
Design Example Report

Title	<i>60 W USB PD Type C Power Supply Using InnoSwitch™ 3-CP GaN-based INN3279C-H215</i>
Specification	90 VAC – 265 VAC Input; 5 V / 3 A; 9 V / 3 A; 15 V / 3 A and 20 V / 3 A Outputs
Application	Mobile Phone / Tablet / Laptop Adapter
Author	Applications Engineering Department
Document Number	DER-601
Date	July 24, 2019
Revision	1.0

Summary and Features

- InnoSwitch-3 is industry first AC/DC IC with isolated, safety rated integrated feedback
- All the benefits of secondary-side control with the simplicity of primary-side regulation
 - Insensitive to transformer variation
 - Built in synchronous rectification for high efficiency
- Meets DOE6 and CoC Tier 2 V5 2016
- <40 mW no-load input power with estimated 10 mW consumption by Weltrend WT6615F USB PD controller
- Primary sensed overvoltage protection
- Very high power density using GaN switch
 - 17.4 W / inch³ with enclosure
 - 11W / inch³ without enclosure
- Very low component count
 - Power stage - 45 components
 - USB PD controller stage - 38 components
- >6 db margin on conducted EMI

Power Integrations

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- Very high average efficiency
 - 5 V Output – 92.0% at 115 VAC and 91.2% at 230 VAC
 - 9 V Output – 92.7% at 115 VAC and 92.7% at 230 VAC
 - 15 V Output – 92.8% at 115 VAC and 93.3% at 230 VAC
 - 20 V Output – 92.7% at 115 VAC and 93.4% at 230 VAC

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 5 V / 3 A or 9 V / 3 A or 15 V / 3 A or 20 V / 3 A output USB Type-C and USB-PD charger using the InnoSwitch-3 and Weltrend WT6615F USB Type-C USB PD Controller. This design shows the high power density and efficiency that is possible due to the high level of integration of the InnoSwitch3-CP controller providing exceptional performance.

This document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, and performance data.



Figure 1 – Populated Circuit Board Photograph, Top.

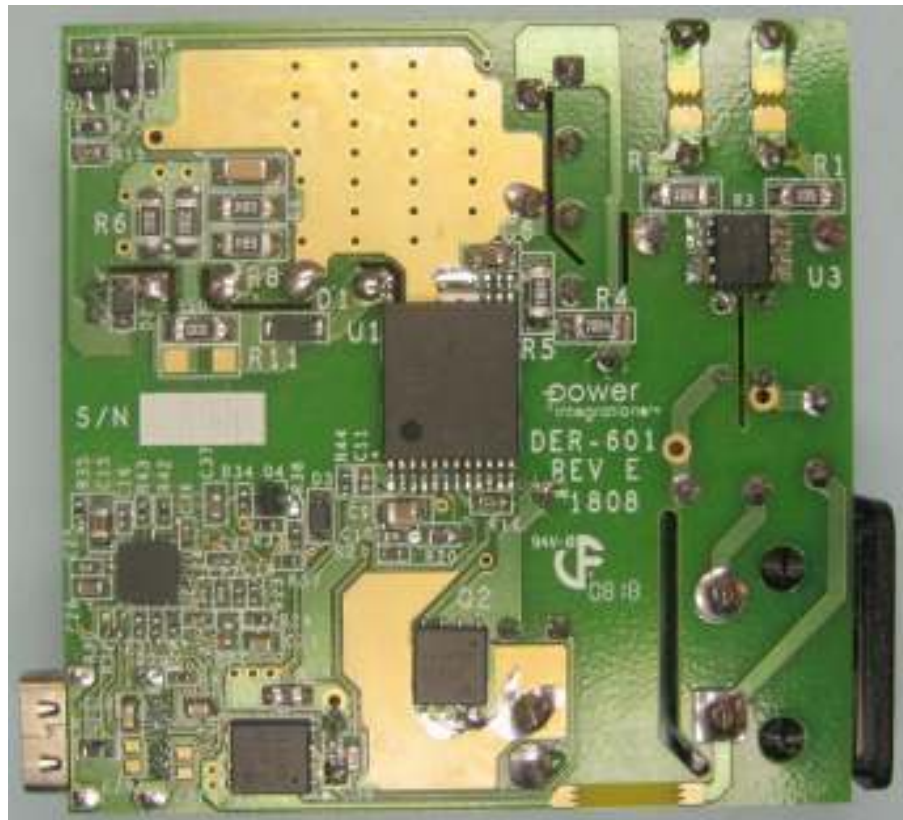


Figure 2 – Populated Circuit Board Photograph, Bottom.

2 Power Supply Specification

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

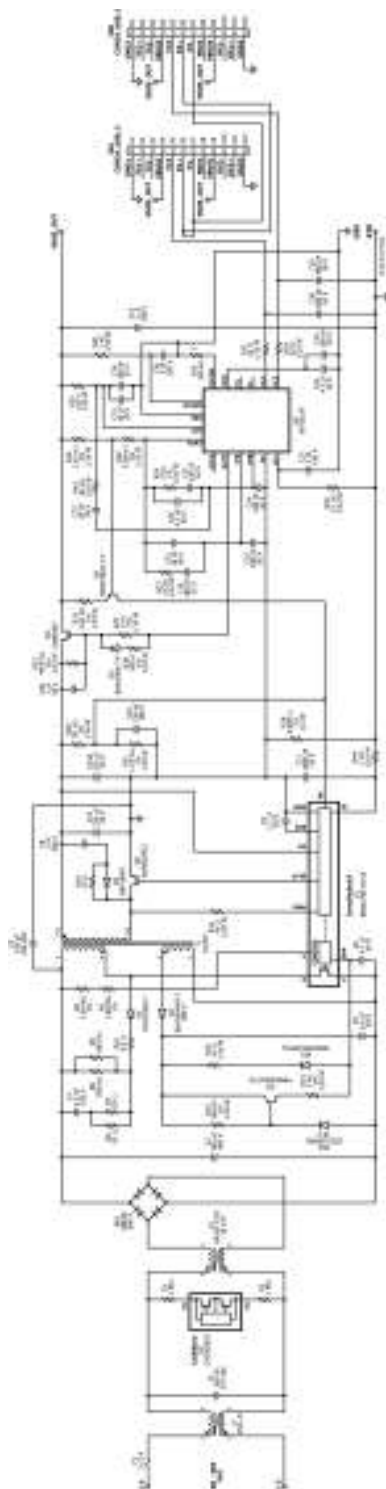
Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)			25	28.2	mW	Measured at 230 VAC.
5 V Output						
Output Voltage	V_{OUT1}		5		V	±3%
Output Ripple Voltage	$V_{RIPPLE1}$			250	mV	On Board.
Output Current	I_{OUT1}	3			A	On Board.
9 V Output						
Output Voltage	V_{OUT1}		9		V	±3%
Output Ripple Voltage	$V_{RIPPLE1}$			250	mV	On Board.
Output Current	I_{OUT1}	3			A	On Board.
15 V Output						
Output Voltage	V_{OUT1}		15		V	±3%
Output Ripple Voltage	$V_{RIPPLE1}$			250	mV	On Board.
Output Current	I_{OUT1}	3			A	On Board.
20 V Output						
Output Voltage	V_{OUT1}		20		V	±3%
Output Ripple Voltage	$V_{RIPPLE1}$			250	mV	On Board.
Output Current	I_{OUT1}	3			A	On Board.
Continuous Output Power	P_{OUT}			60	W	
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC60950 / UL1950 Class II				
Ambient Temperature	T_{AMB}	0		45	°C	Enclosed in Adapter, Sea Level.

Note: In order to upgrade this design to 65 W following changes are needed.

1. Need to redesign the transformer in order to deliver 65 W.
2. Contact Weltrend for firmware update to support 65 W on this design.
3. Check the thermal performance while the power supply is delivering 65 W output.



3 Schematic



**Do not populate R30, R32, C29 and C31*

**Place a 0603 0E jumper across R30 and R32 to short D+ and D- lines on the connector*

Figure 3 – USB PD Controller Stage Schematic.

4 Circuit Description

4.1 *Input EMI Filtering*

Fuse F1 isolates the circuit and provides protection from component failure, and the common mode choke L1 and L2 with capacitor C1 attenuation for EMI. Bridge rectifier BR1 rectifies the AC line voltage and provides a full wave rectified DC across the filter capacitor C2.

Resistors R1 and R2 along with U3 discharges capacitor C1 when the power supply is disconnected from AC mains.

4.2 **InnoSwitch-3 IC Primary**

One end of the transformer (T1) primary is connected to the rectified DC bus; the other is connected to the drain terminal of the SWITCH inside the InnoSwitch-3 IC (U1). Resistors R4 and R5 provide Input voltage sense protection for undervoltage and overvoltage conditions.

A low cost RCD clamp formed by diode D1, resistors R6, R7, R8 and R9, and capacitor C4 limits the peak drain voltage of U1 at the instant of turn off of the SWITCH inside U1. The clamp helps to dissipate the energy stored in the leakage reactance of transformer T1.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor (C7) when AC is first applied. During normal operation the primary side block is powered from an auxiliary winding on the transformer T1. Output of the auxiliary (or bias) winding is rectified using diode D2 and filtered using capacitor C5. Resistor R14 limits the current being supplied to the BPP pin of the InnoSwitch-3 IC (U1). A linear regulator comprising of resistor R13, BJT Q1 and Zener diode VR2 prevent any change in current through R14.

Zener diode VR1 along with R15 offers primary sensed output over voltage protection. In a flyback converter, output of the auxiliary winding tracks the output voltage of the converter. In case of over voltage at output of the converter, the auxiliary winding voltage increases and causes breakdown of VR1 which then causes a current to flow into the BPP pin of InnoSwitch3-CP IC U1. If the current flowing into the BPP pin increases above the I_{SD} threshold, the InnoSwitch3-CP controller will latch off and prevent any further increase in output voltage.

4.3 **InnoSwitch3-CP IC Secondary**

The secondary-side of the InnoSwitch3-CP IC provides output voltage, output current sensing and drive to a MOSFET providing synchronous rectification. The secondary of the transformer is rectified by MOSFET Q2 and filtered by capacitors C12 and C13A. High frequency ringing during switching transients that would otherwise create radiated EMI is

reduced via a RCD snubber R19, C8 and D4. Diode D4 was used to minimize the dissipation in resistor R19.

The gate of Q2 is turned on by secondary side controller inside IC U1, based on the winding voltage sensed via resistor R16 and fed into the FWD pin of the IC.

In continuous conduction mode of operation, the MOSFET is turned off just prior to the secondary side commanding a new switching cycle from the primary. In discontinuous mode of operation, the power MOSFET is turned off when the voltage drop across the MOSFET falls below a threshold of approximately 3 mV. Secondary-side control of the primary-side power SWITCH avoids any possibility of cross conduction of the two SWITCHES and provides extremely reliable synchronous rectification.

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. Capacitor C9 connected to the BPS pin of InnoSwitch3-CP IC U1 provides decoupling for the internal circuitry.

During CC operation, when the output voltage falls, the device 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 decoupling capacitor C13 via resistor R16 and an internal regulator. This allows output current regulation to be maintained down to ~3.4 V. Below this level the unit enters auto-restart until the output load is reduced.

Output current is sensed by monitoring the voltage drop across resistor R18 between the IS and GND pins with a threshold of approximately 35 mV to reduce losses. RC filter R44 and C11 provides filtering on the IS pin from external noise.

Below the CC threshold, the device operates in constant voltage mode. Output voltage is regulated so as to achieve a voltage of 1.265 V on the FB pin. Capacitor C10 provides noise filtering of the signal at the FB pin.

4.4 USB Type-C and PD Interface

In this design, Weltrend WT6615F (U2) is the USB Type-C and PD controller. Output of the InnoSwitch3-CP powers the WT6615F device directly from Vbus.

Resistors R20 and R21 form the feedback divider network to sense the output voltage and provide feedback to the InnoSwitch IC. Resistor R33, R34, Q4, R42 and U2 together will inject the current into the resistor R21 to change the output voltage to required level when there is a request through CC1 and CC2 lines. The default output voltage is maintained at 5 V.

USB PD protocol is communicated over either CC1 or CC2 line depending on the orientation in which Type-C plug is connected.

P-MOSFET Q3 makes the USB Type-C receptacle cold socket when no device is attached to the charger as per the USB Type-C specification. VBUS_OUT is discharged via resistor R41 and U2.



5 PCB Layout

PCB copper thickness is 2.0 oz.

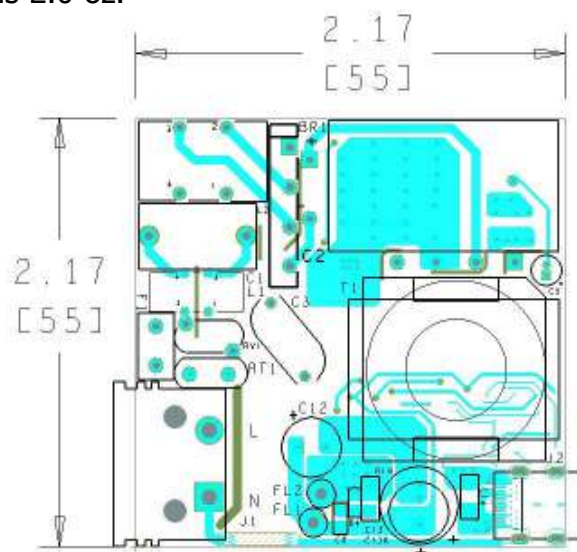


Figure 4 – Printed Circuit Layout, Top.

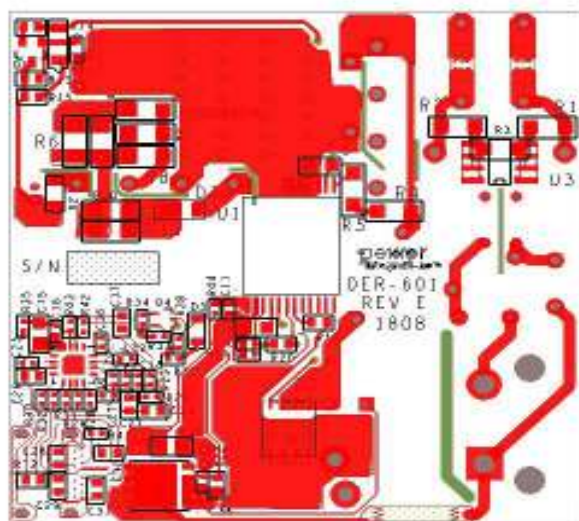


Figure 5 – Printed Circuit Layout, Bottom.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	DIODE BRIDGE 600V 4A GB	GBL06	Genesic Semi
2	1	C1	330 nF, $\pm 10\%$, 275 VAC, Polypropylene Film, X2, 15.00 mm x 8.50 mm	890324024003CS	Wurth
3	1	C10	330 pF, $\pm 10\%$, 100 V, Ceramic, X7R, 0402	C0402C331K4RACTU	Kemet
4	1	C11	1000 pF, $\pm 10\%$, 50 V, X7R, $-55^{\circ}\text{C} \sim 125^{\circ}\text{C}$, Low ESL, 0402	C0402C102K5RACTU	Kemet
5	2	C12 C13A	330 μF , $\pm 20\%$, 25 V, Al Organic Polymer, Gen. Purpose, Can, 18 m Ω , 2000 Hrs @ 105°C , (8 mm x 13 mm)	A750KS337M1EAAE018	KEMET
6	1	C2	100 μF , 400 V, Electrolytic, Low ESR, (16 x 30)	EPAG401ELL101ML30S	Nippon Chemi-Con
7	1	C3	470 pF, Ceramic, Y1	DE1B3KX471KN4A	Murata
8	1	C4	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
9	1	C5	6.8 μF , $\pm 20\%$, 63 V, Electrolytic, Gen Purpose, (4 mm x 11 mm)	UPW1J6R8MDD6	Nichicon
10	1	C6	4.7 μF , $\pm 10\%$, 25 V, Ceramic, X7R, $-55^{\circ}\text{C} \sim 125^{\circ}\text{C}$, 0805	TMK212AB7475KG-T	Taiyo Yuden
11	1	C8	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
12	1	C9	2.2 μF , 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
13	1	C14	1 μF , 100 V, Ceramic, X7R, 1206	C3216X7R2A105K	TDK
14	1	C15	10 μF , 35 V, Ceramic, X5R, 0805	C2012X5R1V106K085AC	TDK
15	2	C16 C18	100 nF, 25 V, Ceramic, Y5V, 0402	CL05A104KA5NNNC	Samsung
16	1	C21	330 nF, $\pm 10\%$, 16 V, Ceramic, X7R, 0603	CC0603KRX7R7BB334	Yageo
17	2	C22 C24	100 pF, $\pm 10\%$, 50 V, Ceramic Capacitor X7R, 0402	04025C101KAT2A	AVX
18	1	C25	100 nF 16 V, Ceramic, X7R, 0402	L05B104KO5NNNC	Samsung
19	1	C26	4.7 μF , 10 V, Ceramic, X5R, 0603	C1608X5R1A475M/0.50	TDK
20	2	C27 C36	1 nF 100 V, Ceramic, X7R, 0402	GCM155R72A102KA37D	Murata
21	2	C28 C30	560 pF, 50 V, Ceramic, X7R, 0603, 0.063" L x 0.031" W (1.60 mm x 0.80 mm)	CL10B561KB8NNNC	Samsung
22	1	C32	10 nF 50 V, Ceramic, X7R, 0402	CL05B103KB5NNNC	Samsung
23	1	C33	4.7 nF 50 V, Ceramic, X7R, 0603	CL10B472KB8NNNC	Samsung
24	1	C37	33 nF 50 V, Ceramic, X7R, 0603	06035C333JAT2A	AVX
25	1	C38	1 μF 35 V, Ceramic, X7R, 0603	C1608X7R1V105M	TDK
26	1	D1	800 V, 1 A, Rectifier, POWERDI123	DFLR1800-7	Diodes, Inc.
27	1	D2	DIODE, GEN PURP, FAST RECOVERY, 300 V, 225 mA, SOD323	BAV3004WS-7	Diodes, Inc.
28	1	D3	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
29	1	D4	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
30	1	F1	3.15 A, 250 V, Slow, RST	507-1181	Belfuse
31	1	J1	Power Entry Connector Receptacle, Male Pins, IEC 320-C8, Non-Polarized, Panel Mount, Snap-In; Through Hole, Right Angle	RAPC322X	Switchcraft
32	1	J2	Connector, "Certified", USB - C, USB 3.1, For 0.031" PCB Material!, Superspeed+, Receptacle Connector, 24 Position, SMT, Right Angle, TH	632723100011	Wurth
33	1	L1	250 μH , Toroidal Common Mode Choke		Power Integrations
34	1	L2	CMC, 18 mH @ 10 kHz, Toroidal, 17.5 mm OD x 11.0 mm thick. 40 turns x 2, 0.40 mm wire 190 m Ω max	04291-T231	Sumida
35	1	Q1	NPN, Small Signal BJT, 80 V, 0.5 A, SOT-23	MMBTA06LT1G	On Semi
36	1	Q2	MOSFET, N-CH, 120 V, 85 A (at VGS=10V), Trench Power AlphaSGT 120 V TM technology, DFN5X6	AONS62922	Alpha & Omega Semi.
37	1	Q3	MOSFET, P-Channel, 30 V, 32 A (Ta), 85 A (Tc), 7.3 W (Ta), 83 W (Tc), 8-DFN (5x6), 8DFN	AON6407	Alpha & Omega Semi
38	1	Q4	PNP, Small Signal BJT, 40 V, 0.6 A, SC70-3, SOT-323	MMST4403-7-F	Diodes, Inc.



39	2	R1 R2	RES, 1 M Ω , 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
40	1	R4	RES, 2.00 M Ω , 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
41	1	R5	RES, 1.80 M Ω , 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1804V	Panasonic
42	2	R6 R7	RES, 20 Ω , 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ200V	Panasonic
43	2	R8 R9	RES, 680 k Ω , 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ684V	Panasonic
44	1	R10	RES, 0 Ω , 5%, 1/4 W, Thick Film, 1206	ERJ-8GEY0R00V	Panasonic
45	1	R13	RES, 100 k Ω , 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
46	1	R14	RES, 3 k Ω , 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ302V	Panasonic
47	2	R15 R16	RES, 47 Ω , 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470V	Panasonic
48	1	R18	RES, 0.005 Ω , $\pm 1\%$, 0.5W, 1/2W, 0805 (2012 Metric), Current Sense, Thick Film, ± 300 ppm/ $^{\circ}$ C, -55 $^{\circ}$ C ~ 155 $^{\circ}$ C	ERJ-6LWFR005V	Panasonic
49	1	R19	RES, 10 Ω , 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ100V	Panasonic
50	1	R20	RES, 191 k Ω , 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1913V	Panasonic
51	1	R21	RES, 11.5 k Ω , 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1152X	Panasonic
52	1	R22	RES, 49.9 k Ω , 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF4992X	Panasonic
53	1	R23	RES, 15 k Ω , 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ153X	Panasonic
54	2	R24 R37	RES, 1.00 k Ω , 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1001X	Panasonic
55	1	R28	RES, 5.1 k Ω , 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ512X	Panasonic
56	2	R29 R31	RES, 22 Ω , 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ220X	Panasonic
57	2	R33 R34	RES, 3.01 k Ω , 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF3011X	Panasonic
58	1	R35	RES, 0 Ω , 1/16 W, Thick Film, 0402	CRCW04020000Z0ED	Panasonic
59	1	R38	RES, 100 Ω , 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1000X	Panasonic
60	2	R41 R44	RES, 1 k Ω , 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ102X	Panasonic
61	1	R42	RES, 9.09 k Ω , 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF9091X	Panasonic
62	1	R43	RES, 30 k Ω , 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ303X	Panasonic
63	1	RT2	NTC Thermistor, 100 k Ω , 3%, 0603	NCP18WF104E03RB	Murata
64	1	T1	Bobbin, EQ2506, 4 pins, 4pri, 0sec	EQ-2506	Shen Zhen Xin Yu Jia Technology
65	1	U1	InnoSwitch-3, INN3279C-H215		Power Integrations
66	1	U2	Custom IC, 16-QFN (4X4)	WT6615F	Weltrend
67	1	U3	CAPZero-2, SO-8C	CAP200DG	Power Integrations
68	1	VR1	DIODE ZENER 47 V 500 mW SOD123	MMSZ5261BT1G	ON Semi
69	1	VR2	10 V, 5%, 150 mW, SSMINI-2	DZ2S100MOL	Panasonic

7 Transformer Specification

7.1 Electrical Diagram

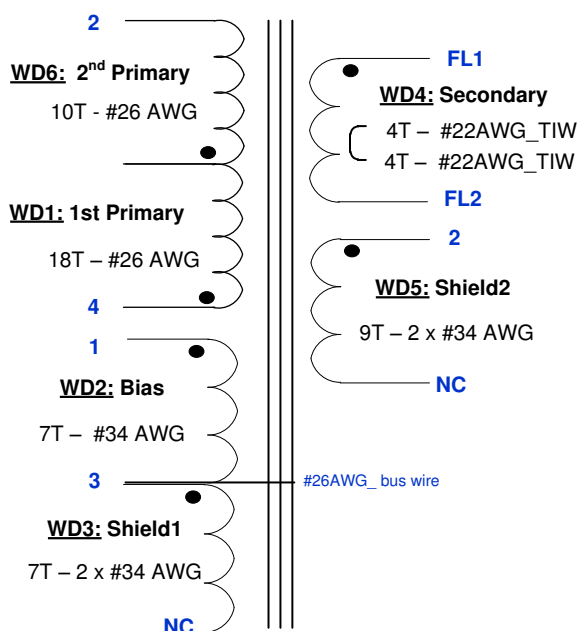


Figure 6 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Electrical Strength	60 second, 60 Hz, from Pins 1, 2, 3, 4 to FL1-FL2.	3000 VAC
Nominal Primary Inductance	Measured at 1 V pk-pk, 100 kHz switching frequency, between pin 2 and 4, with all other windings open.	469 μ H \pm 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	6.5 μ H (Max.)

7.3 Material List

Item	Description
[1]	Core: EQ27
[2]	Bobbin: EQ2506-Vertical - 4pins (4/0), PI#: 25-01095-00.
[3]	Magnet Wire: #26 AWG, Double Coated.
[4]	Magnet Wire: #34 AWG, Double Coated.
[5]	Magnet Wire: #22 AWG, Triple Insulated Wire.
[6]	Bus wire: #26AWG, Alpha Wire, Tinned Copper, 40.0 mm Length.
[7]	Tape: 3M 13450-F, Polyester Film, 1 mil Thickness, 4.2 mm Width.
[8]	Tape: 3M 13450-F, Polyester Film, 1 mil Thickness, 33 mm x 54 mm.
[9]	Varnish: Dolph BC-359.

7.4 Transformer Build Diagram

WD6: 2nd Primary 10T – #26 AWG

WD5: Shield2 9T – 2 x #34 AWG

WD4: Secondary { 4T – #22AWG_TIW
4T – #22AWG_TIW

WD3: Shield 1 7T – 2 x #34 AWG
(wound interleave with...)

WD2: Bias 7T – #34 AWG

WD1: 1st Primary 18T – #26 AWG

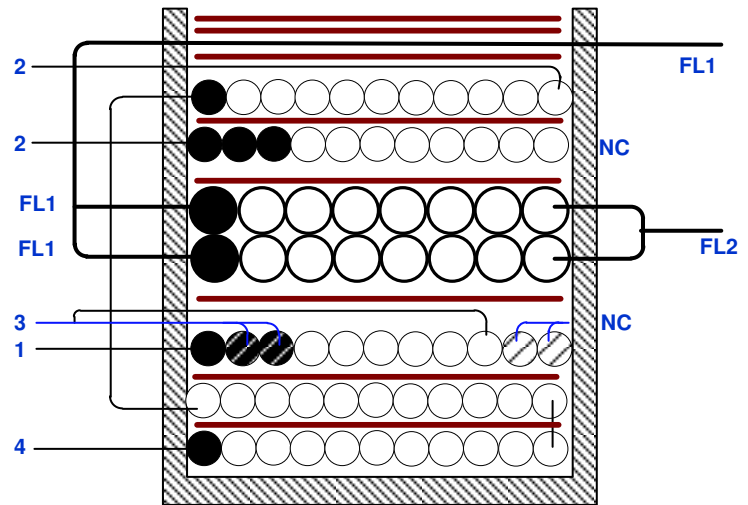




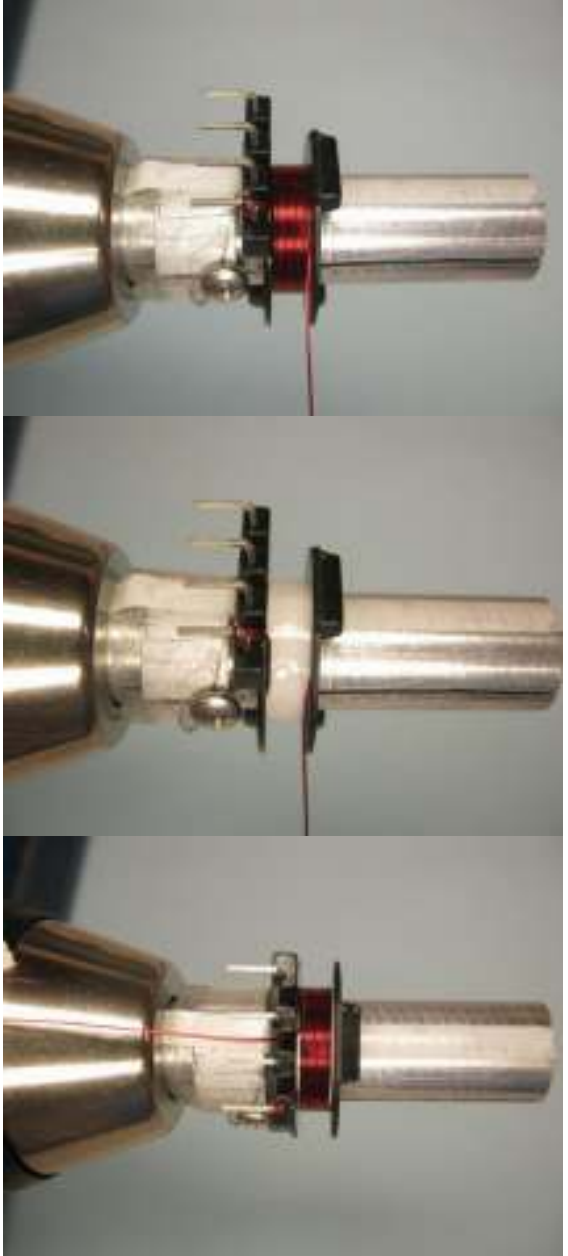

Figure 7 – Transformer Build Diagram.


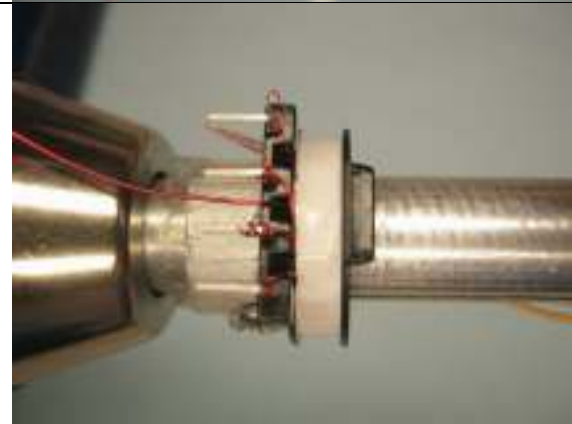
7.5 Transformer Construction

Winding Preparation	Make slots on both sides of secondary flanges, (see picture below). Position the bobbin Item [2] on the mandrel such that the pin side of the bobbin is on the left side. Winding direction is clock-wise direction.
WD1 1st Primary	Start at pin 4, wind 9 turns of wire Item [3] in 1 layer, from left to right, and place 1 layer of tape Item [7]. Continue winding another 9 turns from right to left, at the last turn exit the wire out of the bobbin leave ~ 2 ft for WD6:2 nd Primary.
Insulation	1 layer of tape Item [7].
WD2 & WD3 Bias & 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 7 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	1 layer of tape Item [7].
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 1 st halves of Secondary. Repeat another winding as above for 2 nd halves of Secondary which is parallel with 1 st halves Secondary.
Insulation	1 layer of tape Item [7].
WD5 Shield 2	Start at pin 2, wind 9 bi-filar turns of wire Item [4]. At the last turn cut short the wires as No-Connect.
Insulation	1 layer of tape Item [7].
WD6 2nd Primary	Use wire floating from WD1, wind 10 turns from left to right. At the last turn, bring the wire back to the left to finish at pin 2.
Insulation	1 layer of tape Item [7] and bring the secondary wires FL1 to the right in between layers of tape.
Finish	Gap cores to get 469 μ H, solder bus wire Item [6] to pin 3 which leans along with core halves, and secure with tape. Varnish Item [9]. Places 2 layers of tape Item [8] at the bottom of transformer and wrap up to cover secondary side of transformer. Wrap around the body of transformer 1 layer of tape Item [7], (<i>see illustration beside</i>).

