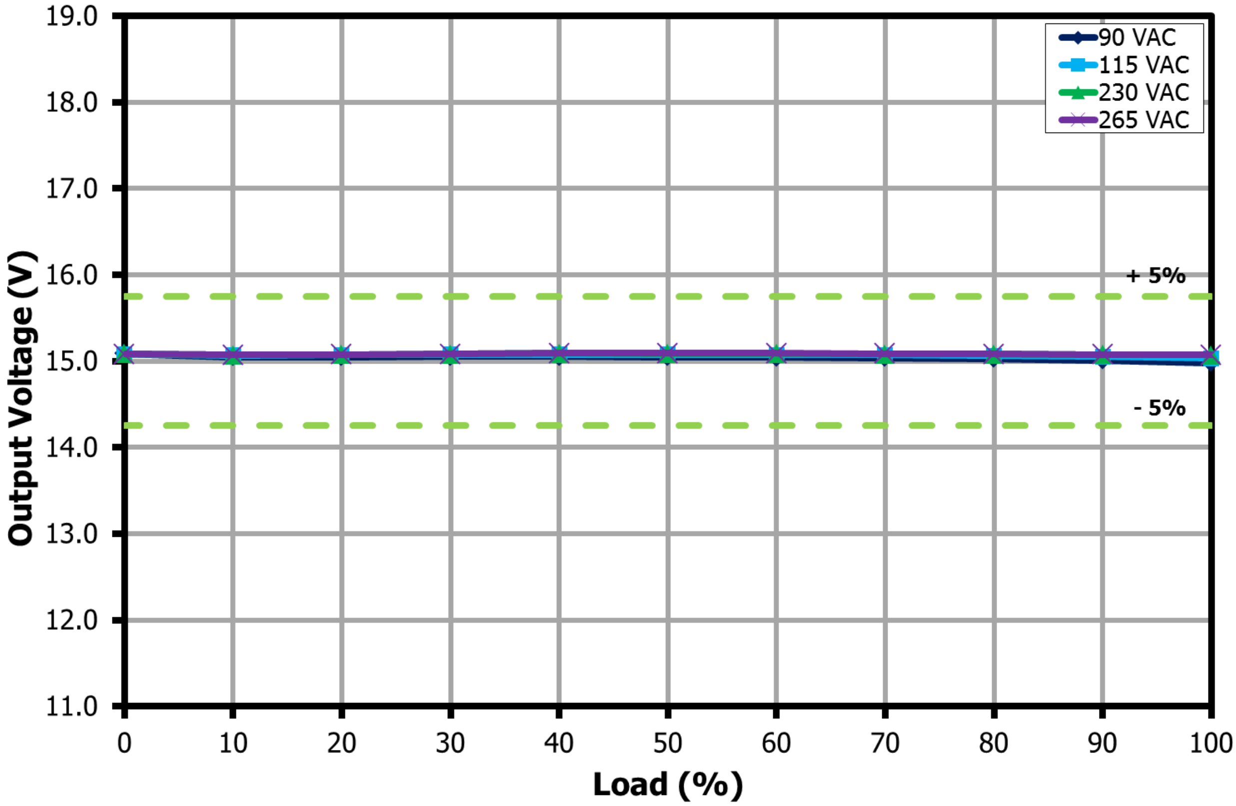

Figure 31 – Output Voltage vs. Output Load for 15 V Output, Room Temperature.

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12.5.4 Output: 20 V / 3 A

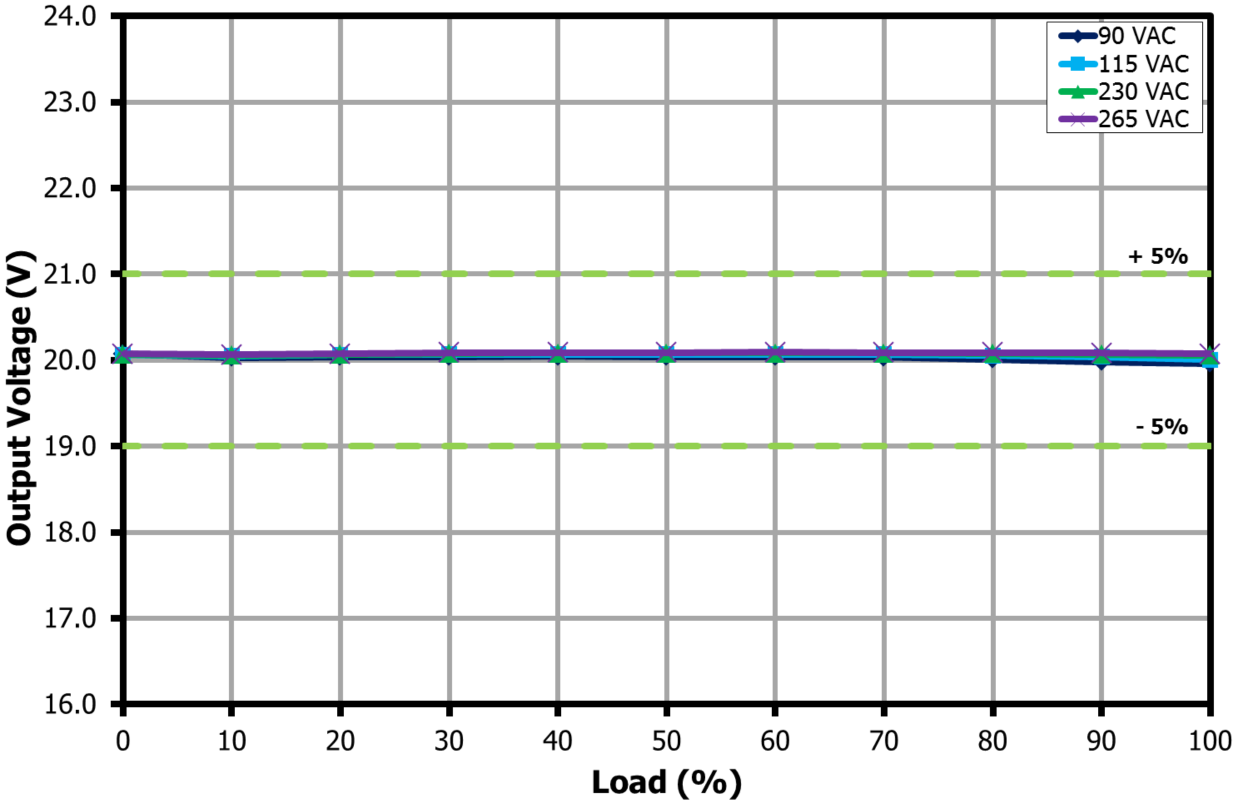

Figure 32 – Output Voltage vs. Output Load for 20 V Output, Room Temperature.

12.6 *Line Regulation (On Board)*

12.6.1 Output: 5 V / 3 A

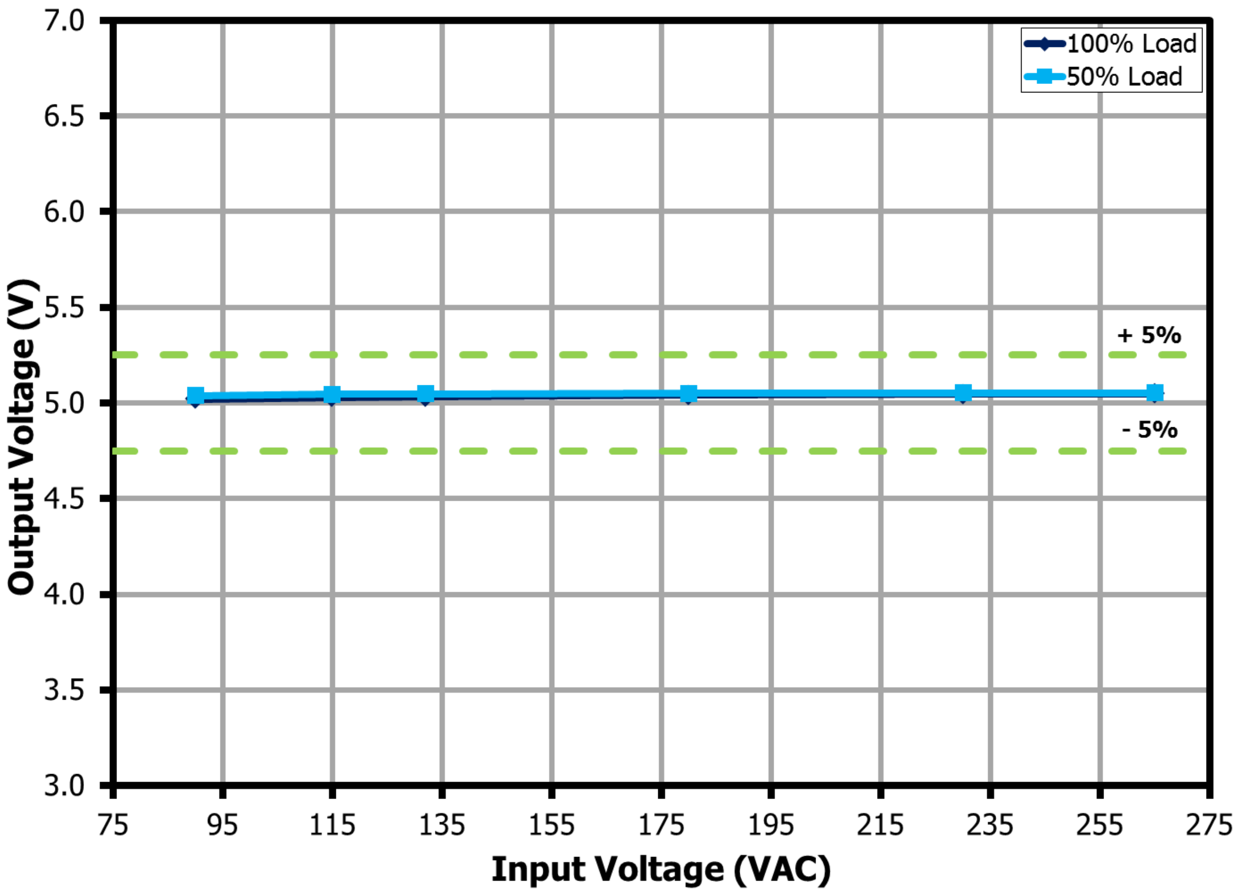

Figure 33 – Output Voltage vs. Input Line Voltage for 5 V Output, Room Temperature.

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12.6.2 Output: 9 V / 3 A

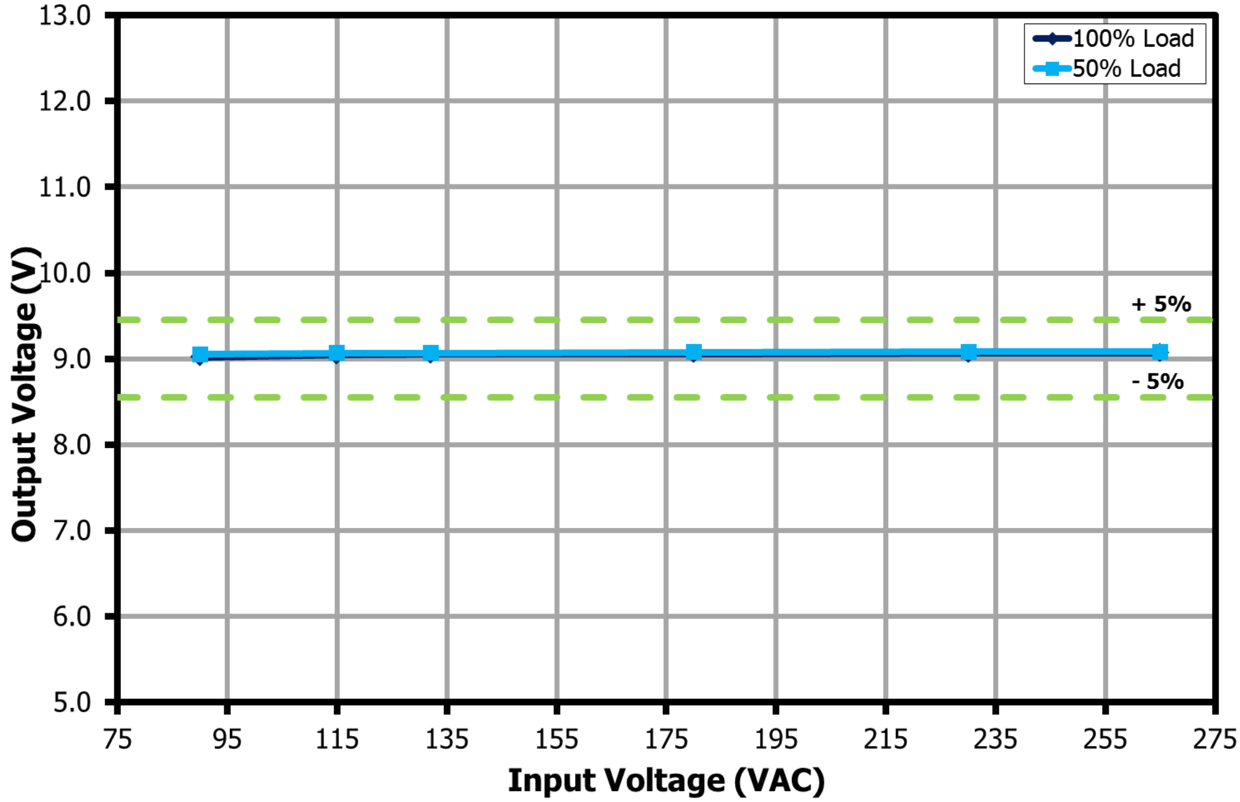

Figure 34 – Output Voltage vs. Input Line Voltage for 9 V Output, Room Temperature.

12.6.3 Output: 15 V / 3 A

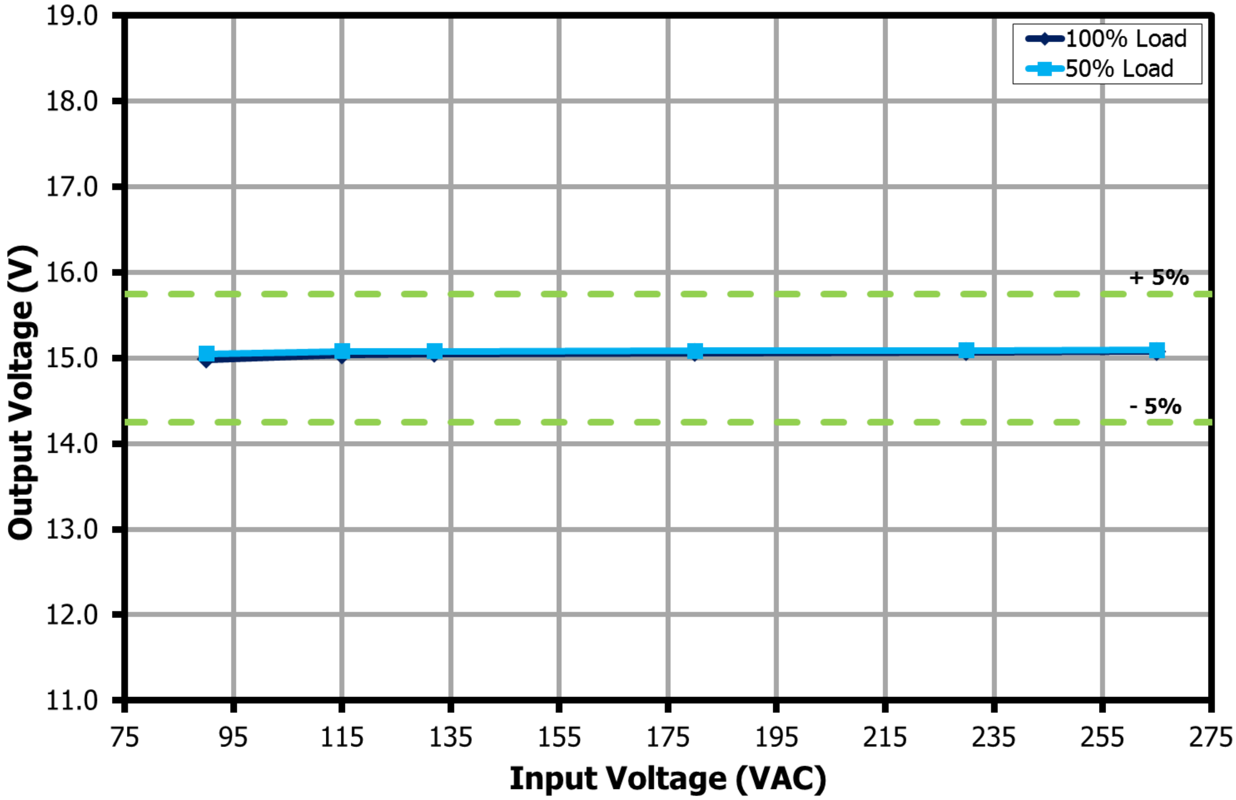

Figure 35 – Output Voltage vs. Input Line Voltage for 15 V Output, Room Temperature.

