Design Example Report

Title	***54 W Dual USB PD Using 2 x InnoSwitch™ 3-CP INN3266C-H210 and Cypress CCG4 CYPD4225***
Specification	85 VAC – 265 VAC Input; 5 V / 3 A, 9 V / 3 A USB PD Outputs
Application	Dual USB PD Charger
Author	Applications Engineering Department
Document Number	DER-551
Date	October 16, 2018
Revision	1.0

Summary and Features

- Meets DOE6 and CoC V5 2016 with at least 1.5% margin
    - Overall average efficiency >88% at nominal AC input.
- All the benefits of secondary-side control with the simplicity of primary-side regulation
    - Insensitive to transformer variation
    - Extremely fast transient response independent of load timing
- USB PD 2.0 compliant for both outputs
    - Single CCG4 USB PD Controller
- Accurate thermal protection with hysteretic shutdown
- Input voltage monitor with accurate line UV / OV protection
- Meets IEC 2.0 kV common mode surge, 1.0 kV differential surge and EN55022 conducted EMI

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

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1 Introduction

This engineering report describes a dual output power supply intended for USB wall outlet charger. The 27 W output (5 V / 3 A or 9 V / 3 A) rails are designed for a Type-C USB PD charger. Both outputs utilize the INN3266C CP version from the InnoSwitch3-CP family of ICs. This design shows high power density and efficiency that is possible due to the high level of integration of the InnoSwitch3-CP controller providing exceptional performance.

DER-551 is a dual flyback design sharing the same EMI filter and input bulk capacitor. The key design goals were high power density, high efficiency, low no load consumption, and USB PD compatible for both the outputs. The design is intended for dual Type-C port configuration.

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

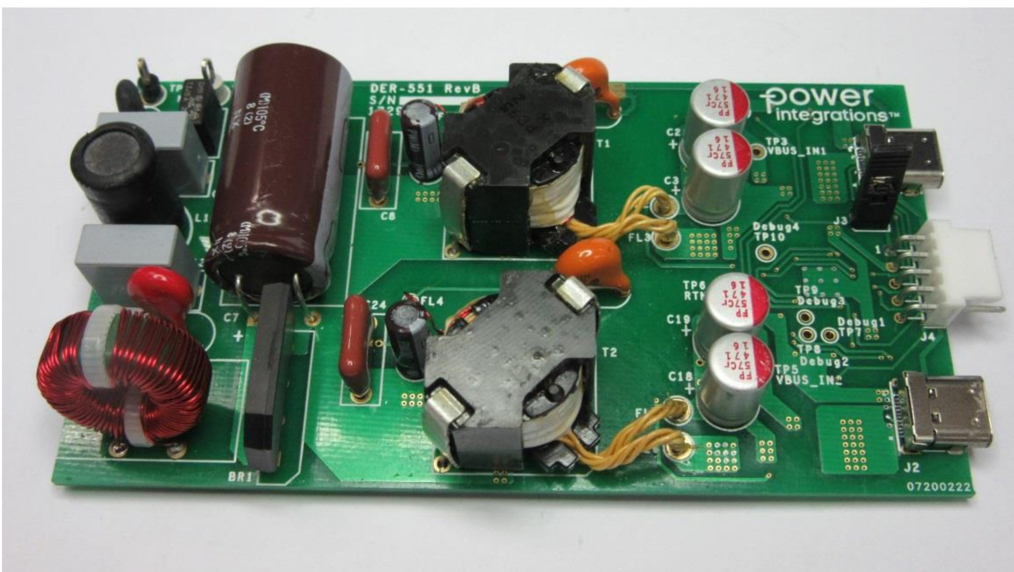

Figure 1 – Populated Circuit Board.

Figure 2 – Populated Circuit Board, Top View.

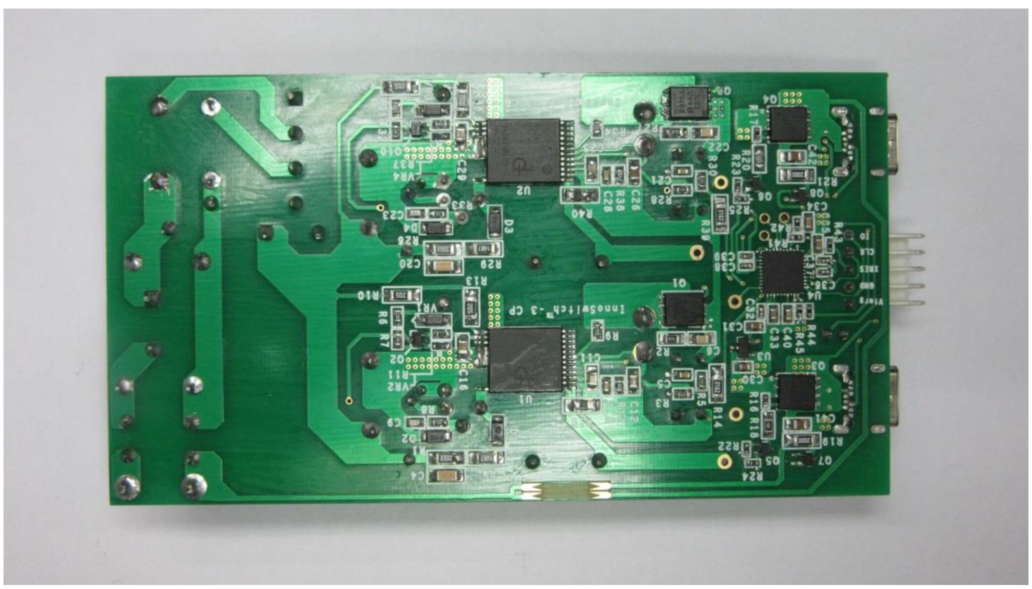

Figure 3 – Populated Circuit Board, Bottom View.

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2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85	115/230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
No-load Input Power (230 VAC)				200	mW	Measured at 230 VAC.
5 V Output						
Output Voltage	V_{OUT}		5.0		V	±3%
Output Ripple Voltage	V_{RIPPLE}			150	mV	At End of Cable. Cable Needs a Resistance of 100 mΩ.
Output Current	I_{OUT}	3.0		3.2	A	20 MHz Bandwidth.
9 V Output						
Output Voltage	V_{OUT}		9.0		V	±5%
Output Ripple Voltage	V_{RIPPLE}			150	mV	At End of Cable. Cable Needs a Resistance of 100 mΩ.
Output Current	I_{OUT}			3	A	
Continuous Output Power	P_{OUT}			18	W	
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC60950 / UL1950 Class II				
Ambient Temperature	T_{AMB}	0		50	ºC	Free Convection, Sea Level.

3 Schematic

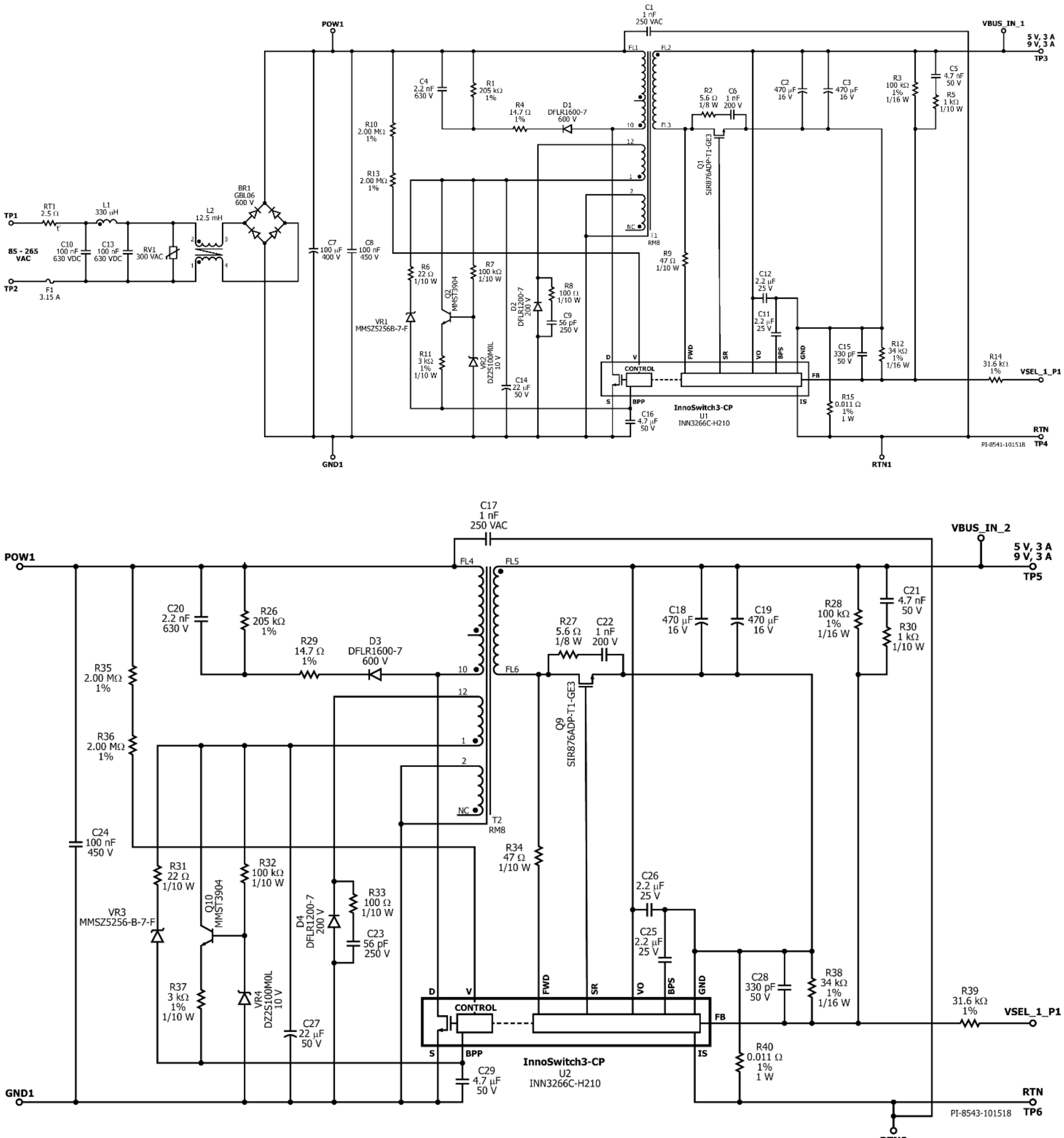

Figure 4 – Schematic.

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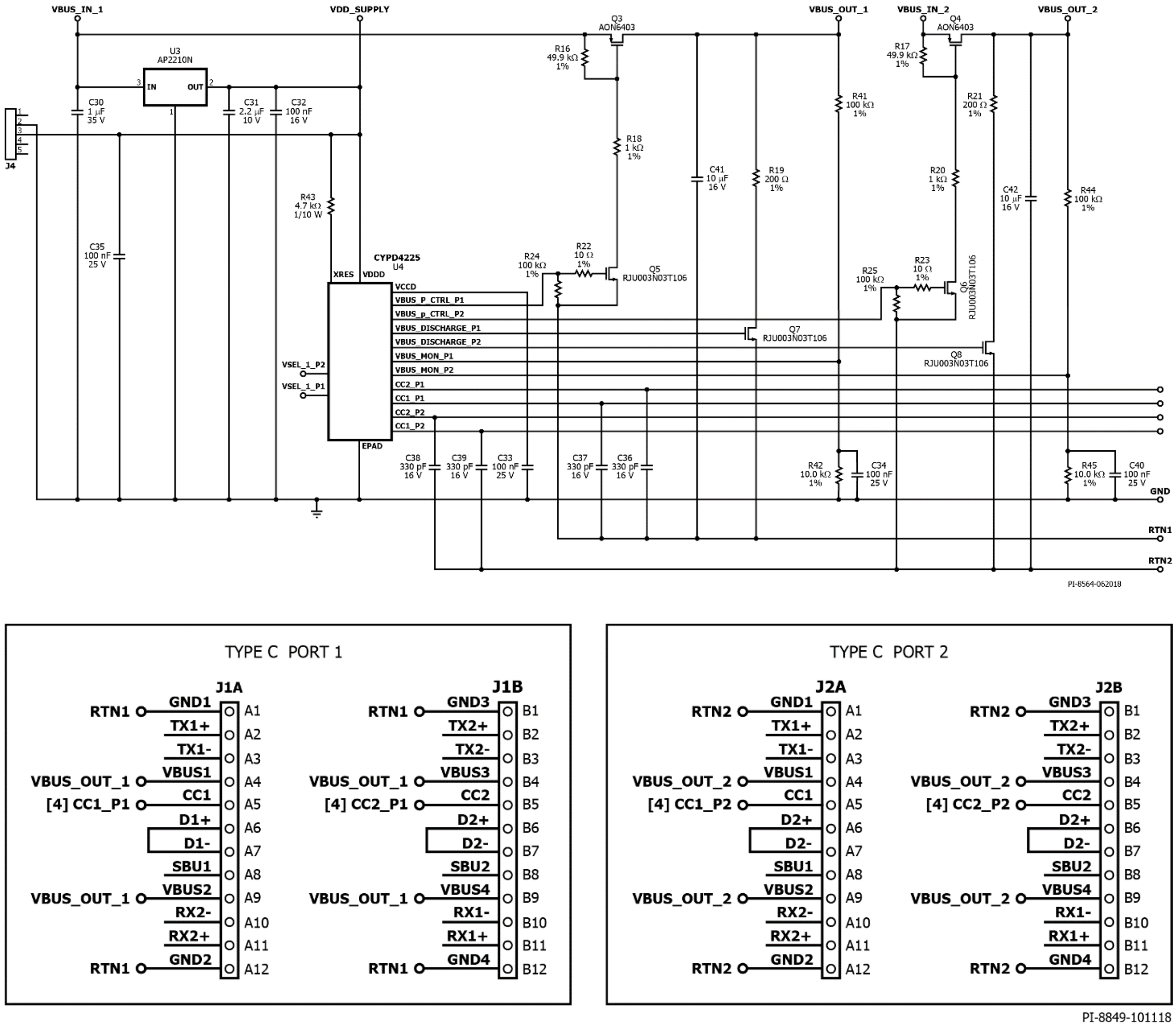

Figure 5 – Schematic.

4 Circuit Description

The InnoSwitch3-CP IC combines primary, secondary and feedback circuits in a single surface mounted off-line flyback switcher IC. The IC incorporates the primary MOSFET, the primary-side controller, the secondary-side controller for synchronous rectification and the Fluxlink™ technology that eliminates the need for an optocoupler needed on a secondary sensed feedback system.

4.1 Input Circuit Description

Fuse F1 isolates the circuit and provides protection from component failure, and the common mode choke L1 with capacitor C1 and C17 provides attenuation for EMI. Inductor L1 and capacitors C10 and C13 form a π – filter that provides additional filtering for differential mode noise. Bridge rectifier BR1 rectify the AC line voltage and provides a full wave rectified DC across the input capacitors C7.

4.2 InnoSwitch3-CP IC Primary

One end of the transformer (T1 or T2) primary is connected to the rectified DC bus; the other is connected to the drain terminal of the MOSFET inside the INN3266C (U1 or U2).

A low cost RCD clamp formed by diode (D1 or D3), resistors (R1 and R4; R26 and R29), and capacitor (C4 or C20) limits the peak Drain voltage of U1 and U2 at the instant of turn-off of the MOSFET. The clamp helps dissipate the energy stored in the leakage reactance of transformer T1 and T2.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor (C16 or C29) when AC is first applied. During normal operation the primary-side block is powered from an auxiliary winding on the transformer. The output of this is configured as a flyback winding which is rectified and filtered using diode (D2 or D4) and capacitor (C14 or C27). Resistor (R4 or R22) limits the current being supplied to the BPP pin of the InnoSwitch3-CP (U1 or U2). The R-C network comprising of resistor (R5 or R19) and capacitor (C6 or C27) offer damping of the high frequency ringing in the voltage across diode (D2 or D4) which reduces radiated EMI.

Output regulation is achieved using Ramp time modulation control, the frequency and I_{LIM} of switching cycles are adjusted based on the output load. At high load, most switching cycles are enabled have high value for I_{LIM} in the selected I_{LIM} range, and at light load or no-load most cycles are disabled and the ones enabled have low value of I_{LIM} in the selected I_{LIM} range. Once a cycle is enabled, the MOSFET will remain on until the primary current ramps to the device current limit for the specific operating state.

Zener diode (VR1 or VR4) offers primary sensed output overvoltage protection. In a flyback converter, output of the auxiliary winding tracks the output voltage of the converter. In case of over voltage at output of the converter, the auxiliary winding voltage increases and causes breakdown of (VR1 or VR4) which then causes a current to

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flow into the BPP pin of InnoSwitch3-CP IC (U1 or U2). 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 INN3266C IC provides output voltage, output current sensing and drive a MOSFET providing synchronous rectification. The secondary of the transformer is rectified by MOSFET Q1 or Q9 and filtered by capacitors C2 and C3 or C18 and C19. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via RC snubbers, R2 and C6 or R27 and C22.

The gate of Q1 or Q9 is turned on by the secondary-side controller inside IC U1 or U2 respectively, based on the winding voltage sensed via resistor R9 or R34 and fed into the FWD pin of the IC.

In continuous conduction mode operation, the power MOSFET is turned off just prior to the secondary-side controller commanding a new switching cycle from the primary. In discontinuous mode the MOSFET is turned off when the voltage drop across the MOSFET falls below ground. Secondary-side control of the primary-side MOSFET ensure that it is never on at the same time with the synchronous rectification MOSFET on time. The MOSFET drive signal is the output on the SR pin.

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. The output voltage powers the device then fed into VO pin and charges the decoupling capacitor C11 or C25 via an internal regulator.

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 MOSFET, the forward voltage that appears across the secondary winding is used to charge the decoupling capacitor C11 or C25 via resistor R9 or R34 and an internal regulator. This allows output current regulation to be maintained down to ~3.0 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 resistors R15 or R40 between the IS and GND pins with a threshold of approximately 30 mV to reduce losses. Once the internal current sense threshold is exceeded the device adjusts the number of switch pulses to maintain a fixed output current.

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. Resistor R5 or R30 and capacitor C5 or C21 form a phase lead network that ensure stable operation and minimize output voltage overshoot and undershoot during transient load conditions. Capacitor C15 or C28 provides noise filtering of the signal at the FB pin.

In order to improve conversion efficiency and reduce switching losses, InnoSwitch3-CP introduces a secondary-based QR functionality. The secondary controller has a means to allow switching when the voltage across the primary switch is near its minimum voltage when the converter operates in critical (CRM) or discontinuous conduction mode (DCM). Rather than detecting the magnetizing ring valley on the primary-side, the peak voltage of the FW-pin voltage as it rises above the output voltage level is used to gate secondary request to initiate the switch "on" cycle in the primary controller.

4.4 USB Type-C and PD Interface

In this design, CCG4 CYPD4225-40LQXIT (U4) is the dual USB Type-C and PD controller. Output of the InnoSwitch3-CP IC powers the CCG4 device using a 3.3 linear regulator (U3).

Resistors R28 and R38 or R3 and R12 form the feedback divider network to sense the output voltage. To change the output to 9 V, resistor R14 or R39 is added in parallel to the bottom resistor R28 or R38 of the feedback divider network respectively. To vary the output voltage using a USB PD interface, the ports must be connected to the terminals GPIO and GND.

USB PD protocol is communicated over either CC1_P1 and CC2_P1 or CC1_P2 and CC2_P2 line depending on the orientation in which Type-C plug is connected.

P-MOSFETS Q3 or Q4 make the USB Type-C receptacle cold socket when no device is attached to the charger as per the USB Type-C specification. VBUS_OUT1 or VBUS_OUT2 is discharged via resistor R19 or R21 by turning on the MOSFET Q7 or Q8.

