Design Example Report

Title	***45 W USB PD 3.0 with 3.3 V – 21 V PPS (APDO 5 A for 3.3 V – 11 V) Power Supply Using InnoSwitch™3-Pro PowiGaN™ INN3379C-H302 and VIA Labs VP302 Controller***
Specification	90 VAC – 265 VAC Input; 5 V / 5 A, 9 V / 5 A, 15 V / 3 A, 20 V / 2.25 A, 3.3 V – 11 V / 5 A PPS (45 W Power-limited), 3.3 V – 16 V / 3 A PPS, or 3.3 V – 21 V / 2.25 A PPS Output
Application	Mobile Phone Charger
Author	Applications Engineering Department
Document Number	DER-856
Date	October 30, 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

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PATENT INFORMATION

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

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Important Note:

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

1 Introduction

This document is an engineering report describing a 45 W USB PD 3.0 power supply using InnoSwitch3-Pro INN3379-H302 IC and VIA Labs VP302 USB PD controller. The USB PD source capabilities of the power supply are listed below.

- 5 V / 5 A (Fixed Supply PDO)
- 9 V / 5 A (Fixed Supply PDO)
- 15 V / 3 A (Fixed Supply PDO)
- 20 V / 2.25 A (Fixed Supply PDO)
- 3.3 V – 11 V / 5 A (Programmable Power Supply APDO, 45 W power-limited)
- 3.3 V – 16 V / 3 A (Programmable Power Supply APDO)
- 3.3 V – 21 V / 2.25 A (Programmable Power Supply APDO)

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.

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Figure 2 – Populated Circuit Board Photograph - Top.

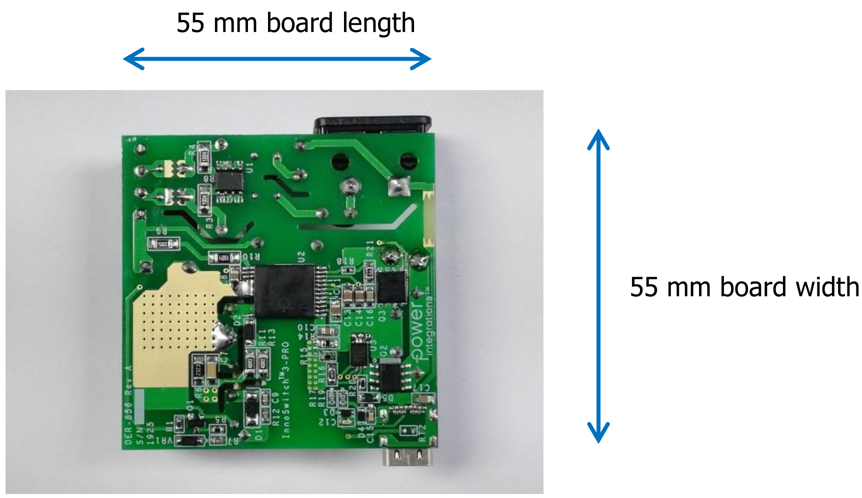

Figure 3 – Populated Circuit Board Photograph - Bottom.

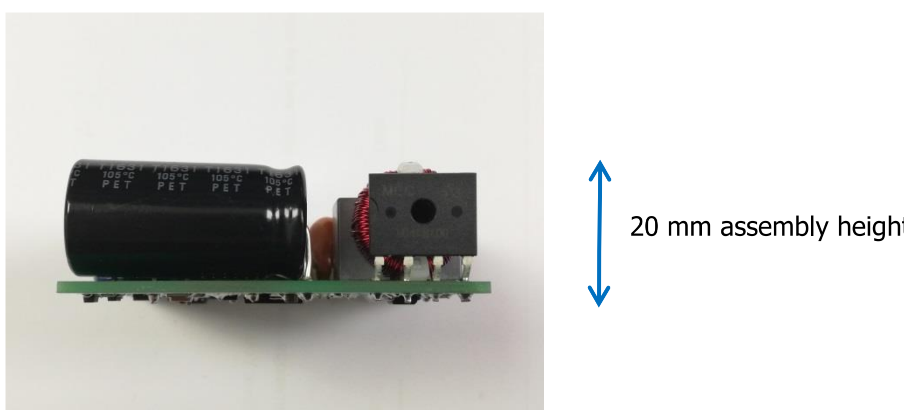

Figure 4 – Populated Circuit Board Photograph - Side.

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				30	mW	Measured at 230 VAC
5 V / 5 A Setting						
Output Voltage	$V_{OUT(5\ V)}$		5.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(5\ V)}$			150	mV	Measured at End of 100 mΩ Cable.
Output Current	$I_{OUT(5\ V)}$			5.0	A	±3%
Average Efficiency	$\eta_{(5\ V)}$		90.4		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(5\ V)}$			25	W	
9 V / 5 A Setting						
Output Voltage	$V_{OUT(9\ V)}$		9.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(9\ V)}$			150	mV	Measured at End of 100 mΩ Cable.
Output Current	$I_{OUT(9\ V)}$			5.0	A	±3%
Average Efficiency	$\eta_{(9\ V)}$		91.4		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(9\ V)}$			45	W	
15 V / 3 A Setting						
Output Voltage	$V_{OUT(15\ V)}$		15.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(15\ V)}$			150	mV	Measured at End of 100 mΩ Cable.
Output Current	$I_{OUT(15\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(15\ V)}$		91.7		%	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 / 2.25 A Setting						
Output Voltage	$V_{OUT(20\ V)}$		20.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(20\ V)}$			150	mV	Measured at End of 100 mΩ Cable.
Output Current	$I_{OUT(20\ V)}$			2.25	A	±3%
Average Efficiency	$\eta_{(20\ V)}$		91.2		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(20\ V)}$			45	W	
3.3 V – 11 V PPS Setting						
Maximum Programmable Output Voltage	$V_{OUT,MAX}$			11	V	APDO Maximum Voltage.
Minimum Programmable Output Voltage	$V_{OUT,MIN}$	3.3			V	APDO Minimum Voltage.
Output Current	$I_{OUT,PPS}$			5.0	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}			45	W	

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3.3 – 16 V PPS Setting						
Maximum Programmable Output Voltage	$V_{OUT,MAX}$			16	V	APDO Maximum Voltage.
Minimum Programmable Output Voltage	$V_{OUT,MIN}$	3.3			V	APDO Minimum Voltage.
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}			45	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 Current	$I_{OUT,PPS}$			2.25	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}			45	W	
Conducted EMI		Meets CISPR22B / EN55022B				
Ambient Temperature	T_{AMB}	0		40	ºC	Free Convection, Sea Level.

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

3 Schematic

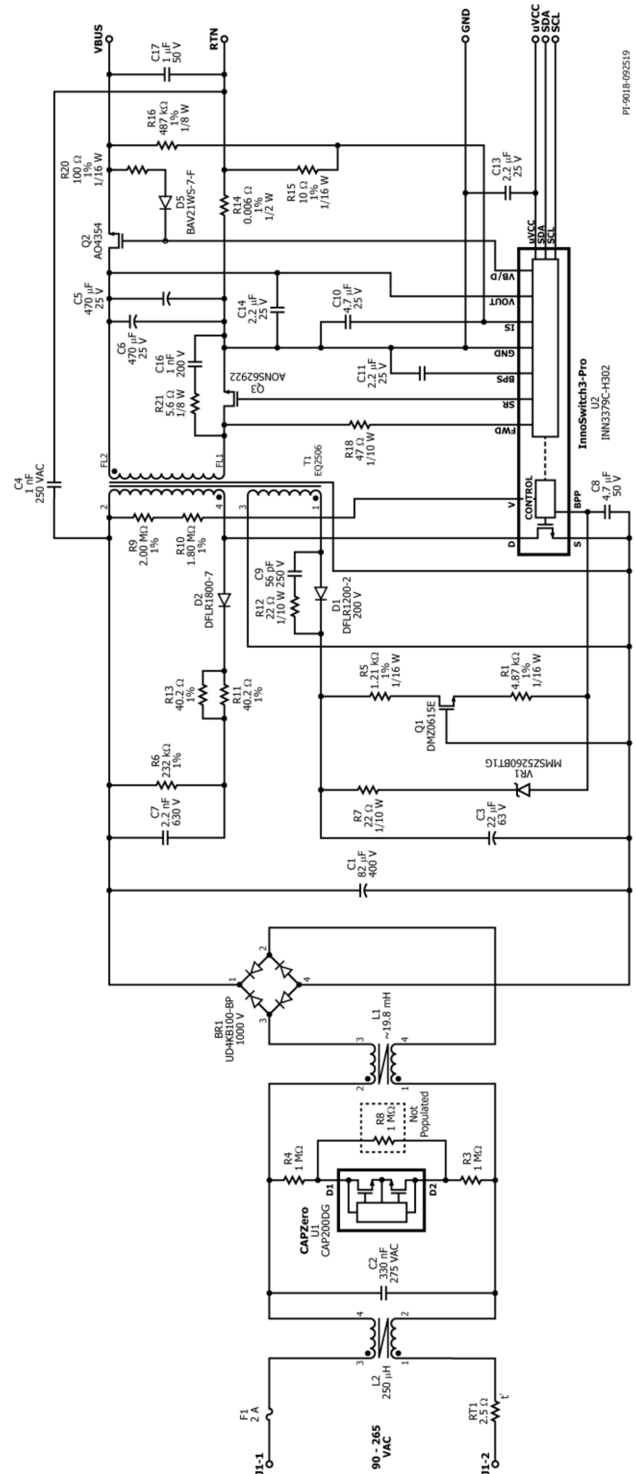

Figure 5 – DER-856 RevA Schematic, Power Section.

Note:
Component reference R8, although present in the layout, should not be populated.

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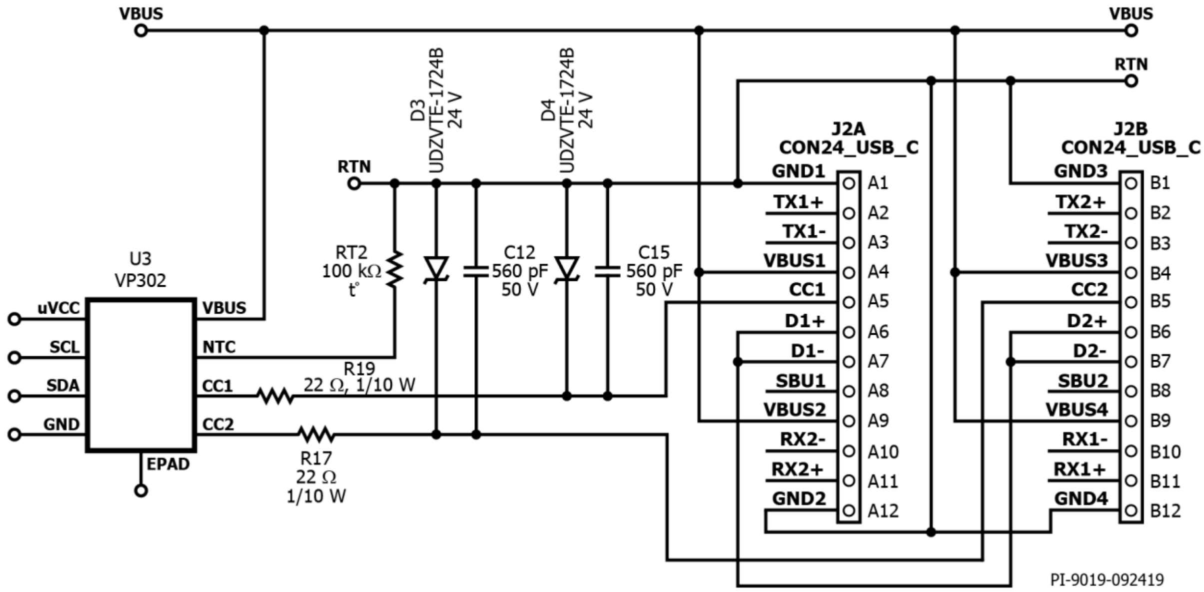

Figure 6 – DER-856 RevA Schematic, USB PD Controller Section.

4 Circuit Description

4.1 *Input Rectifier and EMI Filter*

The input fuse F1 isolates the circuit and provides protection from component failure. NTC thermistor RT1 limits the inrush current when the input AC supply is connected. Common mode chokes L1 and L2, with capacitors C2 and C4 provide common mode and differential mode noise filtering for EMI attenuation. Bridge rectifier BR1 rectifies the AC line voltage to have a full wave rectified DC, which is filtered by the bulk capacitor C1.

Resistors R3 and R4 along with CapZero™-2 IC U1 discharges capacitor C2 when the power supply is disconnected from AC mains.

4.2 *InnoSwitch3-Pro IC Primary*

One end of the flyback transformer T1 primary winding 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 U2. Resistors R9 and R10 provide input voltage sensing for protection in case of AC input undervoltage or overvoltage.

A low-cost RCD clamp formed by diode D2, resistors R6, R11, and R3, and capacitor C7 limits the peak drain-source voltage of U2 at the instant the switch inside U2 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 C8 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 D1 and filtered using capacitor C3. Depletion-mode MOSFET Q1 and resistors R1 and R5 provide sufficient current into the BPP pin of the InnoSwitch3-Pro IC U1 such that the internal current source of U1 is not required to charge C8 during normal operation. The RC network consisting of resistor R12 and capacitor C9 offers damping of the high frequency ringing in the voltage across diode D1 to reduce radiated EMI.

Zener diode VR1 offers primary sensed output overvoltage protection. In a flyback converter, output of the auxiliary winding tracks the output voltage of the converter. In case of 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 R7 limits the current injected to BPP pin when the output overvoltage protection is triggered.

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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 synchronous rectifier FET (SR FET) Q3 and filtered by capacitors C5 and C6. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via a RC snubber, R21 and C16.

The gate of Q3 is turned on by secondary-side controller inside IC U2, based on the secondary winding voltage sensed via resistor R18 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 C11 connected to the BPS pin of InnoSwitch3-Pro IC U2 provides decoupling for the internal circuitry.

The output current is sensed by monitoring the voltage drop across resistor R14. Resistors R15 and R16 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 C10 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 U2 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 U2 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 C11 via resistor R18 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 U2 regulates the output voltage by controlling the number of switch pulses. Capacitor C14 is needed between the VOUT pin and the SECONDARY GROUND pin for ESD protection of the VOUT pin.

N-channel MOSFET Q2 functions as the bus switch which connects or disconnects the output of the flyback converter from the USB Type-C receptacle. MOSFET Q2 is controlled by the VB/D pin on the InnoSwitch3-Pro IC. Resistor R20 and diode D5 are connected across the Source and Gate terminals of the Q2 to provide a discharge path for the bus voltage when the Q2 is turned off. Capacitor C17 is 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.

Capacitor C13 provides decoupling to the µVCC of the InnoSwitch3-Pro IC and VCC of the VP302 IC. Capacitors C12 and C15, resistors R17 and R19, and TVS diodes D3, and D4 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 Q2. The VBUS pin is also used for discharging the capacitor C17 when the bus switch Q2 is opened.

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5 PCB Layout

PCB copper thickness is 0.062 inches.

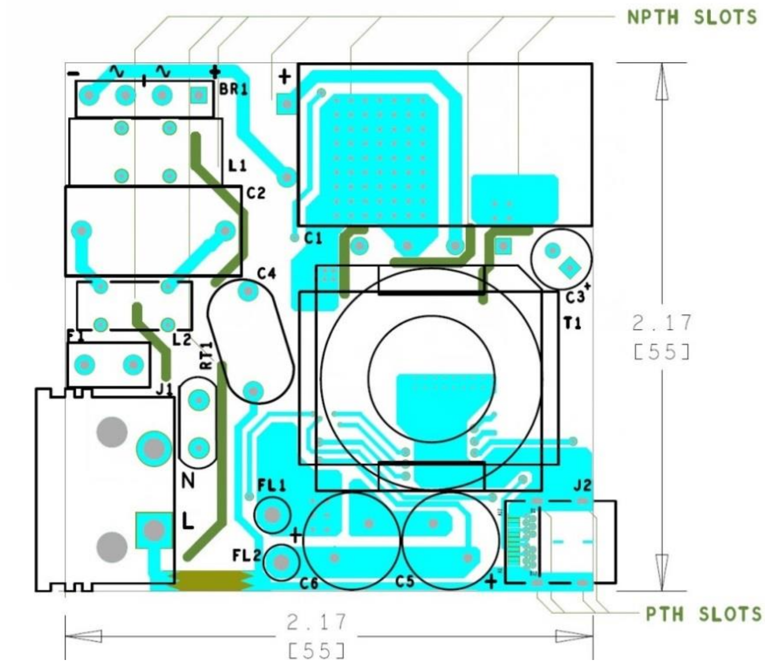

Figure 7 – Printed Circuit Layout, Top.

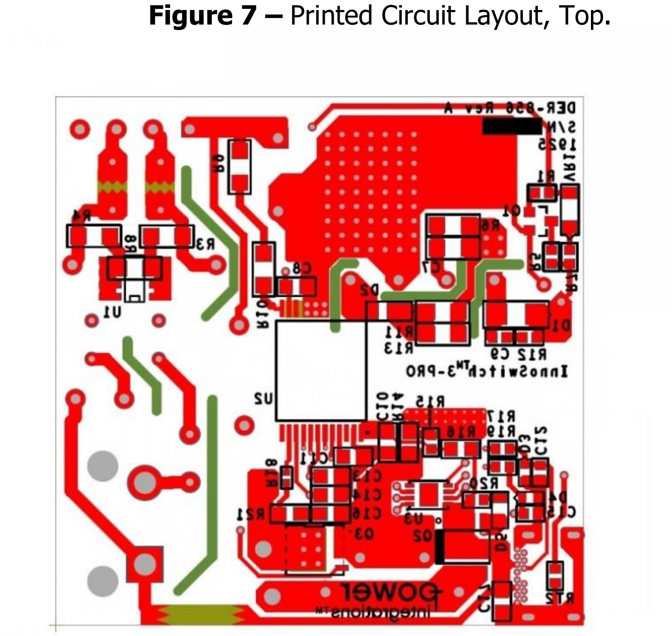

Figure 8 – Printed Circuit Layout, Bottom.

Note:
Component reference R8, although present in the layout, should not be populated.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	Bridge Rectifier, 1000 V, 4 A, 4-ESIP, D3K, -55°C ~ 150°C (TJ), Vf=1V @ 7.5A	UD4KB100-BP	Micro Commercial
2	1	C1	82 µF, ±20%, 400 V, Electrolytic (16 x 33)	400BXW82MEFR16X30	Rubycon
3	1	C2	330 nF, 275 VAC, Film, X2	R46KI333000N1M	Kemet
4	1	C3	22 µF, 63, Electrolytic, Low ESR, 1000 mΩ, (6.3 x 11.5)	ELXZ630ELL220MFB5D	Nippon Chemi-Con
5	1	C4	1 nF, Ceramic, Y1	440LD10-R	Vishay
6	1	C5	470 µF, 25 V,±20%, Al Organic Polymer, Gen. Purpose, Can, 15 mΩ, 2000 Hrs @ 105°C	A750MS477M1EAAE015	KEMET
7	1	C6	470 µF, 25 V,±20%, Al Organic Polymer, Gen. Purpose, Can, 15 mΩ, 2000 Hrs @ 105°C	A750MS477M1EAAE015	KEMET
8	1	C7	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
9	1	C8	4.7 µF, 50 V, Ceramic, X5R, 0805	CL21A475KBQNNNE	Samsung
10	1	C9	56 pF, 250 V, Ceramic, NP0, 0603	GQM1875C2E560JB12D	Murata
11	1	C10	4.7 µF ±10%, 25 V, X7R, 0805,-55°C ~ 125°C	TMK212AB7475KG-T	Taiyo Yuden
12	1	C11	2.2 µF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
13	1	C12	560 pF, 50 V, Ceramic, X7R, 0603, 0.063" L x 0.031" W (1.60 mm x 0.80 mm)	CL10B561KB8NNNC	Samsung
14	1	C13	2.2 µF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
15	1	C14	2.2 µF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
16	1	C15	560 pF, 50 V, Ceramic, X7R, 0603, 0.063" L x 0.031" W (1.60 mm x 0.80 mm)	CL10B561KB8NNNC	Samsung
17	1	C16	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
18	1	C17	1 µF,±20% ,50 V, Ceramic, X7R, AEC-Q200, Automotive, Boardflex Sensitive, 0805	CGA4J3X7R1H105M125AE	TDK
19	1	D1	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
20	1	D2	800 V, 1 A, Rectifier, POWERDI123	DFLR1800-7	Diodes, Inc.
21	1	D3	DIODE, ZENER, 24 V, 200 mW, UMD2, SOD323F,SC-90, SOD-323F	UDZVTE-1724B	Rohm Semiconductor
22	1	D4	DIODE, ZENER, 24 V, 200 mW, UMD2, SOD323F,SC-90, SOD-323F	UDZVTE-1724B	Rohm Semiconductor
23	1	D5	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diode Inc.
24	1	F1	2 A, 250 V, Slow, Long Time Lag, RST	RST 2	Belfuse
25	1	J1	Power Entry Connector Receptacle, Male Pins, IEC 320-C8, Non-Polarized, Panel Mount, Snap-In; TH, RA	RAPC322X	Switchcraft
26	1	J2	Connector, "Certified", USB - C, USB 3.1, For 0.062" PCB Material, Superspeed+, Receptacle Connector, 24 Position, SMT, RA, TH	632723300011	Wurth
27	1	L1	CMC, ~19.8 mH @ 100 kHz, ±25%, Toroidal	30-00463-00	Power Integrations
28	1	L2	250 µH, Toroidal Common Mode Choke, custom, DER-538, wound on 32-00275-00 core.	32-00367-00	Power Integrations
29	1	Q1	MOSFET, N-CH, Depletion Mode, 70 V, 120 mA,SOT23	DMZ0615E	Ark Micro
30	1	Q2	MOSFET, N-CH, 30V, 23A (Ta), 3.1W (Ta),3.7 mΩ (@ 20 A, 10 V), 8SOIC	AO4354	Alpha & Omega Semi
31	1	Q3	MOSFET, N-CH, 120V, 85 A (at VGS=10V), Trench Power AlphaSGT 120 V TM technology, DFN5X6	AONS62922	Alpha & Omega Semi
32	1	R1	RES, 4.87 kΩ, 1%, 1/16 W, Automotive, AEC-Q200,Thick Film, 0603	ERJ-3EKF4871V	Panasonic
33	1	R3	RES, 1 MΩ, 5%, 1/4 W, Automotive, AEC-Q200,Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
34	1	R4	RES, 1 MΩ, 5%, 1/4 W, Automotive, AEC-Q200,Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
35	1	R5	RES, 1.21 kΩ, 1%, 1/16 W, Automotive, AEC-Q200,Thick Film, 0603	ERJ-3EKF1211V	Panasonic
36	1	R6	RES, 232 kΩ, 1%, 1/4 W, Automotive, AEC-Q200,Thick Film, 1206	ERJ-8ENF2323V	Panasonic

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37	1	R7	RES, 22 Ω, 5%, 1/10 W, Automotive, AEC-Q200, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
38	1	R9	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
39	1	R10	RES, 1.80 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1804V	Panasonic
40	1	R11	RES, 40.2 Ω, 1%, 1/4 W, Automotive, AEC-Q200,Thick Film, 1206	ERJ-8ENF40R2V	Panasonic
41	1	R12	RES, 22 Ω, 5%, 1/10 W, Automotive, AEC-Q200, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
42	1	R13	RES, 40.2 Ω, 1%, 1/4 W, Automotive, AEC-Q200,Thick Film, 1206	ERJ-8ENF40R2V	Panasonic
43	1	R14	RES, 0.006 Ω, ±1%, 0.5W, 1/2W, 0805, Current Sense, Automotive AEC-Q200,Thick Film, ±300ppm/°C,-55°C ~ 155°C	ERJ-6LWFR006V	Panasonic
44	1	R15	RES, 10 Ω, 1%, 1/16 W, Automotive, AEC-Q200,Thick Film, 0603	ERJ-3EKF10R0V	Panasonic
45	1	R16	RES, 487 kΩ, 1%, 1/8 W, Automotive, AEC-Q200, Thick Film, 0805	ERJ-6ENF4873V	Panasonic
46	1	R17	RES, 22 Ω, 5%, 1/10 W, Automotive, AEC-Q200, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
47	1	R18	RES, 47 Ω, 5%, 1/10 W, Automotive, AEC-Q200, Thick Film, 0402	ERJ-2GEJ470X	Panasonic
48	1	R19	RES, 22 Ω, 5%, 1/10 W, Automotive, AEC-Q200, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
49	1	R20	RES, 100 Ω, 1%, 1/16 W, Automotive, AEC-Q200,Thick Film, 0603	ERJ-3EKF1000V	Panasonic
50	1	R21	RES, 5.6 Ω, 5%, 1/8 W, Automotive, AEC-Q200,Thick Film, 0805	ERJ-6GEYJ5R6V	Panasonic
51	1	RT1	NTC Thermistor, 2.5 Ω, 3 A	SL08 2R503	Ametherm
52	1	RT2	NTC Thermistor, 100 kΩ, 3%, 0603	NCP18WF104E03RB	Murata
53	1	T1	Bobbin, EQ25, 4 pins, 4pri, 0sec	EQ-2506	Shen Zhen Xin Yu Jia Technology
54	1	U1	CAPZero-2, SO-8C	CAP200DG	Power Integrations
55	1	U2	InnoSwitch3-Pro, InSOP24D	INN3379C-H302	Power Integrations
56	1	U3	IC, USB PD Type-C Controller for SMPS, DFN-8	VP302	VIA Labs
57	1	VR1	DIODE ZENER 43 V 500 mW SOD123	MMSZ5260BT1G	ON Semi

7 Transformer Specification (T1)

7.1 *Electrical Diagram*

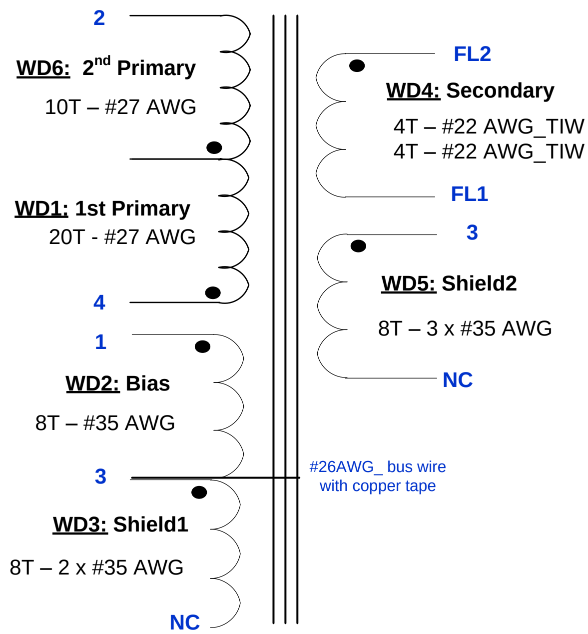

Figure 9 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 2 and 4, with all other windings open.	425 μH ±5%
Resonant Frequency	Between pin 2 and 4, other windings open.	1,200 kHz (Min.)
Primary Leakage Inductance	Between pin 2 and 4, with pins: FL1-FL2 shorted.	8.5 μH (Max.)

7.3 *Material List*

Item	Description
[1]	Core: EQ27
[2]	Bobbin: EQ2506-Vertical - 4pins (4/0), PI#: 25-01095-00.
[3]	Magnet Wire: #27 AWG, Double Coated.
[4]	Magnet Wire: #35 AWG, Double Coated.
[5]	Magnet Wire: #22 AWG, Triple Insulated Wire.
[6]	Bus Wire: #26 AWG, Alpha Wire, Tinned Copper, 40.0 mm Length.
[7]	Copper Foil: Copper Tape, 1 mil Thickness, 8.6 mm Width x 10.0 mm Length.
[8]	Tape: 3M 1350-F, Polyester Film, 1 mil Thickness, 4.0 mm Width.
[9]	Tape: 3M 1350-F, Polyester Film, 1 mil Thickness, 18 mm Width.
[10]	Tape: 3M 1350-F, Polyester Film, 1 mil Thickness, 12.4 mm Width.
[11]	Varnish: Dolph BC-359.

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7.4 *Transformer Build Diagram*

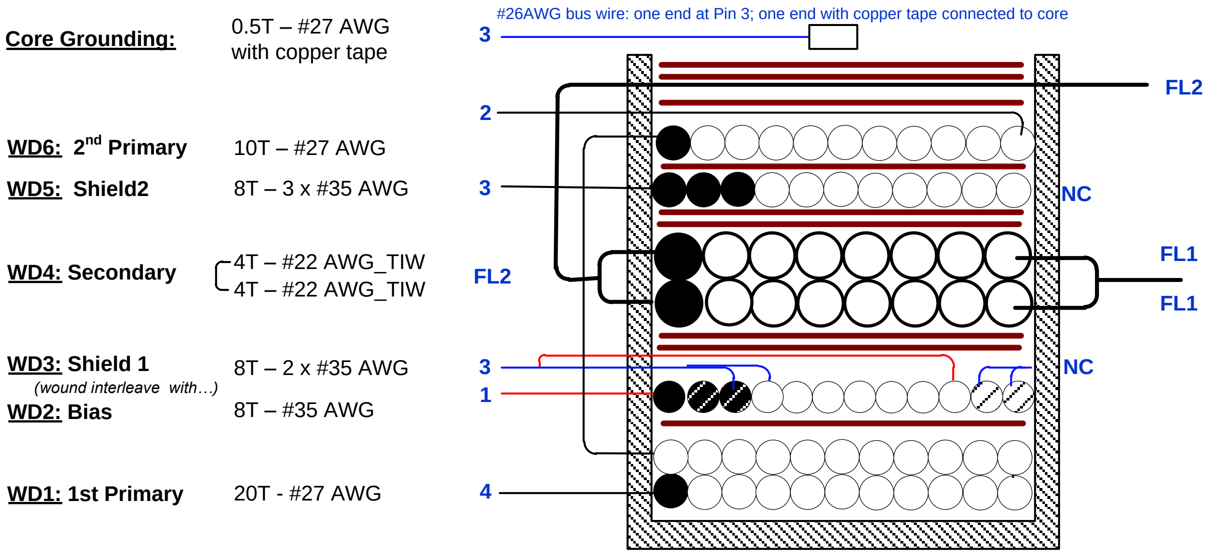

Figure 10 – Transformer Build Diagram.

7.5 *Bobbin Preparation*

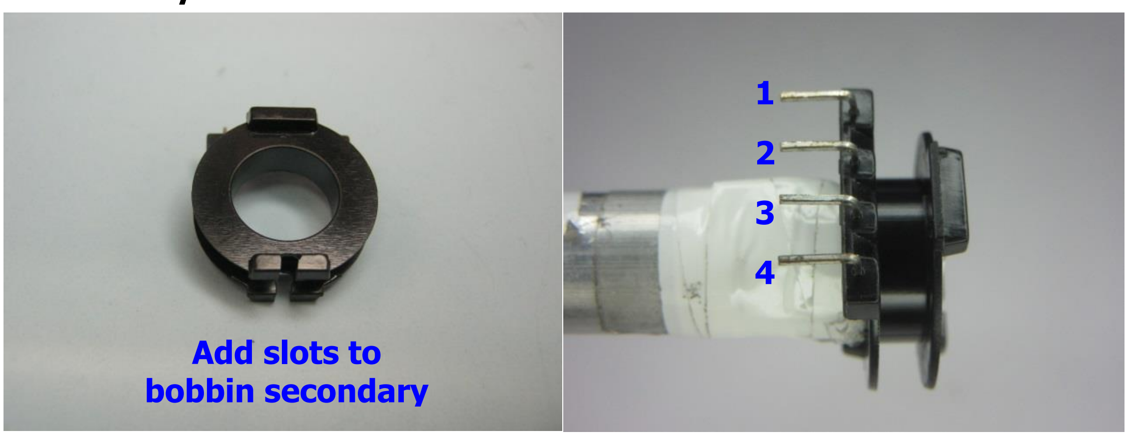

Figure 11 – Transformer Bobbin Modification and Pin Assignment.

7.6 *Transformer Construction*

Winding Preparation	Make slots on both sides of bobbin Item [2] secondary flange. Position the bobbin on the mandrel such that the pin side of the bobbin is on the left side. Rotation of the mandrel is clock-wise as seen from the right side of the setup.
WD1 1st Primary	Start at pin 4, wind 10 turns of wire Item [3] in 1 layer, from left to right, and another 10 turns on the next layer from right to left (total of 20 turns).
Insulation	1 layer of tape Item [8].
WD2 Bias & WD3 Shield 1	Start at pin 1, with 1 wire Item [4] for WD2 and start pin 3 with 2 wires also Item [4] for WD3. Wind all 3 wires 8 turns in parallel, at the last turn, finish 1 wire for WD2 at pin 3, cut short 2 wires for WD3 as No-Connect.
Insulation	2 layers of tape Item [8].
WD4	Start at the slot on the left on secondary flange of the bobbin. Use 1 wire Item [5], leave

Secondary	~2" floating, and mark as FL1. Wind 4 turns in 1 layer. At the last turn, exit the wire at the slot on the right, also leave ~1.5" floating and mark as FL2 for 1st half of Secondary. Repeat another winding as above for 2nd half of Secondary, which is parallel with 1st half Secondary.
Insulation	2 layers of tape Item [8].
WD5 Shield 2	Start at pin 3, wind 8 tri-filar turns of wire Item [4]. At the last turn cut short the wires as No-Connect.
Insulation	1 layer of tape Item [8].
WD6 2nd Primary	Use wire hanging from WD1 and continue winding 10 turns from left to right. At the last turn, finish winding at pin 2.
Insulation	1 layers of tape Item [8] and bring the secondary wires FL2 to the right, then add another 2 layers of tape Item [8]. (total of 3 layers)
Gap and Ground Core	Add gap core to Item [1] to get 425 μH primary inductance. Solder one end of bus wire Item [6] to pin 3 and connect the other end of wire to copper tape Item [7]. Attach the copper tape to the transformer core bottom.
Finish	Wrap the body of transformer along the top and bottom with 3 layers of tape Item [9], and also wrap the transformer sideways with 3 layers of tape Item [10]. Varnish using Item [11].

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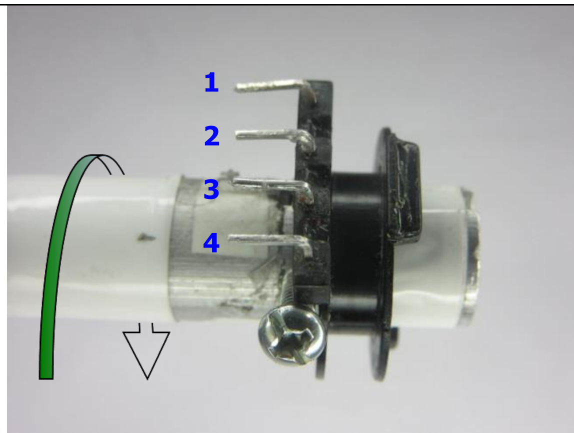
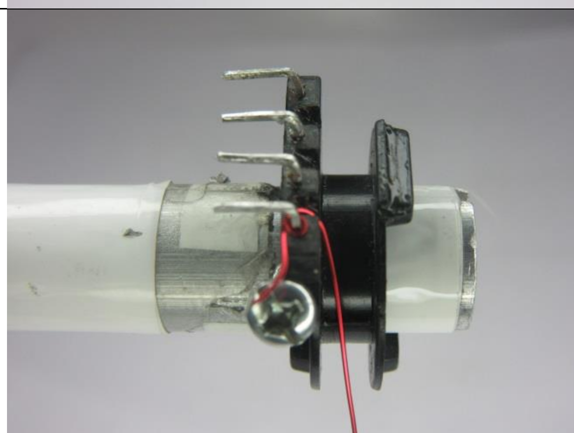
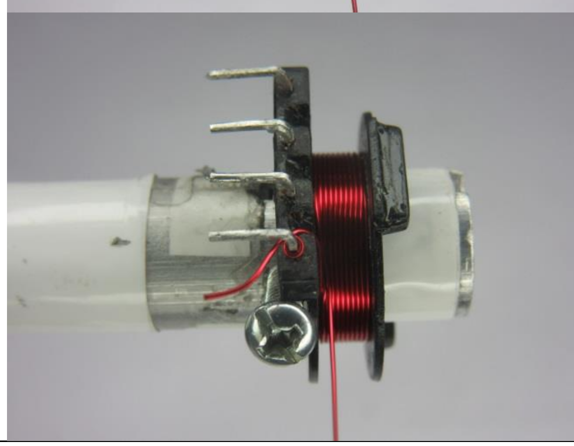
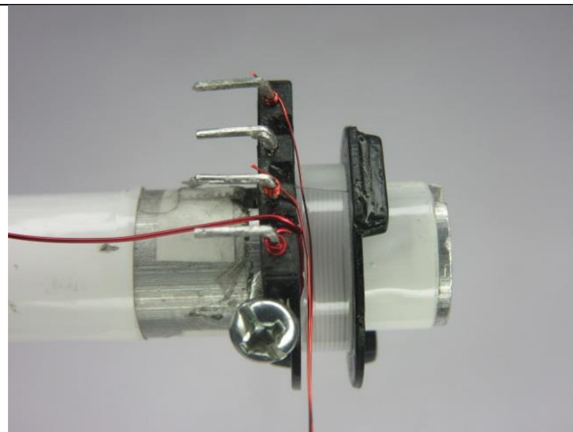
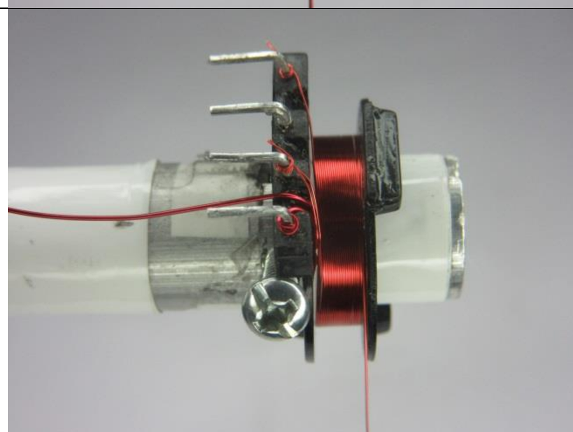
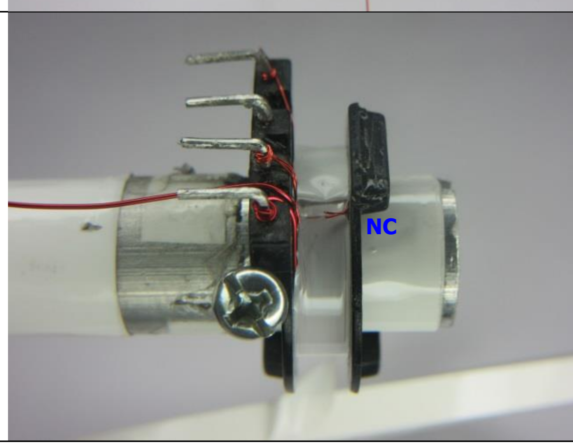
7.7 *Winding Illustrations*

Winding Preparation		Make slots on both sides of bobbin Item [2] secondary flange. Position the bobbin on the mandrel such that the pin side of the bobbin is on the left side. Rotation of the mandrel is clock-wise as seen from the right side of the setup.
WD1 **1st Primary**	 	Start at pin 4, wind 10 turns of wire Item [3] in 1 layer, from left to right, and another 10 turns on the next layer from right to left (total of 20 turns).

Insulation		1 layer of tape Item [8].
WD2: Bias & WD3: Shield 1		Start at pin 1, with 1 wire Item [4] for WD2 and start pin 3 with 2 wires also Item [4] for WD3. Wind all 3 wires 8 turns in parallel, at the last turn, finish 1 wire for WD2 at pin 3, cut short 2 wires for WD3 as No-Connect.
Insulation		2 layers of tape Item [8].

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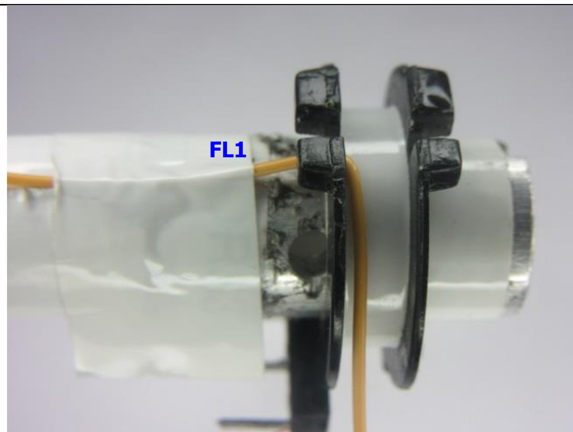
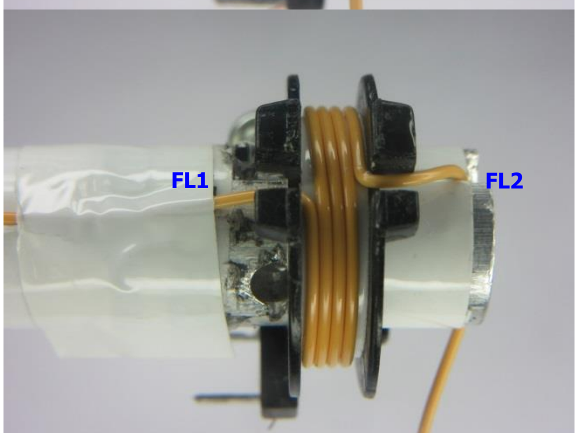
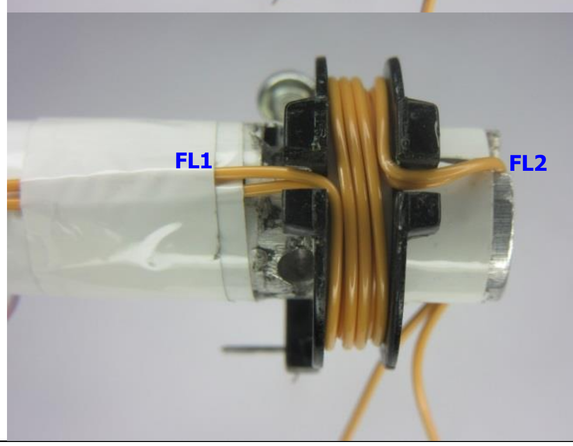
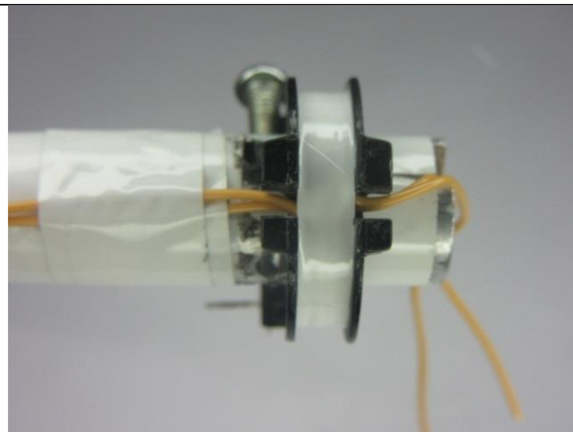
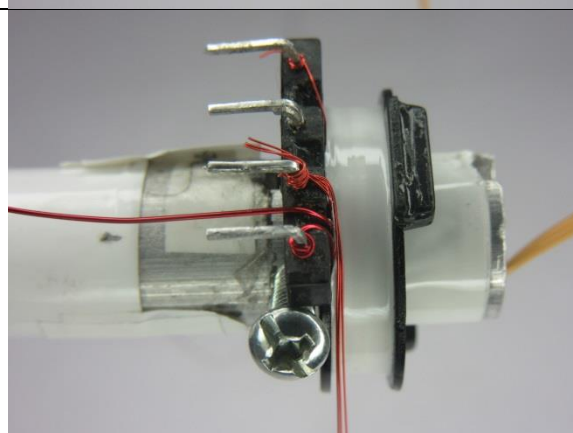
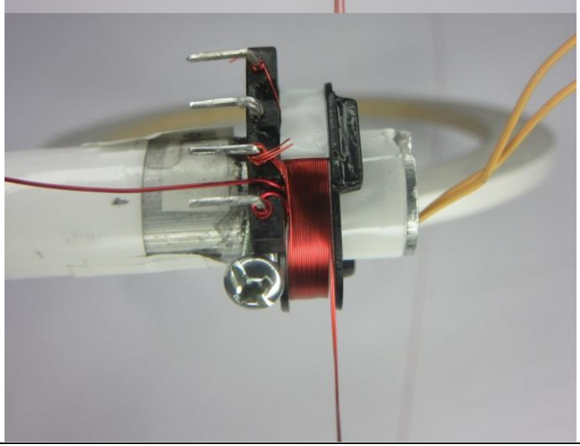
WD4 **Secondary**	  	Start at the slot on the left on secondary flange of the bobbin. Use 1 wire Item [5], leave ~2" floating, and mark as FL1. Wind 4 turns in 1 layer. At the last turn, exit the wire at the slot on the right, also leave ~1.5" floating and mark as FL2 for 1st half of Secondary. Repeat another winding as above for 2nd half of Secondary, which is parallel with 1st half Secondary.

Insulation		2 layers of tape Item [8].
WD5 **Shield2**	 	Start at pin 3, wind 8 tri-filar turns of wire Item [4]. At the last turn cut short the wires as No-Connect.

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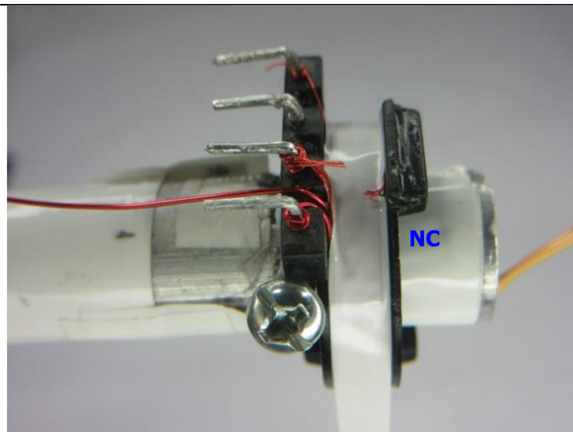
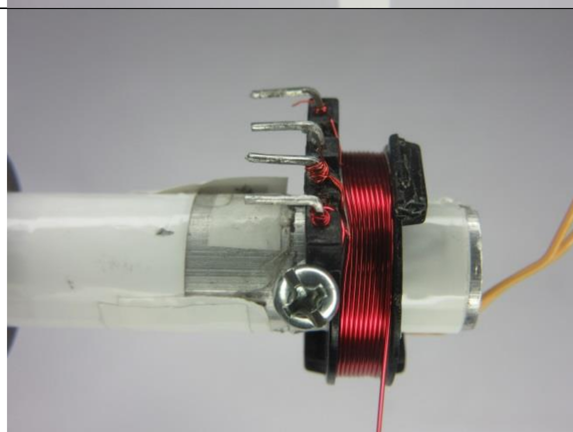
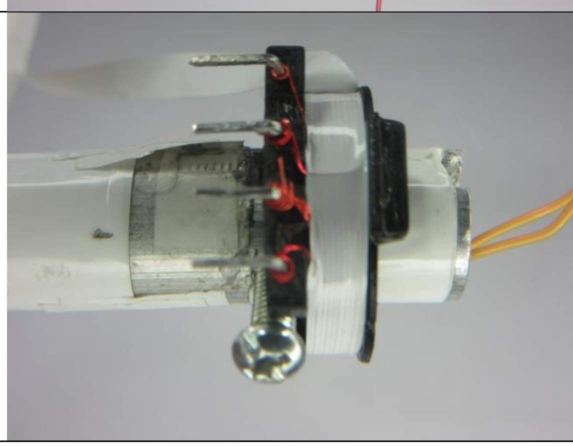
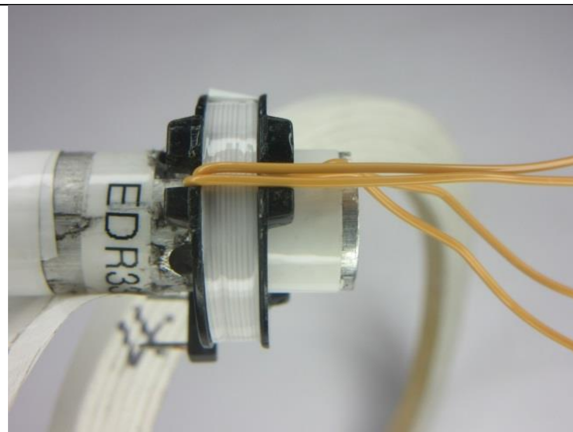
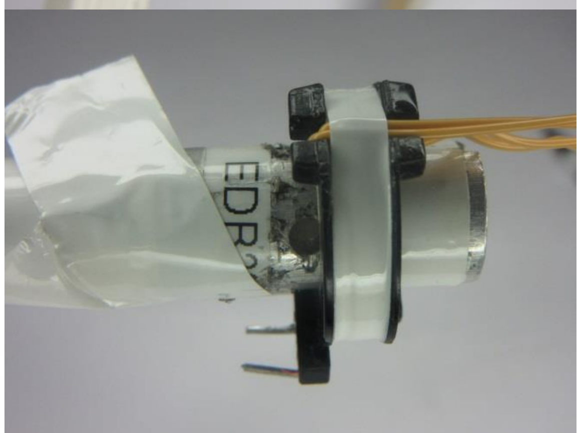
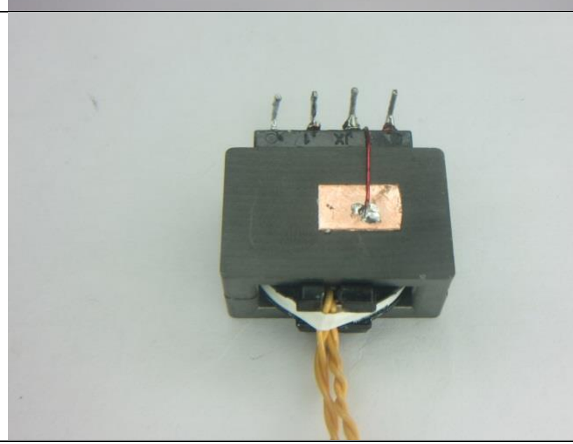
Insulation		1 layer of tape Item [8].
WD6 **2nd Primary**		Use wire hanging from WD1 and continue winding 10 turns from left to right. At the last turn, finish winding at pin 2.
Insulation		1 layer of tape Item [8] and bring the secondary wires FL1 to the right, then add another 2 layers of tape Item [8]. (total of 3 Layers)

	 	
Gap and Ground Core		Add gap core to Item [1] to get 425 μH primary inductance. Solder one end of bus wire Item [6] to pin 3 and connect the other end of wire to copper tape Item [7]. Attach the copper tape to the transformer core bottom.