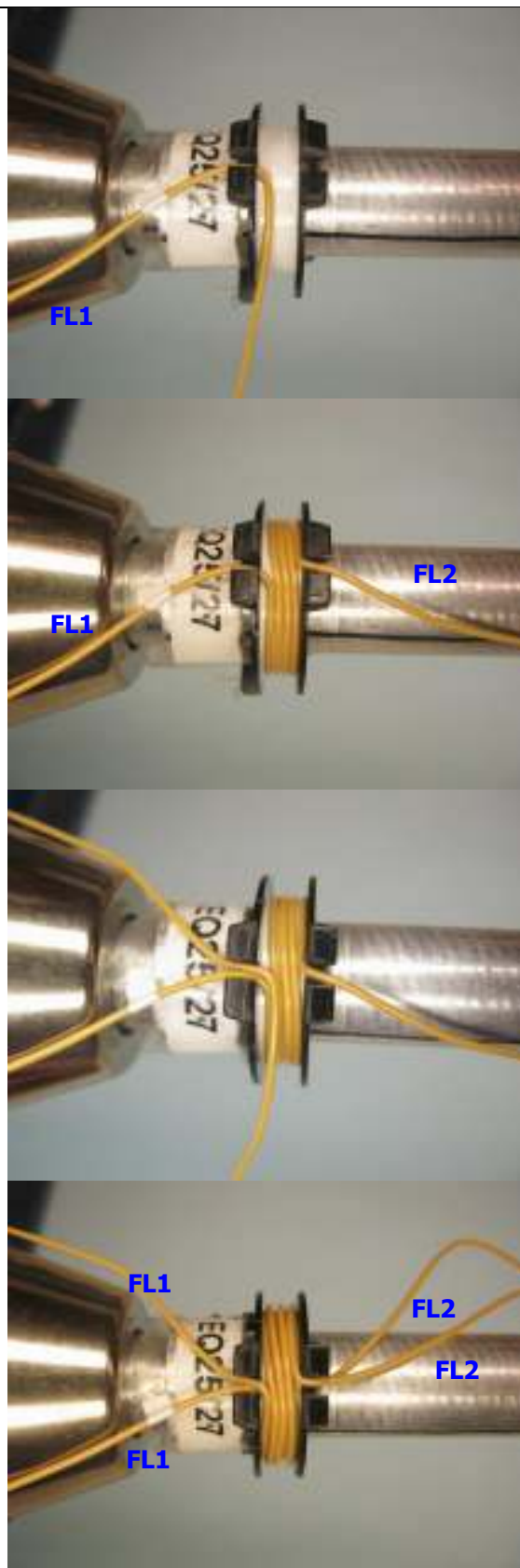
7.6 *Winding Illustrations*

Winding preparation		<p>Make slots on both sides of secondary flange. Position the bobbin Item [2] on the mandrel such that the pin side of the bobbin is on the left side. Winding direction is clock-wise direction.</p>
WD1 1st Primary		<p>Start at pin 4, wind 9 turns of wire Item [3] in 1 layer, from left to right, and place 1 layer of tape Item [7]. Continue winding another 9 turns from right to left, at the last turn exit the wire out of the bobbin leave ~ 2 ft for WD6:2nd Primary.</p>

		
Insulation		1 layer of tape Item [7].

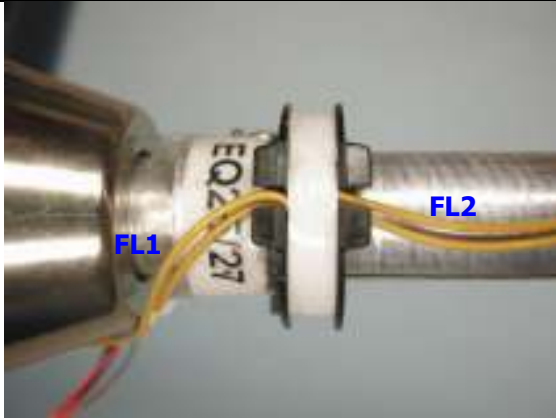
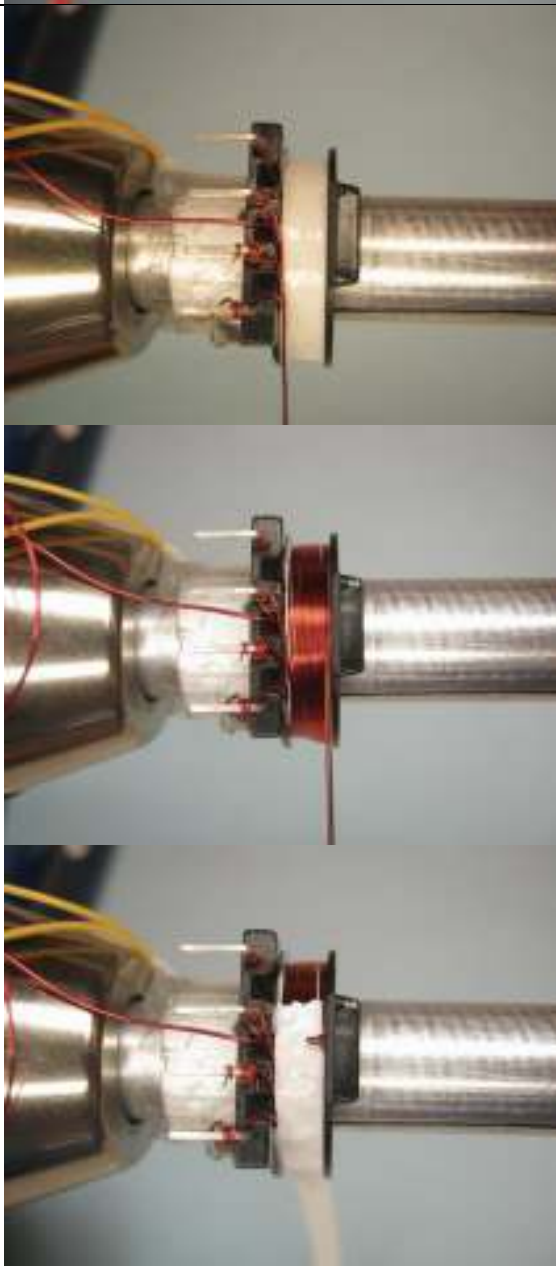
<p>WD2 & WD3 Bias & Shield 1</p>		<p>Start at pin 1, with 1 wire Item [4] for WD2 and start pin 3 with 2 wires also Item [4] for WD3. Wind all 3 wires 7 turns in parallel, at the last turn, finish 1 wire for WD2 at pin 3, cut short 2 wires for WD3 as No-Connect.</p>
<p>Insulation</p>		<p>2 layers of tape Item [7].</p>

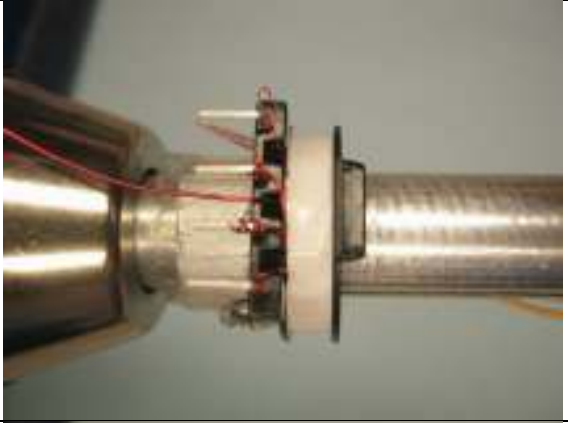
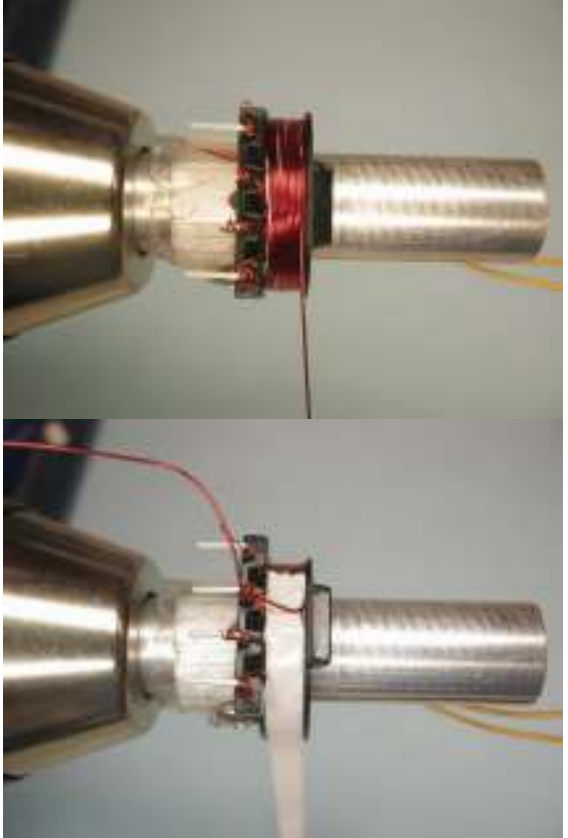




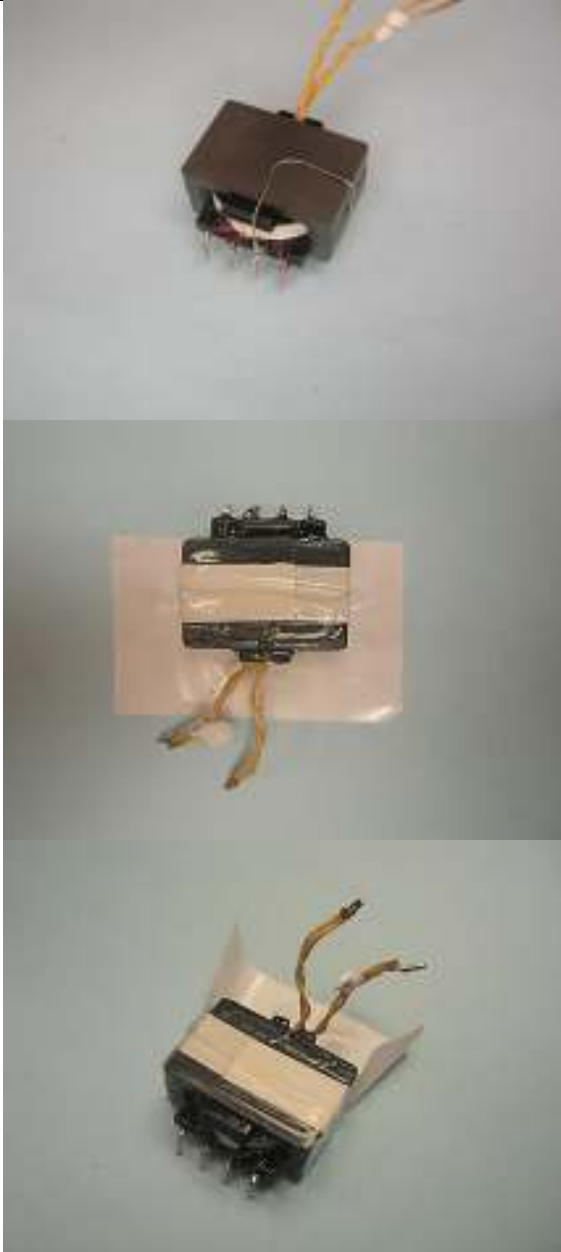
**WD4
Secondary**

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 halves of Secondary.

Repeat another winding as above for 2nd halves of Secondary which is parallel with 1st halves Secondary.

<p>Insulation</p>		<p>2 layers of tape Item [7].</p>
<p>WD5 Shield 2</p>		<p>Start at pin 2, wind 9 bi-filar turns of wire Item [4]. At the last turn cut short the wires as No-Connect.</p>

Insulation		1 layer of tape Item [7].
WD6 2nd Primary		Use wire floating from WD1, wind 10 turns from left to right. At the last turn, bring the wire back to the left to finish at pin 2.
Insulation		3 layers of tape Item [7] and bring the secondary wires FL1 to the right in between layers of tape.

		
Finish		<p>Gap cores to get 469 μH, solder bus wire Item [6] to pin 3 which leans along with core halves, and secure with tape. Varnish Item [9].</p> <p>Places 2 layers of tape Item [8] at the bottom of transformer and wrap up to cover secondary side of transformer.</p> <p>Wrap around the body of transformer 1 layer of tape Item [7], (<i>see illustration beside</i>).</p>



8 Common Mode Choke Specifications

8.1 250 μH Common Mode Choke (L1)

8.1.1 Electrical Diagram

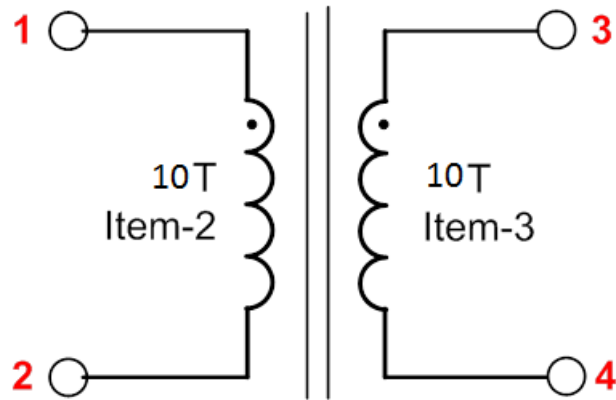


Figure 8 – Inductor Electrical Diagram.

8.1.2 Electrical Specifications

Inductance	Pins 1-2 measured at 100 kHz, 0.4 RMS.	250 μH ±20%
Primary Leakage Inductance	Pins 1-2, with 3-4 shorted.	1 μH

8.1.3 Material List

Item	Description
[1]	Toroid: FERRITE INDUCTOR TOROID .415" O.D.;Mfg Part Number: 35T0375-10H. Dim: 9.53 mm O.D. x 4.75 mm I.D. x 3.18 mm L.
[2]	Magnet Wire: #27 AWG.
[3]	Triple Insulated Wire #27 AWG.



8.1.4 Common Mode Choke Construction

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.



9 Transformer Design Spreadsheet

1	ACDC_6201_Flyback_041318; Rev.0.1; Copyright Power Integrations 2018	INPUT	INFO	OUTPUT	UNITS	6201 Flyback Design Spreadsheet
2	APPLICATION VARIABLES					Design Title
3	VAC_MIN	90		90	V	Minimum AC line voltage
4	VAC_MAX			265	V	Maximum AC input voltage
5	VAC_RANGE			UNIVERSAL		AC line voltage range
6	FLINE			60	Hz	AC line voltage frequency
7	CAP_INPUT	100.0		100.0	uF	Input capacitance
9	SETPOINT 1					
10	VOUT1	20.00		20.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	3.000		3.000	A	Output current 1
12	POUT1			60.00	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	SETPOINT 2					
17	VOUT2	15.00		15.00	V	Output voltage 2
18	IOUT2	3.000		3.000	A	Output current 2
19	POUT2			45.00	W	Output power 2
20	EFFICIENCY2	0.92		0.92		Converter efficiency for output 2
21	Z_FACTOR2	0.50		0.50		Z-factor for output 2
23	SETPOINT 3					
24	VOUT3	9.00		9.00	V	Output voltage 3
25	IOUT3	3.000		3.000	A	Output current 3
26	POUT3			27.00	W	Output power 3
27	EFFICIENCY3	0.91		0.91		Converter efficiency for output 3
28	Z_FACTOR3	0.50		0.50		Z-factor for output 3
30	SETPOINT 4					
31	VOUT4	5.00		5.00	V	Output voltage 4
32	IOUT4	3.000		3.000	A	Output current 4
33	POUT4			15.00	W	Output power 4
34	EFFICIENCY4	0.90		0.90		Converter efficiency for output 4
35	Z_FACTOR4	0.50		0.50		Z-factor for output 4
37	SETPOINT 5					
38	VOUT5			0.00	V	Output voltage 5
39	IOUT5			0.000	A	Output current 5
40	POUT5			0.00	W	Output power 5
41	EFFICIENCY5			0.00		Converter efficiency for output 5
42	Z_FACTOR5			0.00		Z-factor for output 5
44	SETPOINT 6					
45	VOUT6			0.00	V	Output voltage 6
46	IOUT6			0.000	A	Output current 6
47	POUT6			0.00	W	Output power 6
48	EFFICIENCY6			0.00		Converter efficiency for output 6
49	Z_FACTOR6			0.00		Z-factor for output 6
51	SETPOINT 7					
52	VOUT7			0.00	V	Output voltage 7
53	IOUT7			0.000	A	Output current 7
54	POUT7			0.00	W	Output power 7
55	EFFICIENCY7			0.00		Converter efficiency for output 7
56	Z_FACTOR7			0.00		Z-factor for output 7
58	SETPOINT 8					
59	VOUT8			0.00	V	Output voltage 8



60	IOUT8			0.000	A	Output current 8
61	POUT8			0.00	W	Output power 8
62	EFFICIENCY8			0.00		Converter efficiency for output 8
63	Z_FACTOR8			0.00		Z-factor for output 8
65 SETPOINT 9						
66	VOOUT9			0.00	V	Output voltage 9
67	IOUT9			0.000	A	Output current 9
68	POUT9			0.00	W	Output power 9
69	EFFICIENCY9			0.00		Converter efficiency for output 9
70	Z_FACTOR9			0.00		Z-factor for output 9
71						
72	PERCENT_CDC	0%		0%		Percentage (of output voltage) cable drop compensation desired at full load
73	CDC_SCALING_SETPOINT	3		3		Select the setpoint number for the voltage used for cable drop compensation (typically the 5V output)
77 PRIMARY CONTROLLER SELECTION						
78	ENCLOSURE	ADAPTE R		ADAPTER		Power supply enclosure
79	ILIMIT_MODE	INCREA SED		INCREASED		Device current limit mode
80	VDRAIN_BREAKDOWN	725		725	V	Device breakdown voltage
81	DEVICE_GENERIC	Auto		INN3279C		Device selection
82	DEVICE_CODE			INN3279C		Device code
83	PDEVICE_MAX			65	W	Device maximum power capability
84	RDSON_25DEG			0.25	Ω	Primary SWITCH on-time resistance at 25°C
85	RDSON_100DEG			0.60	Ω	Primary SWITCH on-time resistance at 100°C
86	ILIMIT_MIN			1.981	A	Primary SWITCH minimum current limit
87	ILIMIT_TYP			2.130	A	Primary SWITCH typical current limit
88	ILIMIT_MAX			2.279	A	Primary SWITCH maximum current limit
89	VDRAIN_ON_SWITCH			0.43	V	Primary SWITCH on-time voltage drop
90	VDRAIN_OFF_SWITCH			583.31	V	Peak drain voltage on the primary SWITCH during turn-off
94 WORST CASE ELECTRICAL PARAMETERS						
95	FSWITCHING_MAX	79500	Info	79500	Hz	The worst case minimum operating frequency is less than 25kHz: may result in audible noise
96	VOR	140.0		140.0	V	Voltage reflected to the primary winding (corresponding to setpoint 1) when the primary MOSFET turns off
97	VMIN			89.14	V	Valley of the rectified minimum input AC voltage at full load
98	KP			0.781		Measure of continuous/discontinuous mode of operation
99	MODE_OPERATION			CCM		Mode of operation
100	DUTYCYCLE			0.612		Primary SWITCH duty cycle
101	TIME_ON			10.59	us	Primary SWITCH on-time
102	TIME_OFF			4.88	us	Primary SWITCH off-time
103	LPRIMARY_MIN			445.6	uH	Minimum primary magnetizing inductance
104	LPRIMARY_TYP			469.0	uH	Typical primary magnetizing inductance
105	LPRIMARY_TOL			5.0		Primary magnetizing inductance tolerance
106	LPRIMARY_MAX			492.5	uH	Maximum primary magnetizing inductance
108 PRIMARY CURRENT						
109	Iavg_PRIMARY			0.714	A	Primary SWITCH average current
110	IPEAK_PRIMARY			2.147	A	Primary SWITCH peak current
111	IPEDestal_PRIMARY			0.418	A	Primary SWITCH current pedestal
112	IRIPPLE_PRIMARY			2.059	A	Primary SWITCH ripple current
113	IRMS_PRIMARY			1.014	A	Primary SWITCH RMS current



115	SECONDARY CURRENT					
116	IPEAK_SECONDARY			15.028	A	Secondary MOSFET peak current
117	IPEDESTAL_SECONDARY			2.929	A	Secondary MOSFET pedestal current
118	IRMS_SECONDARY			5.652	A	Secondary MOSFET RMS current
119	IRIPPLE_CAP_OUT			4.790	A	Output capacitor ripple current
123	TRANSFORMER CONSTRUCTION PARAMETERS					
124	CORE SELECTION					
125	CORE	Custom		Custom		Core selection
126	CORE NAME	EQ27		EQ27		Core code
127	AE	108.0		108.0	mm ²	Core cross sectional area
128	LE	36.3		36.3	mm	Core magnetic path length
129	AL	7700		7700	nH	Ungapped core effective inductance per turns squared
130	VE	3920		3920	mm ³	Core volume
131	BOBBIN NAME	EQ2506		EQ2506		Bobbin name
132	AW	52.0		52.0	mm ²	Bobbin window area
133	BW	4.50		4.50	mm	Bobbin width
134	MARGIN			0.0	mm	Bobbin safety margin
136	PRIMARY WINDING					
137	NPRIMARY			28		Primary winding number of turns
138	BPEAK			3799	Gauss	Peak flux density
139	BMAX			3453	Gauss	Maximum flux density
140	BAC			1651	Gauss	AC flux density (0.5 x Peak to Peak)
141	ALG			598	nH	Typical gapped core effective inductance per turns squared
142	LG			0.209	mm	Core gap length
143	LAYERS_PRIMARY			3		Primary winding number of layers
144	AWG_PRIMARY			26		Primary wire gauge
145	OD_PRIMARY_INSULATED			0.465	mm	Primary wire insulated outer diameter
146	OD_PRIMARY_BARE			0.405	mm	Primary wire bare outer diameter
147	CMA_PRIMARY			250.5	Cmils/A	Primary winding wire CMA
149	SECONDARY WINDING					
150	NSECONDARY	4		4		Secondary winding number of turns
151	AWG_SECONDARY			19		Secondary wire gauge
152	OD_SECONDARY_INSULATED			1.217	mm	Secondary wire insulated outer diameter
153	OD_SECONDARY_BARE			0.912		Secondary wire bare outer diameter
154	CMA_SECONDARY			227.9	Cmils/A	Secondary winding wire CMA
156	BIAS WINDING					
157	NBIAS			7		Bias winding number of turns
161	PRIMARY COMPONENTS SELECTION					
162	LINE UNDERVOLTAGE					
163	BROWN-IN REQUIRED	75.00		75.00	V	Required line brown-in threshold
164	RLS			3.74	MΩ	Connect two 1.87 MOhm resistors to the V-pin for the required UV/OV threshold
165	BROWN-IN ACTUAL			74.98	V	Actual brown-in threshold using standard resistors
166	BROWN-OUT ACTUAL			67.82	V	Actual brown-out threshold using standard resistors
168	LINE OVERVOLTAGE					
169	OVERVOLTAGE_LINE			312.52	V	Actual AC RMS line over-voltage threshold
170						
171	BIAS WINDING					
172	VBIAS	8.00	Info	8.00	V	The rectified bias voltage maybe too low to supply the BP pin: Increase the rectified bias voltage to a value higher than 9V
173	VF_BIAS			0.70	V	Bias winding diode forward drop

174	VREVERSE_BIASDIODE			101.33	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
175	CBIAS			22	uF	Bias winding rectification capacitor
176	CBPP			4.70	uF	BPP pin capacitor
180 SECONDARY COMPONENTS SELECTION						
181 RECTIFIER						
182	VDRAIN_OFF_SRFET			73.33	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
183	SRFET	AONS62922		AONS62922		Secondary rectifier (Logic MOSFET)
184	VBREAKDOWN_SRFET			120	V	Secondary rectifier breakdown voltage
185	RDSON_SRFET			7.1	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
187 FEEDBACK COMPONENTS						
188	RFB_UPPER			191	kΩ	Upper feedback resistor (connected to the output terminal)
189	RFB_LOWER			11.50	kΩ	Lower feedback resistor required to obtain the output for cable drop compensation
190	CFB_LOWER			330	pF	Lower feedback resistor decoupling capacitor
194 VARIABLE OUTPUTS ANALYSIS						
195 TOLERANCE CORNER						
196	CORNER_VAC			90	V	Input AC RMS voltage corner to be evaluated
197	CORNER_ILIMIT	TYP		2.130	A	Current limit corner to be evaluated
198	CORNER_LPRIMARY	TYP		469.0	uH	Primary inductance corner to be evaluated
200 SETPOINT SELECTION						
201	SETPOINT	1		1		Select the setpoint which needs to be evaluated
202	FSWITCHING			66998.9	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
203	VOR			140.0	V	Voltage reflected to the primary winding when the primary SWITCH turns off
204	VMIN			89.14	V	Valley of the minimum input AC voltage
205	KP			0.851		Measure of continuous/discontinuous mode of operation
206	MODE_OPERATION			CCM		Mode of operation
207	DUTYCYCLE			0.612		Primary SWITCH duty cycle
208	TIME_ON			9.14	us	Primary controller's maximum on-time
209	TIME_OFF			5.79	us	Primary controller's minimum off-time
211 PRIMARY CURRENT						
212	Iavg_PRIMARY			0.714	A	Primary SWITCH average current
213	IPEAK_PRIMARY			2.030	A	Primary SWITCH peak current
214	IPEDESTAL_PRIMARY			0.302	A	Primary SWITCH current pedestal
215	IRIPPLE_PRIMARY			1.728	A	Primary SWITCH ripple current
216	IRMS_PRIMARY			0.992	A	Primary SWITCH RMS current
218 SECONDARY CURRENT						
219	IPEAK_SECONDARY			14.212	A	Secondary MOSFET peak current
220	IPEDESTAL_SECONDARY			2.115	A	Secondary MOSFET pedestal current
221	IRMS_SECONDARY			5.530	A	Secondary MOSFET RMS current
222	IRIPPLE_CAP_OUT			4.646	A	Output capacitor ripple current
224 MAGNETIC FLUX DENSITY						
225	BPEAK			3381	Gauss	Peak flux density
226	BMAX			3149	Gauss	Maximum flux density
227	BAC			1340	Gauss	AC flux density (0.5 x Peak to Peak)



10 Adapter Case Dimensions

10.1 Case Bottom Dimensions

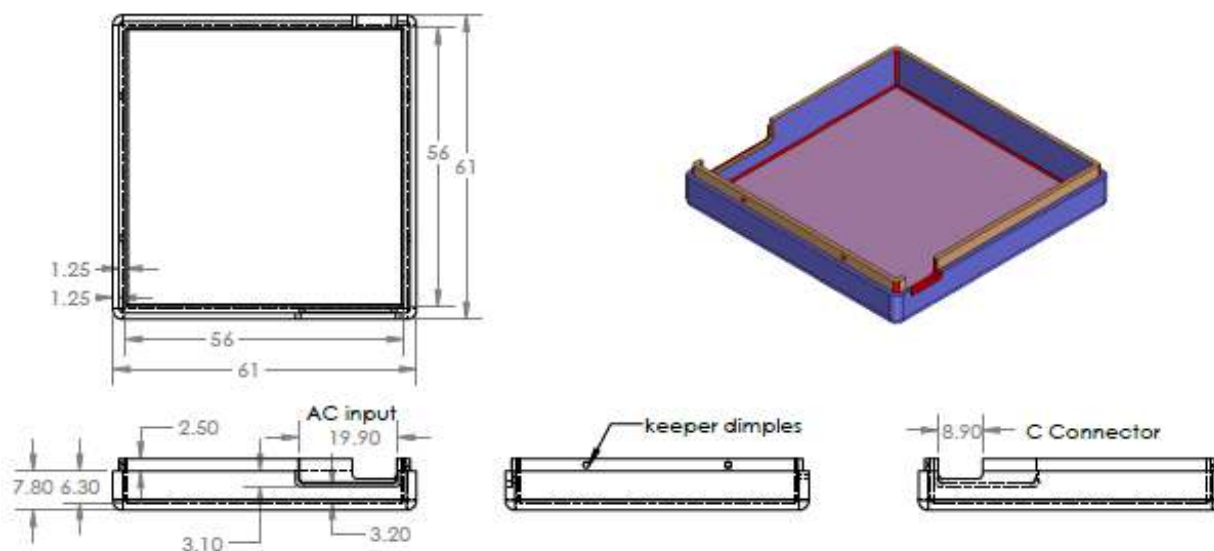


Figure 9 – DER-601 Adapter Case Bottom.