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12.6.4 Output: 20 V / 3 A

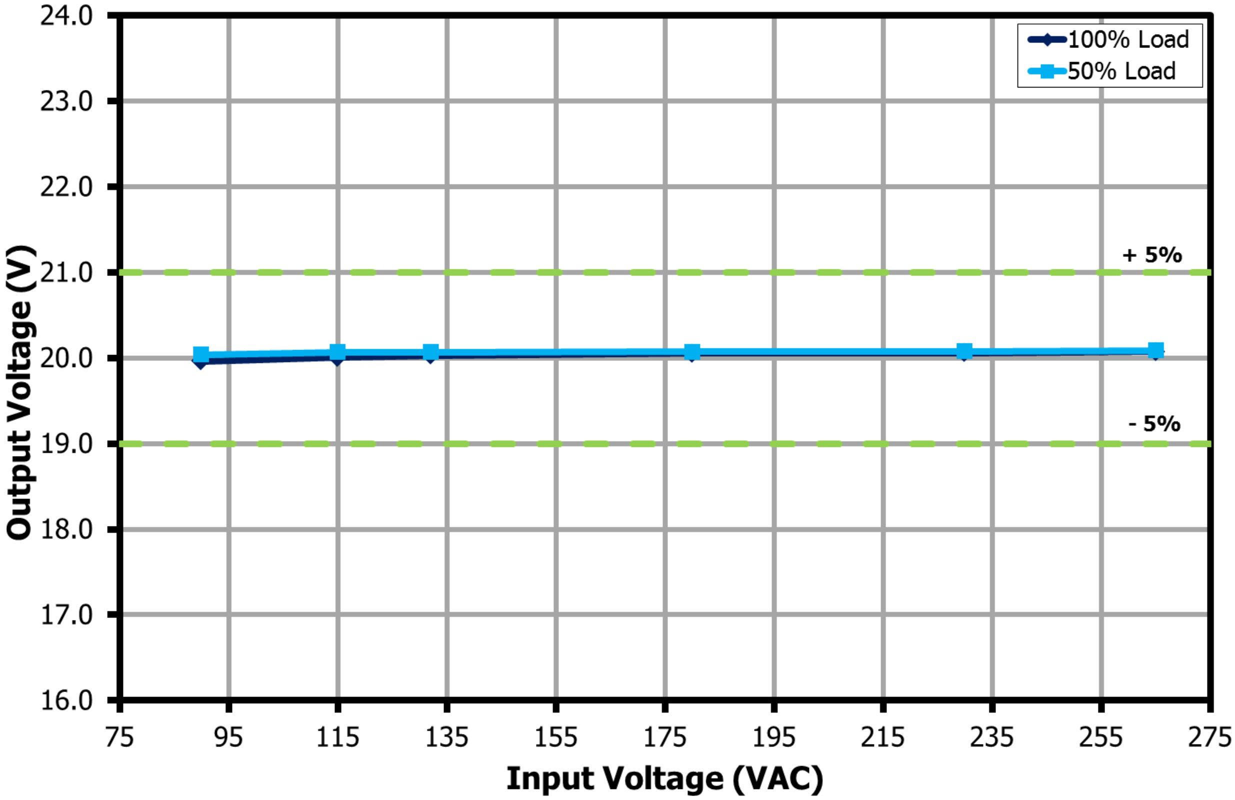

Figure 36 – Output Voltage vs. Input Line Voltage for 20 V Output, Room Temperature.

13 Thermal Performance

13.1 *Thermal Performance in Open Case*

Note 1: InnoSwitch3-Pro Source Pin temperature measured with Type-T thermocouple.
2: Measurements taken at room temperature (approximately 24 °C).

13.1.1 Output: 20 V / 3 A (90 VAC)

InnoSwitch3-Pro temperature (thermocouple) = 85.4 °C.

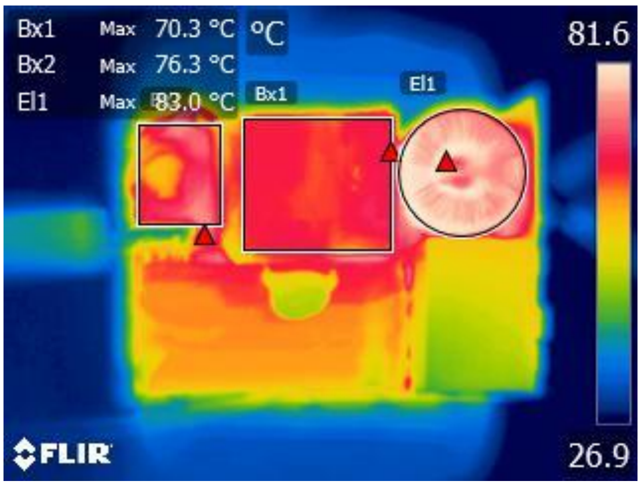

Figure 37 – Top Thermal Image.
Bx1: Transformer T1 = 70.3 ºC.
Bx2: Secondary Winding and SR FET, PCB = 76.3 ºC.
El1: CMC L2 = 83.0 ºC.

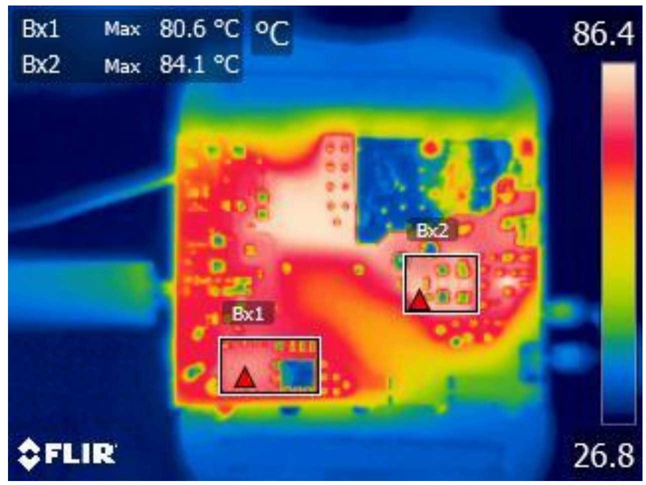

Figure 38 – Bottom Thermal Image.
Bx1: SR FET Q2 = 80.6 ºC.
Bx2: Primary Snubber = 84.1 ºC.
InnoSwitch3-Pro = 85.4 ºC.

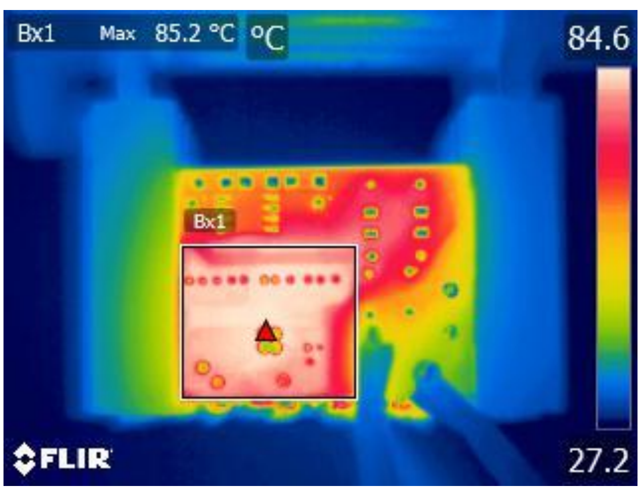

Figure 39 – Side Thermal Image.
El1: Bridge BR1-BR2, PCB = 85.2 ºC.

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13.1.2 Output: 20 V / 3 A (265 VAC)

InnoSwitch3-Pro temperature (thermocouple) = 67.5 °C.

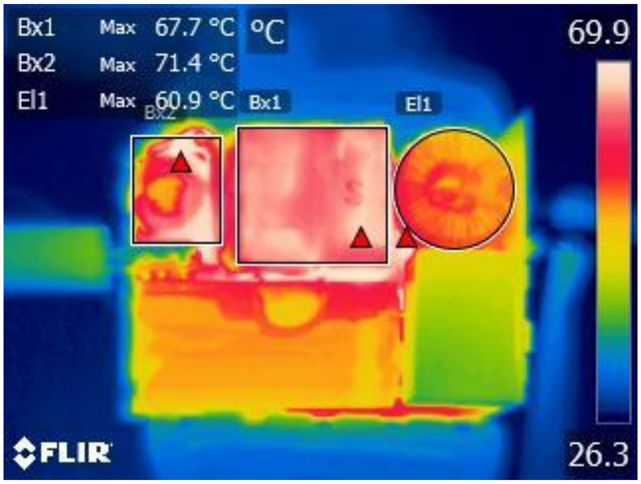

Figure 40 – Top Thermal Image.
Bx1: Transformer T1 = 67.7 ºC.
Bx2: Secondary Winding and SR FET, PCB = 71.4 ºC.
El1: CMC L2 = 60.9 ºC.

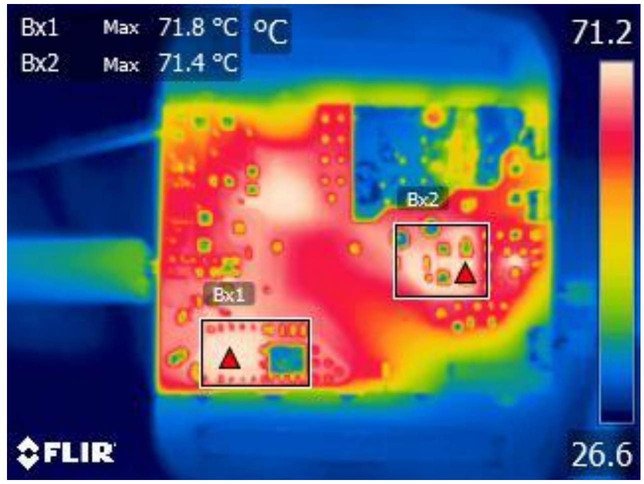

Figure 41 – Bottom Thermal Image.
Bx1: SR FET Q2 = 71.8 ºC.
Bx2: Primary Snubber = 71.4 ºC.
InnoSwitch3-Pro = 67.5 ºC.

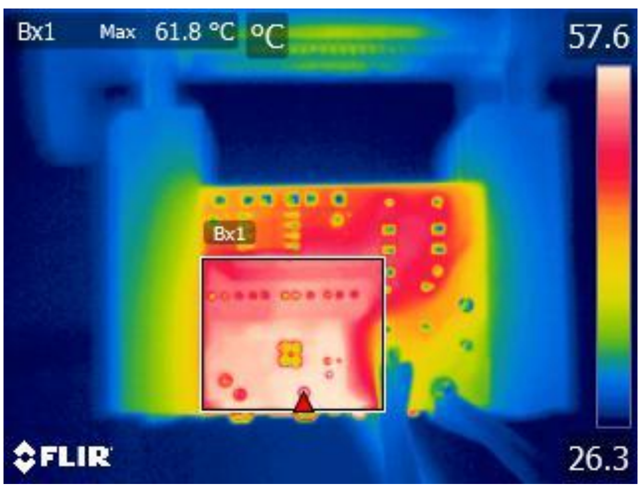

Figure 42 – Side Thermal Image.
El1: Bridge BR1-BR2, PCB = 61.8 ºC.

13.2 *Thermal Performance with Adapter Case Enclosure*

Note: Measurements taken at room temperature (approximately 24 °C).

13.2.1 Output: 20 V / 3 A (90 VAC)

Component	Temperature (°C)
Bridge Rectifier, BR1	102.2
Heat Spreader	92.0
Transformer, T1	92.2
InnoSwitch3-Pro	93.5
CMC, L2	90.9
Bulk Capacitor, C2	90.9
SR FET, Q2	89.2
Board	79.0

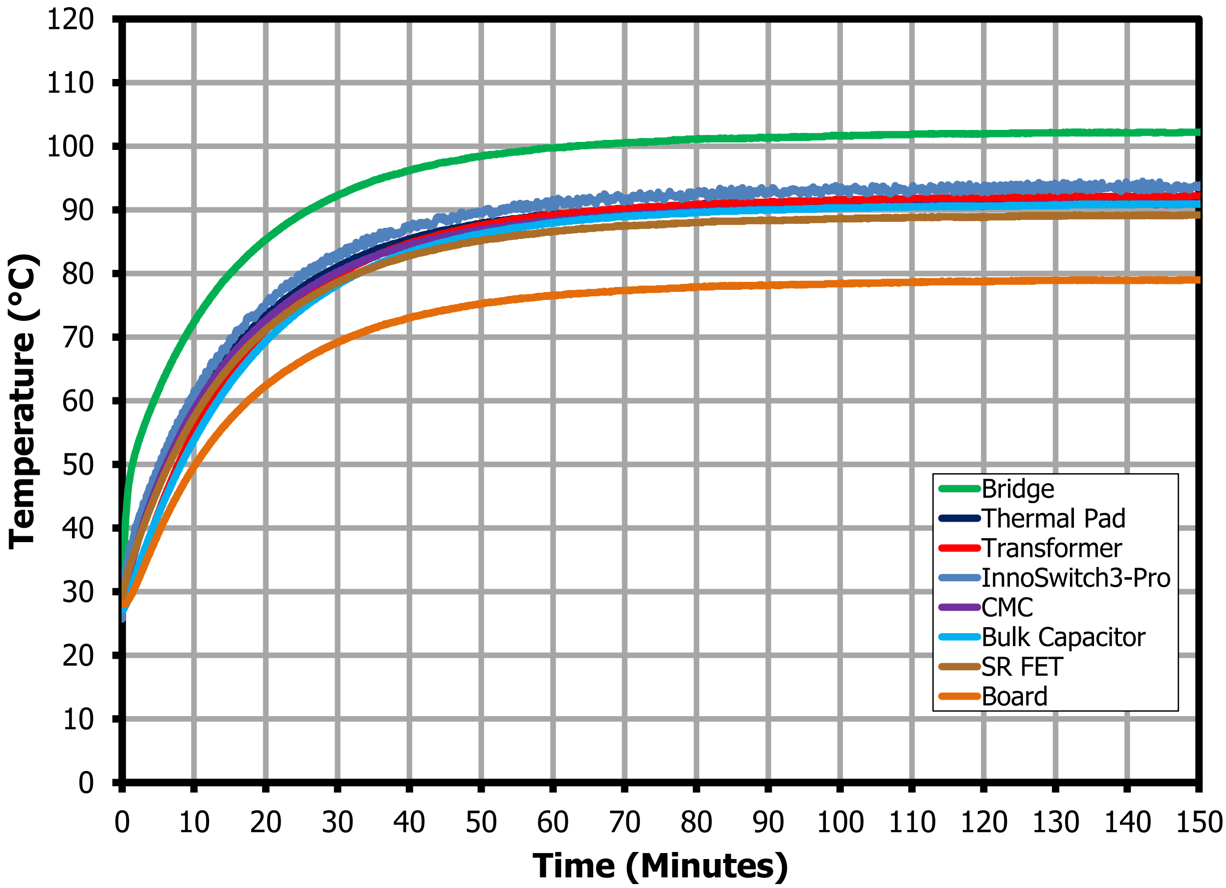

Figure 43 – Enclosed Unit Thermal Performance at 90 VAC, Room Temperature.

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13.2.2 Output: 20 V / 3 A (265 VAC)

Component	Temperature (°C)
Bridge Rectifier, BR1	74.7
Heat Spreader	75.9
Transformer, T1	80.6
InnoSwitch3-Pro	77.6
CMC, L2	72.2
Bulk Capacitor, C2	74.6
SR FET, Q2	77.4
Board	67.8

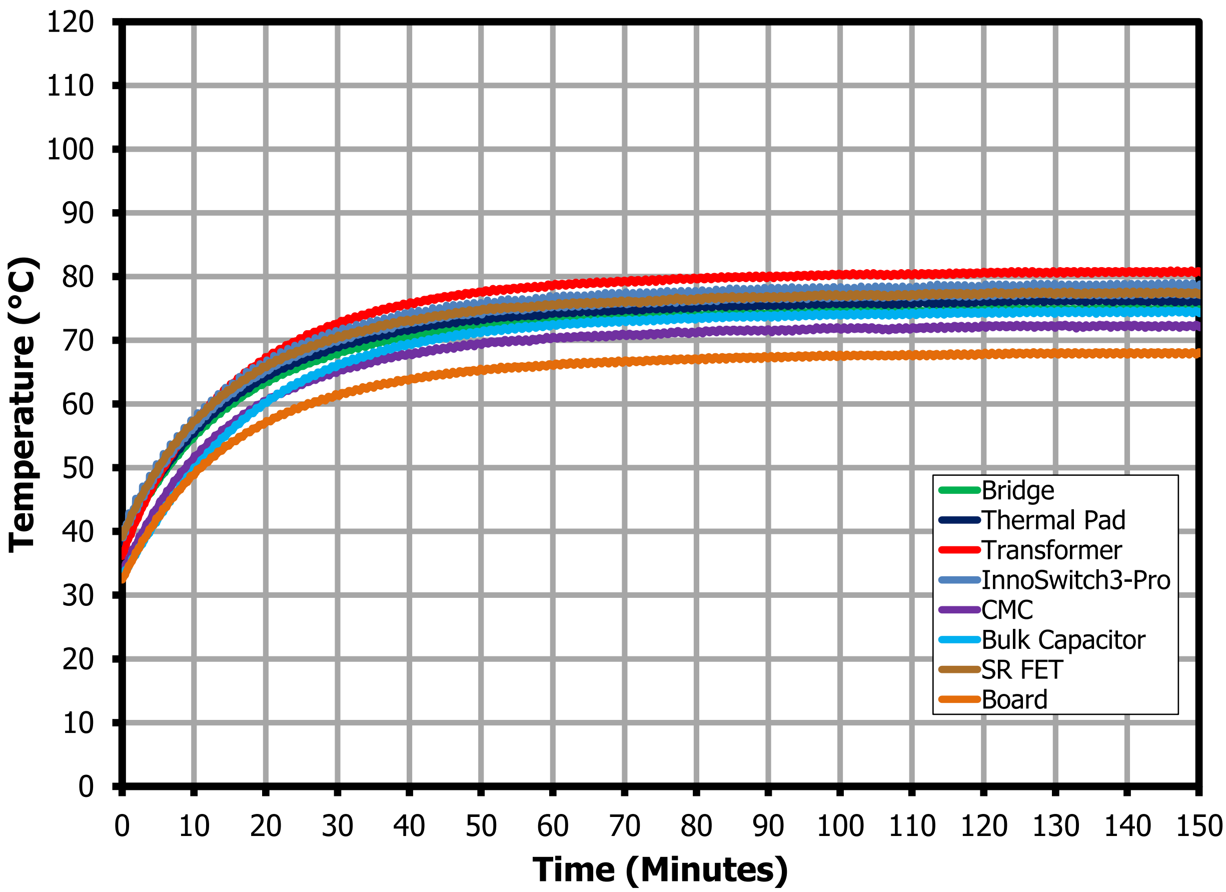

Figure 44 – Enclosed Unit Thermal Performance at 265 VAC, Room Temperature.