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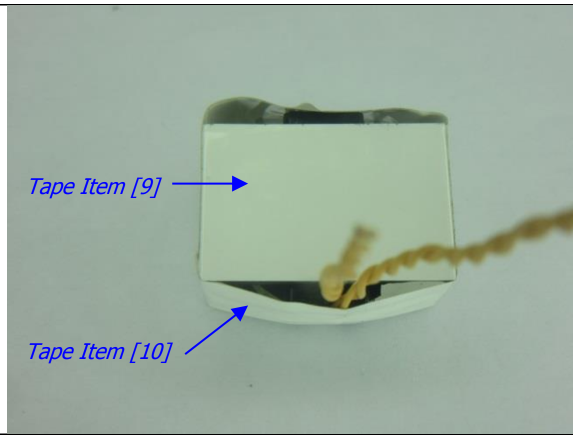
Finish Assembly		Wrap the body of transformer along the top and bottom with 3 layers of tape Item [9], and also wrap the transformer sideways with 3 layers of tape Item [10]. Varnish using Item [11].

8 Common Mode Choke Specifications

8.1 ***19.8 mH Common Mode Choke (L1)***

8.1.1 Electrical Diagram

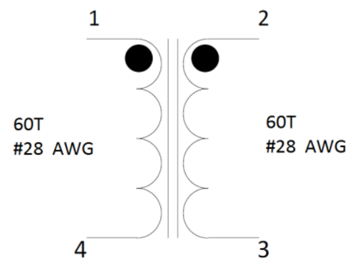


Figure 12 – Inductor Electrical Diagram.

8.1.2 Electrical Specifications

Inductance	Pins 1-4 and pins 2-3 measured at 100 kHz, 0.4 RMS.	~19.8 mH ±25%
Core effective Inductance Index		5500 nH/N^2
Leakage Inductance	Pins 1-4, with pins 2-3 shorted.	80 µH ±10%

8.1.3 Material List

Item	Description
[1]	Toroid: FERRITE INDUCTOR TOROID T14 x 8 x 5.5, PI#: 32-00286-00.
[2]	Divider: Cable Tie, Panduit, PLT.6M-M PI#: 75-00202-00.
[3]	Magnet Wire: #28 AWG Heavy Nyleze.
[4]	Epoxy: Devon, 14270, 5mins Epoxy; or Equivalent.

8.1.4 Winding Instructions

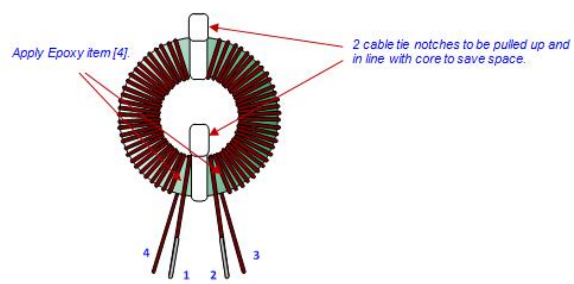


Figure 13 – 19.8 mH CMC Illustration Image.

- 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 60 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 symmetrically with last winding.
- 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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8.2 *250 µH Common Mode Choke (L2)*

8.2.1 Electrical Diagram

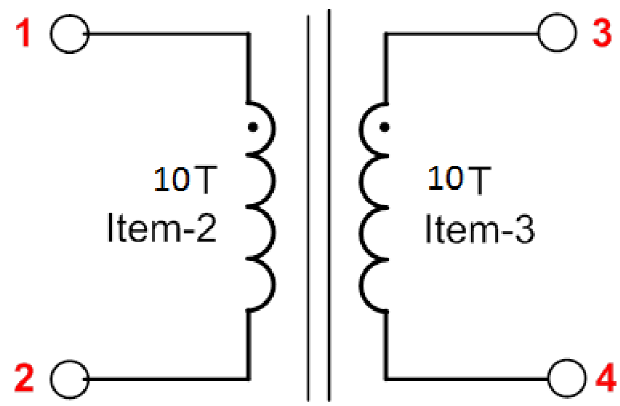


Figure 14 – Inductor Electrical Diagram.

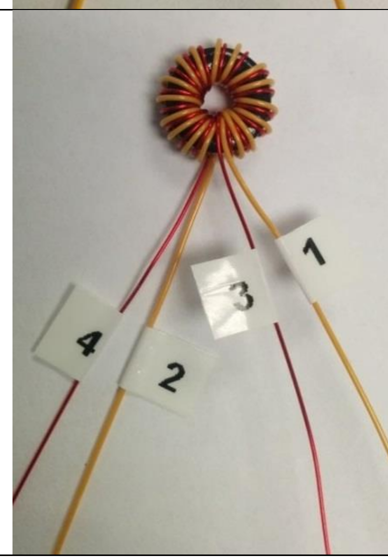
8.2.2 Electrical Specifications

Inductance	Pin 1-pin 2 (pin 3-pin 4), all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	250 µH ±10%
Leakage Inductance	Pins 1-2, with 3-4 shorted.	0.5 µH ±10%

8.2.3 Material List

Item	Description
[1]	Toroid: Ferrite Inductor Toroid.415" OD; Mfg Part Number: 35T0375-10H. PI#: 32-00275-00. Dim: 9.53 mm, O.D. x 4.75 mm, I.D. x 3.18 mm L.
[2]	Magnet Wire: #27 AWG, Triple Insulated Wire.
[3]	Magnet Wire: #27 AWG, Double Coated.

8.2.4 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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9 Transformer Design Spreadsheet

1	Flyback_071219; 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	82.0		82.0	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	2.250		2.250	A	Output current 1
12	POUT1			47.25	W	Output power 1
13	EFFICIENCY1	0.90		0.90		Converter efficiency for output 1
14	Z_FACTOR1	0.50		0.50		Z-factor for output 1
16	SET-POINT 2					
17	VOUT2	20.00		20.00	V	Output voltage 2
18	IOUT2	2.250		2.250	A	Output current 2
19	POUT2			45.00	W	Output power 2
20	EFFICIENCY2	0.90		0.90		Converter efficiency for output 2
21	Z_FACTOR2	0.50		0.50		Z-factor for output 2
23	SET-POINT 3					
24	VOUT3	16.00		16.00	V	Output voltage 3
25	IOUT3	3.000		3.000	A	Output current 3
26	POUT3			48.00	W	Output power 3
27	EFFICIENCY3	0.90		0.90		Converter efficiency for output 3
28	Z_FACTOR3	0.50		0.50		Z-factor for output 3
30	SET-POINT 4					
31	VOUT4	15.00		15.00	V	Output voltage 4
32	IOUT4	3.000		3.000	A	Output current 4
33	POUT4			45.00	W	Output power 4
34	EFFICIENCY4	0.90		0.90		Converter efficiency for output 4
35	Z_FACTOR4	0.50		0.50		Z-factor for output 4
37	SET-POINT 5					
38	VOUT5	11.00		11.00	V	Output voltage 5
39	IOUT5	4.100		4.100	A	Output current 5
40	POUT5			45.10	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	10.00		10.00	V	Output voltage 6
46	IOUT6	4.500		4.500	A	Output current 6
47	POUT6			45.00	W	Output power 6
48	EFFICIENCY6	0.90		0.90		Converter efficiency for output 6
49	Z_FACTOR6	0.50		0.50		Z-factor for output 6
51	SET-POINT 7					
52	VOUT7	9.00		9.00	V	Output voltage 7
53	IOUT7	5.000		5.000	A	Output current 7
54	POUT7			45.00	W	Output power 7
55	EFFICIENCY7	0.90		0.90		Converter efficiency for output 7
56	Z_FACTOR7	0.50		0.50		Z-factor for output 7
58	SET-POINT 8					
59	VOUT8	5.00		5.00	V	Output voltage 8
60	IOUT8	5.000		5.000	A	Output current 8
61	POUT8			25.00	W	Output power 8
62	EFFICIENCY8	0.89		0.89		Converter efficiency for output 8
63	Z_FACTOR8	0.50		0.50		Z-factor for output 8

65	**SET-POINT 9**					
66	VOUT9	3.30		3.30	V	Output voltage 9
67	IOUT9	5.000		5.000	A	Output current 9
68	POUT9			16.50	W	Output power 9
69	EFFICIENCY9	0.89		0.89		Converter efficiency for output 9
70	Z_FACTOR9	0.50		0.50		Z-factor for output 9
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		INN3379C		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			0.35	V	Primary switch on-time voltage drop
89	VDRAIN_OFF_PRSW			596.31	V	Peak drain voltage on the primary switch during turn-off
93	**WORST CASE ELECTRICAL PARAMETERS**					
94	FSWITCHING_MAX	71421		71421	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
95	VOR	153.0		153.0	V	Voltage reflected to the primary winding (corresponding to set-point 1) when the primary switch turns off
96	VMIN			90.08	V	Valley of the rectified minimum input AC voltage at full load
97	KP			0.689		Measure of continuous/discontinuous mode of operation
98	MODE_OPERATION			CCM		Mode of operation
99	DUTYCYCLE			0.589		Primary switch duty cycle
100	TIME_ON			10.32	us	Primary switch on-time
101	TIME_OFF			6.05	us	Primary switch off-time
102	LPRIMARY_MIN			402.2	uH	Minimum primary magnetizing inductance
103	LPRIMARY_TYP			423.3	uH	Typical primary magnetizing inductance
104	LPRIMARY_TOL			5.0	%	Primary magnetizing inductance tolerance
105	LPRIMARY_MAX			444.5	uH	Maximum primary magnetizing inductance
107	**PRIMARY CURRENT**					
108	IAVG_PRIMARY			0.565	A	Primary switch average current
109	IPEAK_PRIMARY			2.112	A	Primary switch peak current
110	IPEDESTAL_PRIMARY			0.586	A	Primary switch current pedestal
111	IRIPPLE_PRIMARY			2.112	A	Primary switch ripple current
112	IRMS_PRIMARY			0.892	A	Primary switch RMS current
114	**SECONDARY CURRENT**					
115	IPEAK_SECONDARY			15.839	A	Secondary winding peak current
116	IPEDESTAL_SECONDARY			4.394	A	Secondary winding pedestal current
117	IRMS_SECONDARY			7.632	A	Secondary winding RMS current
118	IRIPPLE_CAP_OUT			5.765	A	Output capacitor ripple current
122	**TRANSFORMER CONSTRUCTION PARAMETERS**					
123	**CORE SELECTION**					
124	CORE	EQ27	Info	EQ27		The transformer windings may not fit: pick a bigger core or bobbin and refer to the Transformer Parameters tab for fit calculations
125	CORE NAME			ACP95-EQ27/6/18		Core code

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126	AE			108.0	mm^2	Core cross sectional area
127	LE			36.3	mm	Core magnetic path length
128	AL			7700	nH/N^2	Ungapped core effective inductance per turns squared
129	VE			3920	mm^3	Core volume
130	BOBBIN NAME			EQ-2506		Bobbin name
131	AW	10.0		10.0	mm^2	Bobbin window area
132	BW	4.25		4.25	mm	Bobbin width
133	MARGIN			0.0	mm	Bobbin safety margin
135	**PRIMARY WINDING**					
136	NPRIMARY			30		Primary winding number of turns
137	BPEAK			3200	Gauss	Peak flux density
138	BMAX			2857	Gauss	Maximum flux density
139	BAC			1429	Gauss	AC flux density (0.5 x Peak to Peak)
140	ALG			470	nH/N^2	Typical gapped core effective inductance per turns squared
141	LG			0.271	mm	Core gap length
142	LAYERS_PRIMARY			3		Primary winding number of layers
143	AWG_PRIMARY			27		Primary wire gauge
144	OD_PRIMARY_INSULATED			0.418	mm	Primary wire insulated outer diameter
145	OD_PRIMARY_BARE			0.361	mm	Primary wire bare outer diameter
146	CMA_PRIMARY			226.0	Cmils/A	Primary winding wire CMA
148	**SECONDARY WINDING**					
149	NSECONDARY	4		4		Secondary winding number of turns
150	AWG_SECONDARY			18		Secondary wire gauge
151	OD_SECONDARY_INSULATED			1.328	mm	Secondary wire insulated outer diameter
152	OD_SECONDARY_BARE			1.024	mm	Secondary wire bare outer diameter
153	CMA_SECONDARY			212.8	Cmils/A	Secondary winding wire CMA
155	**BIAS WINDING**					
156	NBIAS			12		Bias winding number of turns
160	**PRIMARY COMPONENTS SELECTION**					
161	**LINE UNDERVOLTAGE**					
162	BROWN-IN REQURED	76.00		76.00	V	Required line brown-in threshold
163	RLS			3.82	MΩ	Connect two 1.91 MOhm resistors to the V-pin for the required UV/OV threshold
164	BROWN-IN ACTUAL			76.58	V	Actual brown-in threshold using standard resistors
165	BROWN-OUT ACTUAL			69.26	V	Actual brown-out threshold using standard resistors
167	**LINE OVERVOLTAGE**					
168	OVERVOLTAGE_LINE		Warning	319.20	V	The device voltage stress will be higher than 600V when overvoltage is trigerred
170	**BIAS WINDING**					
171	VBIAS			9.00	V	Rectified bias voltage at the lowest output set-point
172	VF_BIAS			0.70	V	Bias winding diode forward drop
173	VREVERSE_BIASDIODE			158.32	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			70.77	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
182	SRFET	AONS62922		AONS62922		Secondary rectifier (Logic MOSFET)
183	VBREAKDOWN_SRFET			120	V	Secondary rectifier breakdown voltage
184	RDSON_SRFET			7.0	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
188	**SET-POINTS ANALYSIS**					
189	**TOLERANCE CORNER**					
190	USER_VAC	90		90	V	Input AC RMS voltage corner to be

						evaluated
191	USER_ILIMIT	MIN		1.980	A	Current limit corner to be evaluated
192	USER_LPRIMARY	MIN		402.2	uH	Primary inductance corner to be evaluated
194	**SET-POINT SELECTION**					
195	SET-POINT	7		7		Select the set-point which needs to be evaluated
196	FSWITCHING			71421.0	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
197	VOR			66.0	V	Voltage reflected to the primary winding when the primary switch turns off
198	VMIN			92.41	V	Valley of the minimum input AC voltage
199	KP			0.703		Measure of continuous/discontinuous mode of operation
200	MODE_OPERATION			CCM		Mode of operation
201	DUTYCYCLE			0.417		Primary switch duty cycle
202	TIME_ON			7.27	us	Primary switch on-time
203	TIME_OFF			8.16	us	Primary switch off-time
205	**PRIMARY CURRENT**					
206	IAVG_PRIMARY			0.516	A	Primary switch average current
207	IPEAK_PRIMARY			1.905	A	Primary switch peak current
208	IPEDESTAL_PRIMARY			0.566	A	Primary switch current pedestal
209	IRIPPLE_PRIMARY			1.338	A	Primary switch ripple current
210	IRMS_PRIMARY			0.836	A	Primary switch RMS current
212	**SECONDARY CURRENT**					
213	IPEAK_SECONDARY			14.286	A	Secondary winding peak current
214	IPEDESTAL_SECONDARY			4.249	A	Secondary winding pedestal current
215	IRMS_SECONDARY			7.411	A	Secondary winding RMS current
216	IRIPPLE_CAP_OUT			5.470	A	Output capacitor ripple current
218	**MAGNETIC FLUX DENSITY**					
219	BPEAK			2515	Gauss	Peak flux density
220	BMAX			2364	Gauss	Maximum flux density
221	BAC			831	Gauss	AC flux density (0.5 x Peak to Peak)

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10 Adapter Case and Heat Spreader Assembly

10.1 ***Adapter Case Dimensions***

10.1.1 Case Bottom Dimensions

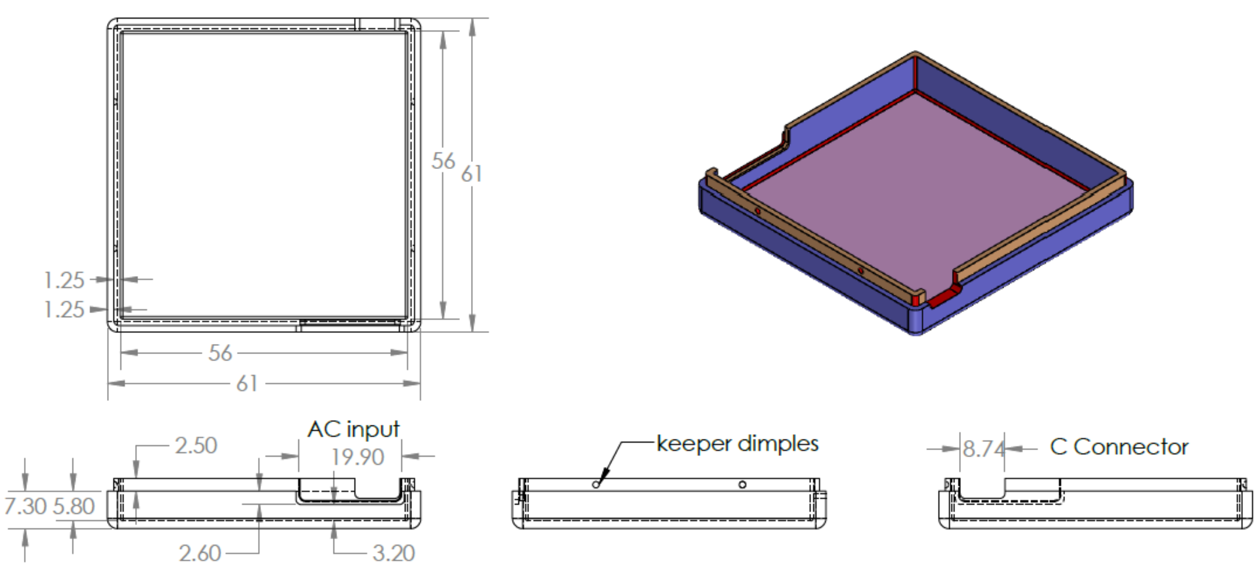

Figure 15 – DER-856 Adapter Case Bottom.

10.1.2 Case Top Dimensions

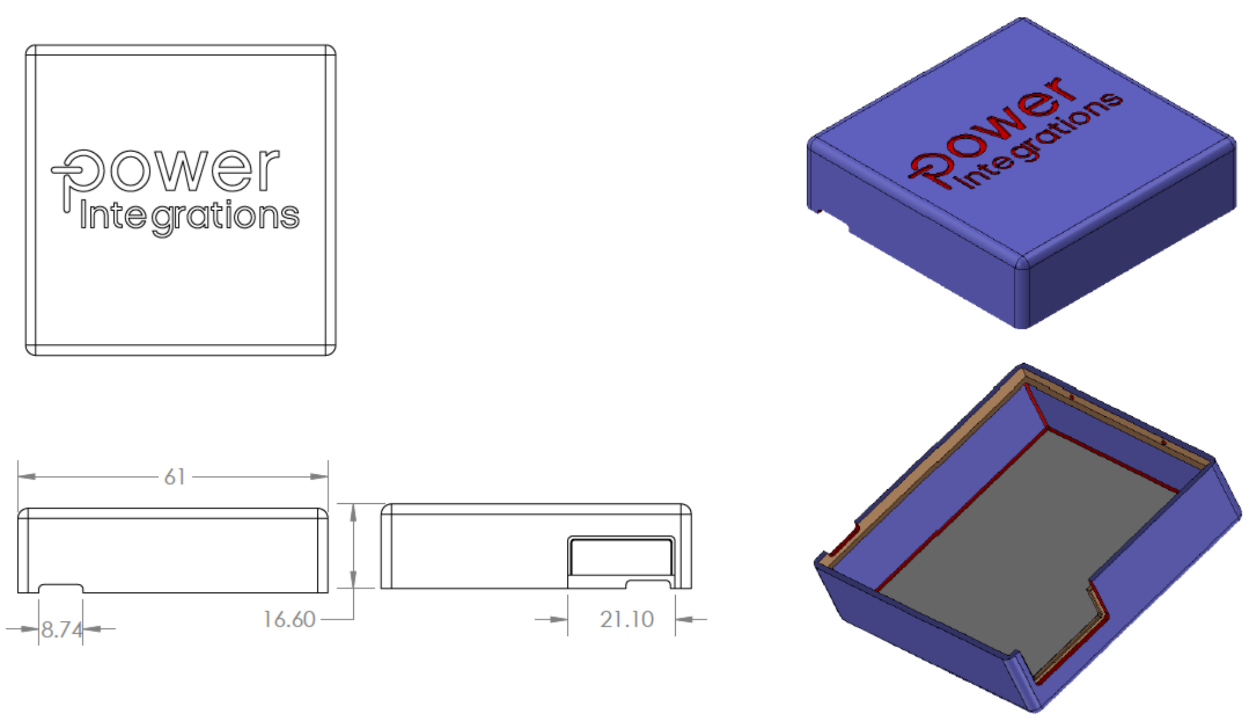

Figure 16 – DER-856 Adapter Case Top.

10.1.3 Adapter Case Assembly

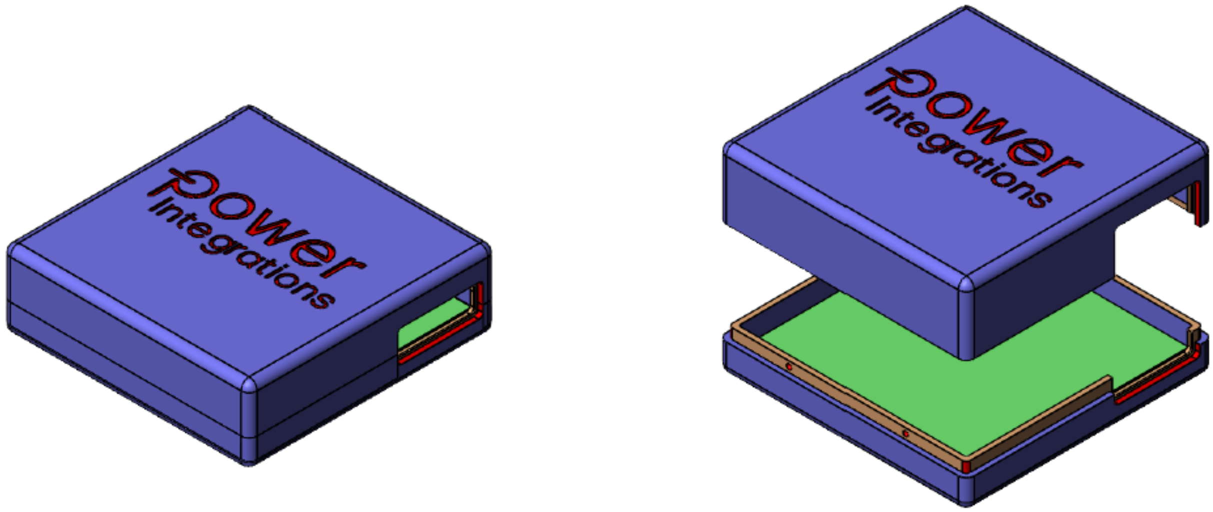

Figure 17 – DER-856 Adapter Assembly Drawing.

10.2 ***Heat Spreader Drawings***

10.2.1 Aluminum Sheet

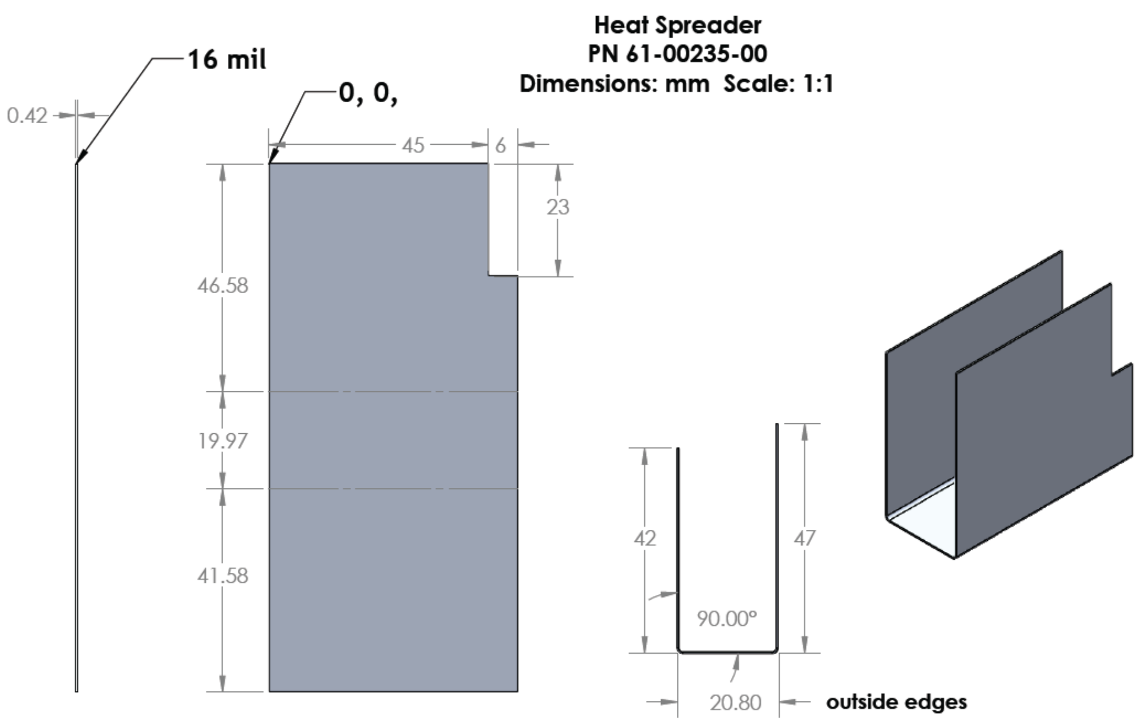

Figure 18 – Aluminum Heat Spreader.

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10.2.2 Thermal Pads

PN 61-00236-01
3M 5549S 210mmx155mm x1.5mm
Dimensions: mm

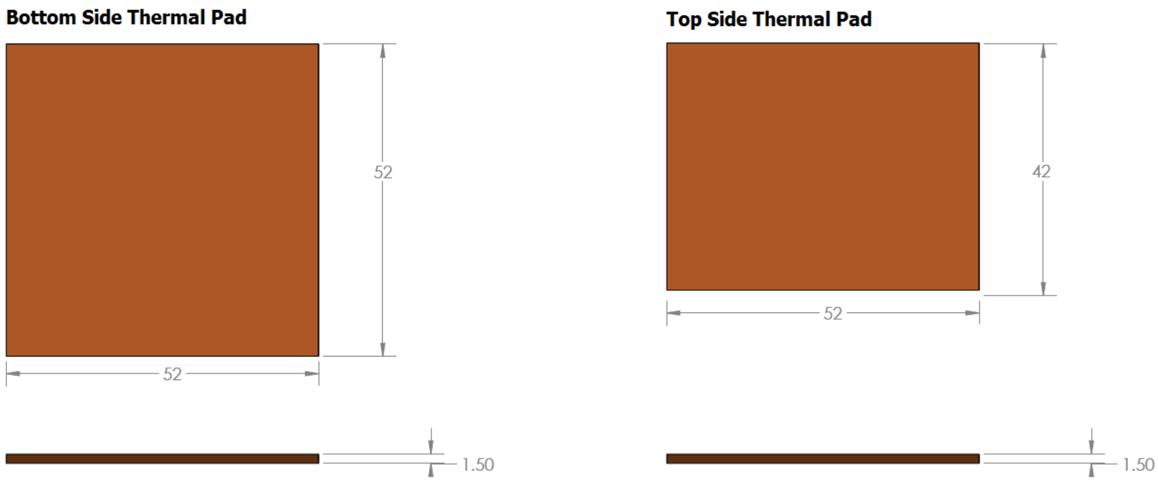


Figure 19 – Bottom Side and Top Side Thermal Pads.

10.2.3 Heat Spreader Assembly

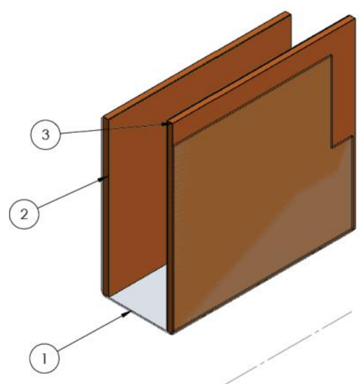
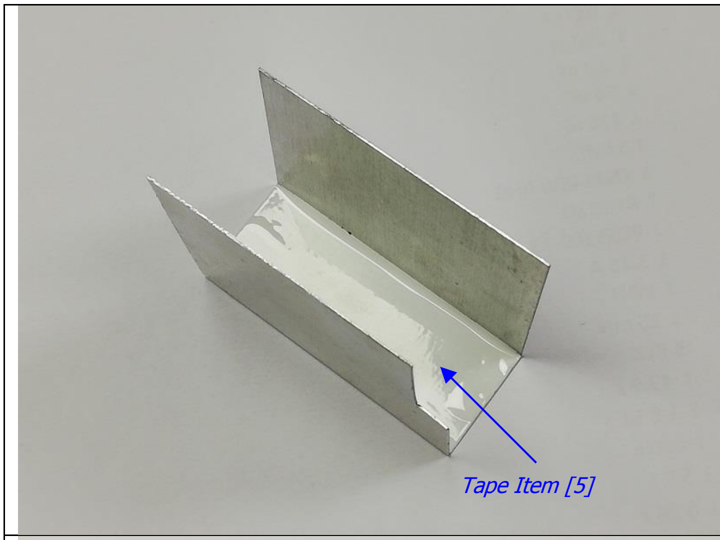


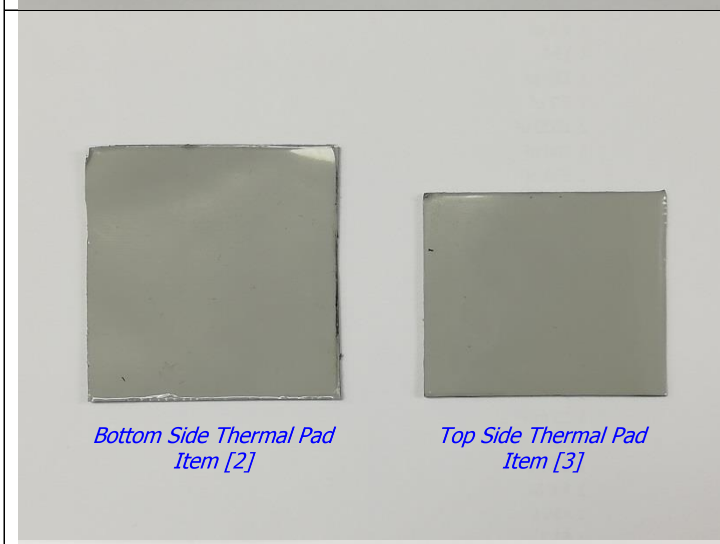
Figure 20 – Aluminum Sheet (1), Top Thermal Pad (2), and Bottom Thermal Pad (3) Assembly.

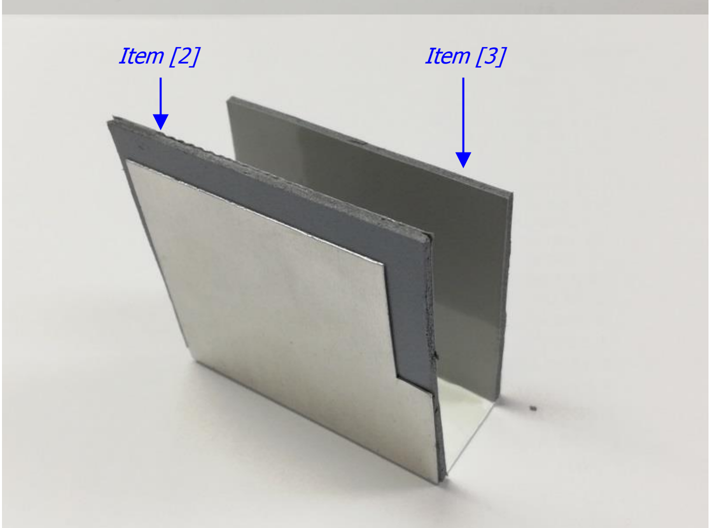
10.3 *Material List*

Item	Description
[1]	Heat Spreader: PI#: 61-00235-00, (Material: Aluminum, 3003, 16 mil thick).
[2]	Bottom Side Thermal Pad, use 3M Thermally Conductive Silicone Pad 5549S, PI#: 66-00236-01 cut into dimension: 52 mm x 52 mm.
[3]	Top Side Thermal Pad, use 3M Thermally Conductive Silicone Pad 5549S, PI#: 66-00236-01 cut into dimension: 52 mm x 42 mm.
[4]	DER-856 Adapter Case Bottom, Adapter Case Top (custom).
[5]	Tape: 3M 1350-F, Polyester Film, 1 mil Thickness, 20 mm Width, 54 mm Length.
[6]	Tape: 3M 1350-F, Polyester Film, 1 mil Thickness, 20 mm Width, 44 mm Length.

10.4 *Assembly Instructions*

<table>
<tr>
<td>


</td>
<td>Place 1 layer of tape Item [5] at inner edge of heat spreader Item [1].</td>
</tr>
<tr>
<td>




</td>
<td>Prepare thermal pads Item [2] (square) and Item [3] (rectangle). Place the thermal pads inside the heat spreader Item [1].</td>
</tr>
</table>

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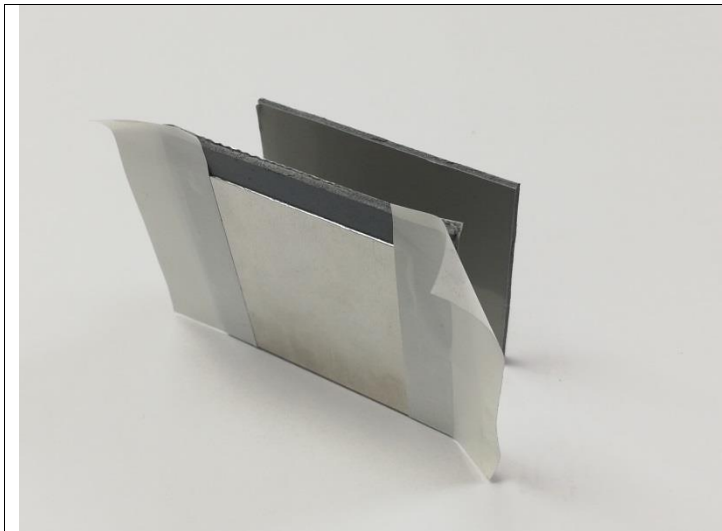
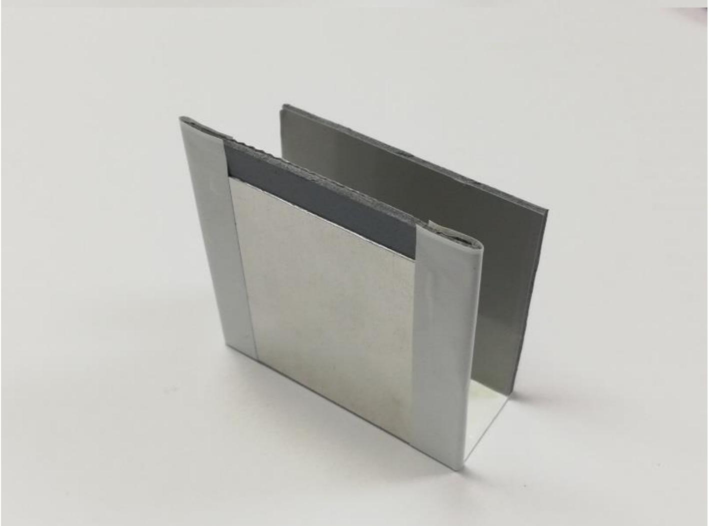
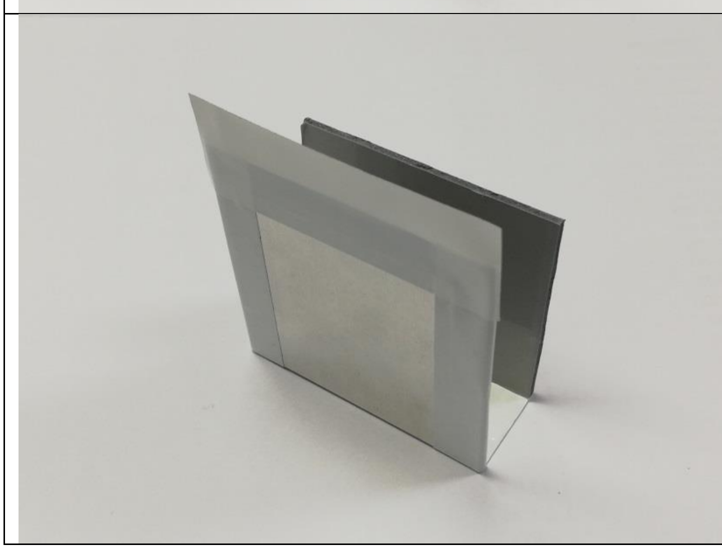
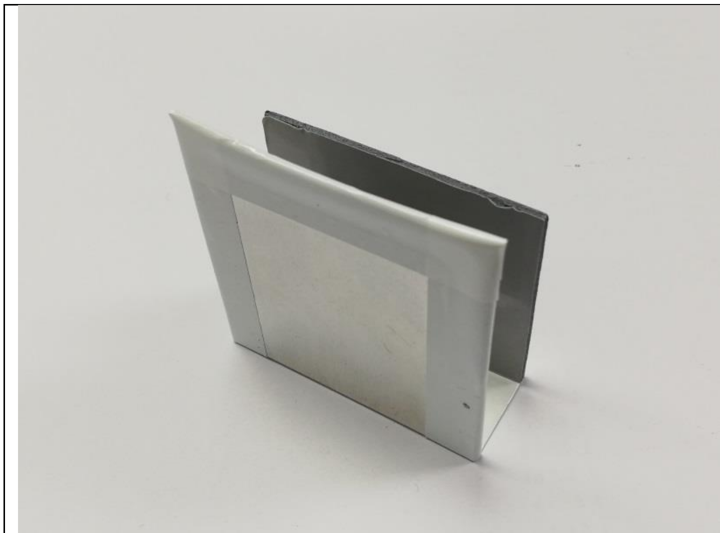
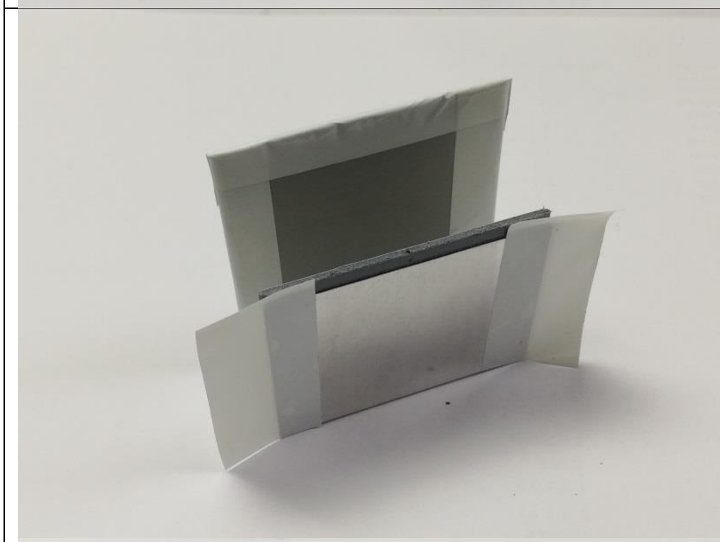
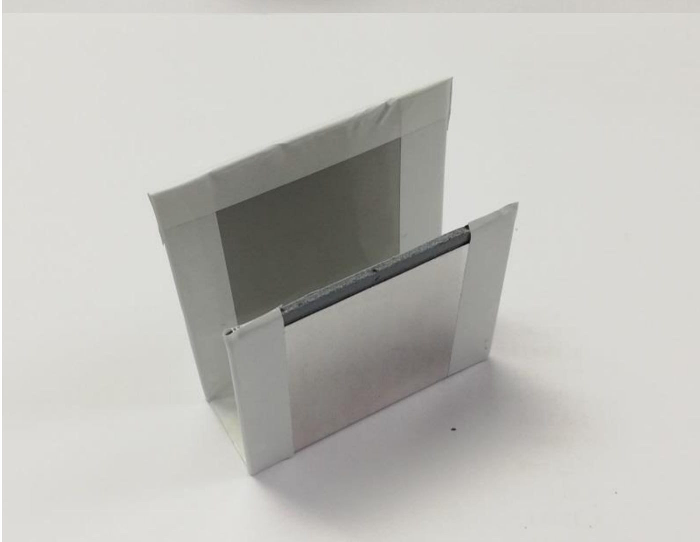
 	Wrap 1 piece of tape Item [5] on each of the side edges of thermal pad Item [2]
	Wrap another 1 piece of tape Item [5] on the front edge of thermal pad Item [2]

	
 	Wrap 1 piece of tape Item [6] on each of the side edges of thermal pad Item [3], and then 1 piece of tape Item [5] on the front edge of thermal pad Item [3].

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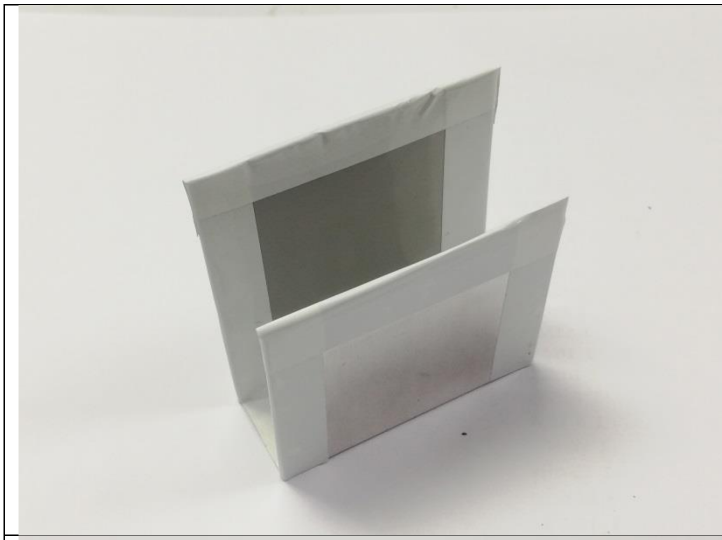
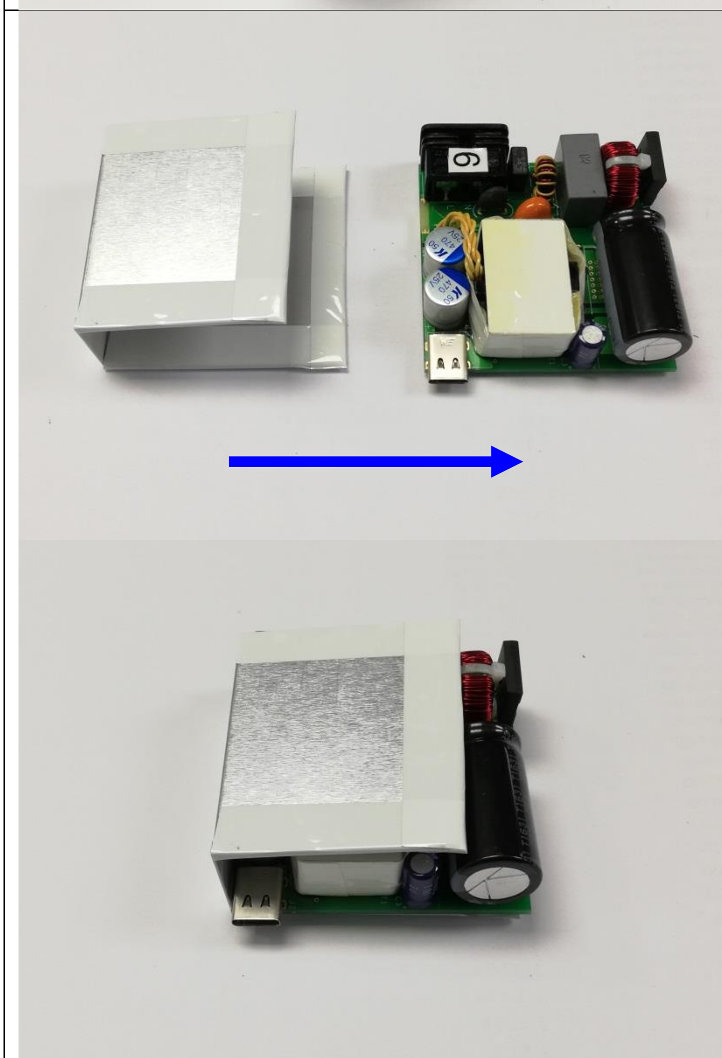
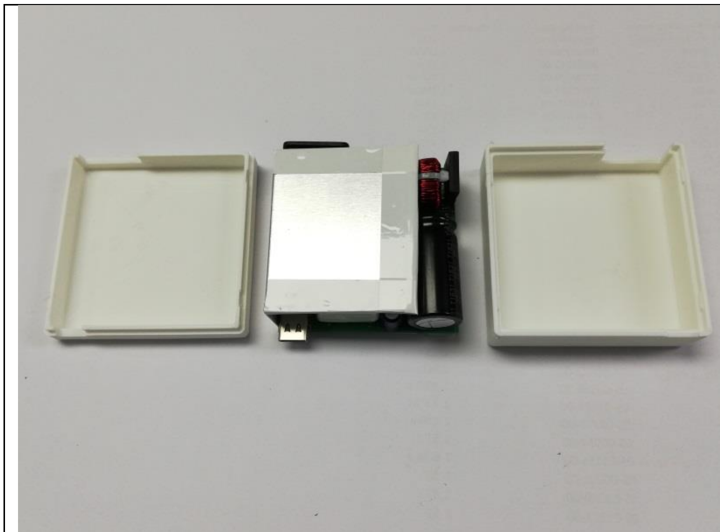
	
	Insert the PCB to the heat spreader assembly as shown, with the shorter side of the heat spreader covering the top side of the PCB.

	Insert the board with heat spreader into the adapter case Item [4] and finish the assembly.
 	

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11 Performance Data

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

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

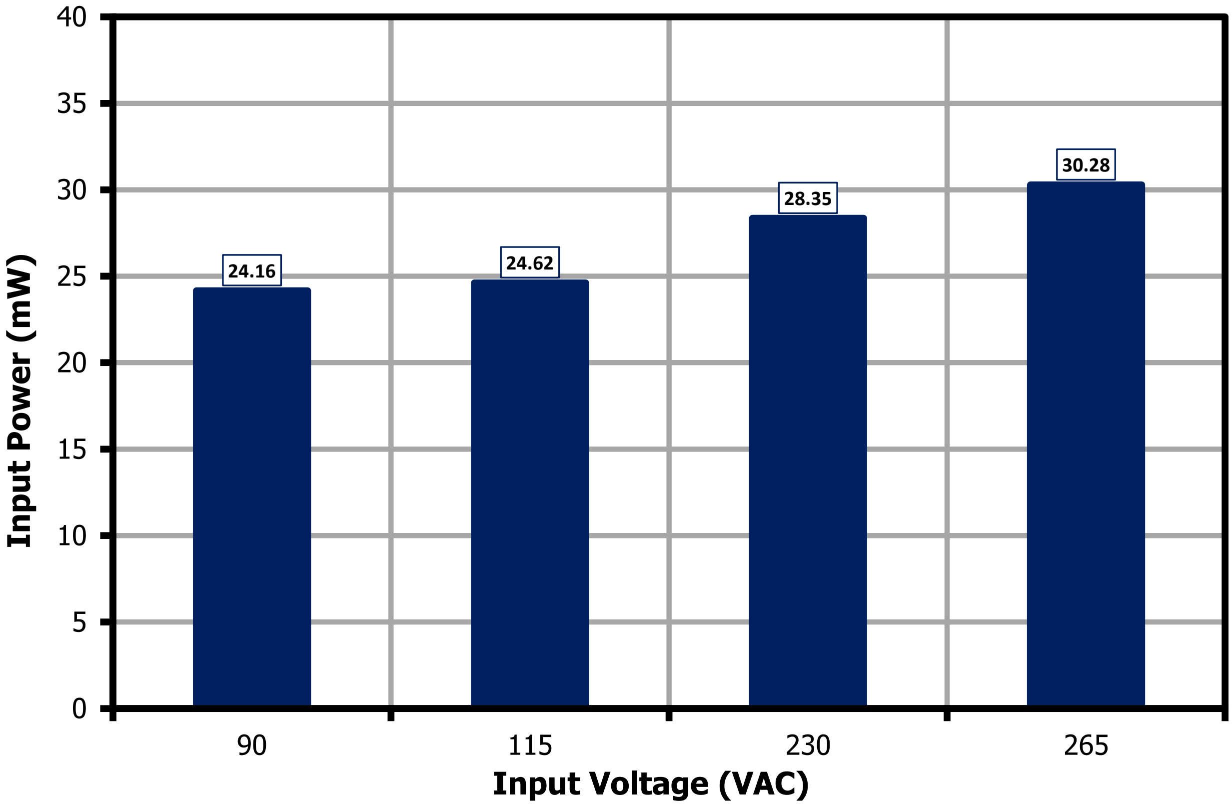

Figure 21 – No-Load Input Power vs. Input Line Voltage.