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5 PCB Layout

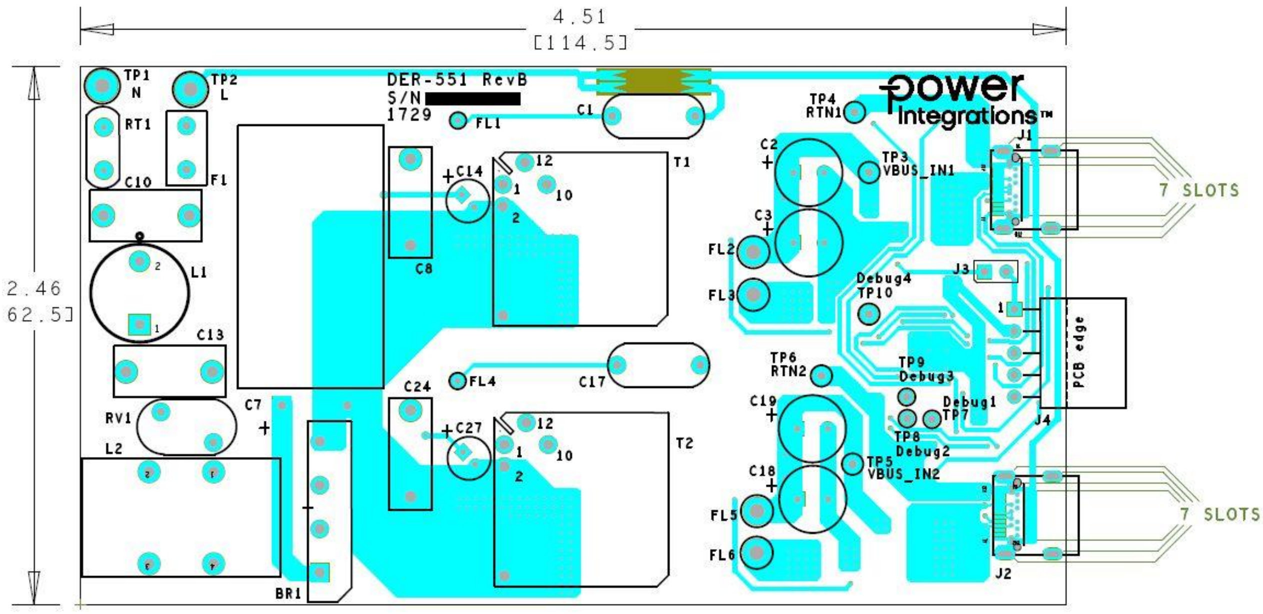

Figure 6 – Top Side.

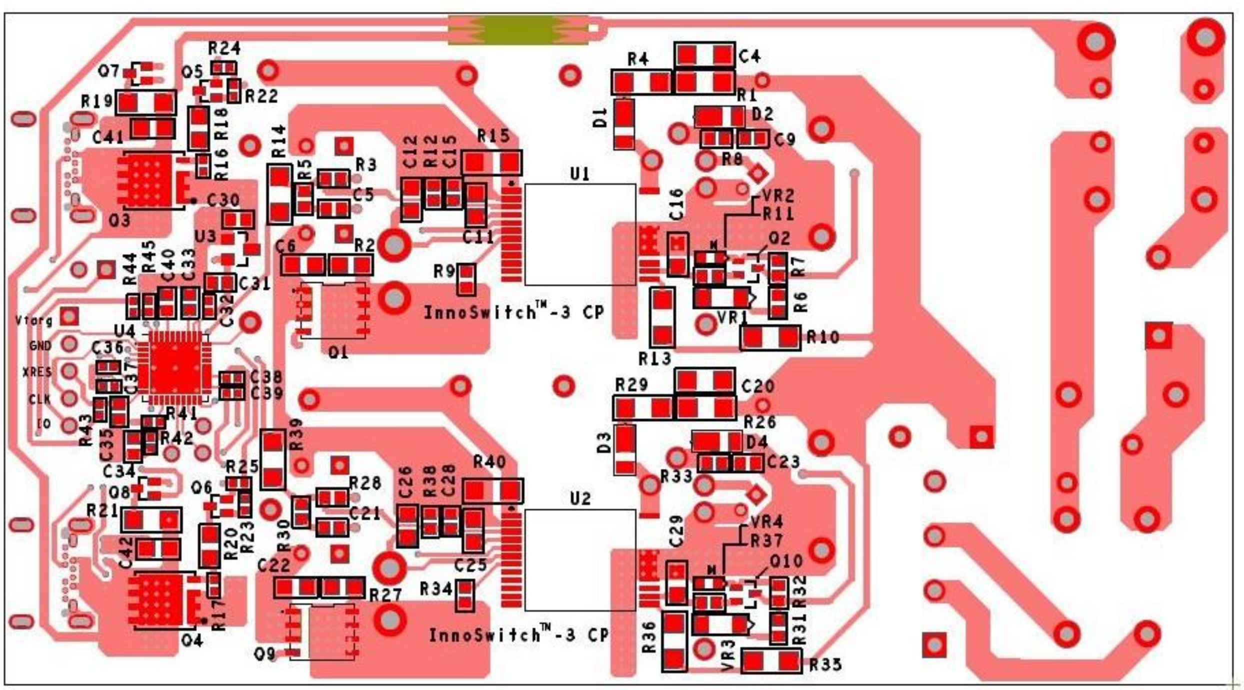

Figure 7 – Bottom Side.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	DIODE BRIDGE 600 V 4 A GB	GBL06	Genesic Semi
2	1	C1	1 nF, Ceramic, Y1	440LD10-R	Vishay
3	1	C2	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
4	1	C3	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
5	1	C4	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
6	1	C5	4.7 nF 50 V, Ceramic, X7R, 0603	GRM188R71H472KA01D	Murata
7	1	C6	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
8	1	C7	100 μF, 400 V, Electrolytic, Low ESR, (16 x 30)	EPAG401ELL101ML30S	Nippon Chemi-Con
9	1	C8	100 nF, 450 V, Polypropylene Film	ECW-F2W104JAQ	Panasonic
10	1	C9	56 pF, 250 V, Ceramic, NPO, 0603	GQM1875C2E560JB12D	Murata
11	1	C10	0.1 μF, ±20%, Film, X2 Safety Rated, 310 VAC, 630 VDC, Polypropylene (PP), Metallized Radial	BFC233920104	Vishay
12	1	C11	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
13	1	C12	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
14	1	C13	0.1 μF, ±20%, Film, X2 Safety Rated, 310 VAC, 630 VDC, Polypropylene (PP), Metallized Radial	BFC233920104	Vishay
15	1	C14	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
16	1	C15	330 pF 50 V, Ceramic, X7R, 0603	CC0603KRX7R9BB331	Yageo
17	1	C16	4.7 μF, 50 V, Ceramic, X5R, 0805	CL21A475KBQNNNE	Samsung
18	1	C17	1 nF, Ceramic, Y1	440LD10-R	Vishay
19	1	C18	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
20	1	C19	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
21	1	C20	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
22	1	C21	4.7 nF 50 V, Ceramic, X7R, 0603	GRM188R71H472KA01D	Murata
23	1	C22	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
24	1	C23	56 pF, 250 V, Ceramic, NPO, 0603	GQM1875C2E560JB12D	Murata
25	1	C24	100 nF, 450 V, Polypropylene Film	ECW-F2W104JAQ	Panasonic
26	1	C25	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
27	1	C26	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
28	1	C27	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
29	1	C28	330 pF 50 V, Ceramic, X7R, 0603	CC0603KRX7R9BB331	Yageo
30	1	C29	4.7 μF, 50 V, Ceramic, X5R, 0805	CL21A475KBQNNNE	Samsung
31	1	C30	1 μf 35 V, Ceramic, X7R, 0603	C1608X7R1V105M	TDK
32	1	C31	2.2 μF, 10 V, Ceramic, X7R, 0603	GRM188R71A225KE15D	Murata
33	1	C32	100 nF 16 V, Ceramic, X7R, 0402	L05B104KO5NNNC	Samsung
34	1	C33	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay
35	1	C34	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay
36	1	C35	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay
37	1	C36	330 pF 16 V, Ceramic, X7R, 0402	C0402C331K4RACTU	Kemet
38	1	C37	330 pF 16 V, Ceramic, X7R, 0402	C0402C331K4RACTU	Kemet
39	1	C38	330 pF 16 V, Ceramic, X7R, 0402	C0402C331K4RACTU	Kemet
40	1	C39	330 pF 16 V, Ceramic, X7R, 0402	C0402C331K4RACTU	Kemet
41	1	C40	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay
42	1	C41	10 μF, 16 V, Ceramic, X5R, 0805	GRM21BR61C106KE15L	Murata
43	1	C42	10 μF, 16 V, Ceramic, X5R, 0805	GRM21BR61C106KE15L	Murata
44	1	D1	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
45	1	D2	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
46	1	D3	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.

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47	1	D4	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
48	1	F1	3.15 A, 250 V, Slow, RST	507-1181	Belfuse
49	1	FL1	Flying Lead , Hole size 30 mils	N/A	N/A
50	1	FL2	Flying Lead , Hole size 70 mils	N/A	N/A
51	1	FL3	Flying Lead , Hole size 70 mils	N/A	N/A
52	1	FL4	Flying Lead , Hole size 30 mils	N/A	N/A
53	1	FL5	Flying Lead , Hole size 70 mils	N/A	N/A
54	1	FL6	Flying Lead , Hole size 70 mils	N/A	N/A
55	1	J1	USB 3.1 CF STD CL1. 75- H3.45 mm type 1.20 mm	A32-0XS1-X12	ShenZhen Ai Lian
56	1	J2	USB 3.1 CF STD CL1. 75- H3.45 mm type 1.20 mm	A32-0XS1-X12	ShenZhen Ai Lian
57	1	J3	2 Pos (1 x 2) header, 0.1 pitch, Vertical	87220-2	Tyco
58	1	J4	CONN, 5 Pos (1 x 5) header, 0.1 pitch, R/A Tin	0022053051	Molex
59	1	L1	330 μH, 1.0 A, 20%	RL-5480-4-330	Renco
60	1	L2	CMC, 12.5 mH @ 100 kHz, ±15%, Toroidal, wound on 30-00398-00 toroidal core, with 75-00082-00 cable tie divider, using #25 AWG Heavy Nyleze wire	30-00465-00	Power Integrations
61	1	Q1	100 V, 40 A, N-Channel, PowerPAK SO-8	SIR876ADP-T1-GE3	Vishay
62	1	Q2	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-323	MMST3904-7-F	Diodes, Inc.
63	1	Q3	MOSFET, P-CH, 30V, 21A, 8DFN	AON6403	Alpha & Omega Semi
64	1	Q4	MOSFET, P-CH, 30V, 21A, 8DFN	AON6403	Alpha & Omega Semi
65	1	Q5	MOSFET, N-CH, 30V, 300 mA, SOT-323	RJU003N03T106	Rohm
66	1	Q6	MOSFET, N-CH, 30V, 300 mA, SOT-323	RJU003N03T106	Rohm
67	1	Q7	MOSFET, N-CH, 30V, 300 mA, SOT-323	RJU003N03T106	Rohm
68	1	Q8	MOSFET, N-CH, 30V, 300 mA, SOT-323	RJU003N03T106	Rohm
69	1	Q9	100 V, 40 A, N-Channel, PowerPAK SO-8	SIR876ADP-T1-GE3	Vishay
70	1	Q10	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-323	MMST3904-7-F	Diodes, Inc.
71	1	R1	RES, 205 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2053V	Panasonic
72	1	R2	RES, 5.6 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ5R6V	Panasonic
73	1	R3	RES, 100 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
74	1	R4	RES, 14.7 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF14R7V	Panasonic
75	1	R5	RES, 1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
76	1	R6	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
77	1	R7	RES, 100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
78	1	R8	RES, 100 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ101V	Panasonic
79	1	R9	RES, 47 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470V	Panasonic
80	1	R10	RES, 2.00 M, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
81	1	R11	RES, 3 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF3001V	Panasonic
82	1	R12	RES, 34 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3402V	Panasonic
83	1	R13	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
84	1	R14	RES, 31.6 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3162V	Panasonic
85	1	R15	0.011 Ω, ±1%, ±75ppm/°C, 1 W, 1206, Automotive AEC-Q200, Current Sense, -55°C ~ 155°C	ERJ-8CWFR011V	Panasonic
86	1	R16	RES, 49.9 kΩ, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF4992X	Panasonic
87	1	R17	RES, 49.9 kΩ, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF4992X	Panasonic
88	1	R18	RES, 1.00 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1001V	Panasonic
89	1	R19	RES, 200 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2000V	Panasonic
90	1	R20	RES, 1.00 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1001V	Panasonic
91	1	R21	RES, 200 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2000V	Panasonic
92	1	R22	RES, 10 Ω, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF10R0X	Panasonic
93	1	R23	RES, 10 Ω, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF10R0X	Panasonic
94	1	R24	RES, 100.0 kΩ, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1003X	Panasonic
95	1	R25	RES, 100.0 kΩ, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1003X	Panasonic
96	1	R26	RES, 205 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2053V	Panasonic
97	1	R27	RES, 5.6 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ5R6V	Panasonic
98	1	R28	RES, 100 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic

99	1	R29	RES, 14.7 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF14R7V	Panasonic
100	1	R30	RES, 1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
101	1	R31	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
102	1	R32	RES, 100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
103	1	R33	RES, 100 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ101V	Panasonic
104	1	R34	RES, 47 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470V	Panasonic
105	1	R35	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
106	1	R36	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
107	1	R37	RES, 3 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF3001V	Panasonic
108	1	R38	RES, 34 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3402V	Panasonic
109	1	R39	RES, 31.6 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3162V	Panasonic
110	1	R40	0.011 Ω, ±1%, ±75ppm/°C, 1 W, 1206, Automotive AEC-Q200, Current Sense,-55 °C ~ 155 °C	ERJ-8CWFR011V	Panasonic
111	1	R41	RES, 100.0 kΩ, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1003X	Panasonic
112	1	R42	RES, 10.0 kΩ, 1%, 1/16 W, Thick Film, 0402	RC0402FR-0710KL	Yageo
113	1	R43	RES, 4.7 kΩ, 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ472X	Panasonic
114	1	R44	RES, 100.0 kΩ, 1%, 1/10 W, Thick Film, 0402	ERJ-2RKF1003X	Panasonic
115	1	R45	RES, 10.0 kΩ, 1%, 1/16 W, Thick Film, 0402	RC0402FR-0710KL	Yageo
116	1	RT1	NTC Thermistor, 2.5 Ω, 5 A	SL10 2R505	Ametherm
117	1	RV1	300 VAC, 25 J, 7 mm, RADIAL	V300LA4P	Littlefuse
118	1	T1	Bobbin, RM8, Vertical, 12 pins	BRM08-1112CP-W-P5.0	MH&W
119	1	T2	Bobbin, RM8, Vertical, 12 pins	BRM08-1112CP-W-P5.0	MH&W
120	1	TP1	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
121	1	TP2	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
122	1	TP3	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
123	1	TP4	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
124	1	TP5	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
125	1	TP6	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
126	1	TP7	Test Point, BLUE, Miniature THRU-HOLE MOUNT	5117	Keystone
127	1	TP8	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
128	1	TP9	Test Point, BLUE, Miniature THRU-HOLE MOUNT	5117	Keystone
129	1	TP10	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
130	1	U1	InnoSwitch3-CP, InSOP24D	INN3266C-H210	Power Integrations
131	1	U2	InnoSwitch3-CP, InSOP24D	INN3266C-H210	Power Integrations
132	1	U3	IC, REG, LDO, 3.3 V, 0.3 A, SOT23-3	P2210N-3.3TRG1	Diodes, Inc.
133	1	U4	IC, Control, USB TYPE-C, CCG4	CYPD4225-40LQXIT	Cypress
134	1	VR1	DIODE ZENER 30 V 500 mW SOD123	MMSZ5256B-7-F	Diodes, Inc.
135	1	VR2	10 V, 5%, 150 mW, SSMINI-2	DZ2S100M0L	Panasonic
136	1	VR3	DIODE ZENER 30 V 500 mW SOD123	MMSZ5256B-7-F	Diodes, Inc.
137	1	VR4	10 V, 5%, 150 mW, SSMINI-2	DZ2S100M0L	Panasonic

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7 Transformer (T1) Specification

7.1 Electrical Diagram

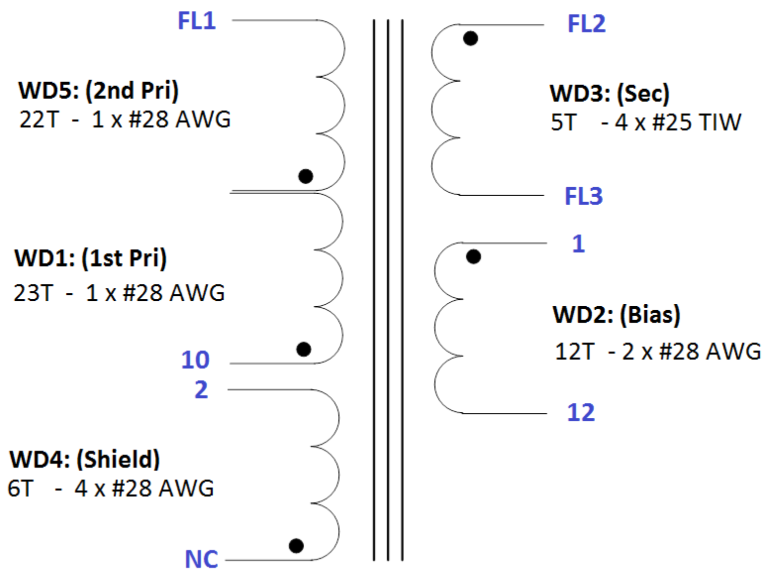

Figure 8 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Electrical Strength	60 second, 60 Hz, from pins 10, FL1, 1, 12 to FL2-FL3.	3000 VAC
Primary Inductance	Pins 10-FL1, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	552 μH ±5%
Primary Leakage Inductance	Pins 10-FL1, with FL1-FL2 shorted, measured at 100 kHz, 0.4 V_{RMS}.	~10 μH

7.3 Material List

Item	Description
[1]	Core: RM8, TDK-PC95, or Equivalent; ALG=295nH/t².
[2]	Bobbin: RM8, Vertical, 12 Pins (6/6), Circular, PI#: 25-01084-00; or Equivalent.
[3]	Magnet Wire: #28 AWG Solderable Double Coated.
[4]	Magnet Wire: #25 AWG Triple Insulated Wire.
[5]	Tape: Polyester Film, 3M, 1mil Thick, 9.3 mm Wide.
[6]	Clip: RM8: Allstar Magnetic, PN: CLI/P-RM8/I.
[7]	Varnish: Dolph BC-359.

7.4 Transformer Build Diagram

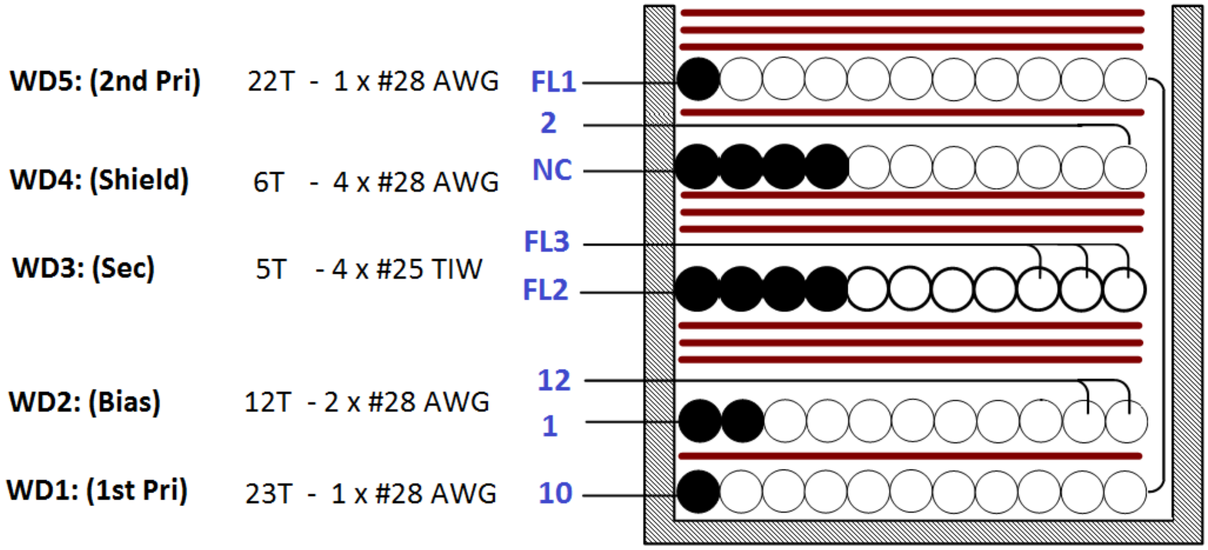

Figure 9 – Transformer Build Diagram.