14 Waveforms

Note: Measurements taken at room temperature (approximately 24 °C).

14.1 *Start-up Waveforms*

14.1.1 Output Voltage and Current

Note: Output voltages captured at the end of 100 mΩ cable.

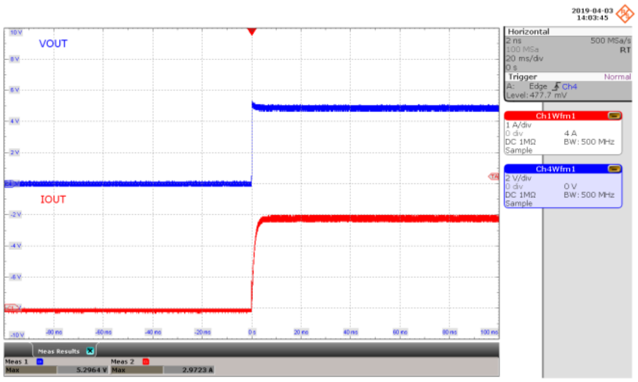

Figure 45 – Output Voltage and Current.
90 VAC, 5.0 V, 3 A Load (5.29 V_{MAX}).
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 20 ms / div.

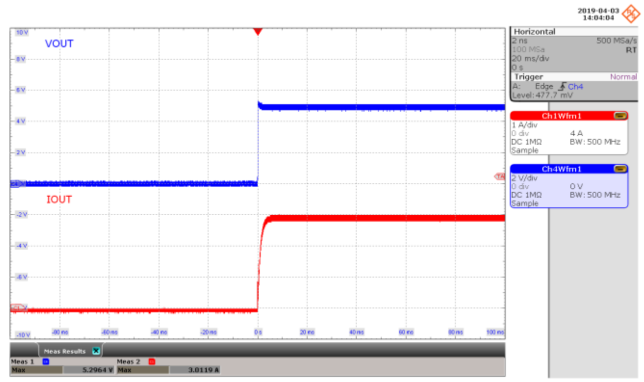

Figure 46 – Output Voltage and Current.
265 VAC, 5.0 V, 3 A Load (5.29 V_{MAX}).
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 20 ms / div.

14.1.2 Primary Drain Voltage and Current

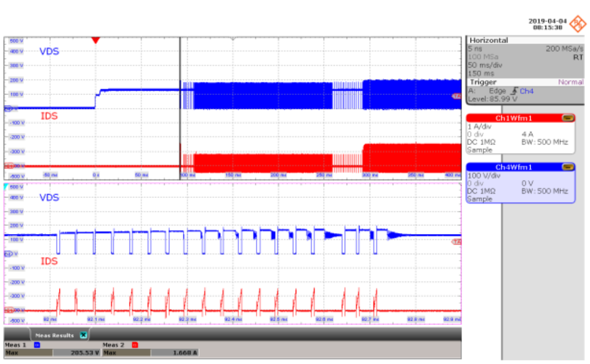

Figure 47 – Primary Drain Voltage and Current.
90 VAC, 5.0 V, 3 A Load (205 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 50 ms / div. (100 µs / div. Zoom)

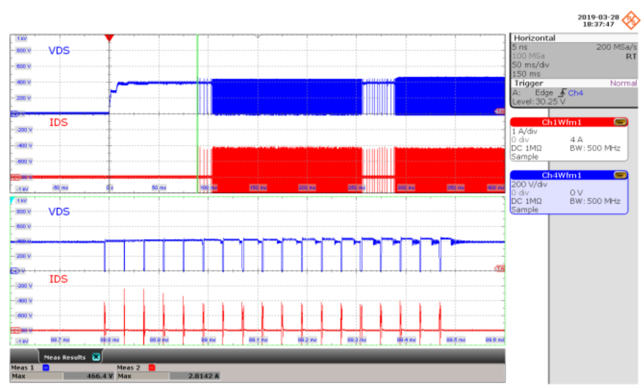

Figure 48 – Primary Drain Voltage and Current.
265 VAC, 5.0 V, 3 A Load (466 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 50 ms / div. (100 µs / div. Zoom)

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14.1.3 SR FET Drain Voltage and Current

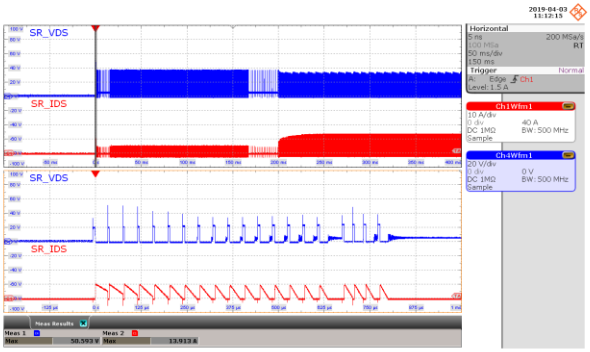

Figure 49 – SR FET Drain Voltage and Current.
90 VAC, 5.0 V, 3 A Load (50.5 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 50 ms / div. (125 µs / div. Zoom)

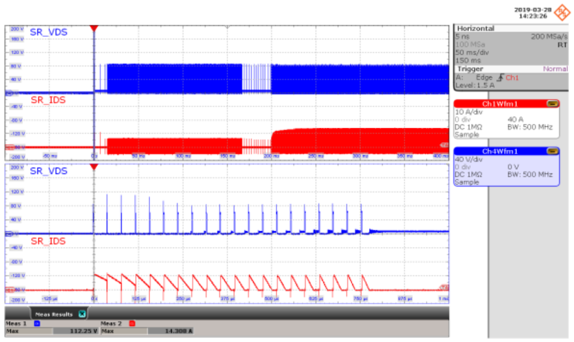

Figure 50 – SR FET Drain Voltage and Current.
265 VAC, 5.0 V, 3 A Load (112 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 40 V / div.
CH1: $I_{DRAIN(SR)}$, 1 A / div.
Time: 50 ms / div. (125 µs / div. Zoom)

14.2 ***Load Transient Response***

Note: Output voltages captured at the end of 100 mΩ cable.

14.2.1 Output: 5 V / 3 A

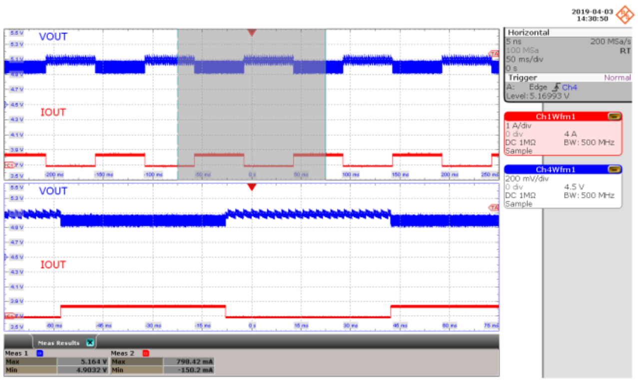

Figure 51 – Transient Response.
90 VAC, 5.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 4.903 V, V_{MAX}: 5.164 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

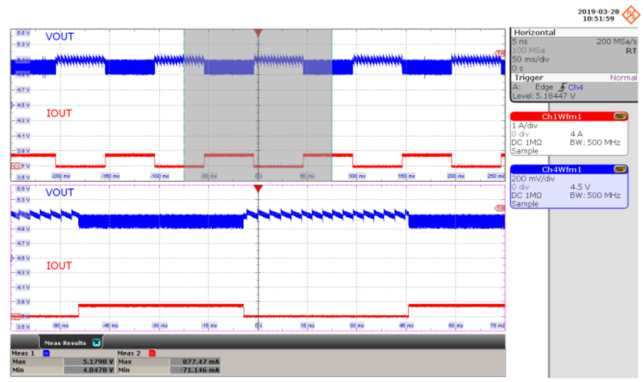

Figure 52 – Transient Response.
265 VAC, 5.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 4.847 V, V_{MAX}: 5.179 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

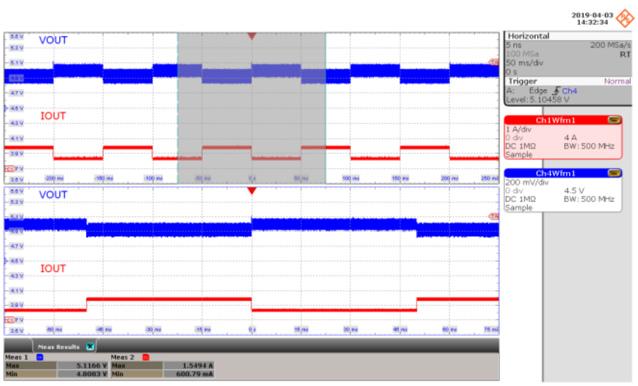

Figure 53 – Transient Response.
90 VAC, 5.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 4.803 V, V_{MAX}: 5.116 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

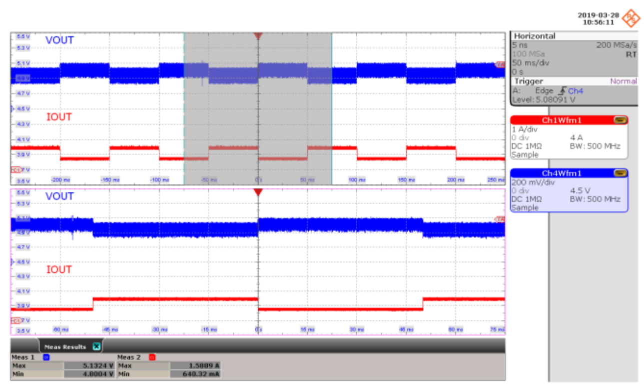

Figure 54 – Transient Response.
265 VAC, 5.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 4.800 V, V_{MAX}: 5.132 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

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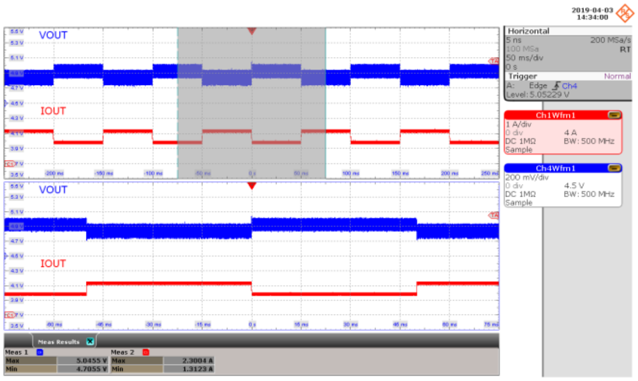

Figure 55 – Transient Response.
90 VAC, 5.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 4.705 V, V_{MAX}: 5.045 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

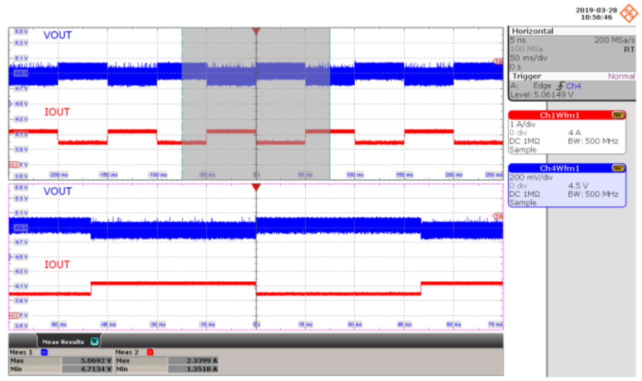

Figure 56 – Transient Response.
265 VAC, 5.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 4.713 V, V_{MAX}: 5.069 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

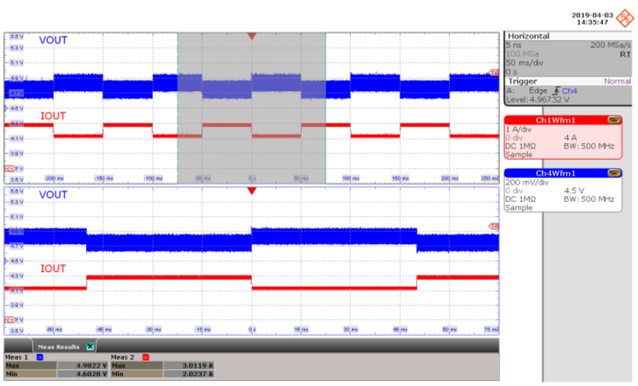

Figure 57 – Transient Response.
90 VAC, 5.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 4.602 V, V_{MAX}: 4.982 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

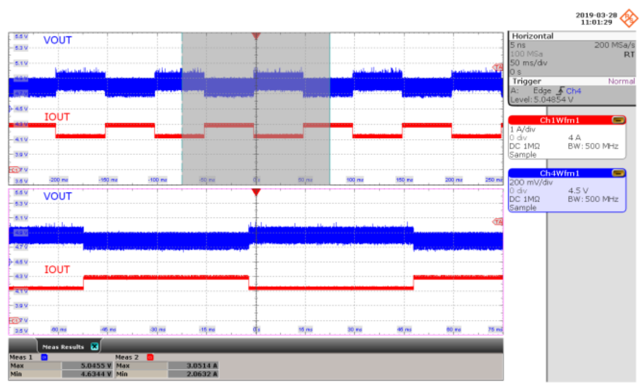

Figure 58 – Transient Response.
265 VAC, 5.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 4.634 V, V_{MAX}: 5.045 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

14.2.2 Output: 9 V / 3 A

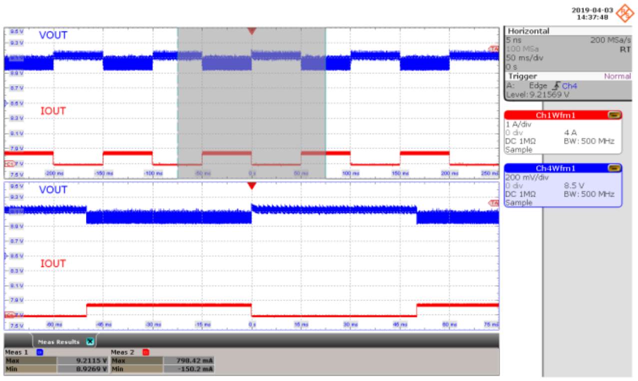

Figure 59 – Transient Response.
90 VAC, 9.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 8.926 V, V_{MAX}: 9.211 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

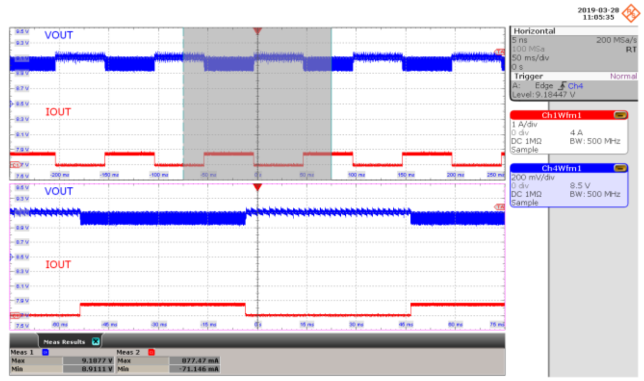

Figure 60 – Transient Response.
265 VAC, 9.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 8.911 V, V_{MAX}: 9.187 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

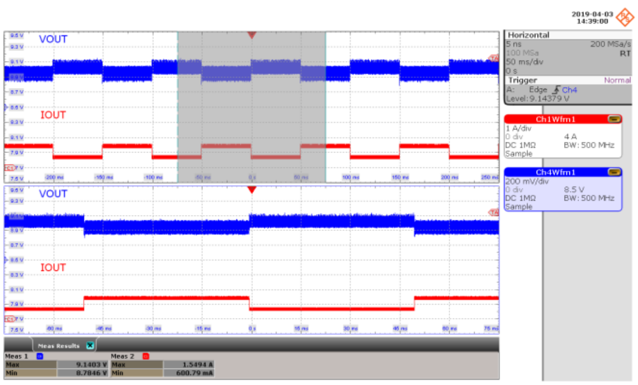

Figure 61 – Transient Response.
90 VAC, 9.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 8.784 V, V_{MAX}: 9.140 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

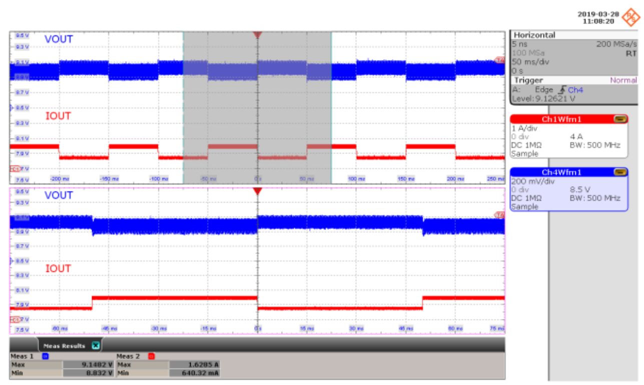

Figure 62 – Transient Response.
265 VAC, 9.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 8.832 V, V_{MAX}: 9.148 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