11.2 *Average and 10% Load Efficiency*

11.2.1 Efficiency Requirements

		Test	Average	Average	10% Load
		Effective	2016	Jan-16	Jan-16
V_{OUT} (V)	Model (V)	Power (W)	New EISA2007	CoC v5 Tier 2	CoC v5 Tier 2
5	<6	25	84.25%	85.00%	75.47%
9	>6	45	87.73%	88.85%	78.85%
15	>6	45	87.73%	88.85%	78.85%
20	>6	45	87.73%	88.85%	78.85%

11.2.2 Efficiency Performance Summary (On Board)

V_{OUT} (V)	Power (W)	Average Efficiency (%)		10% Load Efficiency (%)	
		115 VAC	230 VAC	115 VAC	230 VAC
5	25	90.49	90.40	90.78	87.81
9	45	91.40	92.01	90.71	88.94
15	45	91.76	92.29	86.70	85.32
20	45	91.25	91.75	83.31	81.49

11.2.3 Average and 10% Load Efficiency Measurements

11.2.3.1 Output: 5 V / 5 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	DOE6 Requirement (%)	CoC v5 Tier 2 Requirement (%)	Remarks
115	100	25.01	89.58	**90.49**	84.25	85.00	PASS
	75	18.88	90.21				
	50	12.64	90.70				
	25	6.34	91.49				
	10	2.54	**90.78**			75.47	PASS
230	100	25.09	90.22	**90.40**	84.25	85.00	PASS
	75	18.93	90.56				
	50	12.66	90.64				
	25	6.34	90.19				
	10	2.54	**87.81**			75.47	PASS

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11.2.3.2 Output: 9 V / 5 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	DOE6 Requirement (%)	CoC v5 Tier 2 Requirement (%)	Remarks
115	100	44.89	90.54	**91.40**	87.73	88.85	PASS
	75	33.79	91.32				
	50	22.61	91.72				
	25	11.33	92.02				
	10	4.53	**90.71**			78.85	PASS
230	100	45.01	92.04	**92.01**	87.73	88.85	PASS
	75	33.87	92.15				
	50	22.64	92.20				
	25	11.34	91.66				
	10	4.53	**88.94**			78.85	PASS

11.2.3.3 Output: 15 V / 3 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	DOE6 Requirement (%)	CoC v5 Tier 2 Requirement (%)	Remarks
115	100	44.91	91.78	**91.76**	87.73	88.85	PASS
	75	33.74	91.97				
	50	22.51	92.01				
	25	11.26	91.27				
	10	4.50	**86.70**			78.85	PASS
230	100	44.96	92.90	**92.29**	87.73	88.85	PASS
	75	33.76	92.80				
	50	22.52	92.50				
	25	11.26	90.97				
	10	4.50	**85.32**			78.85	PASS

11.2.3.4 Output: 20 V / 2.25 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	DOE6 Requirement (%)	CoC v5 Tier 2 Requirement (%)	Remarks
115	100	44.83	91.82	**91.25**	87.73	88.85	PASS
	75	33.65	91.81				
	50	22.44	91.53				
	25	11.22	89.85				
	10	4.48	**83.31**			78.85	PASS
230	100	44.88	92.89	**91.75**	87.73	88.85	PASS
	75	33.67	92.62				
	50	22.45	91.97				
	25	11.22	89.50				
	10	4.48	**81.49**			78.85	PASS

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11.3 *Efficiency Across Line at 100% Load (On Board)*

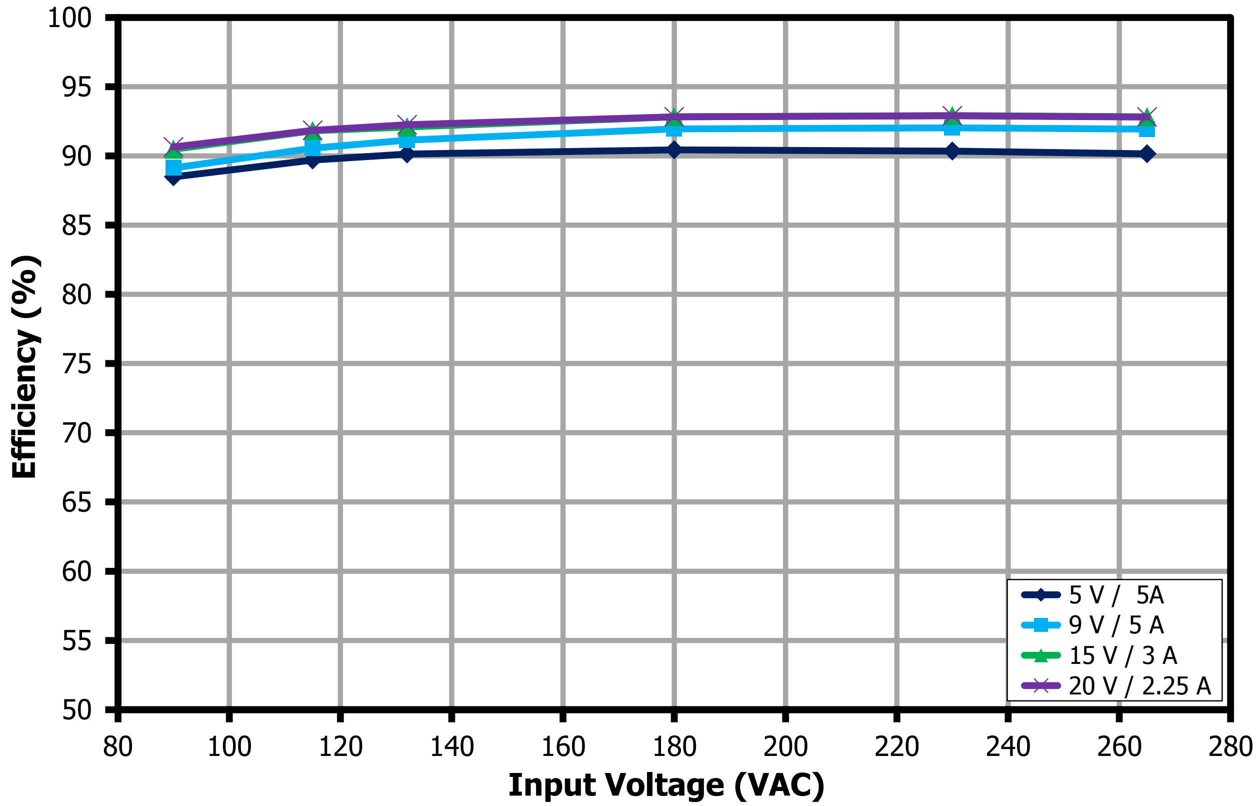

Figure 22 – Full Load Efficiency vs. Input Line for 5 V, 9 V, 15 V, and 20 V Output, Room Temperature.

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

11.4.1 Output: 3.3 V / 5 A

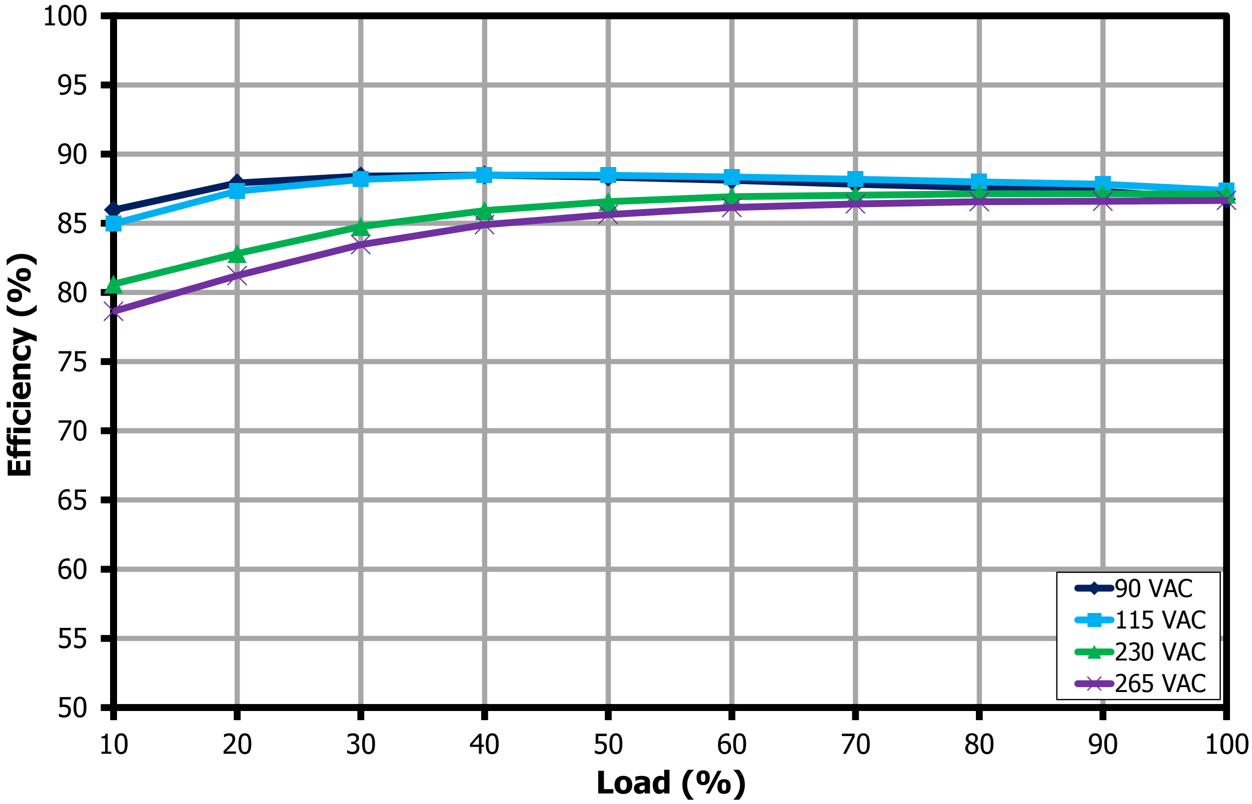

Figure 23 – Efficiency vs. Load for 3.3 V Output, Room Temperature.

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11.4.2 Output: 5 V / 5 A

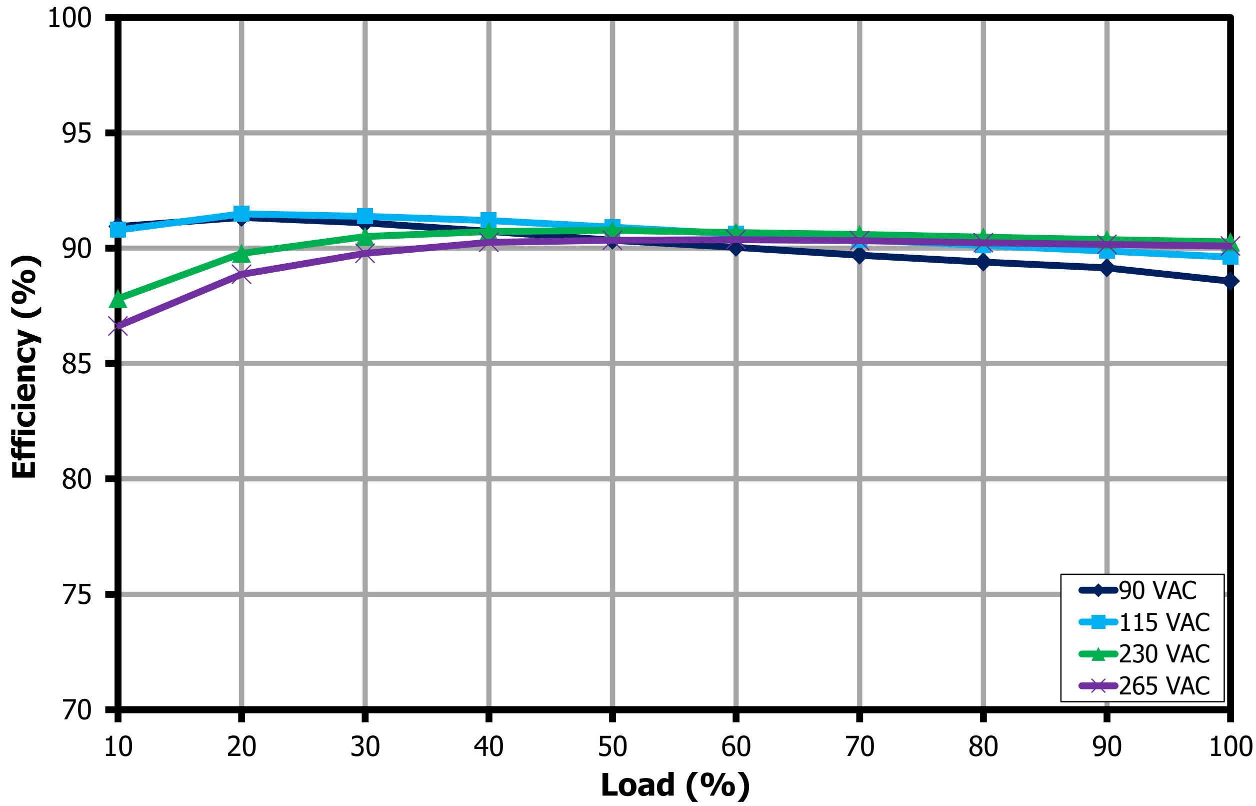

Figure 24 – Efficiency vs. Load for 5 V Output, Room Temperature.

11.4.3 Output: 9 V / 5 A

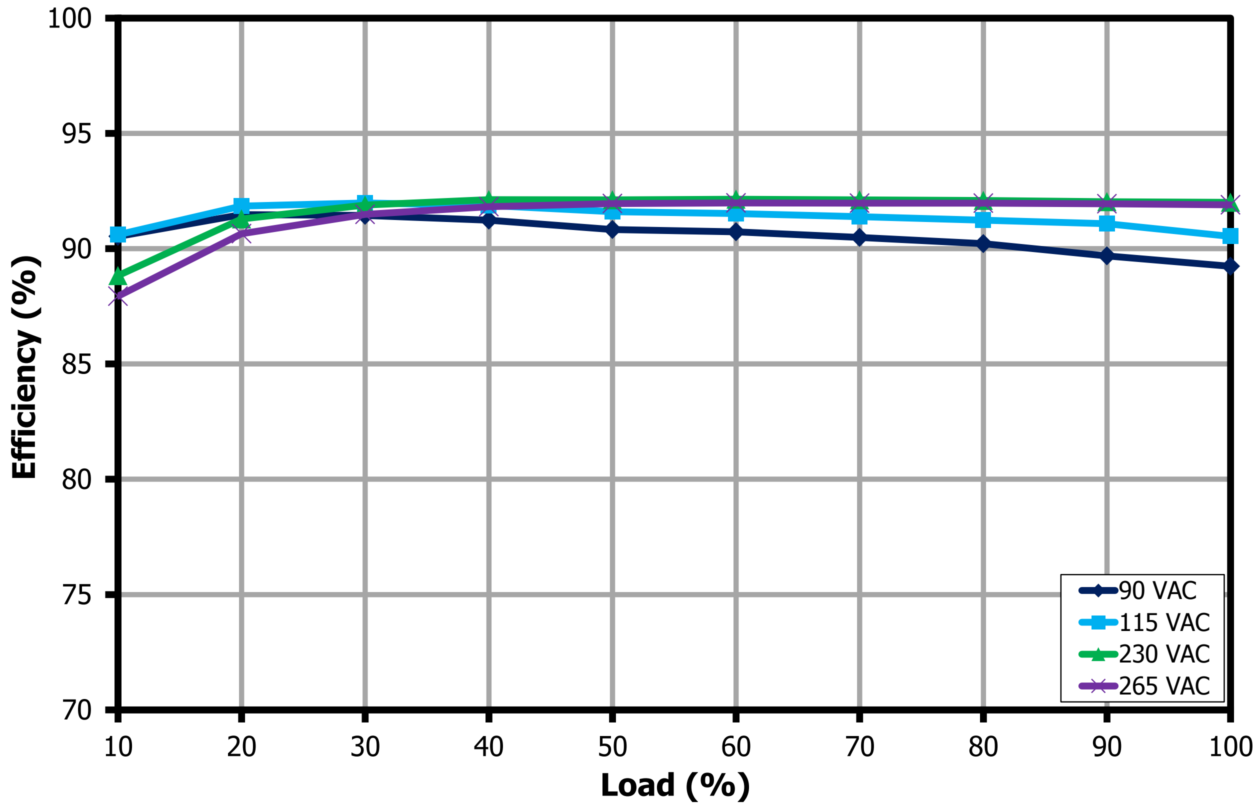

Figure 25 – Efficiency vs. Load for 9 V Output, Room Temperature.

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11.4.4 Output: 11 V / 4.09 A

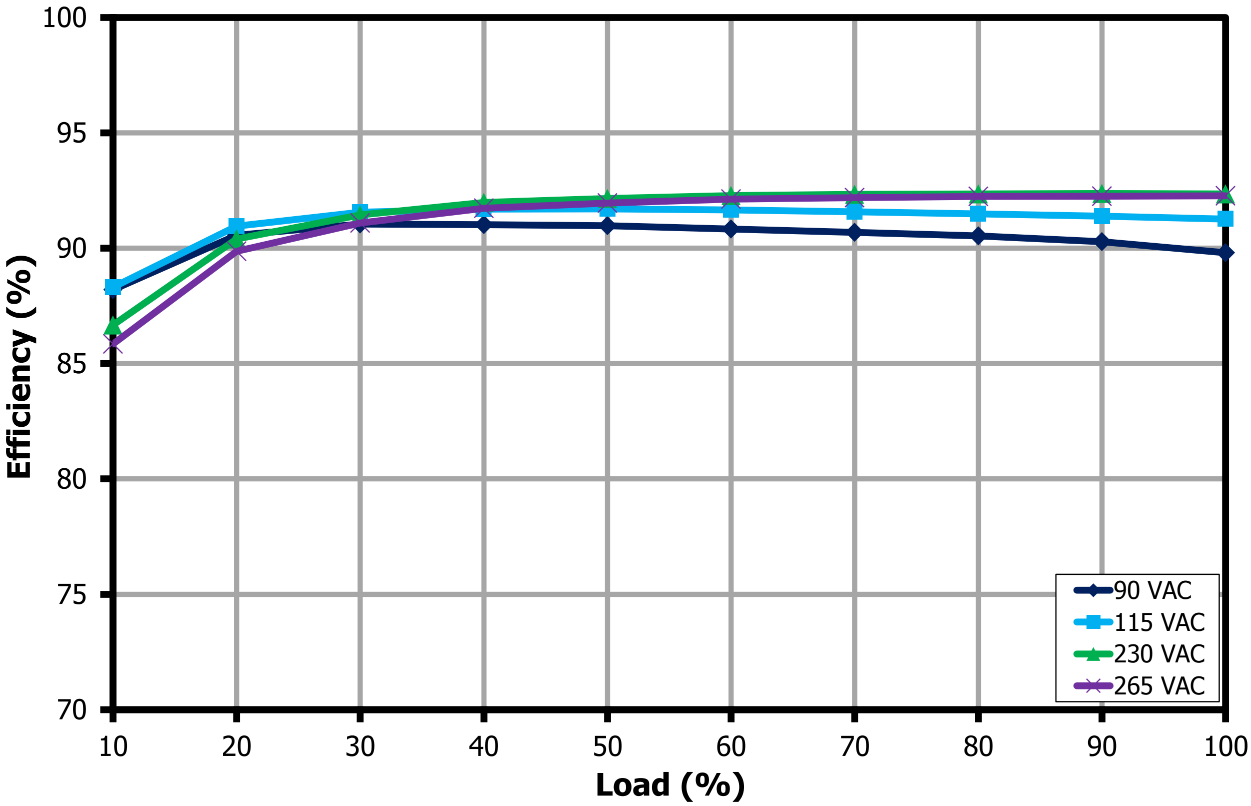

Figure 26 – Efficiency vs. Load for 11 V Output, Room Temperature.

11.4.5 Output: 15 V / 3 A

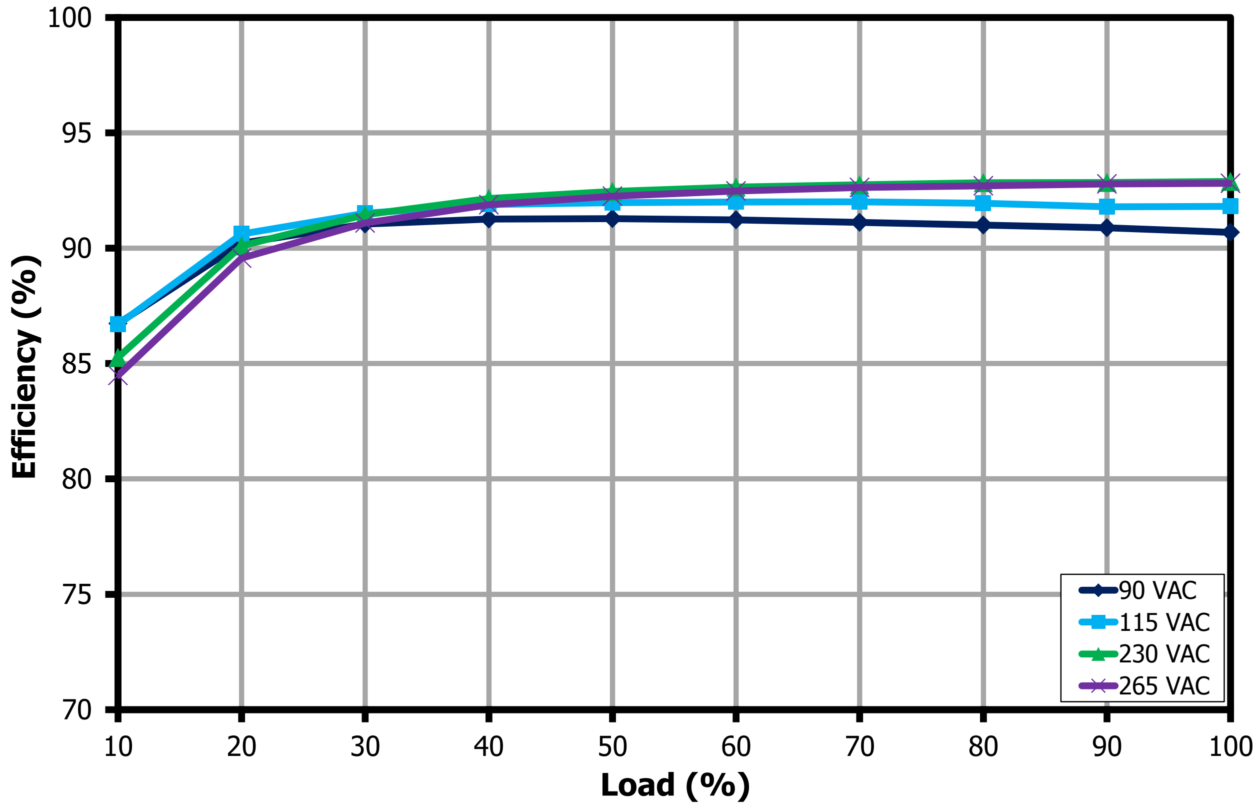

Figure 27 – Efficiency vs. Load for 15 V Output, Room Temperature.

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11.4.6 Output: 16 V / 3 A

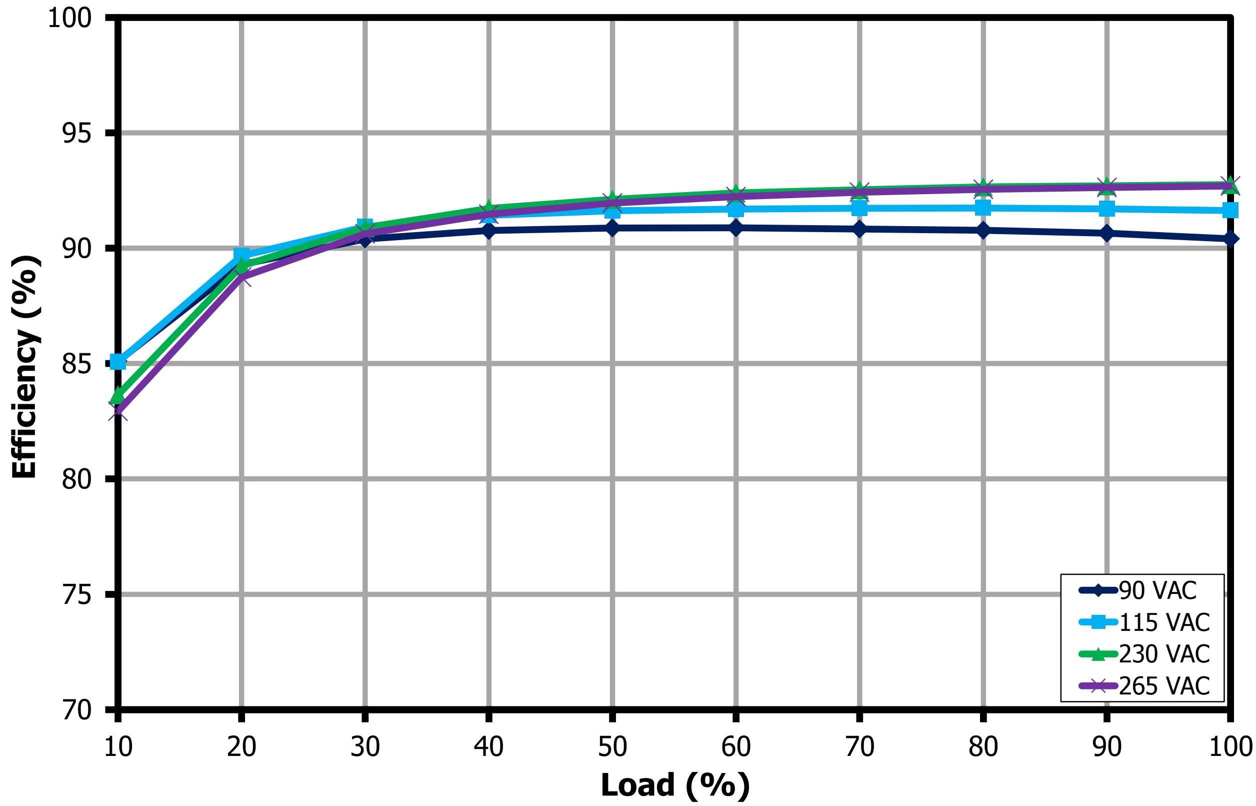

Figure 28 – Efficiency vs. Load for 16 V Output, Room Temperature.

11.4.7 Output: 20 V / 2.25 A

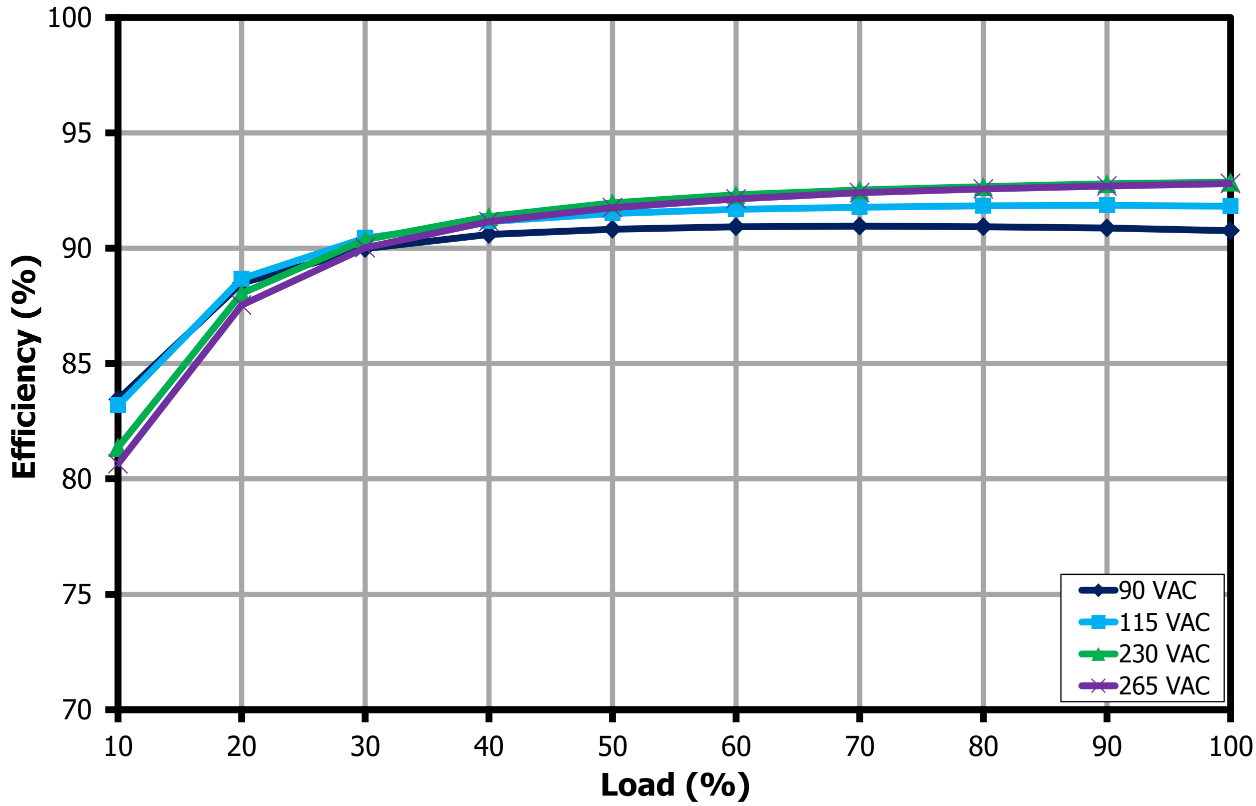

Figure 29 – Efficiency vs. Load for 20 V Output, Room Temperature.

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11.4.8 Output: 21 V / 2.25 A

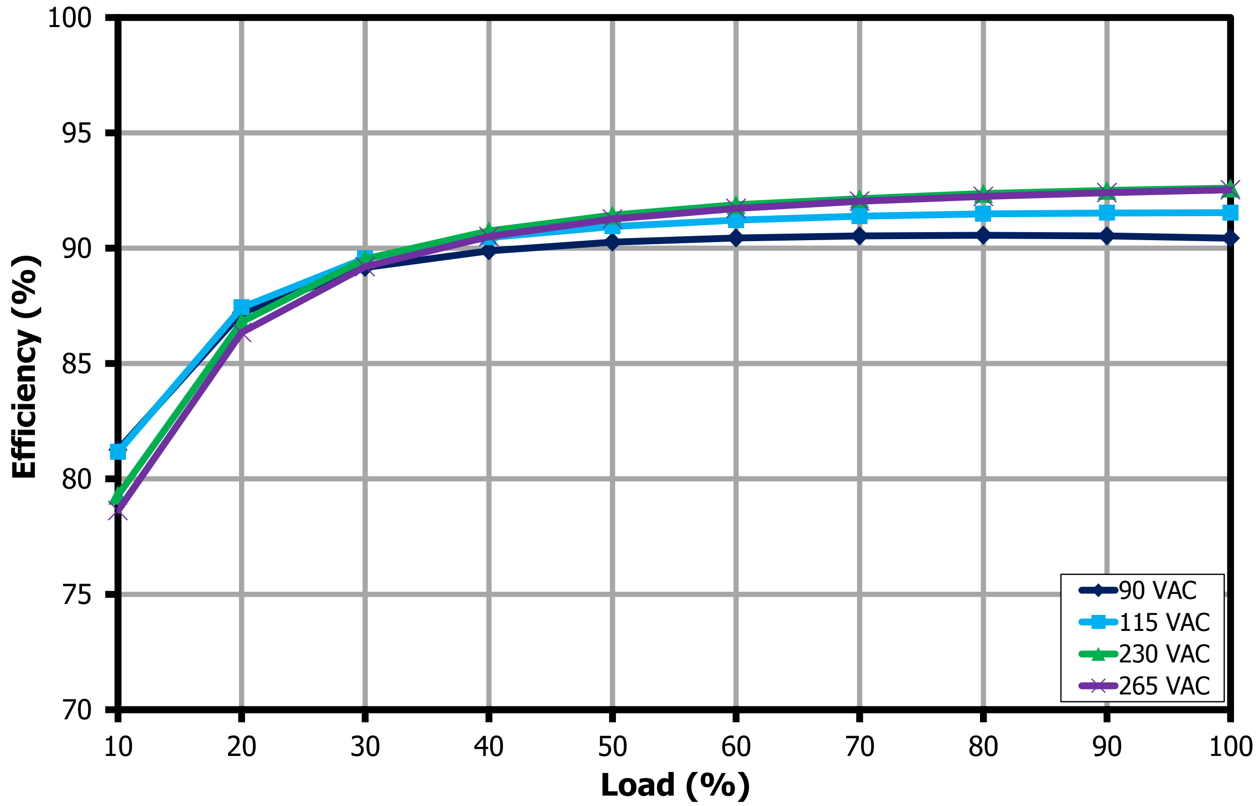

Figure 30 – Efficiency vs. Load for 21 V Output, Room Temperature.

11.5 ***Load Regulation (On Board)***

11.5.1 Output: 3.3 V / 5 A

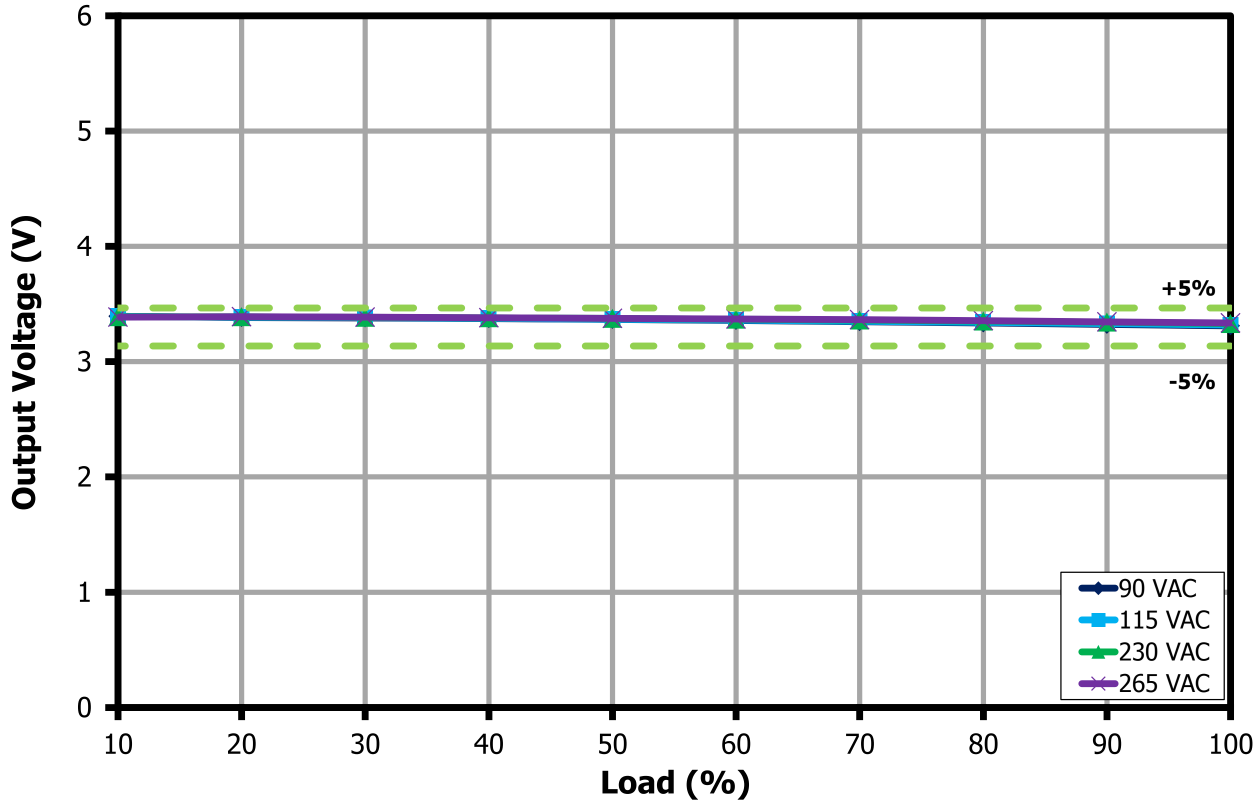

Figure 31 – Output Voltage vs. Output Load for 3.3 V Output, Room Temperature.

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11.5.2 Output: 5 V / 5 A

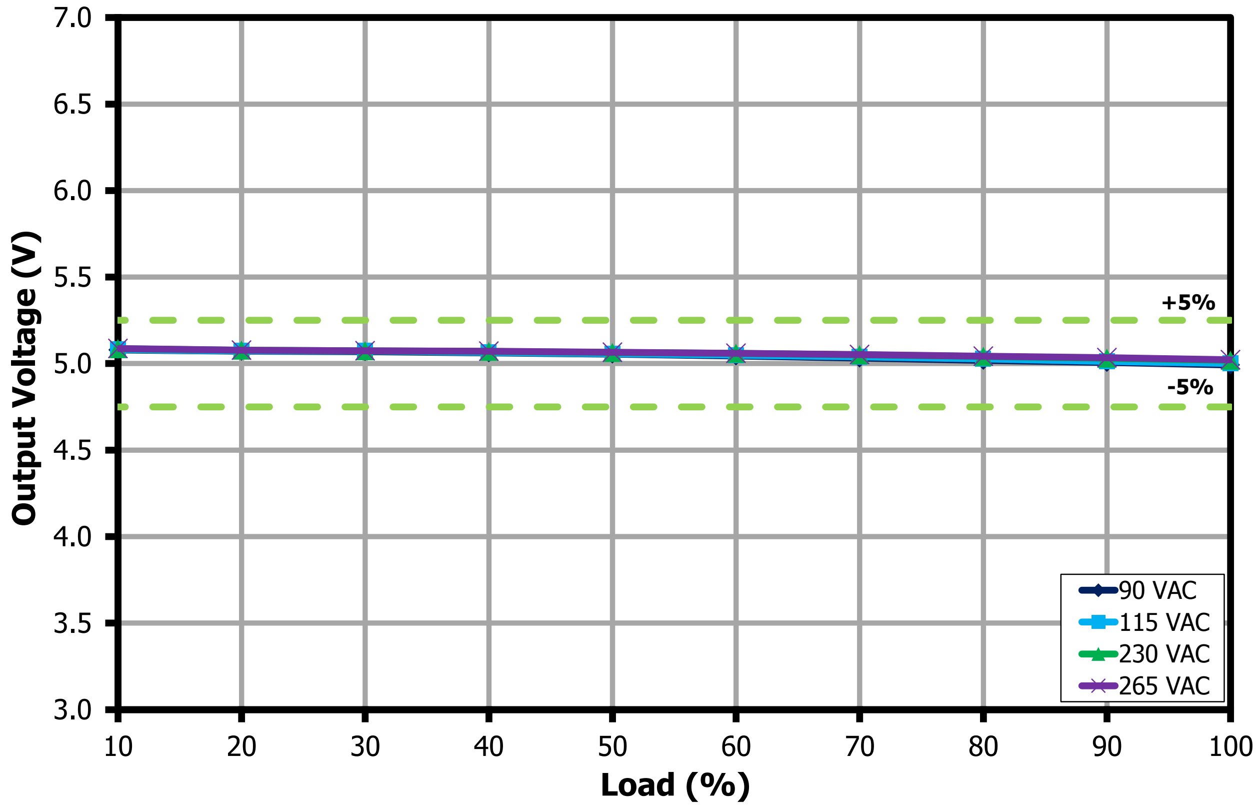

Figure 32 – Output Voltage vs. Output Load for 5 V Output, Room Temperature.

11.5.3 Output: 9 V / 5 A

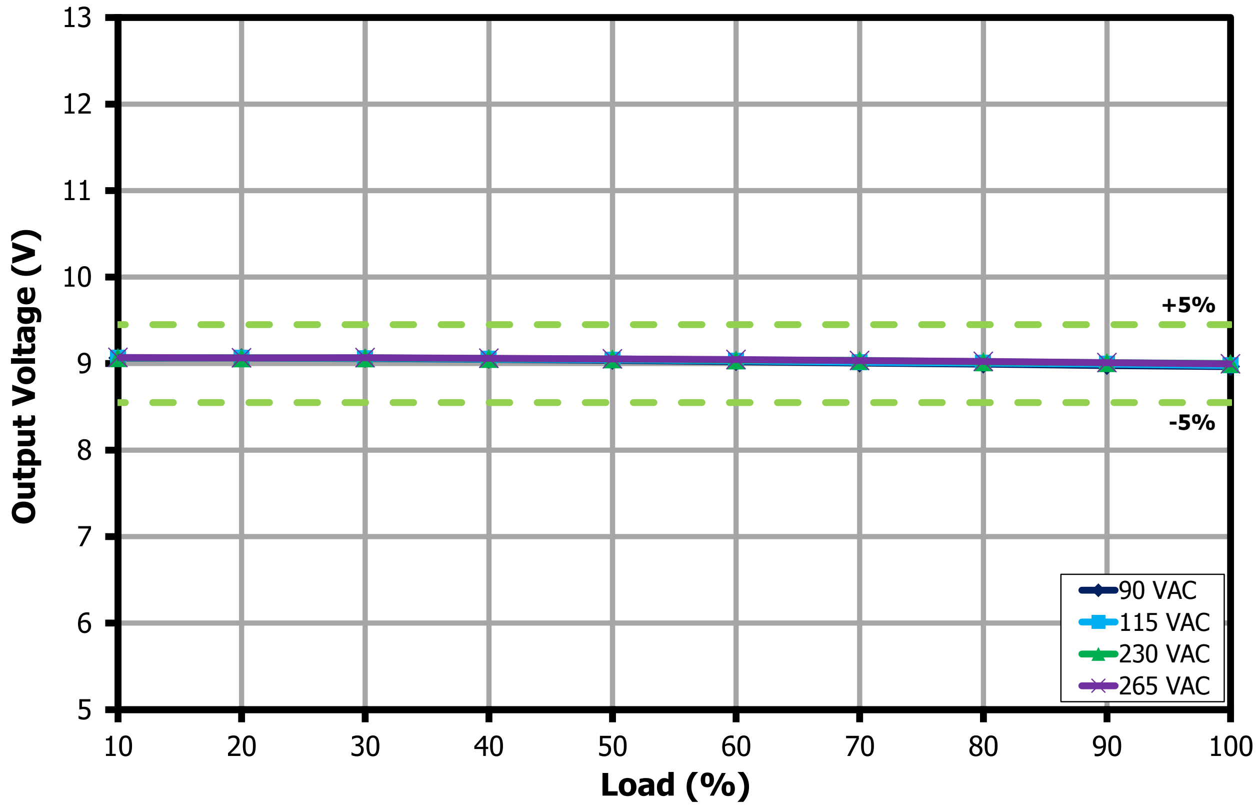

Figure 33 – Output Voltage vs. Output Load for 9 V Output, Room Temperature.

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11.5.4 Output: 11 V / 4.09 A

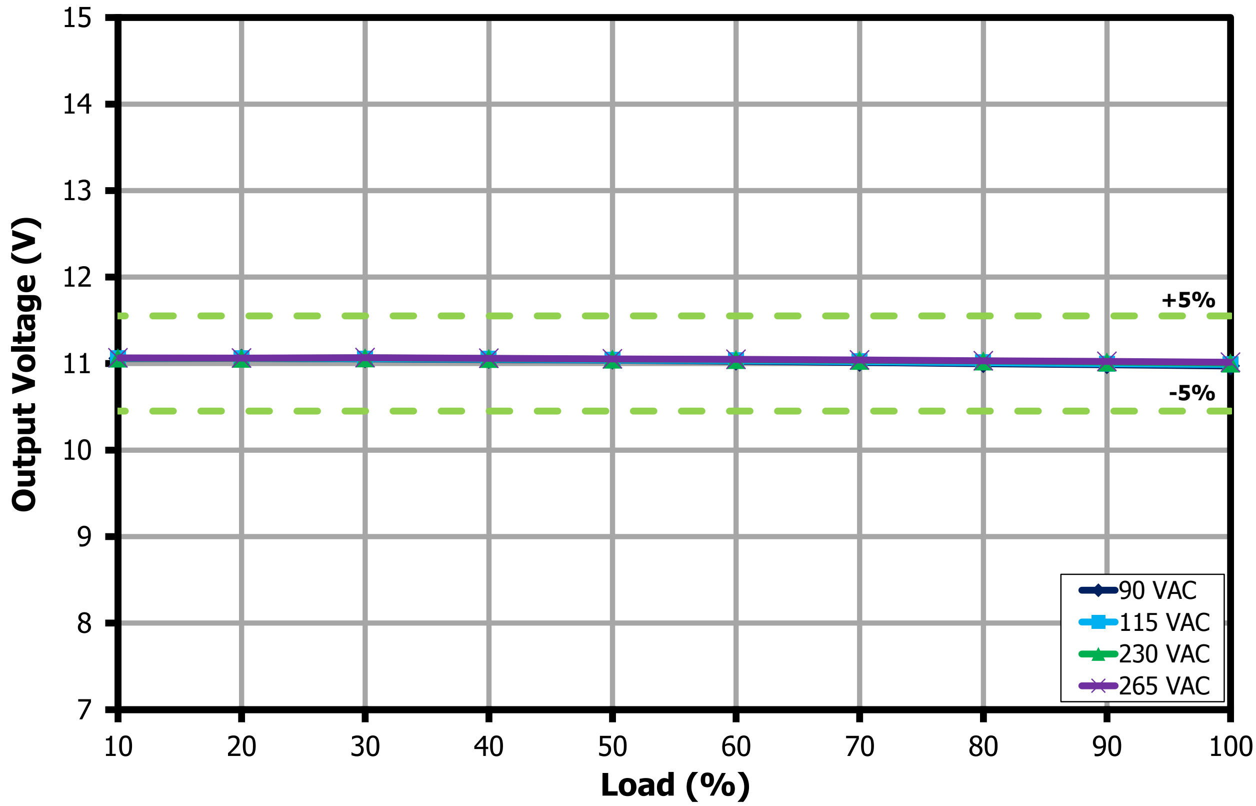

Figure 34 – Output Voltage vs. Output Load for 11 V Output, Room Temperature.

11.5.5 Output: 15 V / 3 A

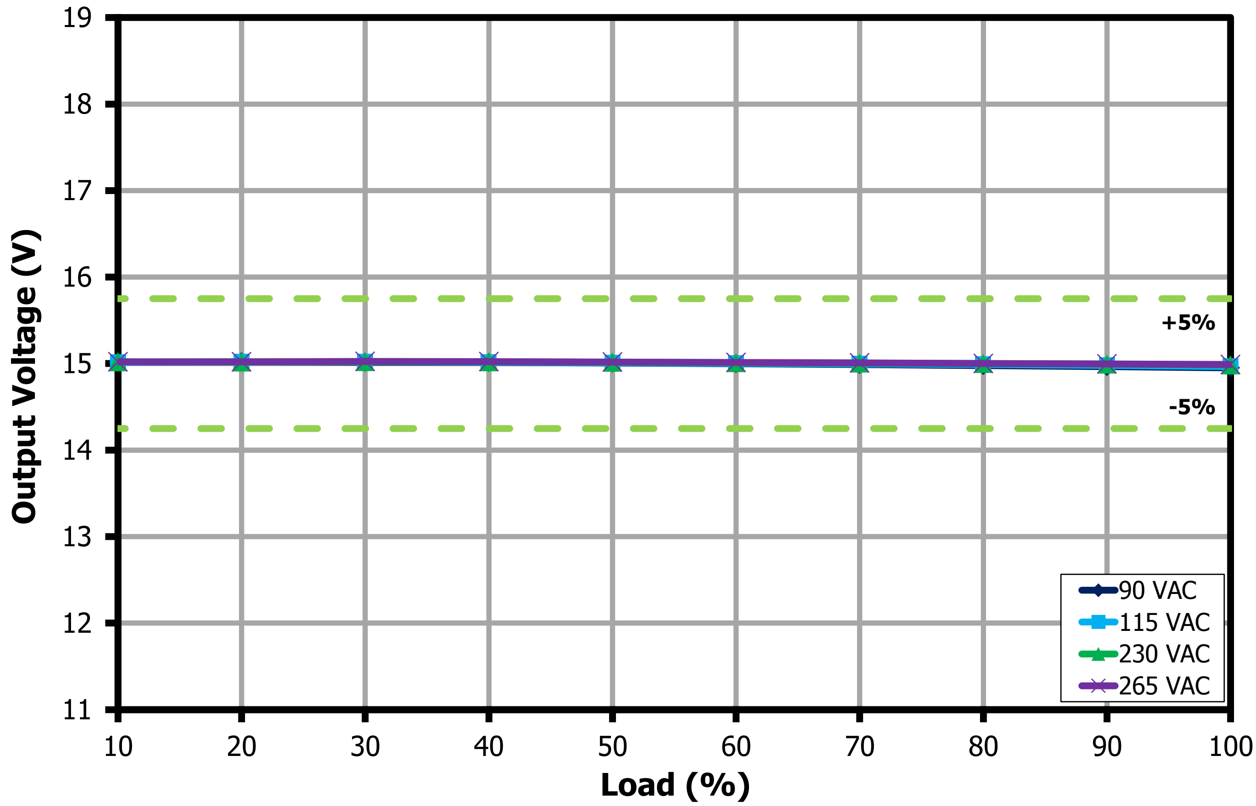

Figure 35 – Output Voltage vs. Output Load for 15 V Output, Room Temperature.