10.2 Case Top Dimensions

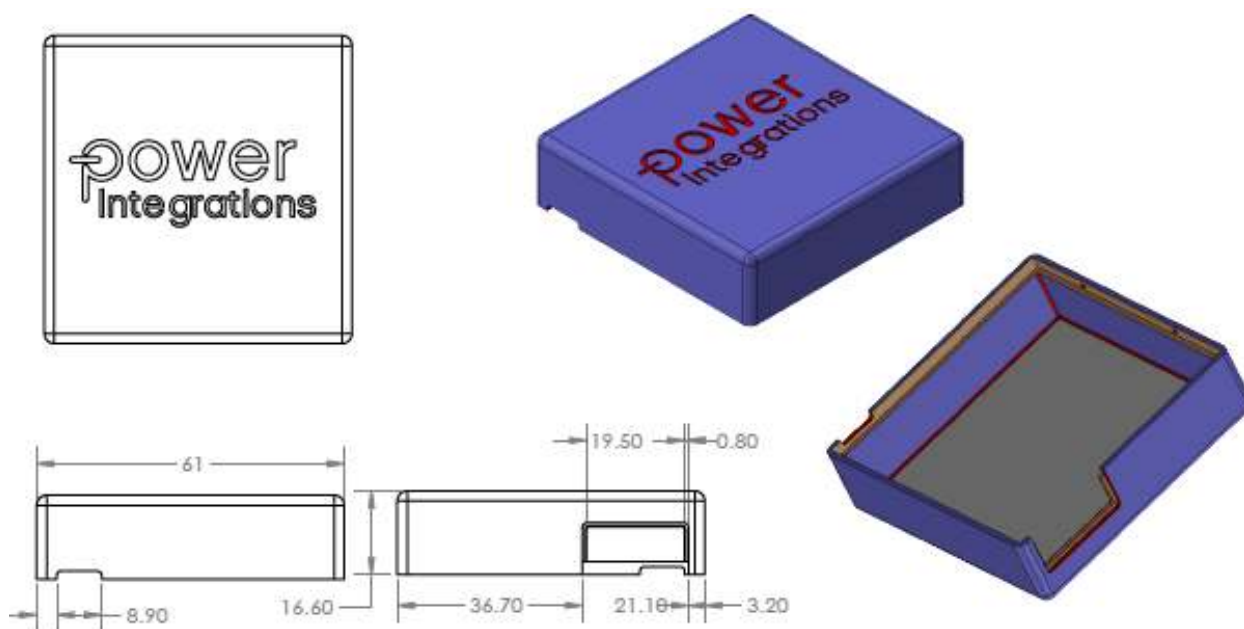


Figure 10 – DER-601 Adapter Case Top.

10.3 ***Adapter Assembly Drawing***

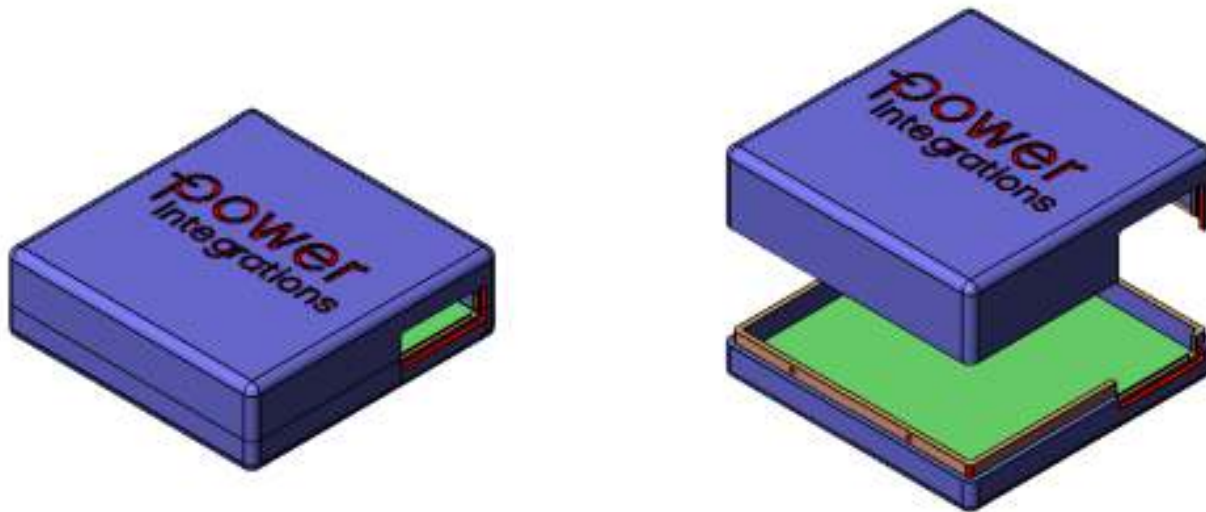
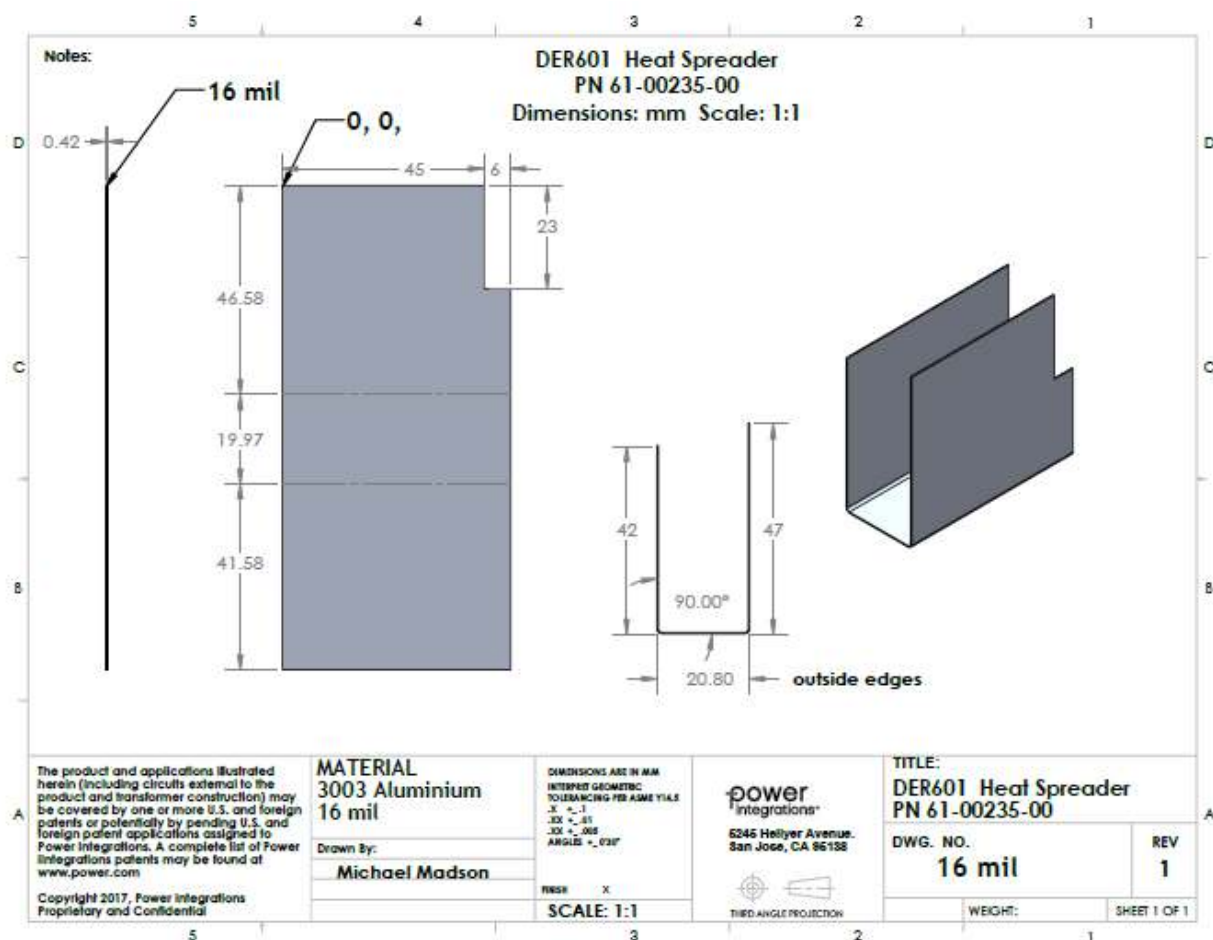
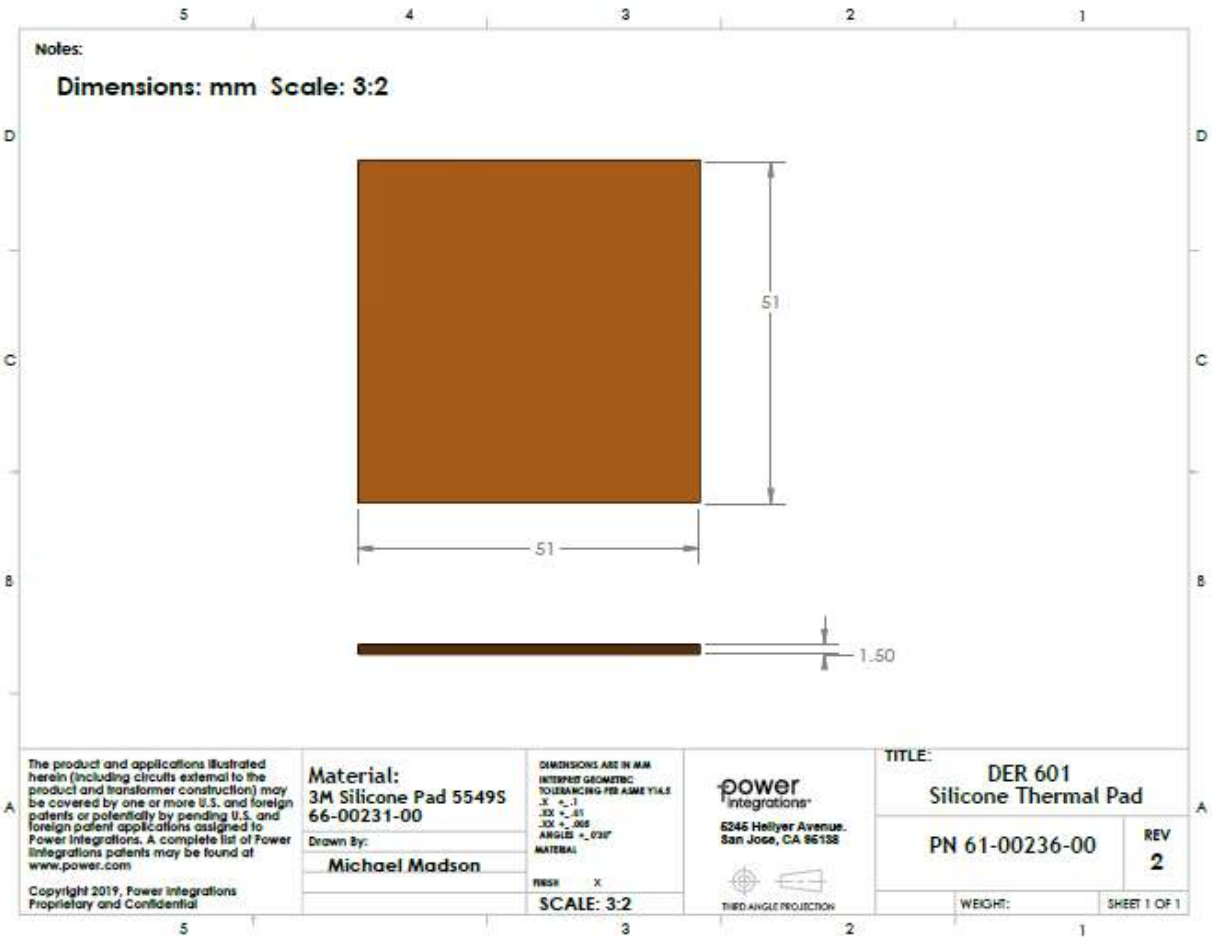
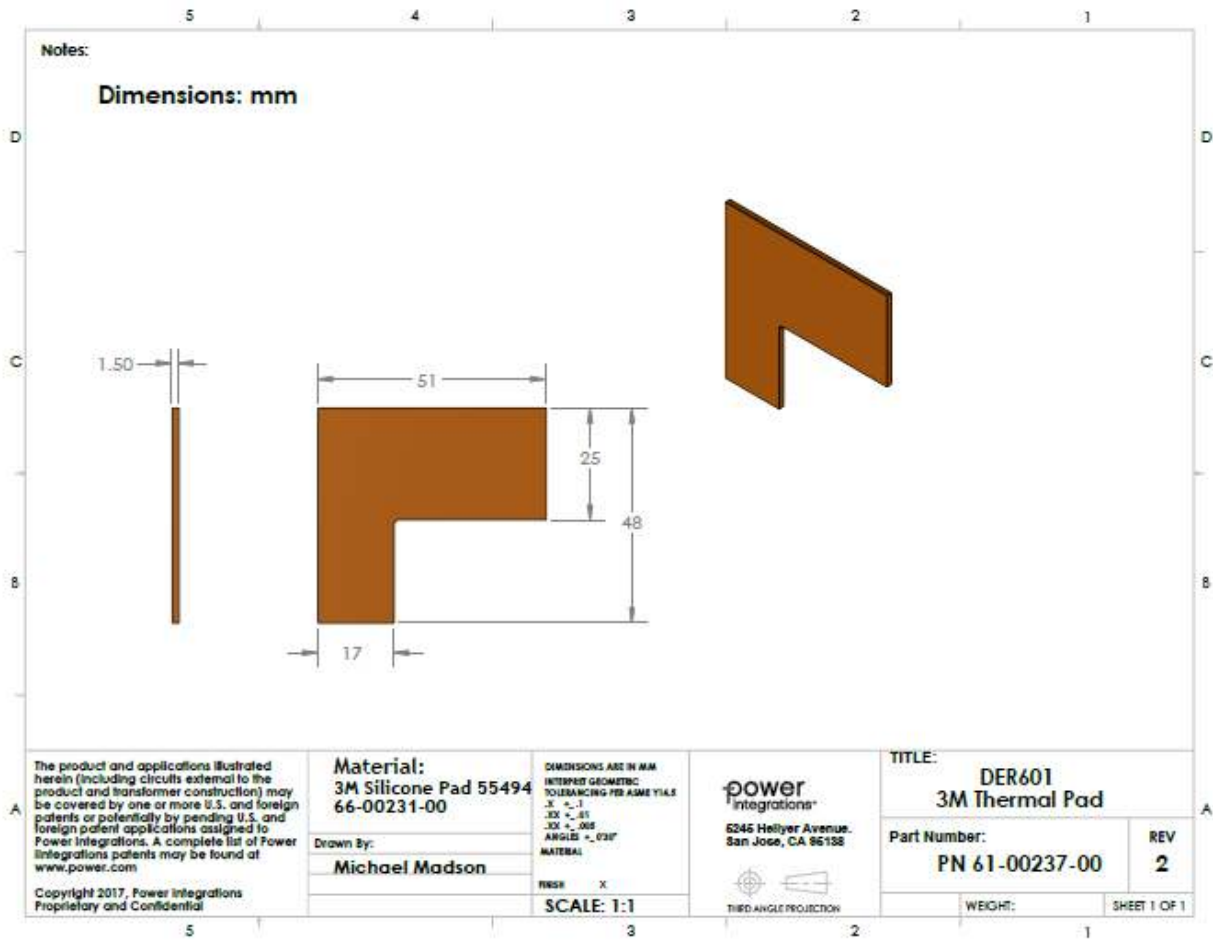


Figure 11 – DER-601 Adapter Assembly Drawing.

11 Heat Spreader Drawings







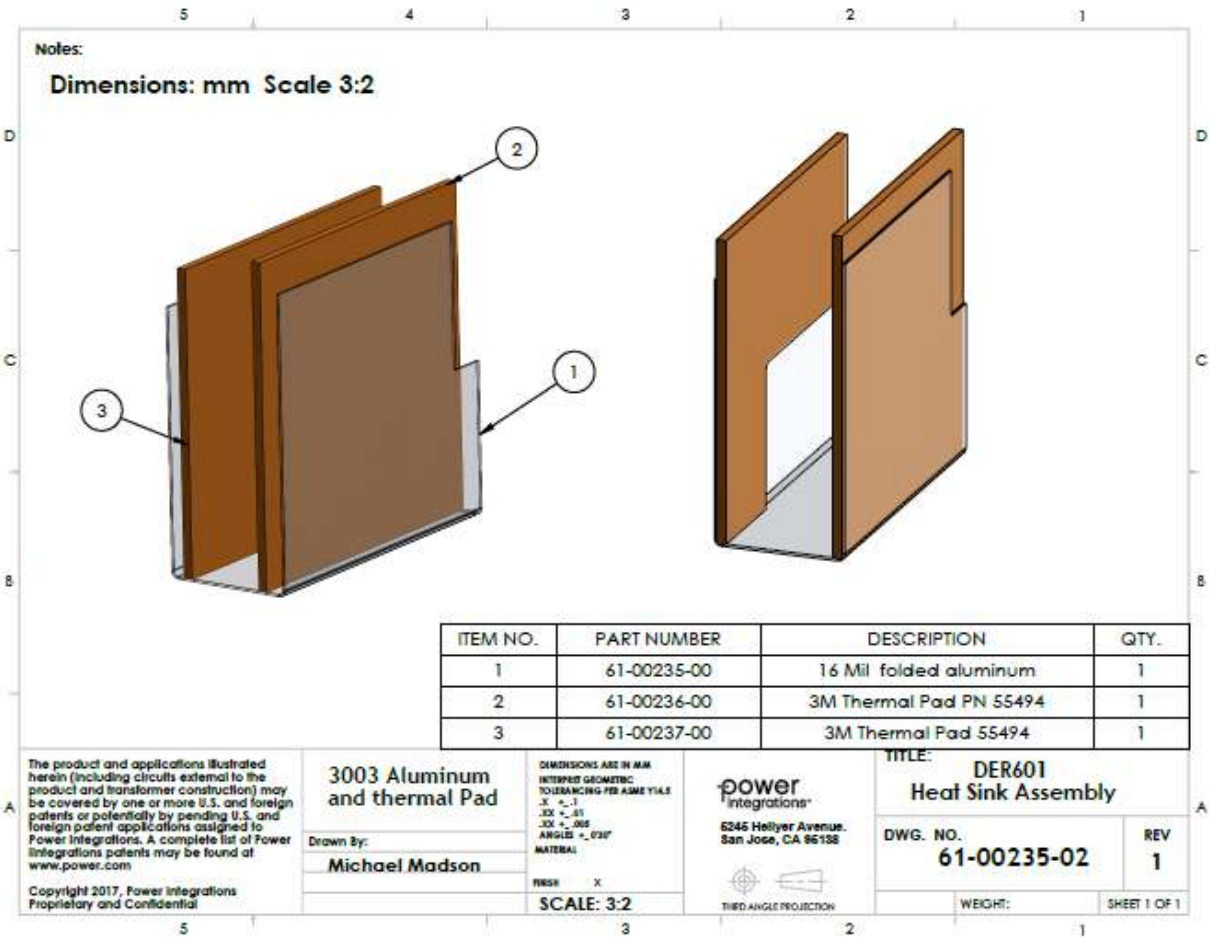


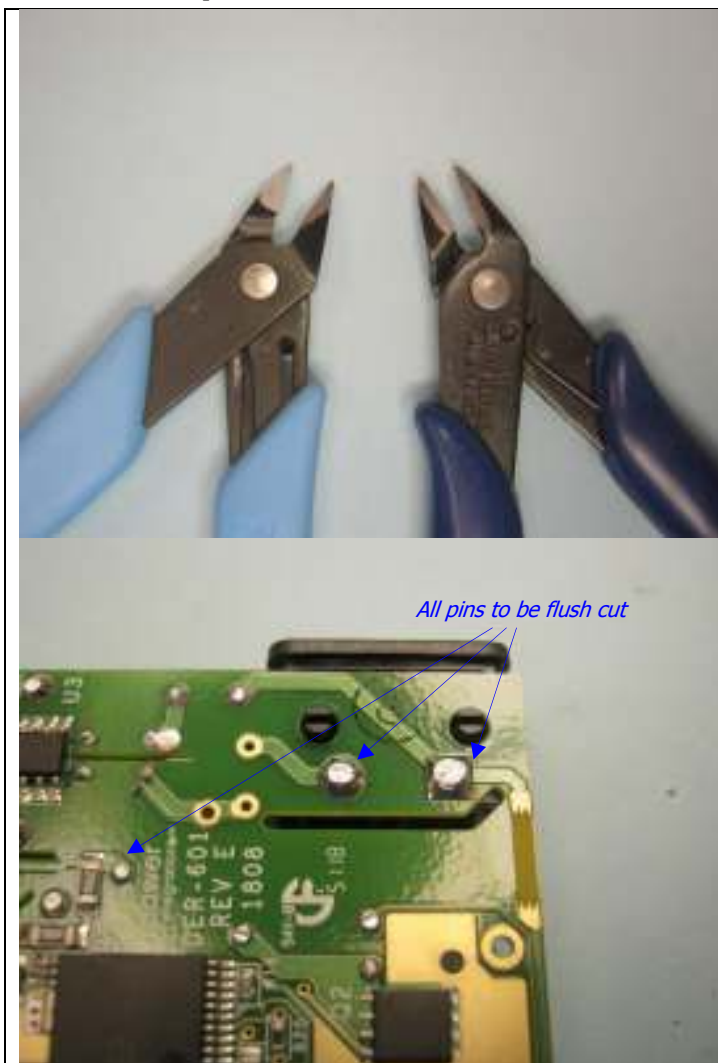
Figure 12 – Heat Spreader, Thermal Pad Drawings and Assembly.

12 Heat Spreader Assembly Instructions

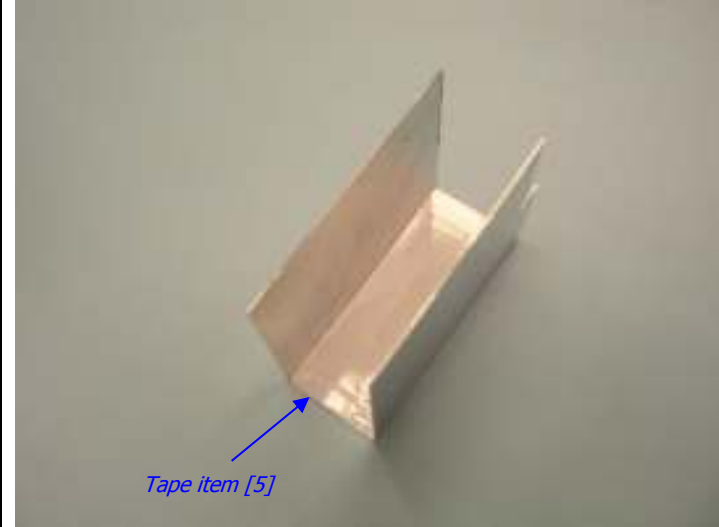
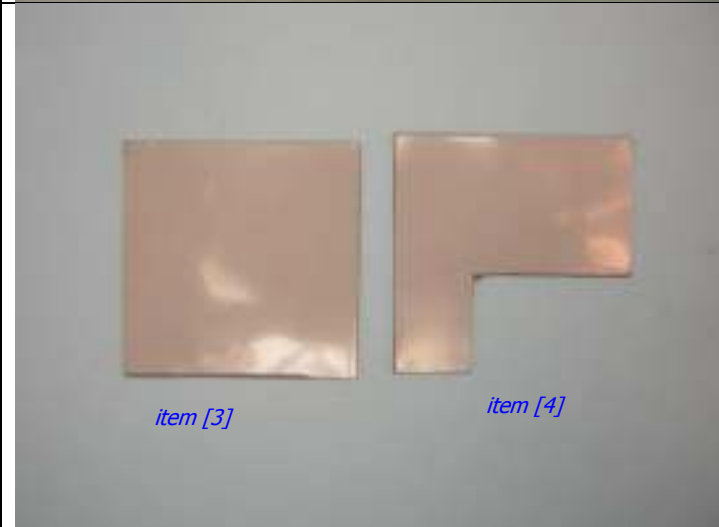
12.1 Materials

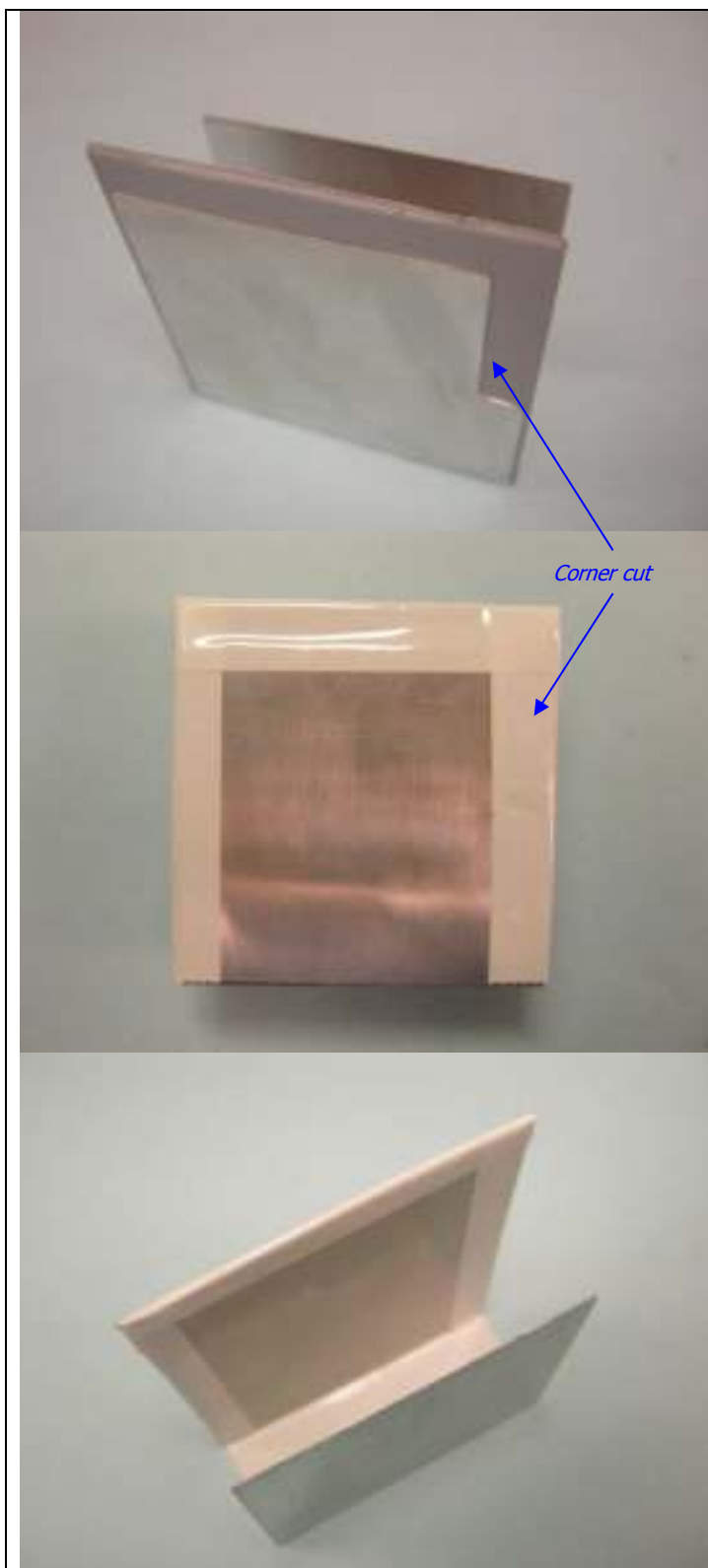
Item	Description
[1]	Heat spreader; PI#: 61-00235-00.
[2]	Thermal pad, PI#: 66-00231-00.
[3]	Use item [2] cut into "Square" shape with dimension as shown in fig.1.
[4]	Use item [2] cut into "L" shape with dimension as shown in fig.1.
[5]	Tape: 3M 1298 Polyester Film, 1 mil thick, 20.0mm wide, 51mm long.
[6]	Tape: 3M 1298 Polyester Film, 1 mil thick, 14.0mm wide, 51mm long.

12.2 Assembly Instructions





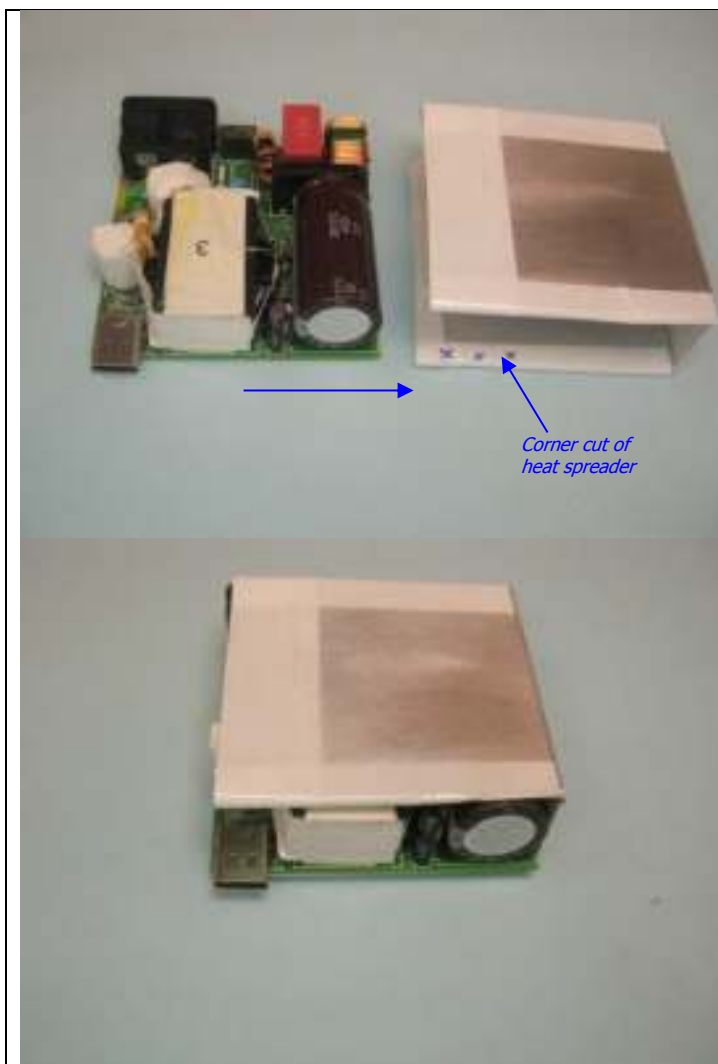
Use proper flush cutters such as shown in this picture to have all pin of PCB to be flush cut in order to avoid any pins poking into the thermal pads. (see illustration beside).