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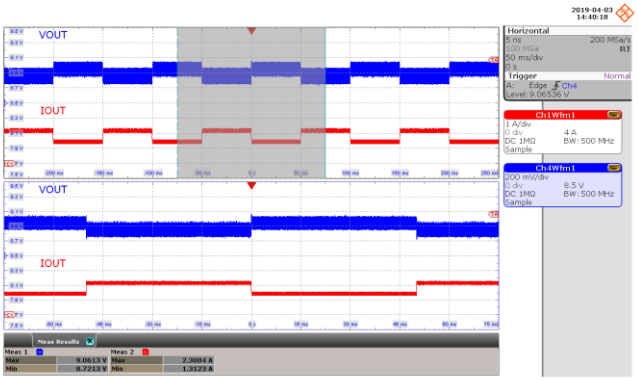

Figure 63 – Transient Response.
90 VAC, 9.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 8.721 V, V_{MAX}: 9.061 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

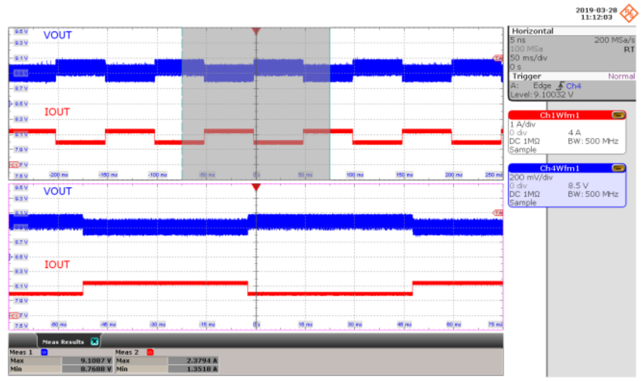

Figure 64 – Transient Response.
265 VAC, 9.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 8.768 V, V_{MAX}: 9.108 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

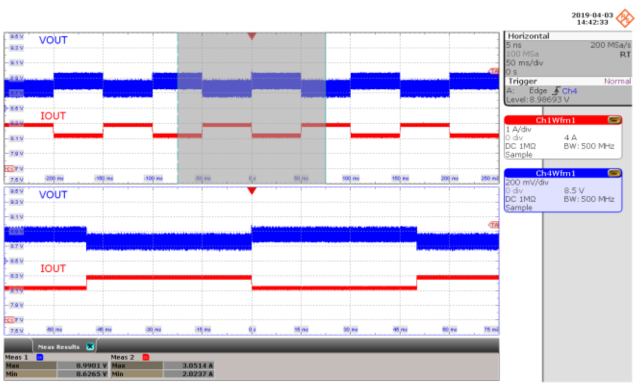

Figure 65 – Transient Response.
90 VAC, 9.0 V, 2.25 –3 A Load Step.
V_{MIN}: 8.626 V, V_{MAX}: 8.990 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

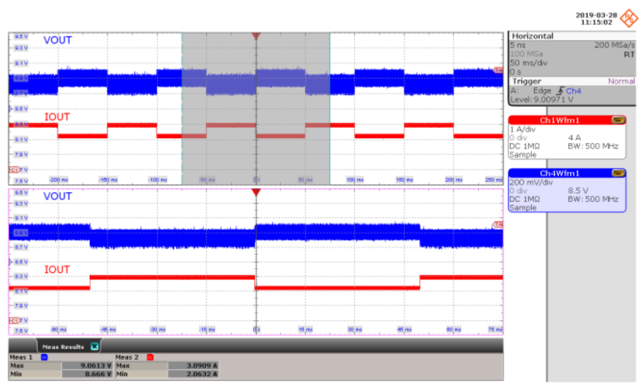

Figure 66 – Transient Response.
265 VAC, 9.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 8.666 V, V_{MAX}: 9.061 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

14.2.3 Output: 15 V / 3 A

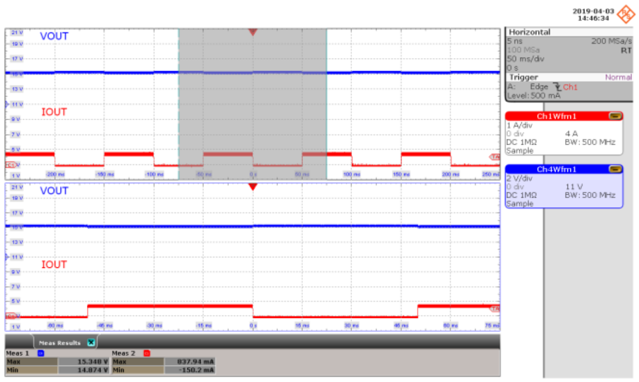

Figure 67 – Transient Response.
90 VAC, 15.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 14.874 V, V_{MAX}: 15.348 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

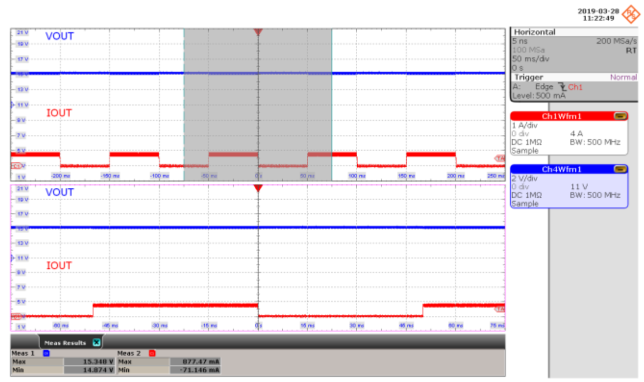

Figure 68 – Transient Response.
265 VAC, 15.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 14.874 V, V_{MAX}: 15.348 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

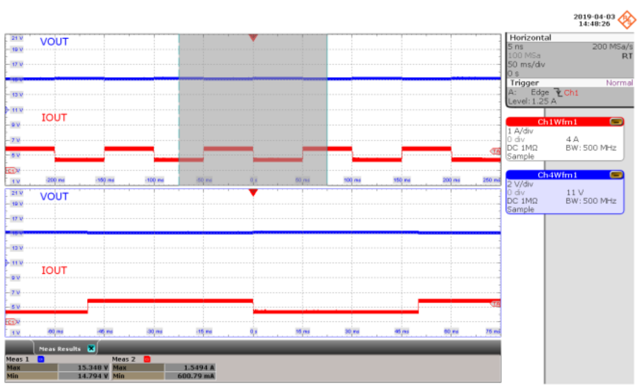

Figure 69 – Transient Response.
90 VAC, 15.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 14.794 V, V_{MAX}: 15.348 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

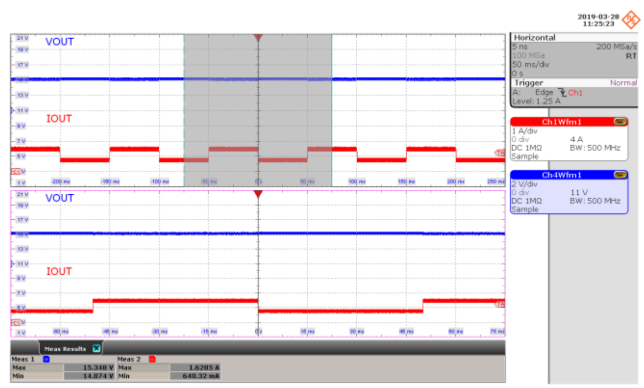

Figure 70 – Transient Response.
265 VAC, 15.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 14.874 V, V_{MAX}: 15.348 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

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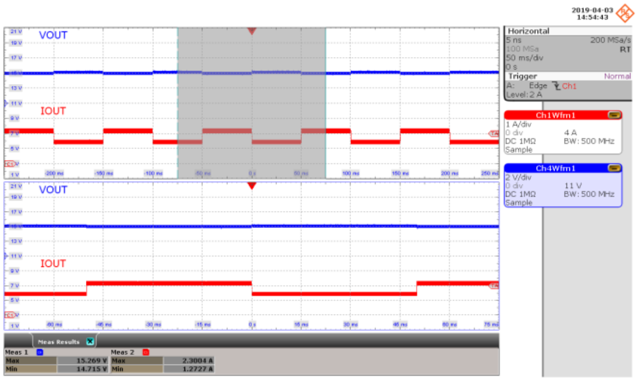

Figure 71 – Transient Response.
90 VAC, 15.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 14.715 V, V_{MAX}: 15.269 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

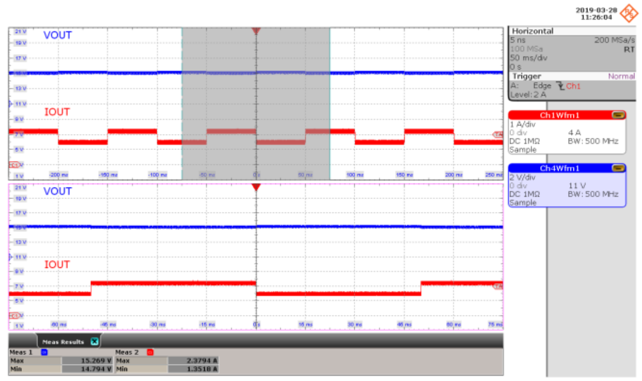

Figure 72 – Transient Response.
265 VAC, 15.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 14.794 V, V_{MAX}: 15.269 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

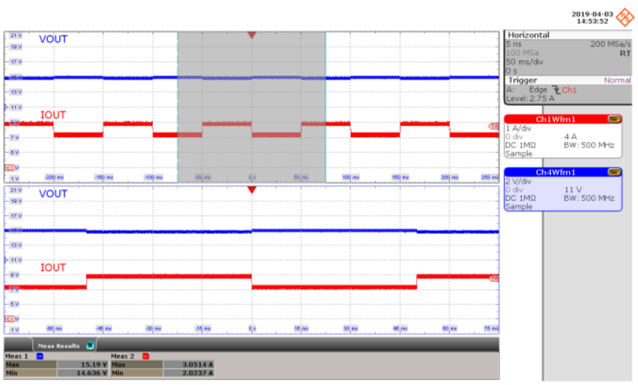

Figure 73 – Transient Response.
90 VAC, 15.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 14.636 V, V_{MAX}: 15.190 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

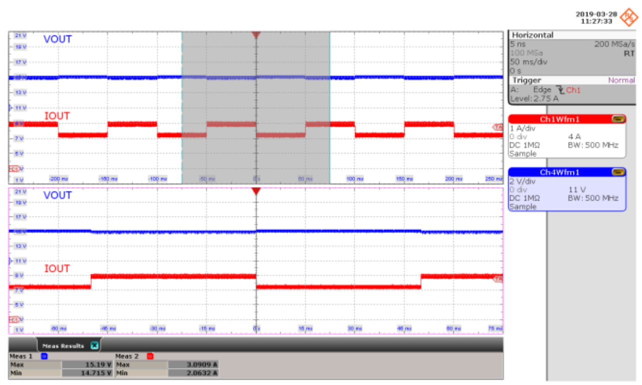

Figure 74 – Transient Response.
265 VAC, 15.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 14.715 V, V_{MAX}: 15.190 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

14.2.4 Output: 20 V / 3 A

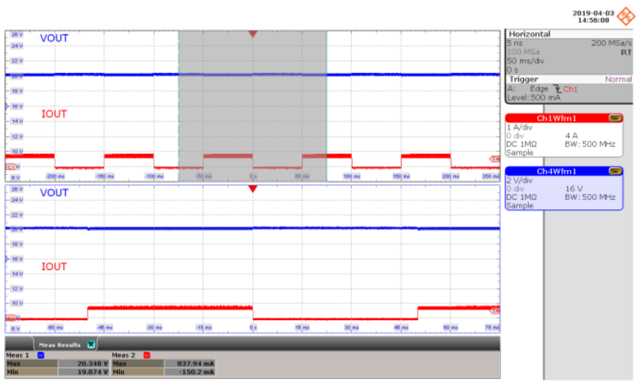

Figure 75 – Transient Response.
90 VAC, 20.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 19.874 V, V_{MAX}: 20.348 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

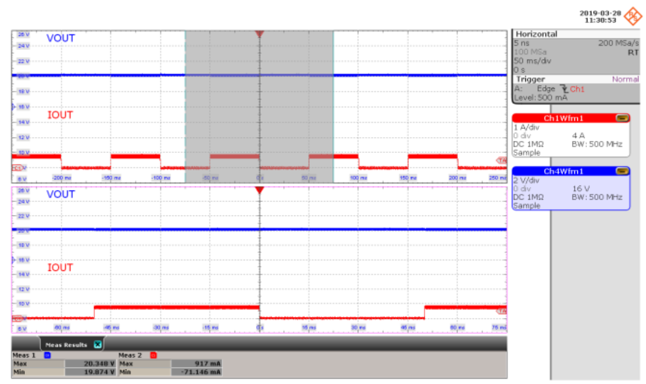

Figure 76 – Transient Response.
265 VAC, 20.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 19.874 V, V_{MAX}: 20.348 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

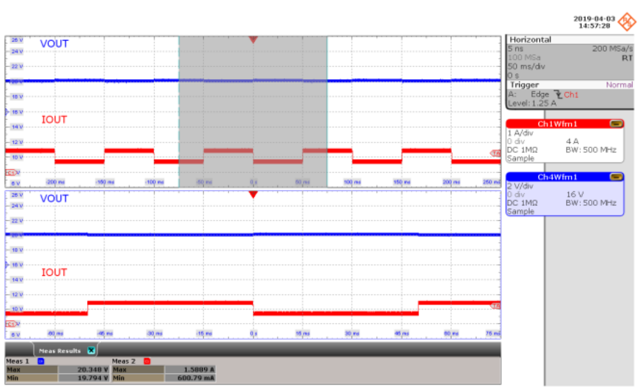

Figure 77 – Transient Response.
90 VAC, 20.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 19.794 V, V_{MAX}: 20.348 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

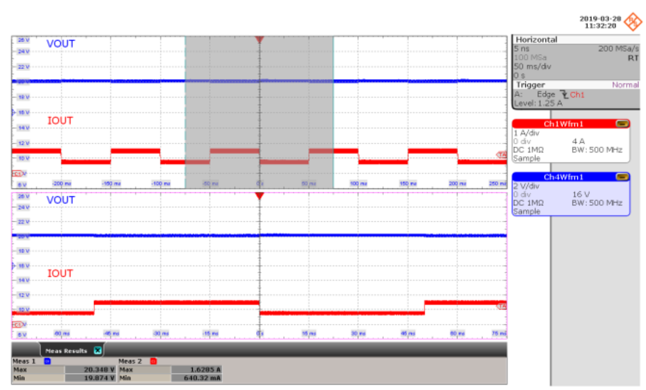

Figure 78 – Transient Response.
265 VAC, 20.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 19.874 V, V_{MAX}: 20.348 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

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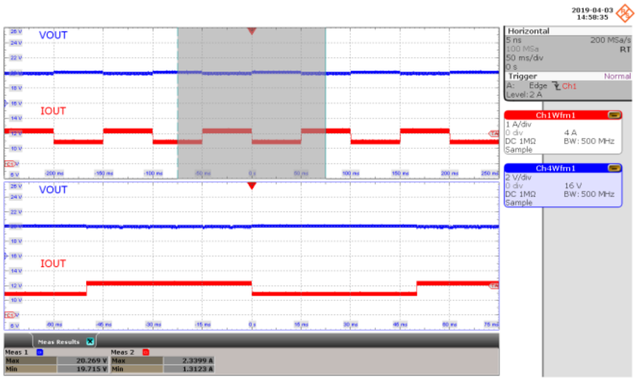

Figure 79 – Transient Response.
90 VAC, 20.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 19.715 V, V_{MAX}: 20.269 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

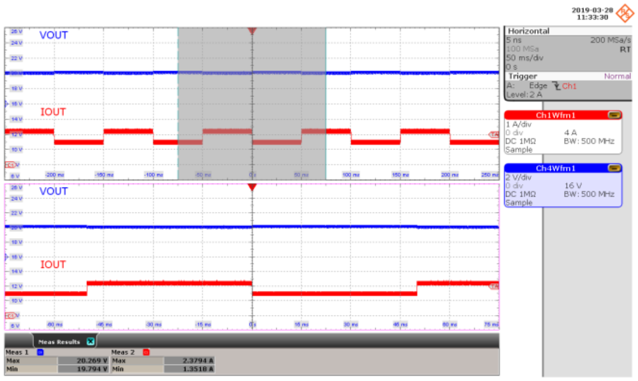

Figure 80 – Transient Response.
265 VAC, 20.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 19.794 V, V_{MAX}: 20.269 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

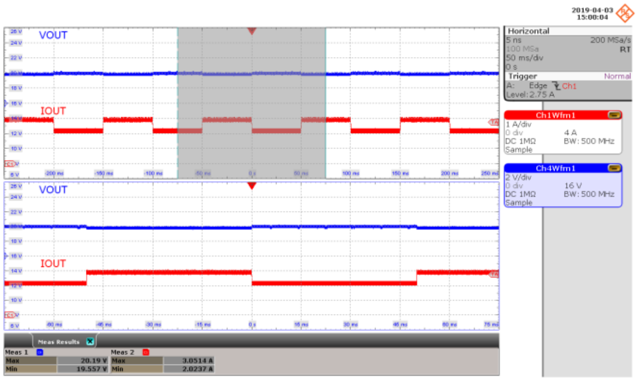

Figure 81 – Transient Response.
90 VAC, 20.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 19.557 V, V_{MAX}: 20.190 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

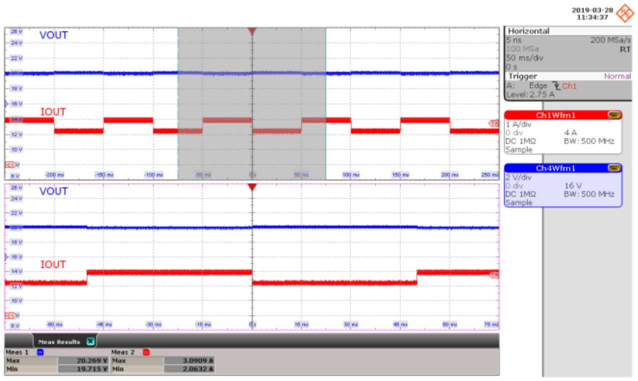

Figure 82 – Transient Response.
265 VAC, 20.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 19.715 V, V_{MAX}: 20.269 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 50 ms / div. (15 ms / div. Zoom)

14.3 ***Primary Drain Voltage and Current (Steady-state)***

14.3.1 Output: 5 V / 3 A

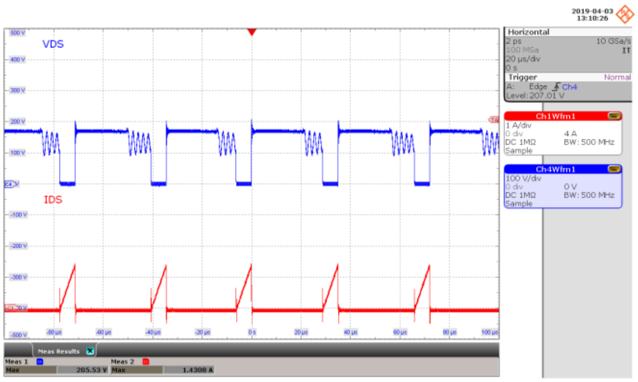

Figure 83 – Primary Drain Voltage and Current.
90 VAC, 5.0 V, 3 A Load (205 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 us / div.