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11.5.6 Output: 16 V / 3 A

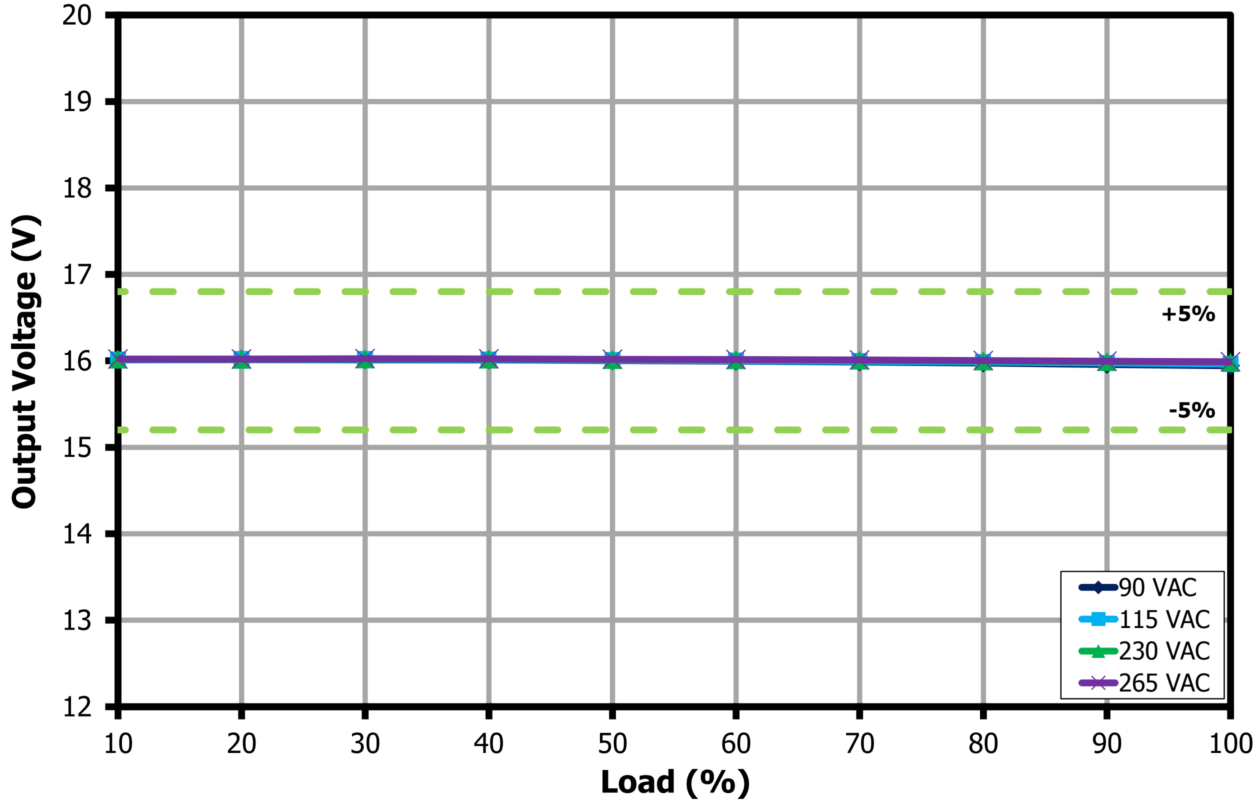

Figure 36 – Output Voltage vs. Output Load for 16 V Output, Room Temperature.

11.5.7 Output: 20 V / 2.25 A

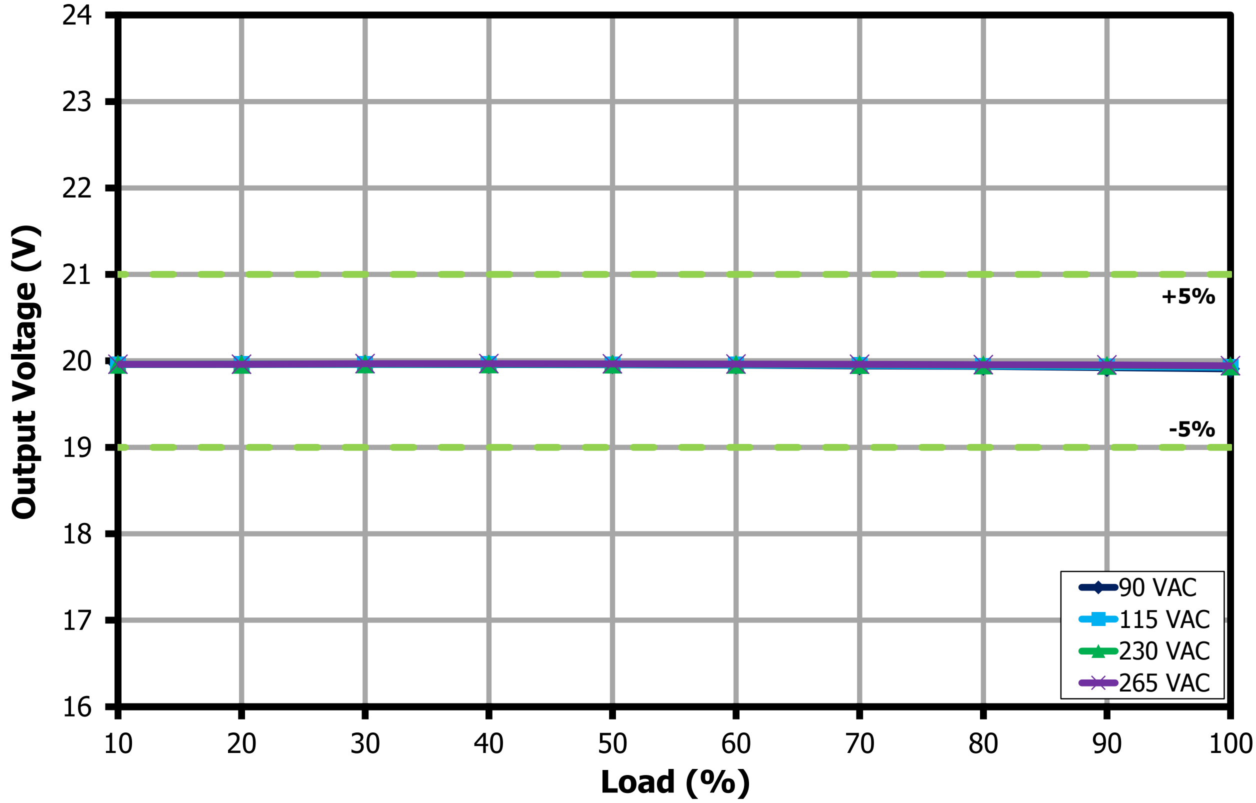

Figure 37 – Output Voltage vs. Output Load for 20 V Output, Room Temperature.

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11.5.8 Output: 21 V / 2.25 A

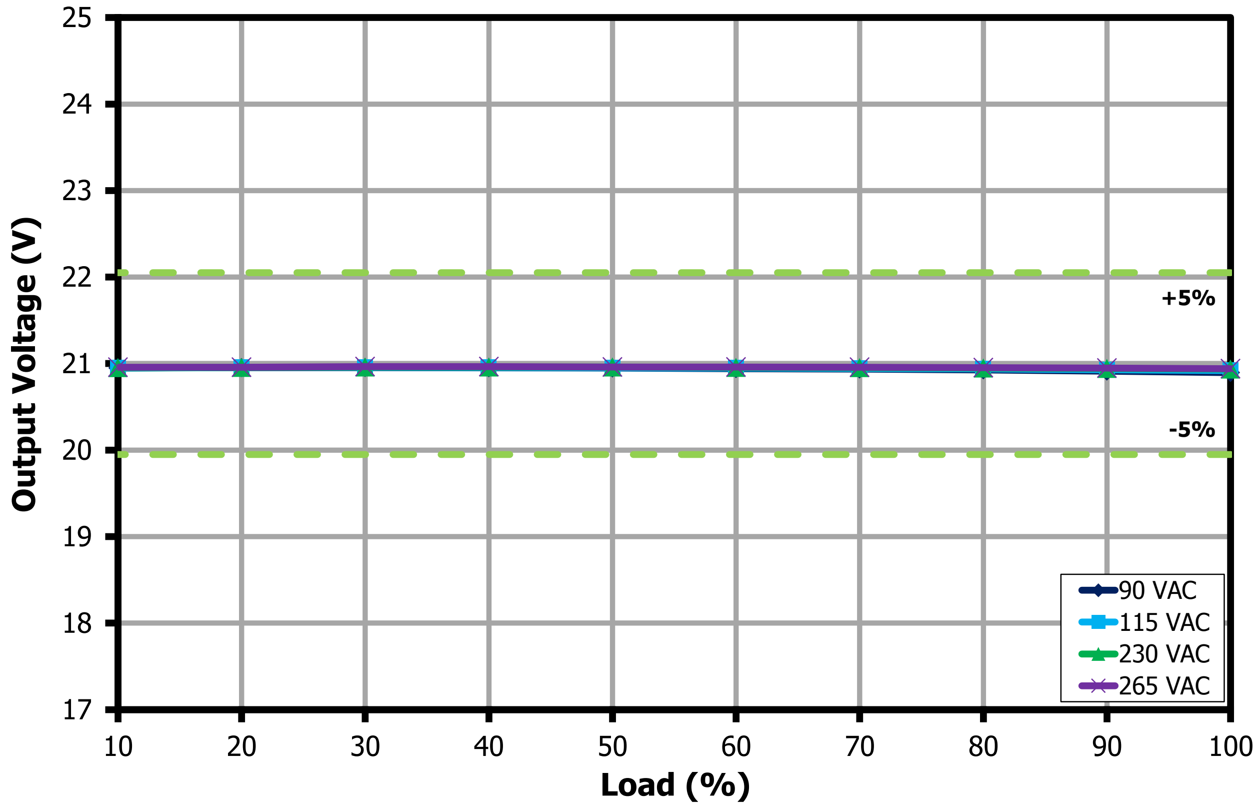

Figure 38 – Output Voltage vs. Output Load for 21 V Output, Room Temperature.

11.6 ***Line Regulation (On Board)***

11.6.1 Output: 3.3 V / 5 A

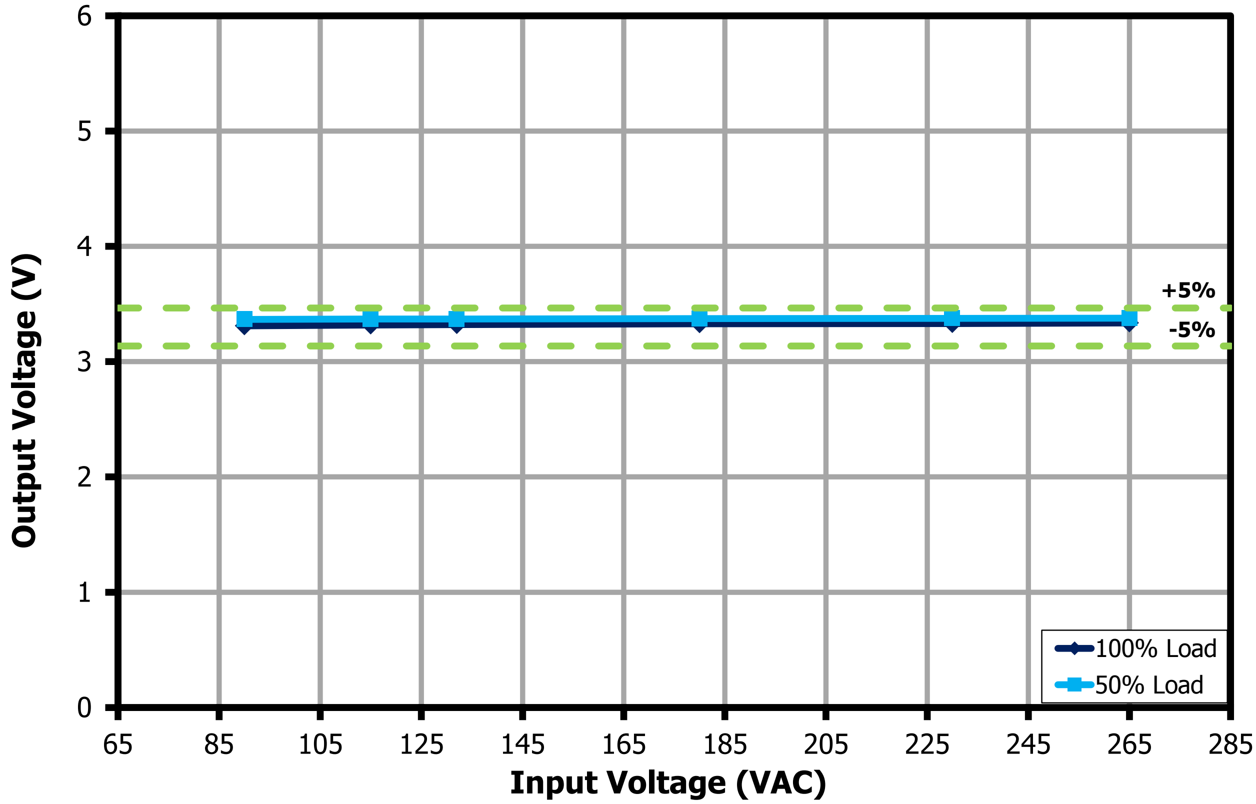

Figure 39 – Output Voltage vs. Input Line Voltage for 3.3 V Output, Room Temperature.

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11.6.2 Output: 5 V / 5 A

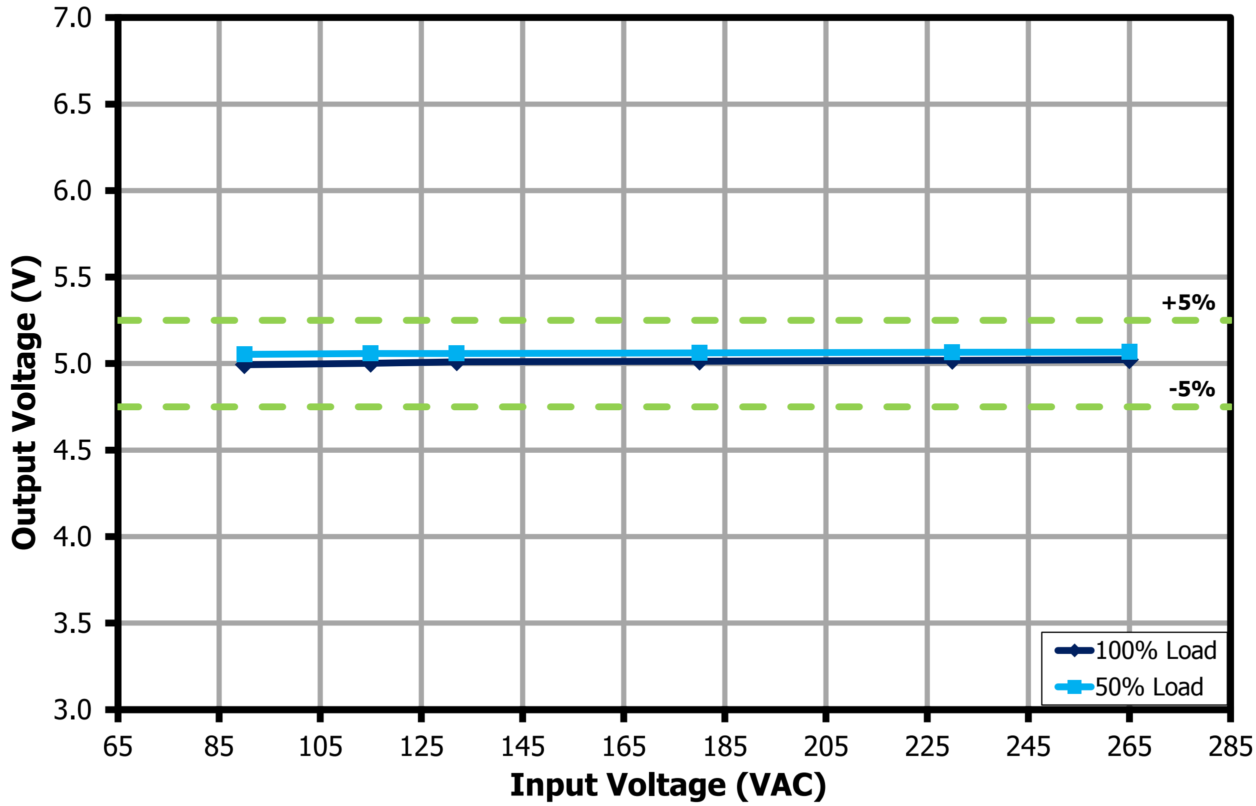

Figure 40 – Output Voltage vs. Input Line Voltage for 5 V Output, Room Temperature.

11.6.3 Output: 9 V / 5 A

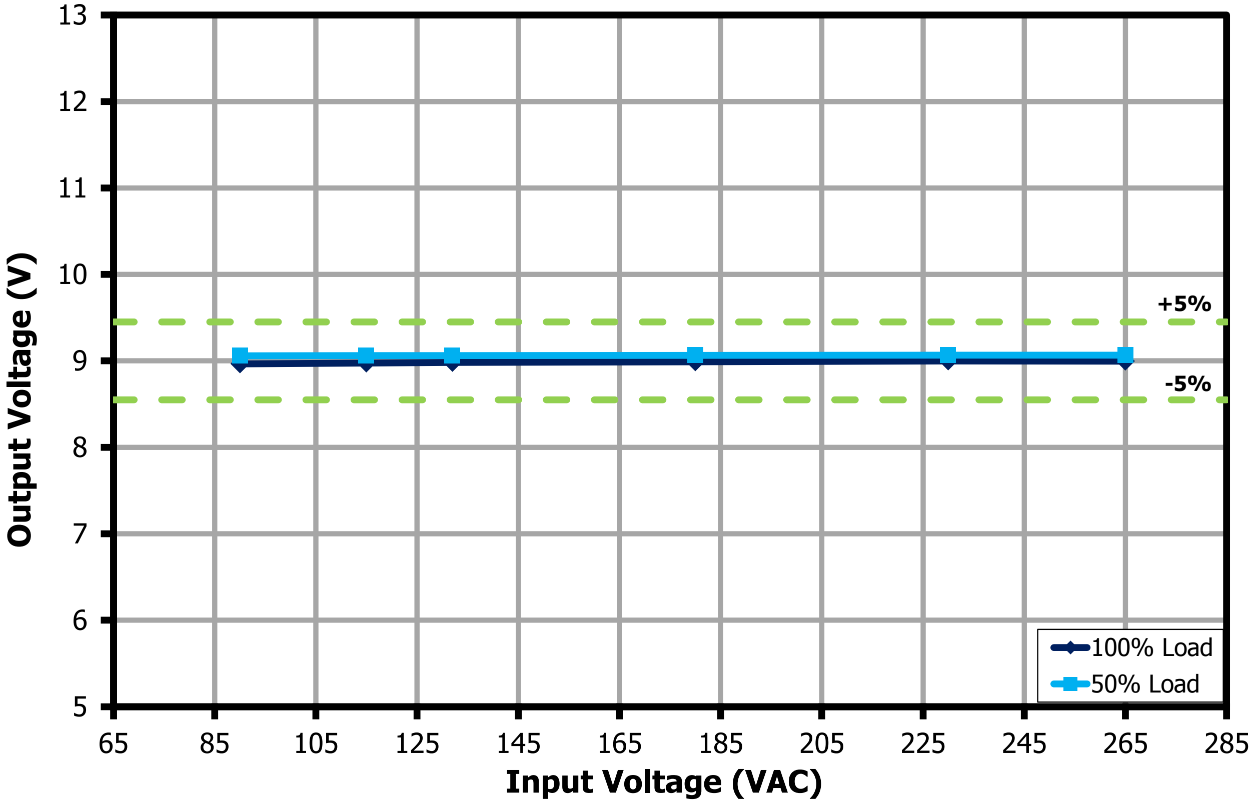

Figure 41 – Output Voltage vs. Input Line Voltage for 9 V Output, Room Temperature.

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11.6.4 Output: 11 V / 4.09 A

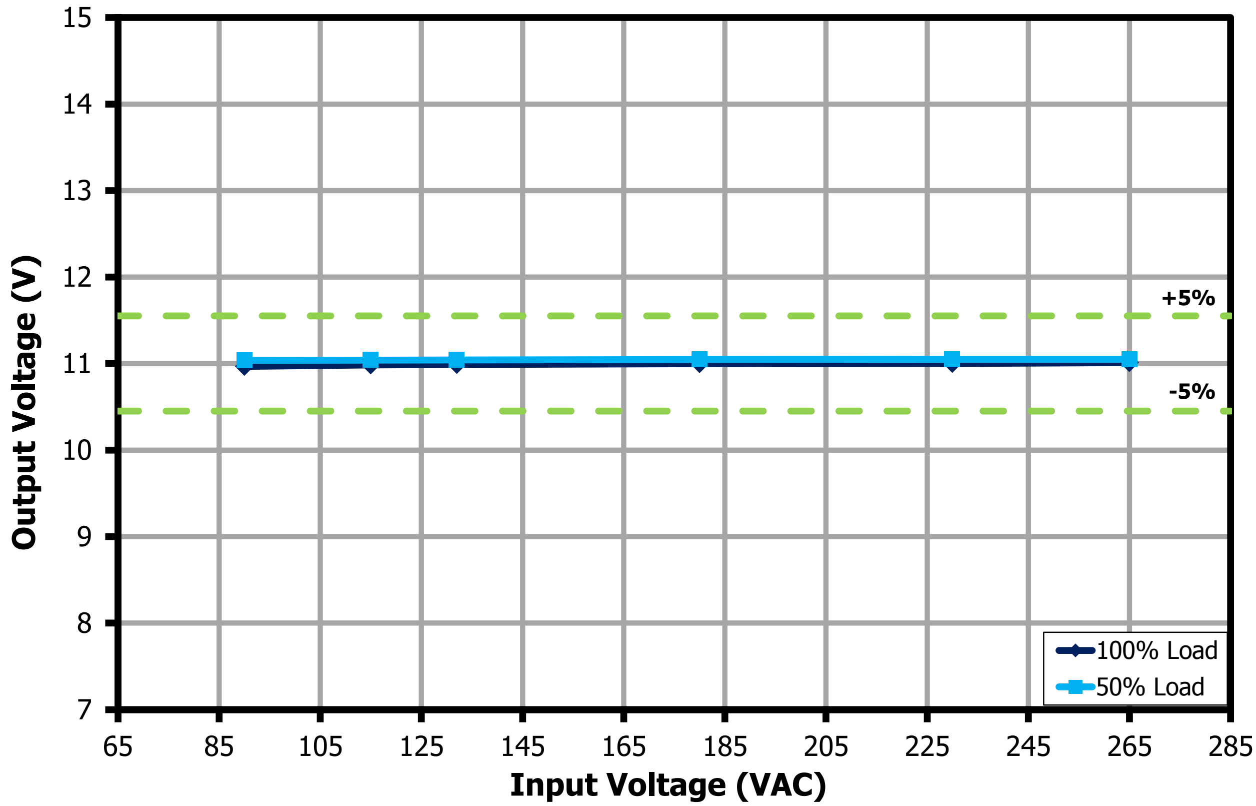

Figure 42 – Output Voltage vs. Input Line Voltage for 11 V Output, Room Temperature.

11.6.5 Output: 15 V / 3 A

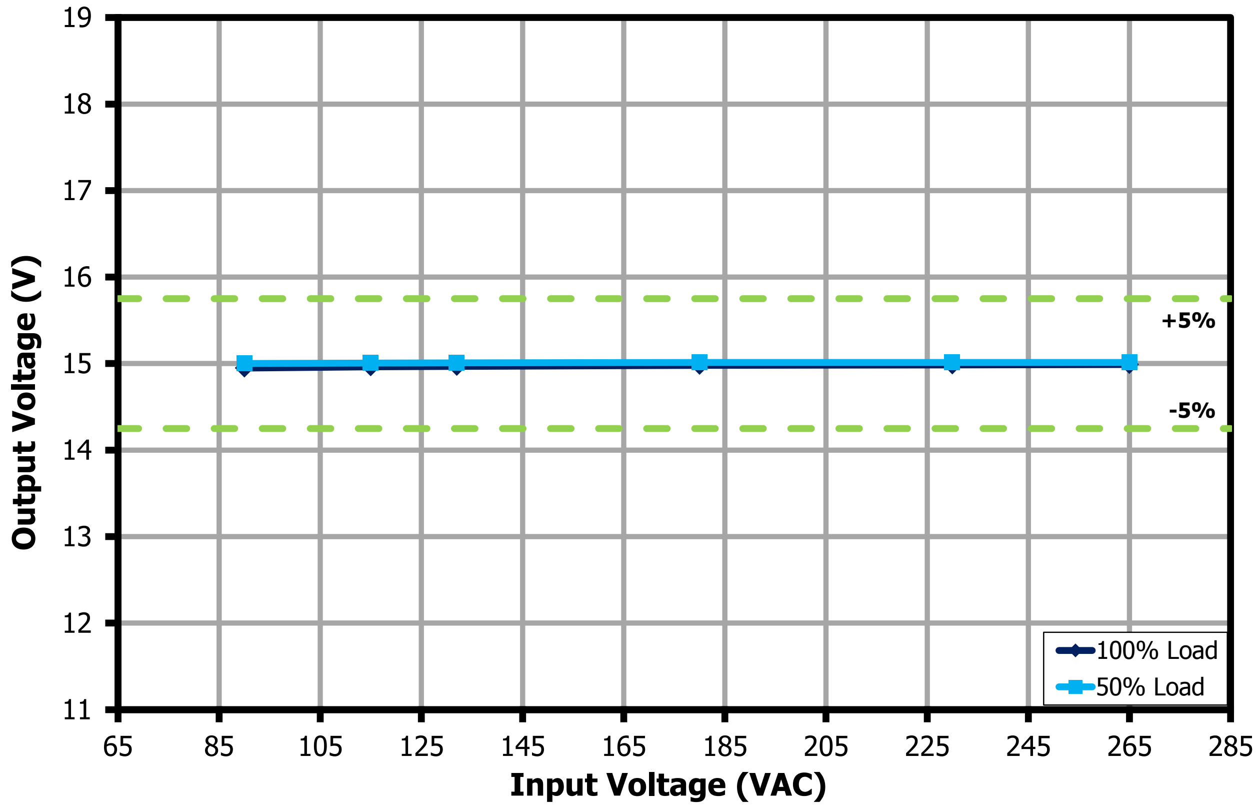

Figure 43 – Output Voltage vs. Input Line Voltage for 15 V Output, Room Temperature.

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11.6.6 Output: 16 V / 3 A

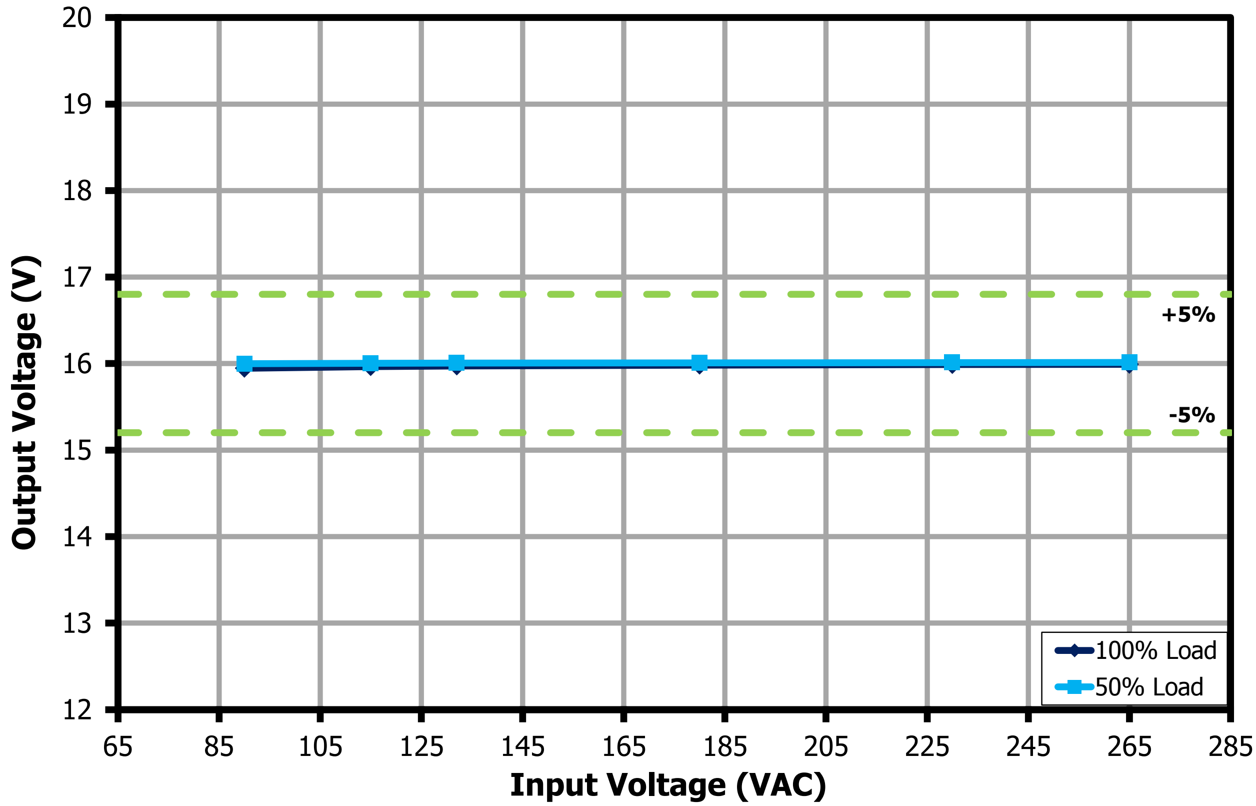

Figure 44 – Output Voltage vs. Input Line Voltage for 16 V Output, Room Temperature.

11.6.7 Output: 20 V / 2.25 A

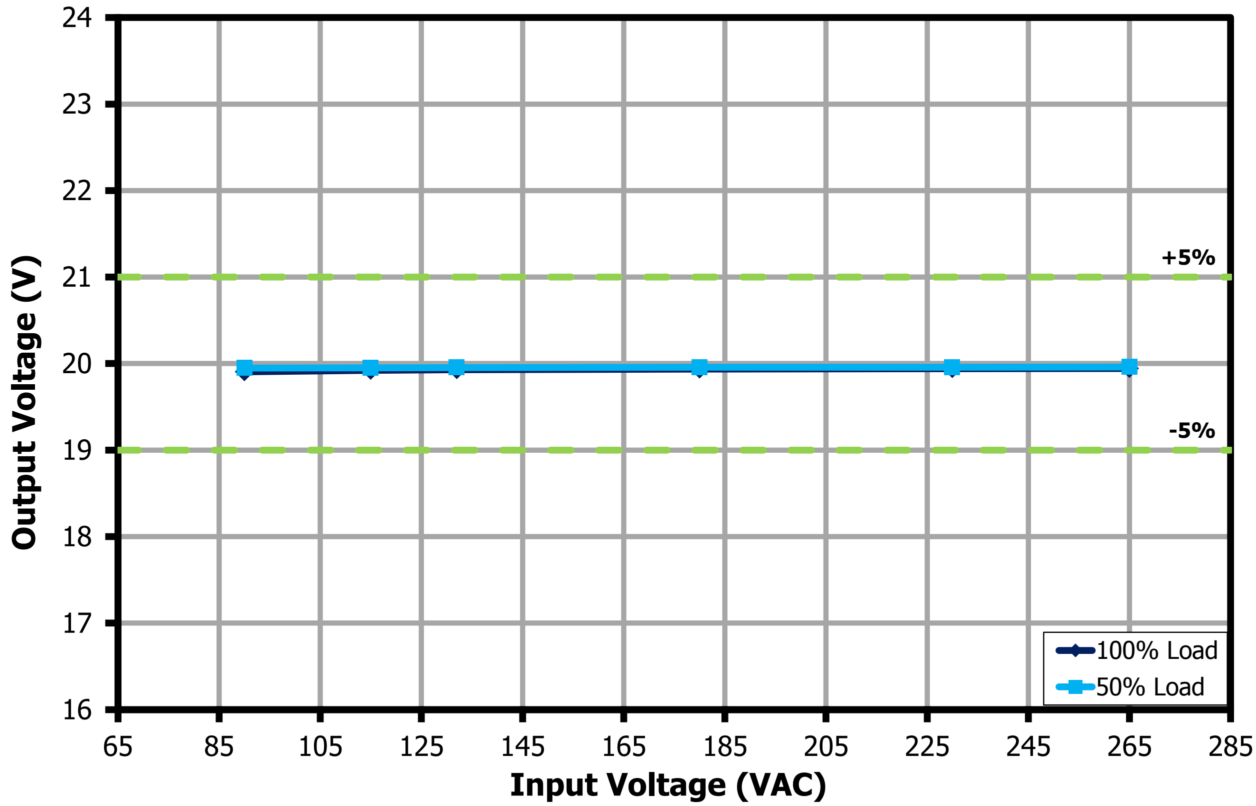

Figure 45 – Output Voltage vs. Input Line Voltage for 20 V Output, Room Temperature.

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11.6.8 Output: 21 V / 2.25 A

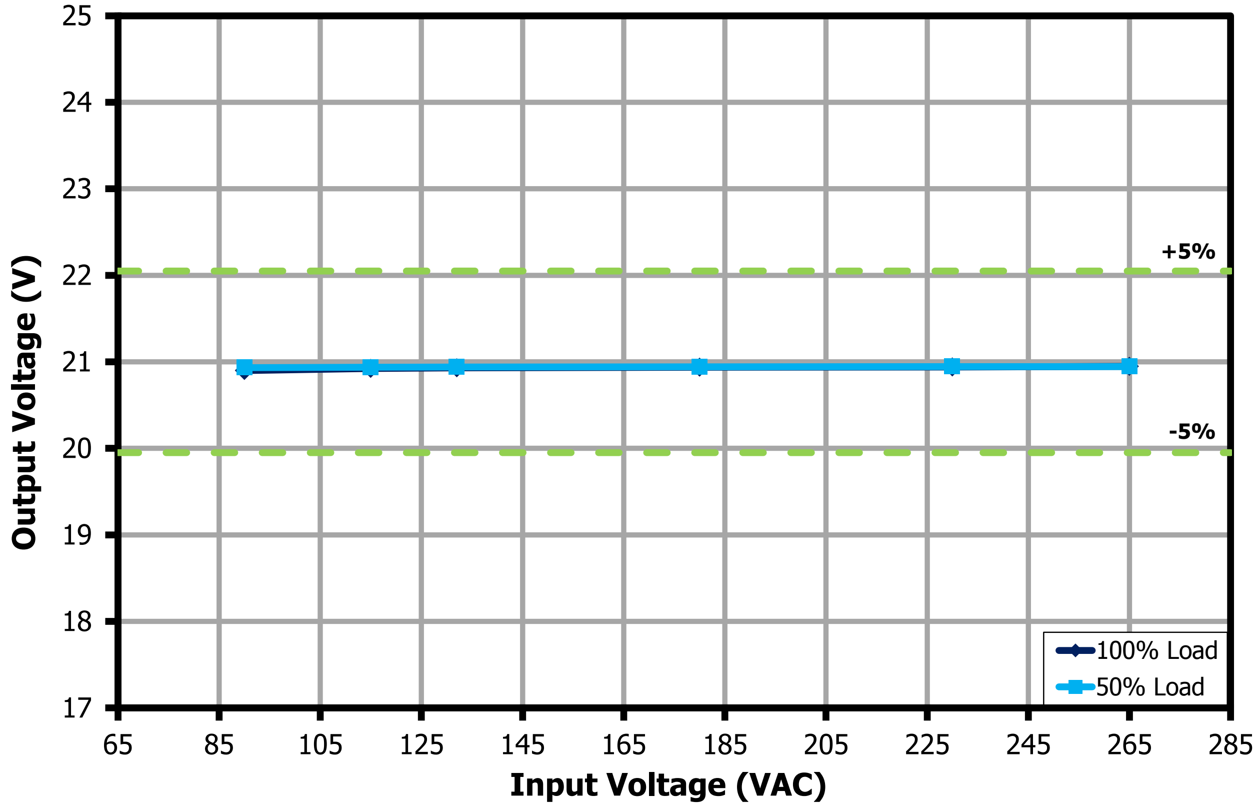

Figure 46 – Output Voltage vs. Input Line Voltage for 21 V Output, Room Temperature.

12 Thermal Performance

12.1 *Thermal Performance in Open Case*

Note 1: Measurements taken at room temperature (approximately 24 °C).

12.1.1 Output: 9 V / 5 A (90 VAC)

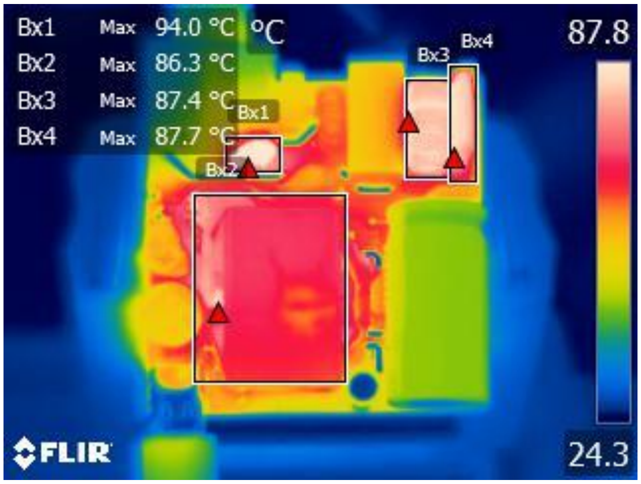

Figure 47 – Top Thermal Image.
Bx1: Thermistor, RT1 = 94.0 ºC.
Bx2: Transformer, T1 = 86.3 ºC.
Bx3: CMC, L1 = 87.4 ºC.
Bx2: Bridge Diode, BR1 = 87.7 ºC.

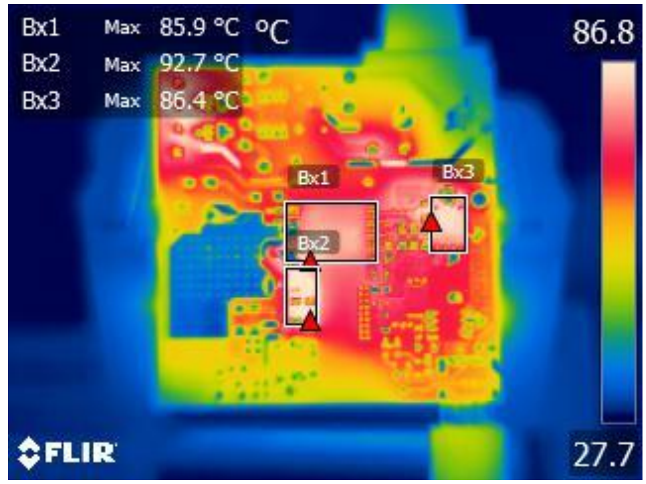

Figure 48 – Bottom Thermal Image.
Bx1: InnoSwitch3-Pro, U2 = 85.9 ºC.
Bx2: Primary Snubber = 92.7 ºC.
Bx3: SR FET, Q3 = 86.4 ºC.

12.1.2 Output: 9 V / 5 A (265 VAC)

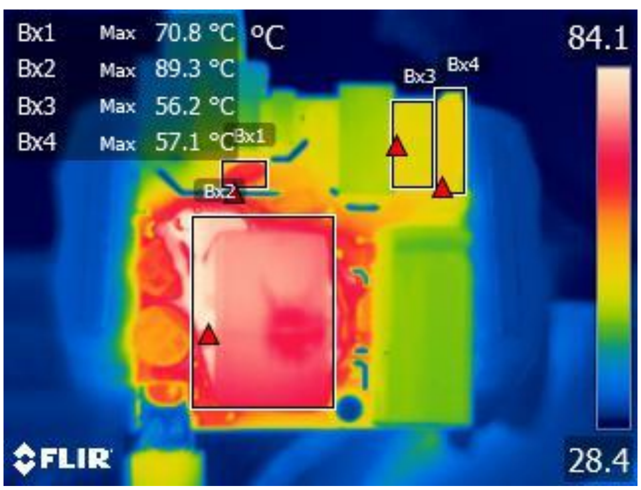

Figure 49 – Top Thermal Image.
Bx1: Thermistor, RT1 = 70.8 ºC.
Bx2: Transformer, T1 = 89.3 ºC.
Bx3: CMC, L1 = 56.2 ºC.
Bx2: Bridge Diode, BR1 = 57.1 ºC.

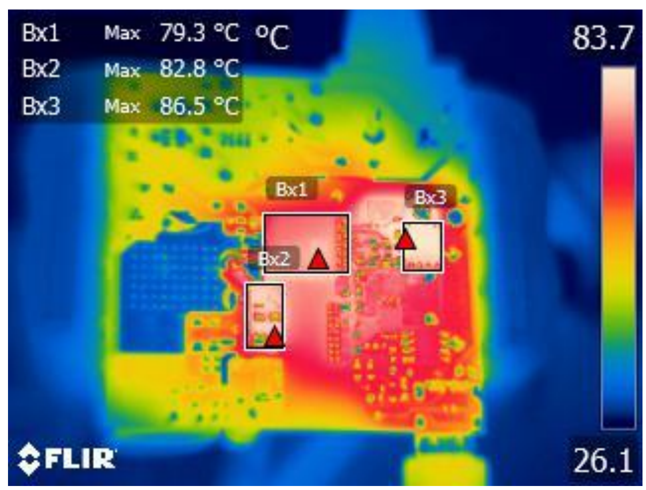

Figure 50 – Bottom Thermal Image.
Bx1: InnoSwitch3-Pro, U2 = 79.3 ºC.
Bx2: Primary Snubber = 82.8 ºC.
Bx3: SR FET, Q3 = 86.5 ºC.

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12.1.3 Output: 16 V / 3 A (90 VAC)

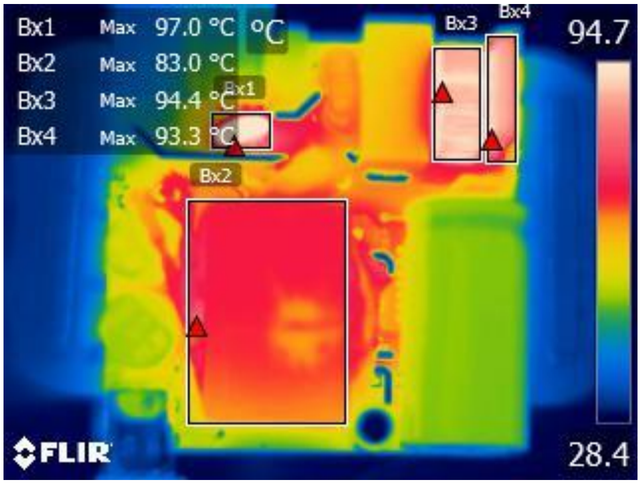

Figure 51 – Top Thermal Image.
Bx1: Thermistor, RT1 = 97.0 ºC.
Bx2: Transformer, T1 = 83.0 ºC.
Bx3: CMC, L1 = 94.4 ºC.
Bx2: Bridge Diode, BR1 = 93.3 ºC.

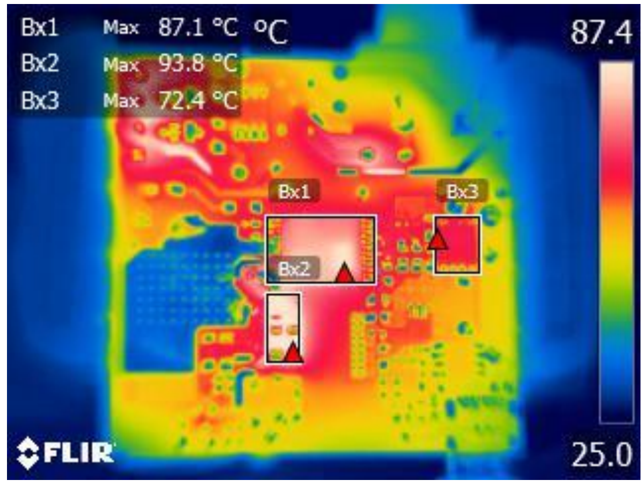

Figure 52 – Bottom Thermal Image.
Bx1: InnoSwitch3-Pro, U2 = 87.1 ºC.
Bx2: Primary Snubber = 93.8 ºC.
Bx3: SR FET, Q3 = 72.4 ºC.

12.1.4 Output: 16 V / 3 A (265 VAC)

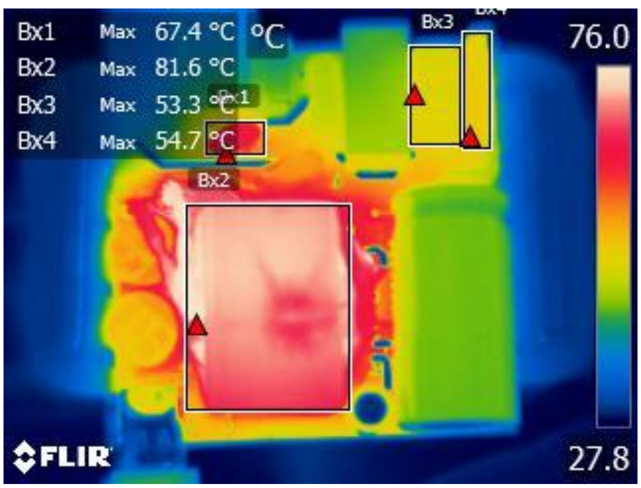

Figure 53 – Top Thermal Image.
Bx1: Thermistor, RT1 = 67.4 ºC.
Bx2: Transformer, T1 = 81.6 ºC.
Bx3: CMC, L1 = 53.3 ºC.
Bx2: Bridge Diode, BR1 = 54.7 ºC.

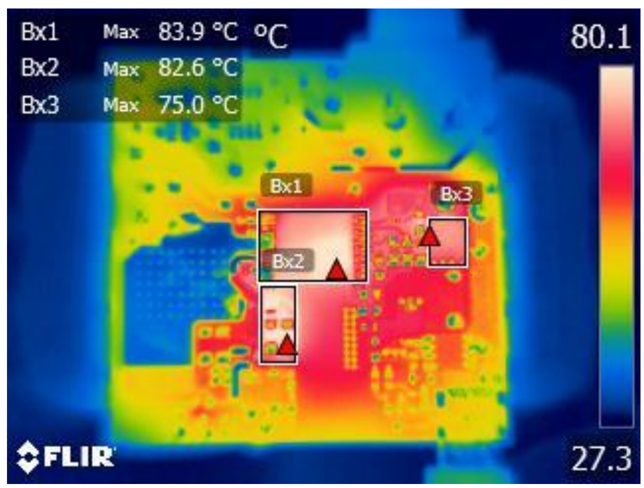

Figure 54 – Bottom Thermal Image.
Bx1: InnoSwitch3-Pro, U2 = 83.9 ºC.
Bx2: Primary Snubber = 82.6 ºC.
Bx3: SR FET, Q3 = 75.0 ºC.

12.1.5 Output: 21 V / 2.25 A (90 VAC)

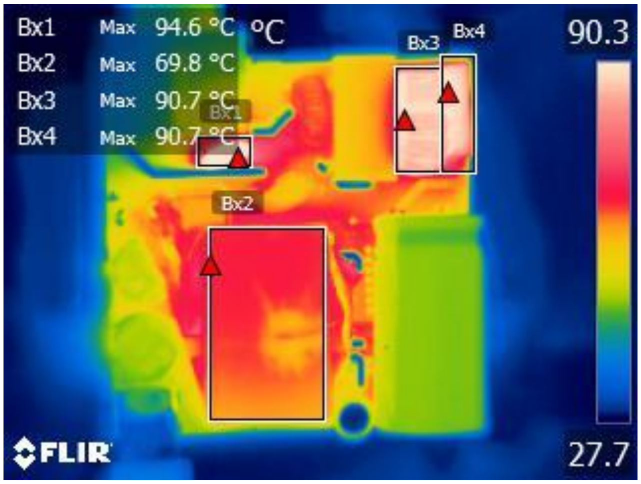

Figure 55 – Top Thermal Image.
Bx1: Thermistor, RT1 = 94.6 ºC.
Bx2: Transformer, T1 = 69.8 ºC.
Bx3: CMC, L1 = 90.7 ºC.
Bx2: Bridge Diode, BR1 = 90.7 ºC.