 <p><i>Tape item [5]</i></p>	<p>Place 1 layer of tape item [5] at inner edge of heat spreader item [1].</p>
 <p><i>item [3]</i> <i>item [4]</i></p>	<p>Prepare item [3] and item [4]</p>



Use item [3], peel the clear plastic cover (sticky side) and attach this side to one side heat spreader item [1], which has corner cut. Wrap around 3 edges with tape item [6].

	<p>Use item [4], peel the clear plastic cover (sticky side) and attach this side to other side of heat spreader item [1]. Wrap around 3 edges with tape item [6].</p>
	<p>The complete heat spreader assembly.</p>



Insert board into heat spreader assembly.



Place whole set onto bottom half of the case and snap top half in place.

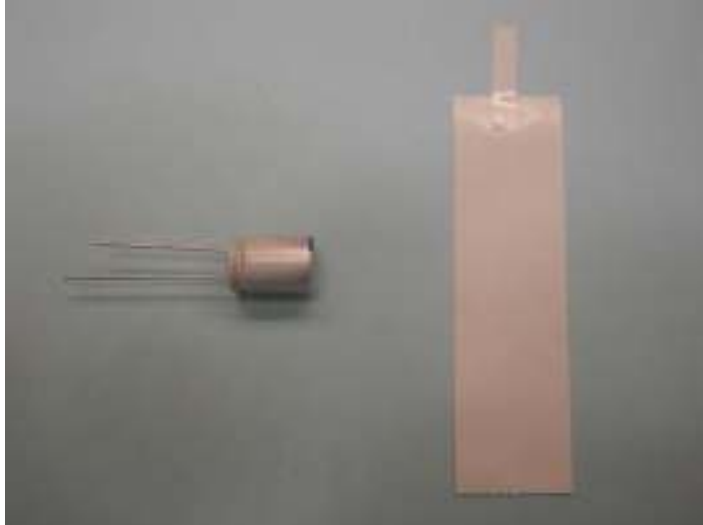
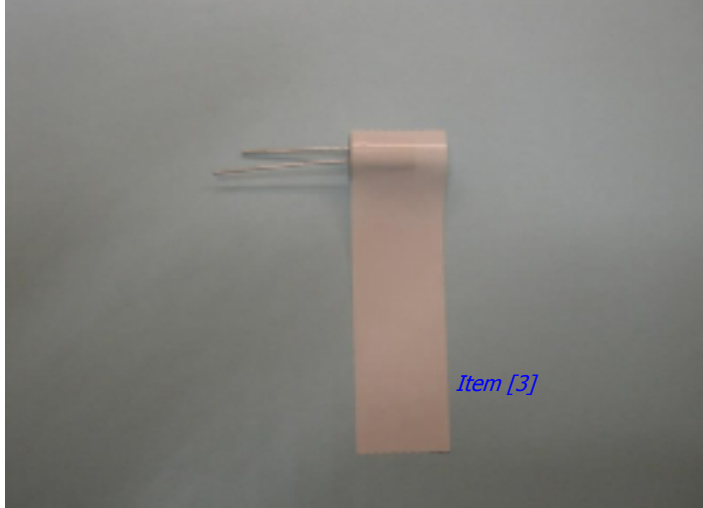


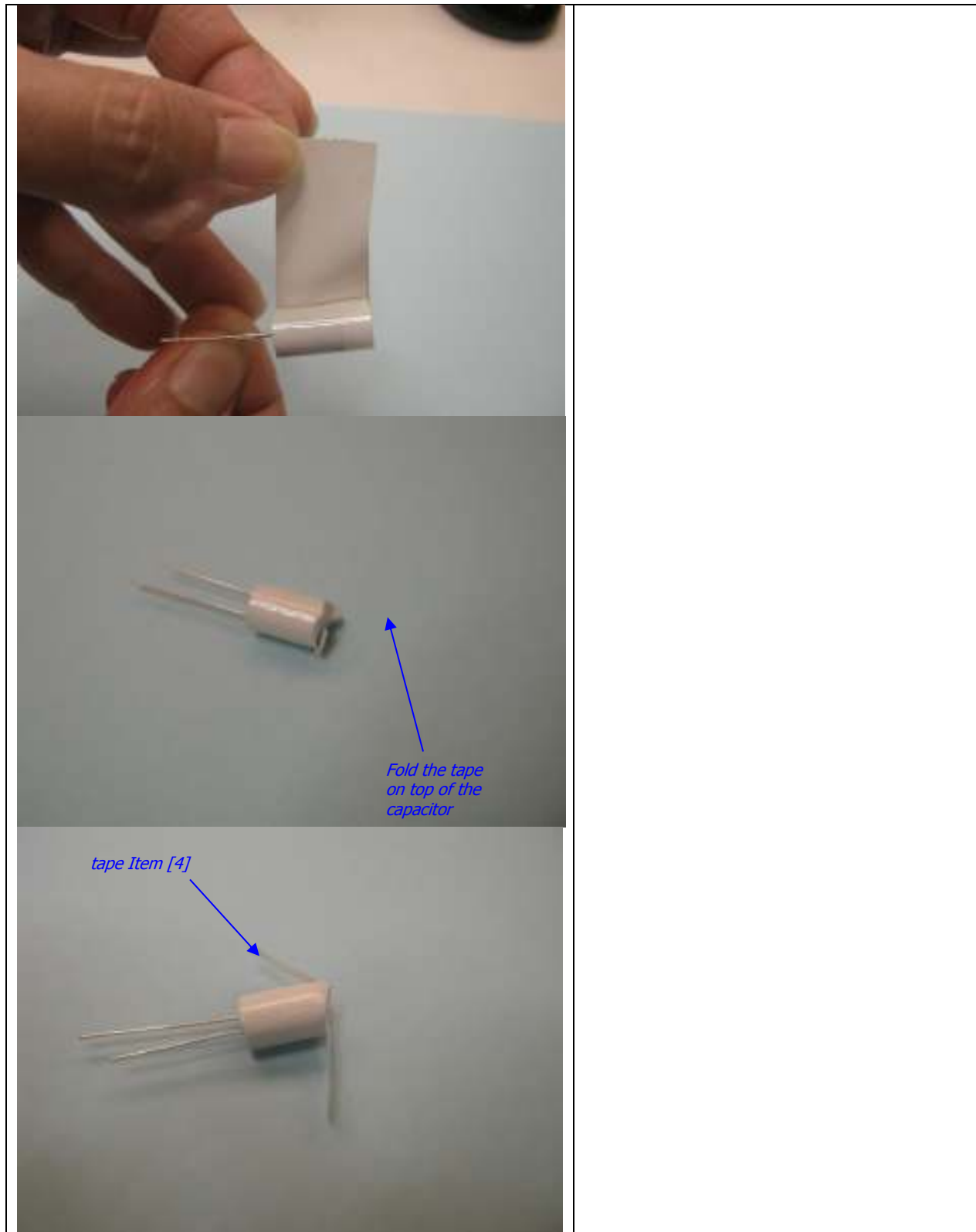
13 Output Capacitor and Transformer Assembly Instructions

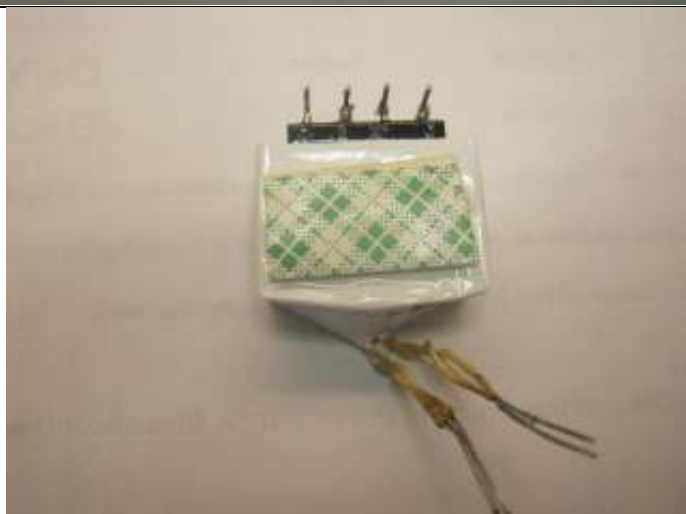
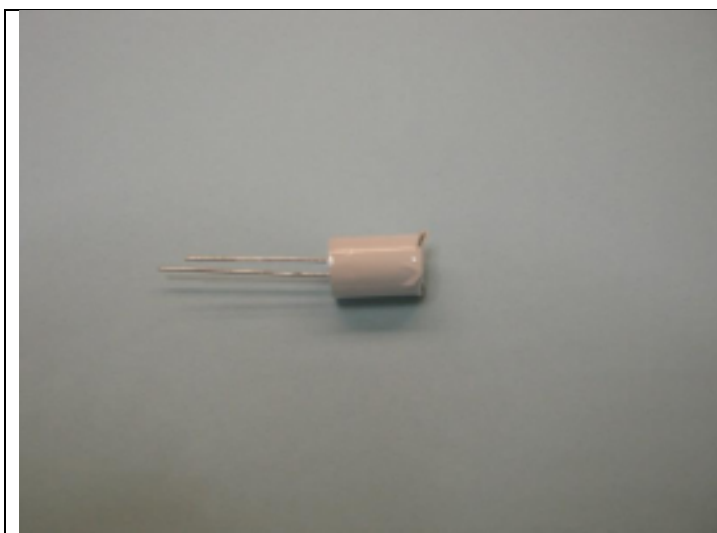
13.1 Materials

Item	Description
[1]	Capacitor C13 on DER-601 Schematic.
[2]	Capacitor C13A on DER-601 Schematic.
[3]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 16.4 mm Wide, 25 mm Long.
[4]	Tape: 3M 1298 Polyester Film, 1 mil Thick, 5.0 mm Wide, 15 mm Long.
[5]	Tape: 3M 4026W Double Coated Urethane Foam Tape 1.6 mm Thick, 12.7 mm Wide, 22 mm Long.

13.2 Output Capacitor and Transformer Assembly Instructions

	
	<p>Wrap C13 and C13A with tape Item [3] to insulate the capacitor from transformer core.</p>





Peel off the tape cover of Item [5] and stick to the transformer in the center. Peel off the tape cover on the other side off the tape before assembling it on to the board.



Finish assembly.

Note: cut all the TH (PTH and NPTH) pins to <0.5 mm on the bottom side of the board after completing the assembly.

14 Performance Data

All the performance data have been taken on the board unless otherwise specifically mentioned.

14.1 Efficiency vs. Line

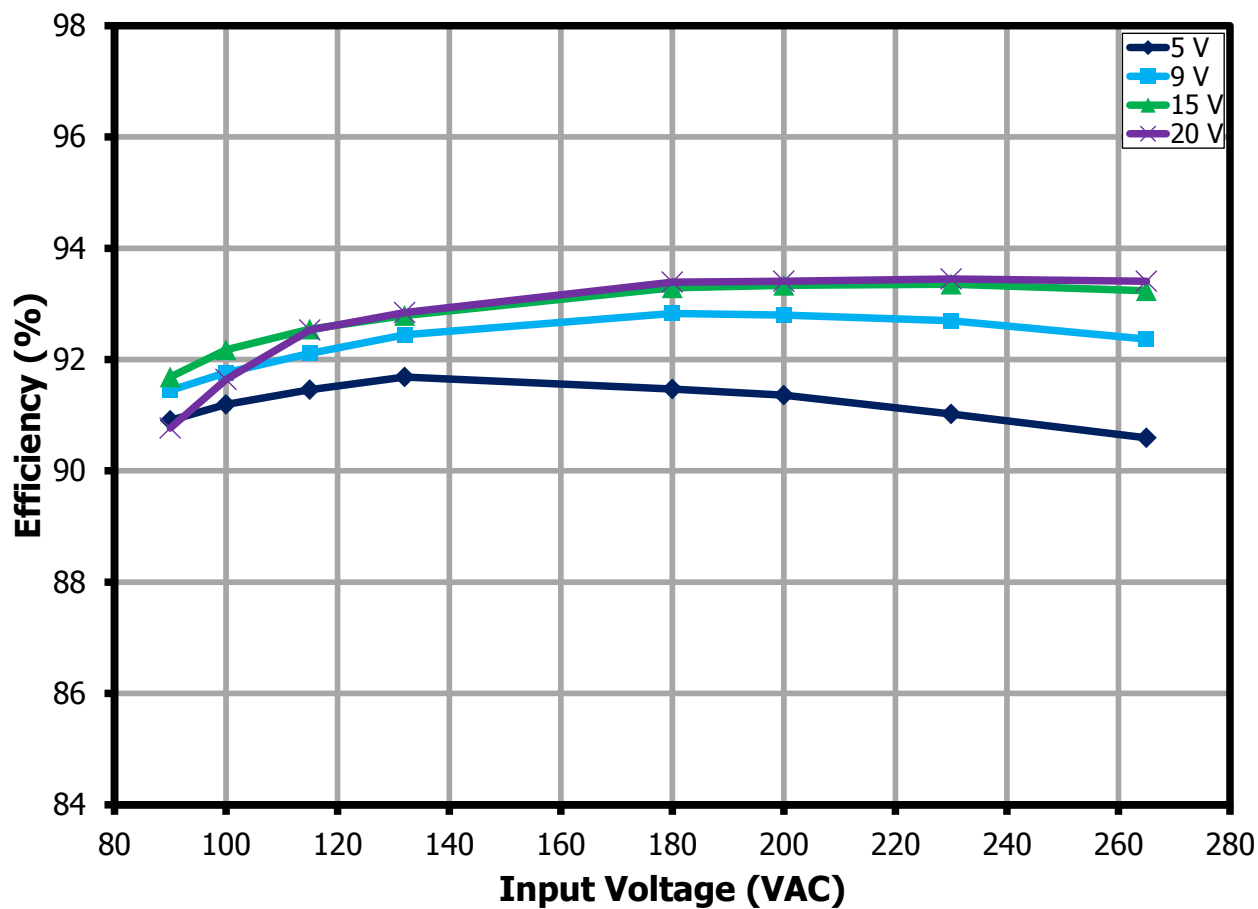


Figure 13 – Efficiency vs. Line, Room Ambient.

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

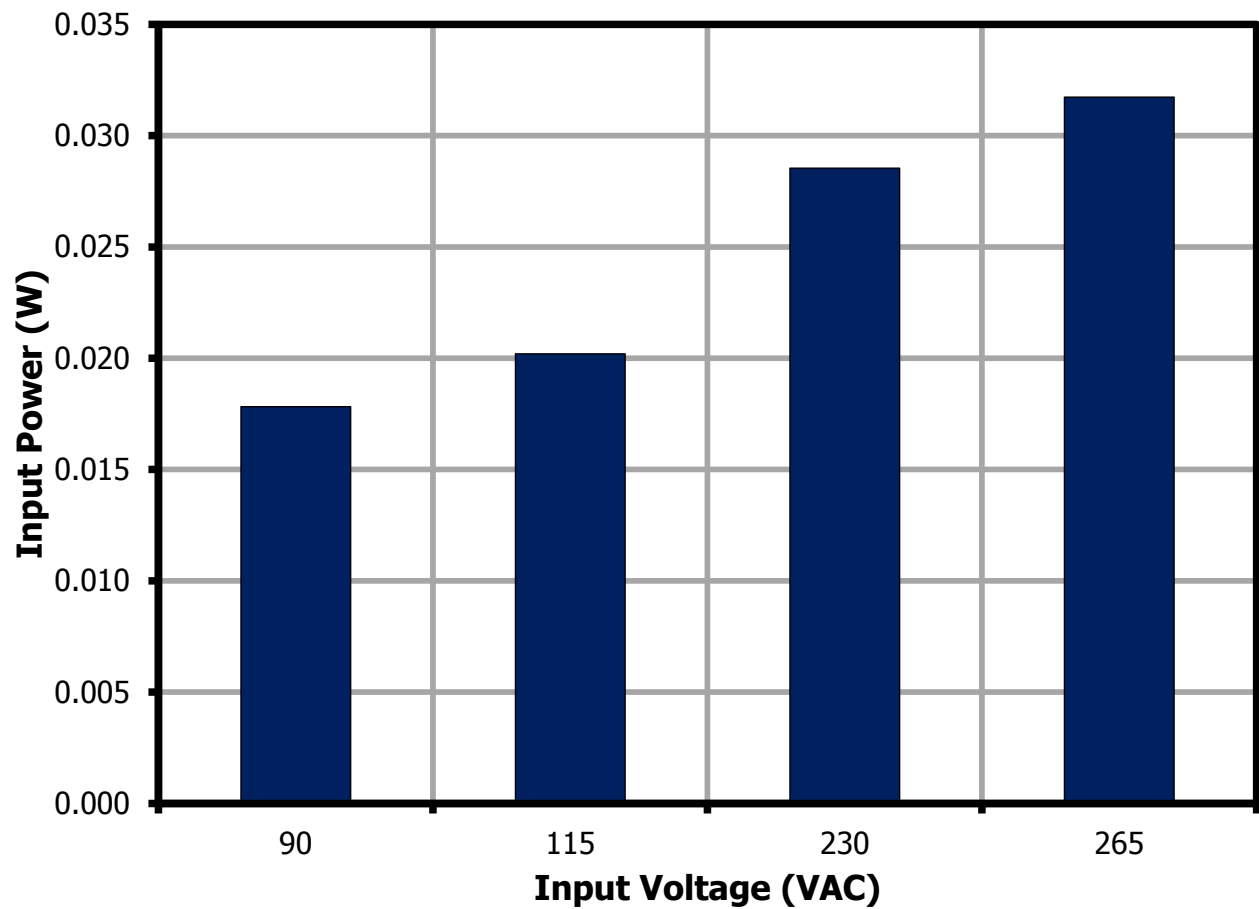


Figure 14 – No-Load Input Power vs. Input Line Voltage, Room Temperature.



14.3 Average Efficiency

14.3.1 Average Efficiency Requirements

		Test	Average	Average	Average	10% Load	10% Load
Output Voltage	Model	Power [W]	DOE6 Limit	CoC v5 Tier 1	CoC v5 Tier 2	CoC v5 Tier 1	CoC v5 Tier 2
5	<6 V	15	81.84%	79.05%	81.84%	69.50%	72.48%
9	>6 V	27	86.62%	85.23%	87.30%	75.23%	77.30%
15	>6 V	45	87.73%	88.43%	88.85%	78.43%	78.85%
20	>6 V	60	88.00%	89.00%	89.00%	79.00%	79.00%

14.4 Average and 10% Efficiency at 115 VAC Input

14.4.1 $V_{OUT} = 5\text{ V}$

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	15.28	91.51	91.94
75	11.58	91.91	
50	7.89	92.20	
25	4.20	92.12	
10	1.52	91.09	

14.4.2 $V_{OUT} = 9\text{ V}$

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	27.27	92.20	92.65
75	20.58	92.68	
50	14.04	92.95	
25	7.49	92.77	
10	2.71	90.98	

14.4.3 $V_{OUT} = 15\text{ V}$

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	45.22	92.58	92.8
75	34.14	92.76	
50	23.28	92.99	
25	12.42	92.84	
10	4.50	90.47	

14.4.4 $V_{OUT} = 20\text{ V}$

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	60.32	92.57	92.69
75	45.54	92.71	
50	31.04	92.71	
25	16.57	92.76	
10	6.00	90.12	

14.5 Average and 10% Efficiency at 230 VAC Input

14.5.1 $V_{OUT} = 5\text{ V}$

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	15.28	91.50	91.18
75	11.58	91.55	
50	7.89	91.31	
25	4.20	90.34	
10	1.52	88.30	

14.5.2 $V_{OUT} = 9\text{ V}$

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	27.27	92.98	92.69
75	20.59	93.02	
50	14.04	92.84	
25	7.49	91.91	
10	2.72	89.02	

14.5.3 $V_{OUT} = 15\text{ V}$

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	45.23	93.58	93.3
75	34.14	93.63	
50	23.28	93.50	
25	12.42	92.65	
10	4.50	89.31	

14.5.4 $V_{OUT} = 20\text{ V}$

% Load	P _{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	60.32	93.71	93.44
75	45.54	93.72	
50	31.05	93.58	
25	16.57	92.74	
10	6.01	89.11	

14.6 Line and Load Regulation

14.6.1 $V_{OUT} = 5\text{ V}$

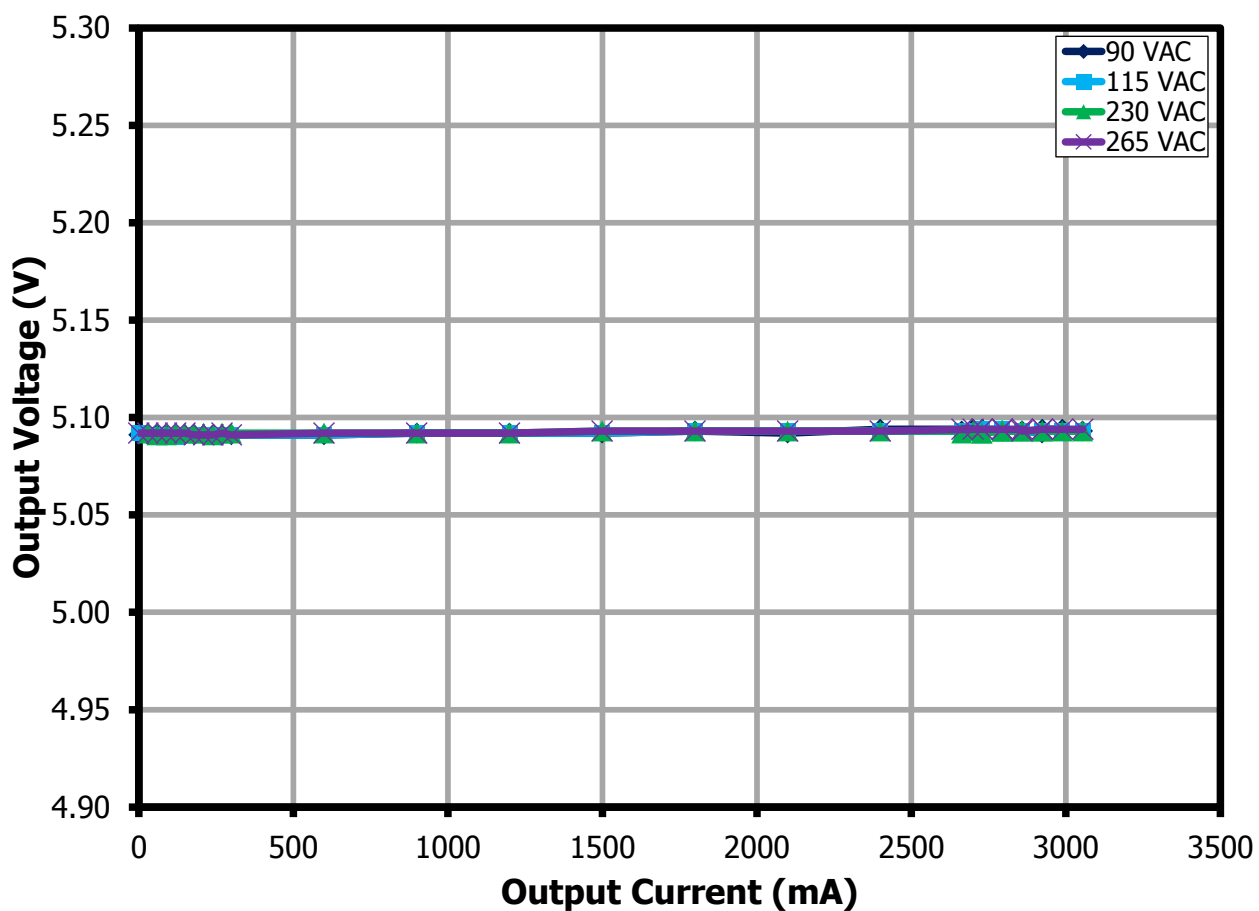
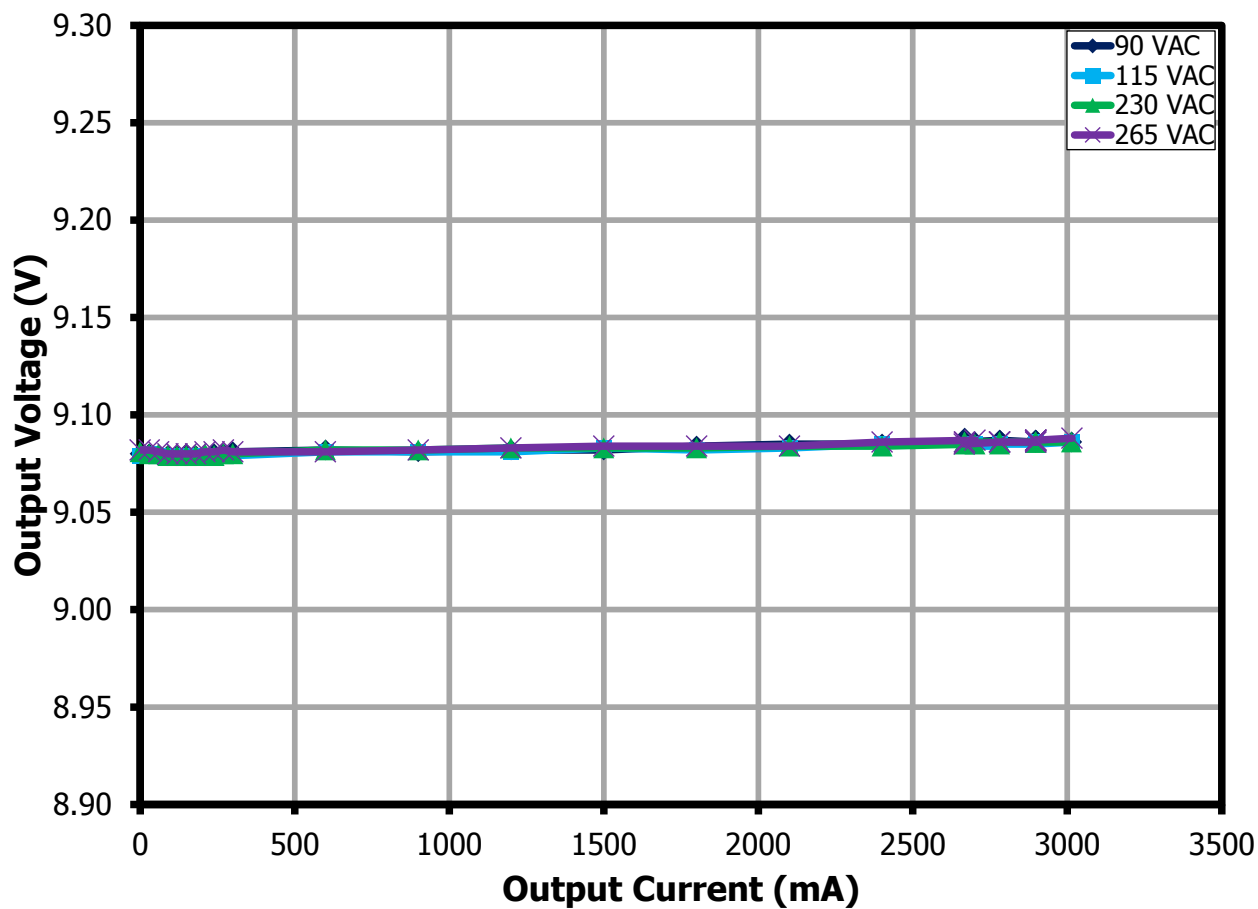


Figure 15 – Output Voltage vs. Load current across AC Input Voltage, Room Temperature.

14.6.2 $V_{OUT} = 9\text{ V}$ **Figure 16** – Output Voltage vs. Load Current Across AC Input Voltage, Room Temperature.