7.5 Transformer Construction

Winding Preparation	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 10, wind 23 turns of wire Item [3] in 1 layer. At the last turn, leave the wire hanging and enough length for the 2nd primary.
Insulation	1 layer of tape Item [5].
WD2 Bias	Start at pin 1, wind 12 bi-filar turns of wire Item [3] in 1 layer, from left to right, spread the wires evenly across the width of the bobbin. At the last turn bring these wires back to the left and finish at pin 12.
Insulation	3 layers of tape Item [5].
WD3 Secondary	Start on the secondary-side of the bobbin, use 3 wires Item [4], leave ~1" floating, and mark as FL2. Wind 5 turns , at the last turn bring these wires back to the left, also leave ~1" floating and mark as FL3.
Insulation	3 layers of tape Item [5].
WD4 Shield	At the primary-side of the bobbin, use 4 wires Item [3], for simplicity leave ~1" floating, and set as NC. Wind 6 Quad-filar turns of wire Item [3] in 1 layer. At the last turn, bring these wires back to the left and finish at pin 2. Cut the NC wires.
Insulation	1 layer of tape Item [5].
WD1 2nd Primary	Use wire hanging from WD1; continue winding 22 turns from right to left. At the last turn, leave ~ 1" of wire floating and mark as FL1.
Insulation	3 layers of tape Item [5].
Finish	Gap cores to get 552 μH and secure with clips Item [6]. Varnish with Item [7].

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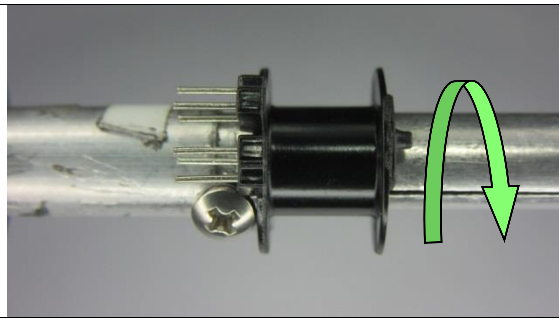
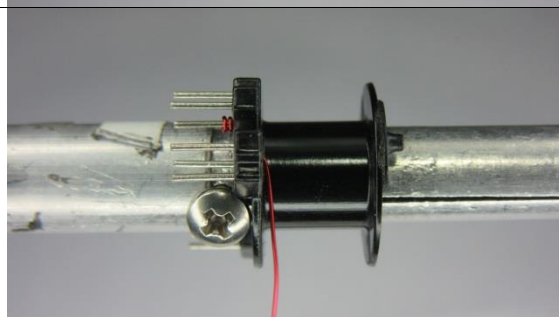
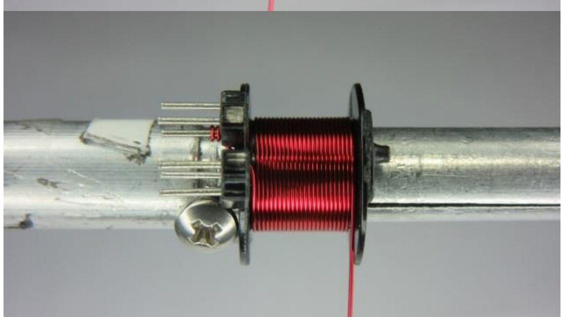
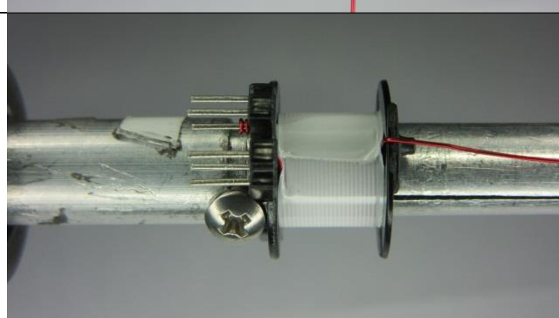
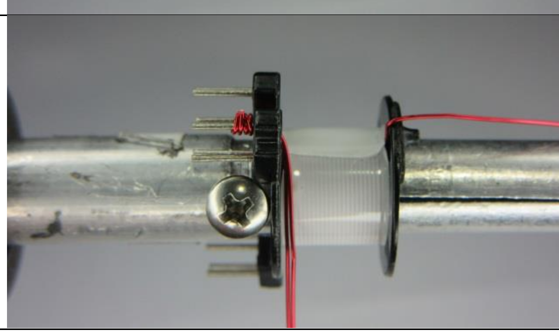
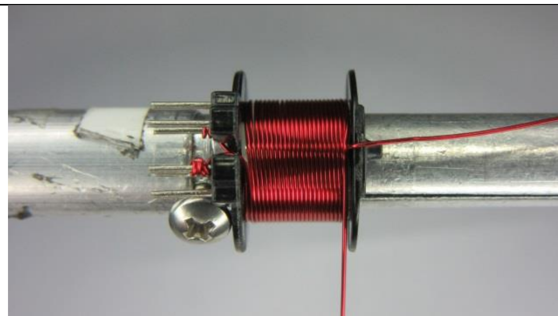
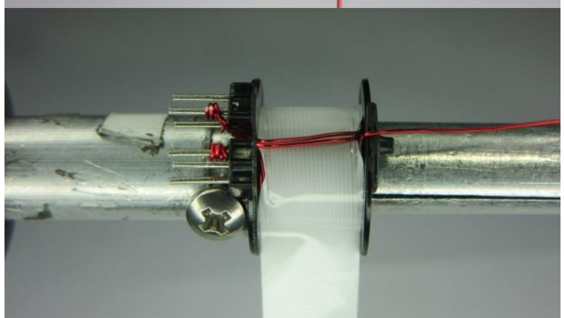
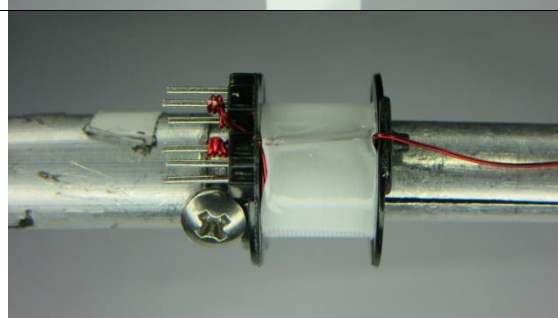
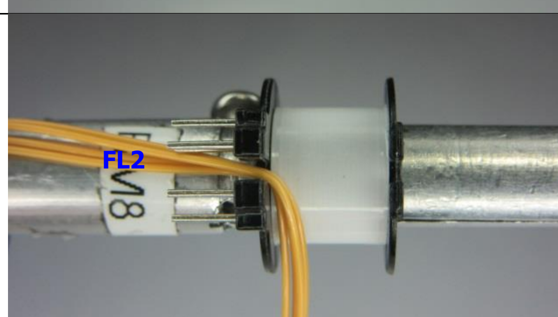
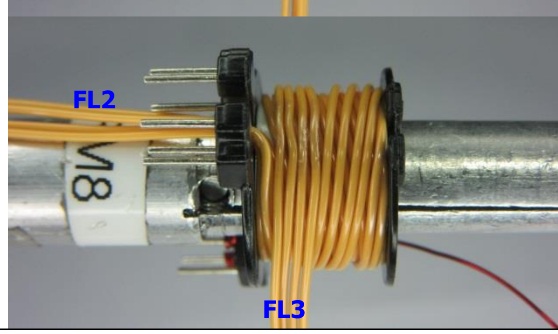
7.6 Winding Illustrations

Winding Preparation		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 10, wind 23 turns of wire Item [3] in 1 layer. At the last turn, leave the wire hanging and enough length for the 2nd primary.
Insulation		1 layer of tape Item [5].
WD2 **Bias**		Start at pin 1, wind 12 bi-filar turns of wire Item [3] in 1 layer, from left to right, spread the wires evenly across the width of the bobbin. At the last turn bring these wires back to the left and finish at pin 12.

	 	
Insulation		3 layers of tape Item [5].
WD3 Secondary	 	Start on the secondary-side of the bobbin, use 3 wires Item [4], leave ~1" floating, and mark as FL2. Wind 5 turns, at the last turn bring these wires back to the left, also leave ~1" floating and mark as FL3.

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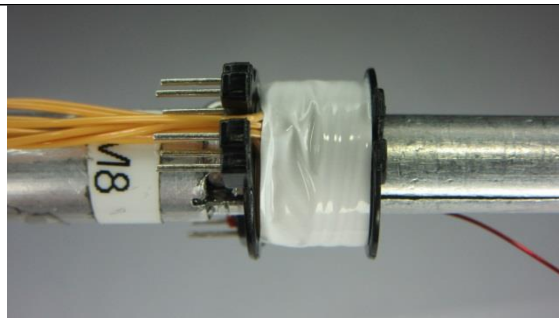
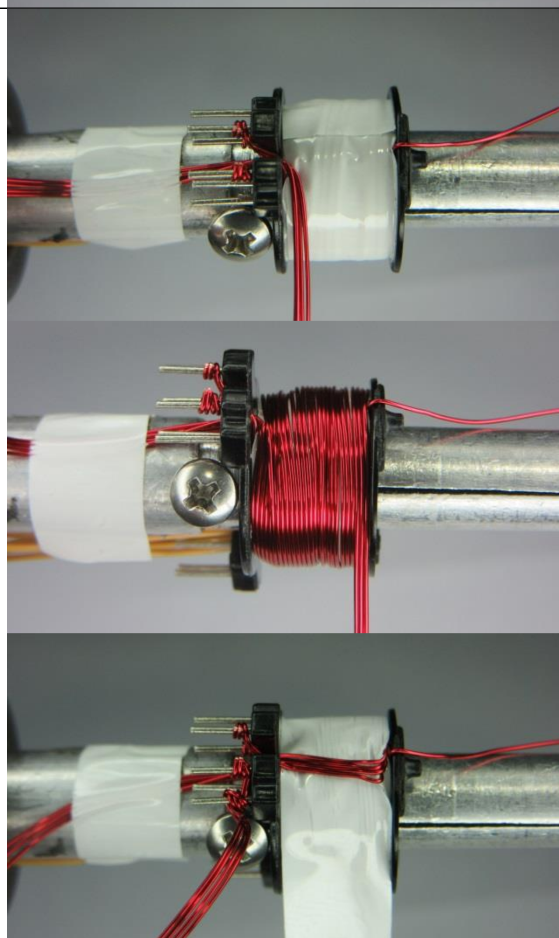
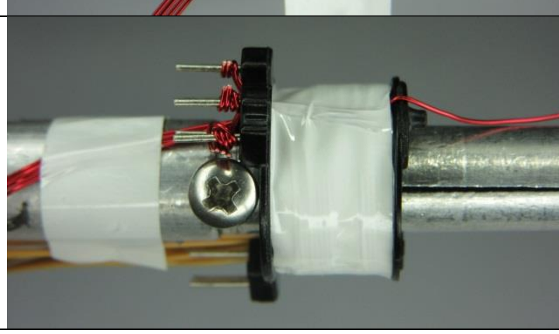
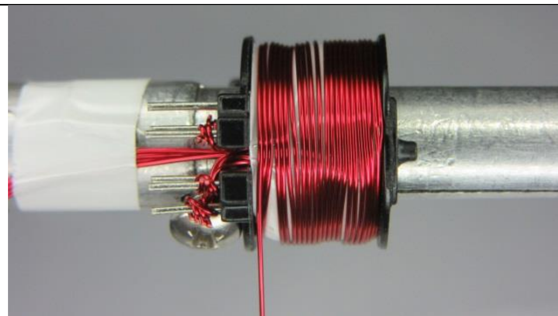
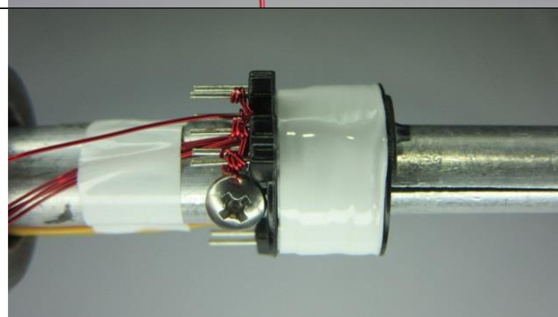
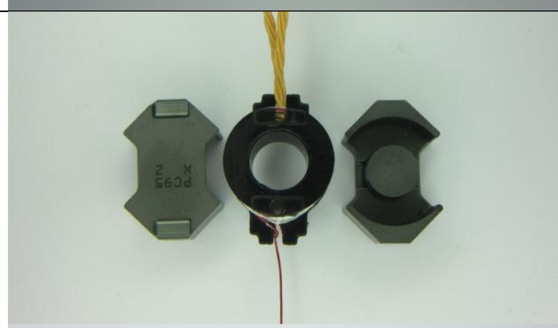
Insulation		3 layers of tape Item [5].
WD4 Shield		At the primary-side of the bobbin, use 4 wires Item [3], for simplicity leave ~1" floating, and set as NC. Wind 6 quad-filar turns of wire Item [3] in 1 layer. At the last turn, bring these wires back to the left and finish at pin 2. Cut the NC wires.
Insulation		1 layer of tape Item [5].

WD1 **2nd Primary**		Use wire hanging from WD1; continue winding 22 turns from right to left. At the last turn, leave ~1” of wire floating and mark as FL1.
Insulation		3 layers of tape Item [5].
Finish	 	Gap cores to get 552 μH and secure with clips Item [6]. Varnish with Item [7].

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8 Transformer (T2) Specification

8.1 Electrical Diagram

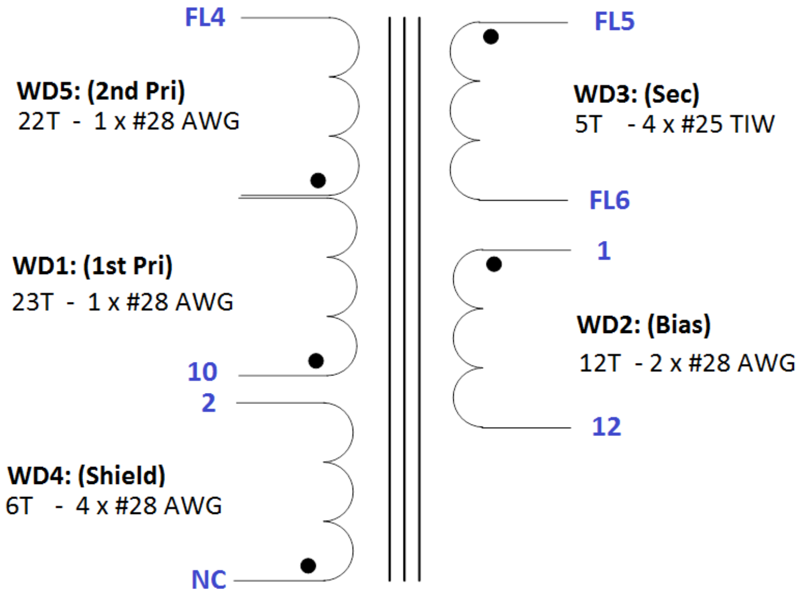

Figure 10 – Transformer Electrical Diagram.

8.2 Electrical Specifications

Electrical Strength	60 second, 60 Hz, from pins 10, FL4, 1, 12 to FL5-FL6.	3000 VAC
Primary Inductance	Pins 10-FL4, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	552 µH ±5%
Primary Leakage Inductance	Pins 10-FL4, with FL5-FL6 shorted, measured at 100 kHz, 0.4 V_{RMS}.	~10 µH

8.3 Material List

Item	Description
[1]	Core: RM8, TDK-PC95, or Equivalent; ALG=295nH/t².
[2]	Bobbin: RM8, Vertical, 12 Pins (6/6), Circular, PI#: 25-01084-00; or Equivalent.
[3]	Magnet Wire: #28 AWG Solderable Double Coated.
[4]	Magnet Wire: #25 AWG Triple Insulated Wire.
[5]	Tape: Polyester film, 3M, 1 mil Thick, 9.3 mm Wide.
[6]	Clip: RM8: Allstar Magnetic, PN: CLI/P-RM8/I.
[7]	Varnish: Dolph BC-359.

8.4 Transformer Build Diagram

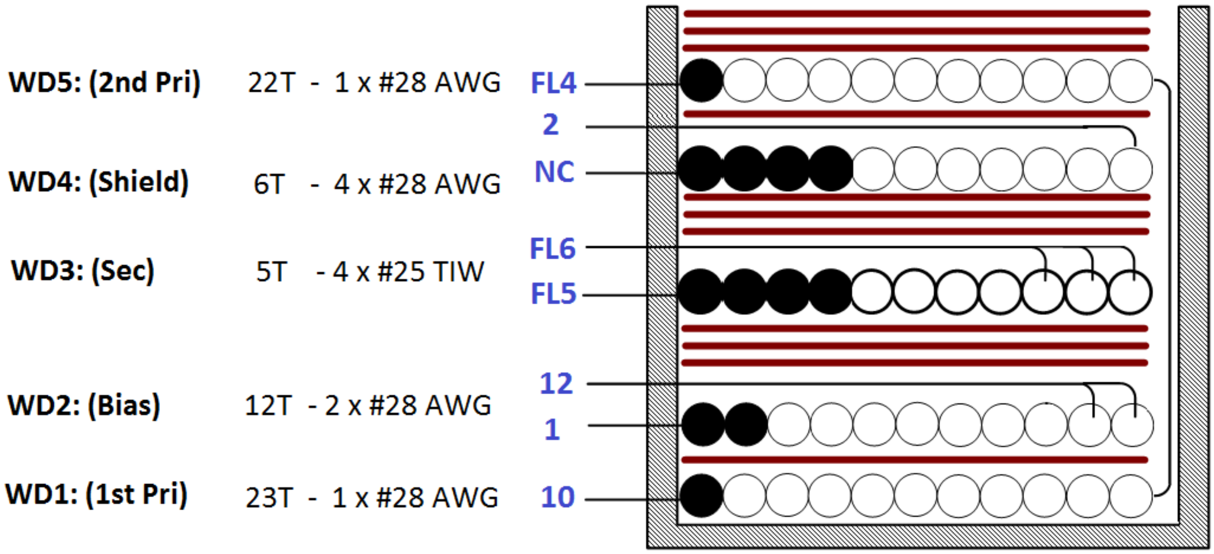

Figure 11 – Transformer Build Diagram.

8.5 Transformer Construction

Winding Preparation	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 10, wind 23 turns of wire Item [3] in 1 layer. At the last turn, leave the wire hanging and enough length for the 2nd primary.
Insulation	1 layer of tape Item [5].
WD2 Bias	Start at pin 1, wind 12 bi-filar turns of wire Item [3] in 1 layer, from left to right, spread the wires evenly across the width of the bobbin. At the last turn bring these wires back to the left and finish at pin 12.
Insulation	3 layers of tape Item [5].
WD3 Secondary	Start on the secondary-side of the bobbin, use 3 wires Item [4], leave ~1" floating, and mark as FL5. Wind 5 turns , at the last turn bring these wires back to the left, also leave ~1" floating and mark as FL6
Insulation	3 layers of tape Item [5].
WD4 Shield	At the primary-side of the bobbin, use 4 wires Item [3], for simplicity leave ~1" floating, and set as NC. Wind 6 quad-filar turns of wire Item [3] in 1 layer. At the last turn, bring these wires back to the left and finish at pin 2. Cut the NC wires.
Insulation	1 layer of tape Item [5].
WD1 2nd Primary	Use wire hanging from WD1; continue winding 22 turns from right to left. At the last turn, leave ~ 1" of wire floating and mark as FL4.
Insulation	3 layers of tape Item [5].
Finish	Gap cores to get 552 μH and secure with clips Item [6]. Varnish with Item [7].