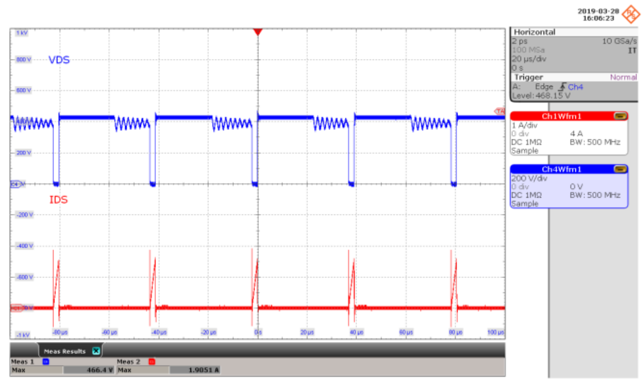

Figure 84 – Primary Drain Voltage and Current.
265 VAC, 5.0 V, 3 A Load (466 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 us / div.

14.3.2 Output: 9 V / 3 A

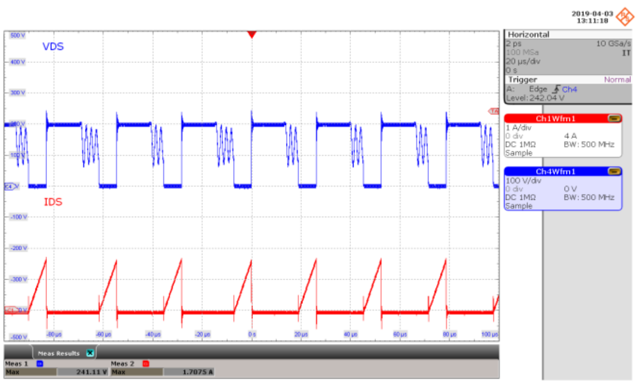

Figure 85 – Primary Drain Voltage and Current.
90 VAC, 9.0 V, 3 A Load (241 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

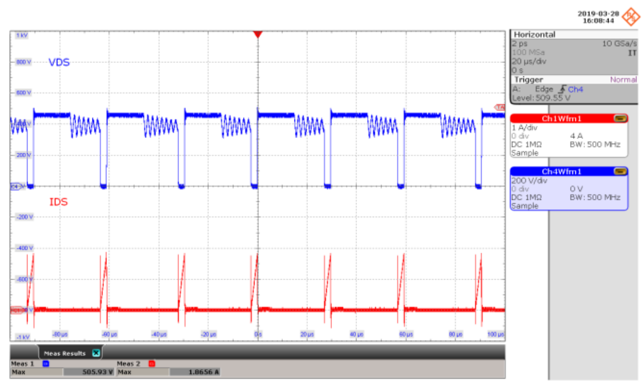

Figure 86 – Primary Drain Voltage and Current.
265 VAC, 9.0 V, 3 A Load (505 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

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14.3.3 Output: 15 V / 3 A

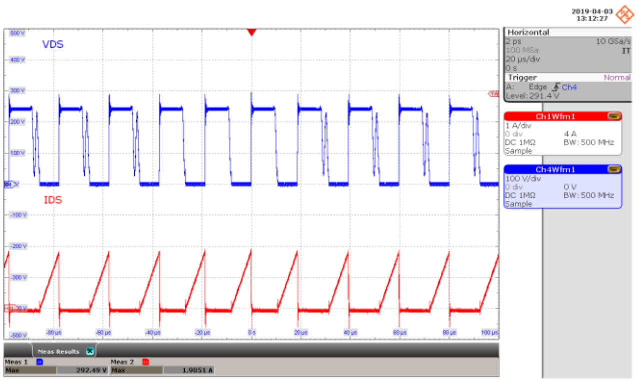

Figure 87 – Primary Drain Voltage and Current.
90 VAC, 15.0 V, 3 A Load (292 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

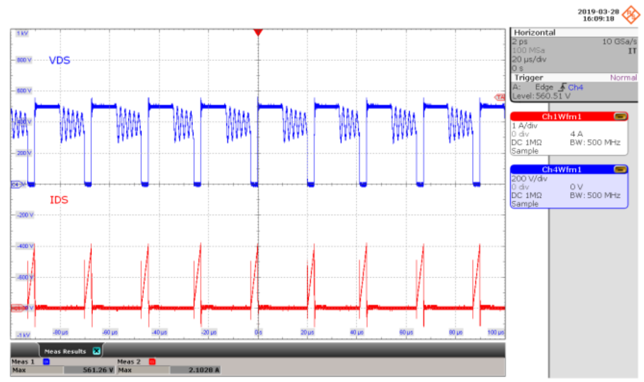

Figure 88 – Primary Drain Voltage and Current.
265 VAC, 15.0 V, 3 A Load (561 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

14.3.4 Output: 20 V / 3 A

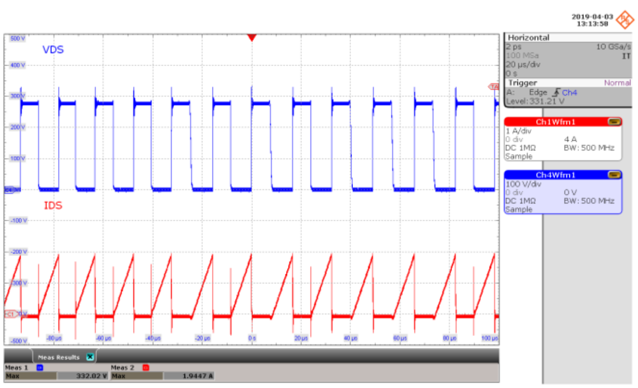

Figure 89 – Primary Drain Voltage and Current.
90 VAC, 20.0 V, 3 A Load (332 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

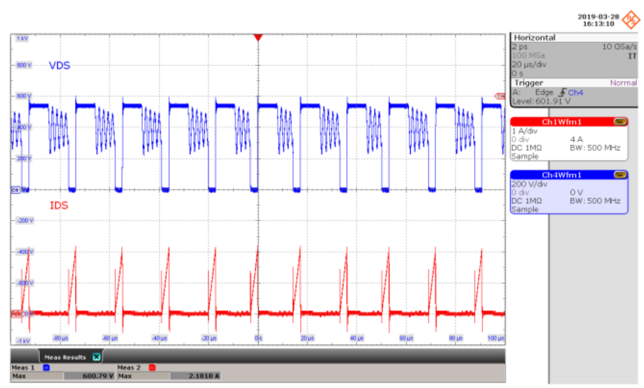

Figure 90 – Primary Drain Voltage and Current.
265 VAC, 20.0 V, 3 A Load (600 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

14.4 ***SR FET Drain Voltage and Current (Steady-state)***

14.4.1 Output: 5 V / 3 A

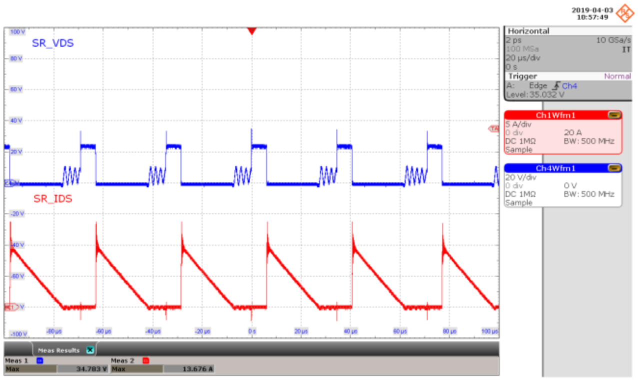

Figure 91 – SR FET Drain Voltage and Current.
90 VAC, 5.0 V, 3 A Load (34.7 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 μs / div.

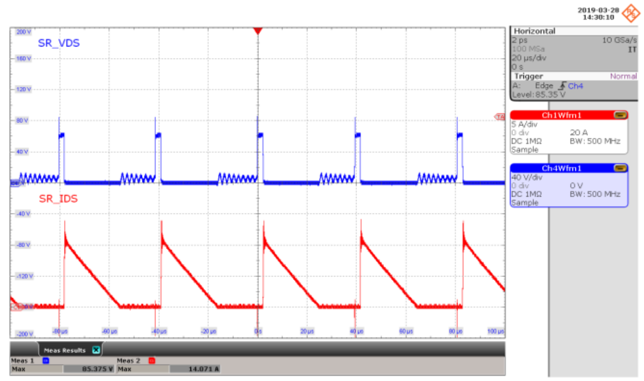

Figure 92 – SR FET Drain Voltage and Current.
265 VAC, 5.0 V, 3 A Load (85.3 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 40 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 μs / div.

14.4.2 Output: 9 V / 3 A

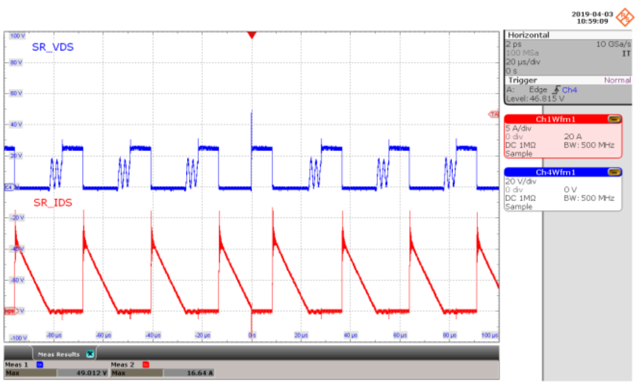

Figure 93 – SR FET Drain Voltage and Current.
90 VAC, 9.0 V, 3 A Load (49.0 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 μs / div.

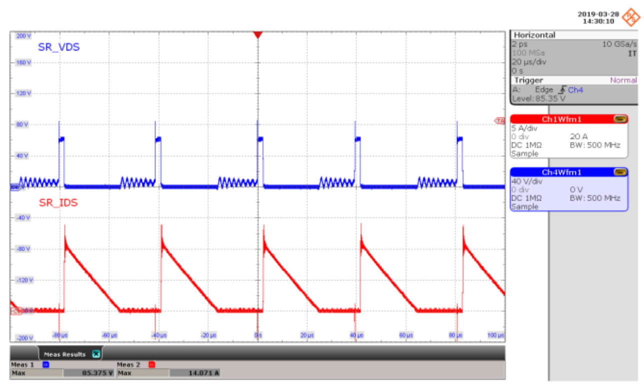

Figure 94 – SR FET Drain Voltage and Current.
265 VAC, 5.0 V, 3 A Load (85.3 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 40 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 μs / div.

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14.4.3 Output: 15 V / 3 A

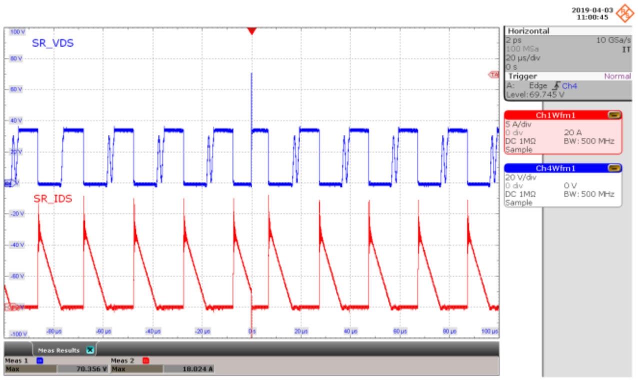

Figure 95 – SR FET Drain Voltage and Current.
90 VAC, 15.0 V, 3 A Load (70.3 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 µs / div.

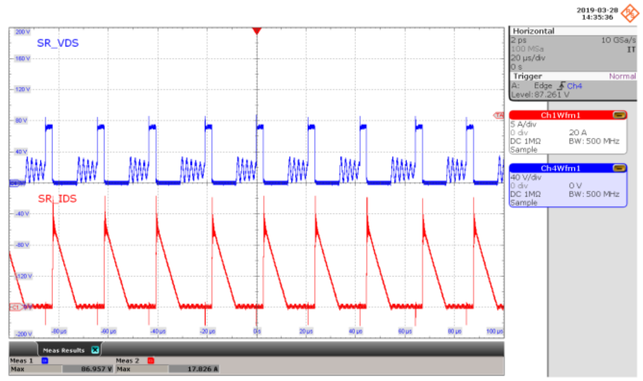

Figure 96 – SR FET Drain Voltage and Current.
265 VAC, 15.0 V, 3 A Load (86.9 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 40 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 µs / div.

14.4.4 Output: 20 V / 3 A

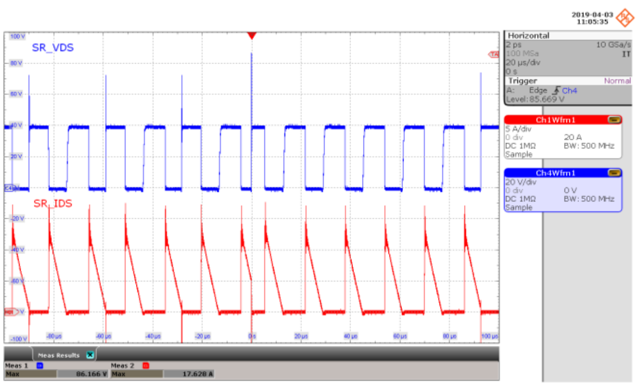

Figure 97 – SR FET Drain Voltage and Current.
90 VAC, 20.0 V, 3 A Load (86.1 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 µs / div.

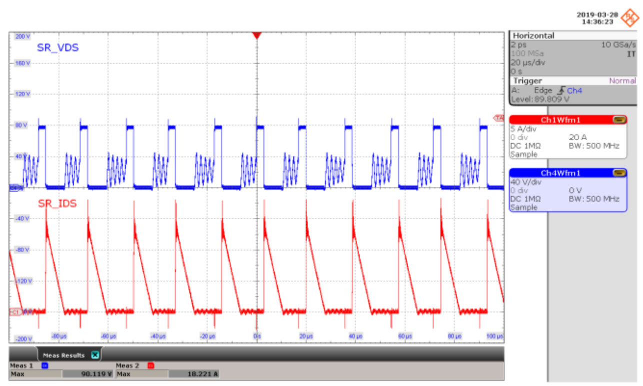

Figure 98 – SR FET Drain Voltage and Current.
265 VAC, 20.0 V, 3 A Load (90.1 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 5 A / div.
Time: 20 µs / div.

15 Output Ripple Measurements

15.1 *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).