14.6.3 $V_{OUT} = 15\text{ V}$

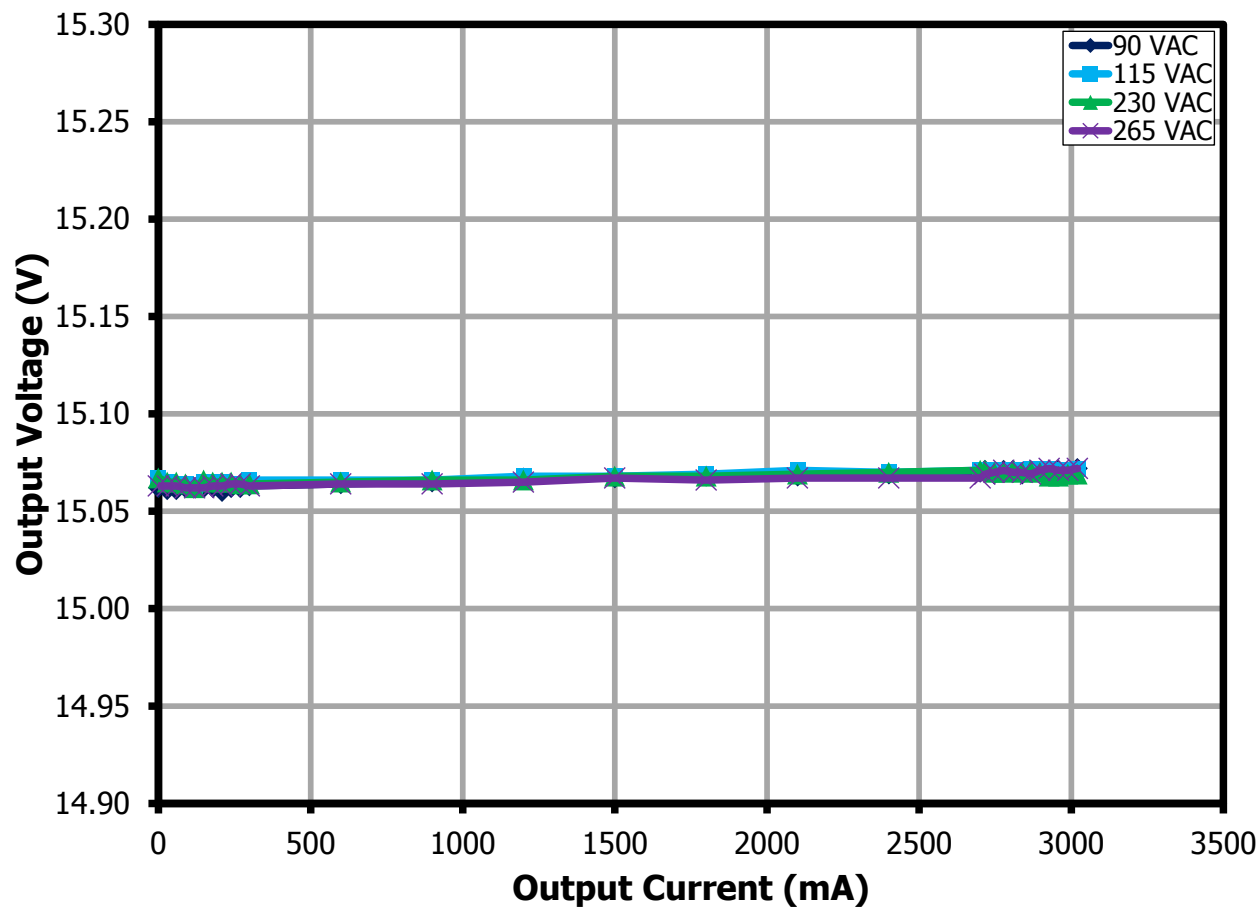
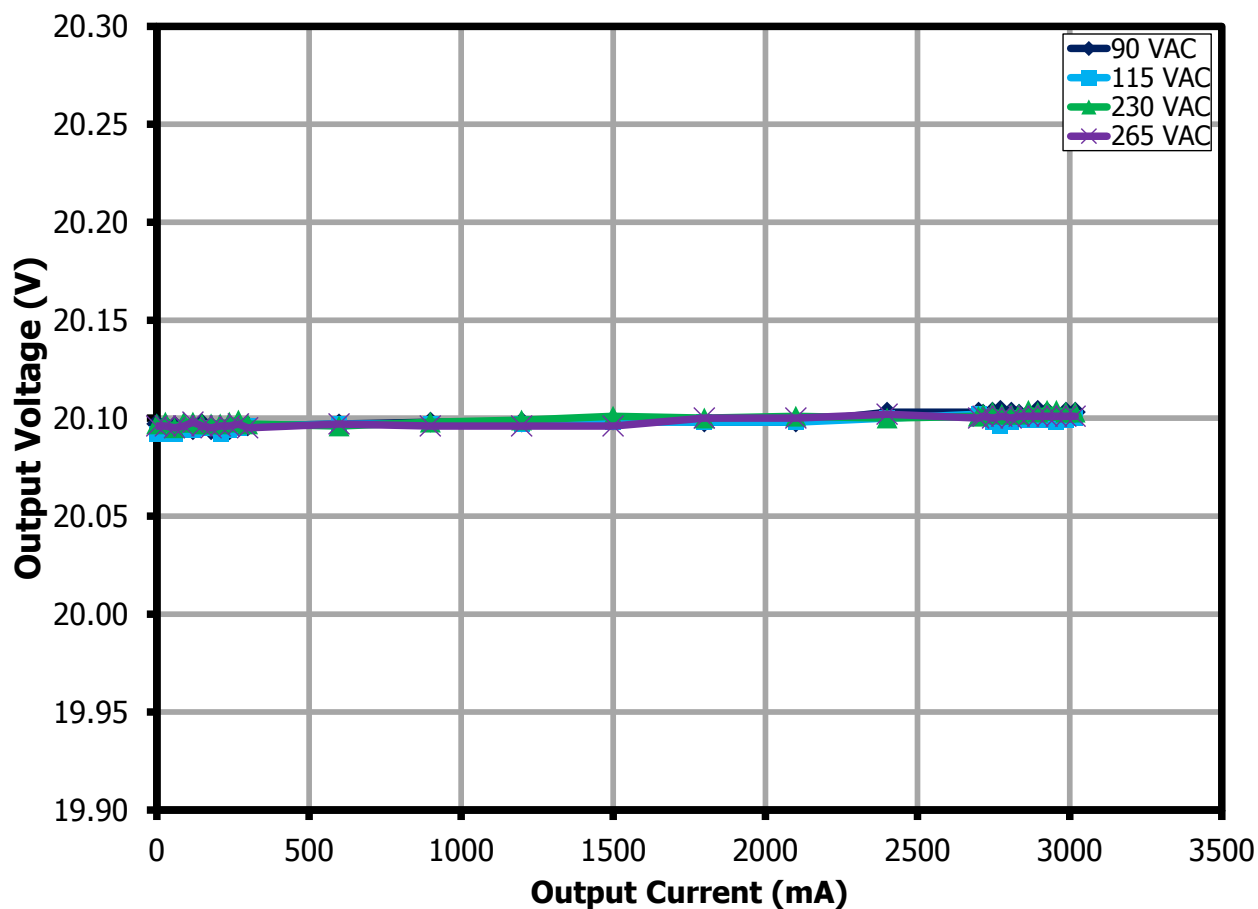


Figure 17 – Output Voltage vs. Load Current Across AC Input Voltage, Room Temperature.



14.6.4 $V_{OUT} = 20\text{ V}$ **Figure 18** – Output Voltage vs. Load Current Across AC Input Voltage, Room Temperature.

14.7 CV/CC

14.7.1 $V_{OUT} = 5\text{ V}$

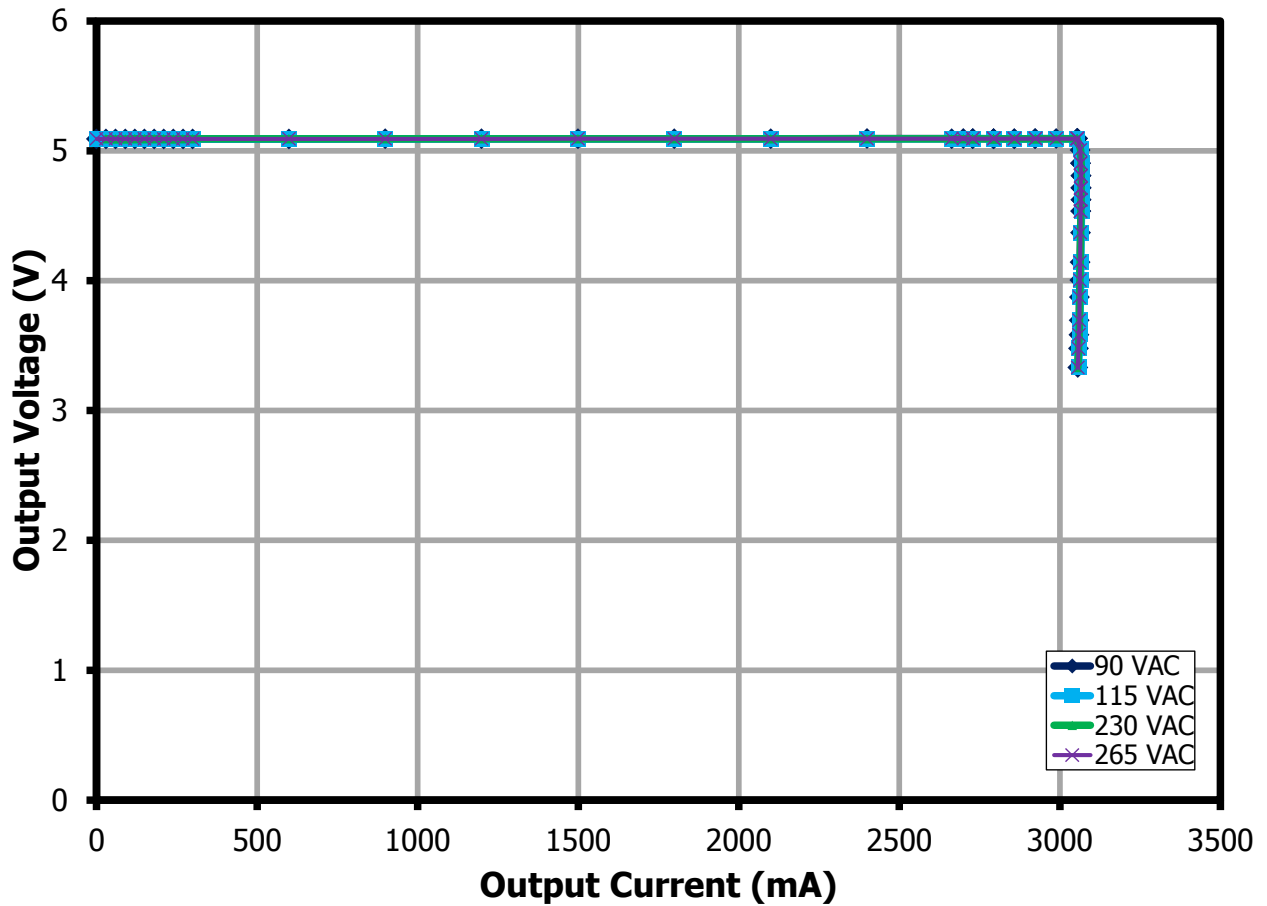
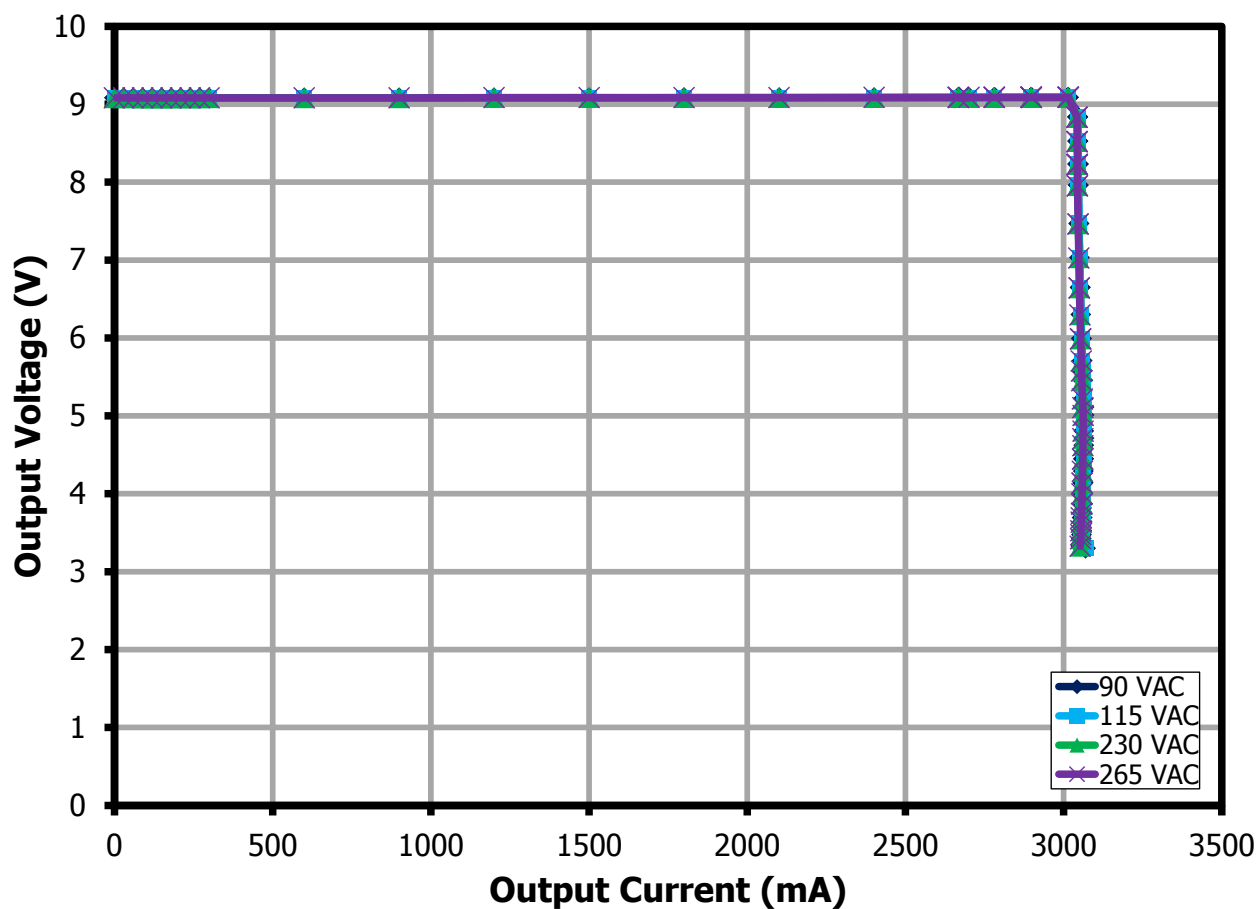
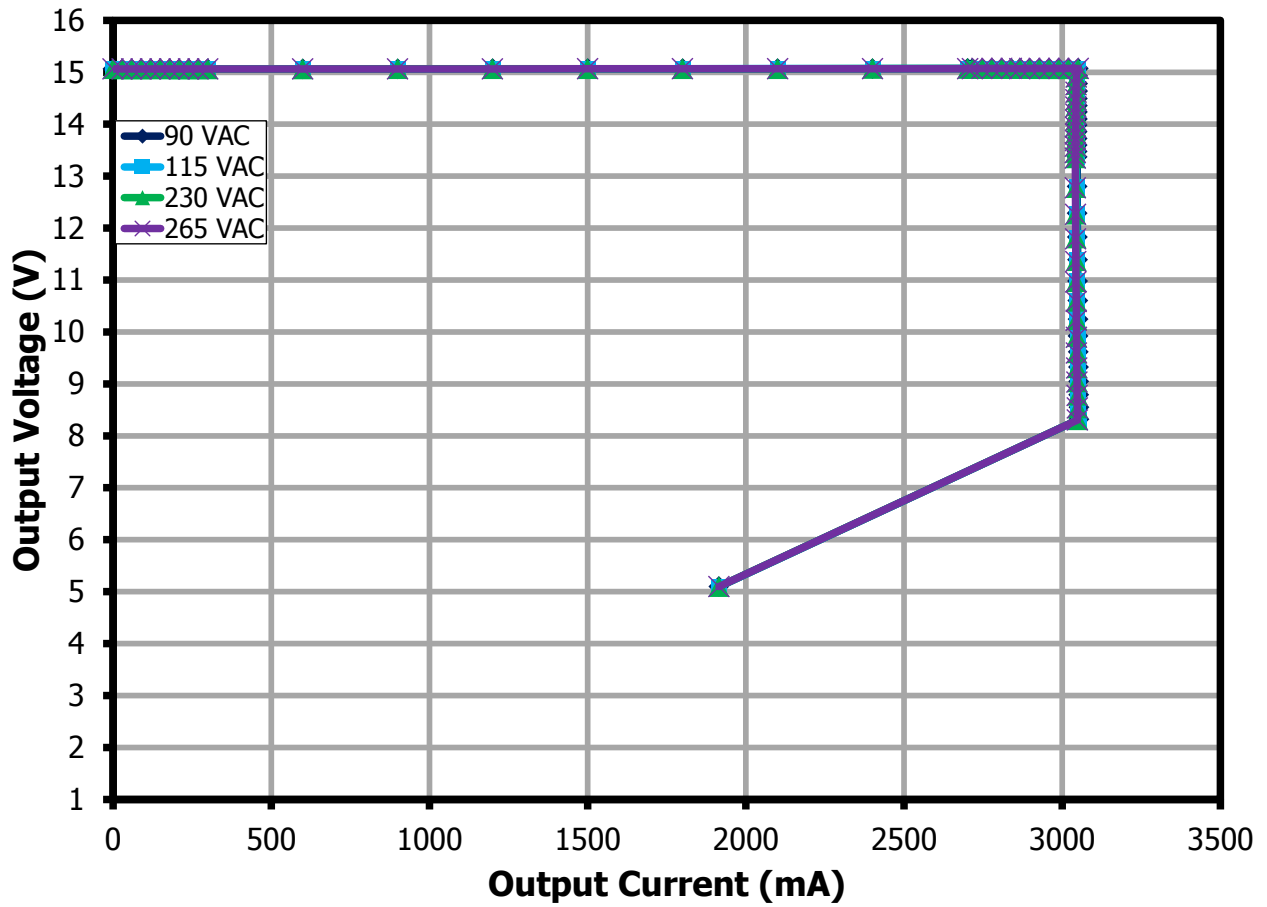
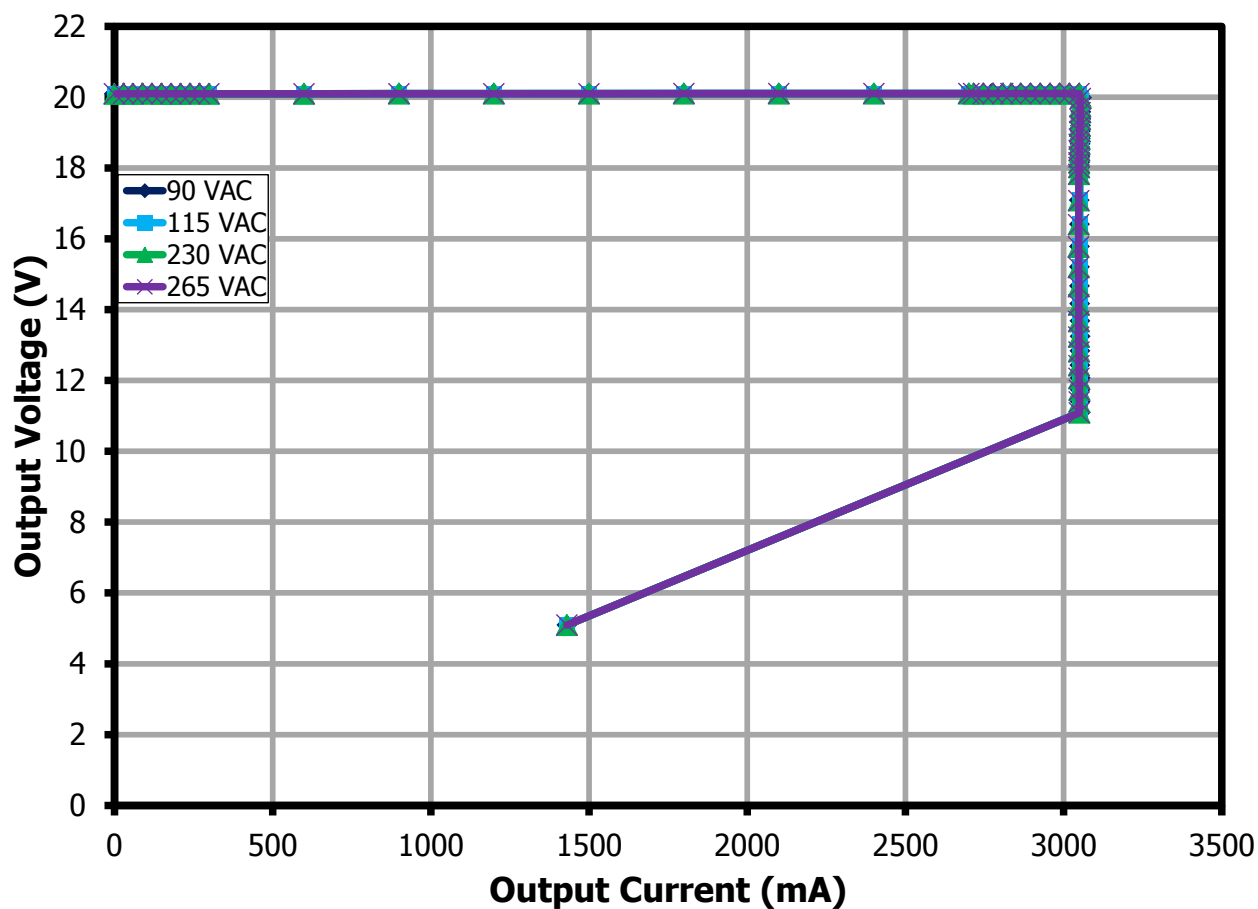


Figure 19 – Output Voltage vs. Output Current Across AC Input Voltage, Room Temperature, 5 V.

14.7.2 $V_{OUT} = 9\text{ V}$ **Figure 20** – Output Voltage vs. Output Current Across AC Input Voltage, Room Temperature, 9 V.

14.7.3 $V_{OUT} = 15\text{ V}$ **Figure 21** – Output Voltage vs. Output Current Across AC Input Voltage, Room Temperature, 15 V.

14.7.4 $V_{OUT} = 20\text{ V}$ **Figure 22** – Output Voltage vs. Output Current Across AC Input Voltage, Room Temperature, 20 V.

15 Thermal Performance

Thermal performance is measured in thermal chamber by using an adapter case enclosure.

15.1 90 VAC Input 20 V, 3 A at 26.1 °C Ambient

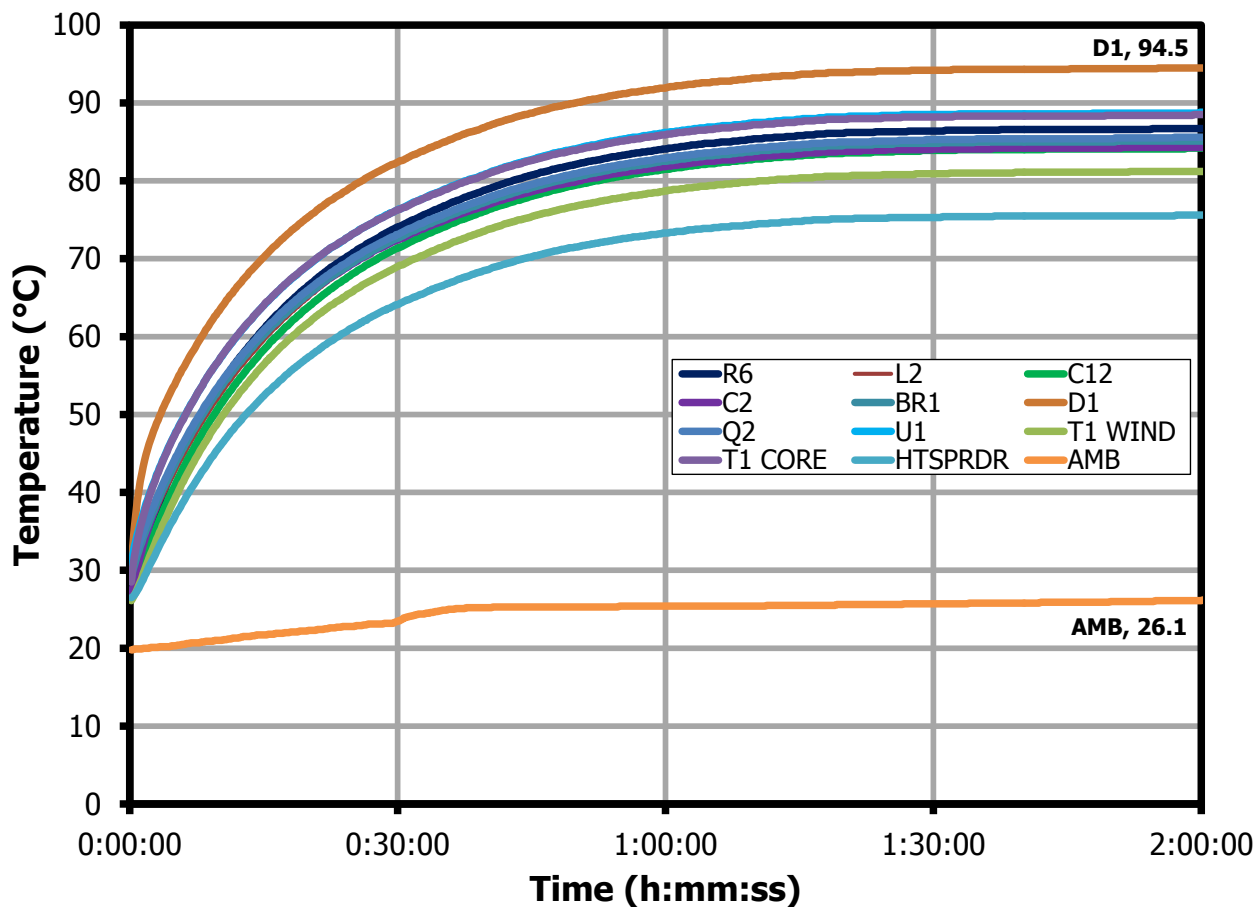


Figure 23 – Thermal performance Over Time.

Note: Adapter case temperature is 67.4 °C at an ambient of 26.1 °C.

15.2 90 VAC Input 20 V, 3 A at 45.2 °C Ambient

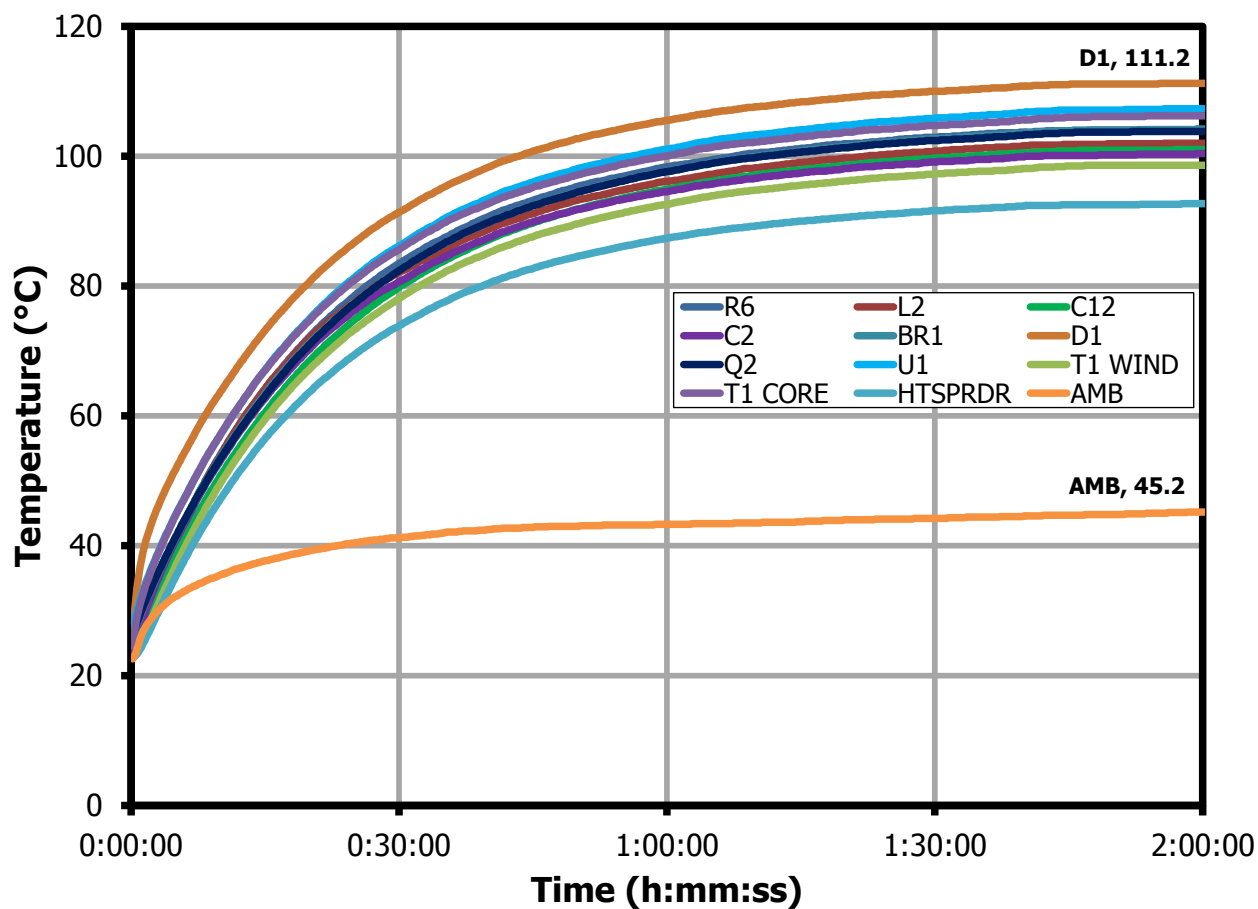


Figure 24 – Thermal Performance Over Time.

Note: Adapter Case Temperature is 85.2 °C at an Ambient of 45.2 °C.