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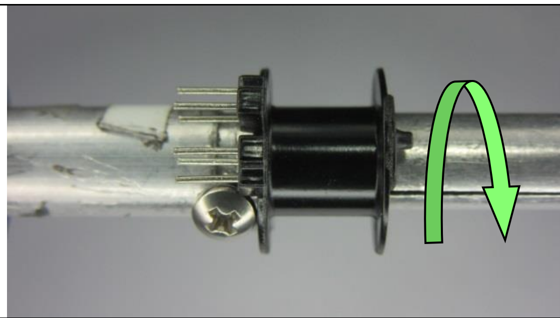
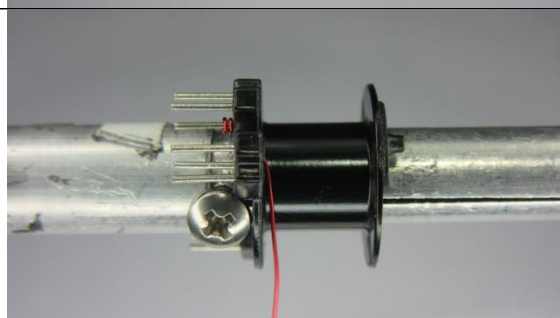
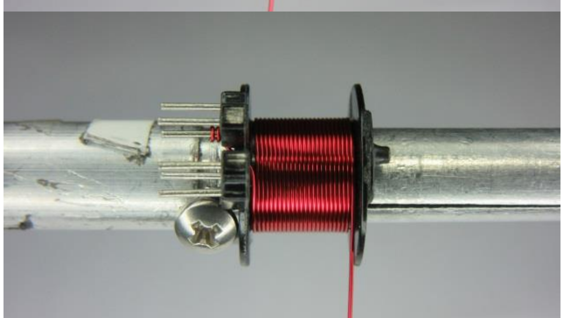
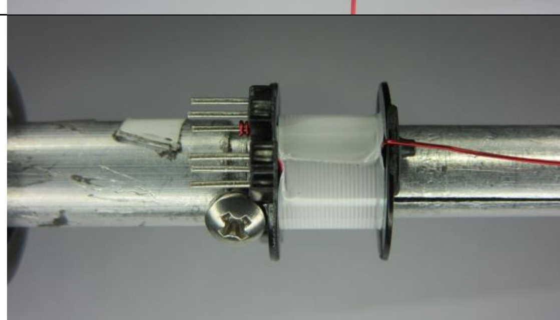
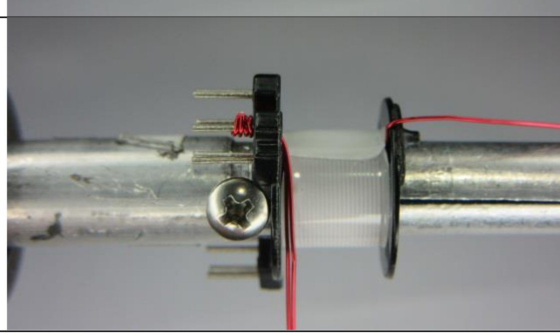
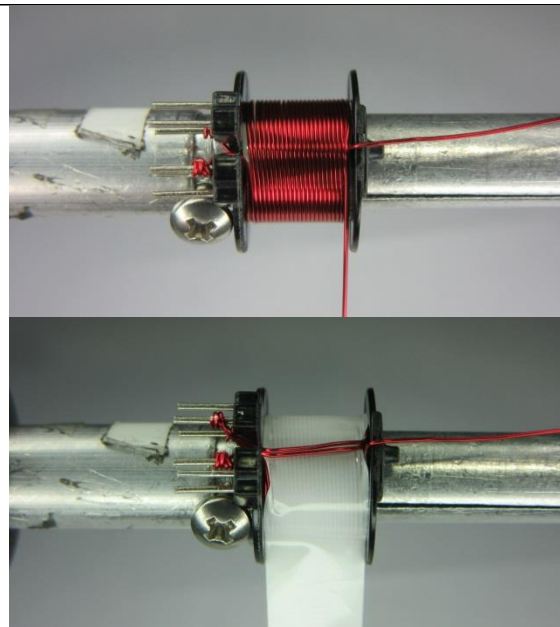
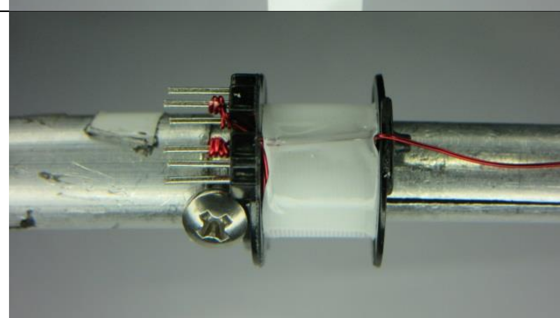
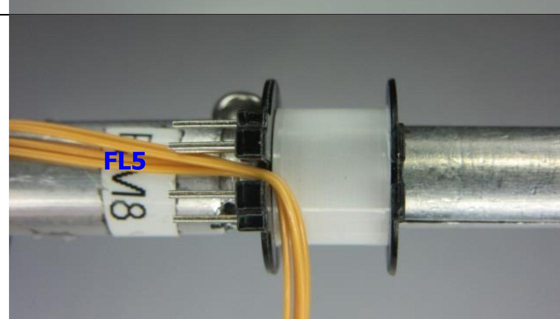
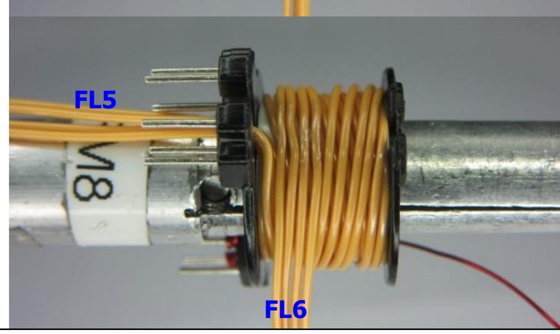
8.6 Winding Illustration

Winding Preparation		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 10, wind 23 turns of wire Item [3] in 1 layer. At the last turn, leave the wire hanging and enough length for the 2nd primary.
Insulation		1 layer of tape Item [5].
WD2 Bias		Start at pin 1, wind 12 bi-filar turns of wire Item [3] in 1 layer, from left to right, spread the wires evenly across the width of the bobbin. At the last turn bring these wires back to the left and finish at pin 12.

		
Insulation		3 layers of tape Item [5].
WD3 Secondary	 	Start on the secondary-side of the bobbin, use 3 wires Item [4], leave ~1" floating, and mark as FL5. Wind 5 turns, at the last turn bring these wires back to the left, also leave ~1" floating and mark as FL6.

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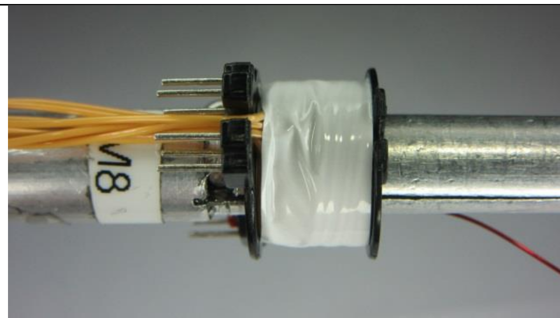
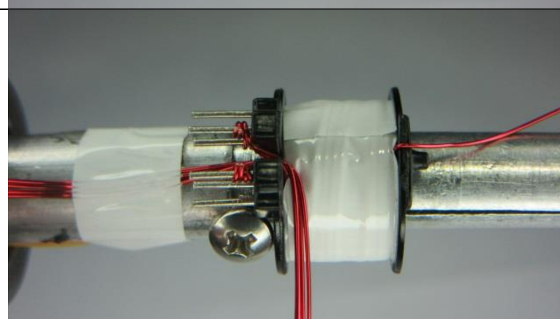
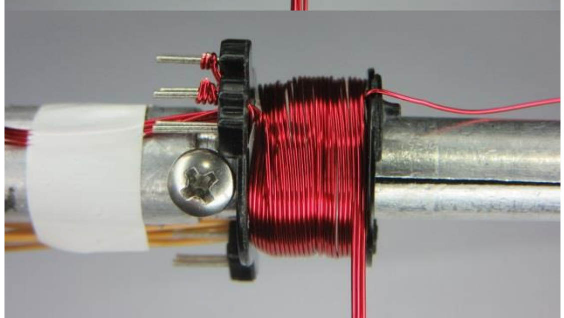
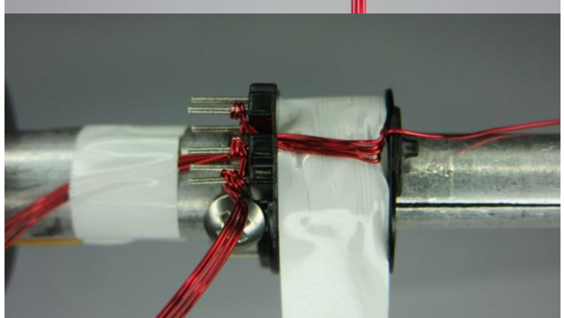
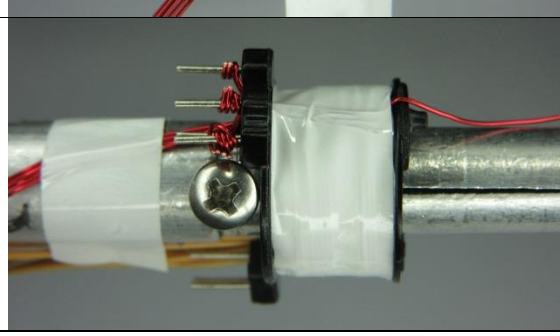
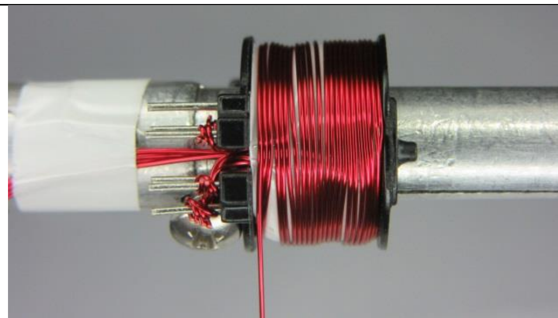
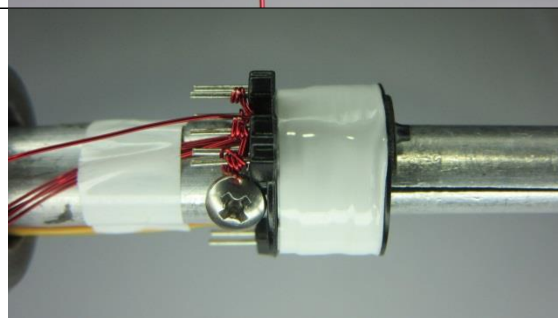
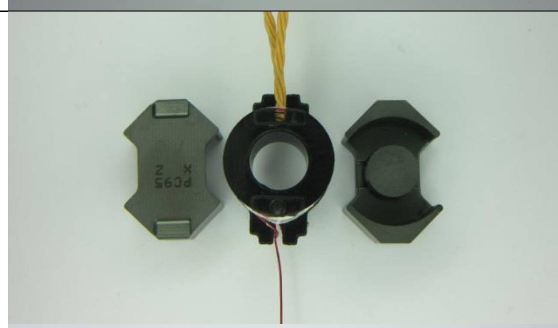
Insulation		3 layers of tape Item [5].
WD4 Shield	  	At the primary-side of the bobbin, use 4 wires Item [3], for simplicity leave ~1” floating, and set as NC. Wind 6 quad-filar turns of wire Item [3] in 1 layer. At the last turn, bring these wires back to the left and finish at pin 2. Cut the NC wires.
Insulation		1 layer of tape Item [5].

WD1 **2nd Primary**		Use wire hanging from WD1; continue winding 22 turns from right to left. At the last turn, leave ~1” of wire floating and mark as FL4.
Insulation		3 layers of tape Item [5].
Finish	 	Gap cores to get 552 μH and secure with clips Item [6]. Varnish with Item [7].

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9 12.5 mH (L2) Common Mode Choke Specification

9.1 Electrical Diagram

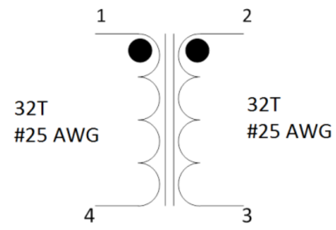


Figure 12 – Inductor Electrical Diagram.

9.2 Electrical Specifications

Inductance	Pins 1-4 and pins 2-3 measured at 100 kHz, 0.4 V_{RMS}.	~12.5 mH ±15%
Primary Leakage Inductance	Pins 1-4, with 2-3 shorted.	~25 µH

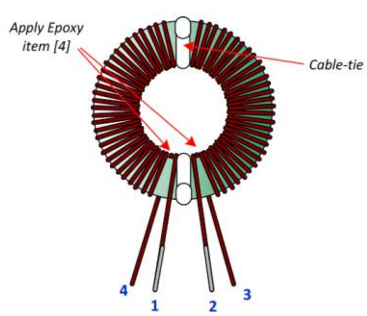
9.3 Material List

Item	Description
[1]	Core: JL15 (JLW ELECTRONICS (HONG KONG) LIMITED). AL = 8000 nH/N^2. Mfg P/N: T18x10x7C-JL15*. PI P/N: 30-00398-00.
[2]	Divider: Cable Tie, Panduit, PLT.7M-M,75-00082-00.
[3]	Magnet Wire: #25 AWG Heavy Nyleze.
[4]	Epoxy: Devcon, 14270, 5 min Epoxy; or Equivalent.

9.4 Winding Instructions

- Place 2 pieces of cable tie Item [2] onto toroid Item [1] to divide 2 equal sections.
- Use 4 ft of wire Item [3], start as pin 1 wind 32 turns and end at pin 4.
- Do the same for another section of toroid, start at pin 2 then end at pin 3 symmetrically with last winding.

9.5 Illustration



10 Transformer Design Spreadsheet

ACDC_InnoSwitch3-CP_Flyback_092217; Rev.1.0; Copyright Power Integrations 2017	**INPUT**	**OUTPUT**	**UNITS**	**InnoSwitch3-CP Flyback Design Spreadsheet**
APPLICATION VARIABLES				
VAC_MIN		85	V	Minimum AC line voltage
VAC_MAX		265	V	Maximum AC input voltage
VAC_RANGE		UNIVERSAL		AC line voltage range
FLINE		60	Hz	AC line voltage frequency
CAP_INPUT	100.0	100.0	uF	Input capacitance
SETPOINT 1				
VOUT1	9.00	9.00	V	Output voltage 1, should be the highest output voltage required
IOUT1	3.00	3.00	A	Output current 1
POUT1		27.00	W	Output power 1
EFFICIENCY1	0.90	0.90		Converter efficiency for output 1
Z_FACTOR1	0.50	0.50		Z-factor for output 1
SETPOINT 2				
VOUT2	5.00	5.00	V	Output voltage 2
IOUT2	3.00	3.00	A	Output current 2
POUT2		15.00	W	Output power 2
EFFICIENCY2	0.85	0.85		Converter efficiency for output 2
Z_FACTOR2	0.50	0.50		Z-factor for output 2
PERCENT_CDC	0%	0%		Percentage (of output voltage) cable drop compensation desired at full load
CDC_SCALING_SETPOINT	1	1		Select the setpoint number for the voltage used for cable drop compensation (typically the 5V output)
PRIMARY CONTROLLER SELECTION				
ENCLOSURE	ADAPTER	ADAPTER		Power supply enclosure
ILIMIT_MODE	INCREASED	INCREASED		Device current limit mode
VDRAIN_BREAKDOWN	650	650	V	Device breakdown voltage
DEVICE_GENERIC	INN32X6	INN32X6		Device selection
DEVICE_CODE		INN3266C		Device code
PDEVICE_MAX		27	W	Device maximum power capability
RDSON_25DEG		1.50	Ω	Primary MOSFET on-time resistance at 25°C
RDSON_100DEG		2.32	Ω	Primary MOSFET on-time resistance at 100°C
ILIMIT_MIN		1.319	A	Primary MOSFET minimum current limit
ILIMIT_TYP		1.450	A	Primary MOSFET typical current limit
ILIMIT_MAX		1.581	A	Primary MOSFET maximum current limit
VDRAIN_ON_MOSFET		0.65	V	Primary MOSFET on-time voltage drop
VDRAIN_OFF_MOSFET		524.31	V	Peak drain voltage on the primary MOSFET during turn-off
WORST CASE ELECTRICAL PARAMETERS				
FSWITCHING_MAX	68355	68355	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
VOR	81.0	81.0	V	Voltage reflected to the primary winding (corresponding to setpoint 1) when the primary MOSFET turns off
VMIN		101.64	V	Valley of the minimum input AC voltage
KP		0.983		Measure of continuous/discontinuous mode of operation
MODE_OPERATION		CCM		Mode of operation
DUTYCYCLE		0.445		Primary MOSFET duty cycle
TIME_ON		8.16	us	Primary MOSFET on-time
TIME_OFF		8.12	us	Primary MOSFET off-time
LPRIMARY_MIN		524.4	uH	Minimum primary magnetizing inductance
LPRIMARY_TYP		552.0	uH	Typical primary magnetizing inductance
LPRIMARY_TOL		5.0		Primary magnetizing inductance tolerance
LPRIMARY_MAX		579.6	uH	Maximum primary magnetizing inductance
PRIMARY CURRENT				
IAVG_PRIMARY		0.28	A	Primary MOSFET average current
IPEAK_PRIMARY		1.44	A	Primary MOSFET peak current

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IPEDESTAL_PRIMARY		0.02	A	Primary MOSFET current pedestal
IRIPPLE_PRIMARY		1.44	A	Primary MOSFET ripple current
IRMS_PRIMARY		0.52	A	Primary MOSFET RMS current
SECONDARY CURRENT				
IPEAK_SECONDARY		12.99	A	Secondary MOSFET peak current
IPEDESTAL_SECONDARY		0.20	A	Secondary MOSFET pedestal current
IRMS_SECONDARY		5.24	A	Secondary MOSFET RMS current
IRIPPLE_CAP_OUT		4.29	A	Output capacitor ripple current
TRANSFORMER CONSTRUCTION PARAMETERS				
CORE SELECTION				
CORE	RM8	RM8		The transformer windings may not fit: pick a bigger core or bobbin and refer to the Transformer Parameters tab for fit calculations
CORE NAME		PC95RM08Z		Core code
AE		64.0	mm^2	Core cross sectional area
LE		38.0	mm	Core magnetic path length
AL		5290	nH	Ungapped core effective inductance per turns squared
VE		2430	mm^3	Core volume
BOBBIN NAME		B-RM08-V		Bobbin name
AW		30.0	mm^2	Bobbin window area
BW		8.8	mm	Bobbin width
MARGIN		0.0	mm	Bobbin safety margin
PRIMARY WINDING				
NPRIMARY		45		Primary winding number of turns
BPEAK		3257	Gauss	Peak flux density
BMAX		2862	Gauss	Maximum flux density
BAC		1431	Gauss	AC flux density
ALG		273	nH	Typical gapped core effective inductance per turns squared
LG		0.280	mm	Core gap length
LAYERS_PRIMARY	2	2		Primary winding number of layers
AWG_PRIMARY		28		Primary wire gauge
OD_PRIMARY_INSULATED		0.375	mm	Pimary wire insulated outer diameter
OD_PRIMARY_BARE		0.321	mm	Primary wire bare outer diameter
CMA_PRIMARY		306.7	Cmils/A	Primary winding wire CMA
SECONDARY WINDING				
NSECONDARY	5	5		Secondary winding number of turns
AWG_SECONDARY		19		Secondary wire gauge
OD_SECONDARY_INSULATED		1.217	mm	Secondary wire insulated outer diameter
OD_SECONDARY_BARE		0.912		Secondary wire bare outer diameter
CMA_SECONDARY		246.0	Cmils/A	Secondary winding wire CMA
BIAS WINDING				
NBIAS		12		Bias winding number of turns
PRIMARY COMPONENTS SELECTION				
LINE UNDERVOLTAGE				
BROWN-IN REQURED		68.00	V	Required line brown-in threshold
RLS		3.38	MΩ	Connect two 1.69 MOhm resistors to the V-pin for the required UV/OV threshold
BROWN-IN ACTUAL		67.81	V	Actual brown-in threshold using standard resistors
BROWN-OUT ACTUAL		61.33	V	Actual brown-out threshold using standard resistors
LINE OVERVOLTAGE				
OVERVOLTAGE_LINE		282.48	V	Actual AC RMS line over-voltage threshold
BIAS WINDING				
VBIAS	11.00	11.00	V	Rectified bias voltage
VF_BIAS		0.70	V	Bias winding diode forward drop
VREVERSE_BIASDIODE		110.55	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
CBIAS		22	uF	Bias winding rectification capacitor
CBPP		4.70	uF	BPP pin capacitor
SECONDARY COMPONENTS SELECTION				