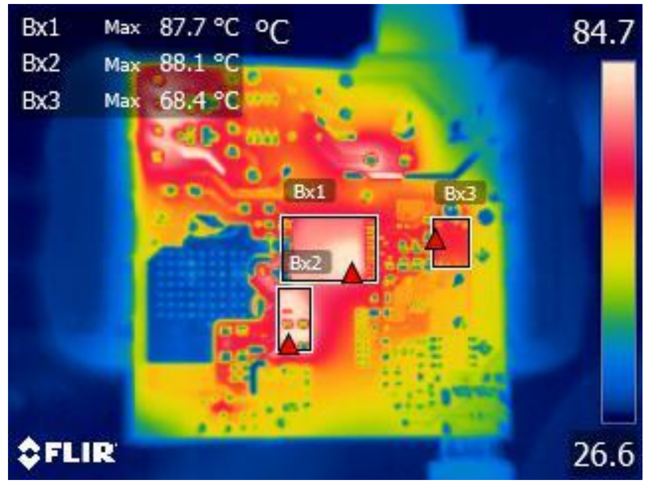

Figure 56 – Bottom Thermal Image.
Bx1: InnoSwitch3-Pro, U2 = 87.7 ºC.
Bx2: Primary Snubber = 88.1 ºC.
Bx3: SR FET, Q3 = 68.4 ºC.

12.1.6 Output: 21 V / 2.25 A (265 VAC)

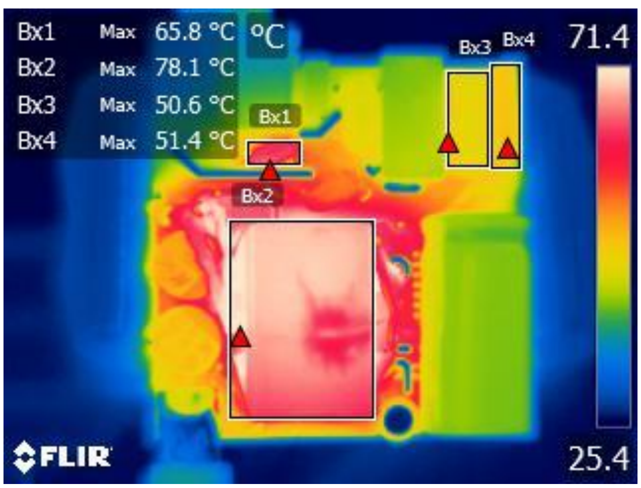

Figure 57 – Top Thermal Image.
Bx1: Thermistor, RT1 = 65.8 ºC.
Bx2: Transformer, T1 = 78.1 ºC.
Bx3: CMC, L1 = 50.6 ºC.
Bx2: Bridge Diode, BR1 = 51.4 ºC.

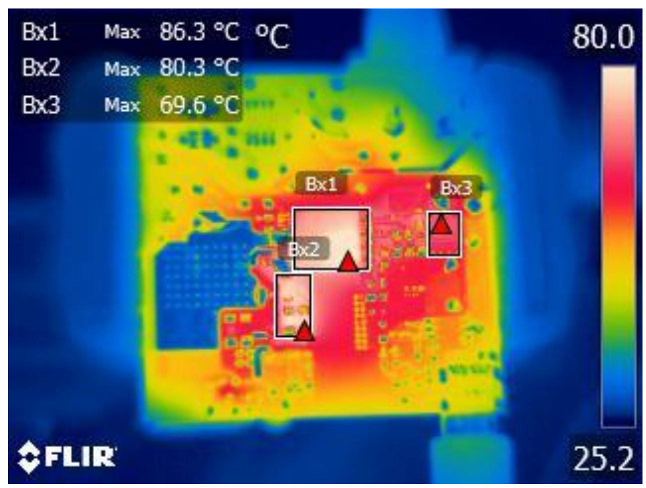

Figure 58 – Bottom Thermal Image.
Bx1: InnoSwitch3-Pro, U2 = 86.3 ºC.
Bx2: Primary Snubber = 80.3 ºC.
Bx3: SR FET, Q3 = 69.6 ºC.

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12.2 *Thermal Performance with Enclosure, 25 ºC Ambient*

12.2.1 Components Temperature Summary

Condition	Component	Temperature (°C)					
		9 V / 5 A (90 VAC)	9 V / 5 A (265 VAC)	16 V / 3 A (90 VAC)	16 V / 3 A (265 VAC)	21 V / 2.25 A (90 VAC)	21 V / 2.25 A (265 VAC)
Enclosed Unit, Room Temperature Ambient	RT1	94.7	68.0	95.2	67.7	90.8	67.1
	BR1	96.6	58.8	98.0	59.3	92.6	59.3
	L1	97.3	59.7	98.1	59.4	92.4	59.1
	INN3379	91.1	71.5	83.1	69.5	78.4	71.0
	SR FET	84.3	77.8	77.9	69.3	71.2	68.4
	T1-core	87.1	76.8	80.7	72.5	75.7	72.3
	T1-wire	84.3	73.5	77.3	68.1	71.5	68.1
	RCLAMP	98.7	73.6	84.5	71.0	79.3	71.6
	CIN	72.2	57.0	67.6	55.0	64.0	55.3
	Pass FET	74.9	65.5	68.9	60.2	63.6	59.7
	VP302	81.7	70.8	74.8	64.8	69.1	65.5

12.2.2 Output: 9 V / 5 A (90 VAC)

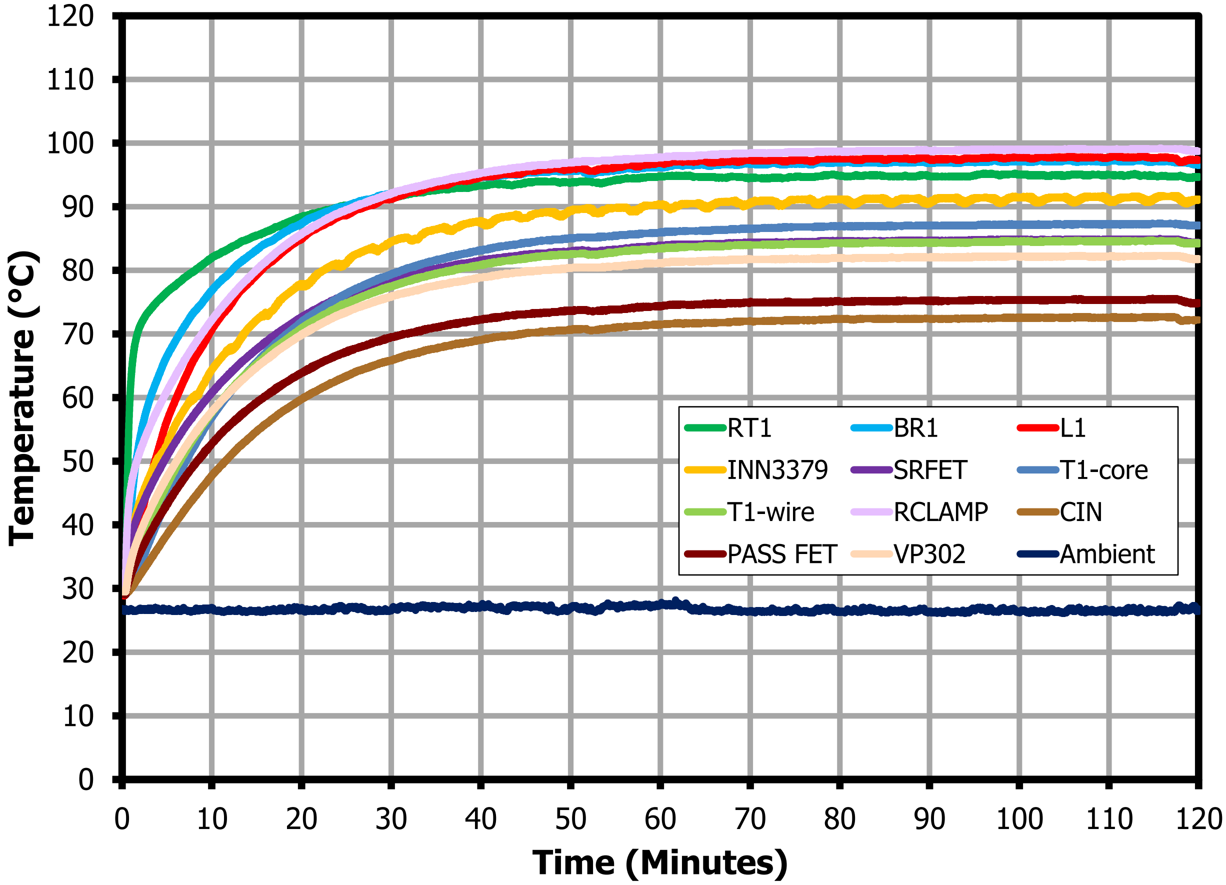

Figure 59 – Enclosed Unit Thermal Performance at 9 V / 5 A Output, 90 VAC, Room Temperature.

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12.2.3 Output: 9 V / 5 A (265 VAC)

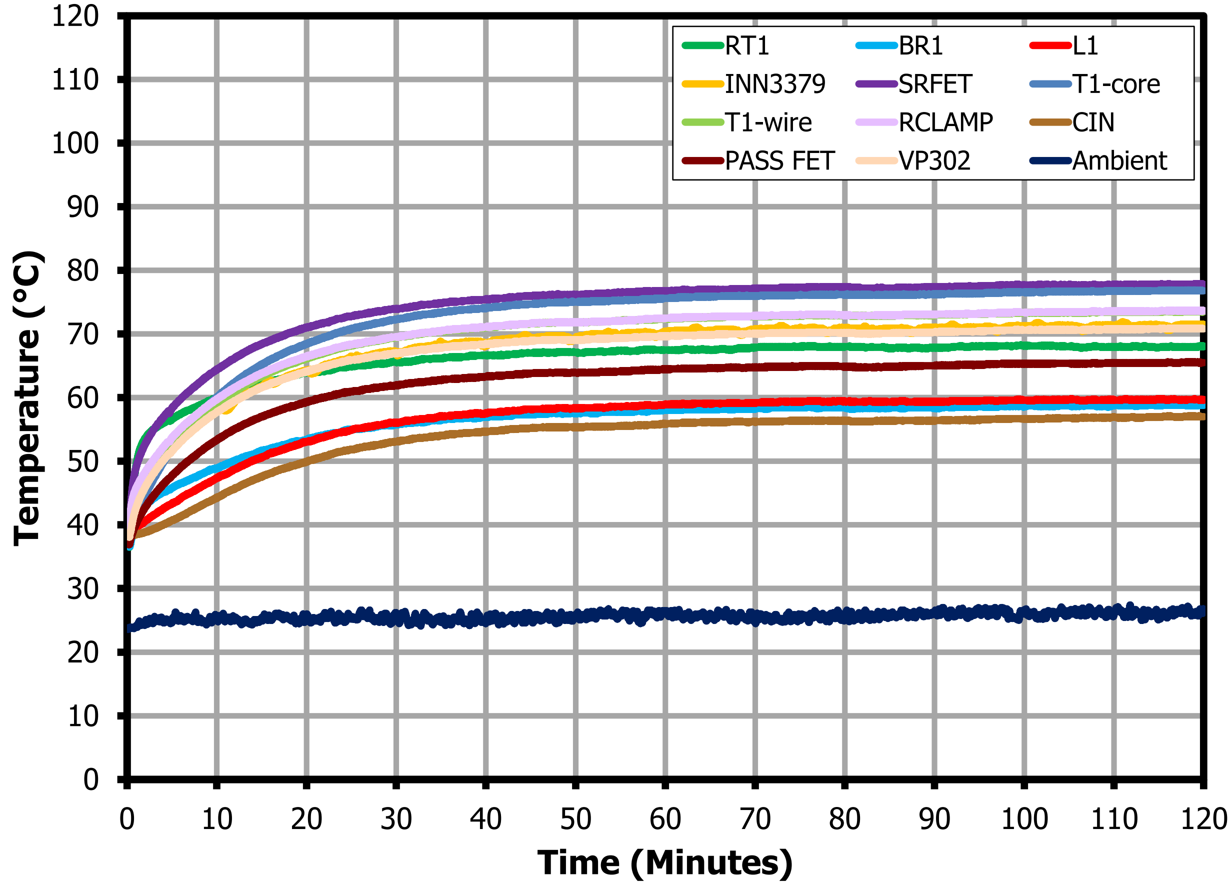

Figure 60 – Enclosed Unit Thermal Performance at 9 V / 5 A Output, 265 VAC, Room Temperature.

12.2.4 Output: 16 V / 3 A (90 VAC)

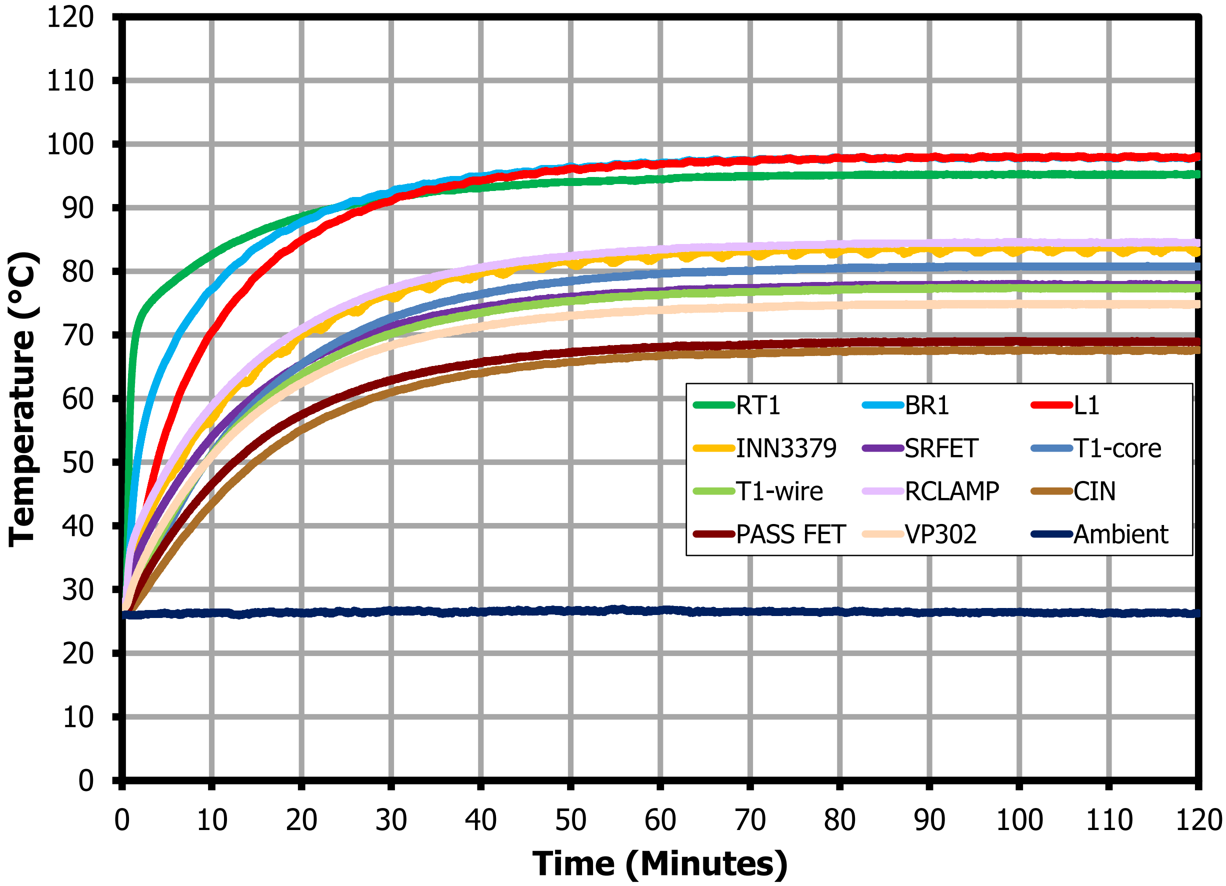

Figure 61 – Enclosed Unit Thermal Performance at 16 V / 3 A Output, 90 VAC, Room Temperature.

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12.2.5 Output: 16 V / 3 A (265 VAC)

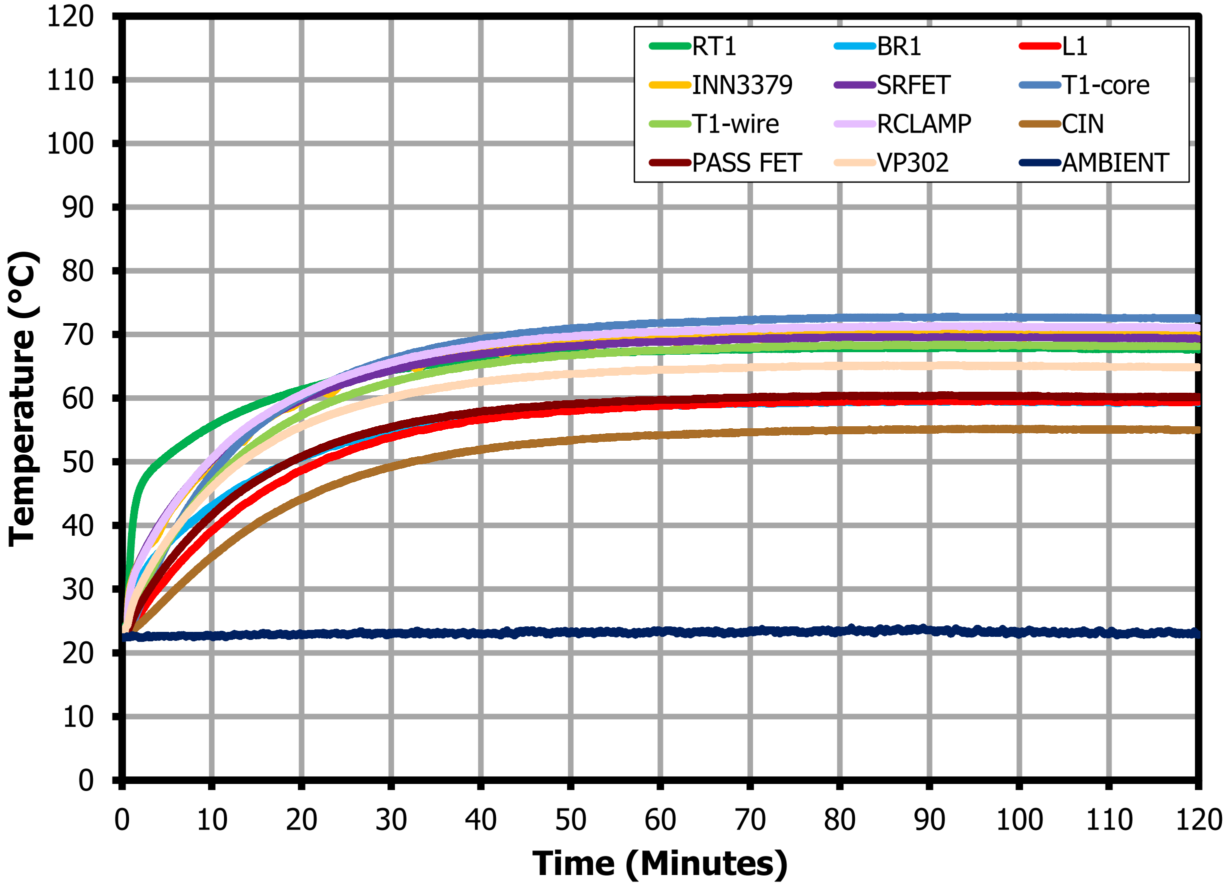

Figure 62 – Enclosed Unit Thermal Performance at 16 V / 3 A Output, 265 VAC, Room Temperature.

12.2.6 Output: 21 V / 2.25 A (90 VAC)

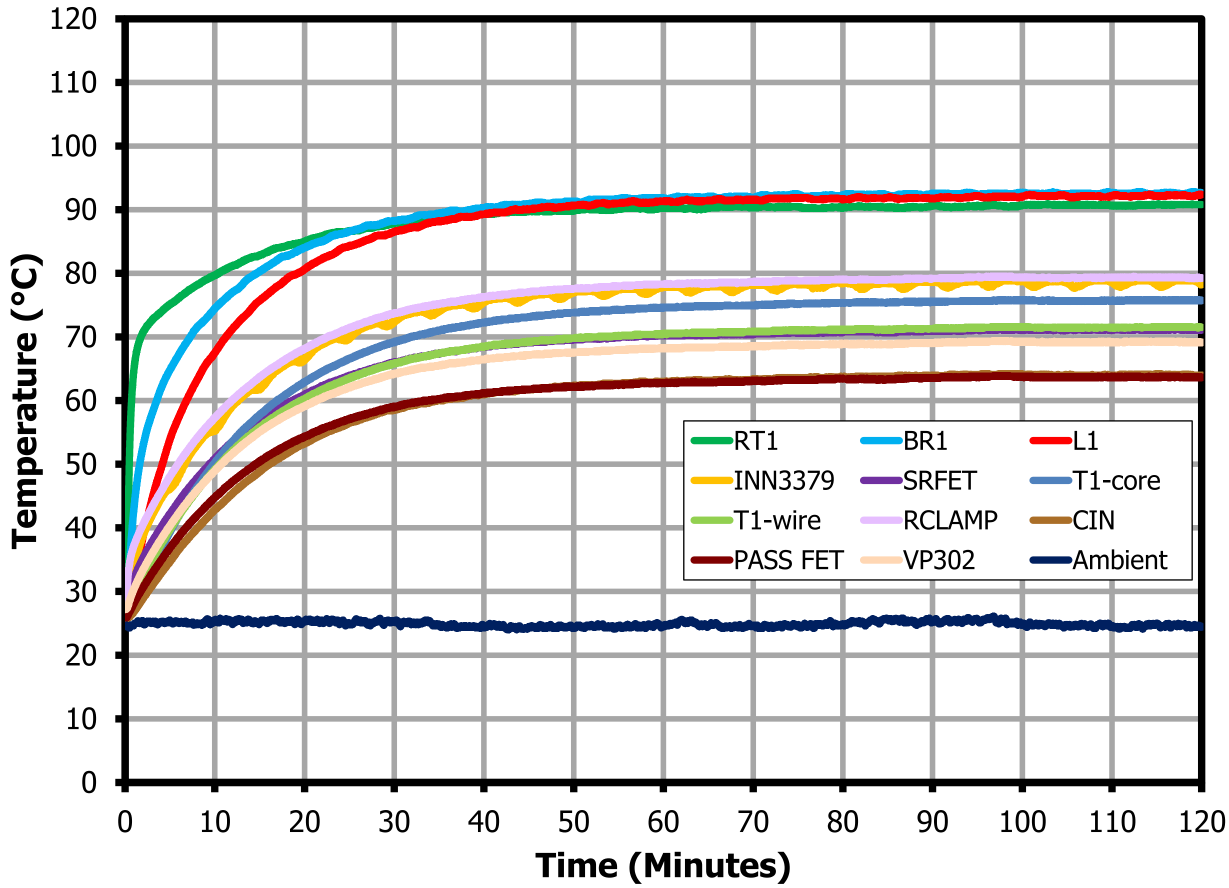

Figure 63 – Enclosed Unit Thermal Performance at 21 V / 2.25 A Output, 90 VAC, Room Temperature.

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12.2.7 Output: 21 V / 2.25 A (265 VAC)

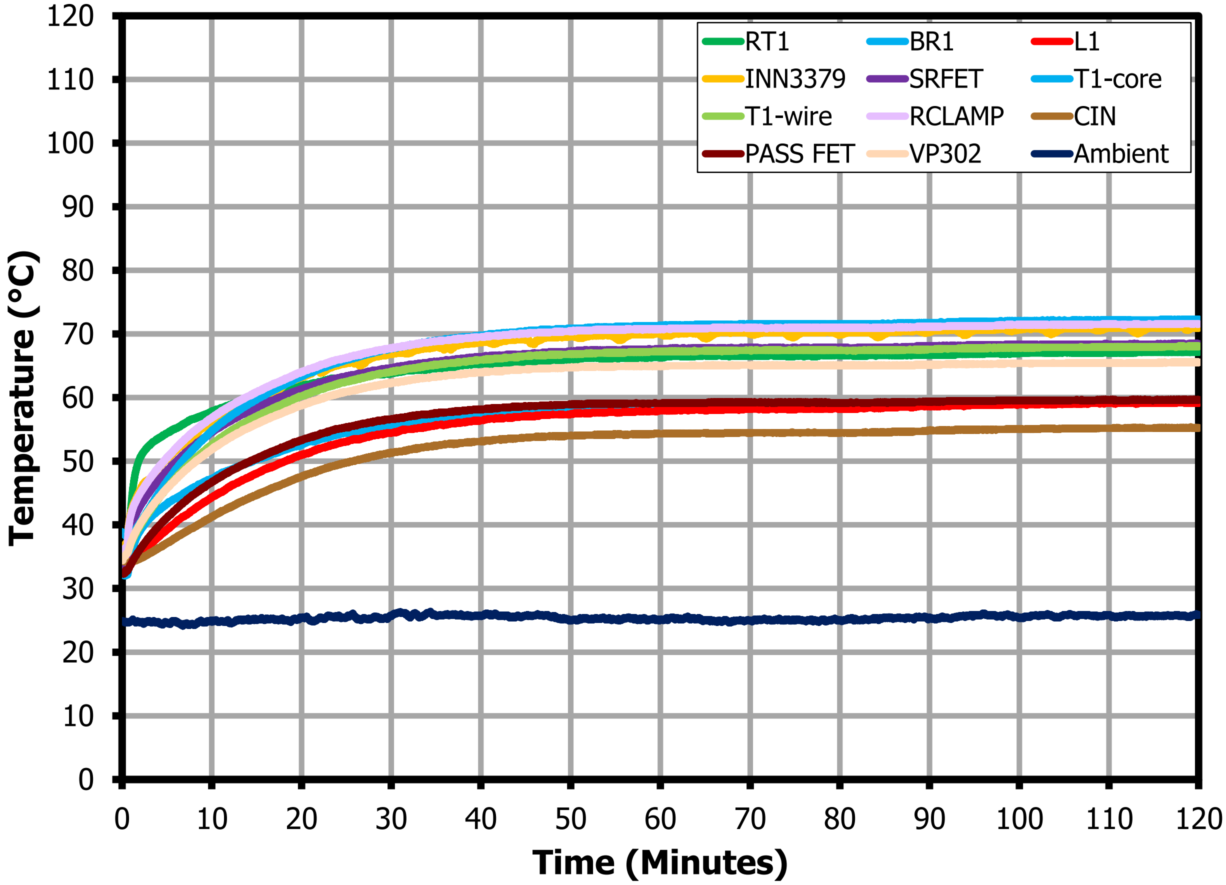

Figure 64 – Enclosed Unit Thermal Performance at 21 V / 2.25 A Output, 265 VAC, Room Temperature.

12.3 ***Thermal Performance with Enclosure, 45 ºC Ambient***

12.3.1 Components Temperature Summary

Condition	**Component**	**Temperature (°C)**		
		9 V / 5 A (90 VAC)	**16 V / 3 A (90 VAC)**	**21 V / 2.25 A (90 VAC)**
Enclosed Unit, 45°C Ambient	RT1	107.8	107.6	104.4
	BR1	111.8	114.6	110.3
	L1	113.8	115.2	111.3
	INN3379	106.0	102.8	99.7
	SR FET	107.7	96.9	91.4
	T1-core	104.8	99.8	96.0
	T1-wire	102.2	96.0	92.0
	RCLAMP	108.1	103.8	100.6
	CIN	87.5	86.6	84.2
	Pass FET	94.2	88.2	83.6
	VP302	99.7	93.6	89.3

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12.3.2 Output: 9 V / 5 A (90 VAC)

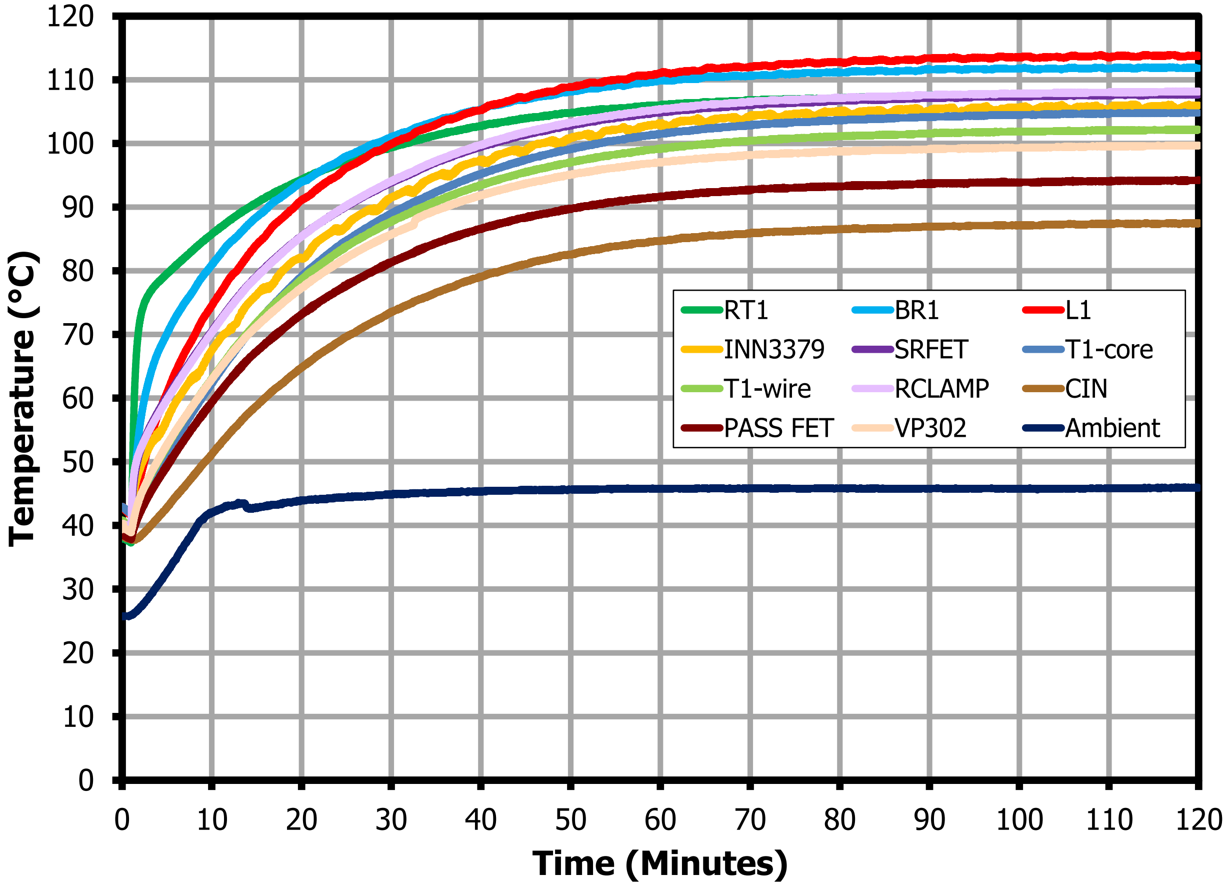

Figure 65 – Enclosed Unit Thermal Performance at 9 V / 5 A Output, 90 VAC, 45 °C Ambient.

12.3.3 Output: 16 V / 3 A (90 VAC)

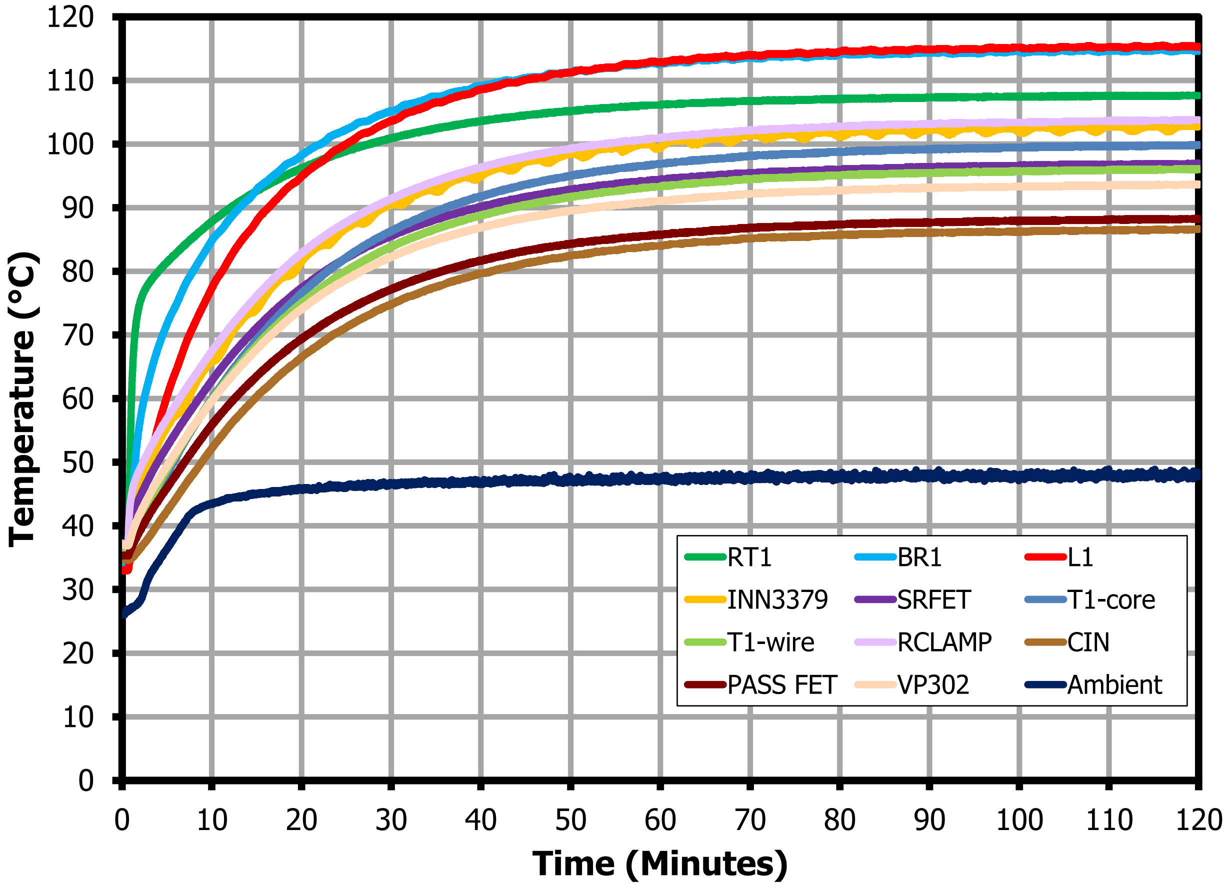

Figure 66 – Enclosed Unit Thermal Performance at 16 V / 3 A Output, 90 VAC, Room Temperature.

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12.3.4 Output: 21 V / 2.25 A (90 VAC)

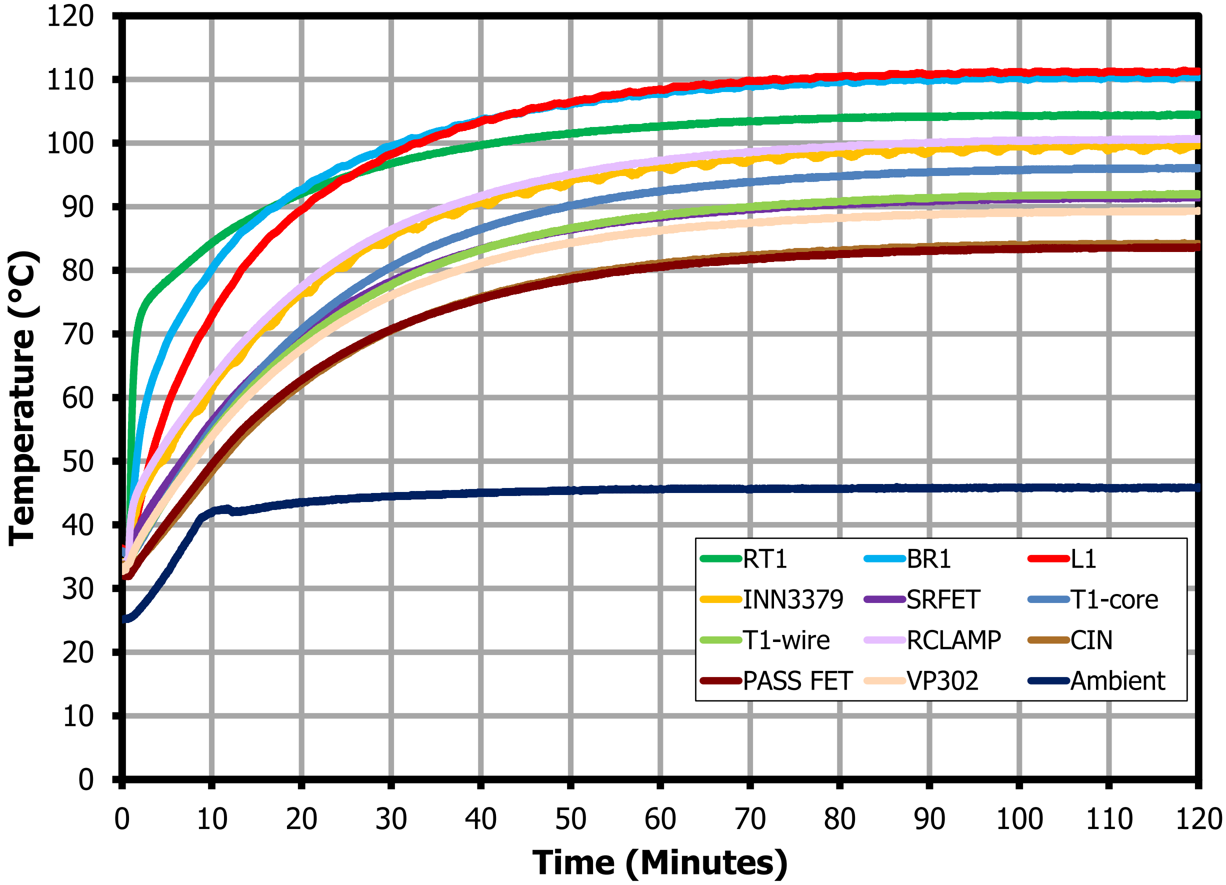

Figure 67 – Enclosed Unit Thermal Performance at 21 V / 2.25 A Output, 90 VAC, Room Temperature.

13 Waveforms

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

13.1 *Start-up Waveforms*

13.1.1 Output Voltage and Current

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

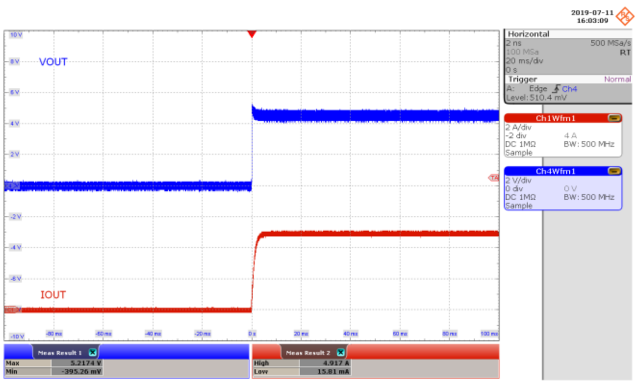

Figure 68 – Output Voltage and Current.
90 VAC, 5.0 V, 5 A Load (5.21 V_{MAX}).
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 2 A / div.
Time: 20 ms / div.

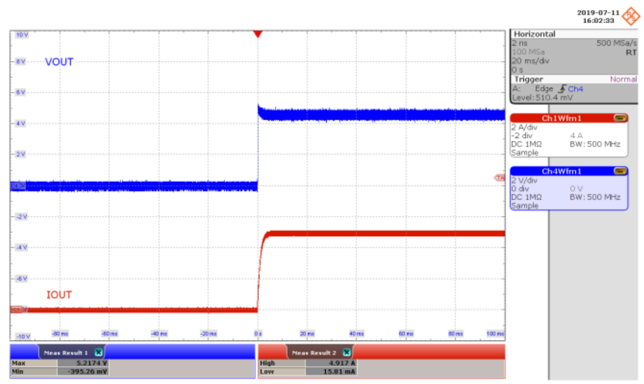

Figure 69 – Drain Voltage and Current.
265 VAC, 5.0 V, 5 A Load (5.21 V_{MAX}).
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 2 A / div.
Time: 20 ms / div.

13.1.2 Primary Drain Voltage and Current

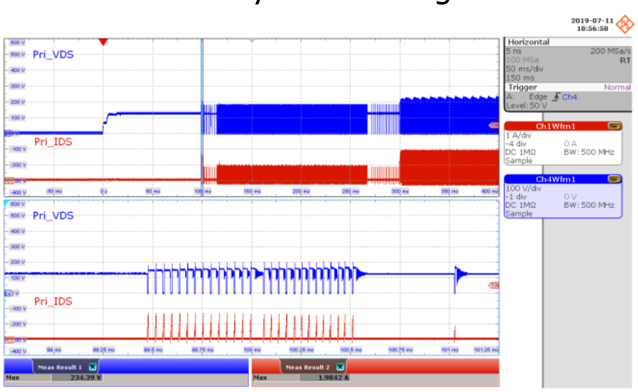

Figure 70 – Primary Drain Voltage and Current.
90 VAC, 5.0 V, 5 A Load (234 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 50 ms / div. (250 μs / div. Zoom)

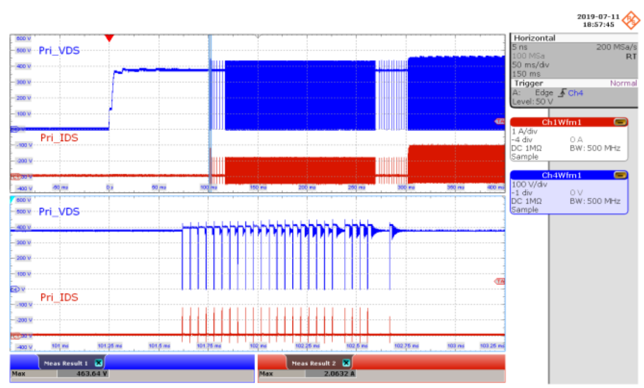

Figure 71 – Primary Drain Voltage and Current.
265 VAC, 5.0 V, 5 A Load (463 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 50 ms / div. (250 μs / div. Zoom)

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13.1.3 SR FET Drain Voltage and Current

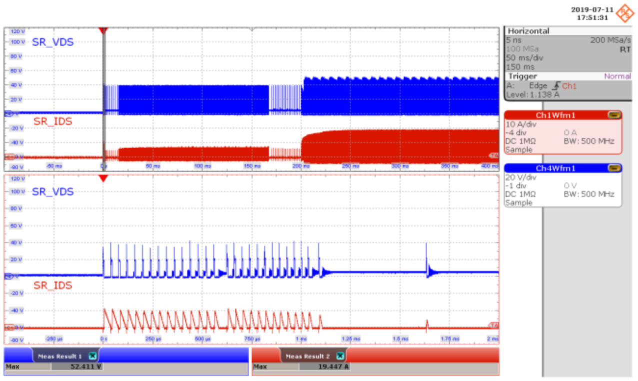

Figure 72 – SR FET Drain Voltage and Current.
90 VAC, 5.0 V, 5 A Load (52.4 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 50 ms / div. (250 µs / div. Zoom)

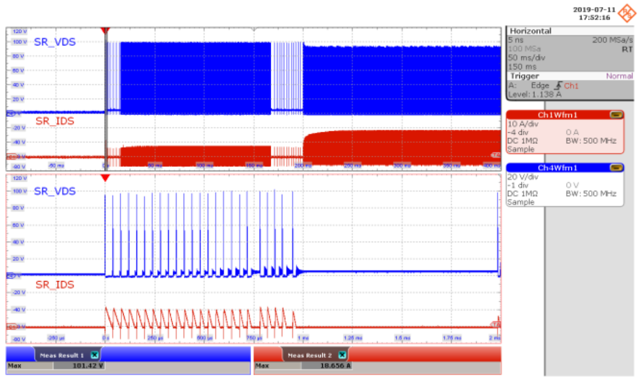

Figure 73 – SR FET Drain Voltage and Current.
265 VAC, 5.0 V, 5 A Load (101 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 50 ms / div. (250 µs / div. Zoom)

13.2 ***Load Transient Response***

Note: Output voltages captured on PCB end.