15.3 115 VAC Input 20 V, 3 A at 45.2 °C Ambient

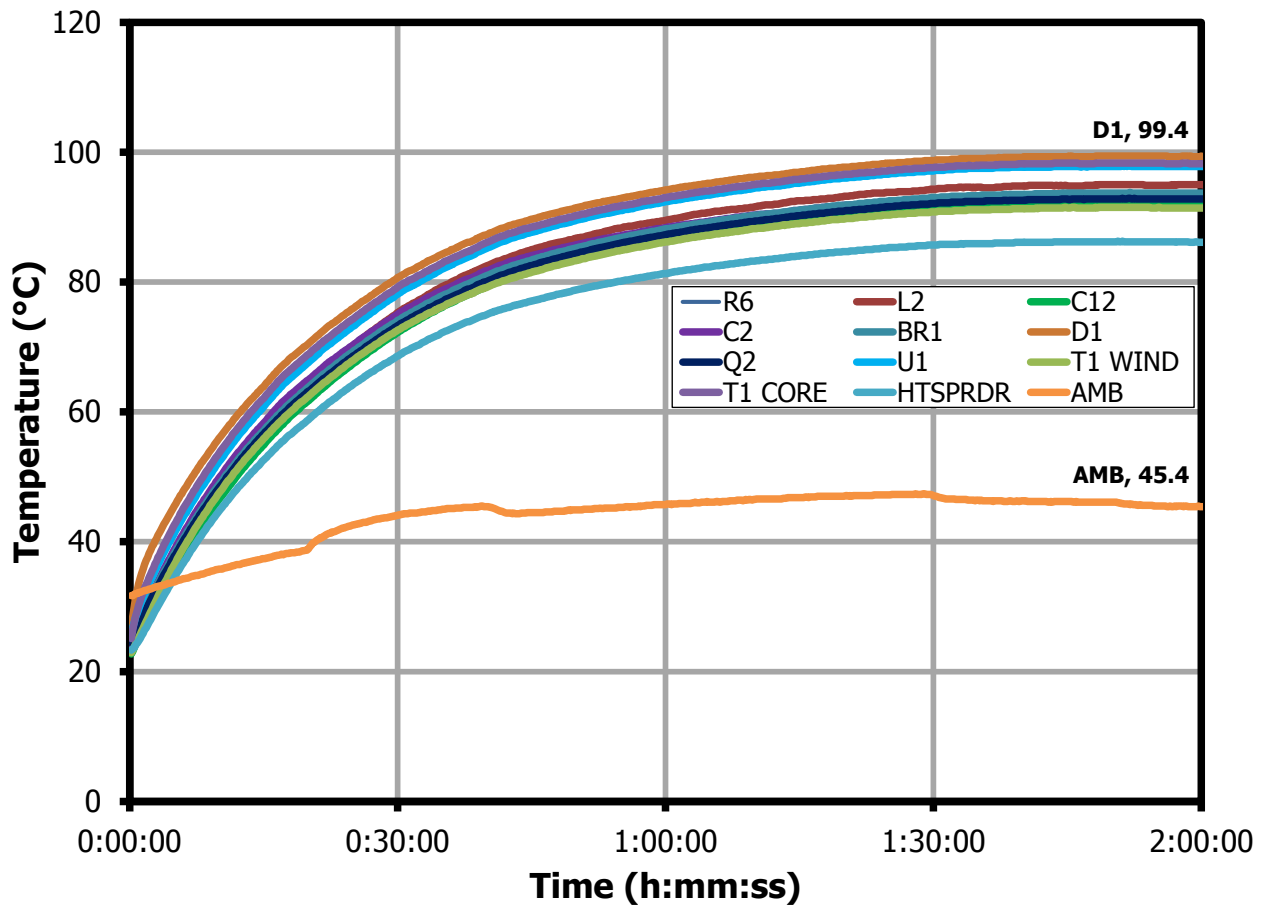


Figure 25 – Thermal performance over time

Note: Adapter case temperature is 78.8 °C at an ambient of 45.4 °C.

15.4 265 VAC Input 20 V, 3 A at 42.9 °C Ambient

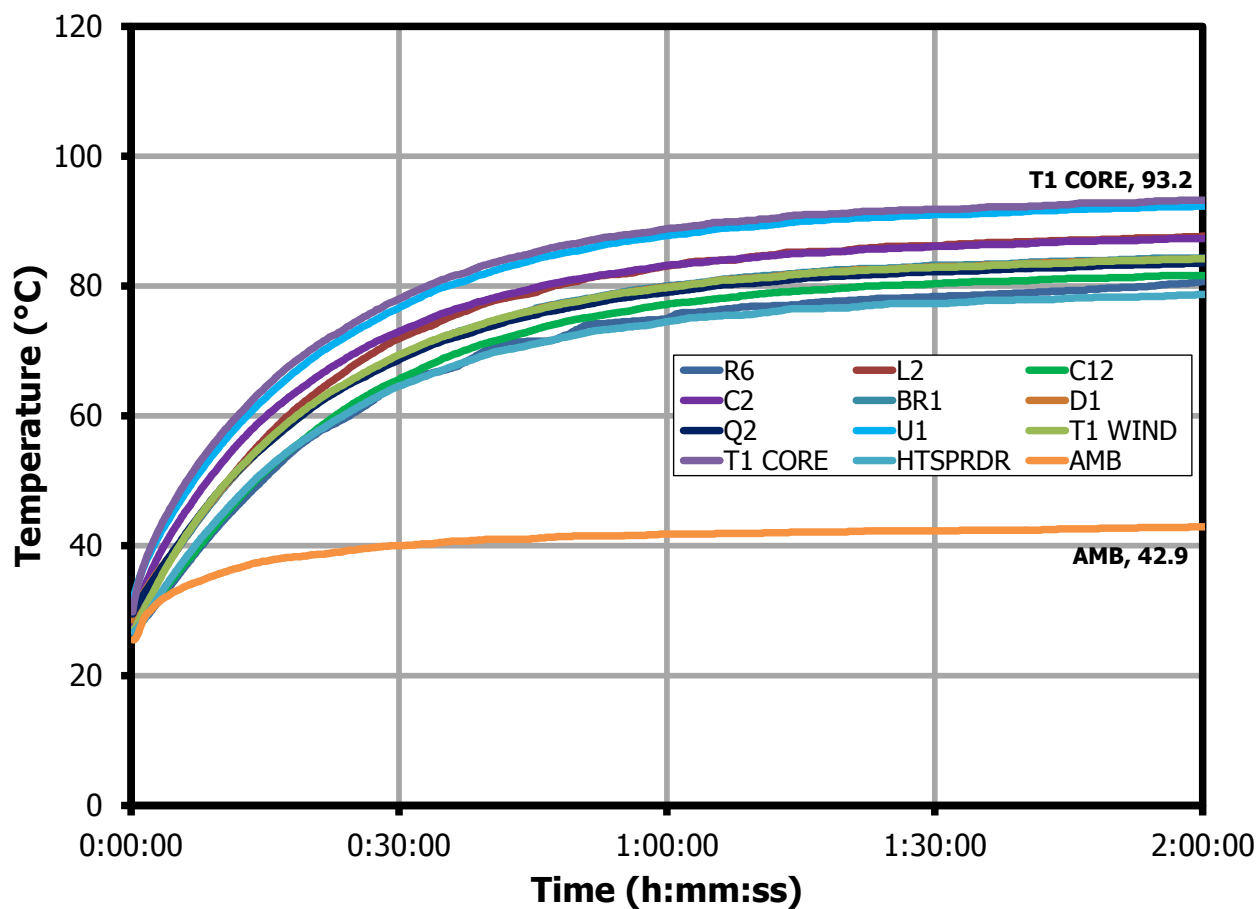


Figure 26 – Thermal Performance Over Time.

Note: Adapter case temperature is 73.7 °C at an ambient of 42.9 °C.

16 Waveforms

16.1 Load Transient Response (On the Board)

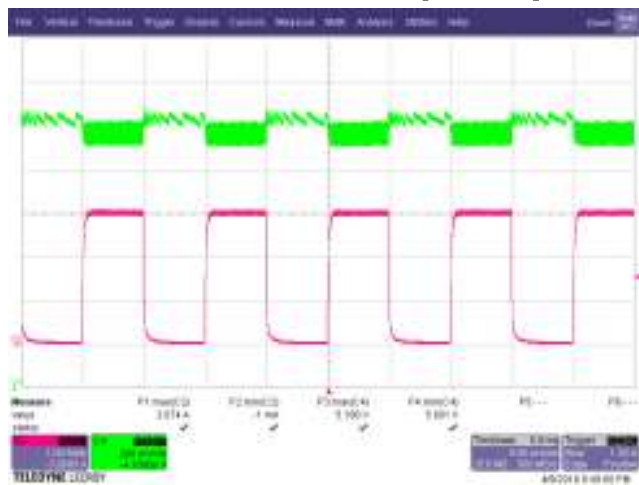


Figure 27 – Transient Response.
 90 VAC, 5.0 V, 0 – 3 A Load Step.
 V_{MIN} 5.001 V, V_{MAX} 5.196 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.

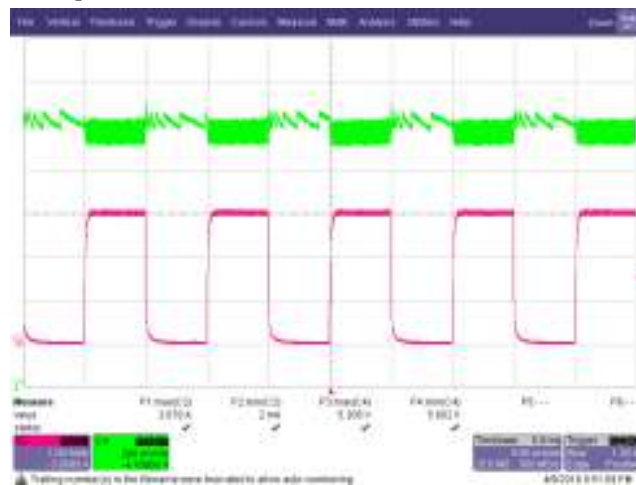


Figure 28 – Transient Response.
 265 VAC, 5.0 V, 0 – 3 A Load Step.
 V_{MIN} : 5.002 V, V_{MAX} : 5.206 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.

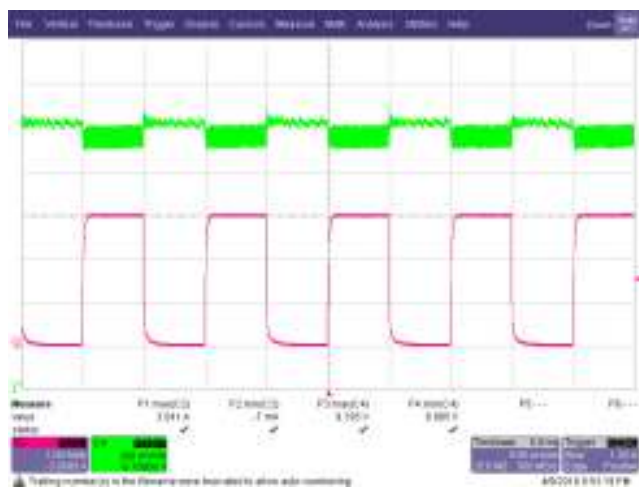


Figure 29 – Transient Response.
 90 VAC, 9 V, 0 – 3 A Load Step.
 V_{MIN} : 8.995 V, V_{MAX} : 9.195 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.

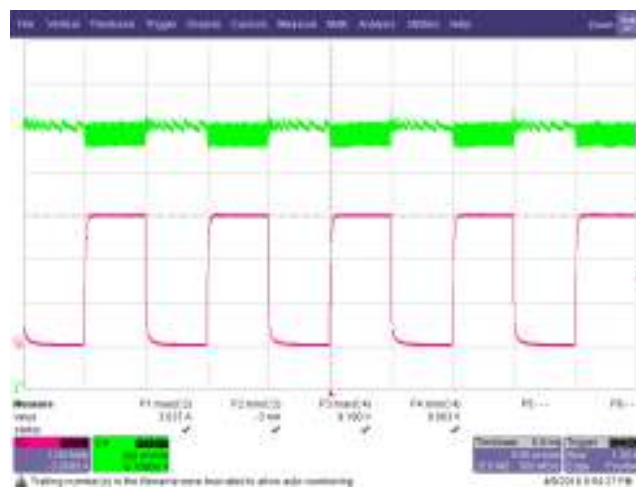


Figure 30 – Transient Response.
 265 VAC, 9 V, 0 – 3 A Load Step.
 V_{MIN} : 9.003 V, V_{MAX} : 9.19 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.



Figure 31 – Transient Response.
 90 VAC, 15 V, 0 – 3 A Load Step.
 V_{MIN} : 14.983 V, V_{MAX} : 15.189 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.

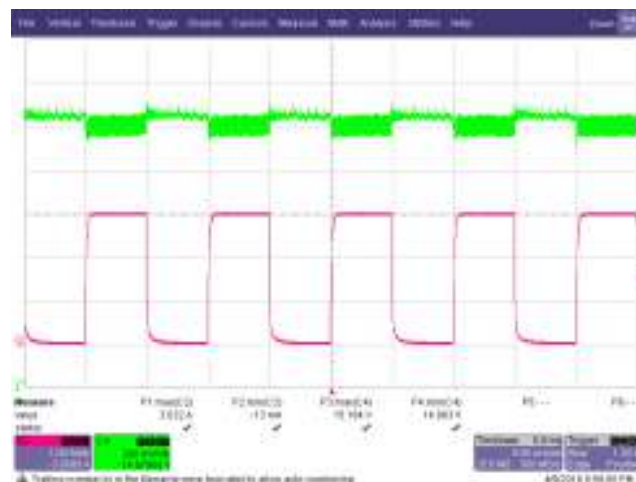


Figure 32 – Transient Response.
 265 VAC, 15 V, 0 – 3 A Load Step.
 V_{MIN} : 14.983 V, V_{MAX} : 15.184 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.

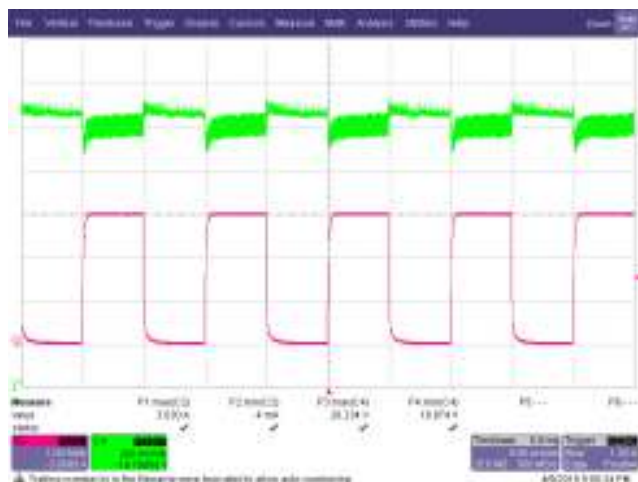


Figure 33 – Transient Response.
 90 VAC, 20 V, 0 – 3 A Load Step.
 V_{MIN} : 19.974 V, V_{MAX} : 20.234 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.

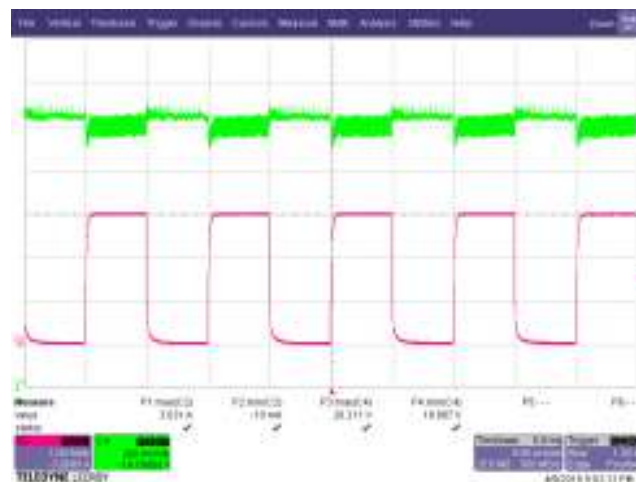


Figure 34 – Transient Response.
 265 VAC, 20 V, 0 – 3 A Load Step.
 V_{MIN} : 19.997 V, V_{MAX} : 20.211 V.
 Upper: V_{OUT} , 0.2 V / div., 5 ms / div.
 Lower: I_{LOAD} , 1 A / div.

16.2 *Switching Waveforms*

16.2.1 Drain Voltage and Current



Figure 35 – Drain Voltage and Current Waveforms.
90 VAC, 5.0 V, 3 A Load, (209.5 V_{MAX}).
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 1 A / div., 10 μs / div.



Figure 36 – Drain Voltage and Current Waveforms.
265 VAC, 5 V, 5 A Load, (451 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A / div., 10 μs / div.

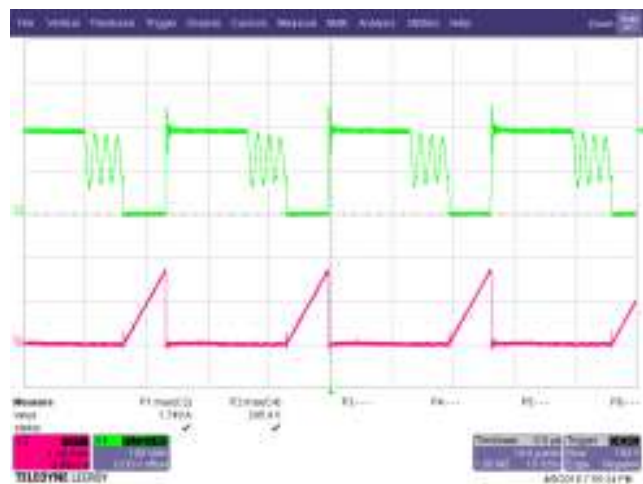


Figure 37 – Drain Voltage and Current Waveforms.
90 VAC, 9.0 V, 3 A Load, (245.4 V_{MAX}).
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 1 A / div., 10 μs / div.



Figure 38 – Drain Voltage and Current Waveforms.
265 VAC, 9.0 V, 3 A Load, (489 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A / div., 10 μs / div.



Figure 39 – Drain Voltage and Current Waveforms.
90 VAC, 15 V, 3 A Load, (298 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A / div., 5 μs / div.



Figure 40 – Drain Voltage and Current Waveforms.
265 VAC, 15 V, 3 A Load, (537 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A / div., 5 μs / div.



Figure 41 – Drain Voltage and Current Waveforms.
90 VAC, 20 V, 3 A Load, (328 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A / div., 5 μs / div.



Figure 42 – Drain Voltage and Current Waveforms.
265 VAC, 9.0 V, 3 A Load, (574 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A / div., 5 μs / div.

16.2.2 SR FET Voltage



Figure 43 – SR FET Voltage Waveforms.
90 VAC, 5 V, 3 A Load, (35.16 V_{MAX}).
C4: SR_V_{DRAIN}, 10 V / div., 10 μs / div.



Figure 44 – SR FET Voltage Waveforms.
265 VAC, 5 V, 3 A Load, (88.3 V_{MAX}).
C4: SR_V_{DRAIN}, 20 V / div., 10 μs / div.



Figure 45 – SR FET Voltage Waveforms.
90 VAC, 9 V, 3 A Load, (36.83 V_{MAX}).
C4: SR_V_{DRAIN}, 10 V / div., 10 μs / div.



Figure 46 – SR FET Voltage Waveforms.
265 VAC, 9 V, 3 A Load, (88.1 V_{MAX}).
C4: SR_V_{DRAIN}, 20 V / div., 10 μs / div.

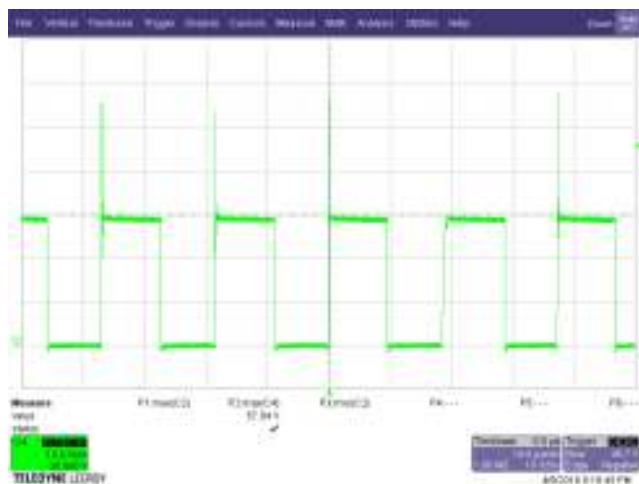


Figure 47 – SR FET Voltage Waveforms.
90 VAC, 15 V, 3 A Load, (57.94 V_{MAX}).
C4: SR_V_{DRAIN}, 10 V / div., 10 μs / div.



Figure 48 – SR FET Voltage Waveforms.
265 VAC, 15 V, 3 A Load, (86.5 V_{MAX}).
C4: SR_V_{DRAIN}, 20 V / div., 5 μs / div.



Figure 49 – SR FET Voltage Waveforms.
90 VAC, 20 V, 3 A Load, (74.8 V_{MAX}).
C4: SR_V_{DRAIN}, 20 V / div., 5 μs / div.

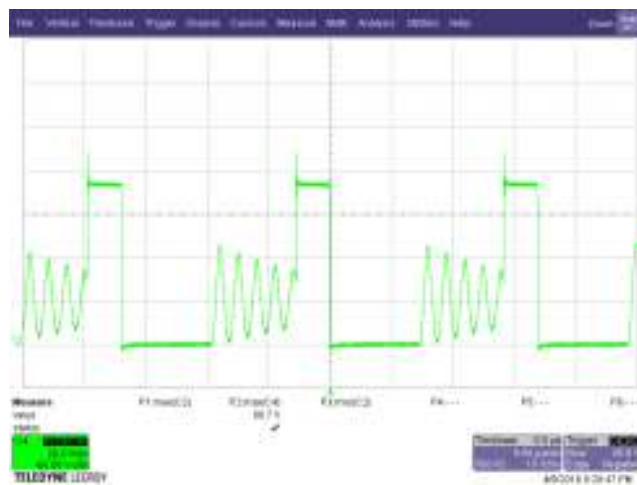


Figure 50 – SR FET Voltage Waveforms.
265 VAC, 20 V, 3 A Load, (88.7 V_{MAX}).
C4: SR_V_{DRAIN}, 20 V / div., 5 μs / div.

16.3 ***Output Ripple Measurements***

16.3.1 Ripple Measurement Technique

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

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 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).

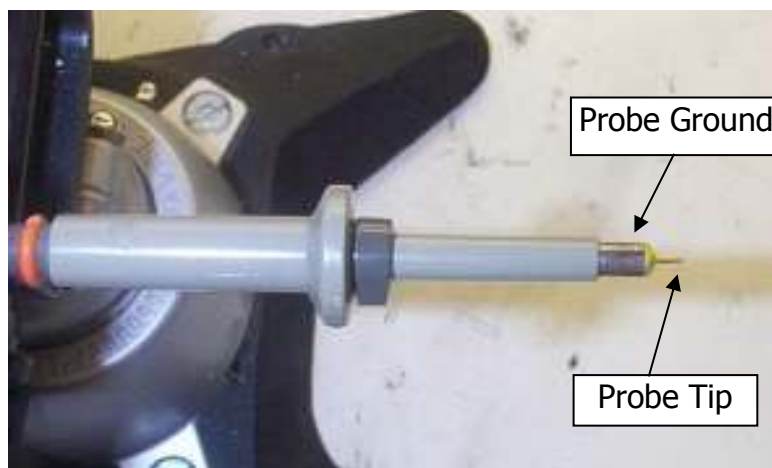


Figure 51 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)



Figure 52 – Oscilloscope Probe with Probe Master (www.probemaster.com) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

16.3.2 Ripple Amplitude vs. Line

16.3.2.1 5.0 V Ripple Plot

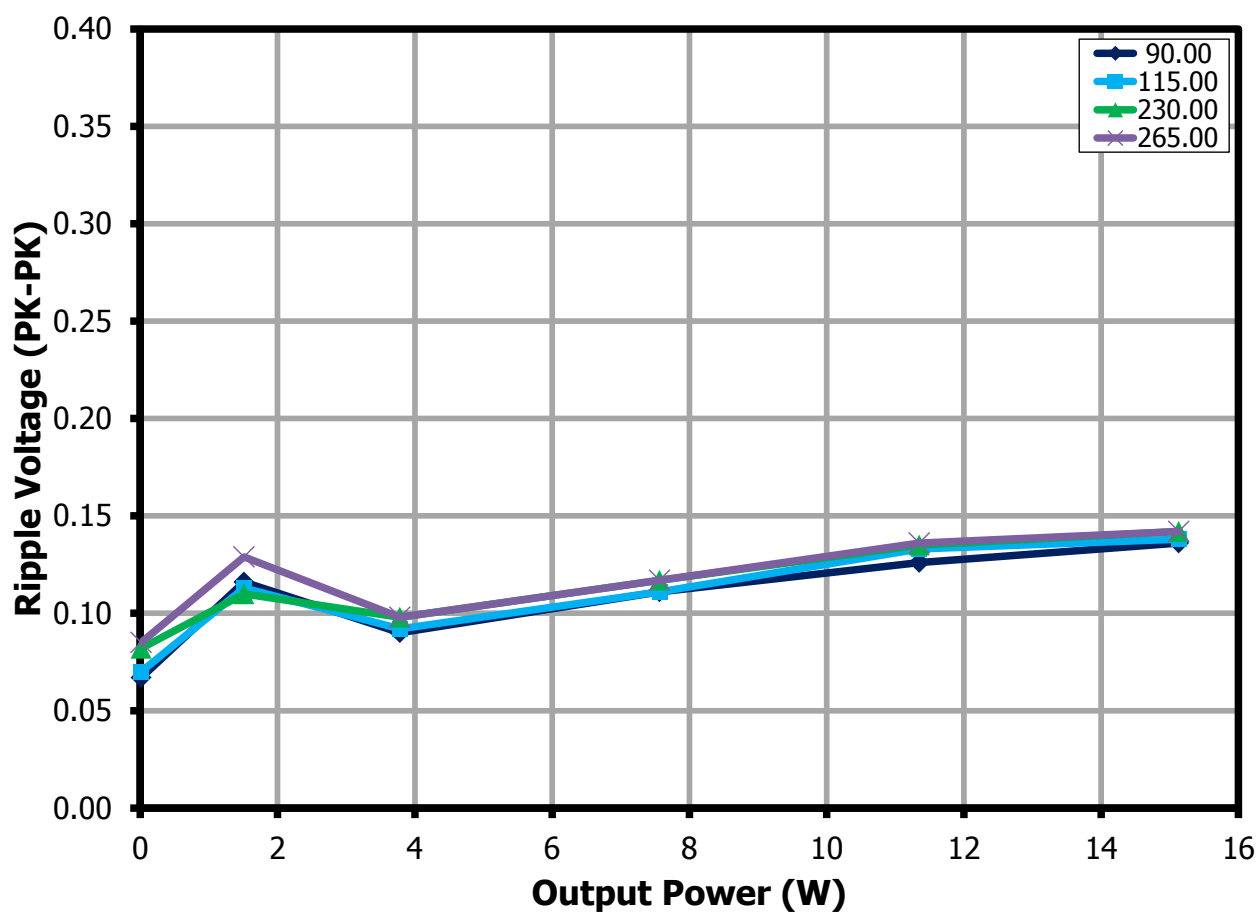
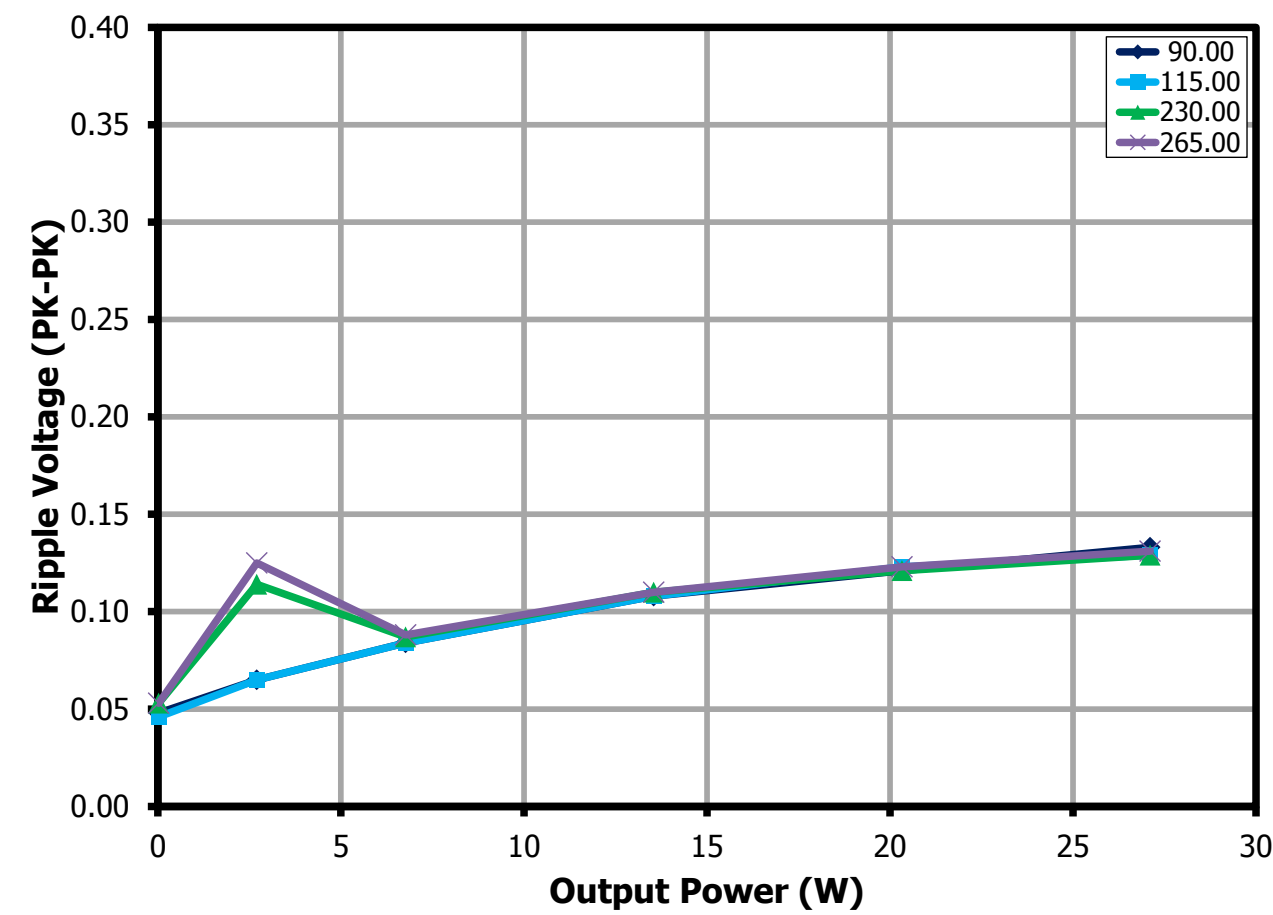


Figure 53 – Ripple Amplitude vs. Output Power 5 V.