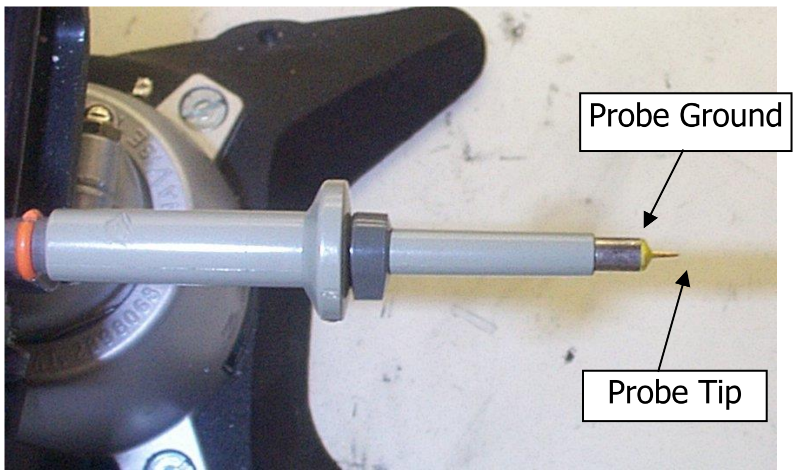

Figure 99 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

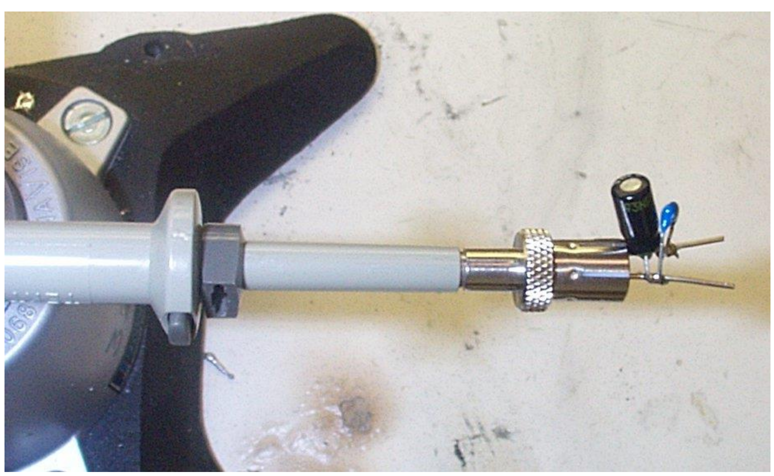

Figure 100 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

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15.2 ***Output Voltage Ripple Waveforms***

Note 1: Output voltages captured at the end of 100 mΩ cable
2: Measurements taken at room temperature (approximately 24 °C)

15.2.1 Output: 5 V / 3 A

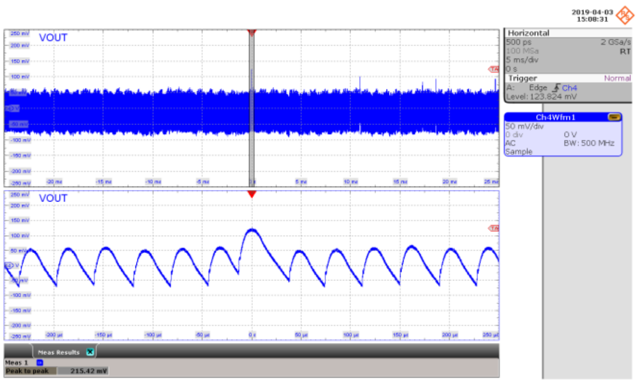

Figure 101 – Output Voltage Ripple.
90 VAC, 5.0 V, 3 A Load (215 mVpp).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

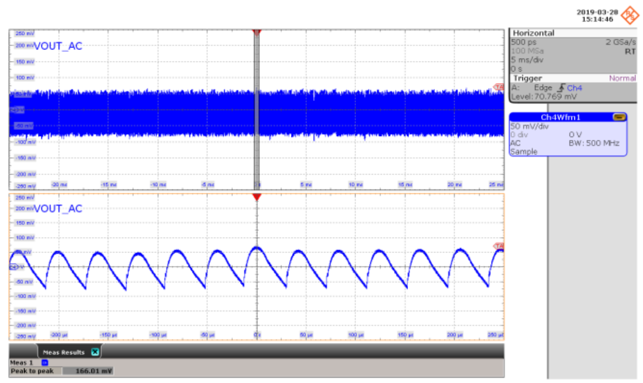

Figure 102 – Output Voltage Ripple.
265 VAC, 5.0 V, 3 A Load (166 mVpp).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

15.2.2 Output: 9 V / 3 A

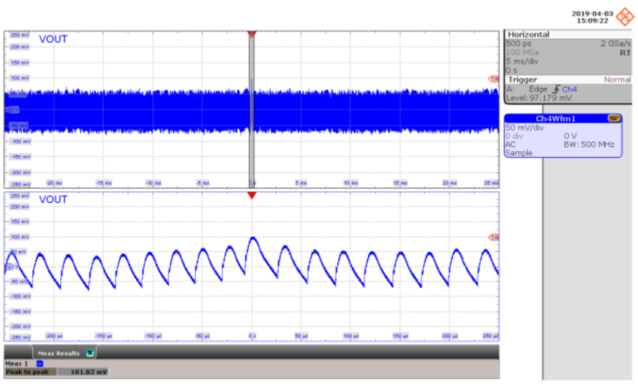

Figure 103 – Output Voltage Ripple.
90 VAC, 9.0 V, 3 A Load (181 mVpp).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

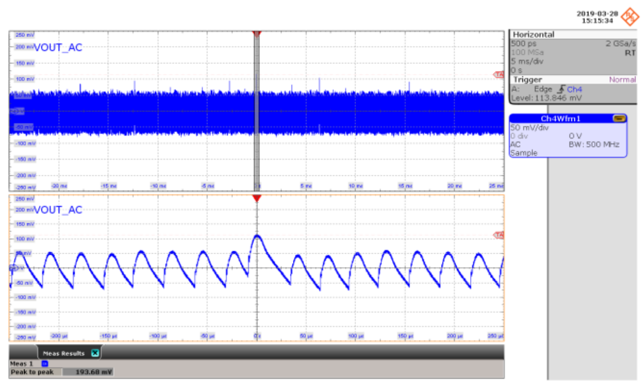

Figure 104 – Output Voltage Ripple.
265 VAC, 9.0 V, 3 A Load (193 mVpp).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

15.2.3 Output: 15 V / 3 A

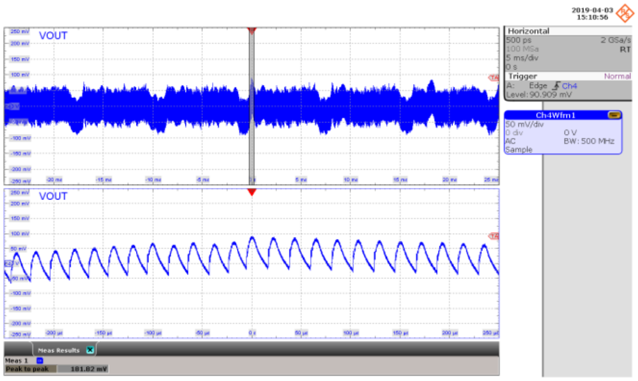

Figure 105 – Output Voltage Ripple.
90 VAC, 15.0 V, 3 A Load (181 mVpp).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

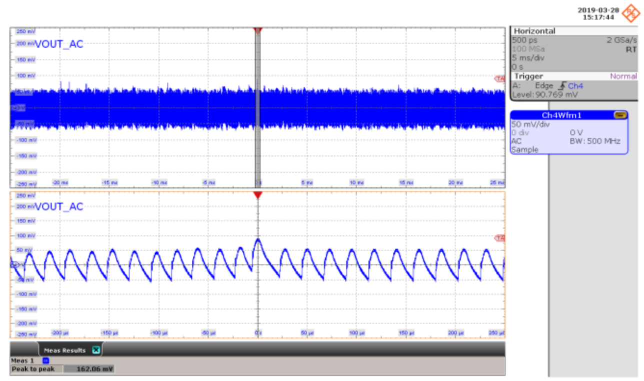

Figure 106 – Output Voltage Ripple.
265 VAC, 5.0 V, 3 A Load (76.3 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 50 mV / div.
Time: 10 µs / div.

15.2.4 Output: 20 V / 3 A

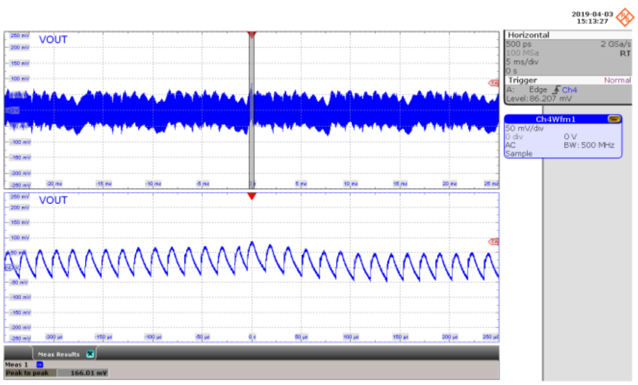

Figure 107 – Output Voltage Ripple.
90 VAC, 20.0 V, 3 A Load (166 mVpp).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

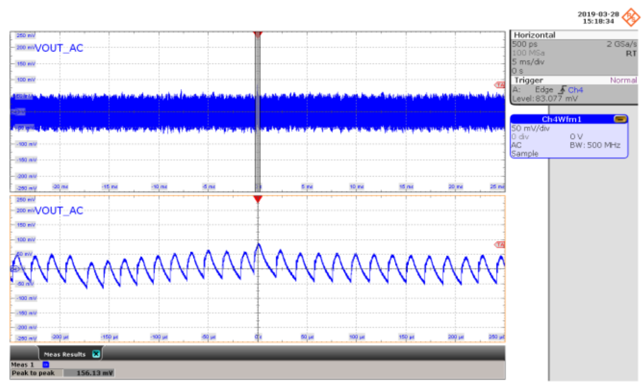

Figure 108 – Output Voltage Ripple.
265 VAC, 20.0 V, 3 A Load (156 mVpp).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

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15.3 *Output Voltage Ripple Amplitude vs. Load*

15.3.1 Output: 5 V / 3 A

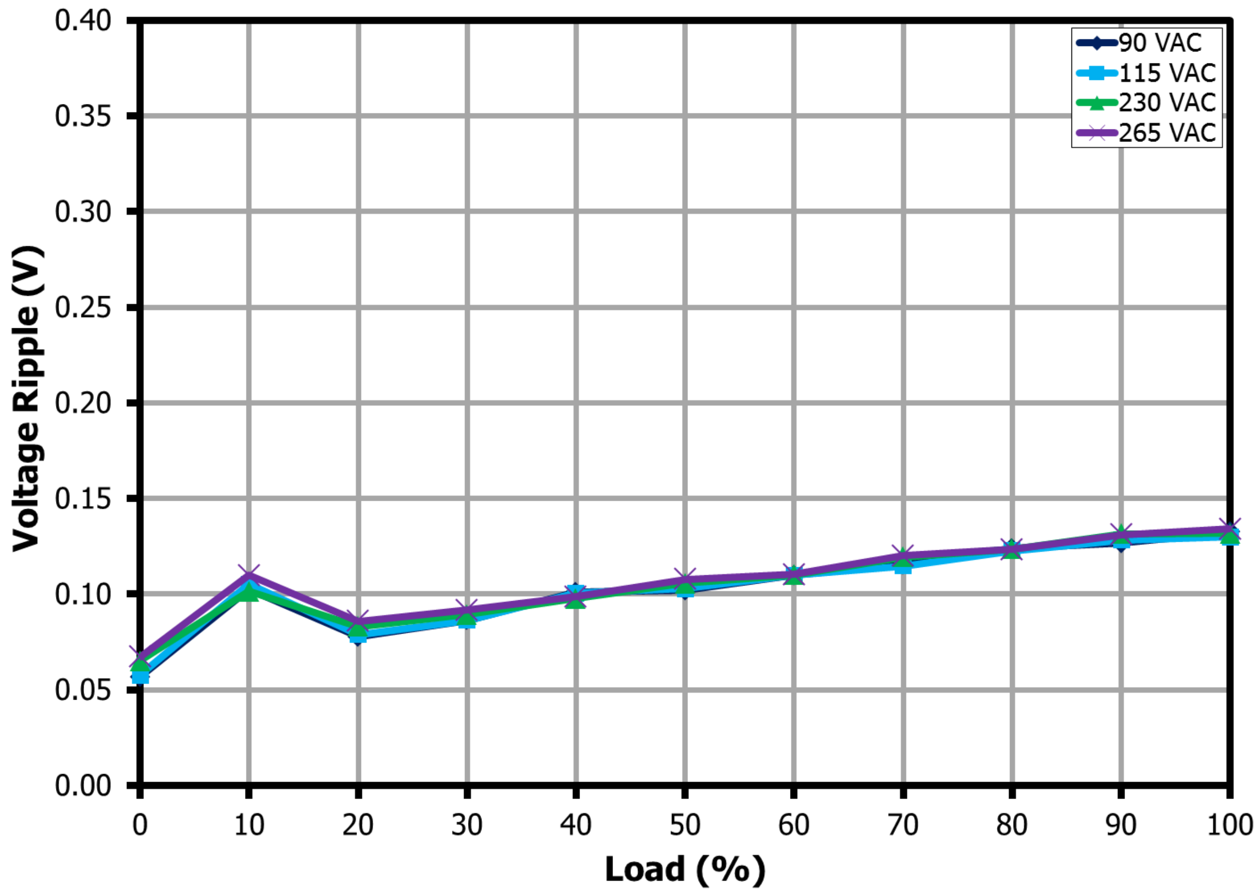

Figure 109 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 5 V Output.

15.3.2 Output: 9 V / 3 A

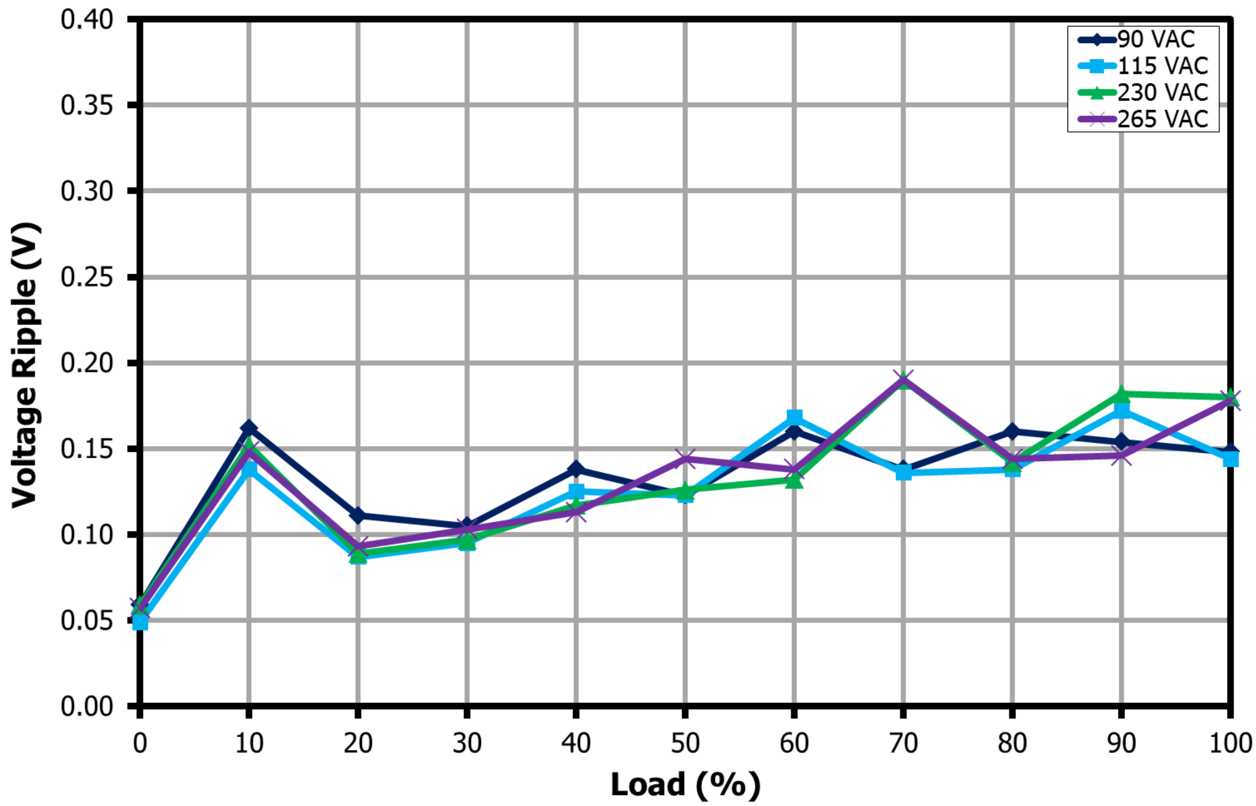

Figure 110 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 9 V Output.