RECTIFIER				
VDRAIN_OFF_SRFET		50.48	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
SRFET	Auto	AOD2816		Secondary rectifier (Logic MOSFET)
VBREAKDOWN_SRFET		80	V	Secondary rectifier breakdown voltage
RDSON_SRFET		29.0	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
FEEDBACK COMPONENTS				
RFB_UPPER		100.00	kΩ	Upper feedback resistor (connected to the output terminal)
RFB_LOWER		16.50	kΩ	Lower feedback resistor required to obtain the output for cable drop compensation
CFB_LOWER		330	pF	Lower feedback resistor decoupling capacitor
VARIABLE OUTPUTS ANALYSIS				
TOLERANCE CORNER				
CORNER_VAC		85	V	Input AC RMS voltage corner to be evaluated
CORNER_ILIMIT	TYP	1.450	A	Current limit corner to be evaluated
CORNER_LPRIMARY	TYP	552.0	uH	Primary inductance corner to be evaluated
SETPOINT SELECTION				
SETPOINT	1	1		Select the setpoint which needs to be evaluated
FSWITCHING		57006.4	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
VOR		81.0	V	Voltage reflected to the primary winding when the primary MOSFET turns off
VMIN		101.64	V	Valley of the minimum input AC voltage
KP		1.110		Measure of continuous/discontinuous mode of operation
MODE_OPERATION		DCM		Mode of operation
DUTYCYCLE		0.419		Primary MOSFET duty cycle
TIME_ON		7.36	us	Primary controller's maximum on-time
TIME_OFF		10.19	us	Primary controller's minimum off-time
PRIMARY CURRENT				
IAVG_PRIMARY		0.28	A	Primary MOSFET average current
IPEAK_PRIMARY		1.35	A	Primary MOSFET peak current
IPEDESTAL_PRIMARY		0.00	A	Primary MOSFET current pedestal
IRIPPLE_PRIMARY		1.35	A	Primary MOSFET ripple current
IRMS_PRIMARY		0.50	A	Primary MOSFET RMS current
SECONDARY CURRENT				
IPEAK_SECONDARY		12.11	A	Secondary MOSFET peak current
IPEDESTAL_SECONDARY		0.00	A	Secondary MOSFET pedestal current
IRMS_SECONDARY		5.06	A	Secondary MOSFET RMS current
IRIPPLE_CAP_OUT		4.07	A	Output capacitor ripple current

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11 Performance Data

11.1 Efficiency

Note: Output voltages measured at PCB end.

11.1.1 Efficiency vs. Line

Note: Both outputs at full load.

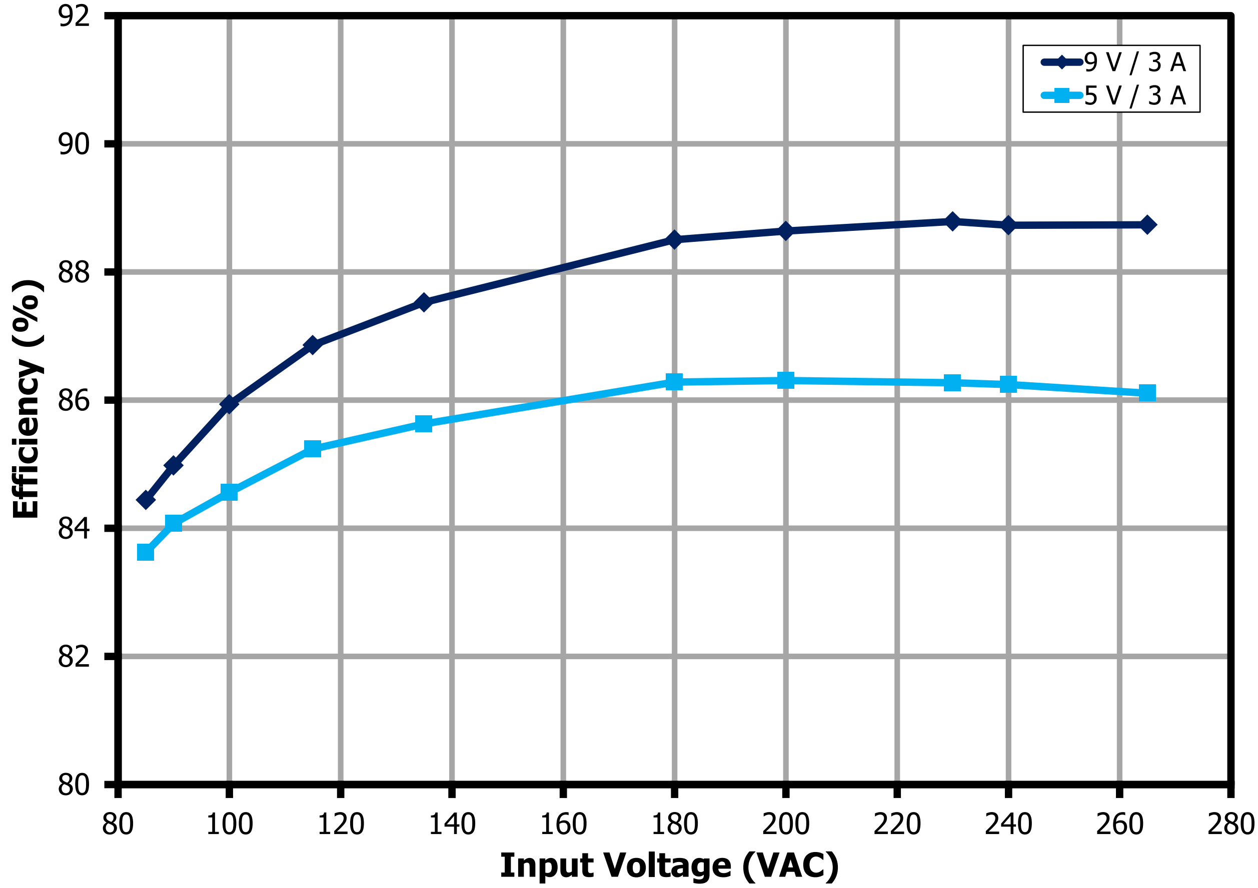

Figure 13 – Efficiency vs. Input Line Voltage.

11.1.2 Efficiency vs. Load (5 V / 3 A; 5 V / 3 A)

Note: Both outputs at variable loading.

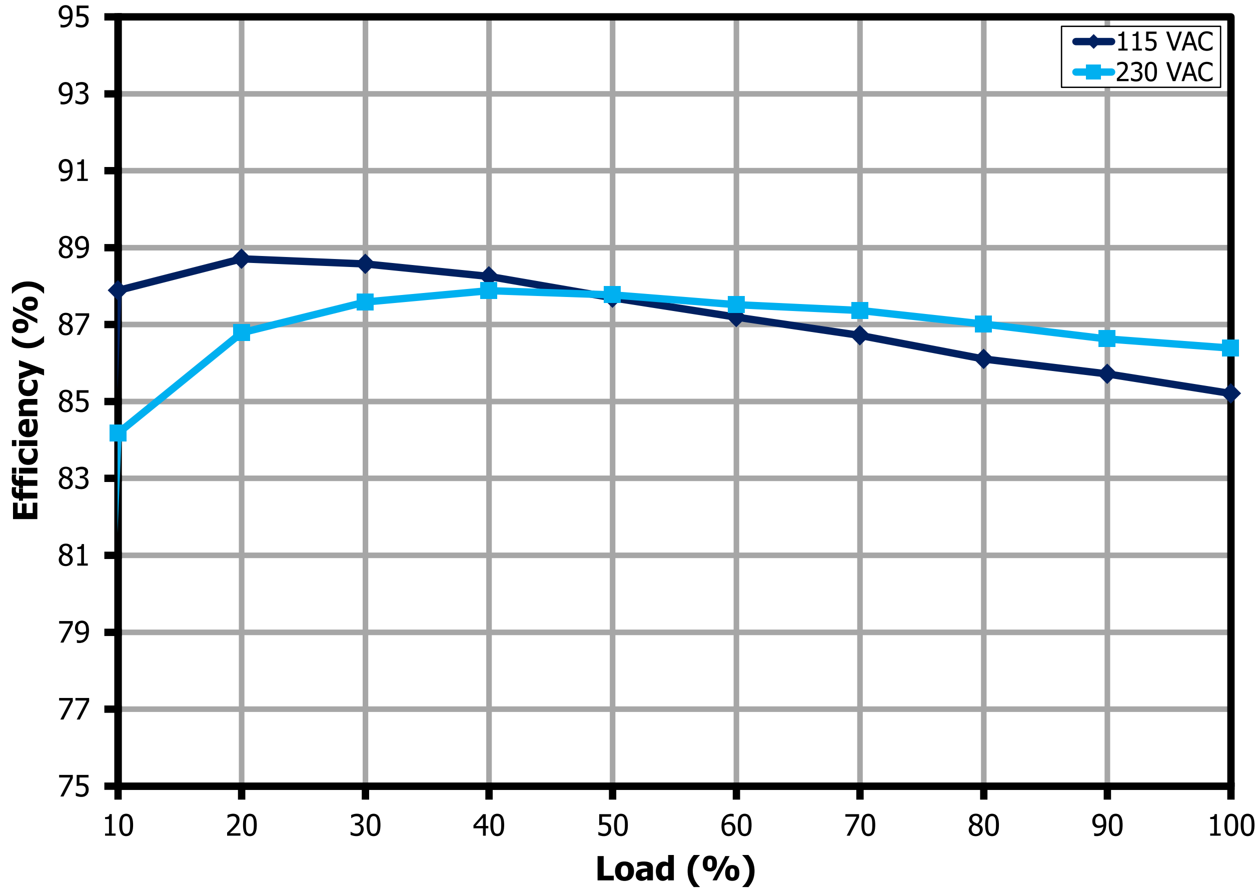

Figure 14 – Efficiency vs. Percent Load.

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11.1.3 Efficiency vs. Load (9 V / 3 A; 9 V / 3 A)

Note: Both outputs at variable loading.

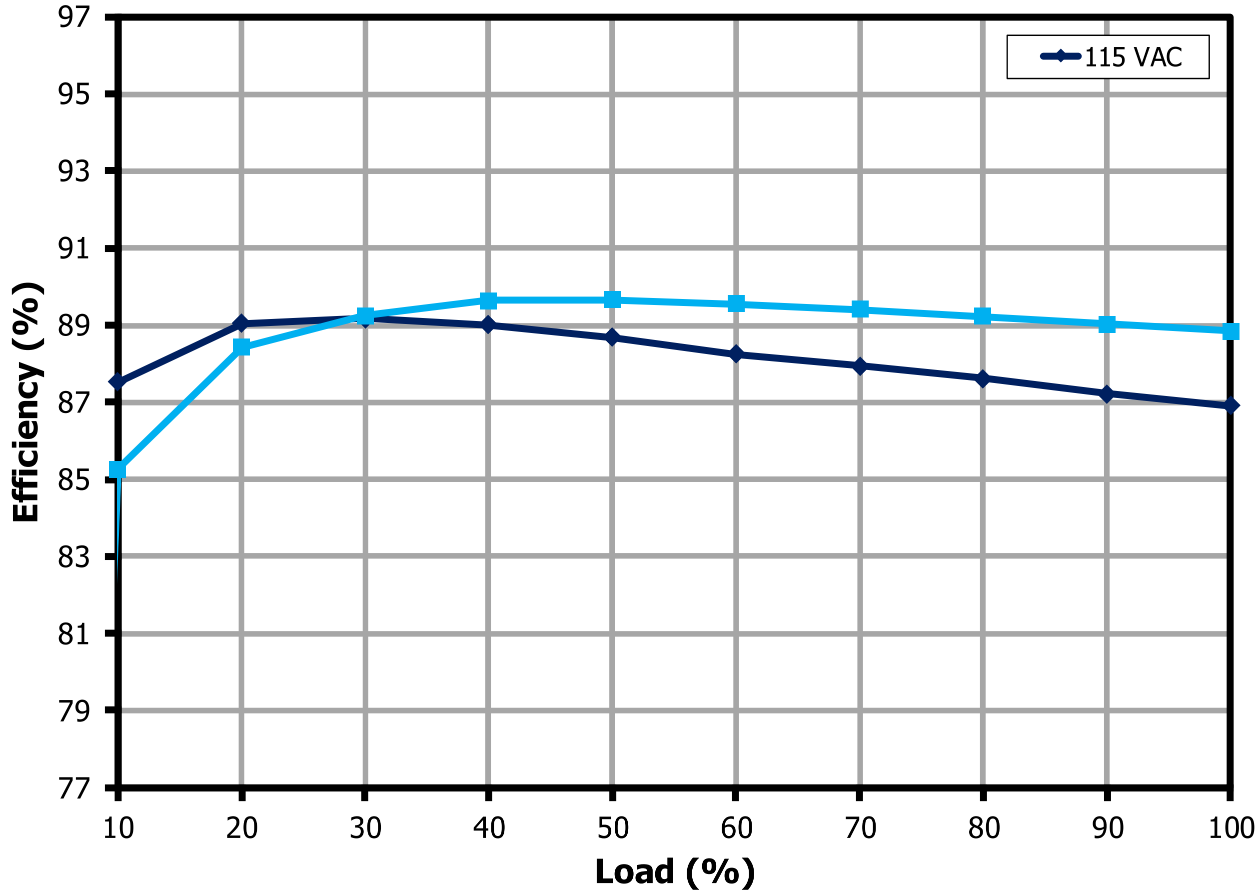

Figure 15 – Efficiency vs. Percent Load.

11.1.4 No-Load Input Power

Note: 5 V outputs at no-load.

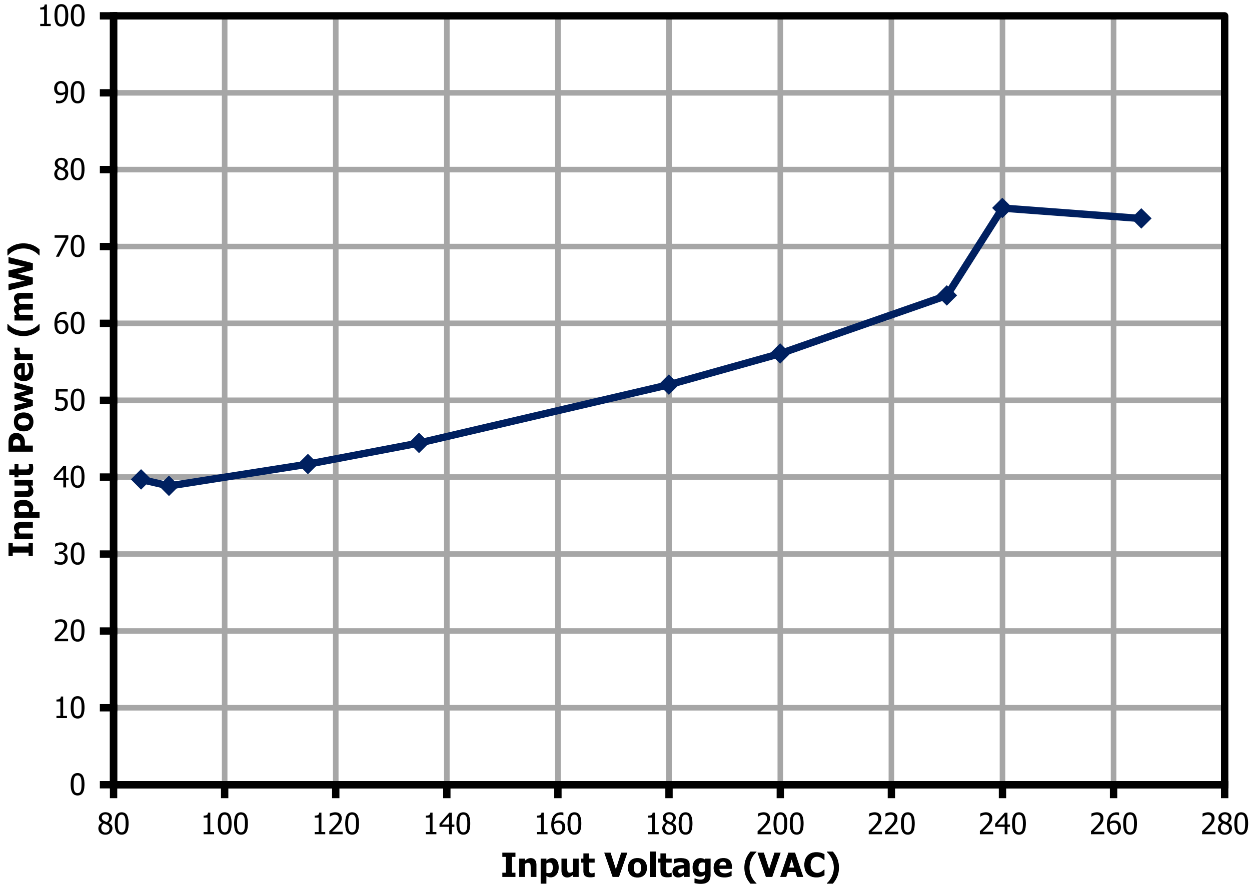

Figure 16 – No-Load Power vs. Input Line Voltage (with CCG4 Circuit).

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11.2 Line and Load Regulation

11.2.1 5 V Line Regulation

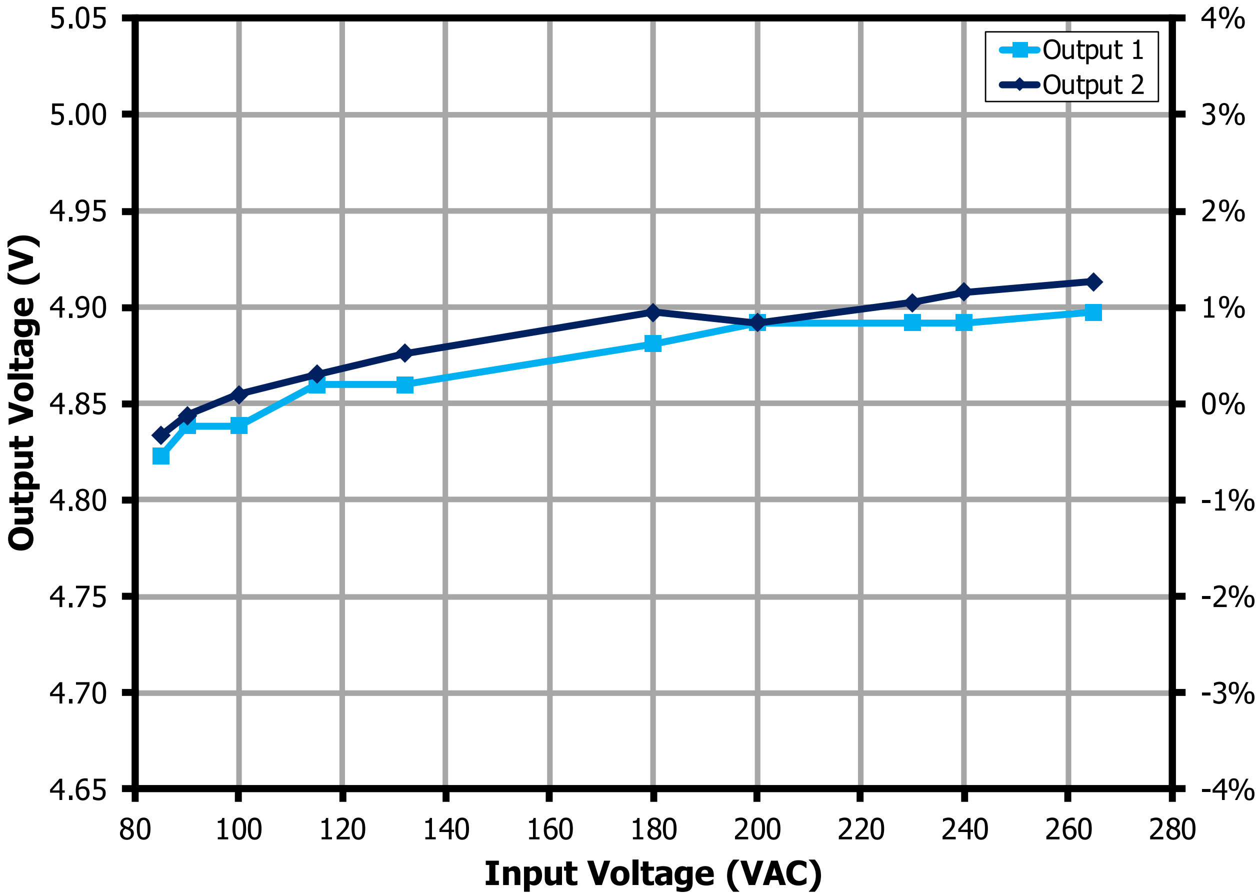

Figure 17 – 5 V Output Regulation vs. Input Line Voltage.