16.3.2.2 9.0 V Ripple Plot

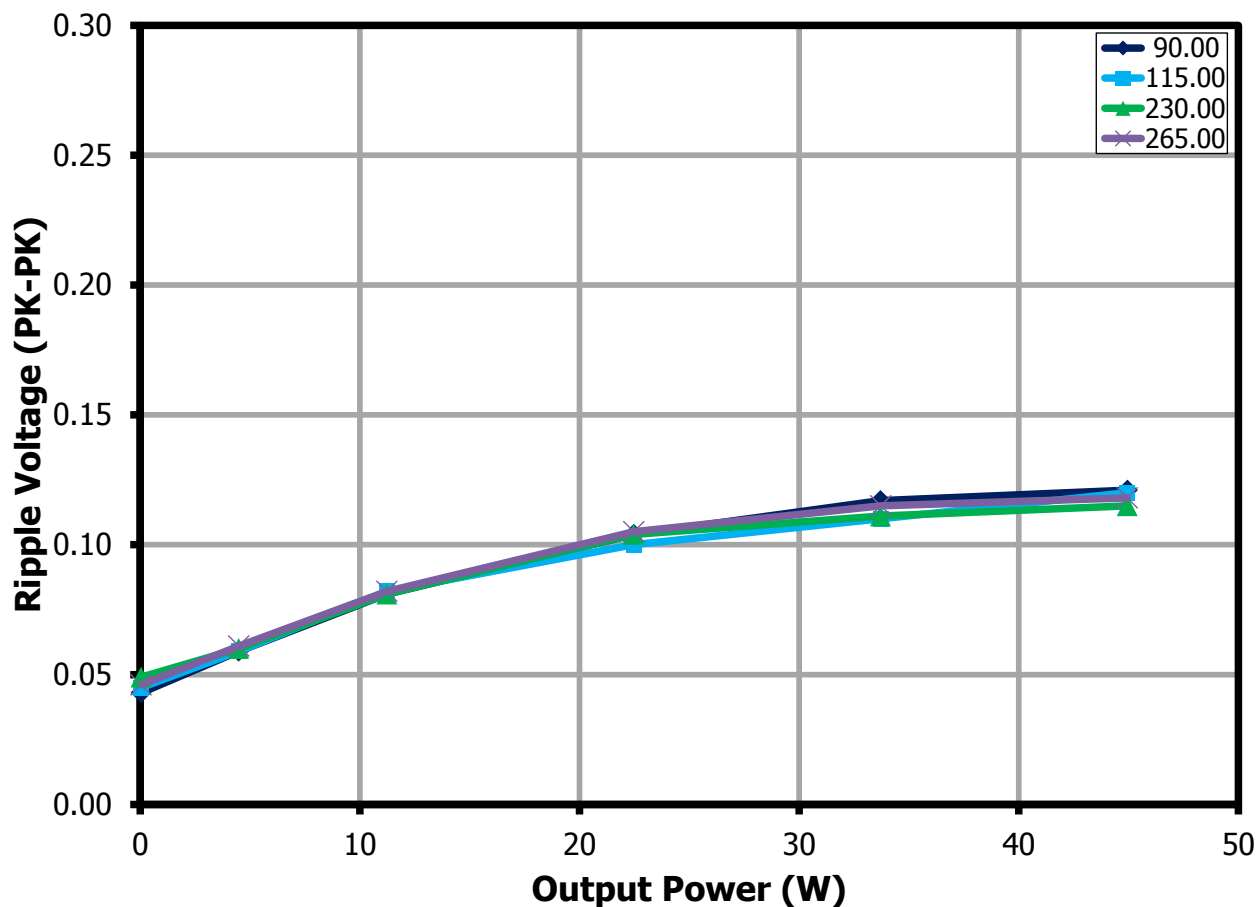


Input	90 VAC	115 VAC	230 VAC	265 VAC
Max Ripple (mV)	133	129	129	131

Figure 54 – Ripple Amplitude vs. Output Power 9 V.



16.3.2.3 15.0 V Ripple Plot



Input	90 VAC	115 VAC	230 VAC	265 VAC
Max Ripple (mV)	121	120	115	118

Figure 55 – Ripple Amplitude vs. Output Power 15 V.

16.3.2.4 20.0 V Ripple Plot

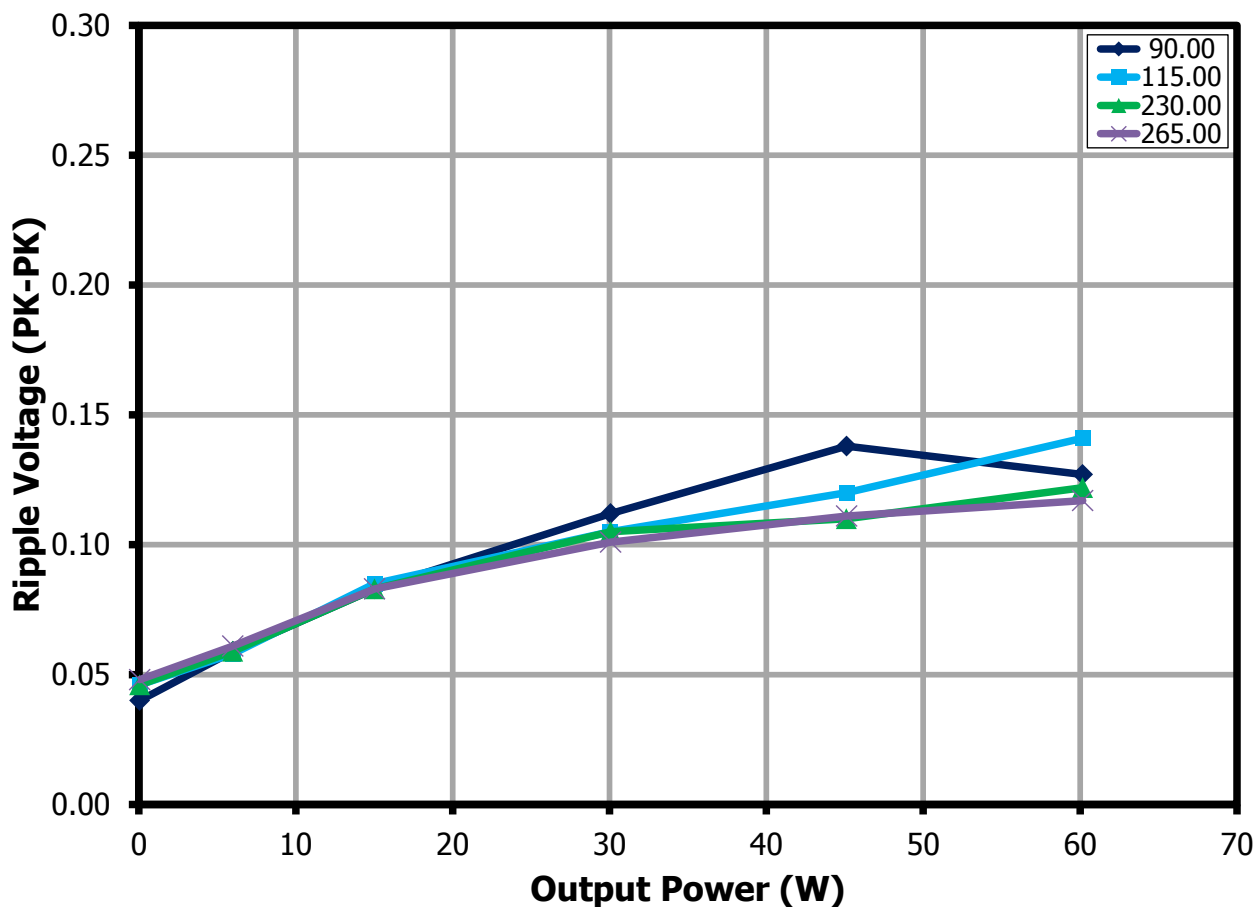


Figure 56 – Ripple Amplitude vs. Output Power 20 V.

16.3.2.5 5 V Ripple waveforms

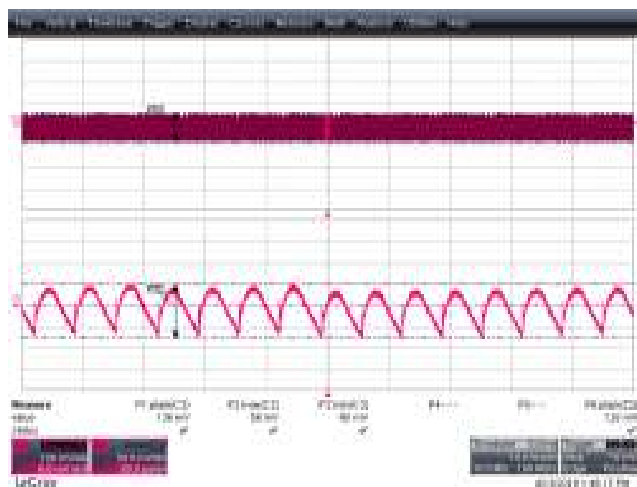


Figure 57 – Output Ripple.(pk-pk – 136 mV)
90 VAC Input 5.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

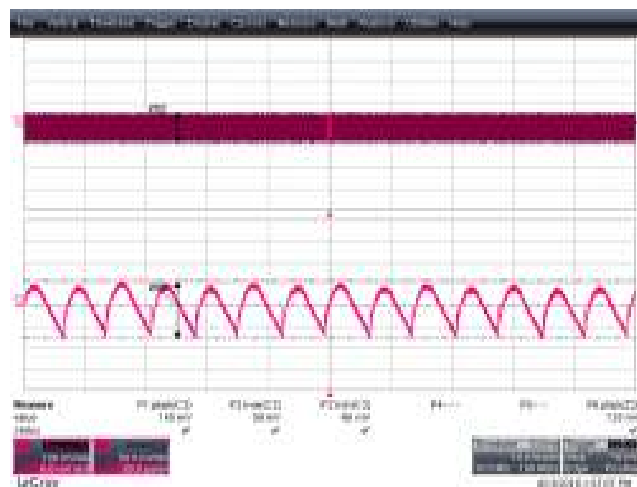


Figure 58 – Output Ripple.(pk-pk – 145 mV)
265 VAC Input 5.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

16.3.2.6 9 V Ripple waveforms



Figure 59 – Output Ripple.(pk-pk – 129 mV)
90 VAC Input, 9.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

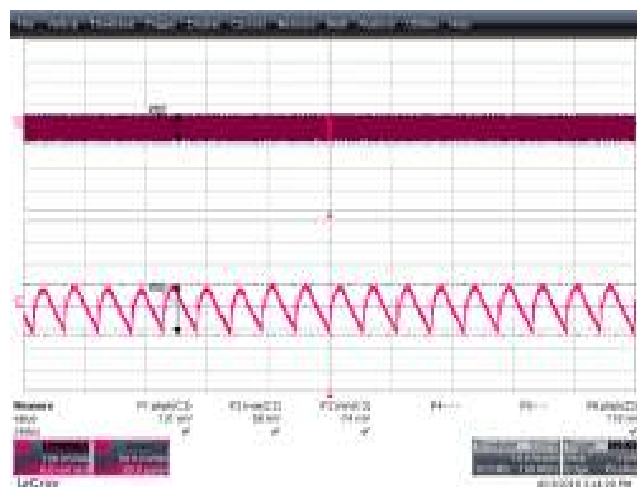


Figure 60 – Output Ripple.(pk-pk – 131 mV)
265 VAC Input 9.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

16.3.2.7 15 V Ripple waveforms



Figure 61 – Output Ripple.(pk-pk – 123 mV)
90 VAC Input, 15.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

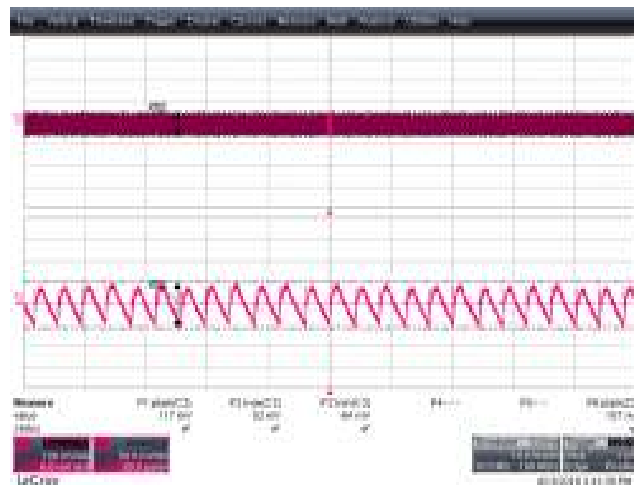


Figure 62 – Output Ripple.(pk-pk – 117 mV)
265 VAC Input 15.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

16.3.2.8 20 V Ripple waveforms

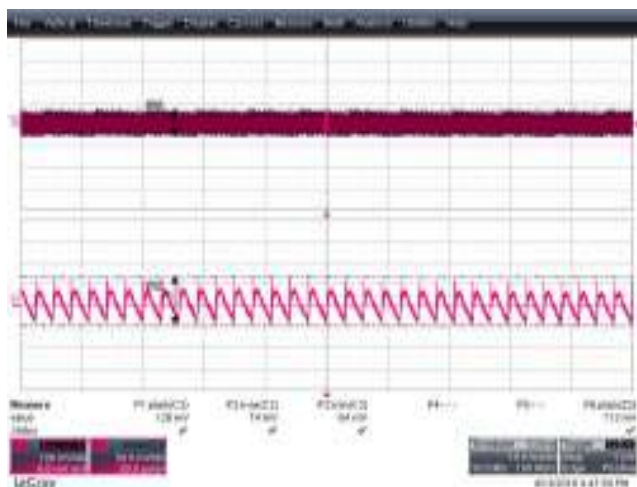


Figure 63 – Output Ripple.(pk-pk – 128 mV)
90 VAC Input, 20.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

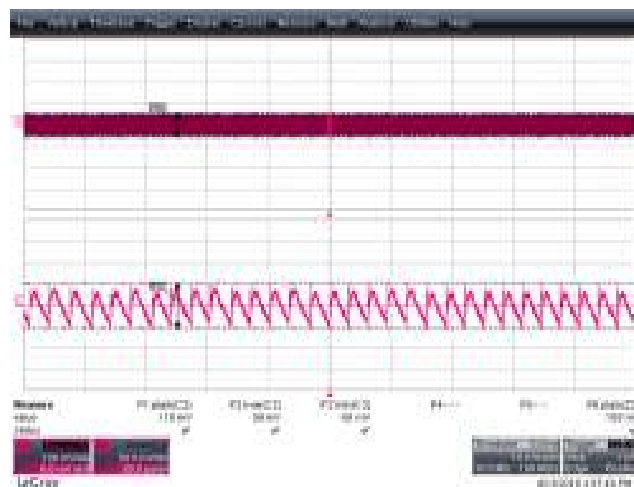


Figure 64 – Output Ripple.(pk-pk – 118 mV)
265 VAC Input 15.0 V, 3 A Load.
 V_{OUT} , 100 mV / div., 10 ms / div.

17 Conducted EMI

17.1 Floating Output (PK / AV)

17.1.1 5 V, 3 A

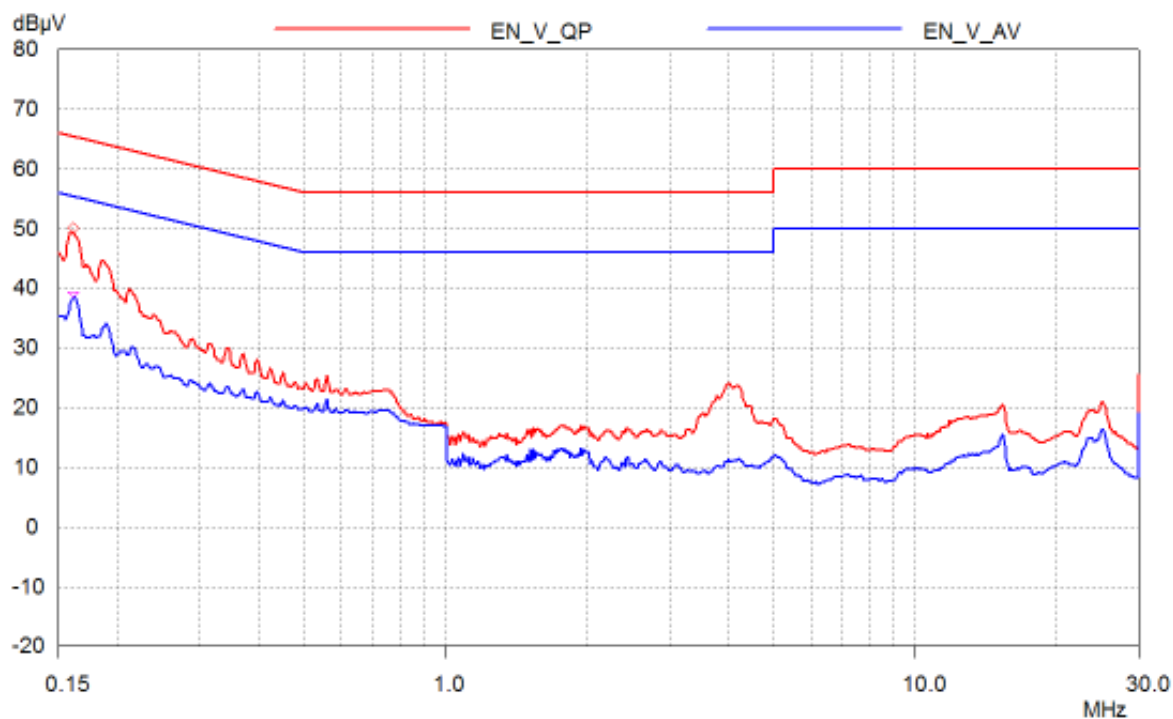


Figure 65 – Floating Ground EMI, 5 V / 3 A Load for 115 VAC

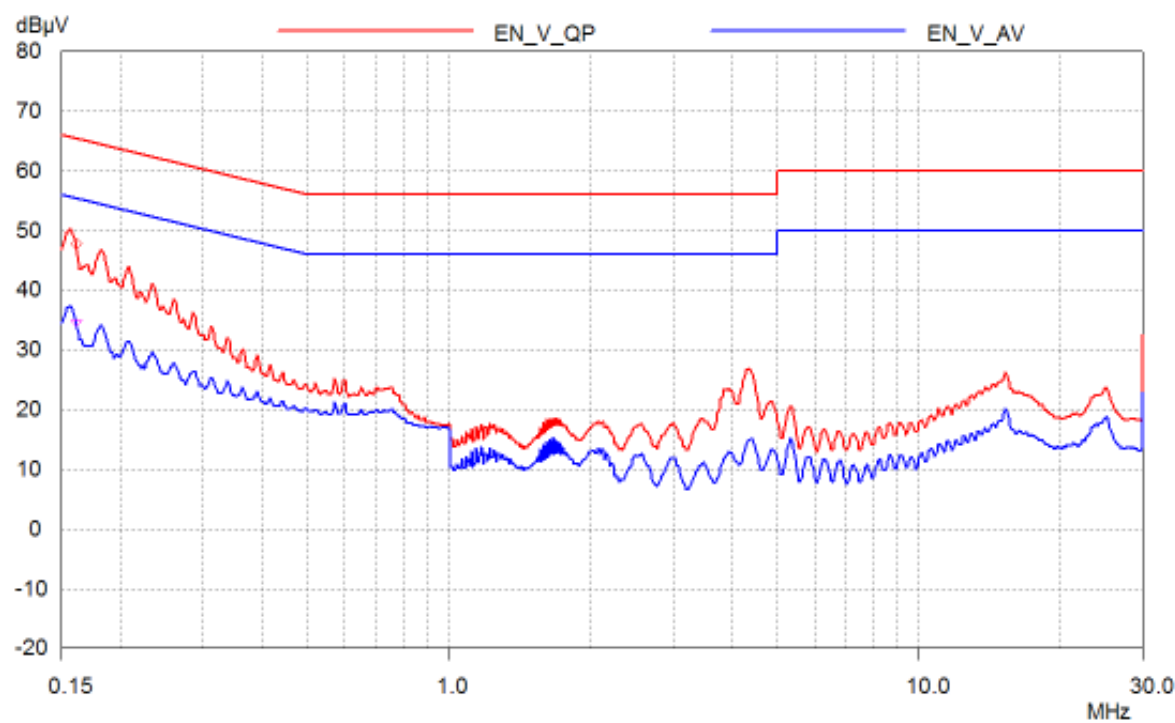
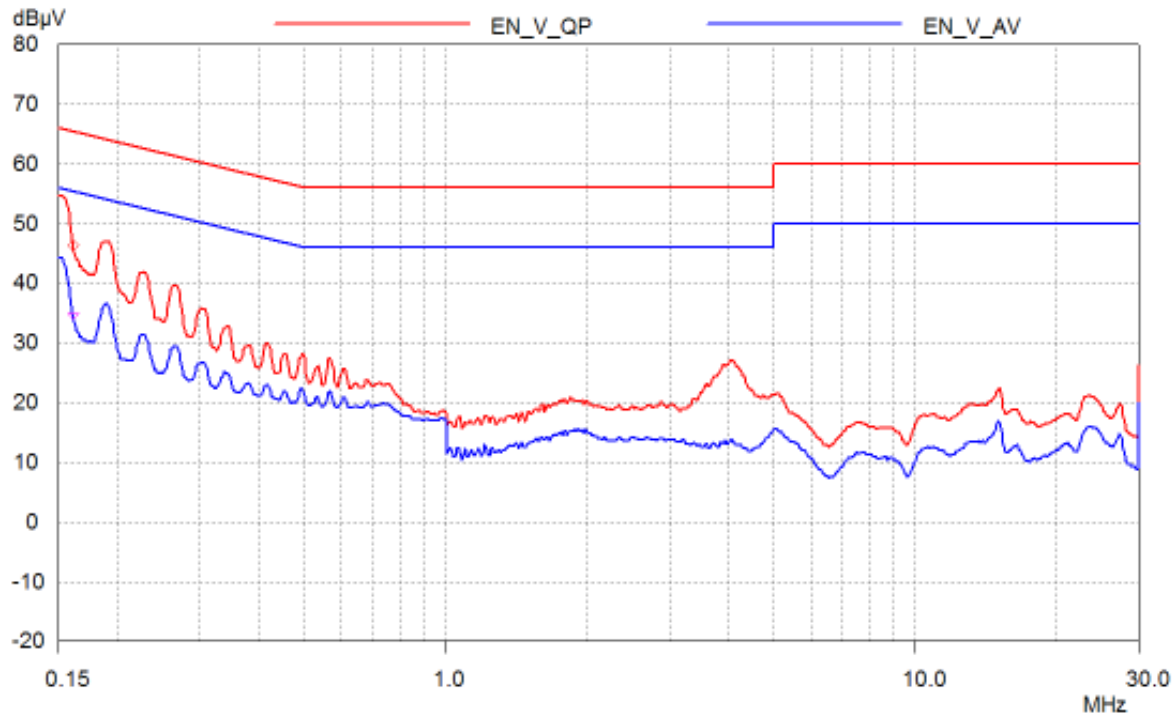


Figure 66 – Floating Ground EMI, 5 V / 3 A Load for 230 VAC.



17.1.2 9 V, 3 A

**Figure 67** – Floating Ground EMI, 9 V / 3 A Load for 115 VAC.

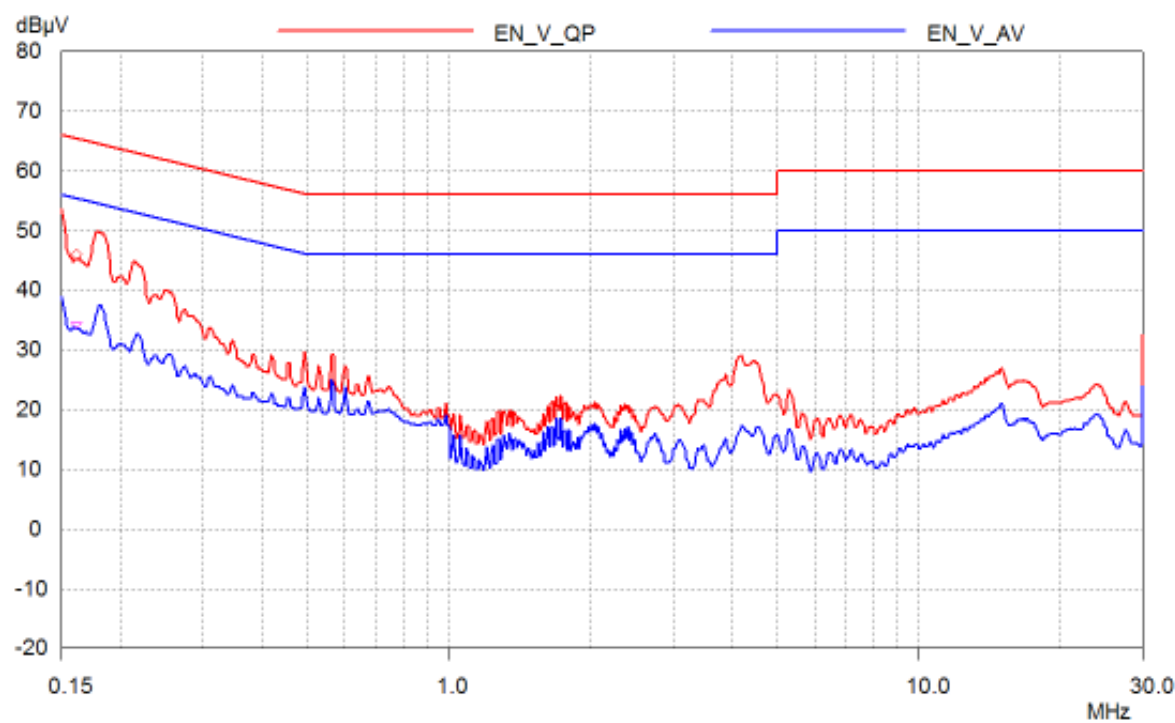
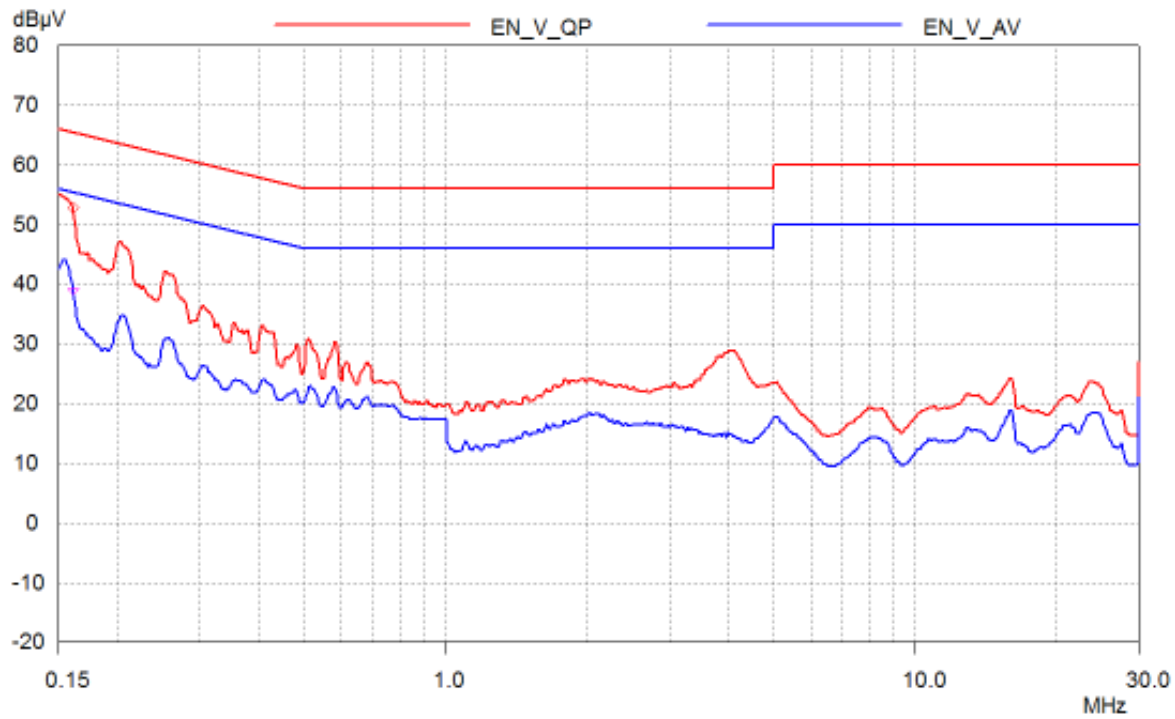


Figure 68 – Floating Ground EMI, 9 V / 3 A Load for 230 VAC.