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15.3.3 Output: 15 V / 3 A

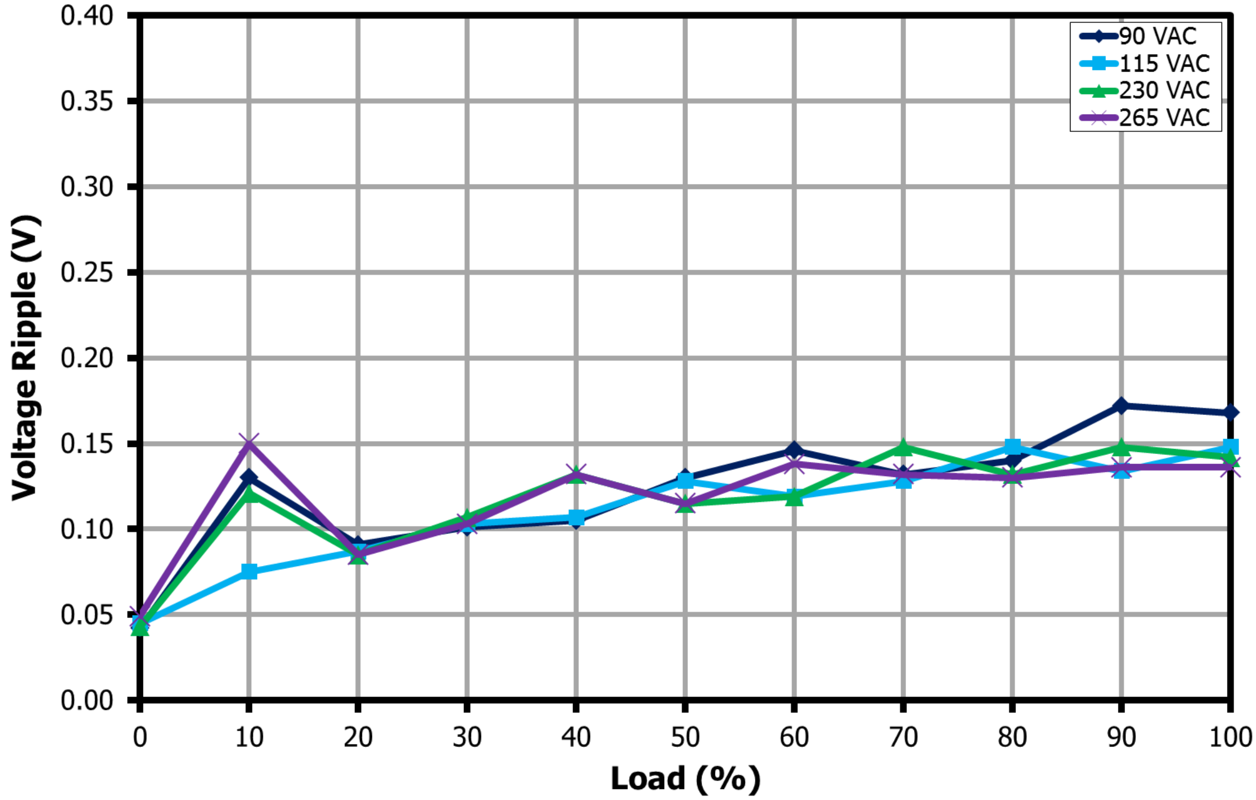

Figure 111 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 15 V Output.

15.3.4 Output: 20 V / 3 A

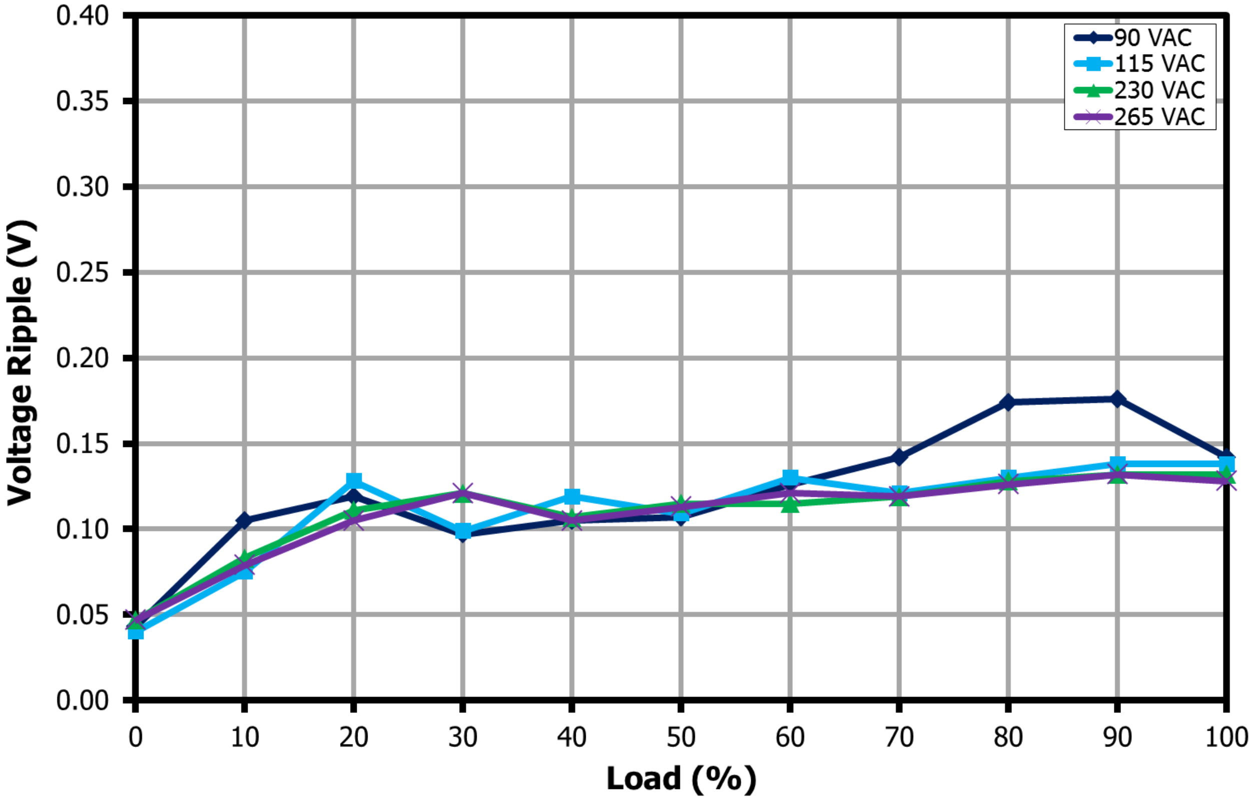

Figure 112 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 20 V Output.

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16 CV/CC Profile

Note: 1. Voltages measured on the PCB end.
2. Positive slope in CC region is per the guidelines of USB PD3.0 PPS specification.

16.1 *Output: 20 V / 3 A*

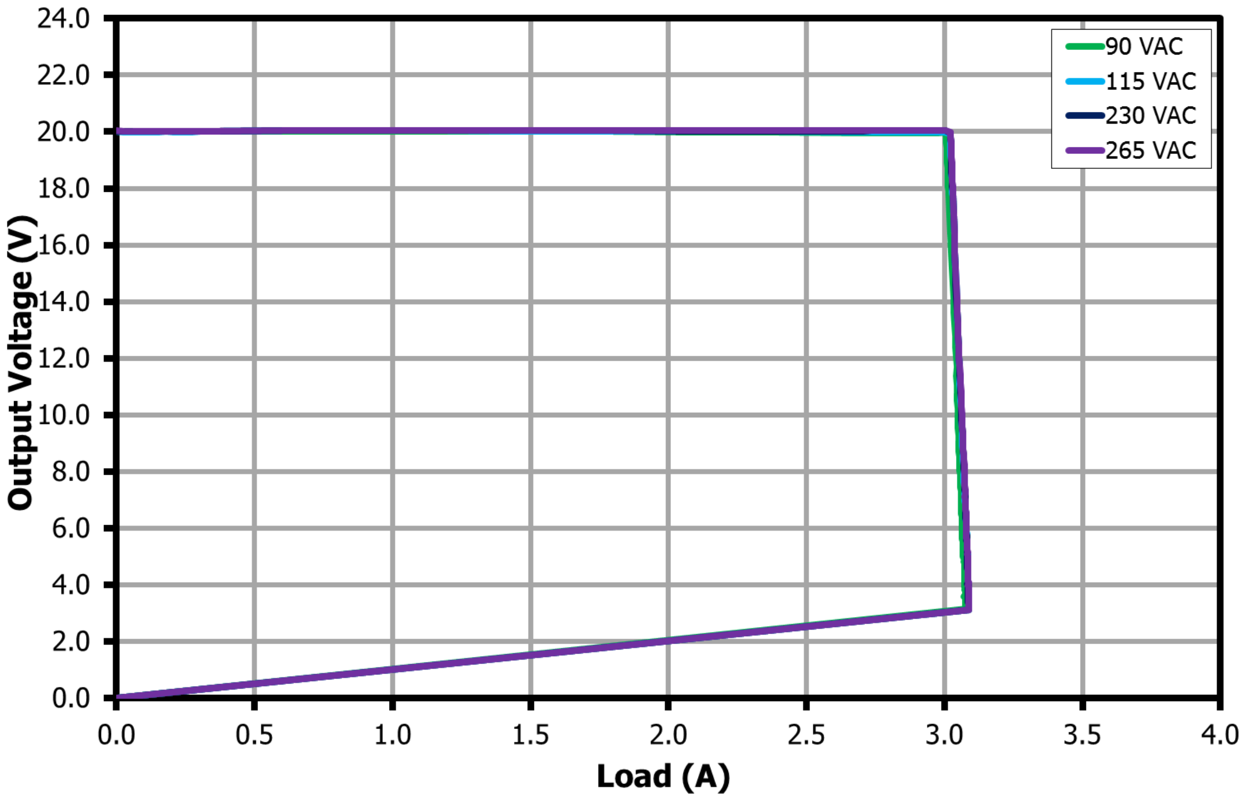

Figure 113 – CV/CC Profile for 20 V, 3 A Output.

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

17.1 *Voltage Step Test (VST)*

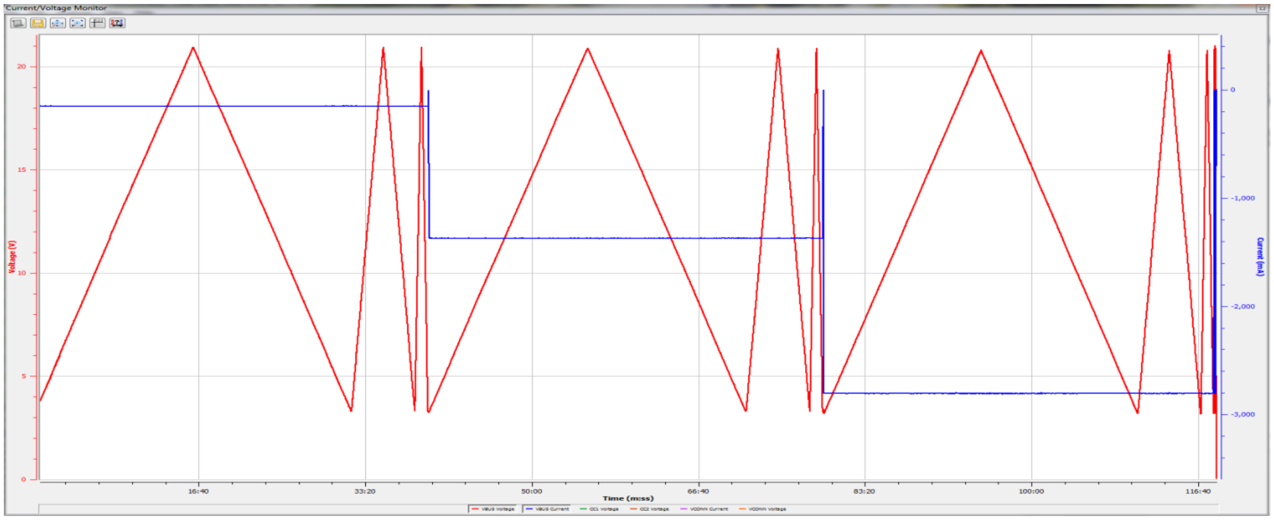

Figure 114 – Plot of SPT.6 VST from Total Phase Analyzer.

17.2 *Current Limit Test (CLT)*

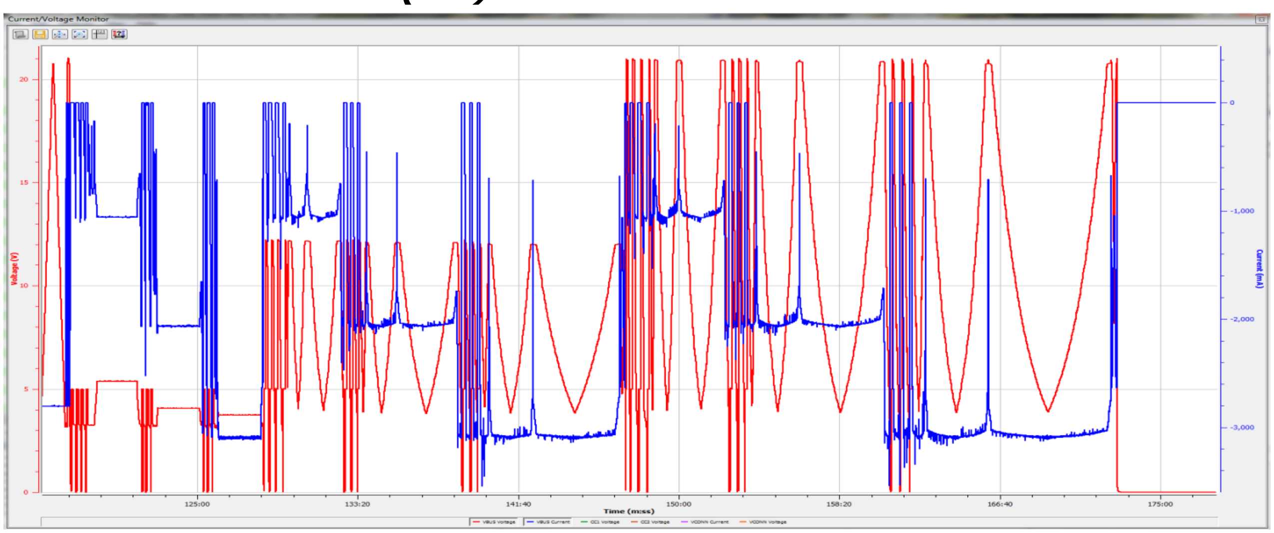

Figure 115 – Plot of SPT.7 CLT from Total Phase Analyzer.

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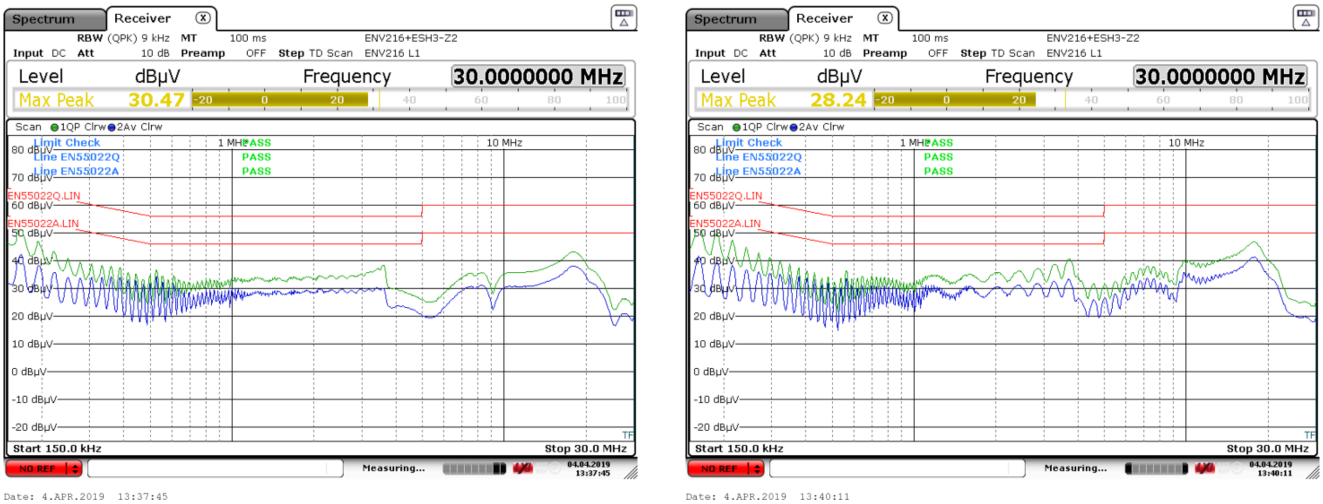
18 Conducted EMI

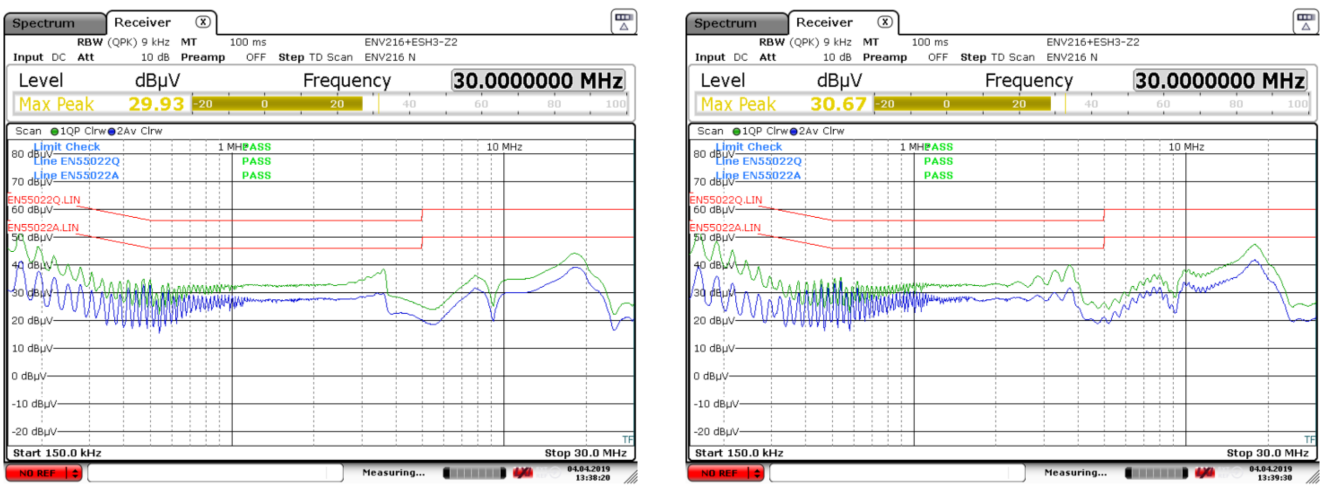
18.1 *Floating Ground (QPK / AV)*

18.1.1 Output: 5 V / 3 A



115 VAC. 230 VAC.

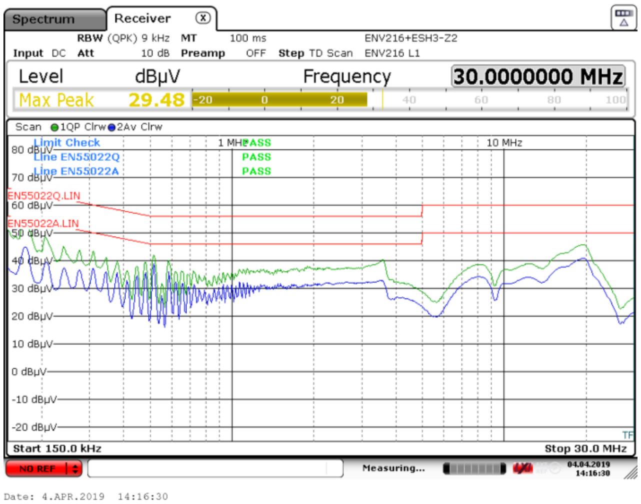
Figure 116 – Floating Ground EMI, 5 V / 3 A Load [Line Scan].