13.2.1 Output: 5 V / 5 A

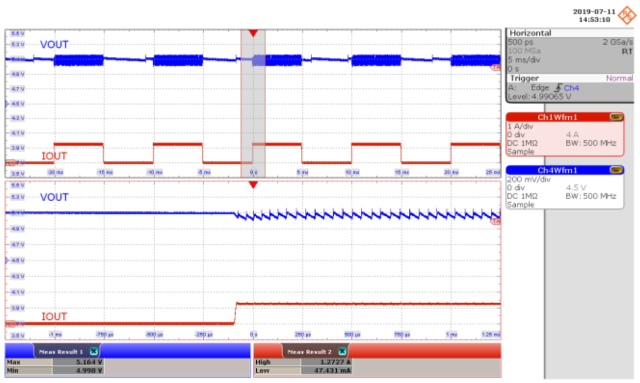

Figure 74 – Transient Response.
90 VAC, 5.0 V, 0 – 1.25 A Load Step.
V_{MIN}: 4.998 V, V_{MAX}: 5.164 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

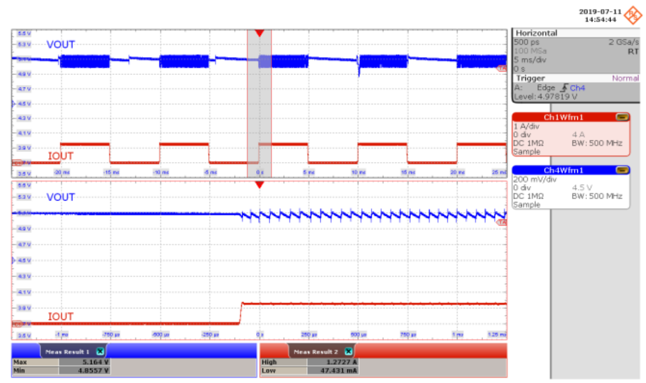

Figure 75 – Transient Response.
265 VAC, 5.0 V, 0 – 1.25 A Load Step.
V_{MIN}: 4.855 V, V_{MAX}: 5.164 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

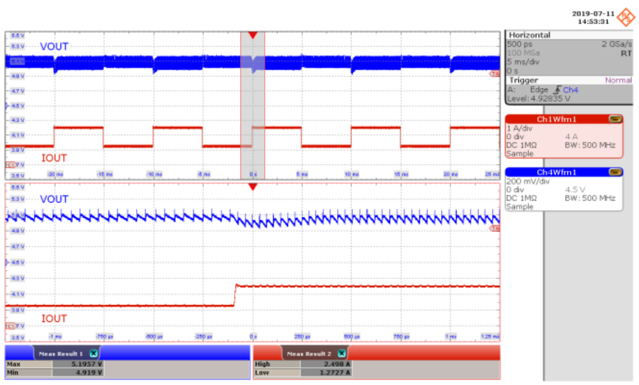

Figure 76 – Transient Response.
90 VAC, 5.0 V, 1.25 – 2.5 A Load Step.
V_{MIN}: 4.919 V, V_{MAX}: 5.195 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

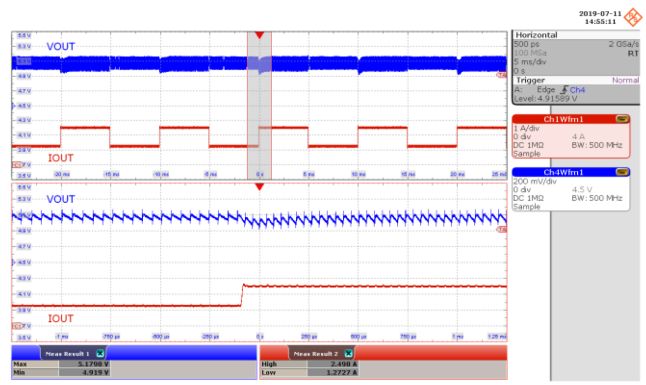

Figure 77 – Transient Response.
265 VAC, 5.0 V, 1.25 – 2.5 A Load Step.
V_{MIN}: 4.919 V, V_{MAX}: 5.179 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

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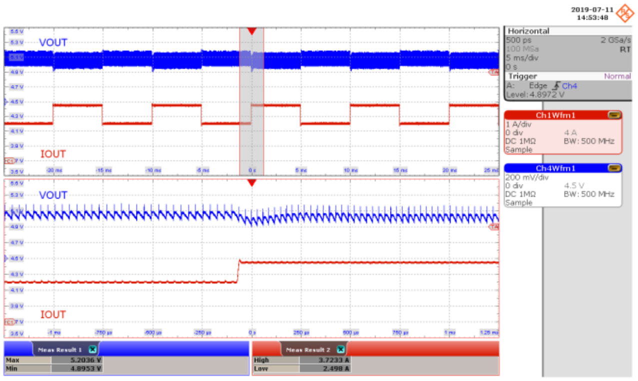

Figure 78 – Transient Response.
90 VAC, 5.0 V, 2.5 – 3.75 A Load Step.
V_{MIN}: 4.895 V, V_{MAX}: 5.203 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

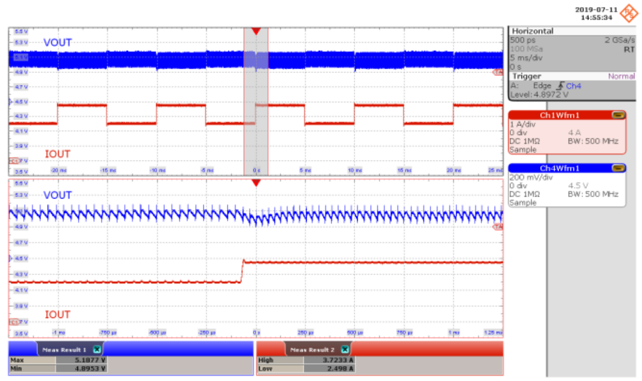

Figure 79 – Transient Response.
265 VAC, 5.0 V, 2.5 – 3.75 A Load Step.
V_{MIN}: 4.895 V, V_{MAX}: 5.187 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

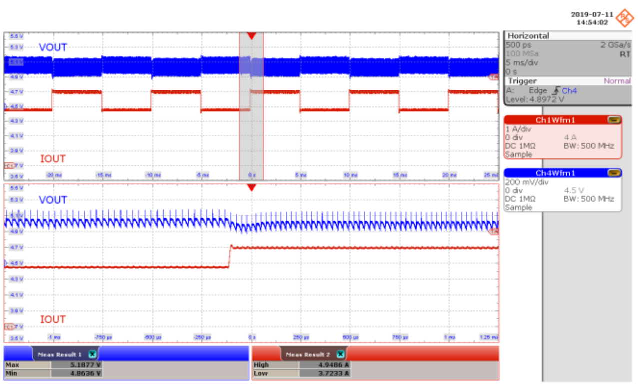

Figure 80 – Transient Response.
90 VAC, 5.0 V, 3.75 – 5 A Load Step.
V_{MIN}: 4.863 V, V_{MAX}: 5.187 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

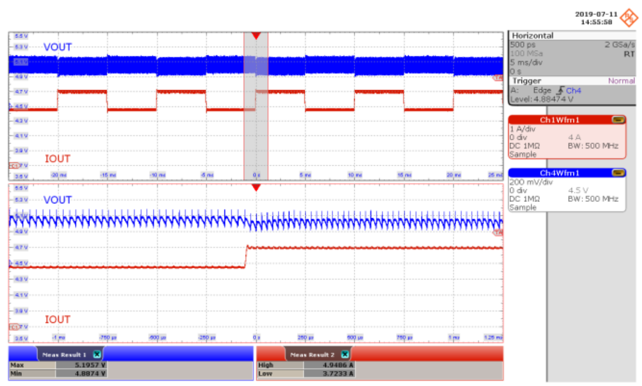

Figure 81 – Transient Response.
90 VAC, 5.0 V, 3.75 – 5 A Load Step.
V_{MIN}: 4.887 V, V_{MAX}: 5.195 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

13.2.2 Output: 9 V / 5 A

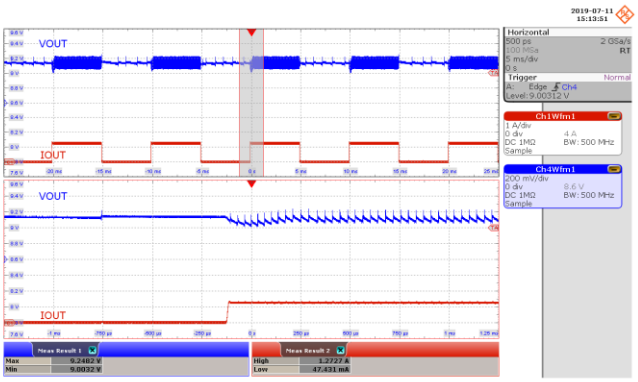

Figure 82 – Transient Response.
90 VAC, 9.0 V, 0 – 1.25 A Load Step.
V_{MIN}: 9.003 V, V_{MAX}: 9.248 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

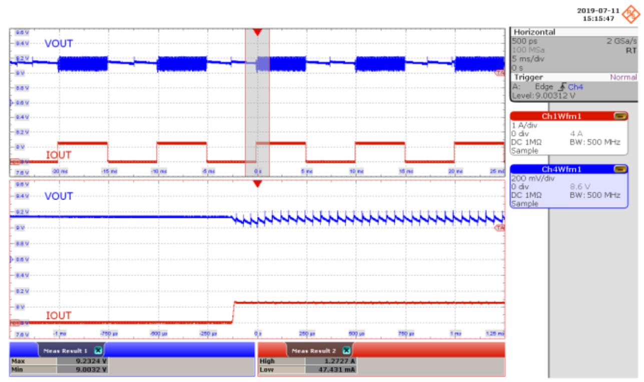

Figure 83 – Transient Response.
265 VAC, 9.0 V, 0 – 1.25 A Load Step.
V_{MIN}: 9.003 V, V_{MAX}: 9.232 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

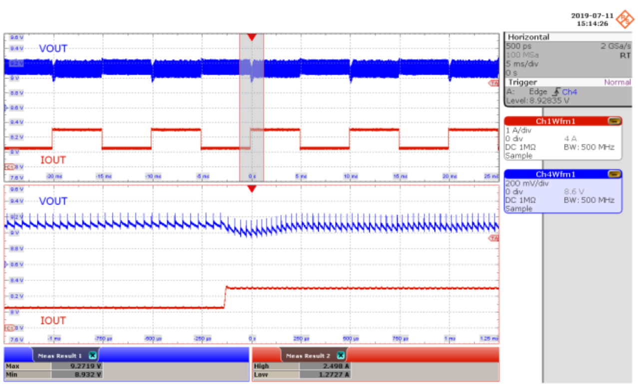

Figure 84 – Transient Response.
90 VAC, 9.0 V, 1.25 – 2.5 A Load Step.
V_{MIN}: 8.932 V, V_{MAX}: 9.271 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

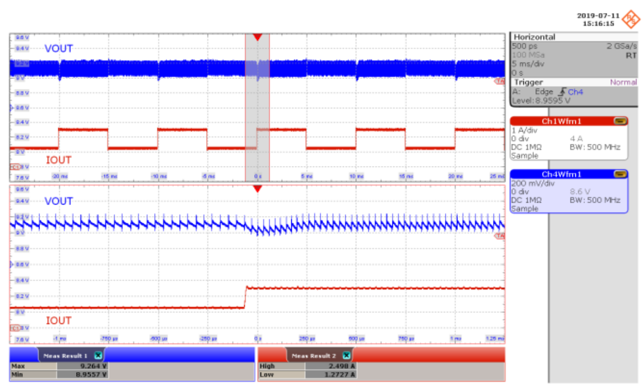

Figure 85 – Transient Response.
265 VAC, 9.0 V, 1.25 – 2.5 A Load Step.
V_{MIN}: 8.955 V, V_{MAX}: 9.264 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

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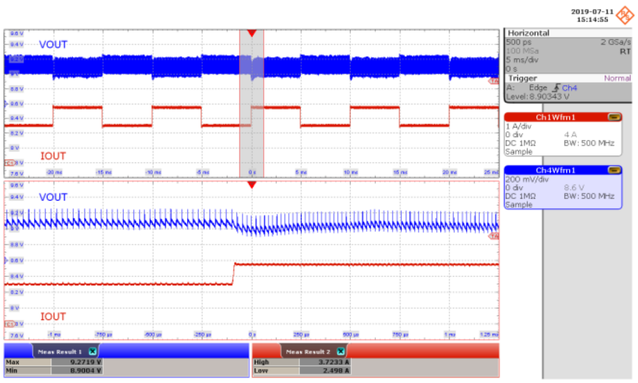

Figure 86 – Transient Response.
90 VAC, 9.0 V, 2.5 – 3.75 A Load Step.
V_{MIN}: 8.900 V, V_{MAX}: 9.271 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

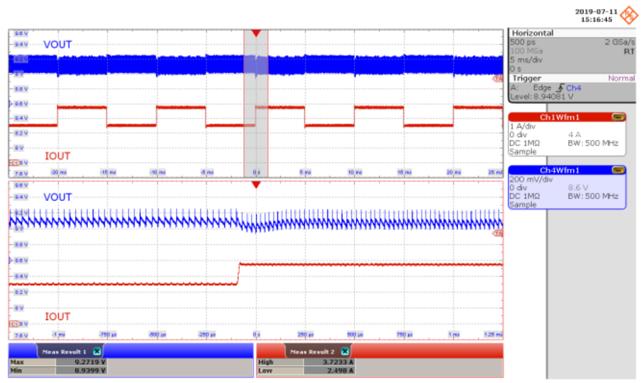

Figure 87 – Transient Response.
265 VAC, 9.0 V, 2.5 – 3.75 A Load Step.
V_{MIN}: 8.939 V, V_{MAX}: 9.271 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

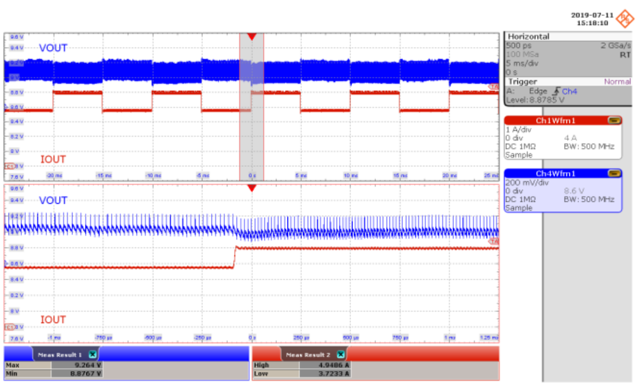

Figure 88 – Transient Response.
90 VAC, 9.0 V, 3.75 – 5 A Load Step.
V_{MIN}: 8.876 V, V_{MAX}: 9.264 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

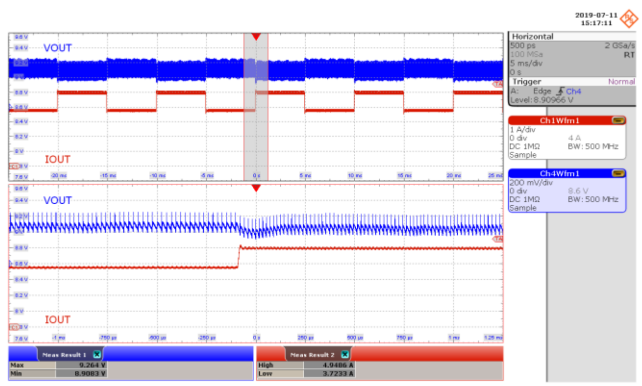

Figure 89 – Transient Response.
265 VAC, 9.0 V, 3.75 – 5 A Load Step.
V_{MIN}: 8.908 V, V_{MAX}: 9.264 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

13.2.3 Output: 15 V / 3 A

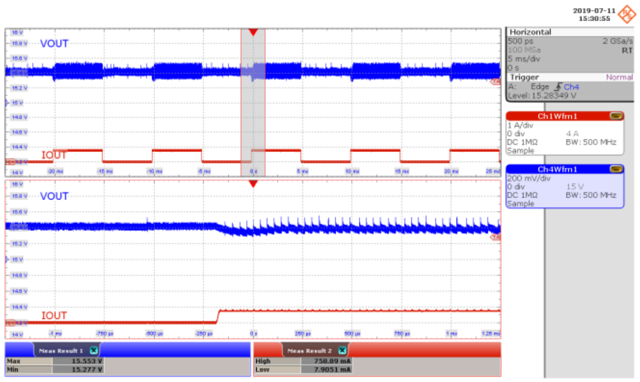

Figure 90 – Transient Response.
90 VAC, 15.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 15.277 V, V_{MAX}: 15.553 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

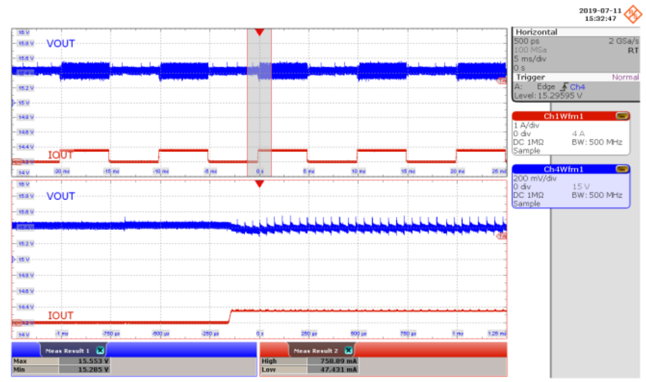

Figure 91 – Transient Response.
265 VAC, 15.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 15.285 V, V_{MAX}: 15.553 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

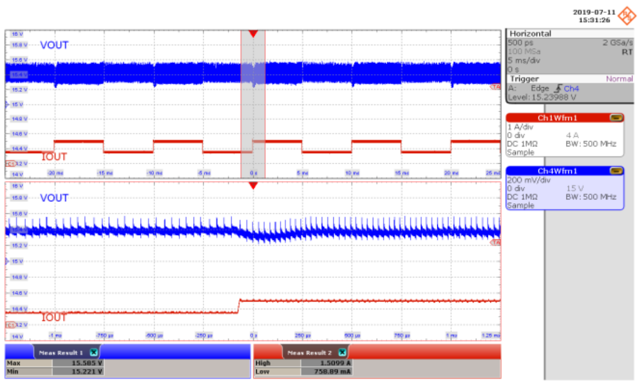

Figure 92 – Transient Response.
90 VAC, 15.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 15.221 V, V_{MAX}: 15.585 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

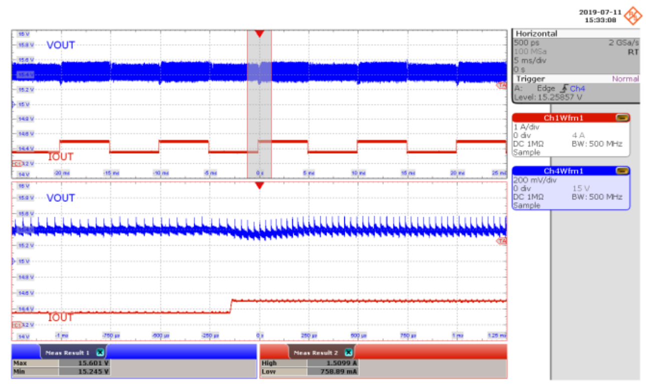

Figure 93 – Transient Response.
265 VAC, 15.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 15.245 V, V_{MAX}: 15.601 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

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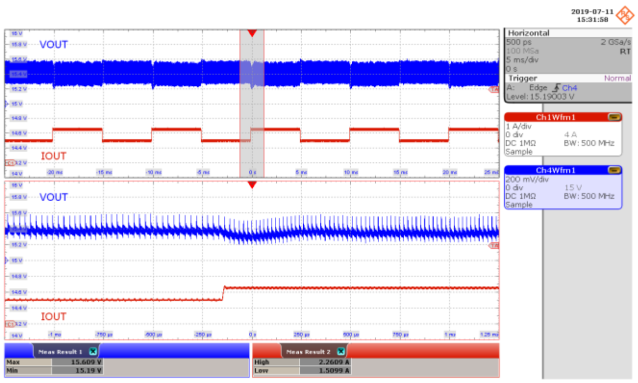

Figure 94 – Transient Response.
90 VAC, 15.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 15.190 V, V_{MAX}: 15.609 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

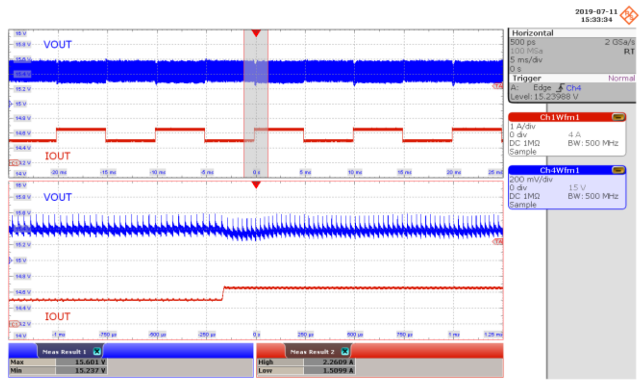

Figure 95 – Transient Response.
265 VAC, 15.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 15.237 V, V_{MAX}: 15.601 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

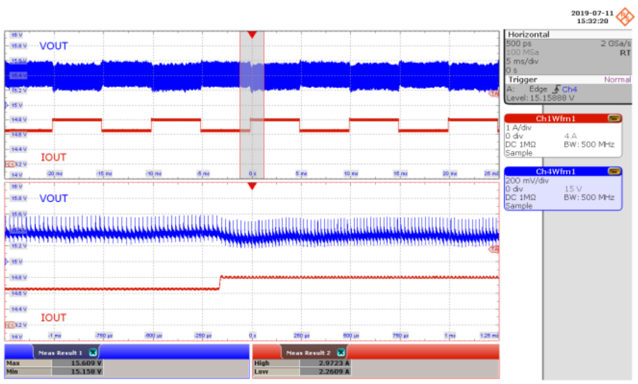

Figure 96 – Transient Response.
90 VAC, 15.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 15.158 V, V_{MAX}: 15.609 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

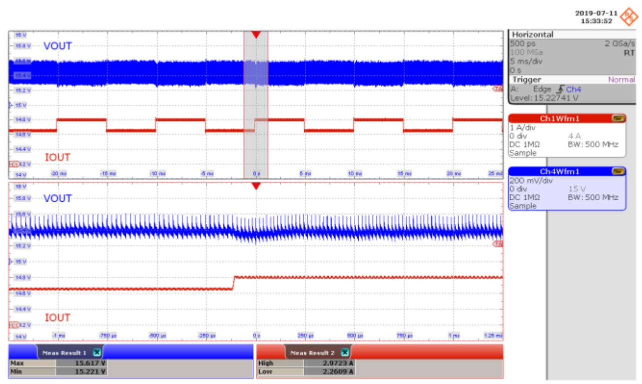

Figure 97 – Transient Response.
265 VAC, 15.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 15.221 V, V_{MAX}: 15.617 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 μs / div. Zoom)

13.2.4 Output: 20 V / 2.25 A

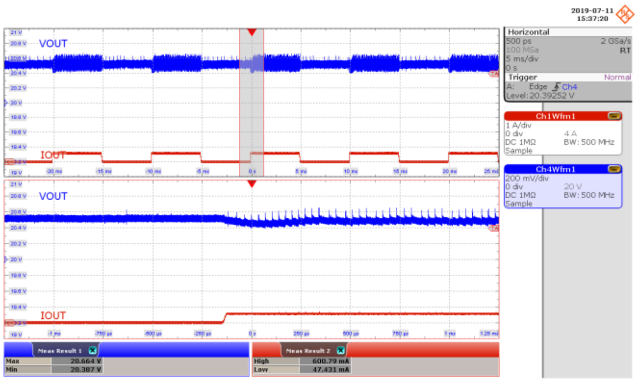

Figure 98 – Transient Response.
90 VAC, 20.0 V, 0 – 0.56 A Load Step.
V_{MIN}: 20.387 V, V_{MAX}: 20.664 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

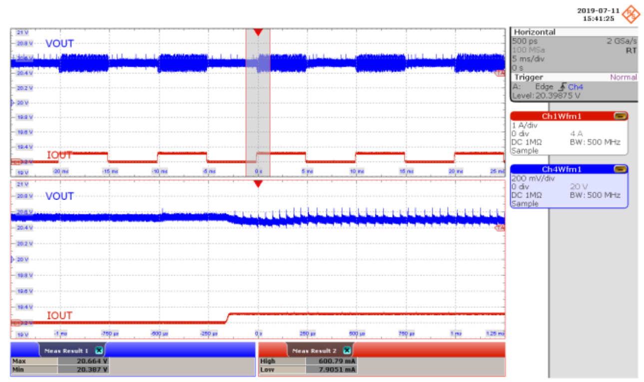

Figure 99 – Transient Response.
265 VAC, 20.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 20.387 V, V_{MAX}: 20.664 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

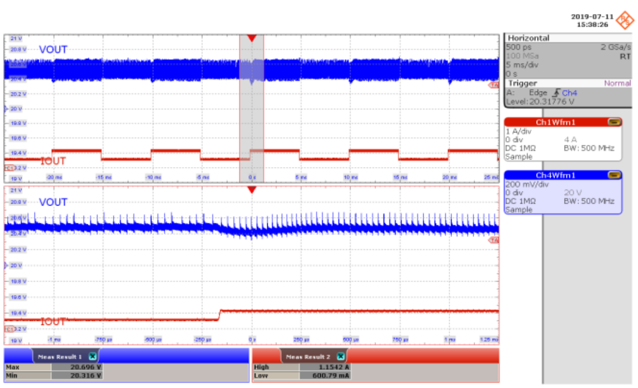

Figure 100 – Transient Response.
90 VAC, 20.0 V, 0.56 – 1.12 A Load Step.
V_{MIN}: 20.316 V, V_{MAX}: 20.696 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

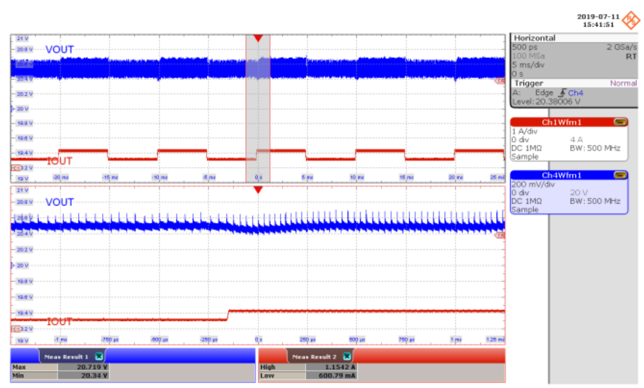

Figure 101 – Transient Response.
265 VAC, 20.0 V, 0.56 – 1.12 A Load Step.
V_{MIN}: 20.340 V, V_{MAX}: 20.719 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

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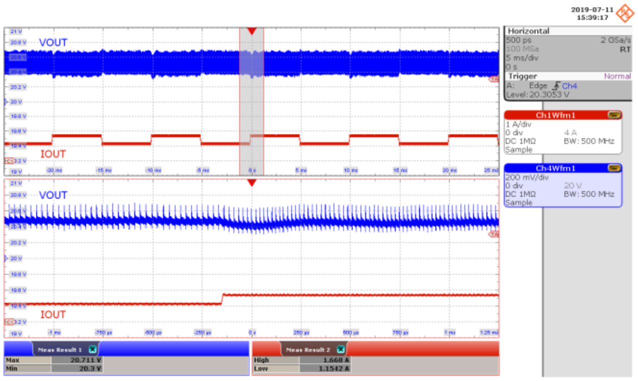

Figure 102 – Transient Response.
90 VAC, 20.0 V, 1.12 – 1.68 A Load Step.
V_{MIN}: 20.300 V, V_{MAX}: 20.711 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

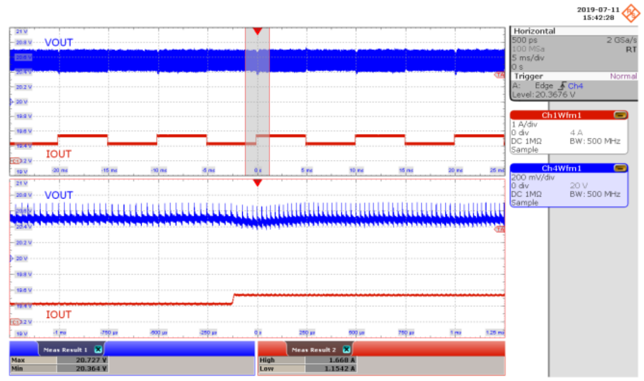

Figure 103 – Transient Response.
265 VAC, 20.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 20.364 V, V_{MAX}: 20.727 V.
CH4: V_{OUT}, 2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

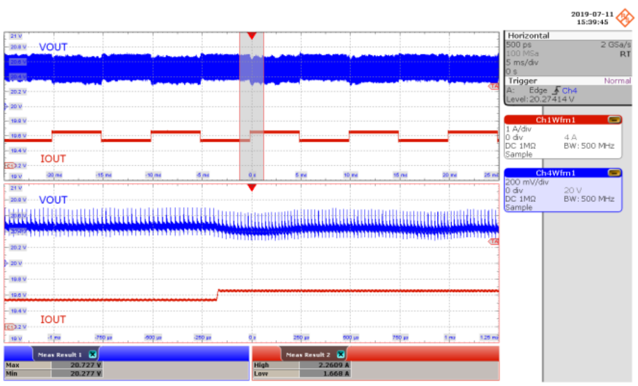

Figure 104 – Transient Response.
90 VAC, 20.0 V, 1.68 – 2.25 A Load Step.
V_{MIN}: 20.227 V, V_{MAX}: 20.727 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

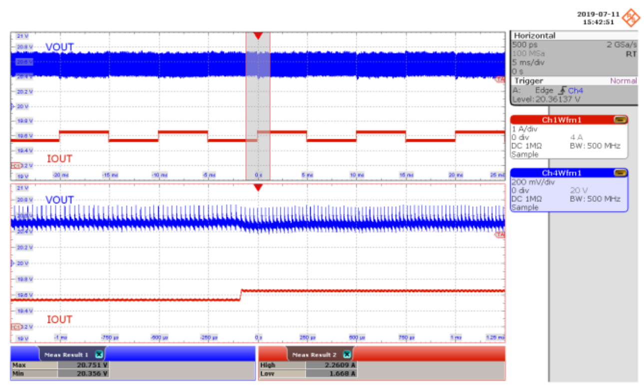

Figure 105 – Transient Response.
265 VAC, 20.0 V, 1.68 – 2.25 A Load Step.
V_{MIN}: 20.356 V, V_{MAX}: 20.751 V.
CH4: V_{OUT}, 0.2 V / div.
CH1: I_{LOAD}, 1 A / div.
Time: 5 ms / div. (250 µs / div. Zoom)

13.3 *Primary Drain Voltage and Current (Steady-State)*

13.3.1 Output: 5 V / 5 A

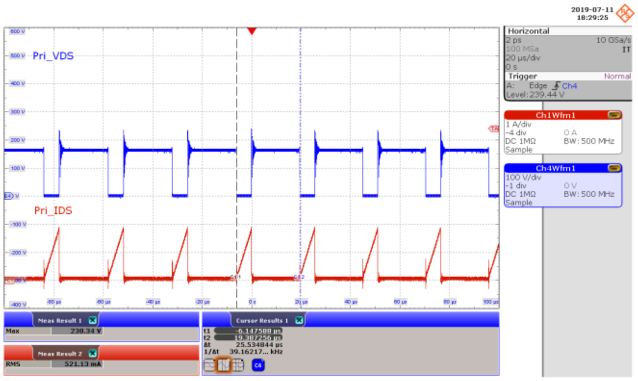

Figure 106 – Primary Drain Voltage and Current.
90 VAC, 5.0 V, 5 A Load (238 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

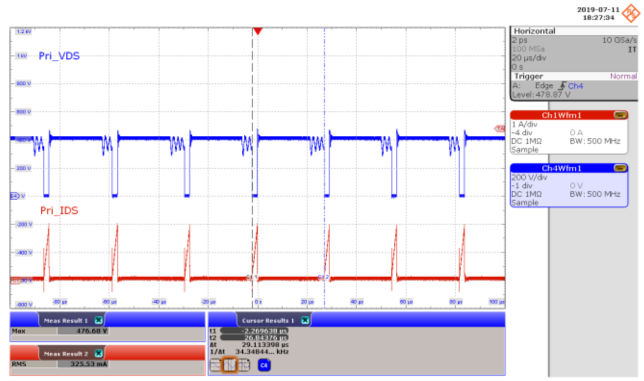

Figure 107 – Primary Drain Voltage and Current.
265 VAC, 5.0 V, 5 A Load (476 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

13.3.2 Output: 9 V / 5 A

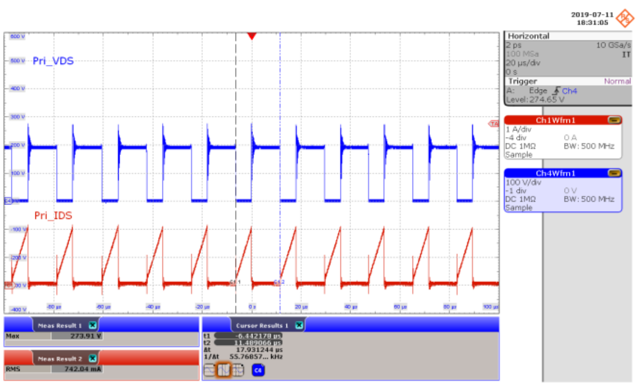

Figure 108 – Primary Drain Voltage and Current.
90 VAC, 9.0 V, 5 A Load (273 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

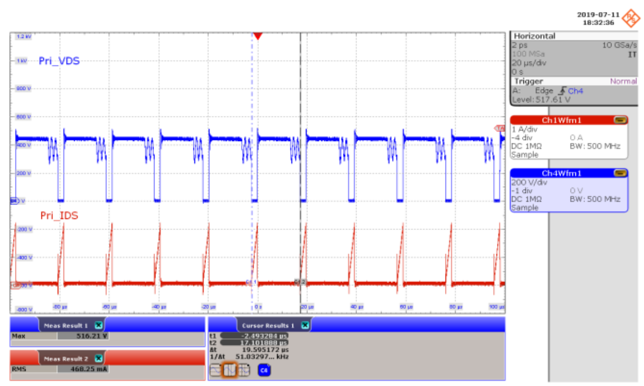

Figure 109 – Primary Drain Voltage and Current.
265 VAC, 9.0 V, 5 A Load (516 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 μs / div.

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13.3.3 Output: 15 V / 3 A

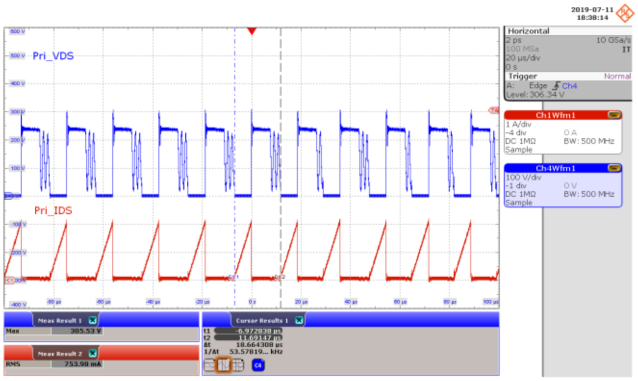

Figure 110 – Primary Drain Voltage and Current.
90 VAC, 15.0 V, 3 A Load (305 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 µs / div.

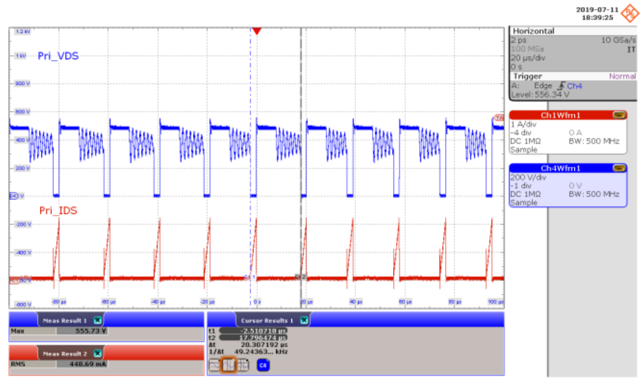

Figure 111 – Primary Drain Voltage and Current.
265 VAC, 15.0 V, 3 A Load (555 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 µs / div.

13.3.4 Output: 20 V / 2.25 A

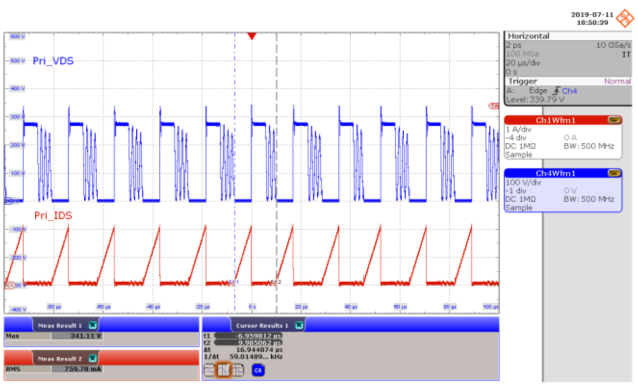

Figure 112 – Primary Drain Voltage and Current.
90 VAC, 20.0 V, 2.25 A Load (341 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 µs / div.

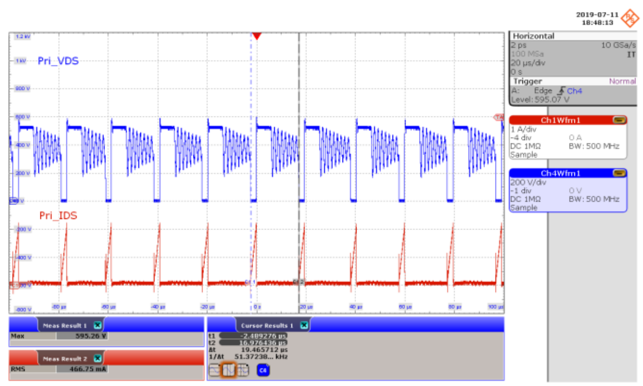

Figure 113 – Primary Drain Voltage and Current.
265 VAC, 20.0 V, 2.25 A Load (595 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 µs / div.

13.4 ***SR FET Drain Voltage and Current (Steady-State)***

13.4.1 Output: 5 V / 5 A

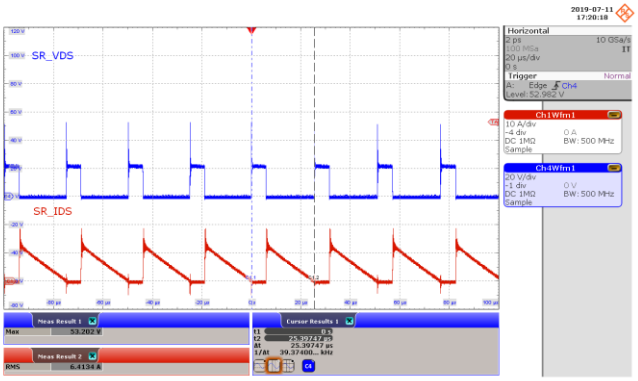

Figure 114 – SR FET Drain Voltage and Current.
90 VAC, 5.0 V, 5 A Load (53.2 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 μs / div.

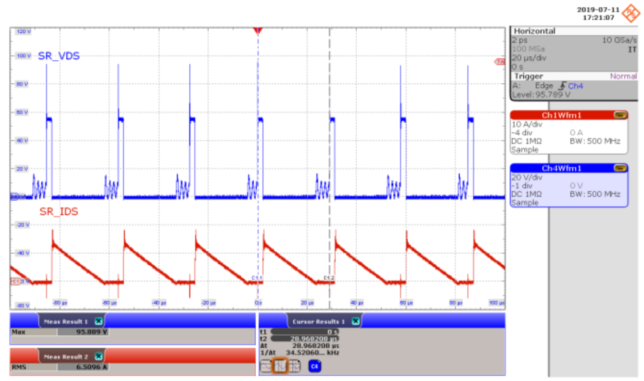

Figure 115 – SR FET Drain Voltage and Current.
265 VAC, 5.0 V, 5 A Load (95.8 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 μs / div.

13.4.2 Output: 9 V / 5 A

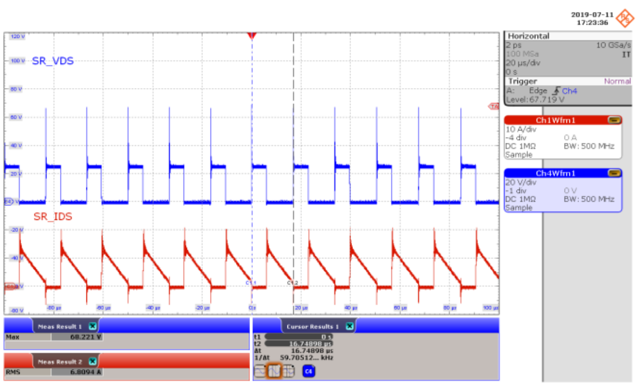

Figure 116 – SR FET Drain Voltage and Current.
90 VAC, 9.0 V, 5 A Load (68.2 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 μs / div.

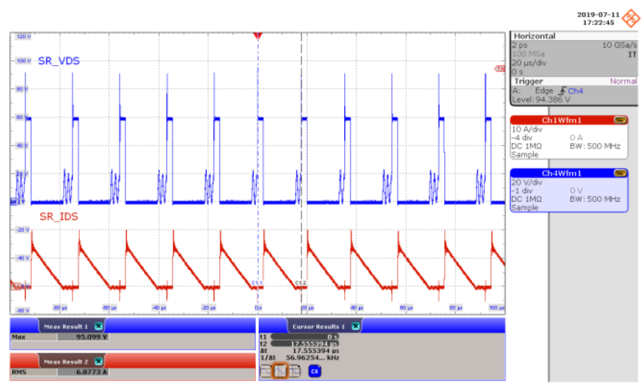

Figure 117 – SR FET Drain Voltage and Current.
265 VAC, 9.0 V, 5 A Load (95.0 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 μs / div.

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13.4.3 Output: 15 V / 3 A

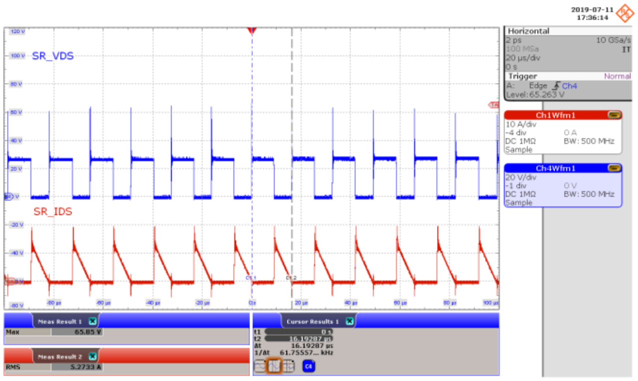

Figure 118 – SR FET Drain Voltage and Current.
90 VAC, 15.0 V, 3 A Load (65.8 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 µs / div.

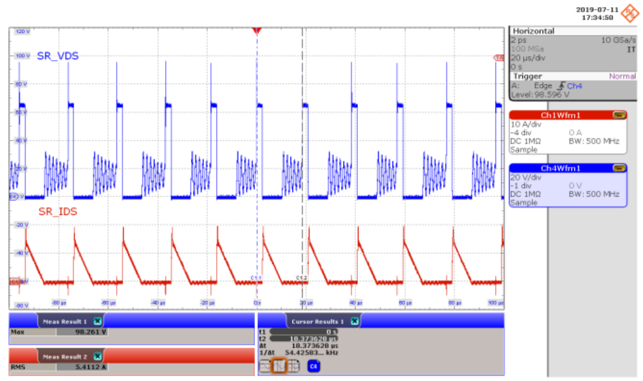

Figure 119 – SR FET Drain Voltage and Current.
265 VAC, 15.0 V, 3 A Load (98.2 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 µs / div.

13.4.4 Output: 20 V / 2.25 A

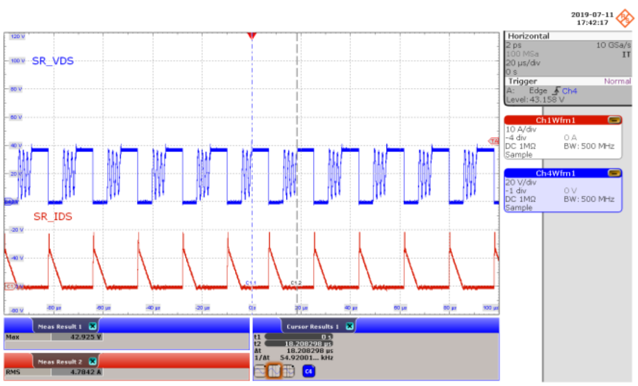

Figure 120 – SR FET Drain Voltage and Current.
90 VAC, 20.0 V, 2.25 A Load (42.9 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 µs / div.

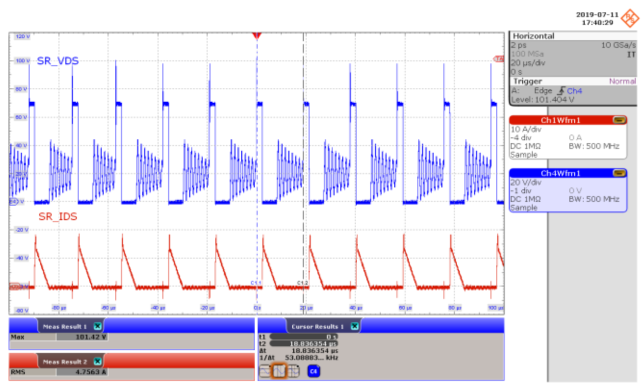

Figure 121 – SR FET Drain Voltage and Current.
265 VAC, 20.0 V, 2.25 A Load (101 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 µs / div.

13.5 ***Primary and SR FET Drain Voltage and Current (during Output Voltage Transition)***

13.5.1 Primary Drain Voltage and Current, 3.3 V to 21 V Transition / 2.25 A Load

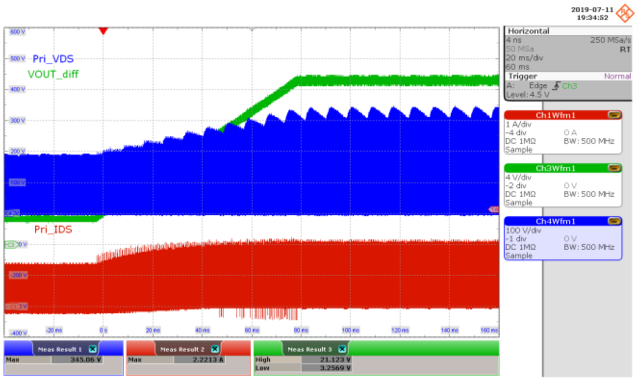

Figure 122 – Primary Drain Voltage and Current. 90 VAC, 3.3 V to 21 V Output Transition, 2.25 A Load (345 V_{MAX}).
CH4: V_{DRAIN}, 100 V / div.
CH3: V_{OUT}, 4 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 ms / div.

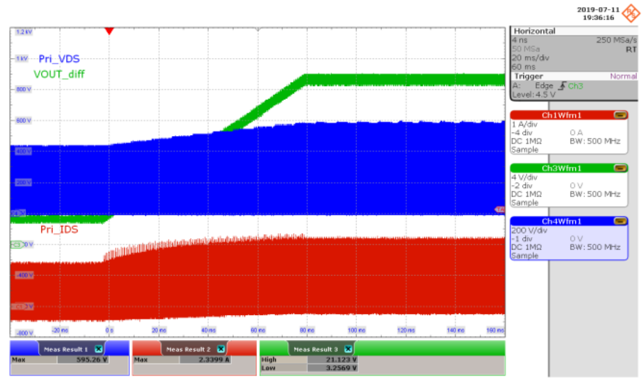

Figure 123 – Primary Drain Voltage and Current. 265 VAC, 3.3 V to 21 V Output Transition, 2.25 A Load (595 V_{MAX}).
CH4: V_{DRAIN}, 200 V / div.
CH3: V_{OUT}, 4 V / div.
CH1: I_{DRAIN}, 1 A / div.
Time: 20 ms / div.

13.5.2 SR FET Drain Voltage and Current, 3.3 V to 21 V Transition / 2.25 A Load

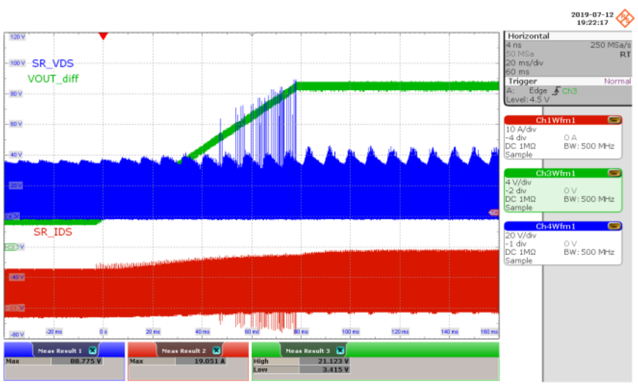

Figure 124 – SR FET Drain Voltage and Current. 90 VAC, 3.3 V to 21 V Output Transition, 2.25 A Load (88 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
CH3: V_{OUT}, 4 V / div.
CH1: $I_{DRAIN(SR)}$, 10 A / div.
Time: 20 ms / div.

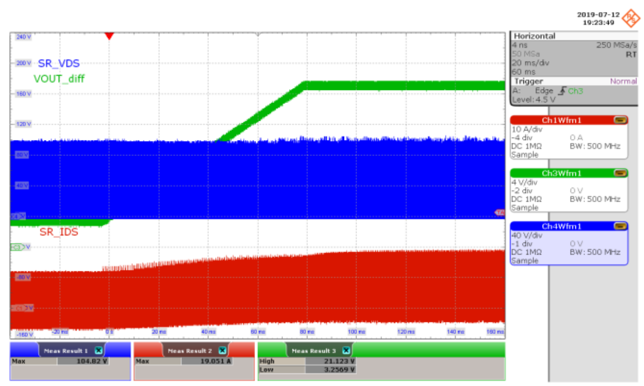

Figure 125 – SR FET Drain Voltage and Current. 265 VAC, 3.3 V to 21 V Output Transition, 2.25 A Load (104 V_{MAX}).
CH4: $V_{DRAIN(SR)}$, 40 V / div.
CH3: V_{OUT}, 4 V / div.
CH1: $I_{DRAIN(SR)}$, 1 A / div.
Time: 20 ms / div.