17.1.3 15 V, 3 A

**Figure 69** – Floating Ground EMI, 15 V / 3 A Load for 115 VAC.

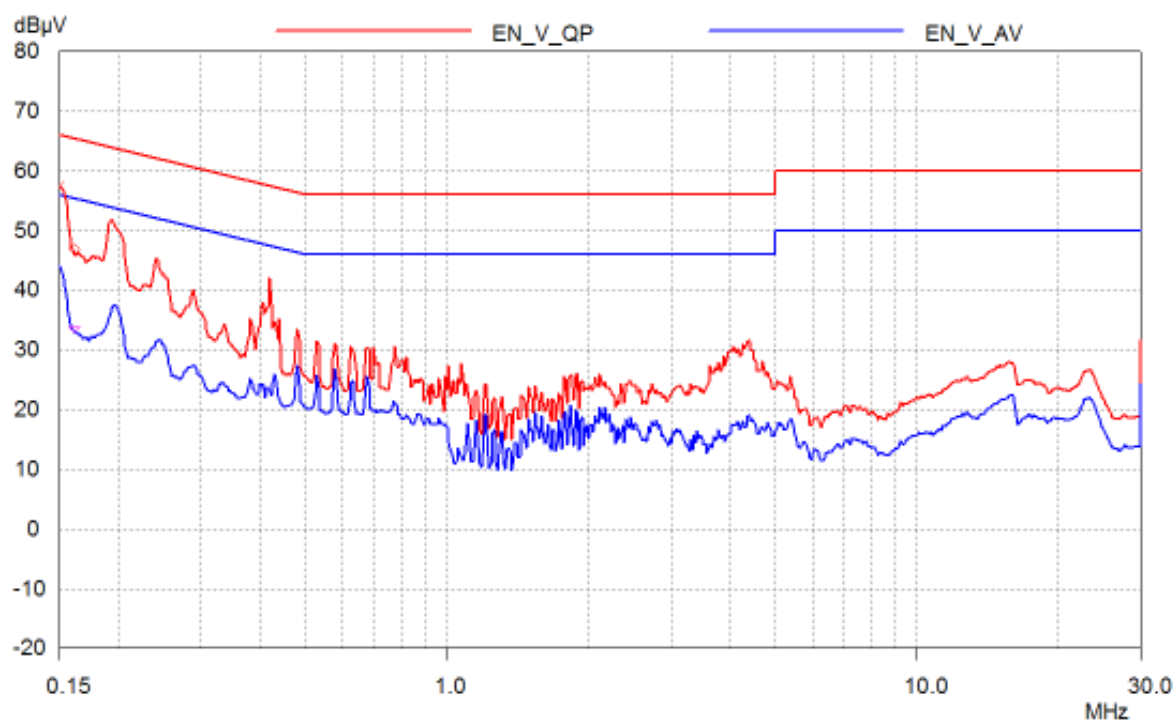
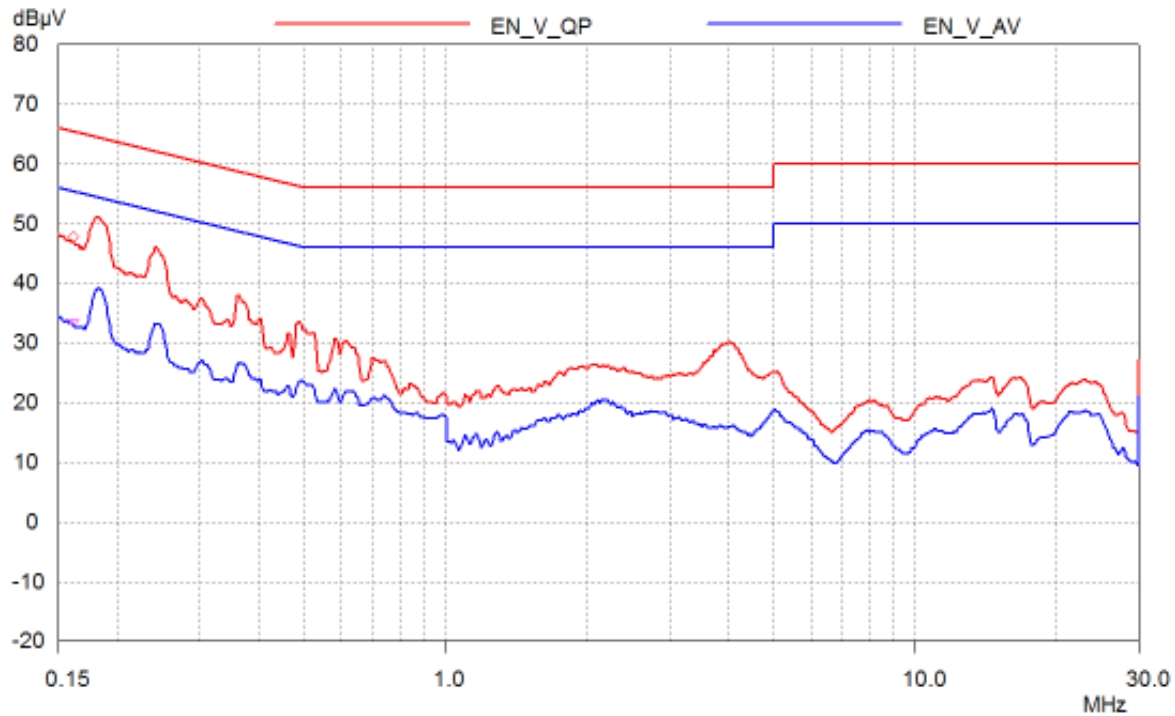


Figure 70 – Floating Ground EMI, 15 V / 3 A Load for 230 VAC.

17.1.4 20 V, 3 A

**Figure 71** – Floating Ground EMI, 20 V / 3 A Load for 115 VAC.

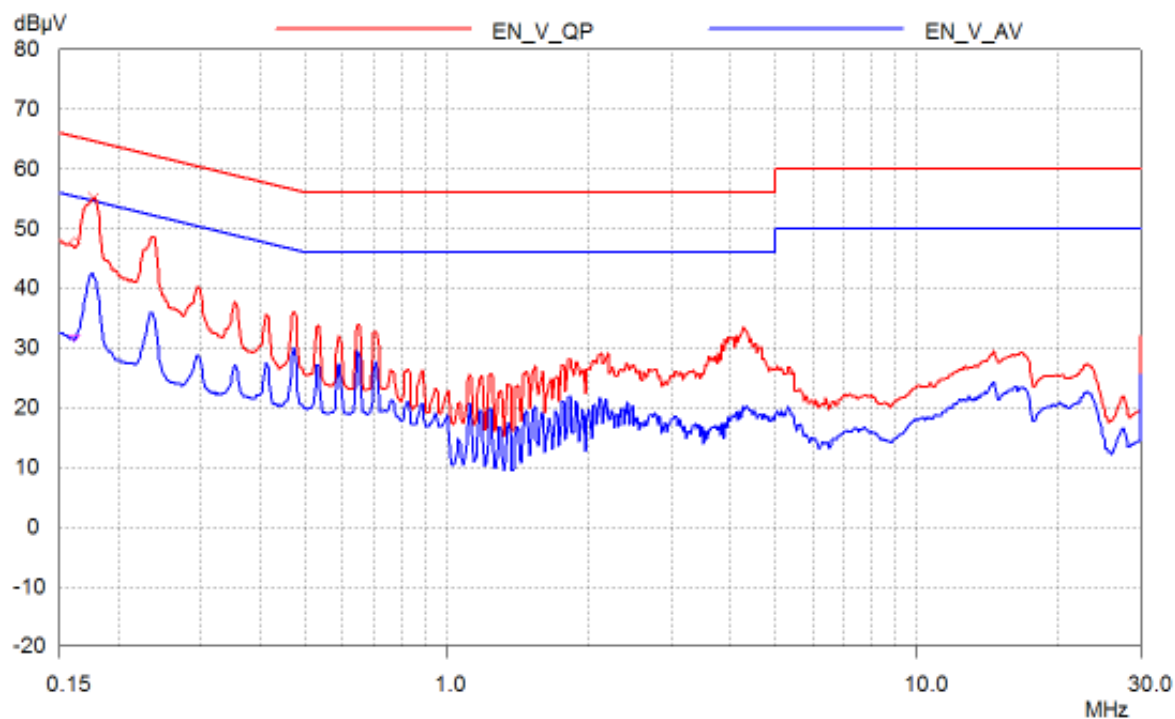


Figure 72 – Floating Ground EMI, 20 V / 3 A Load for 230 VAC.

17.2 Earth Ground (PK / AV)

17.2.1 5 V, 3 A

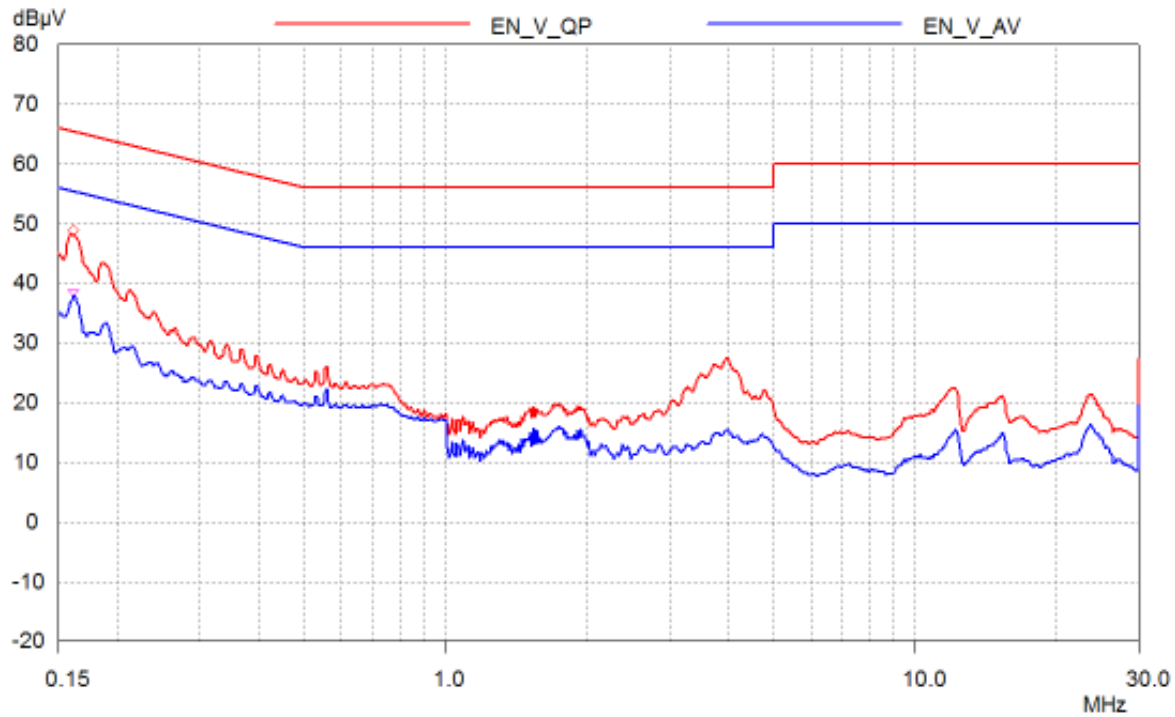


Figure 73 – Earth Ground EMI, 5 V / 3 A Load for 115 VAC.

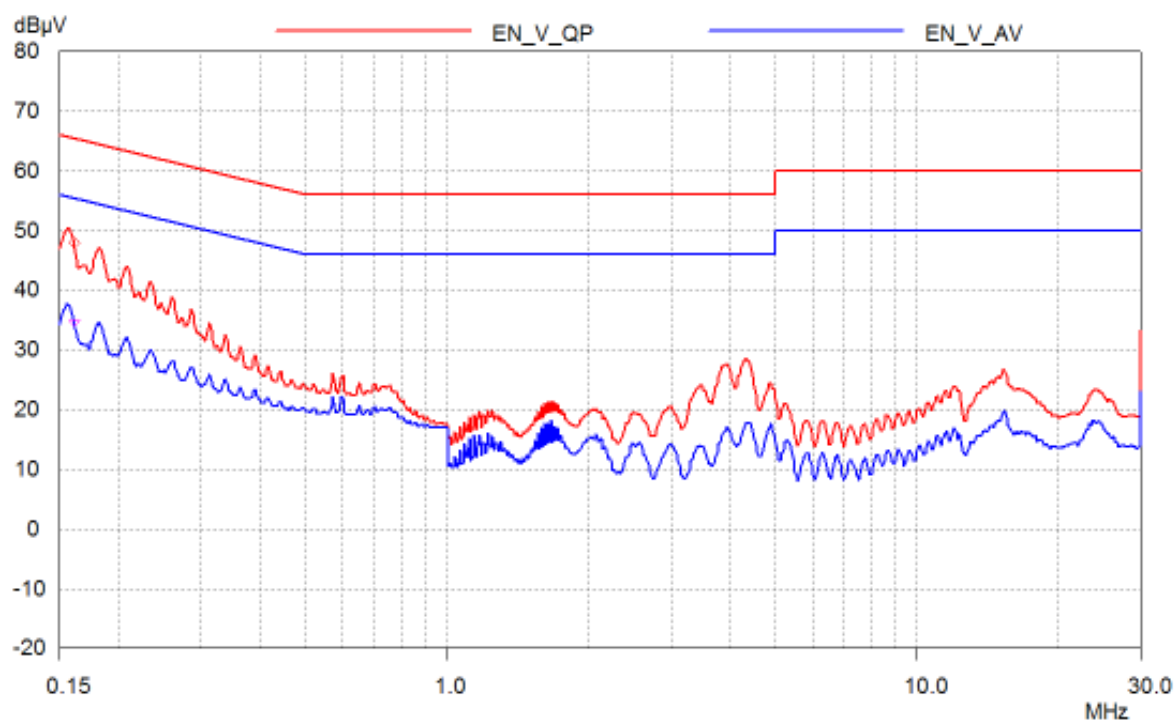
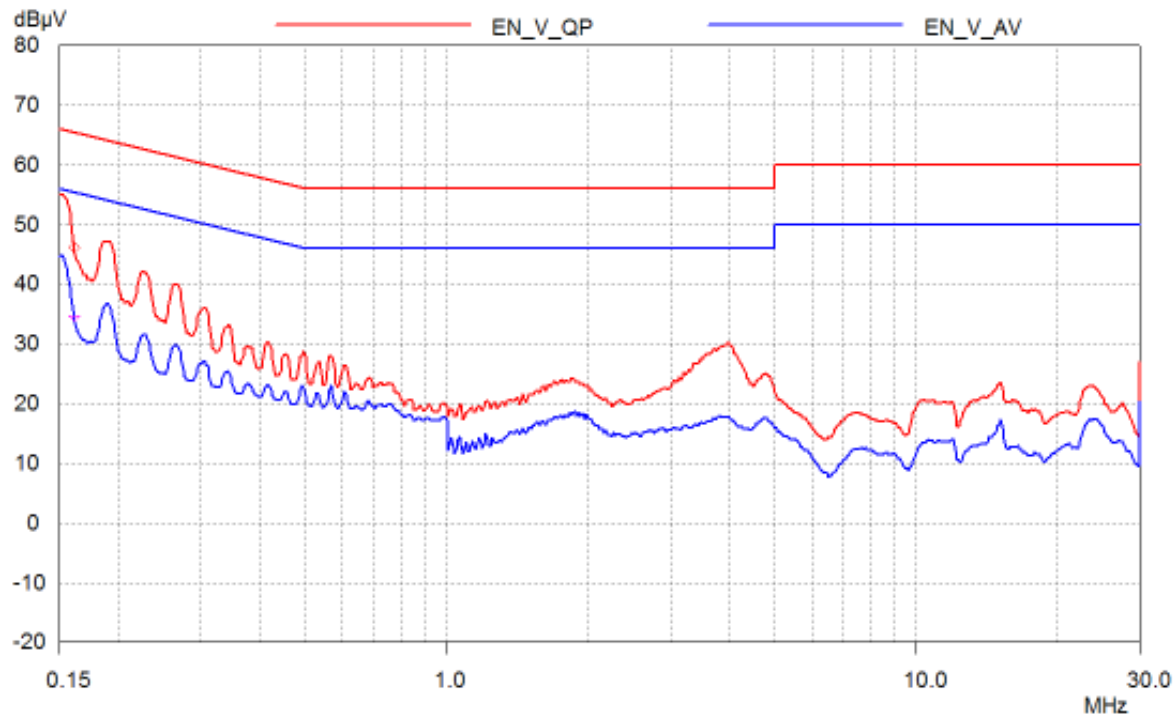


Figure 74 – Earth Ground EMI, 5 V / 3 A Load for 230 VAC.

17.2.2 9 V, 3 A

**Figure 75** – Earth Ground EMI, 9 V / 3 A Load for 115 VAC.

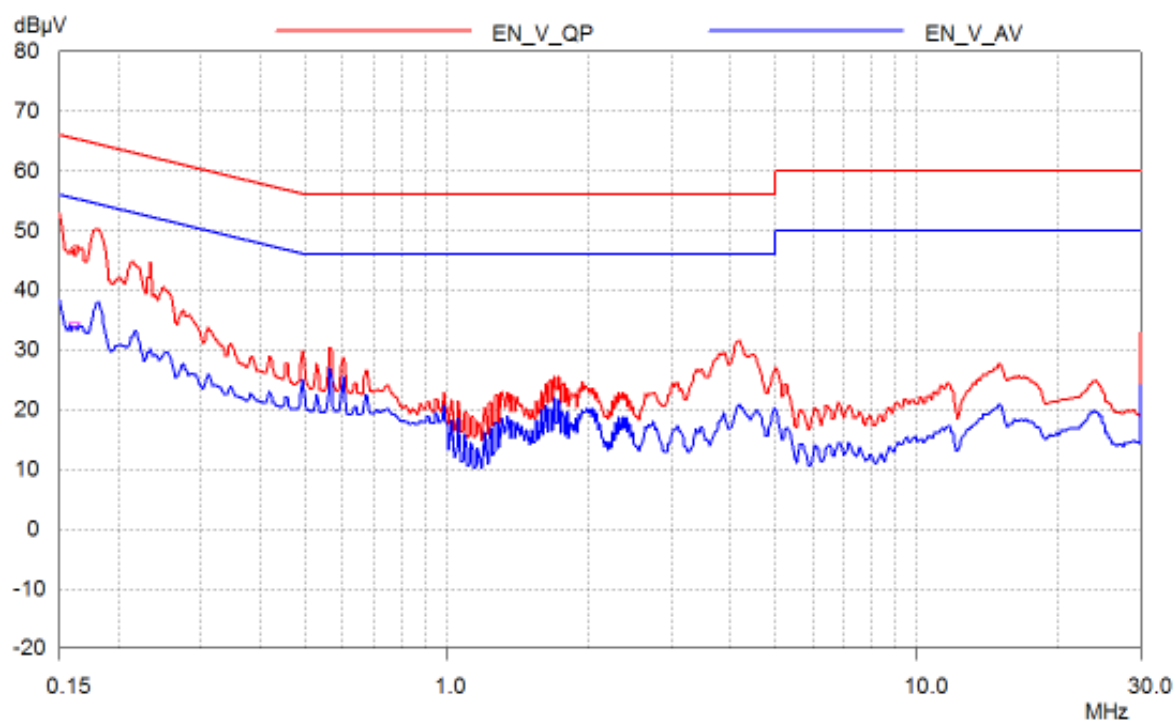
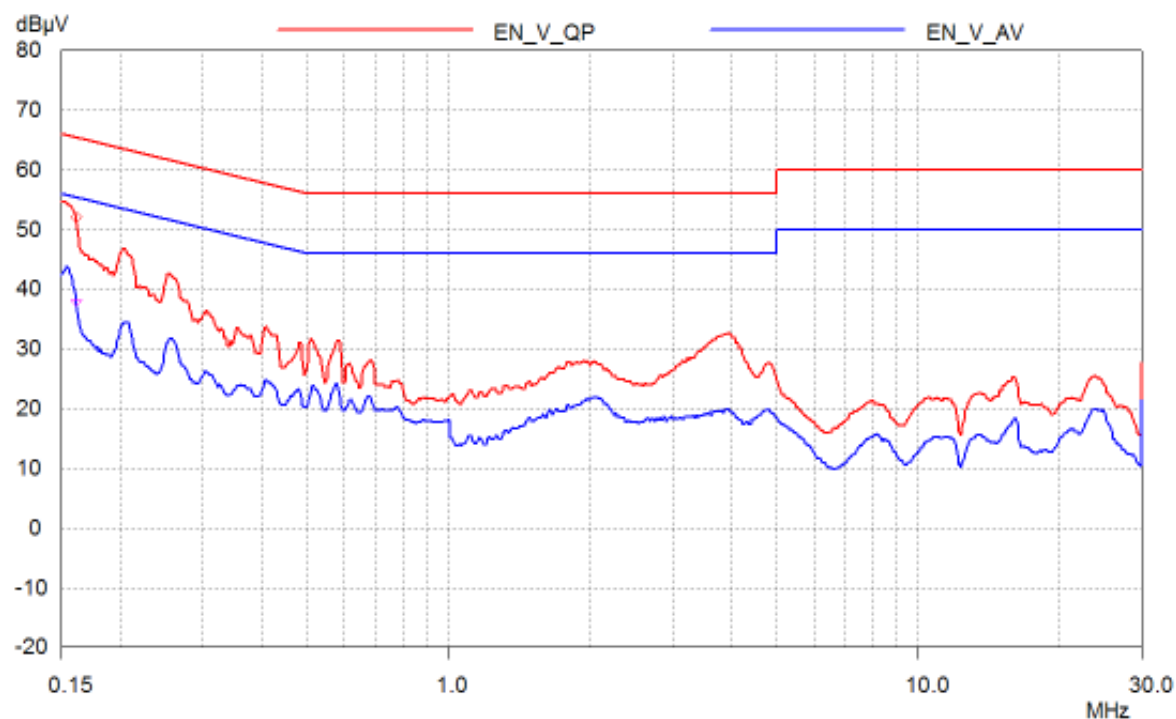


Figure 76 – Earth Ground EMI, 9 V / 3 A Load for 230 VAC.

17.2.3 15 V, 3 A

**Figure 77** – Earth Ground EMI, 15 V / 3 A Load for 115 VAC.

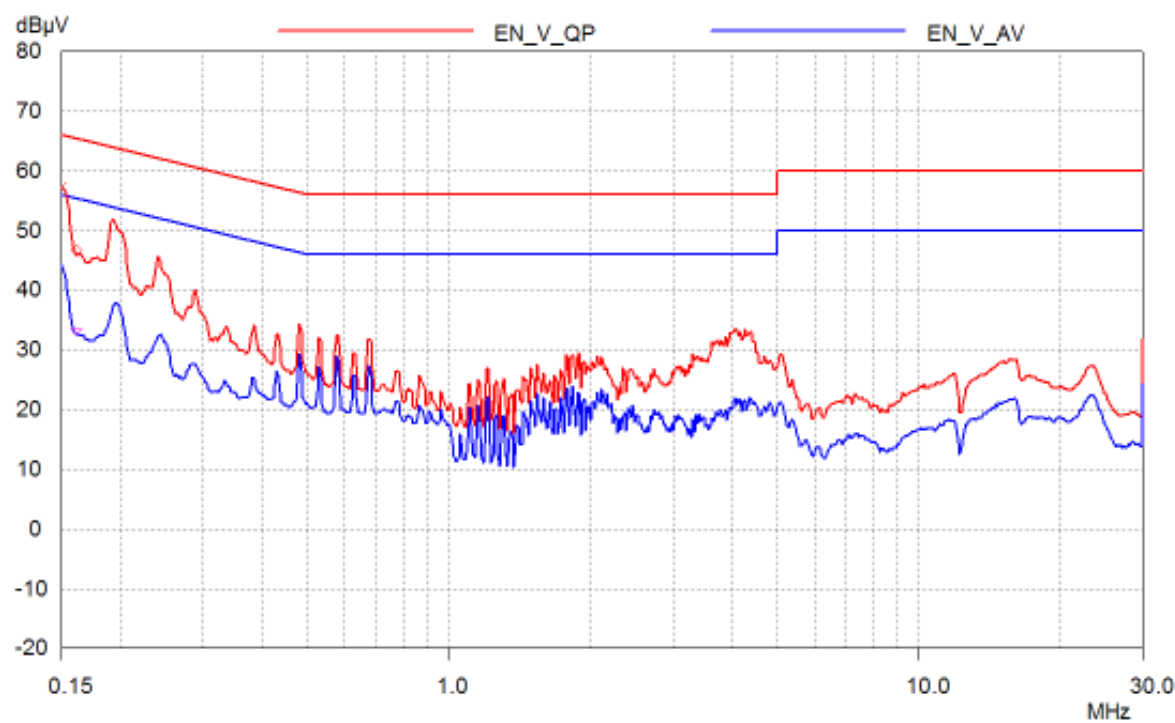
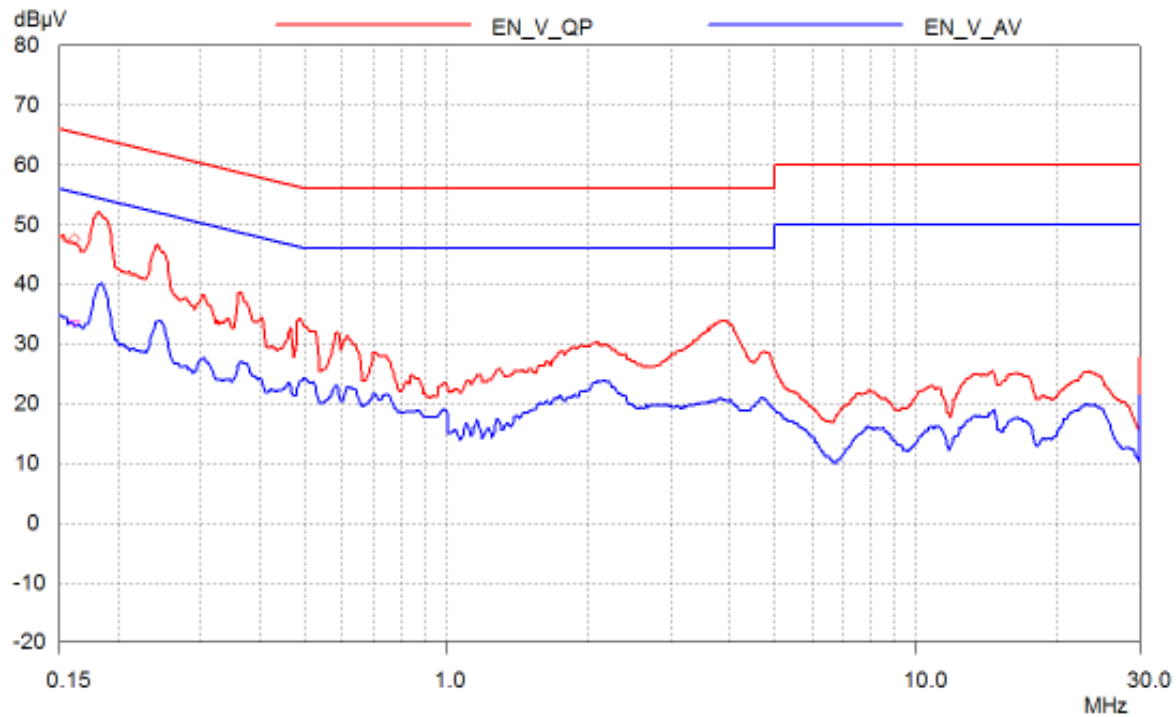


Figure 78 – Earth Ground EMI, 15 V / 3 A Load for 230 VAC.



17.2.4 20 V, 3 A

**Figure 79** – Earth Ground EMI, 20 V / 3 A Load for 115 VAC.

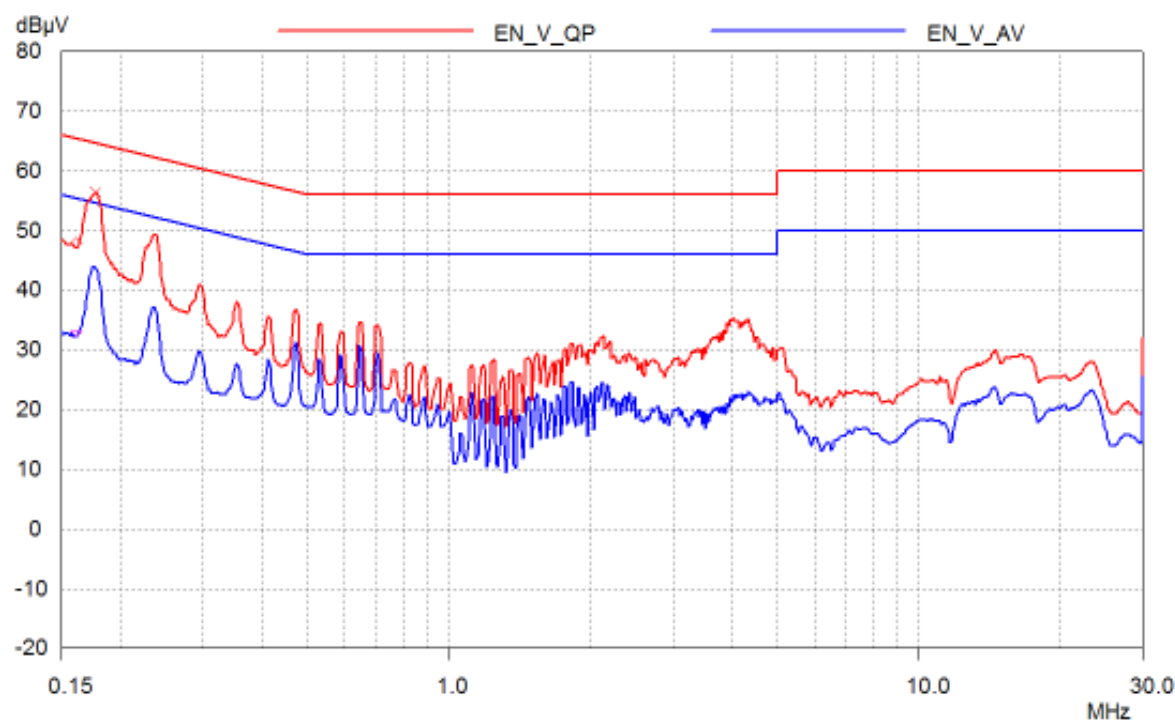


Figure 80 – Earth Ground EMI, 20 V / 3 A Load for 230 VAC.



18 Line Surge

18.1 *Combination Wave Differential Mode Test*

Passed ± 1 kV.

Surge Voltage (kV)	Phase Angle (°)	Generator Impedance (W)	Number of Strikes	Test Result
± 1	0	2	10	PASS
± 1	90	2	10	PASS
± 1	180	2	10	PASS
± 1	270	2	10	PASS

Note: Input line OVP gets triggered when the test is done at no load.

19 ESD

ESD is done on GND pin since only GND is accessible to the user from the adapter.

Passed ± 16.5 kV air discharge and 8 kV contact discharge GND pin.

Air Discharge (kV)	Number of Strikes	Test Result
+16.5	10	PASS
-16.5	10	PASS

Contact Discharge (kV)	Number of Strikes	Test Result
+8	10	PASS
-8	10	PASS

20 Revision History

Date	Author	Revision	Description & Changes	Reviewed
24-Jul-19	SS	1	First draft	NZ

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