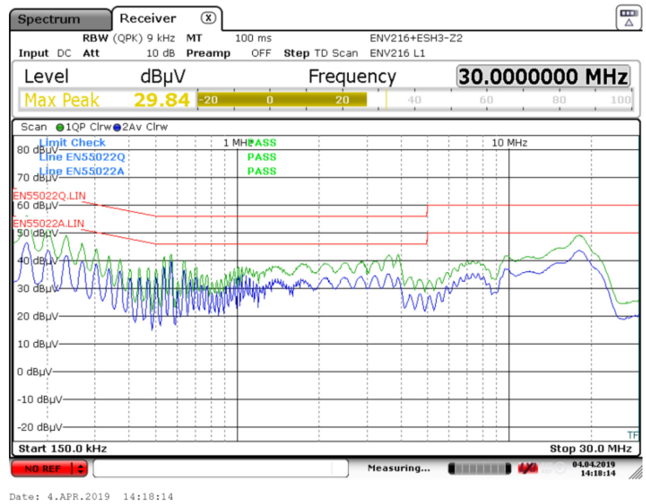


115 VAC. 230 VAC.

Figure 117 – Floating Ground EMI, 5 V / 3 A Load [Neutral Scan].

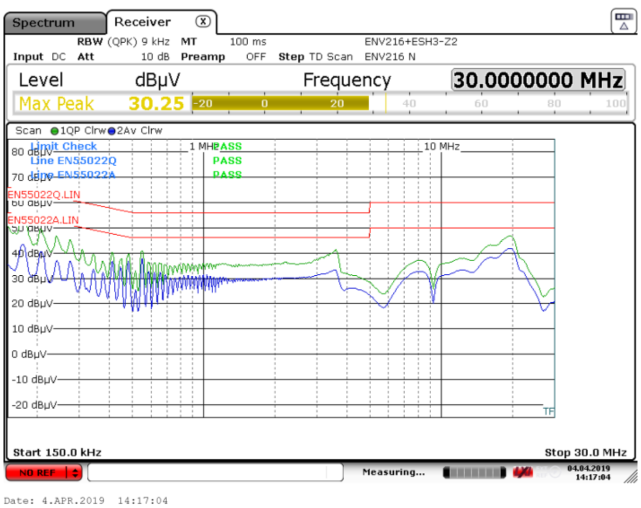
18.1.2 Output: 9 V / 3 A

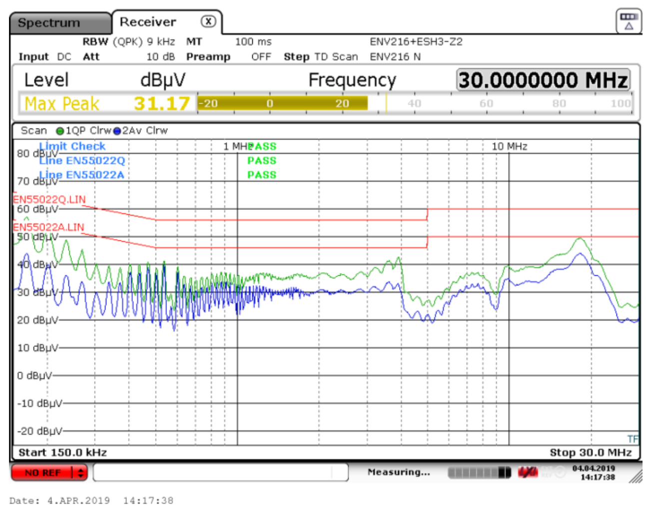




115 VAC. 230 VAC.

Figure 118 – Floating Ground EMI, 9 V / 3 A Load [Line Scan].





115 VAC. 230 VAC.

Figure 119 – Floating Ground EMI, 9 V / 3 A Load [Neutral Scan].

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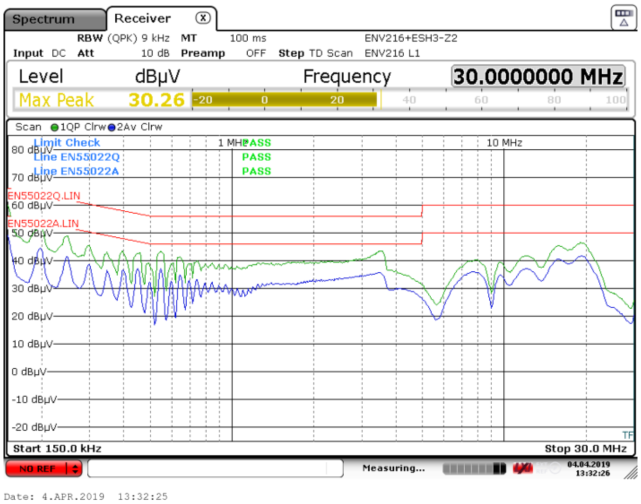
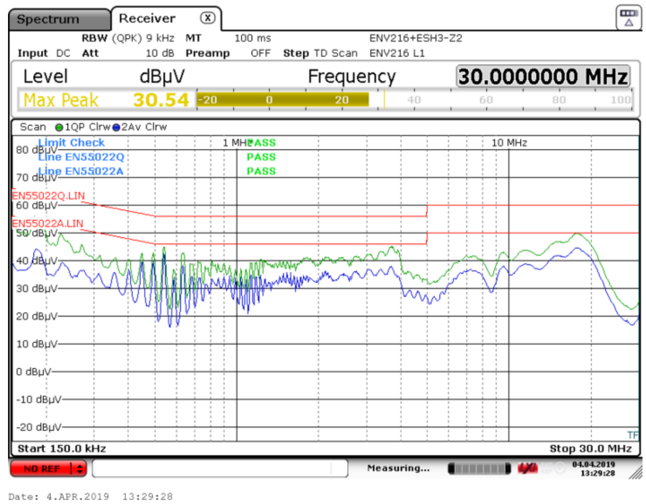
18.1.3 Output: 15 V / 3 A

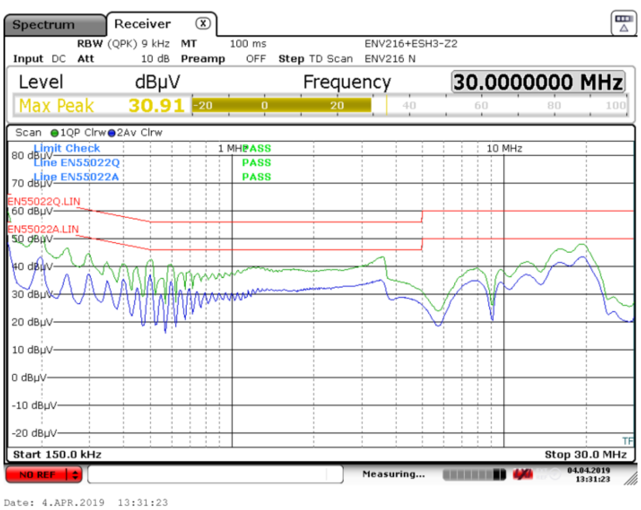


115 VAC.

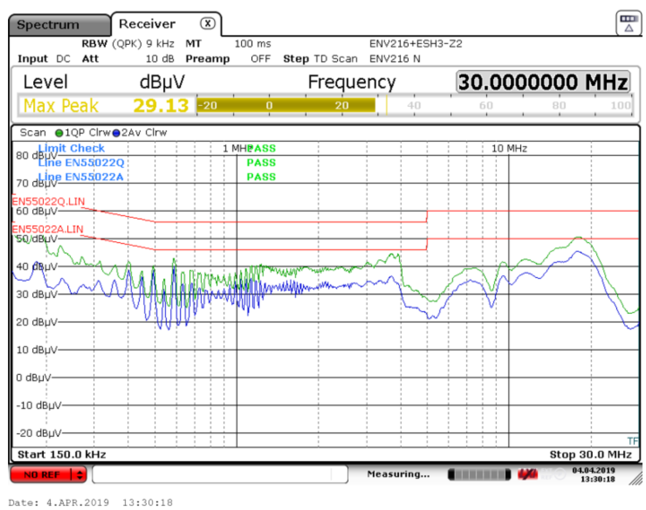


230 VAC.

Figure 120 – Floating Ground EMI, 15 V / 3 A Load [Line Scan].



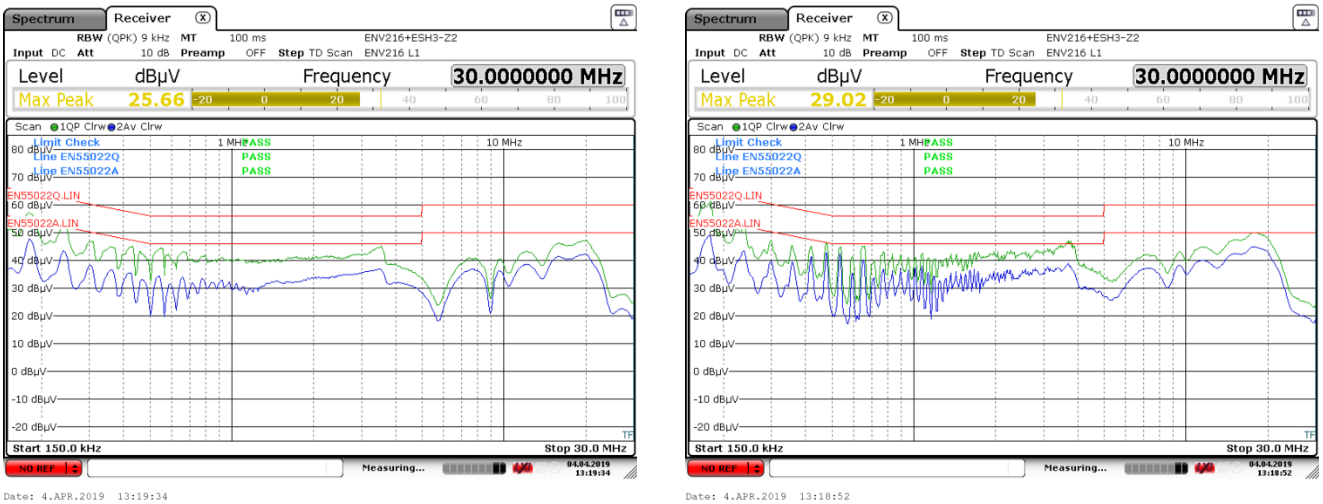
115 VAC.



230 VAC.

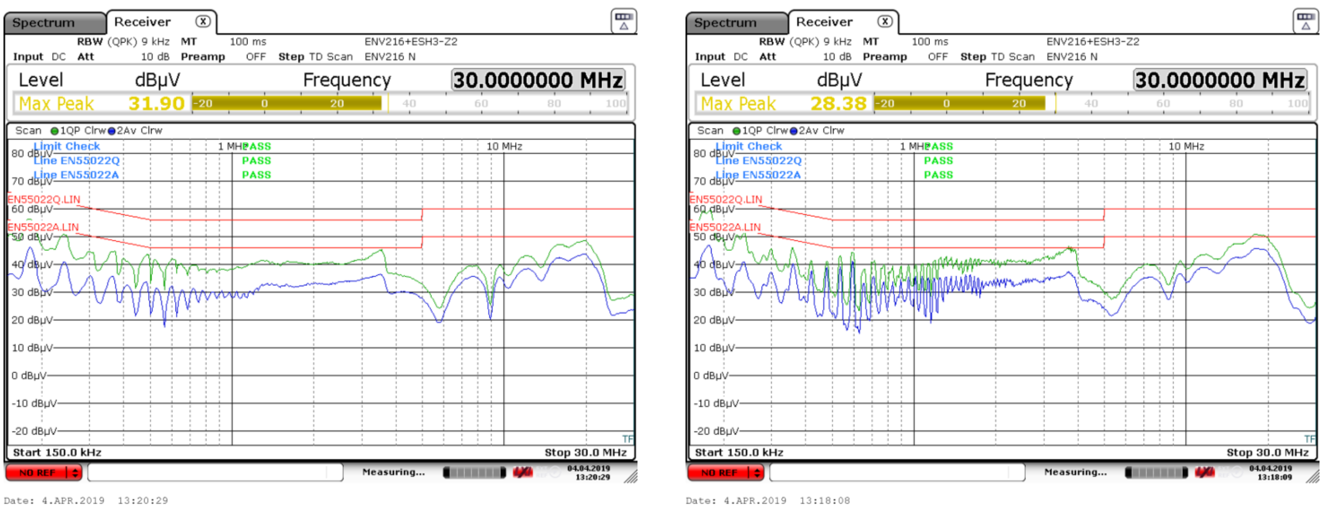
Figure 121 – Floating Ground EMI, 15 V / 3 A Load [Neutral Scan].

18.1.4 Output: 20 V / 3 A



115 VAC. 230 VAC.

Figure 122 – Floating Ground EMI, 20 V / 3 A Load [Line Scan].



115 VAC. 230 VAC.

Figure 123 – Floating Ground EMI, 20 V / 3 A Load [Neutral Scan].

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19 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.

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

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+1000	L1 to L2	0	Pass	Pass
-1000	L1 to L2	0	Pass	Pass
+1000	L1 to L2	90	Pass	Pass
-1000	L1 to L2	90	Pass	Pass
+1000	L1 to L2	180	Pass	Pass
-1000	L1 to L2	180	Pass	Pass
+1000	L1 to L2	270	Pass	Pass
-1000	L1 to L2	270	Pass	Pass

19.2 *Common Mode Surge (L1 to PE), 230 VAC Input*

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+2000	L1 to PE	0	Pass	Pass
-2000	L1 to PE	0	Pass	Pass
+2000	L1 to PE	90	Pass	Pass
-2000	L1 to PE	90	Pass	Pass
+2000	L1 to PE	180	Pass	Pass
-2000	L1 to PE	180	Pass	Pass
+2000	L1 to PE	270	Pass	Pass
-2000	L1 to PE	270	Pass	Pass

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

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+2000	L2 to PE	0	Pass	Pass
-2000	L2 to PE	0	Pass	Pass
+2000	L2 to PE	90	Pass	Pass
-2000	L2 to PE	90	Pass	Pass
+2000	L2 to PE	180	Pass	Pass
-2000	L2 to PE	180	Pass	Pass
+2000	L2 to PE	270	Pass	Pass
-2000	L2 to PE	270	Pass	Pass

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

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+2000	L1, L2 to PE	0	Pass	Pass
-2000	L1, L2 to PE	0	Pass	Pass
+2000	L1, L2 to PE	90	Pass	Pass
-2000	L1, L2 to PE	90	Pass	Pass
+2000	L1, L2 to PE	180	Pass	Pass
-2000	L1, L2 to PE	180	Pass	Pass
+2000	L1, L2 to PE	270	Pass	Pass
-2000	L1, L2 to PE	270	Pass	Pass

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20 Electrostatic Discharge

The unit was tested with ±8 kV to ±16.5 kV air discharge and ±8.8 kV contact discharge at the positive and negative nodes of the output 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.

20.1 *Contact Discharge, 230 VAC input*

Discharge Voltage (kV)	ESD Strike Location (End of Type-C Cable)	Test Result 20 V / 0 A	Test Result 20 V / 3 A
+8.8	+VOUT	Pass	Pass
	GND	Pass	Pass
-8.8	+VOUT	Pass	Pass
	GND	Pass	Pass

20.2 *Air Discharge, 230 VAC input*

Discharge Voltage (kV)	ESD Strike Location (End of Type-C Cable)	Test Result 20 V / 0 A	Test Result 20 V / 3 A
+8	+VOUT	Pass	Pass
	GND	Pass	Pass
-8	+VOUT	Pass	Pass
	GND	Pass	Pass
+10	+VOUT	Pass	Pass
	GND	Pass	Pass
-10	+VOUT	Pass	Pass
	GND	Pass	Pass
+12	+VOUT	Pass	Pass
	GND	Pass	Pass
-12	+VOUT	Pass	Pass
	GND	Pass	Pass
+14	+VOUT	Pass	Pass
	GND	Pass	Pass
-14 kV	+VOUT	Pass	Pass
	GND	Pass	Pass
+16.5	+VOUT	Pass	Pass
	GND	Pass	Pass
-16.5	+VOUT	Pass	Pass
	GND	Pass	Pass

21 Revision History

Date	Author	Revision	Description & Changes	Reviewed
24-Jul-19	JW / DB	1.0	Initial Release.	Apps & Mktg

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