11.2.2 9 V Line Regulation

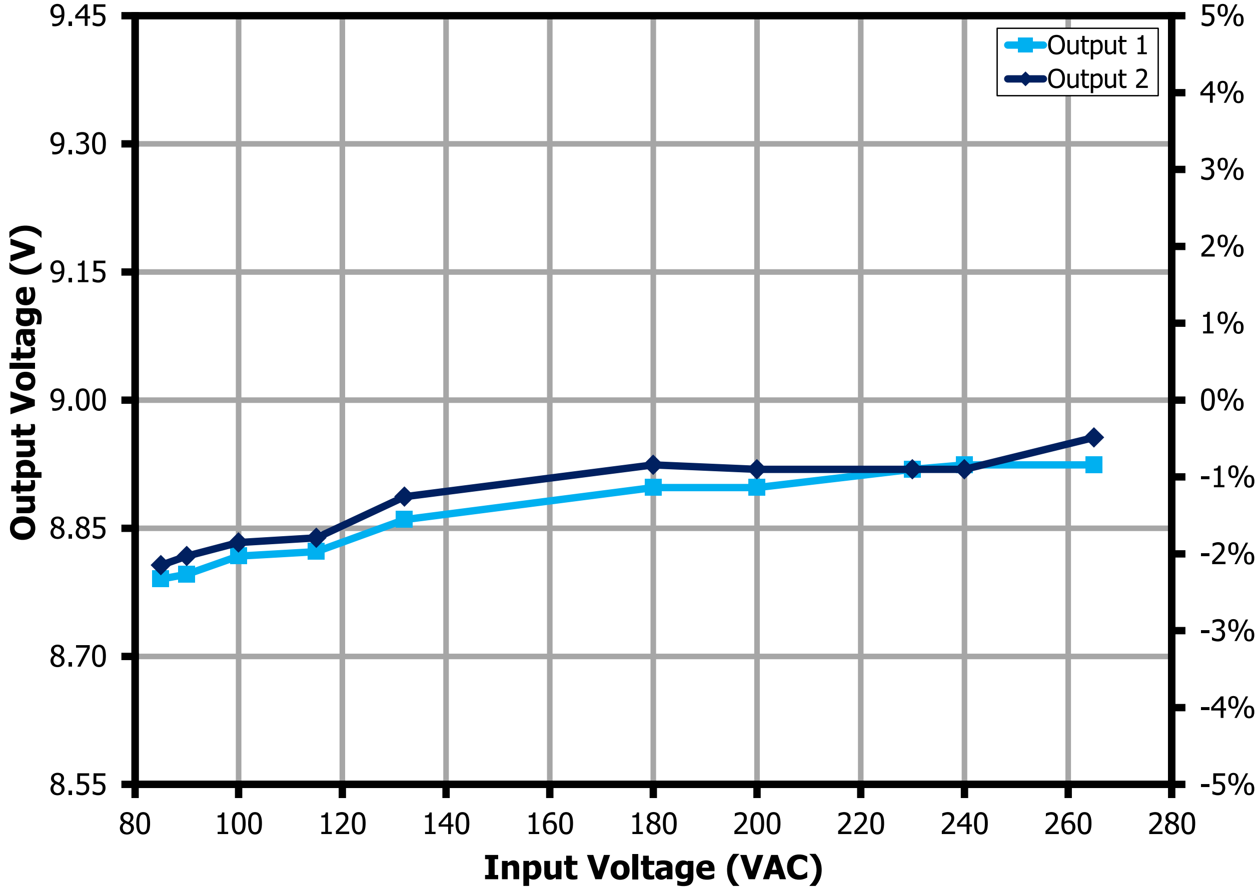

Figure 18 – 9 V Output Regulation vs. Input Line Voltage.

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11.2.3 5 V Load Regulation

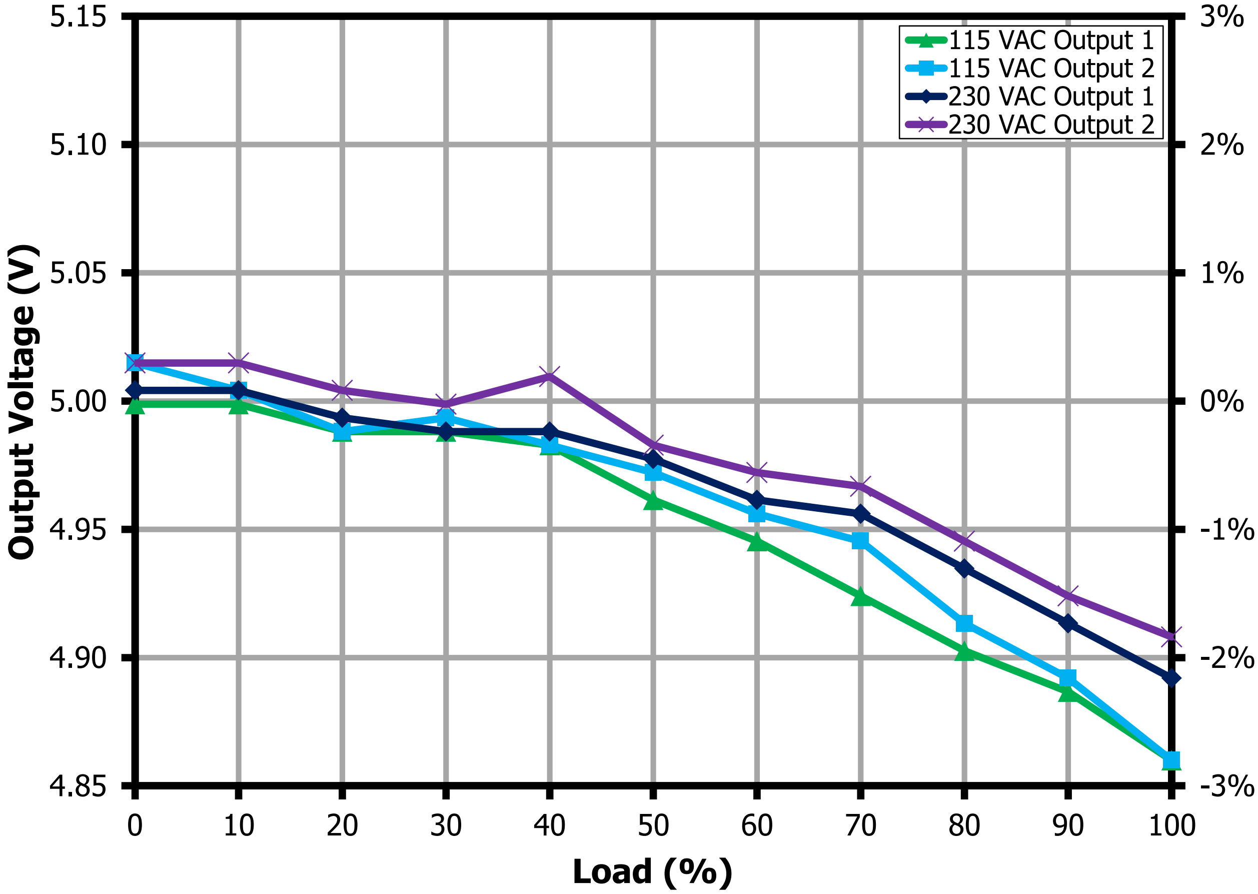

Figure 19 – 5 V Output Regulation vs. Percent Load.

11.2.4 9 V Load Regulation

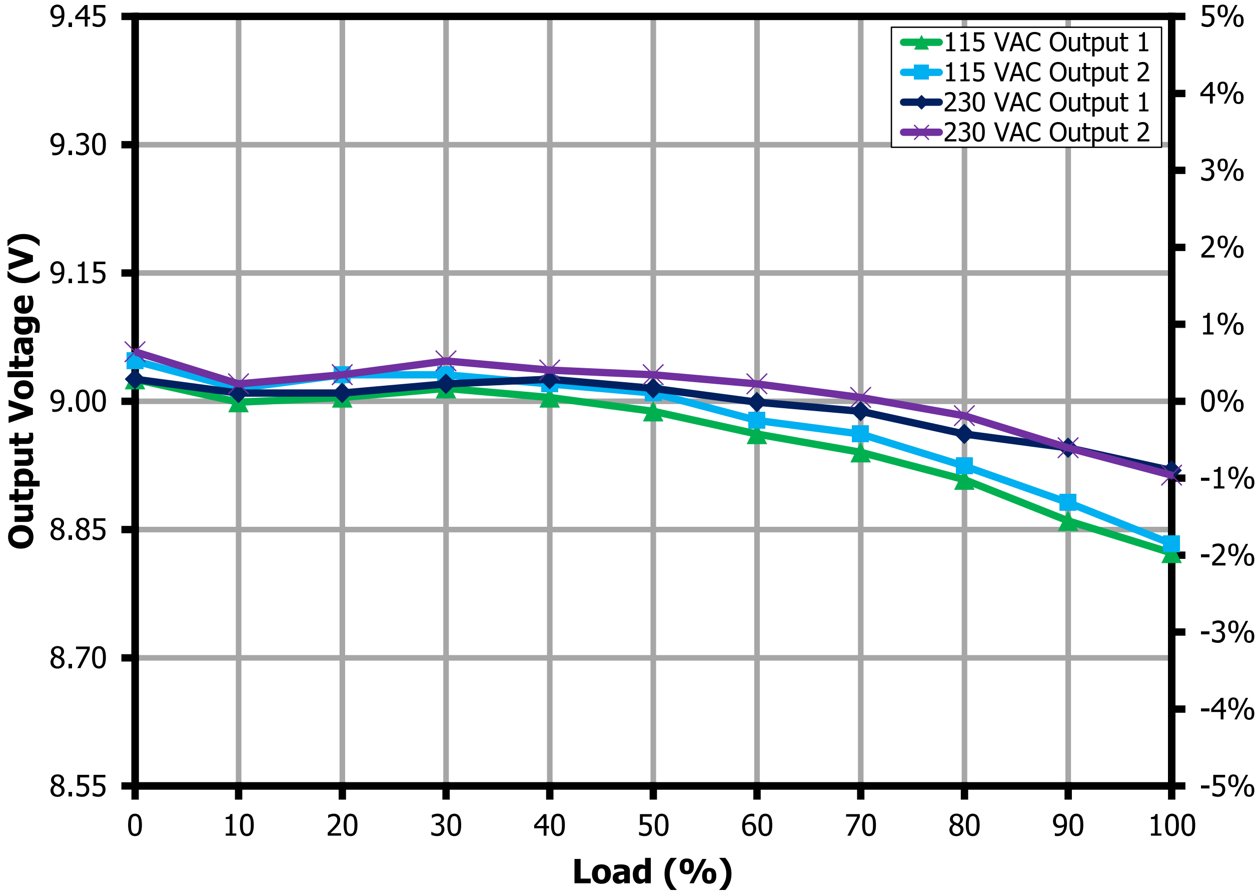

Figure 20 – 9 V Output Regulation vs. Percent Load.

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11.2.5 CV/CC vs. Line (5 V / 3 A Output)

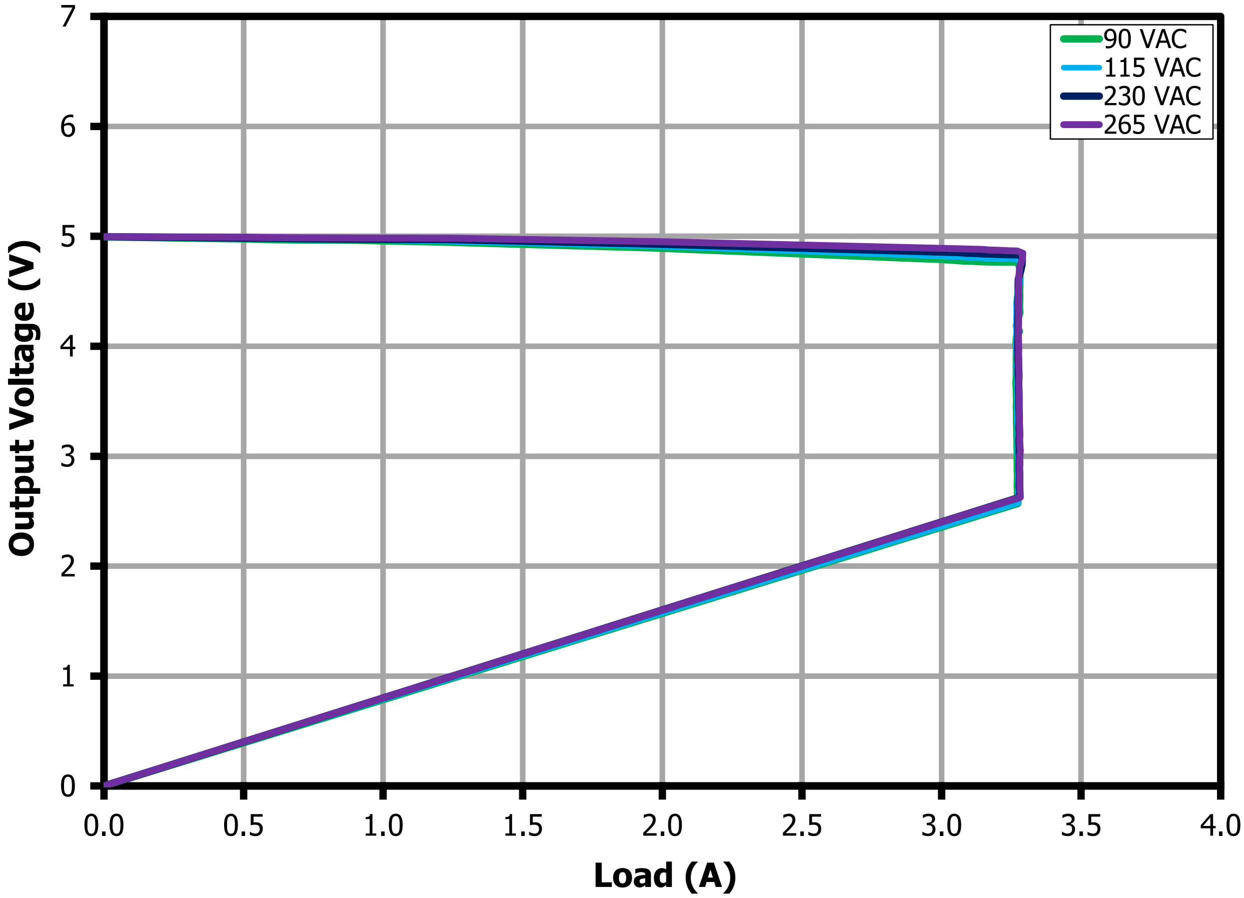

Figure 21 – CV/CC for 5 V Output at Different Input Line.

11.2.6 CV/CC vs. Line (9 V / 3 A Output)

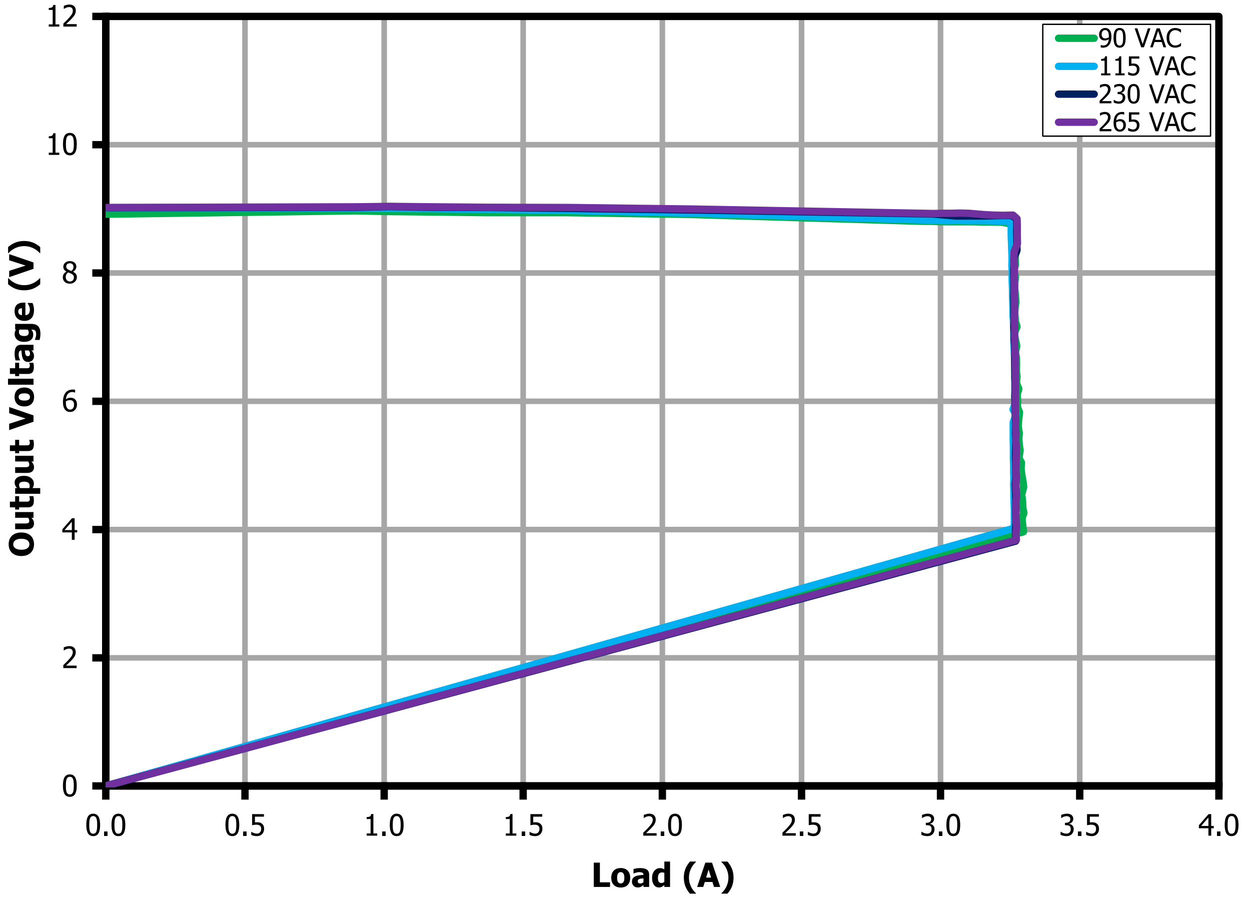

Figure 22 – CV/CC for 9 V Output at Different Input Line.