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14 Output Ripple Measurements

14.1 *Ripple Measurement Technique*

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

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

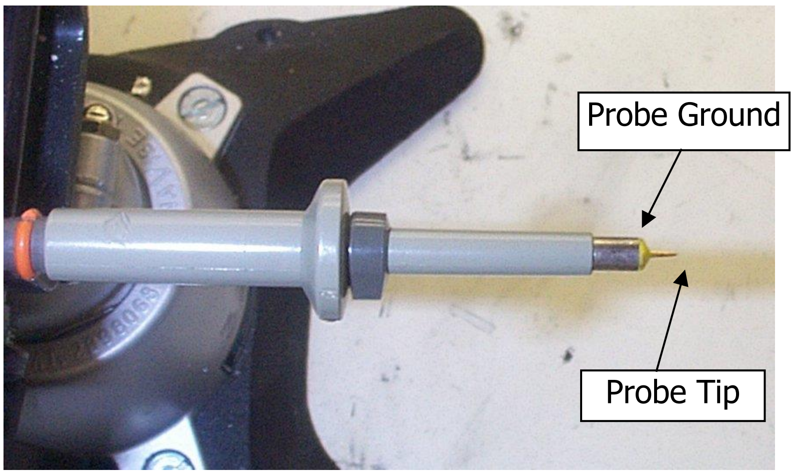

Figure 126 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

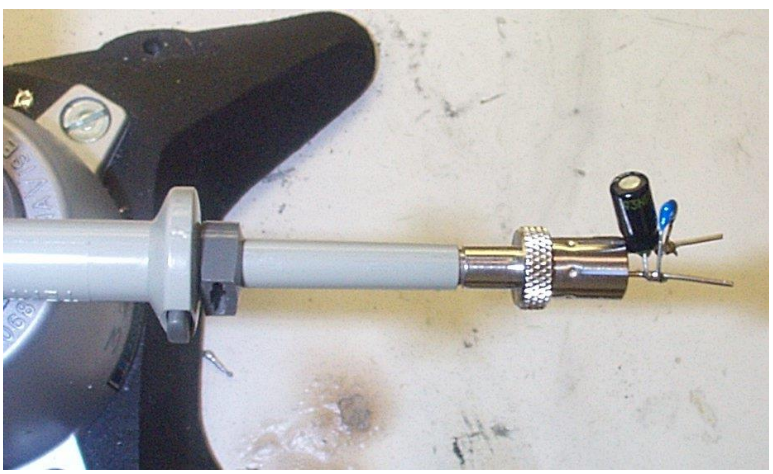

Figure 127 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

14.2 *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)

14.2.1 Output: 5 V / 5 A

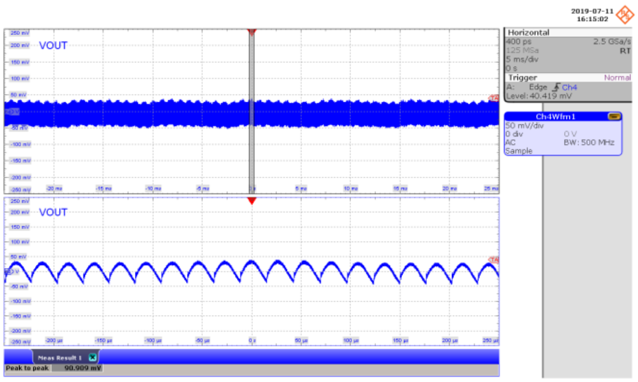

Figure 128 – Output Voltage Ripple.
90 VAC, 5.0 V, 5 A Load (90 mV_{PP}).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

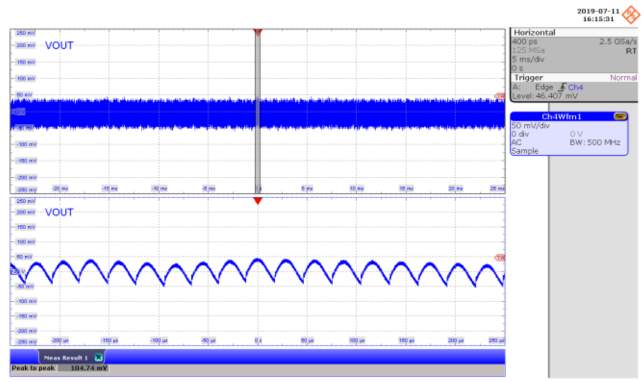

Figure 129 – Output Voltage Ripple.
265 VAC, 5.0 V, 5 A Load (104 mV_{PP}).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

14.2.2 Output: 9 V / 5 A

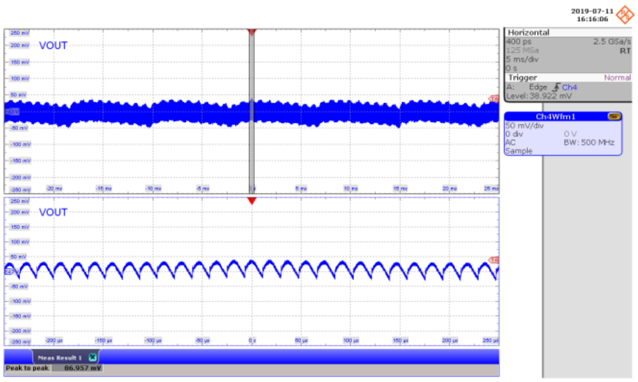

Figure 130 – Output Voltage Ripple.
90 VAC, 9.0 V, 3 A Load (86 mV_{PP}).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

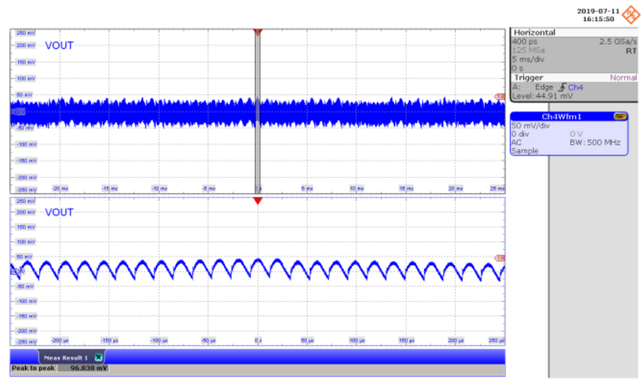

Figure 131 – Output Voltage Ripple.
265 VAC, 9.0 V, 3 A Load (96 mV_{PP}).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

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14.2.3 Output: 15 V / 3 A

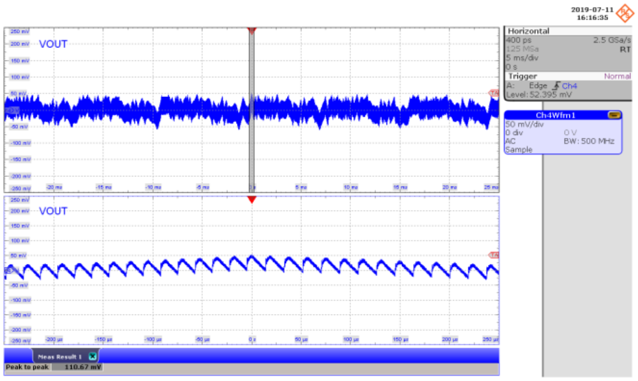

Figure 132 – Output Voltage Ripple.
90 VAC, 15.0 V, 3 A Load (110 mV_{PP}).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

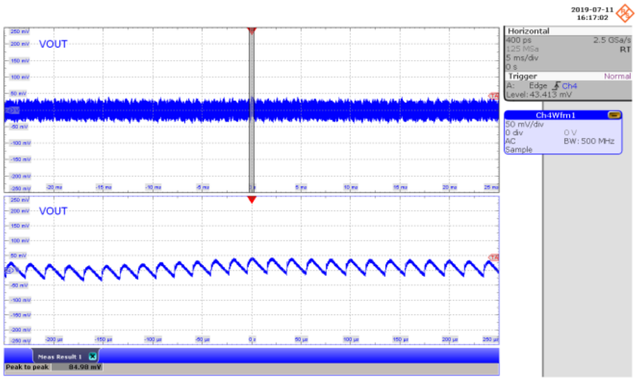

Figure 133 – Output Voltage Ripple.
265 VAC, 5.0 V, 3 A Load (84 mV_{PP}).
CH4: $V_{DRAIN(SR)}$, 20 V / div.
Time: 10 µs / div.

14.2.4 Output: 20 V / 2.25 A

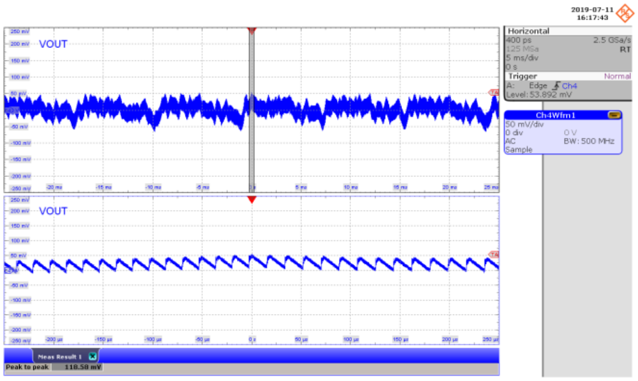

Figure 134 – Output Voltage Ripple.
90 VAC, 20.0 V, 2.25 A Load (118 mV_{PP}).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

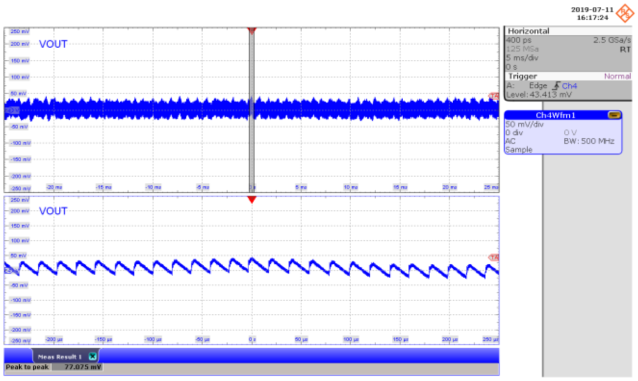

Figure 135 – Output Voltage Ripple.
265 VAC, 20.0 V, 2.25 A Load (77 mV_{PP}).
CH4: $V_{OUT(AC)}$, 50 mV / div.
Time: 5 ms / div. (50 µs / div. Zoom)

14.3 *Output Voltage Ripple Amplitude vs. Load*

14.3.1 Output: 5 V / 5 A

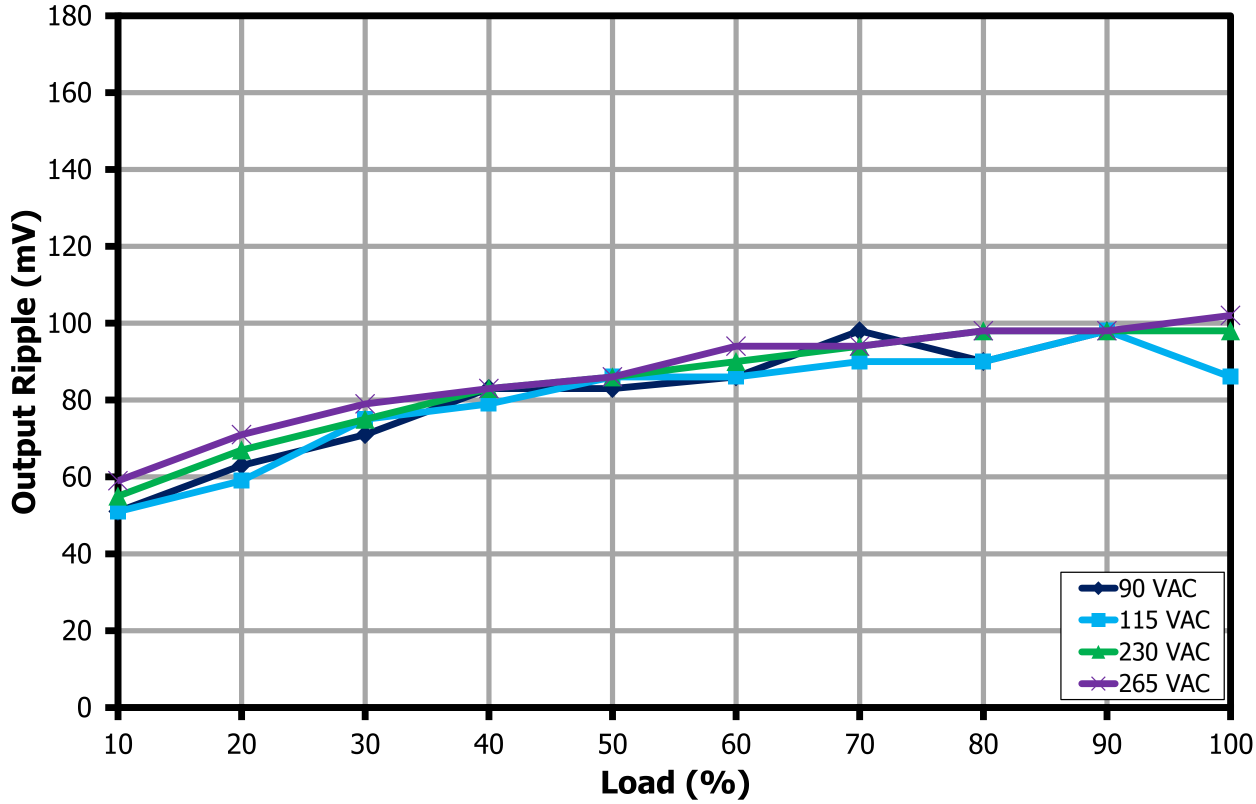

Figure 136 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 5 V Output.

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14.3.2 Output: 9 V / 5 A

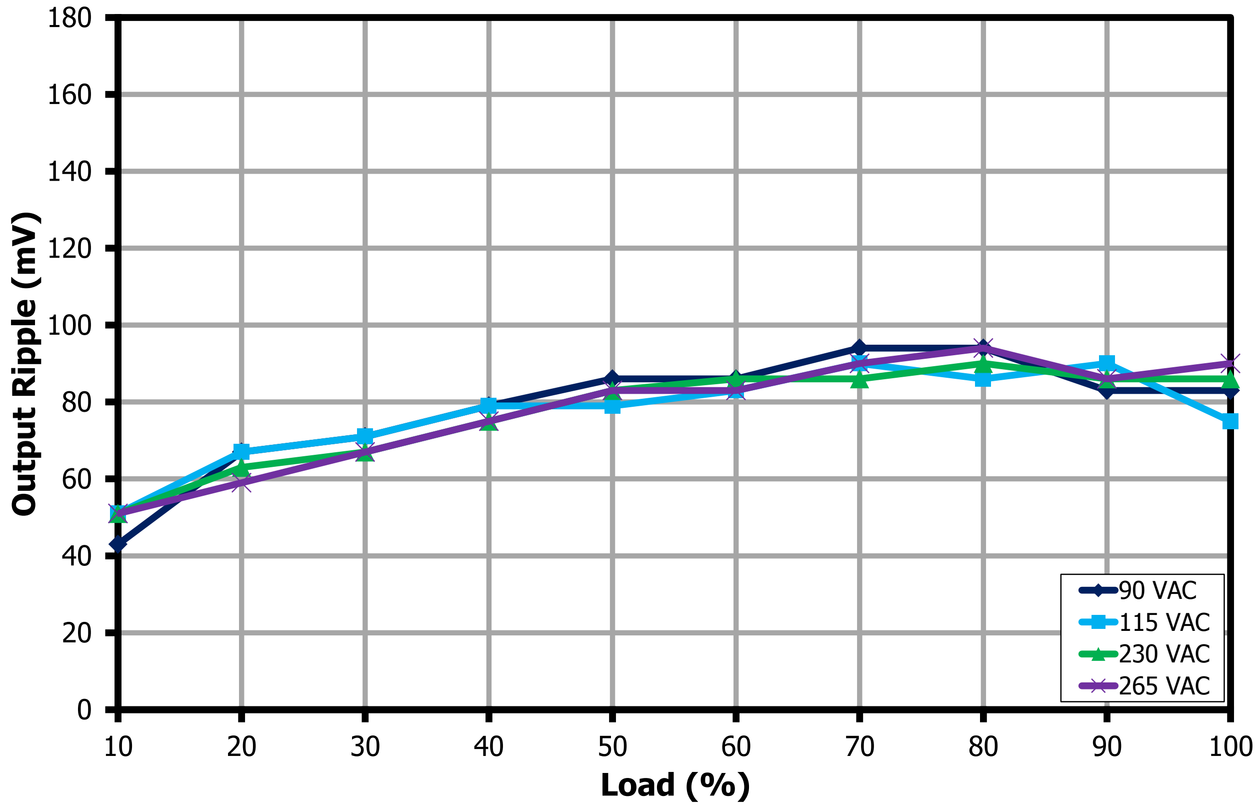

Figure 137 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 9 V Output.

14.3.3 Output: 15 V / 3 A

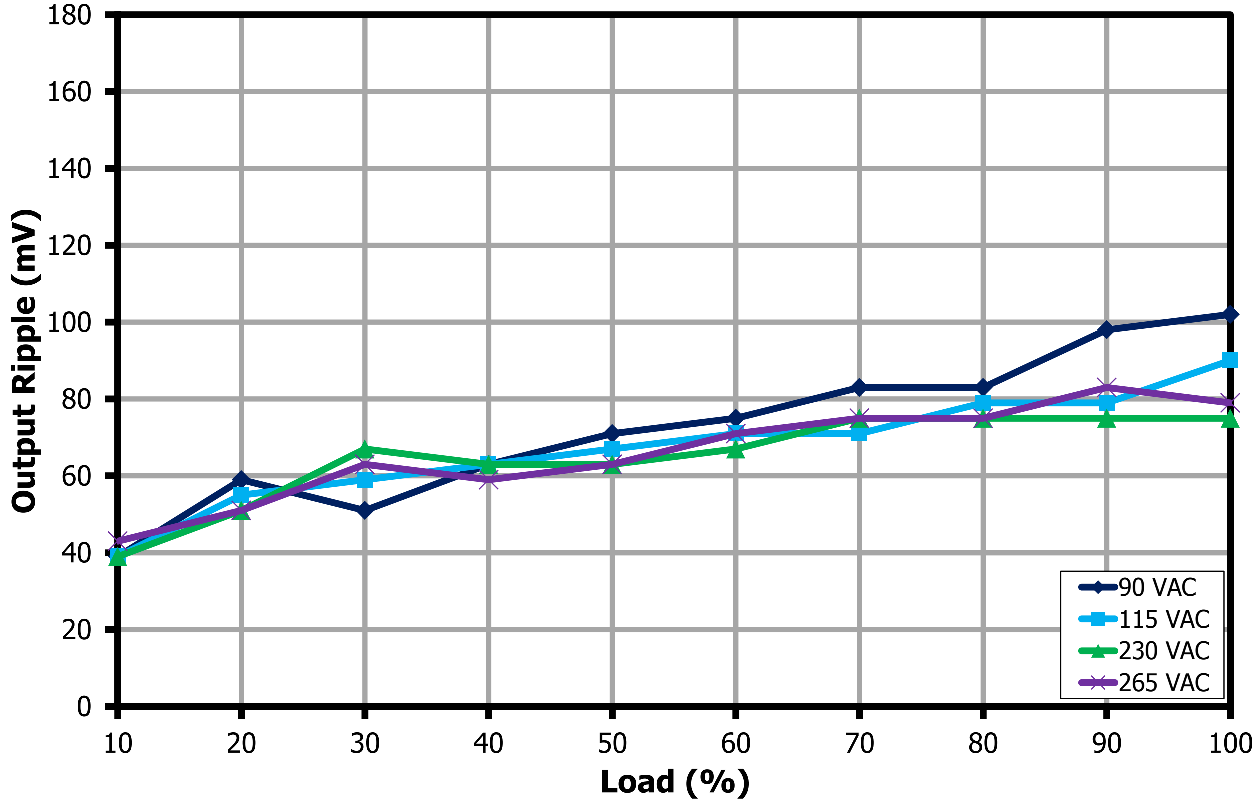

Figure 138 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 15 V Output.

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14.3.4 Output: 20 V / 2.25 A

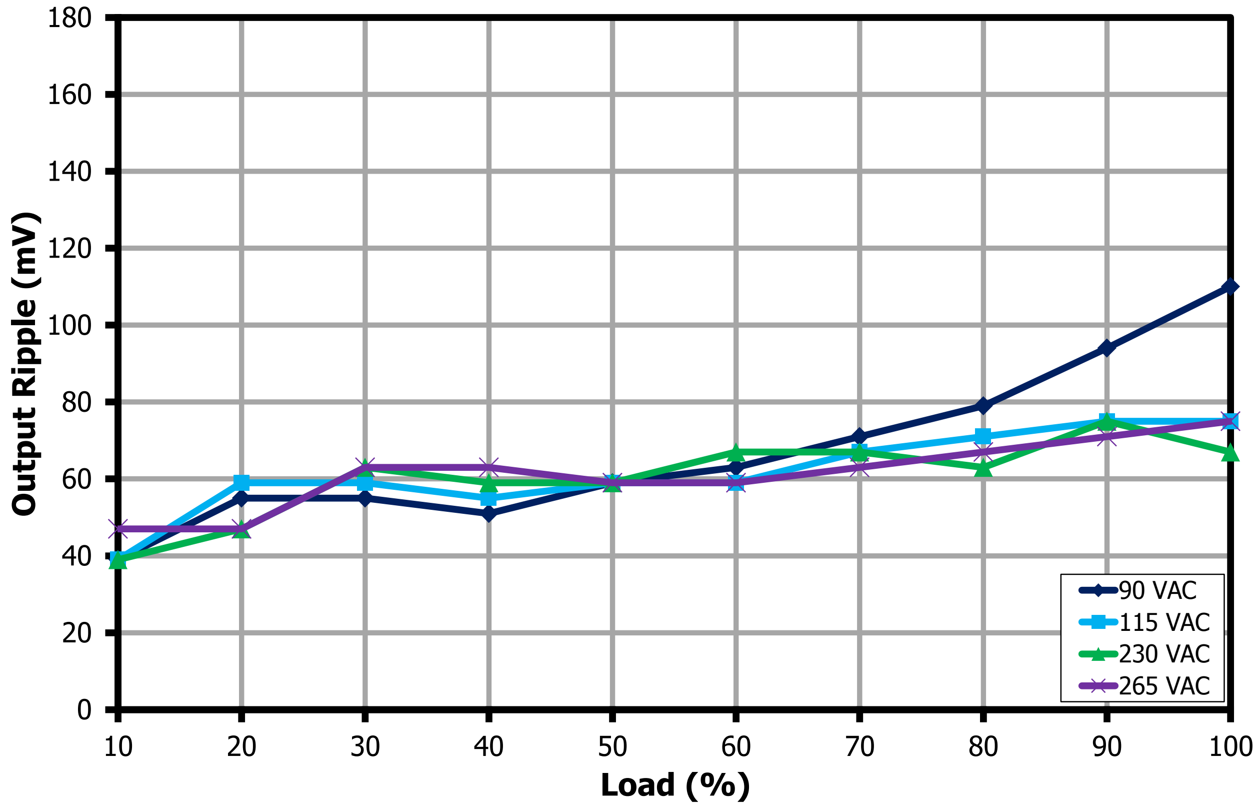

Figure 139 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 20 V Output.

15 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.

15.1 *Output: 9 V / 5 A*

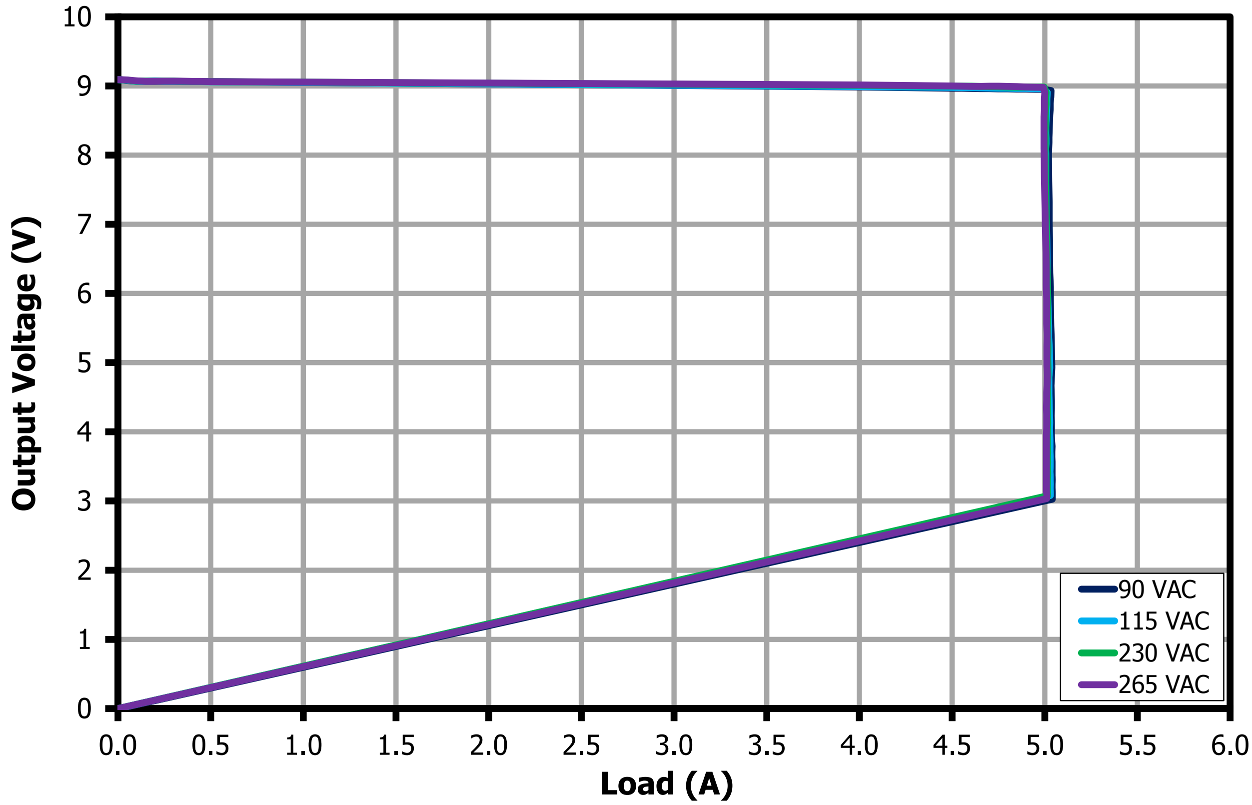

Figure 140 – CV/CC Profile for 9 V / 5 A PPS Output.

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15.2 ***Output: 11 V / 4.09 A***

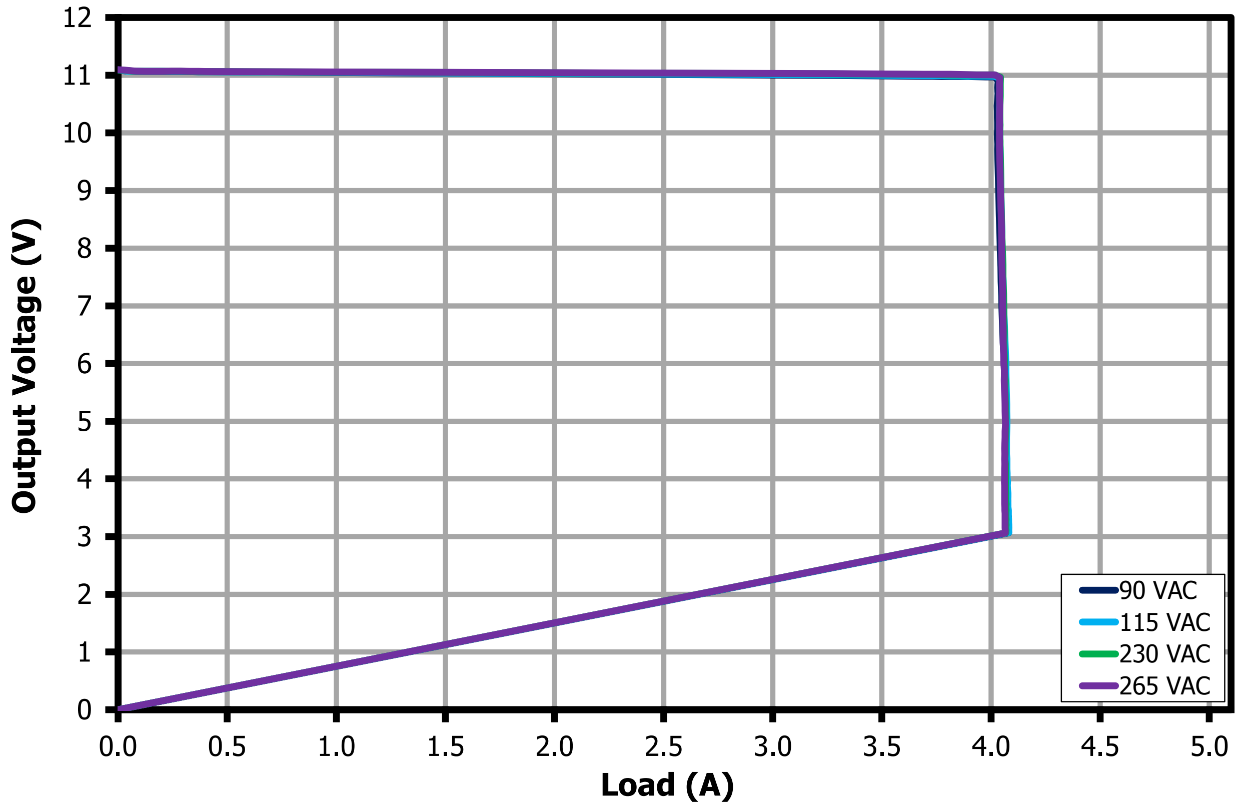

Figure 141 – CV/CC Profile for 11 V / 5 A (45 W Power-limited) PPS Output.

15.3 *Output: 16 V / 3 A*

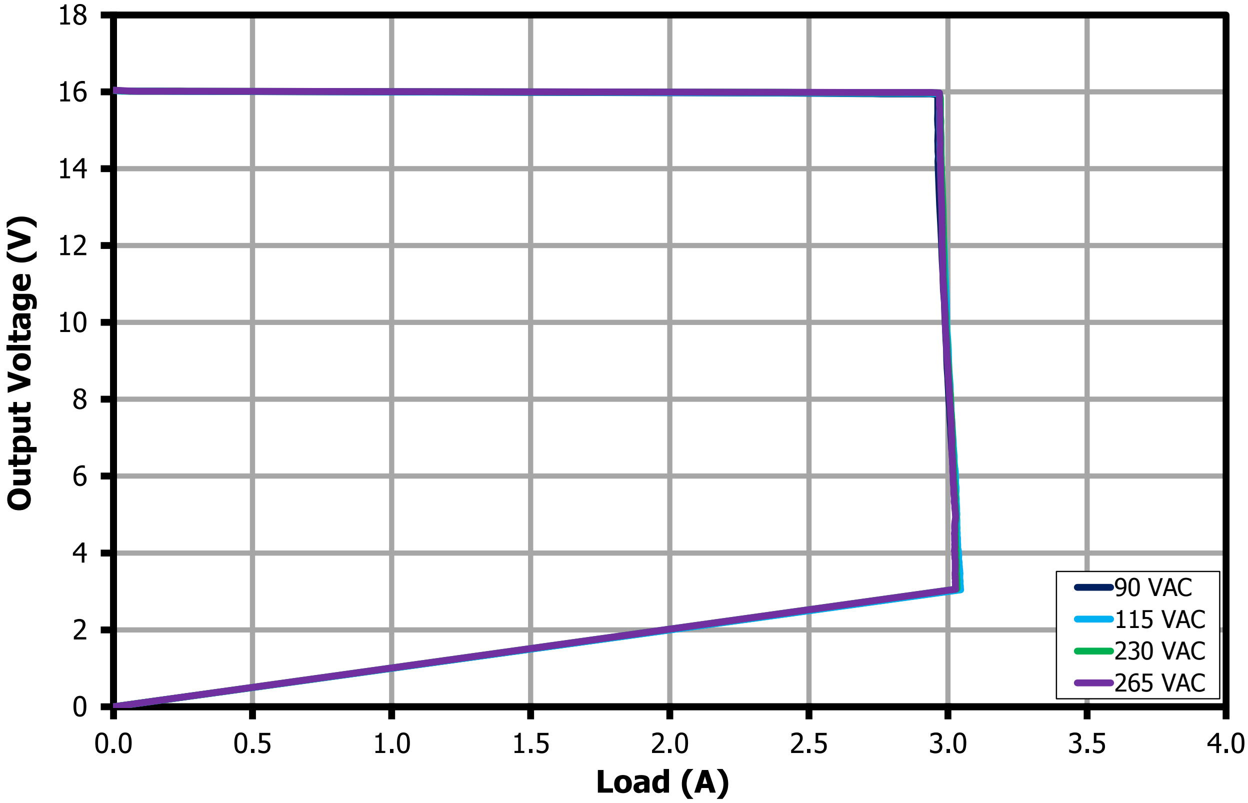

Figure 142 – CV/CC Profile for 16 V / 3 A PPS Output.

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15.4 ***Output: 21 V / 2.25 A***

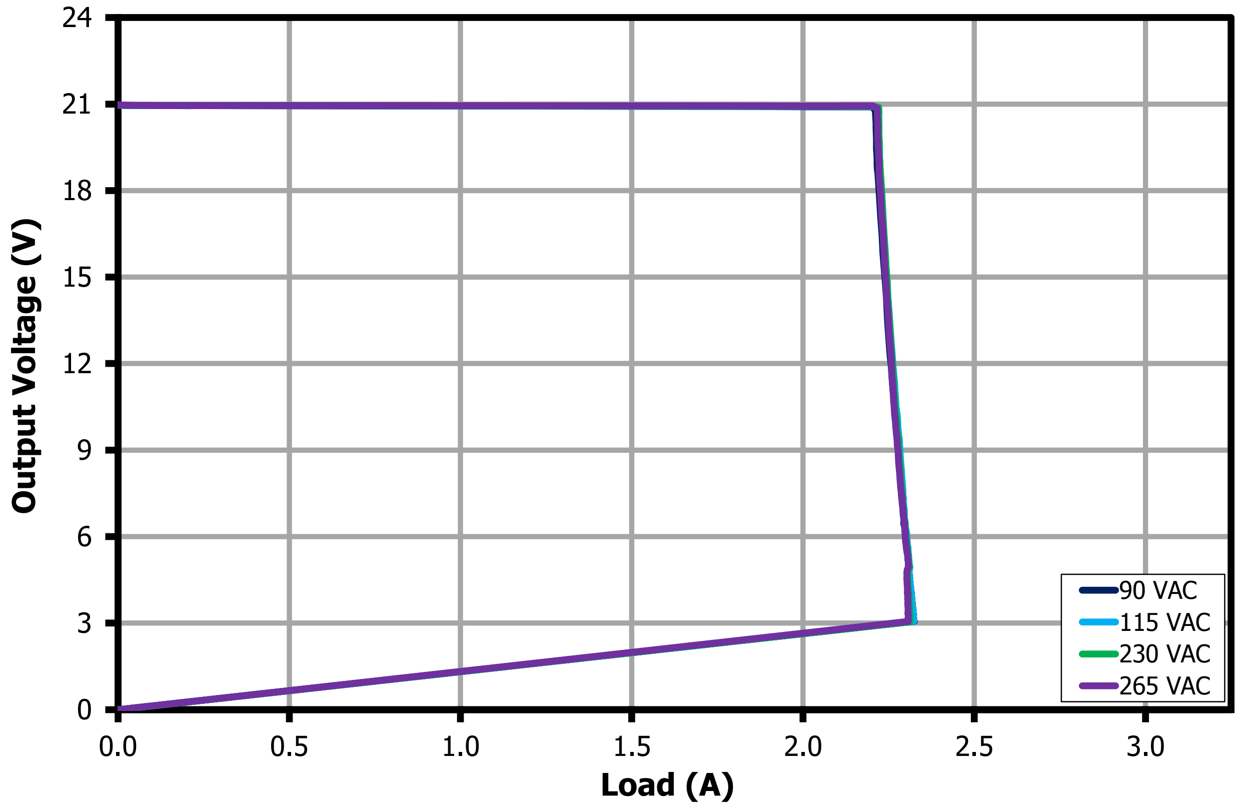

Figure 143 – CV/CC Profile for 21 V / 2.25 A PPS Output.

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

16.1 *Voltage Step Test (VST)*

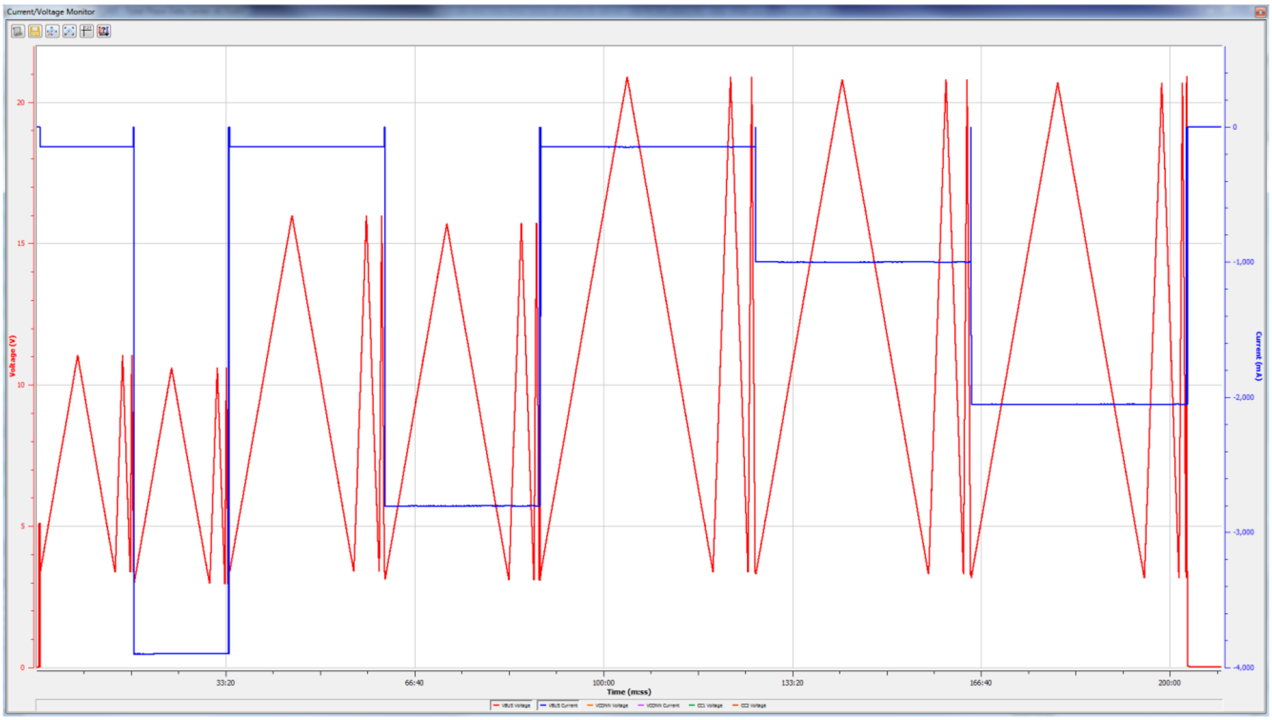

Figure 144 – Plot of SPT.6 VST from Total Phase Analyzer.

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16.2 *Current Limit Test (CLT)*

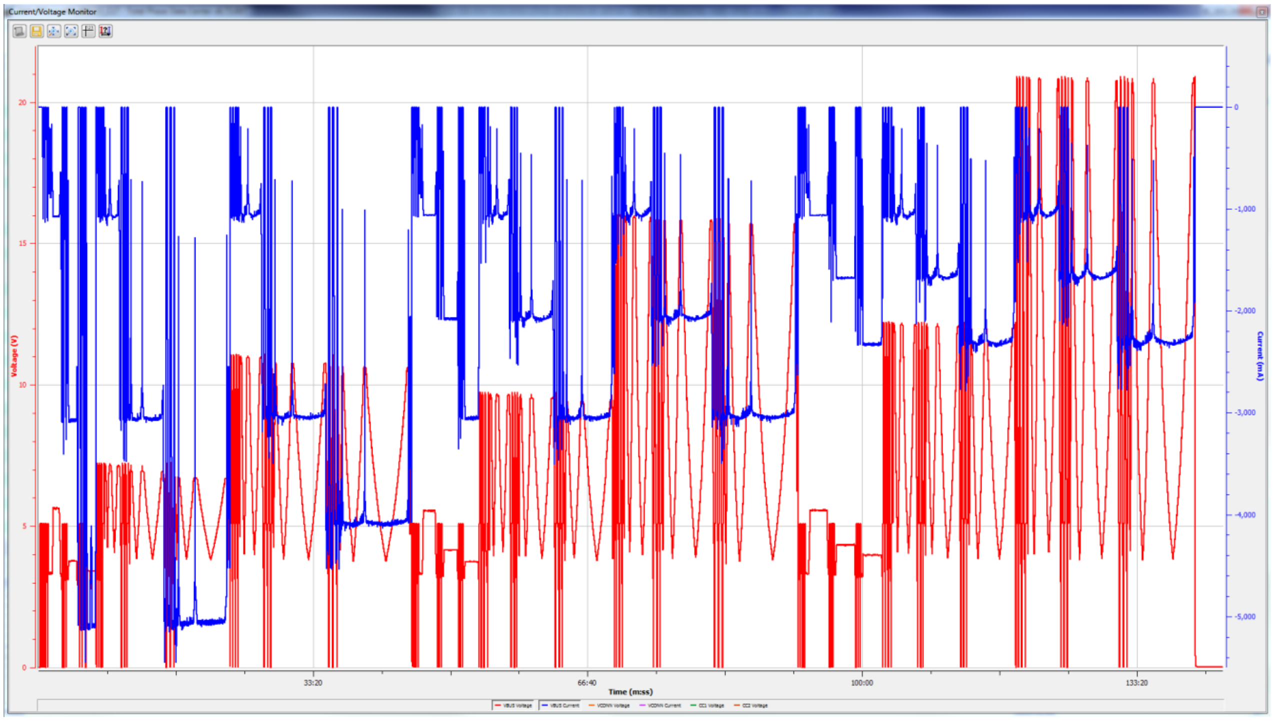
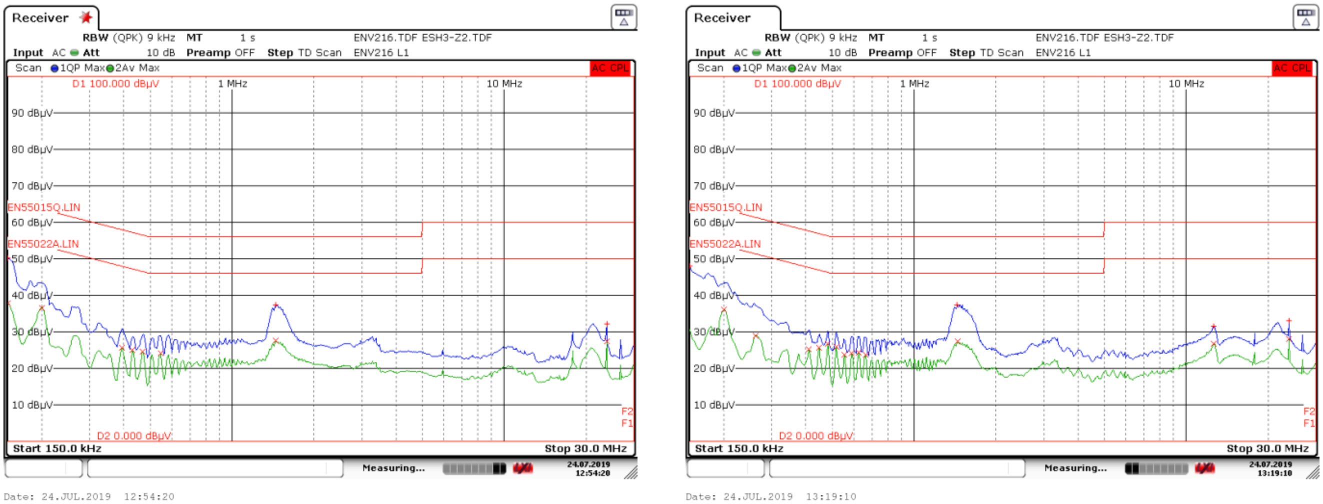


Figure 145 – Plot of SPT.7 CLT from Total Phase Analyzer.

17 Conducted EMI

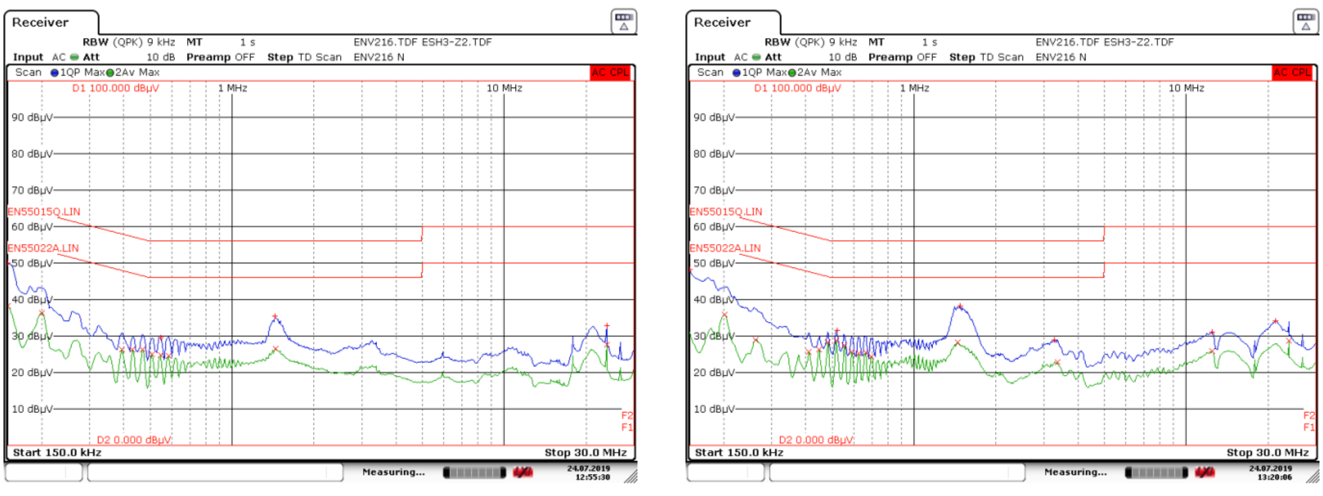
17.1 *Floating Ground (QPK / AV)*

17.1.1 Output: 5 V / 5 A



115 VAC. 230 VAC.

Figure 146 – Floating Ground EMI, 5 V / 5 A Load [Line Scan].



115 VAC. 230 VAC.

Figure 147 – Floating Ground EMI, 5 V / 5 A Load [Neutral Scan].

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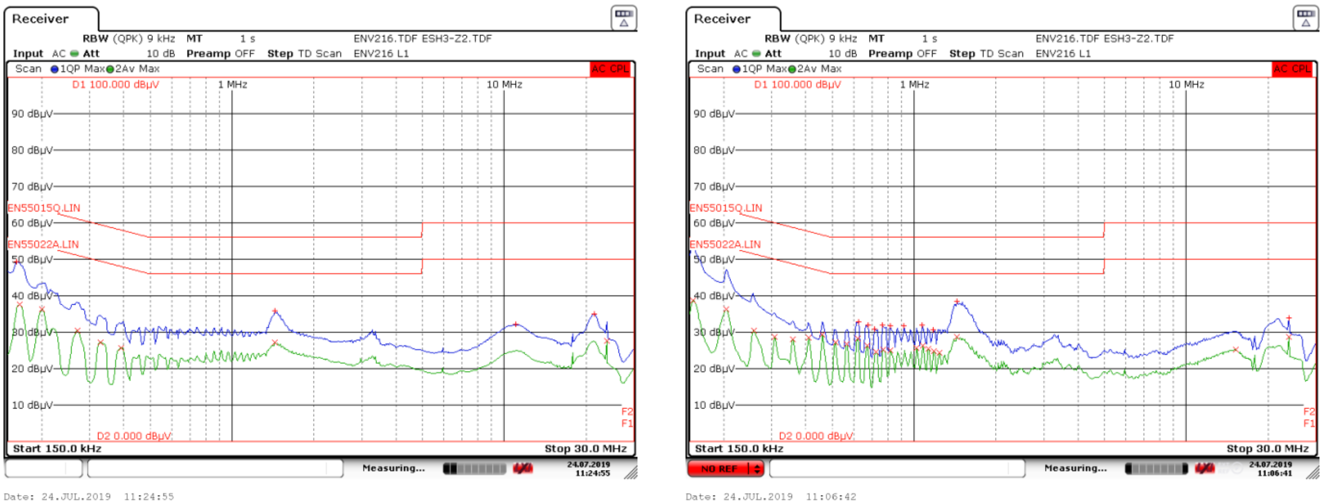
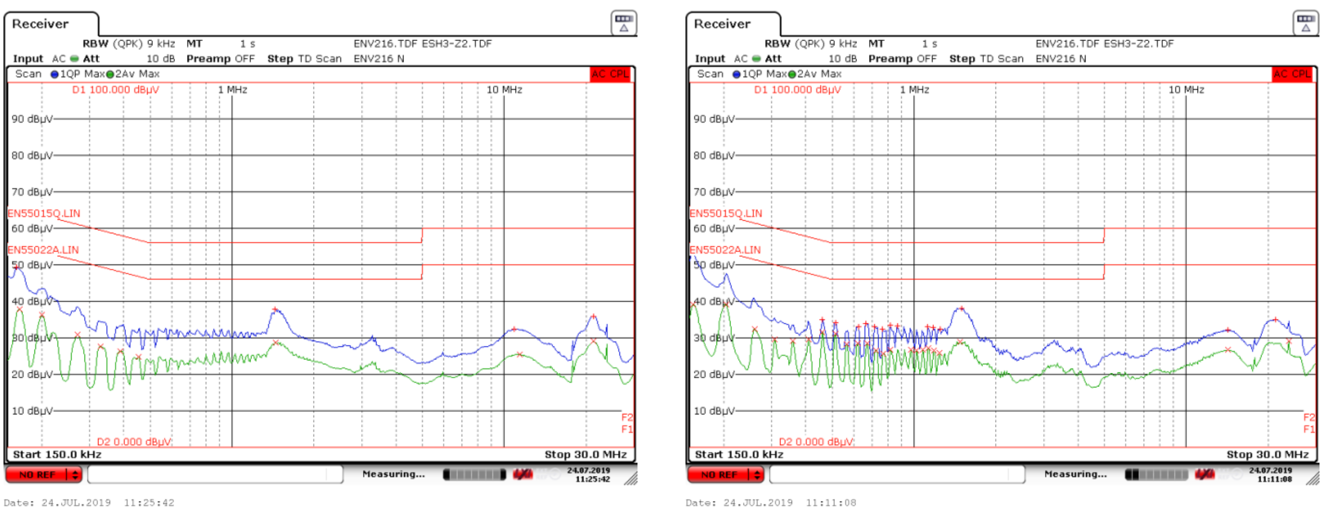
17.1.2 Output: 9 V / 5 A



115 VAC. 230 VAC.

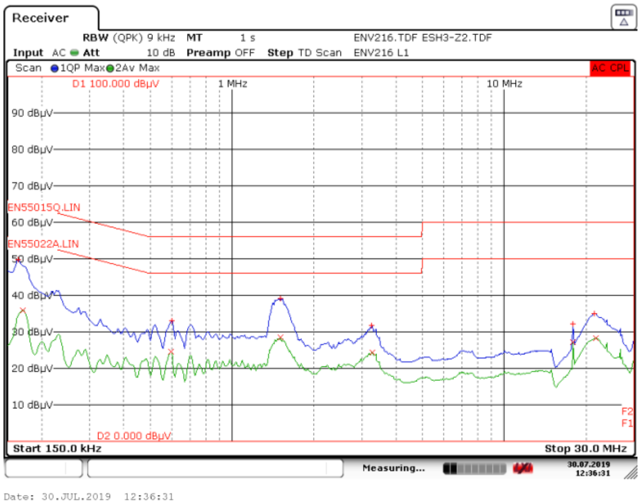
Figure 148 – Floating Ground EMI, 9 V / 5 A Load [Line Scan].



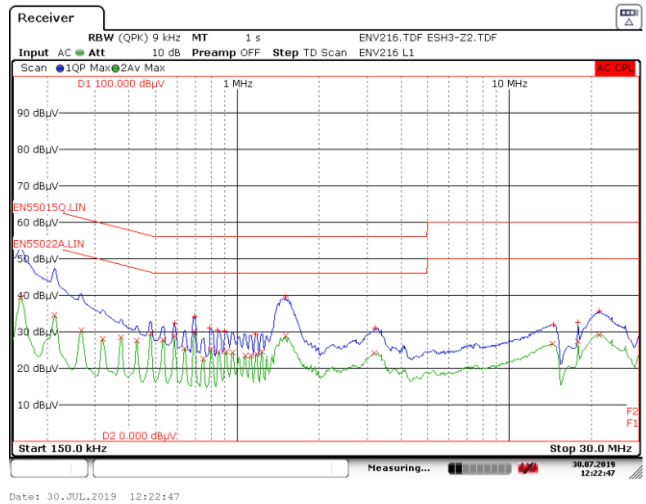
115 VAC. 230 VAC.

Figure 149 – Floating Ground EMI, 9 V / 5 A Load [Neutral Scan].

17.1.3 Output: 15 V / 3 A

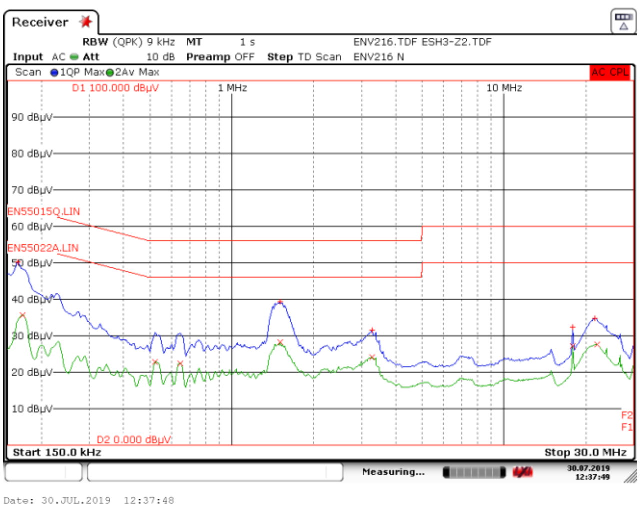


115 VAC.

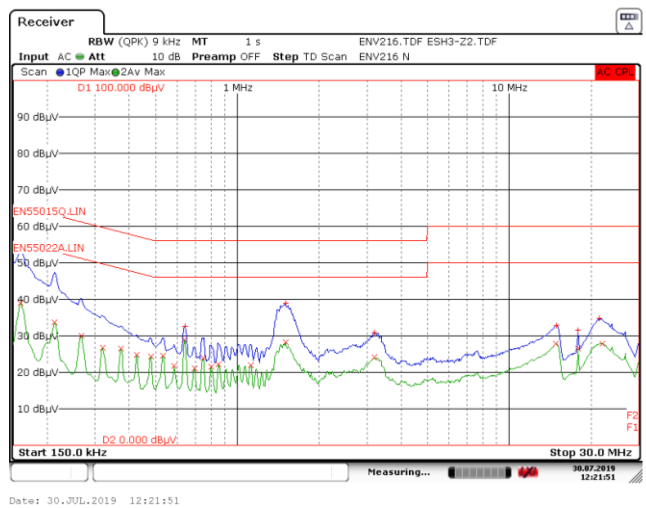


230 VAC.

Figure 150 – Floating Ground EMI, 15 V / 3 A Load [Line Scan].



115 VAC.



230 VAC.

Figure 151 – Floating Ground EMI, 15 V / 3 A Load [Neutral Scan].

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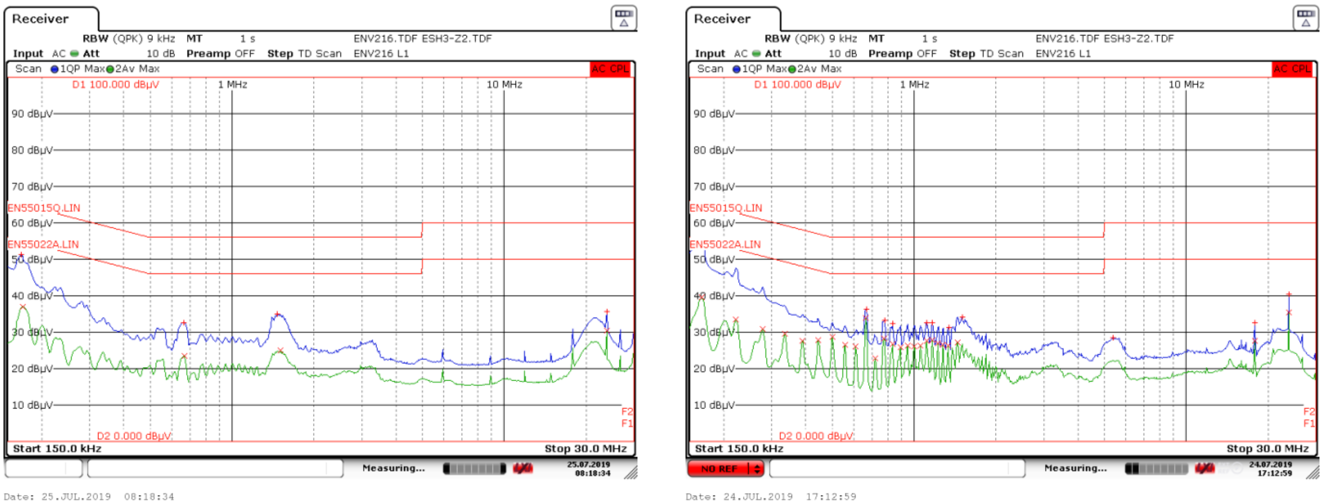
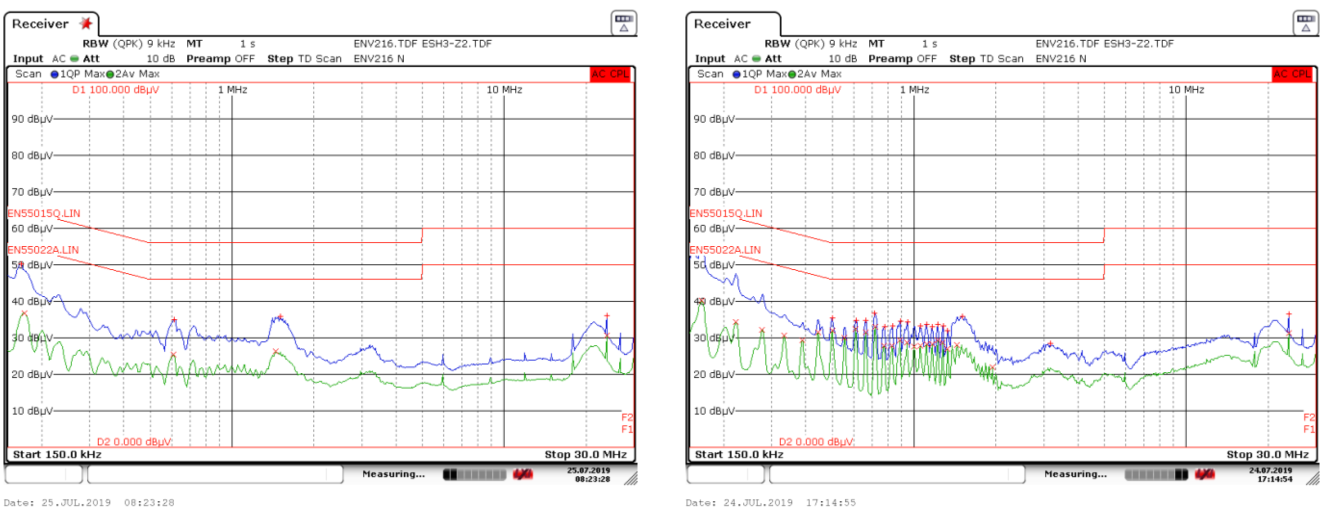
17.1.4 Output: 20 V / 2.25 A



115 VAC. 230 VAC.

Figure 152 – Floating Ground EMI, 20 V / 2.25 A Load [Line Scan].

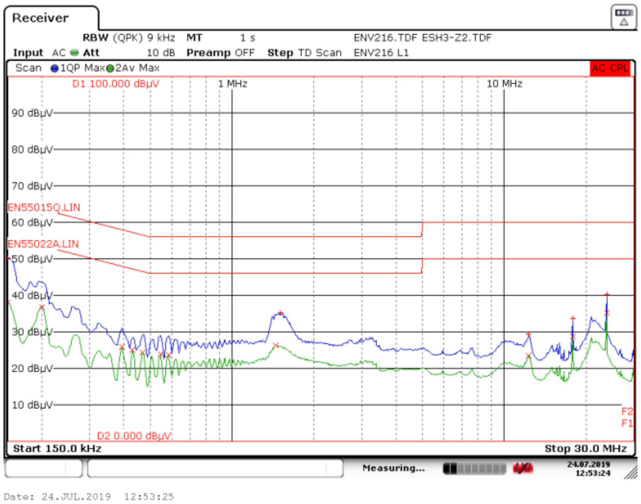


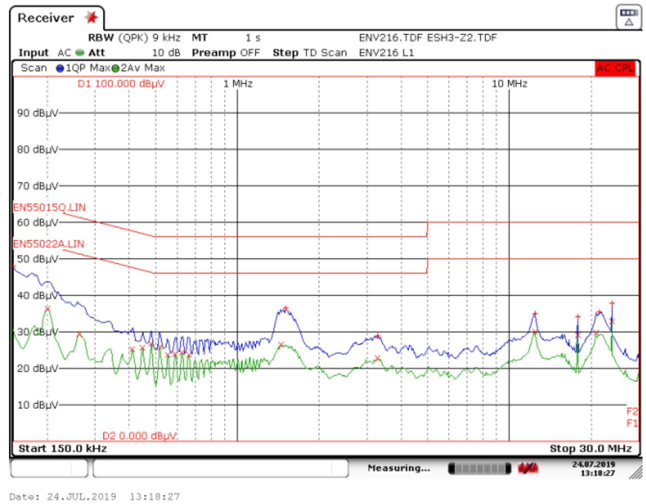
115 VAC. 230 VAC.

Figure 153 – Floating Ground EMI, 20 V / 2.25 A Load [Neutral Scan].

17.2 ***Artificial Hand (QPK / AV)***

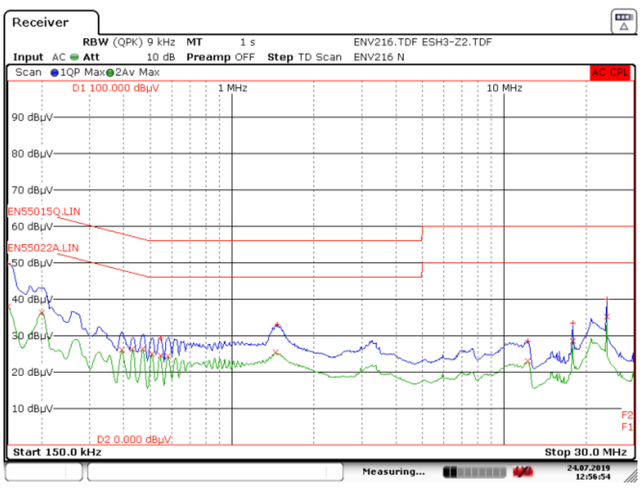
17.2.1 Output: 5 V / 5 A

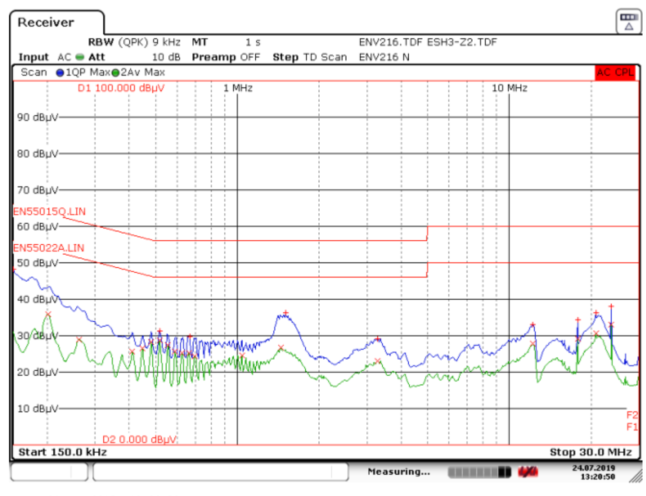




115 VAC. 230 VAC.

Figure 154 – Artificial Hand EMI, 5 V / 5 A Load [Line Scan].





115 VAC. 230 VAC.

Figure 155 – Artificial Hand EMI, 5 V / 5 A Load [Neutral Scan].

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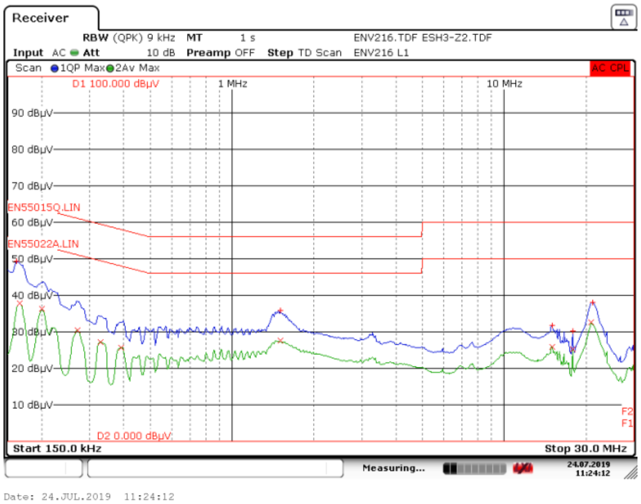
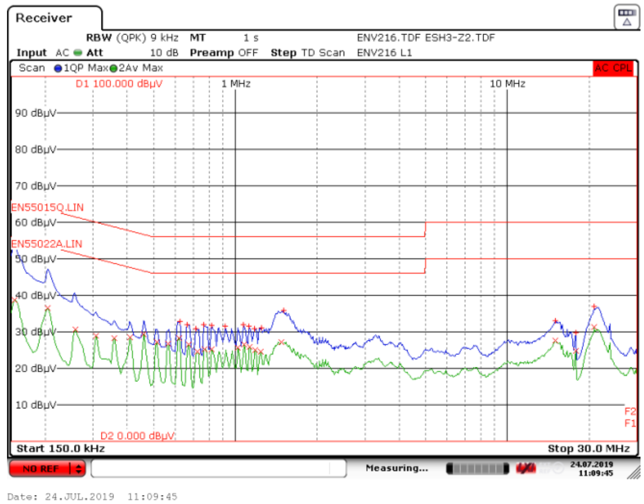
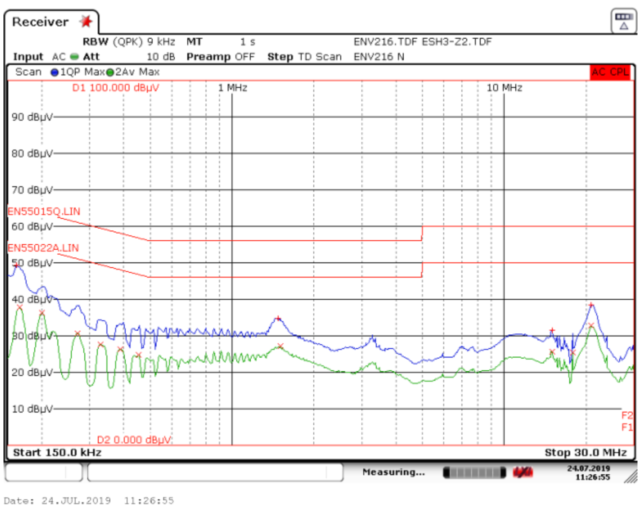
17.2.2 Output: 9 V / 5 A

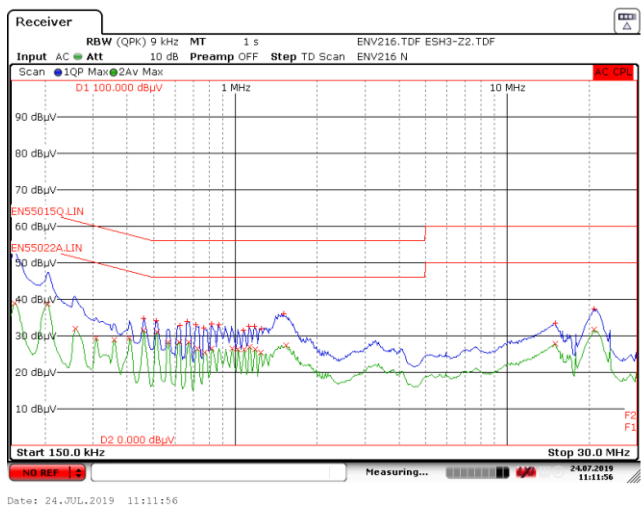




115 VAC. 230 VAC.

Figure 156 – Artificial Hand EMI, 9 V / 5 A Load [Line Scan].

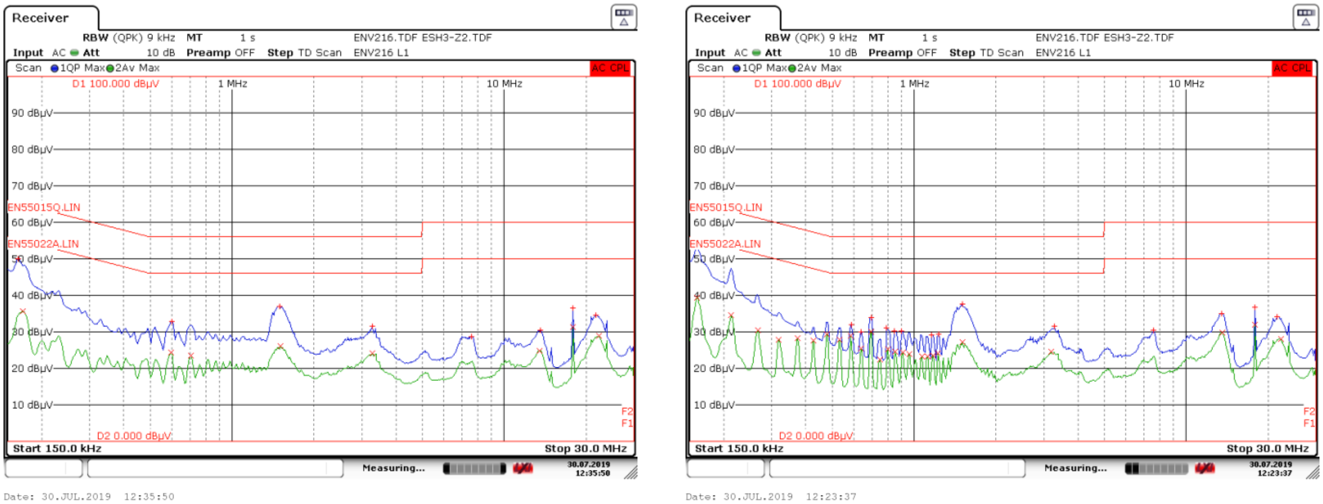




115 VAC. 230 VAC.

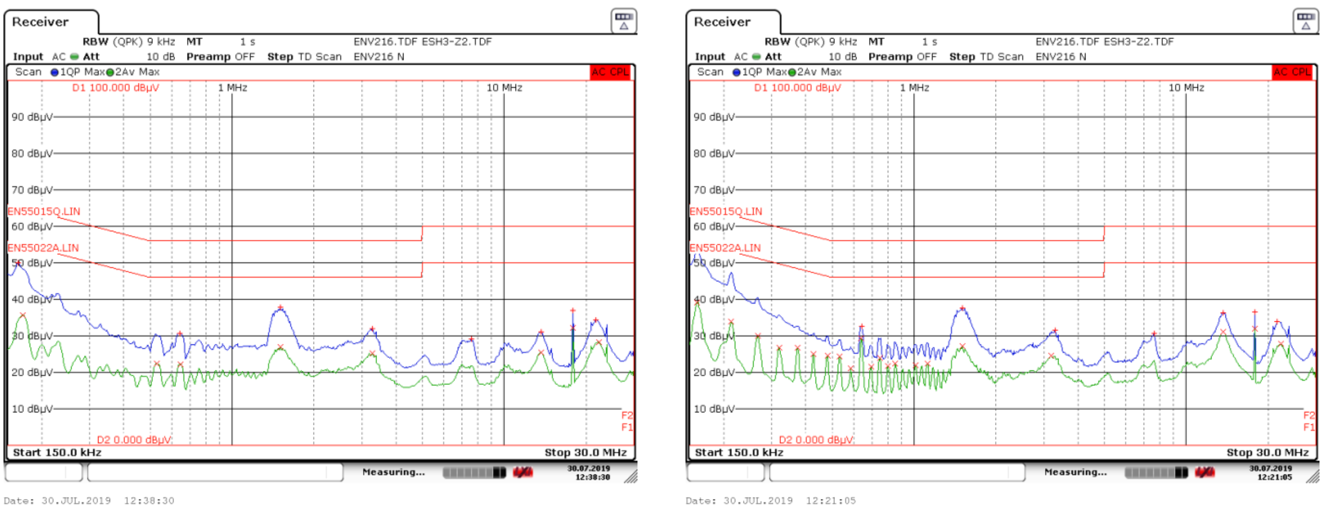
Figure 157 – Artificial Hand EMI, 9 V / 5 A Load [Neutral Scan].

17.2.3 Output: 15 V / 3 A



115 VAC. 230 VAC.

Figure 158 – Artificial Hand EMI, 15 V / 3 A Load [Line Scan].



115 VAC. 230 VAC.

Figure 159 – Artificial Hand EMI, 15 V / 3 A Load [Neutral Scan].

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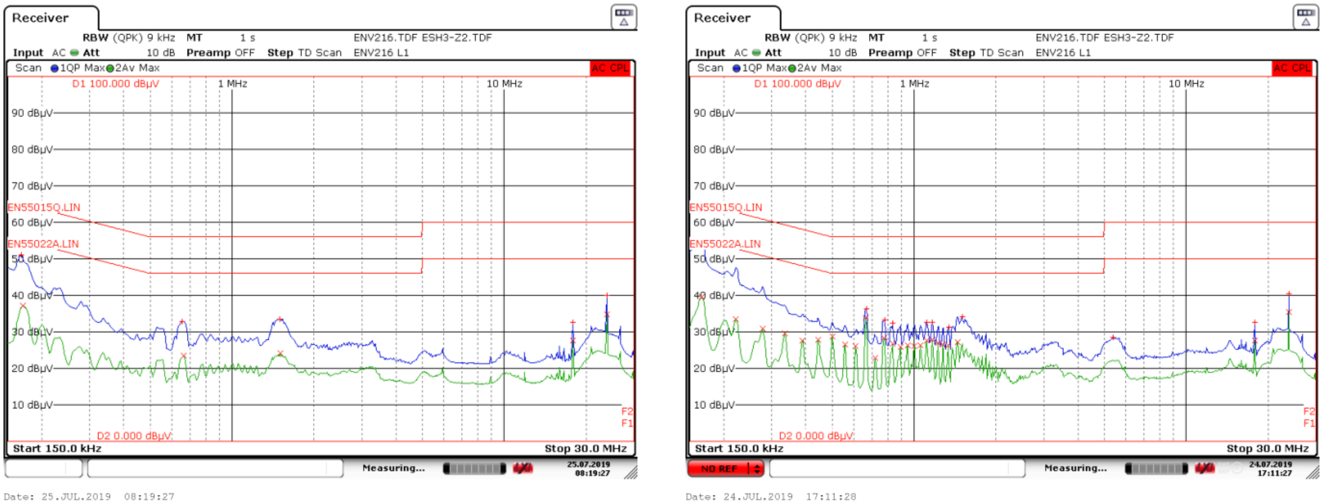
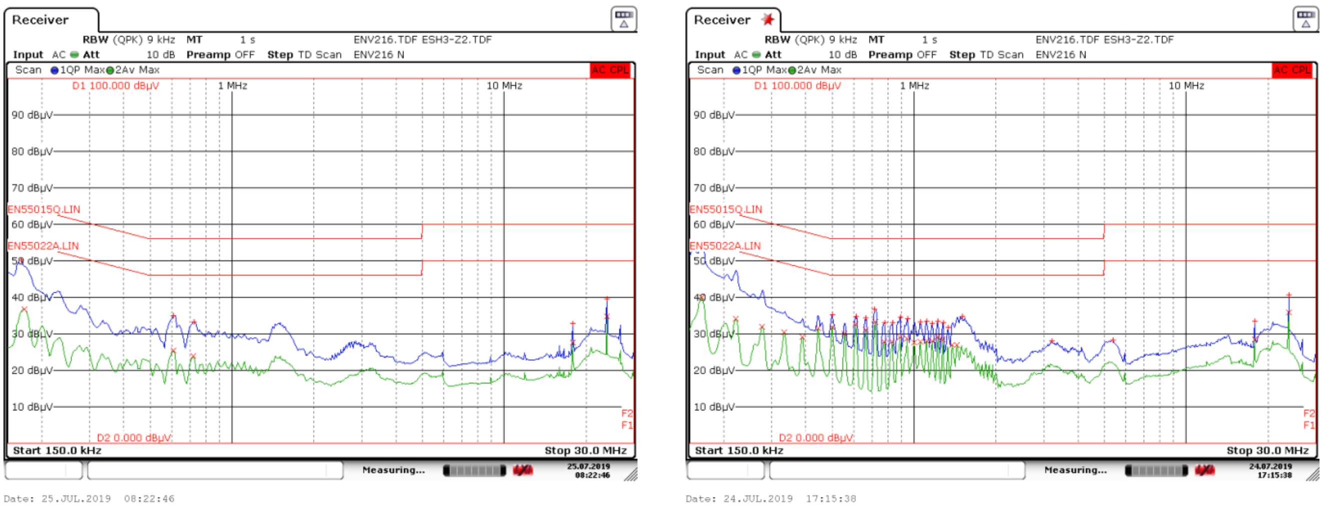
17.2.4 Output: 20 V / 2.25 A



115 VAC. 230 VAC.

Figure 160 – Artificial Hand EMI, 20 V / 2.25 A Load [Line Scan].

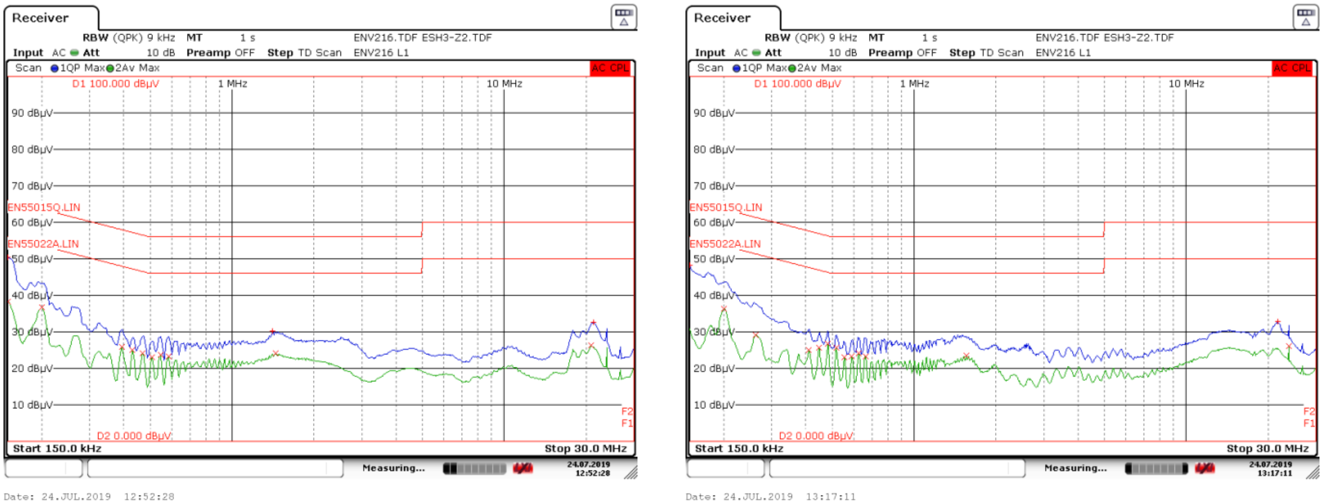


115 VAC. 230 VAC.

Figure 161 – Artificial Hand EMI, 20 V / 2.25 A Load [Neutral Scan].

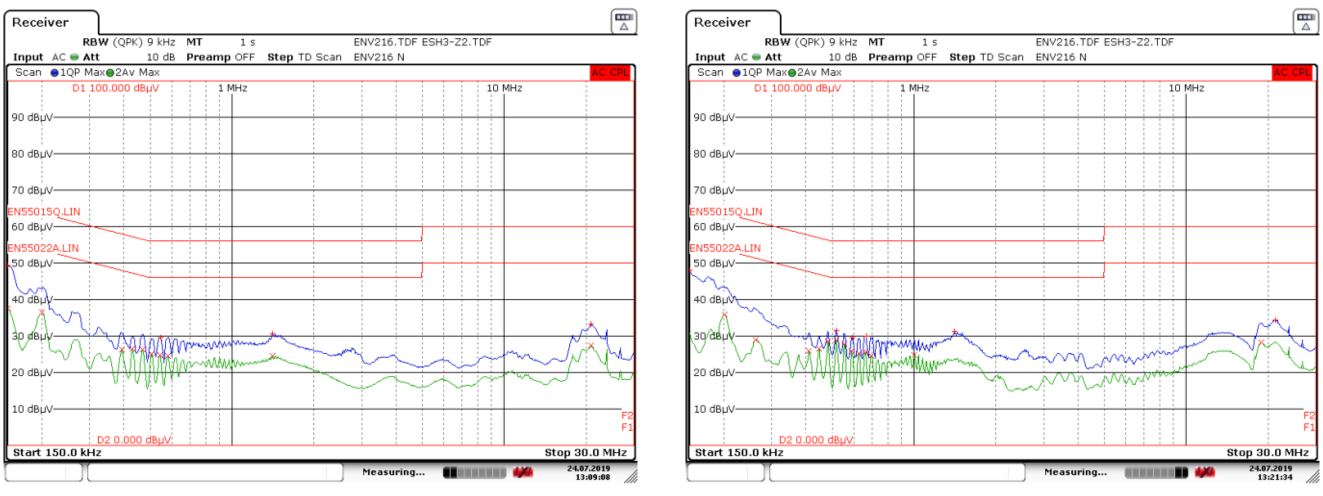
17.3 ***Earthed Output (QPK / AV)***

17.3.1 Output: 5 V / 5 A



115 VAC. 230 VAC.

Figure 162 – Floating Ground EMI, 5 V / 5 A Load [Line Scan].



115 VAC. 230 VAC.

Figure 163 – Floating Ground EMI, 5 V / 5 A Load [Neutral Scan].

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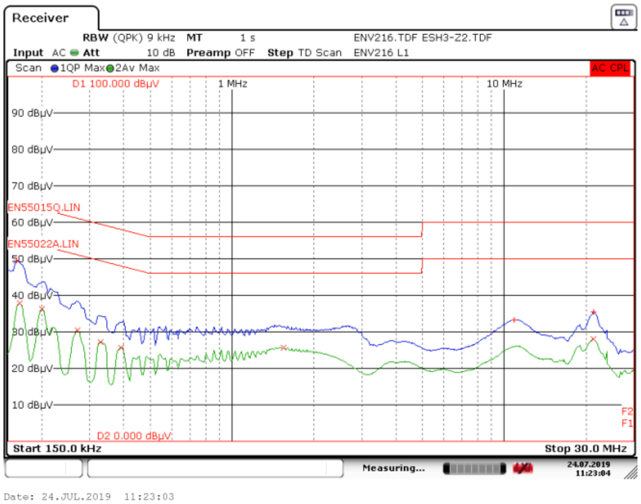
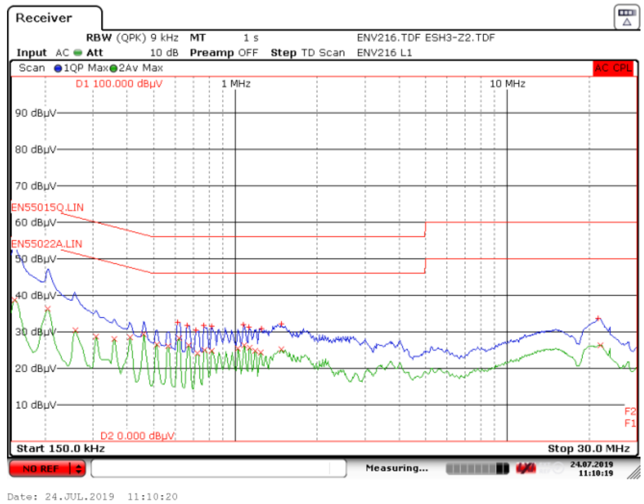
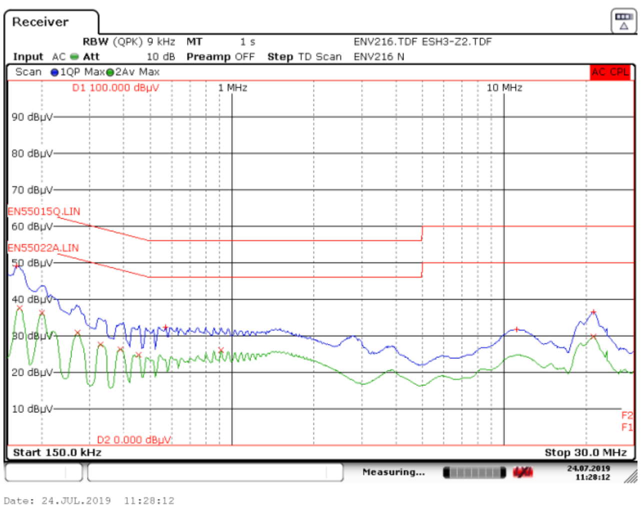
17.3.2 Output: 9 V / 5 A

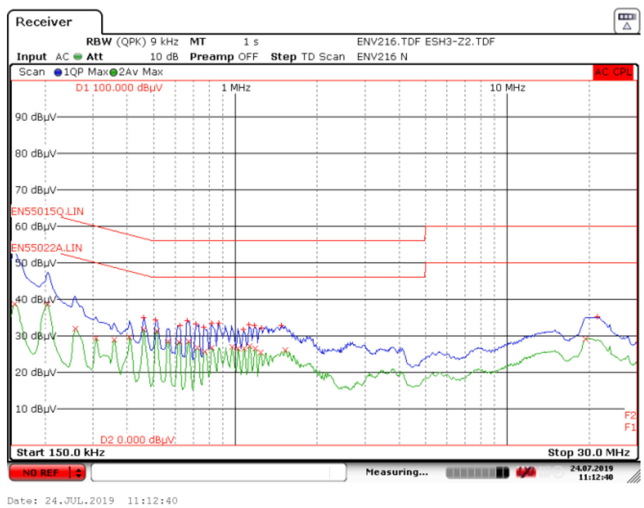




115 VAC. 230 VAC.

Figure 164 – Floating Ground EMI, 9 V / 5 A Load [Line Scan].

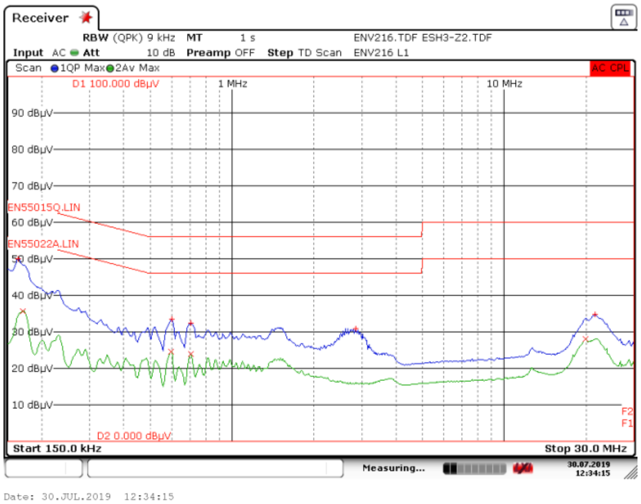




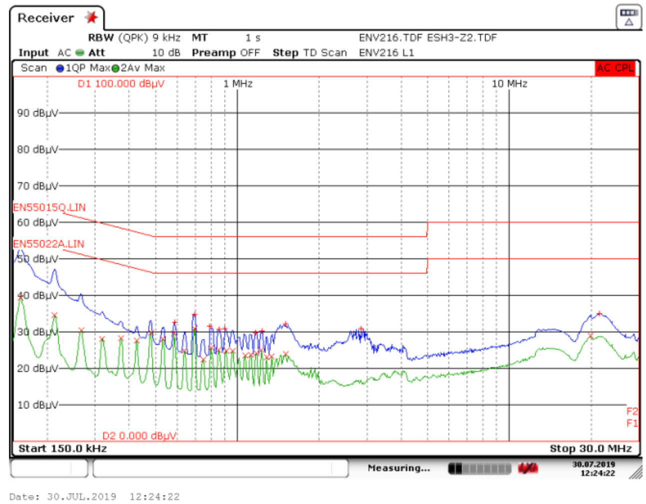
115 VAC. 230 VAC.

Figure 165 – Floating Ground EMI, 9 V / 5 A Load [Neutral Scan].

17.3.3 Output: 15 V / 3 A

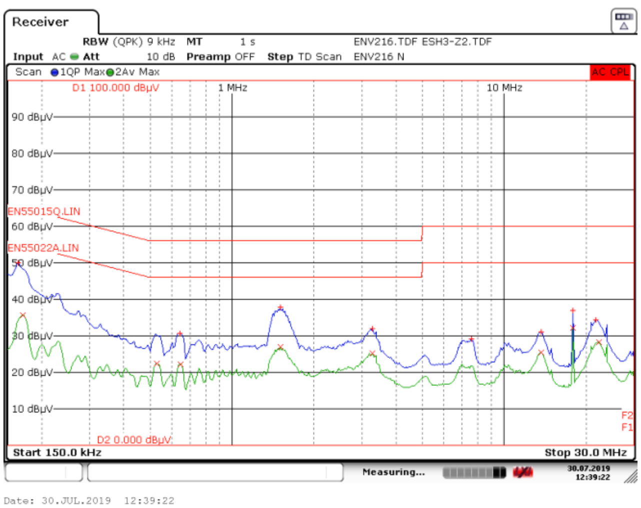


115 VAC.

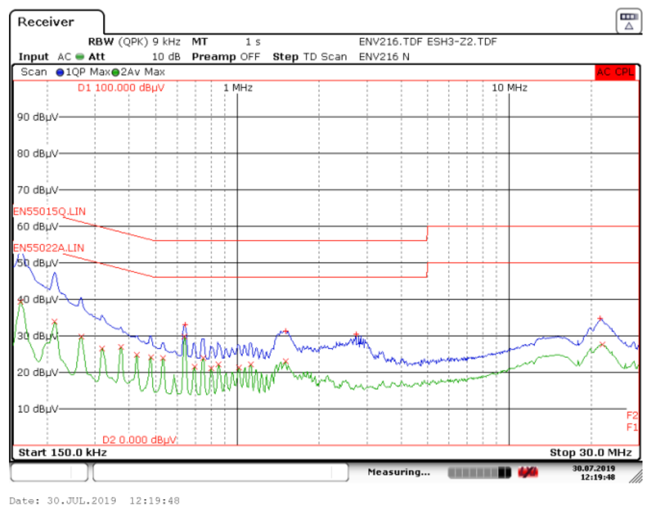


230 VAC.

Figure 166 – Floating Ground EMI, 15 V / 3 A Load [Line Scan].



115 VAC.



230 VAC.

Figure 167 – Floating Ground EMI, 15 V / 3 A Load [Neutral Scan].

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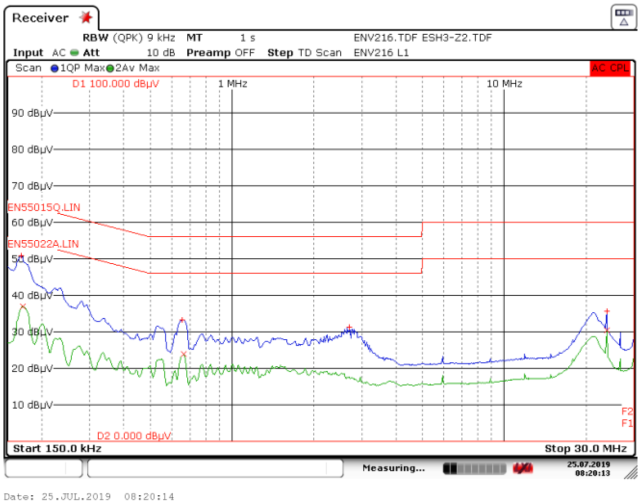
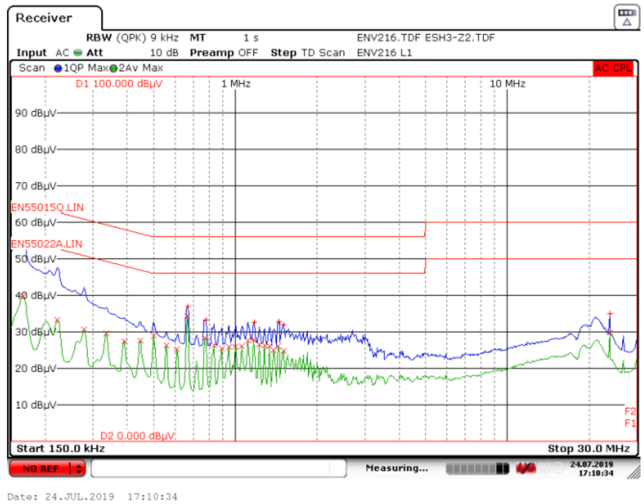
17.3.4 Output: 20 V / 2.25 A

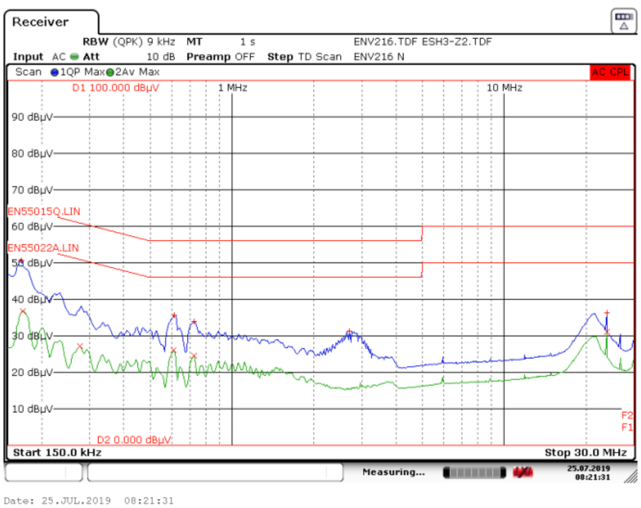


115 VAC.

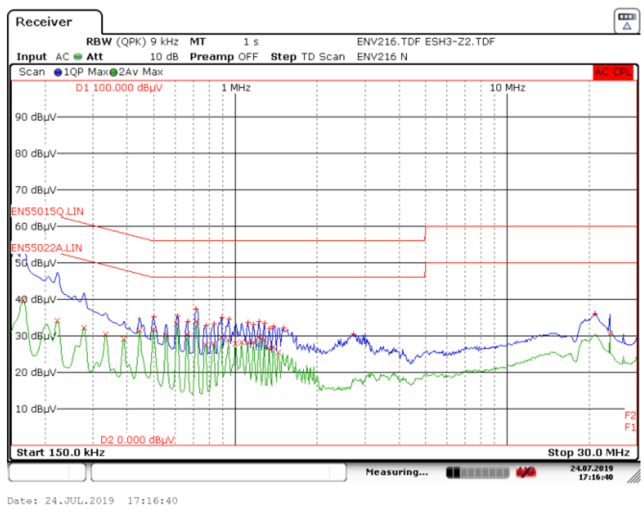


230 VAC.

Figure 168 – Floating Ground EMI, 20 V / 2.25 A Load [Line Scan].



115 VAC.



230 VAC.

Figure 169 – Floating Ground EMI, 20 V / 2.25 A Load [Neutral Scan].

18 Combination Wave Surge

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

A test failure was defined as an output latch-off that needs operator intervention to recover, or a complete loss of function that is not recoverable.

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

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 5 V / 5 A	Test Result 9 V / 5 A	Test Result 20 V / 2.25 A
+1000	L1 to L2	0	Pass	Pass	Pass
-1000	L1 to L2	0	Pass	Pass	Pass
+1000	L1 to L2	90	Pass	Pass	Pass
-1000	L1 to L2	90	Pass	Pass	Pass
+1000	L1 to L2	180	Pass	Pass	Pass
-1000	L1 to L2	180	Pass	Pass	Pass
+1000	L1 to L2	270	Pass	Pass	Pass
-1000	L1 to L2	270	Pass	Pass	Pass

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

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 5 V / 5 A	Test Result 9 V / 5 A	Test Result 20 V / 2.25 A
+2000	L1, L2 to PE	0	Pass	Pass	Pass
-2000	L1, L2 to PE	0	Pass	Pass	Pass
+2000	L1, L2 to PE	90	Pass	Pass	Pass
-2000	L1, L2 to PE	90	Pass	Pass	Pass
+2000	L1, L2 to PE	180	Pass	Pass	Pass
-2000	L1, L2 to PE	180	Pass	Pass	Pass
+2000	L1, L2 to PE	270	Pass	Pass	Pass
-2000	L1, L2 to PE	270	Pass	Pass	Pass

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

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 5 V / 5 A	Test Result 9 V / 5 A	Test Result 20 V / 2.25 A
+2000	L1 to PE	0	Pass	Pass	Pass
-2000	L1 to PE	0	Pass	Pass	Pass
+2000	L1 to PE	90	Pass	Pass	Pass
-2000	L1 to PE	90	Pass	Pass	Pass
+2000	L1 to PE	180	Pass	Pass	Pass
-2000	L1 to PE	180	Pass	Pass	Pass
+2000	L1 to PE	270	Pass	Pass	Pass
-2000	L1 to PE	270	Pass	Pass	Pass

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

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 5 V / 5 A	Test Result 9 V / 5 A	Test Result 20 V / 2.25 A
+2000	L2 to PE	0	Pass	Pass	Pass
-2000	L2 to PE	0	Pass	Pass	Pass
+2000	L2 to PE	90	Pass	Pass	Pass
-2000	L2 to PE	90	Pass	Pass	Pass
+2000	L2 to PE	180	Pass	Pass	Pass
-2000	L2 to PE	180	Pass	Pass	Pass
+2000	L2 to PE	270	Pass	Pass	Pass
-2000	L2 to PE	270	Pass	Pass	Pass

19 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 an output latch-off that needs operator intervention to recover, or a complete loss of function that is not recoverable.

19.1 *Contact Discharge, +VOUT and GND, 230 VAC Input*

Discharge Voltage (kV)	ESD Strike Location		Test Result 5 V / 5 A	Test Result 9 V / 5 A	Test Result 20 V / 2.25 A
+8.8	End of Cable	+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-8.8		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+8.8	On the Board	+VOUT	Pass[1]	Pass[1]	Pass[1]
		GND	Pass	Pass	Pass
-8.8		+VOUT	Pass[1]	Pass[1]	Pass[1]
		GND	Pass	Pass	Pass

[1]Power supply might initiate Auto-Restart

19.2 *Contact Discharge, CC1 and CC2, 230 VAC Input*

Discharge Voltage (kV)	ESD Strike Location		Test Result 5 V / 0 A
+8.8	End of Cable	CC1	Pass
-8.8		CC2	Pass
+8.8	On the Board	CC1	Pass
-8.8		CC2	Pass

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19.3 *Air Discharge, +VOUT and GND, 230 VAC Input*

Discharge Voltage (kV)	ESD Strike Location (End of Type-C Cable)		Test Result 5 V / 5 A	Test Result 9 V / 5 A	Test Result 20 V / 2.25 A
+8	End of Cable	+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-8		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+10		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-10		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+12		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-12		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+14		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-14		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+16.5		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-16.5		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+8	On the Board	+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-8		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+10 kV		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-10		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+12		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-12		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+14		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-14		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
+16.5		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass
-16.5		+VOUT	Pass	Pass	Pass
		GND	Pass	Pass	Pass

19.4 *Air Discharge, CC1 and CC2, 230 VAC Input*

Discharge Voltage (kV)	ESD Strike Location		Test Result 5 V / 0 A
+8	End of Cable	CC1	Pass
		CC2	Pass
-8		CC1	Pass
		CC2	Pass
+10		CC1	Pass
		CC2	Pass
-10		CC1	Pass
		CC2	Pass
+12		CC1	Pass
		CC2	Pass
-12		CC1	Pass
		CC2	Pass
+14		CC1	Pass
		CC2	Pass
-14		CC1	Pass
		CC2	Pass
+16.5		CC1	Pass
		CC2	Pass
-16.5		CC1	Pass
		CC2	Pass
+8	On the Board	CC1	Pass
		CC2	Pass
-8		CC1	Pass
		CC2	Pass
+10		CC1	Pass
		CC2	Pass
-10		CC1	Pass
		CC2	Pass
+12		CC1	Pass
		CC2	Pass
-12		CC1	Pass
		CC2	Pass
+14		CC1	Pass
		CC2	Pass
-14		CC1	Pass
		CC2	Pass
+16.5 kV		CC1	Pass
		CC2	Pass
-16.5 kV		CC1	Pass
		CC2	Pass

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20 Revision History

Date	Author	Revision	Description & Changes	Reviewed
30-Oct-19	DB	1.0	Initial Release.	Apps & Mktg

For the latest updates, visit our website: www.power.com

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