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11.3 Average Efficiency

11.3.1 Average Efficiency Requirements

		Test	**Average**	**Average**	**Average**	**Average**	**10% Load**	**10% Load**
		Effective	Now	2016	Jan-14	Jan-16	Jan-14	Jan-16
Output Voltage	**Model**	**Power [W]**	**Energy Star 2**	**New IESA2007**	**CoC v5 Tier 1**	**CoC v5 Tier 2**	**CoC v5 Tier 1**	**CoC v5 Tier 2**
5	<6 V	15	77.21%	81.39%	79.05%	81.84%	69.50%	72.48%
9	>6V	27	83.58%	86.62%	85.23%	87.30%	75.23%	77.30%

11.4 Average and 10% Efficiency (on the board) at 115 VAC Input

11.4.1 Output: 5 V

% Load	**P_{OUT} (W)**	**Efficiency (%)**	**Average Efficiency (%)**
100	29.14	85.2	87.0
75	22.15	86.4	
50	14.89	87.7	
25	7.49	88.8	
10	3.00	88.0	

11.4.2 Output: 9 V

% Load	**P_{OUT} (W)**	**Efficiency (%)**	**Average Efficiency (%)**
100	52.94	86.9	88.1
75	40.18	87.7	
50	26.98	88.7	
25	13.54	89.2	
10	5.40	87.6	

11.5 Average and 10% Efficiency (on the board) at 230 VAC Input

11.5.1 Output: 5 V

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	29.37	86.3	87.2
75	22.28	87.2	
50	14.93	87.7	
25	7.50	87.4	
10	3.00	84.2	

11.5.2 Output: 9 V

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	53.53	88.8	89.2
75	40.45	89.3	
50	27.08	89.6	
25	13.56	89.0	
10	5.41	85.2	

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12 Thermal Performance

12.1 Open Case at 9 V / 3 A; 9 V / 3

12.1.1 85 VAC

12.1.1.1 Temperature Summary

Ambient	INN3266C (U1)	INN3266C (U2)	SR FET (Q1)	SR FET (Q2)	Transformer (T1)	Transformer (T2)	Bridge (BR1)	Inductor (L2)
27	83.4	81.3	66.4	71.6	68.6	71.4	80.4	80.3

Figure 23 – Output 1 Rail.
INN3266C, U1 = 83.4 ºC.

Figure 24 –Output 2 Rail.
INN3266C, U2 = 81.3 ºC.

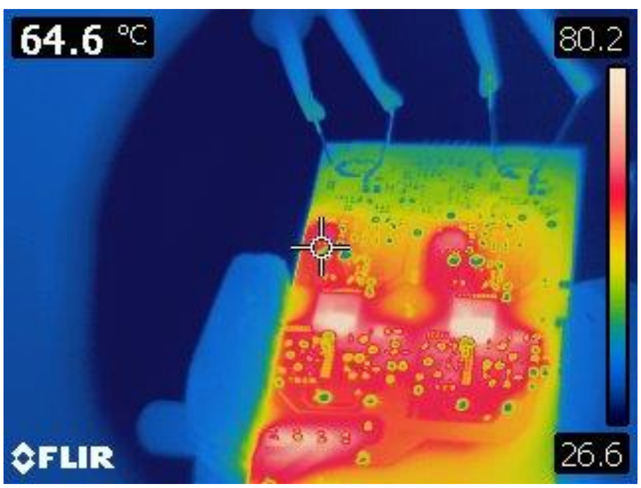

Figure 25 – Output 1 Rail.
SR FET, Q1 = 64.4 ºC.

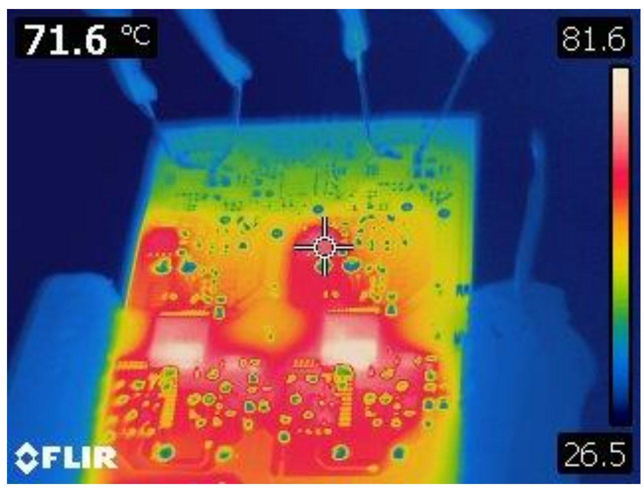

Figure 26 – Output 2 Rail.
SR FET, Q2 = 71.6 ºC.

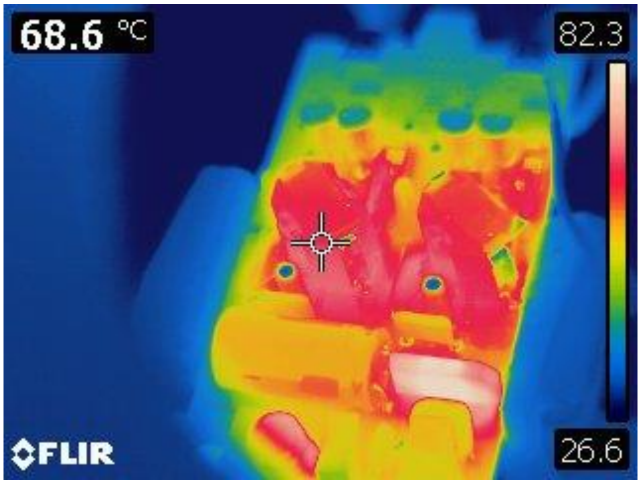

Figure 27 – Output 1 Rail.
Transformer T1 = 68.6 ºC.

Figure 28 – Output 2 Rail.
Transformer T2 = 71.4 ºC.

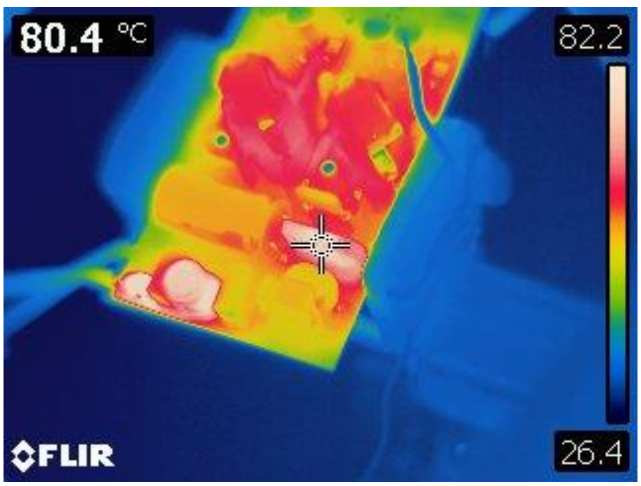

Figure 29 – Input Side.
Bridge, BR1 = 80.4 ºC.

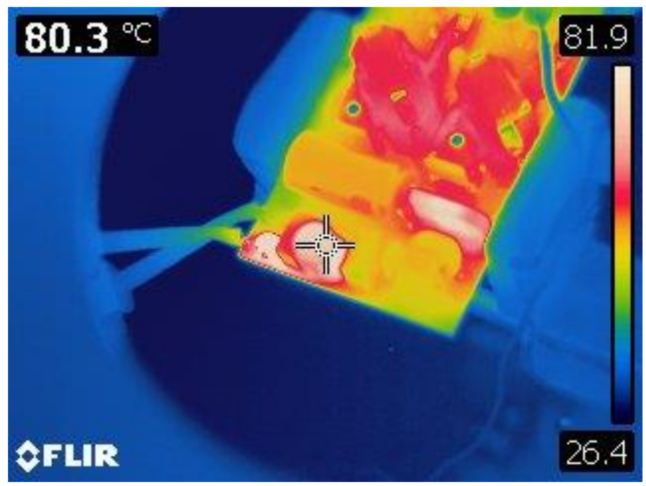

Figure 30 – Input Side.
Inductor, L2 = 80.3 ºC.

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12.1.2 265 VAC

12.1.2.1 Temperature Summary

Ambient	INN3266C (U1)	INN3266C (U2)	SR FET (Q1)	SR FET (Q2)	Transformer (T1)	Transformer (T2)	Bridge (BR1)	Inductor (L2)
27	75.7	75.5	70.2	76.0	71.6	70.1	56.0	46.2

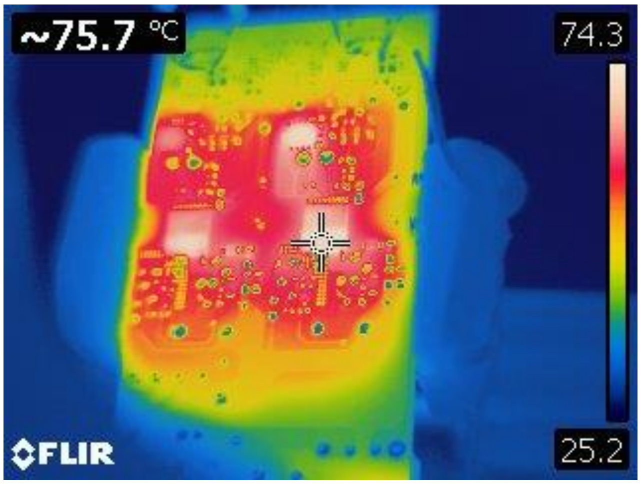

Figure 31 – Output 1 Rail.
INN3266C, U1 = 75.7 ºC.

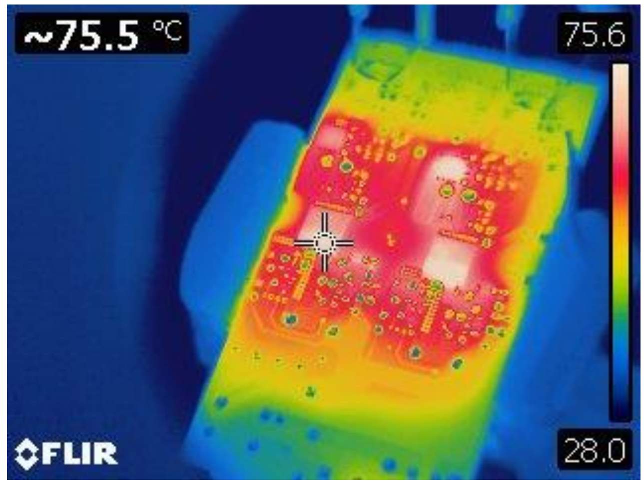

Figure 32 – Output 2 Rail.
INN3266C, U2 = 75.5 ºC.

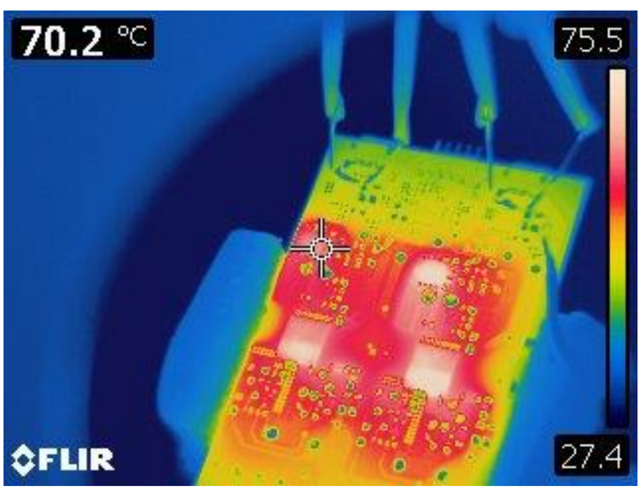

Figure 33 – Output 1 Rail.
SR FET, Q1 = 70.2 ºC.

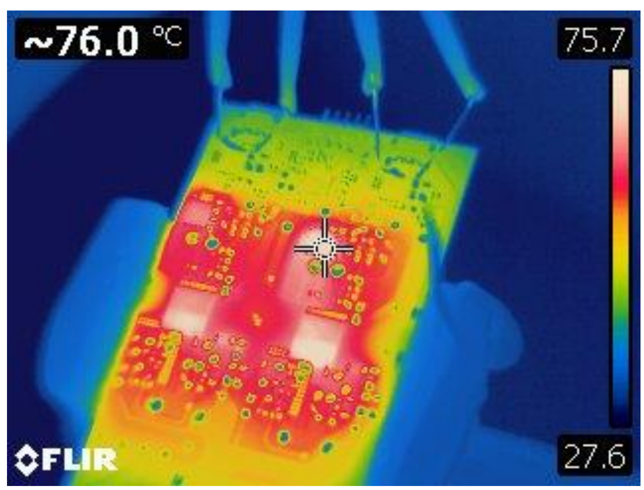

Figure 34 – Output 2 Rail.
SR FET, Q2 = 76.0 ºC.

12.2 Open Case at 5 V / 3 A; 5 V / 3 A

12.2.1 85 VAC

12.2.1.1 Temperature Summary

Ambient	INN3266C (U1)	INN3266C (U2)	SR FET (Q1)	SR FET (Q2)	Transformer (T1)	Transformer (T2)	Bridge (BR1)	Inductor (L2)
27	57.8	57.6	61.7	57.4	59.8	55.6	60.2	53.2

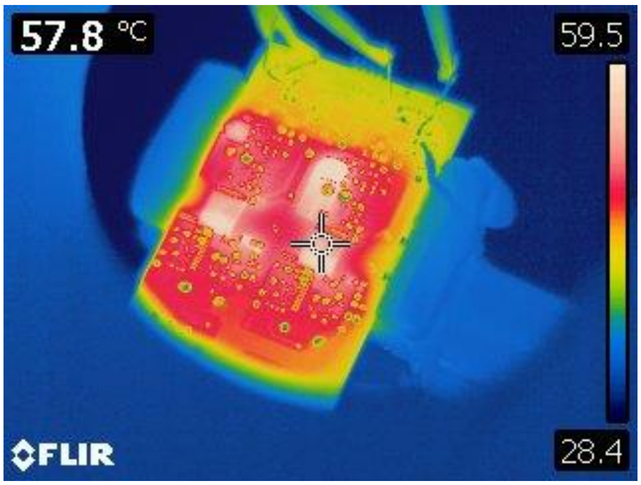

Figure 35 – Output 1 Rail.
INN3266C, U1 = 57.8 ºC.

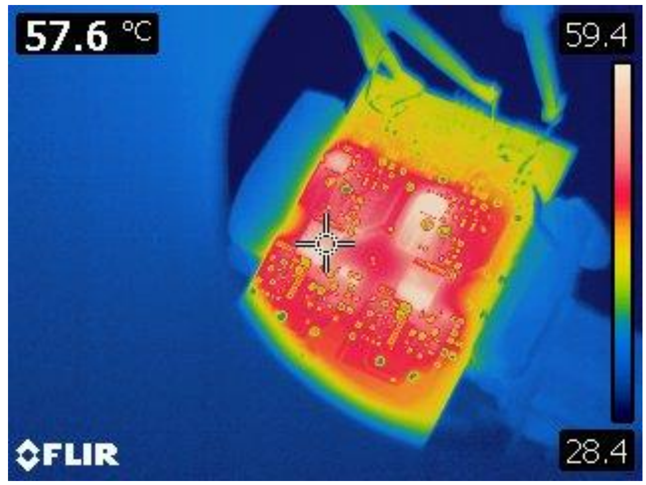

Figure 36 – Output 2 Rail.
INN3266C, U2 = 57.6 ºC.

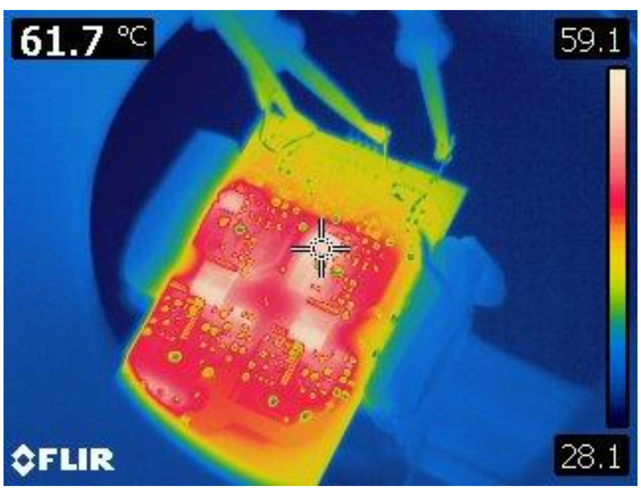

Figure 37 – Output 1 Rail.
SR FET, Q1 = 61.7 ºC.

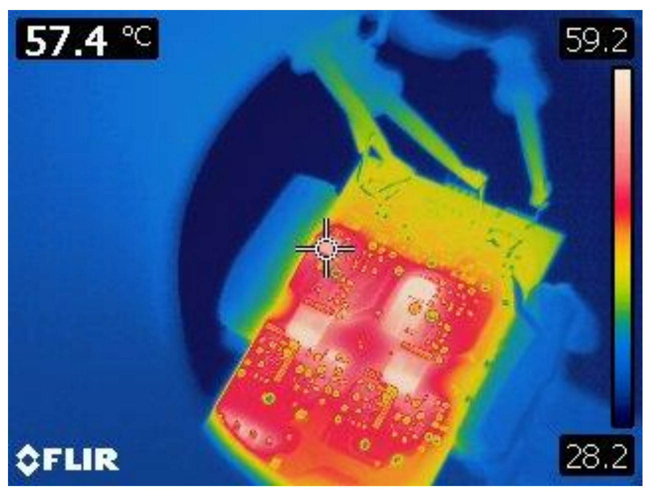

Figure 38 – Output 2 Rail.
SR FET, Q2 = 57.4 ºC.

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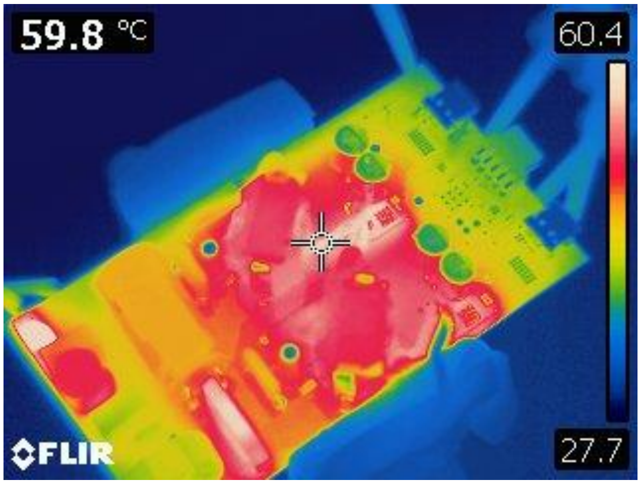

Figure 39 – Output 1 Rail.
Transformer T1 = 59.8 ºC.

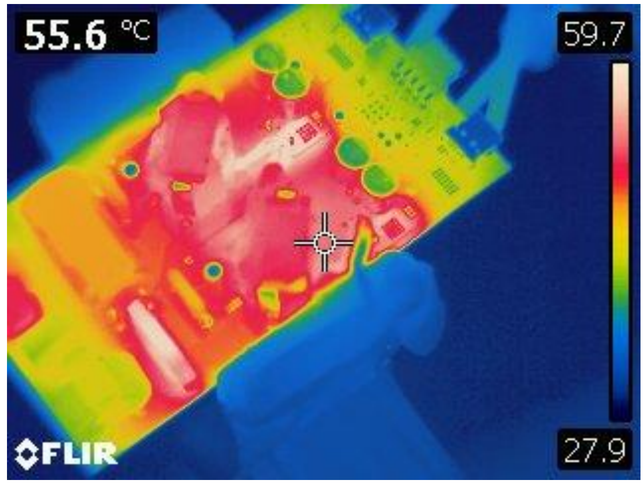

Figure 40 – Output 2 Rail.
Transformer T2 = 55.6 ºC.

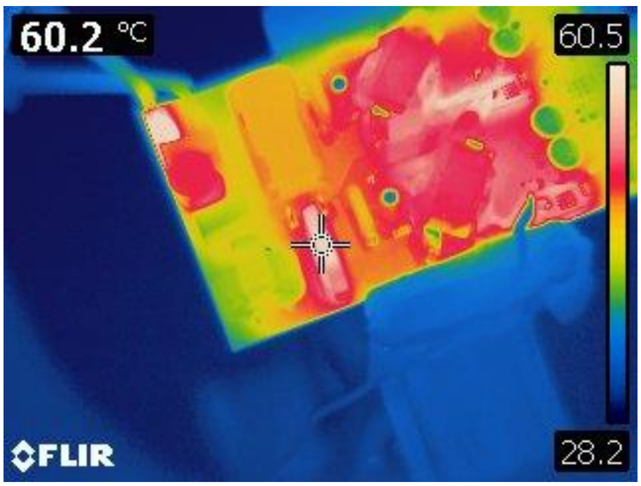

Figure 41 – Input Side.
Bridge, BR1 = 60.2 ºC.

Figure 42 – Input Side.
Inductor, L2 = 53.2 ºC.

12.2.2 265 VAC

12.2.2.1 Temperature Summary

Ambient	INN3266C (U1)	INN3266C (U2)	SR FET (Q1)	SR FET (Q2)	Transformer (T1)	Transformer (T2)	Bridge (BR1)	Inductor (L2)
27	60.7	61.1	66.4	60.7	60.6	56.9	46.6	37.9

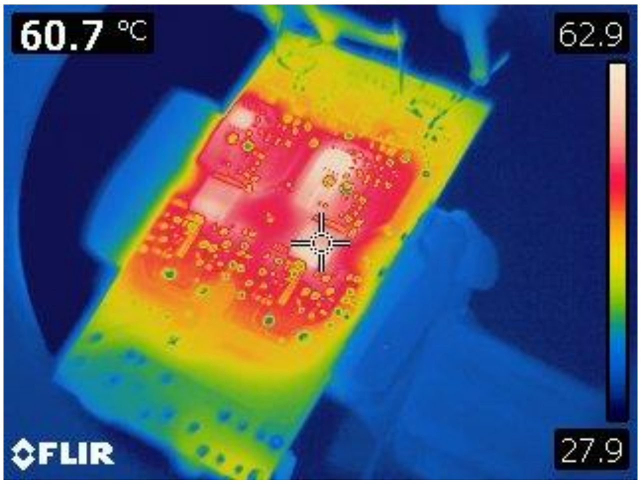

Figure 43 – Output 1 Rail.
INN3266C, U1 = 60.7 ºC.

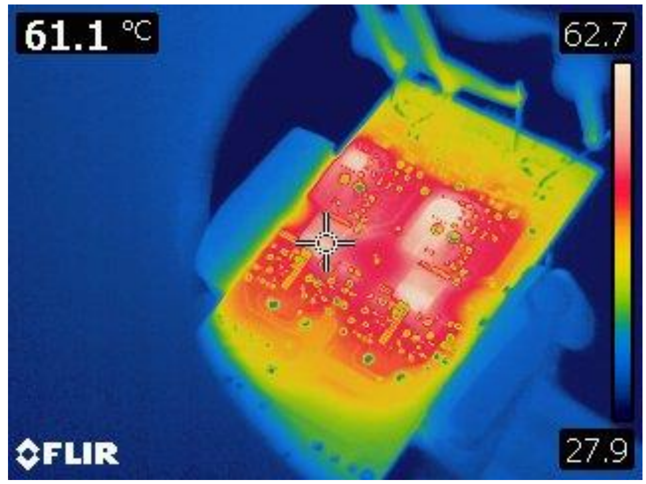

Figure 44 – Output 2 Rail.
INN3266C, U2 = 61.1 ºC.

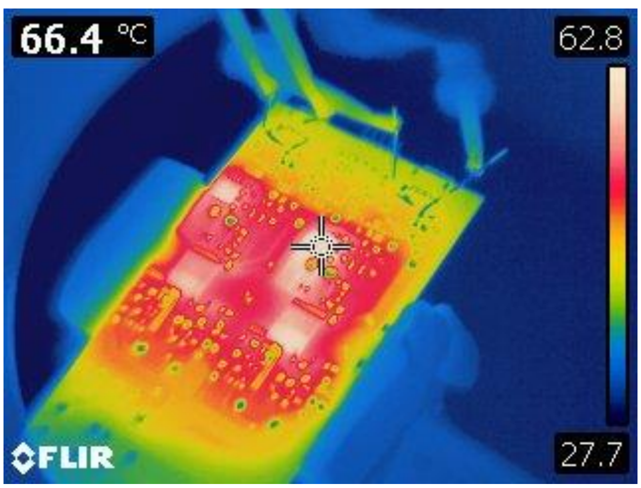

Figure 45 – Output 1 Rail.
SR FET, Q1 = 66.4 ºC.

Figure 46 – Output 2 Rail.
SR FET, Q2 = 60.7 ºC.

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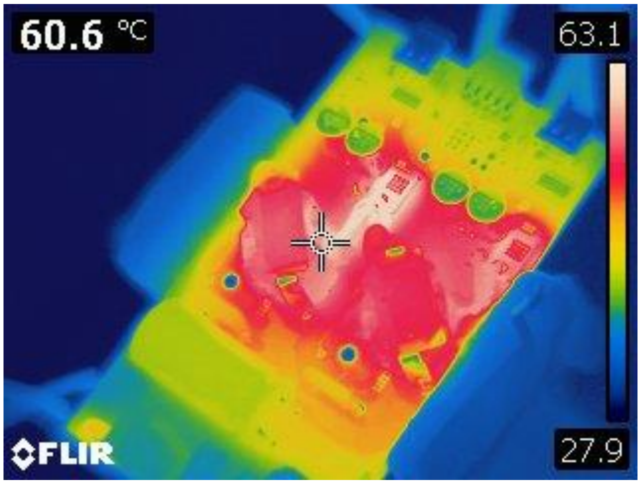

Figure 47 – Output 1 Rail.
Transformer T1 = 60.6 ºC.

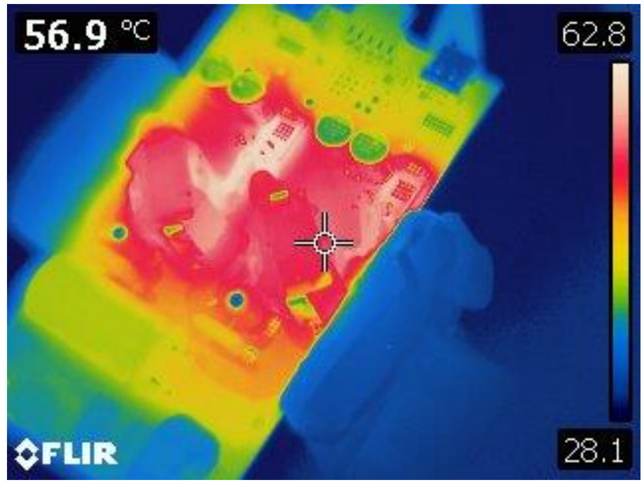

Figure 48 – Output 2 Rail.
Transformer T2 = 56.9 ºC.

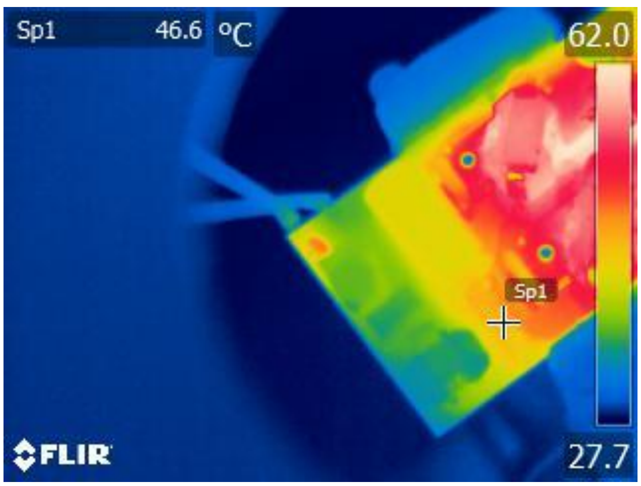

Figure 49 – Input Side.
Bridge, BR1 = 46.6 ºC.

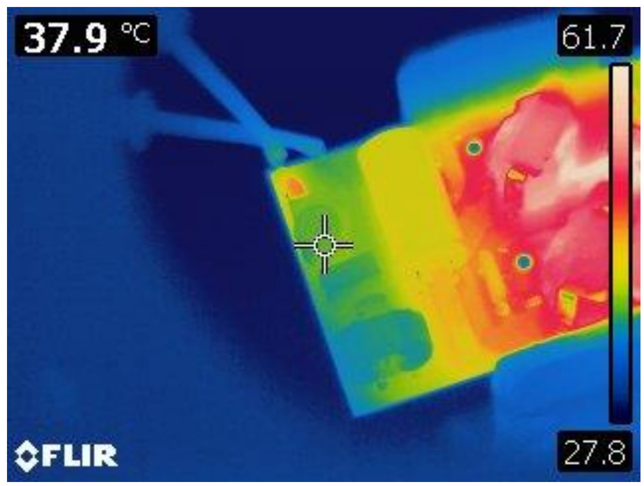

Figure 50 – Input Side.
Inductor, L2 = 37.9 ºC.

13 Waveforms

13.1 Load Transient Response (PCB End)

13.1.1 5 V Output

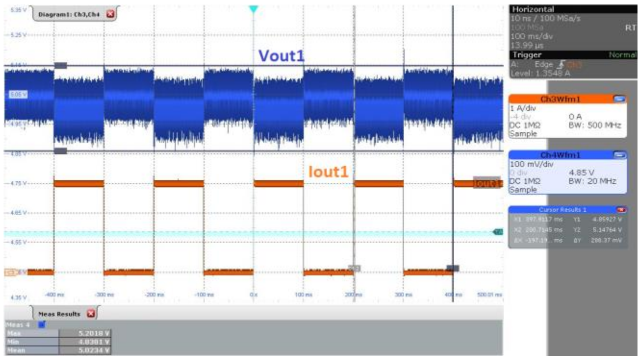

Figure 51 – Transient Response.
115 VAC, 5.0 V, 0 – 3 A Load Step.
V_{MIN} 4.82 V, V_{MAX}: 5.17 V.
Upper: V_{OUT}, 0.1 V / div., 100 ms / div.
Lower: I_{LOAD}, 1 A / div.

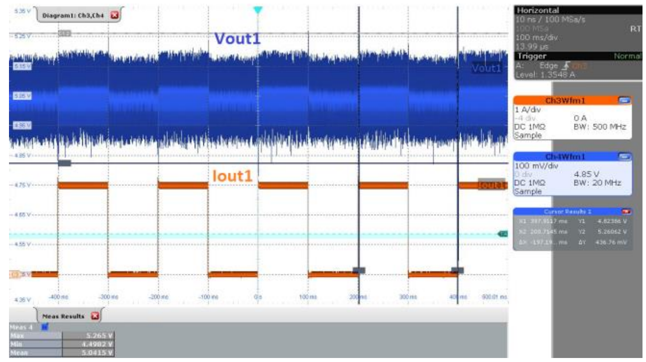

Figure 52 – Transient Response.
230 VAC, 5.0 V, 0 – 3 A Load Step.
V_{MIN} 4.5 V, V_{MAX}: 5.27 V.
Upper: V_{OUT}, 0.1 V / div., 100 ms / div.
Lower: I_{LOAD}, 1 A / div.

13.1.2 9 V Output

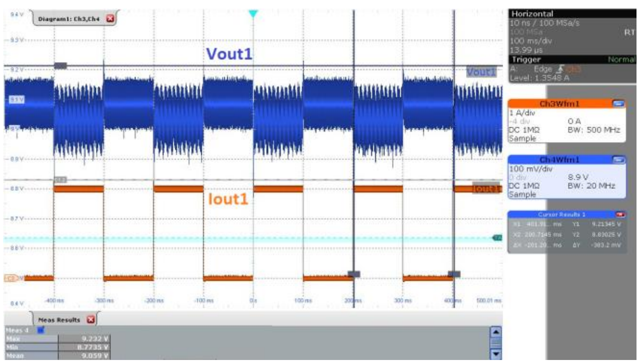

Figure 53 – Transient Response.
115 VAC, 9.0 V, 0 – 3 A Load Step.
V_{MIN}: 8.77 V, V_{MAX}: 9.23 V.
Upper: V_{OUT}, 0.1 V / div., 100 ms / div.
Lower: I_{LOAD}, 1 A / div.

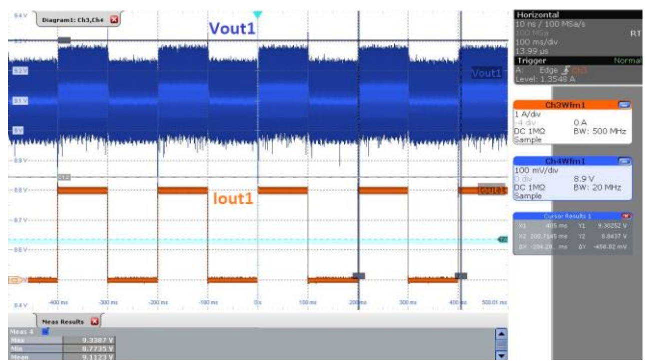

Figure 54 – Transient Response.
230 VAC, 9.0 V, 0 – 3 A Load Step.
V_{MIN}: 8.77 V, V_{MAX}: 9.33 V.
Upper: V_{OUT}, 0.1 V / div., 100 ms / div.
Lower: I_{LOAD}, 1 A / div.

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13.2 Switching Waveforms

13.2.1 Drain Voltage and Current

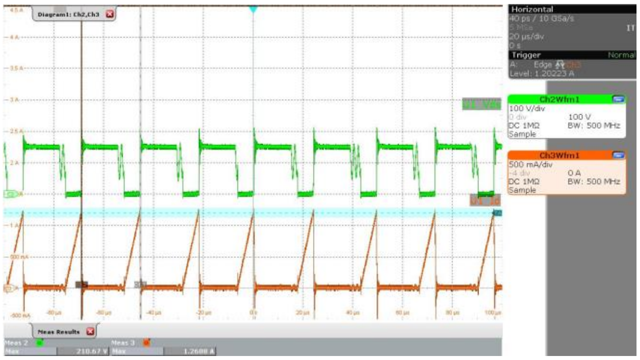

Figure 55 – Drain Voltage and Current Waveforms.
85 VAC, 5.0 V, 3.0 A Load, (210 V_{MAX}).
Upper: V_{DRAIN}, 100 V, 20 µs / div.
Lower: I_{DRAIN}, 500 mA / div.

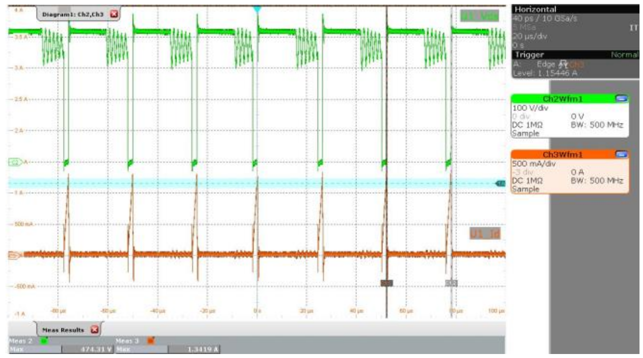

Figure 56 – Drain Voltage and Current Waveforms.
265 VAC, 5.0 V, 3.0 A Load, (474 V_{MAX}).
Upper: V_{DRAIN}, 100 V, 20 µs / div.
Lower: I_{DRAIN}, 500 mA / div.

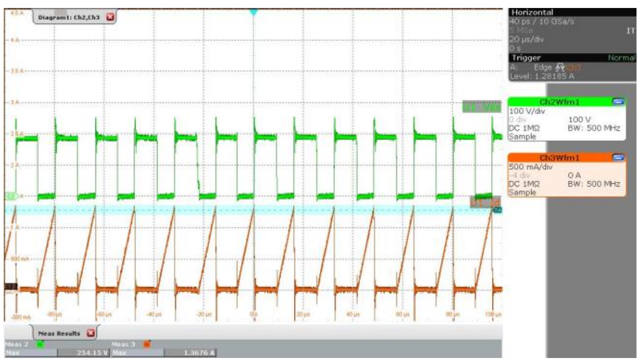

Figure 57 – Drain Voltage and Current Waveforms.
85 VAC, 9.0 V, 3.0 A Load, (254 V_{MAX}).
Upper: V_{DRAIN}, 100 V, 20 µs / div.
Lower: I_{DRAIN}, 500 mA / div.

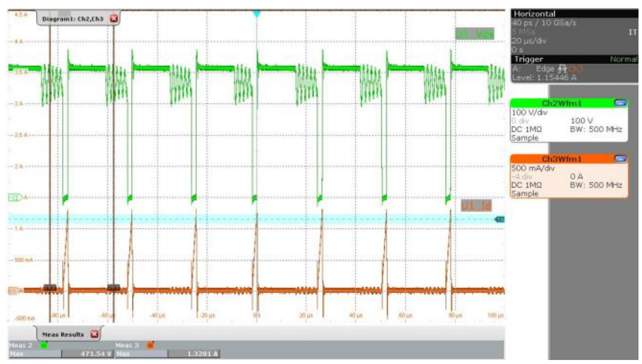

Figure 58 – Drain Voltage and Current Waveforms.
265 VAC, 9.0 V, 3.0 A Load, (471 V_{MAX}).
Upper: V_{DRAIN}, 100 V, 20 µs / div.
Lower: I_{DRAIN}, 500 mA / div.

13.2.2 Drain Voltage and Current Start-up

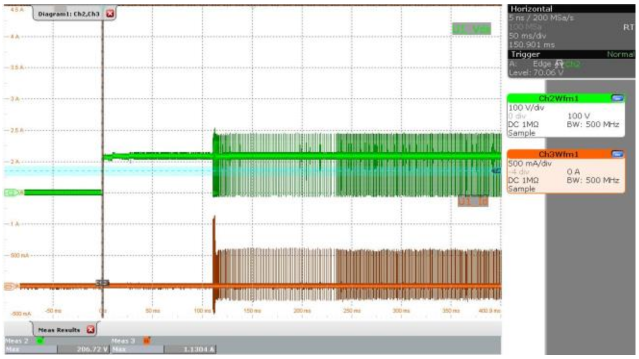

Figure 59 – Drain Voltage and Current Waveforms.
85 VAC, 5.0 V, 3.0 A Load, (206 V_{MAX})
Upper: V_{DRAIN}, 100 V, 50 ms / div.
Lower: I_{DRAIN}, 500 mA / div.

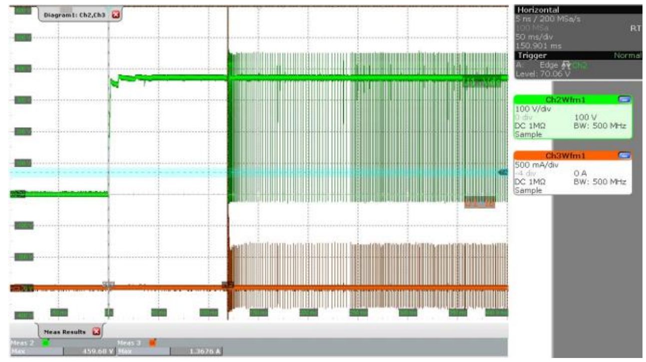

Figure 60 – Drain Voltage and Current Waveforms.
265 VAC, 5.0 V, 3.0 A Load, (459 V_{MAX})
Upper: V_{DRAIN}, 100 V, 50 ms / div.
Lower: I_{DRAIN}, 500 mA / div.

13.2.3 SR FET Voltage

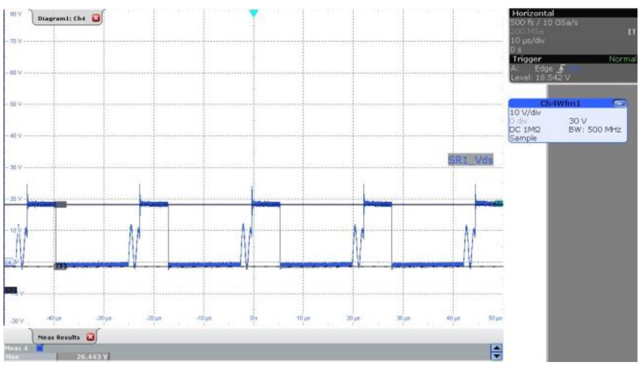

Figure 61 – SR1 FET Voltage Waveform.
85 VAC, 5.0 V, 3.0 A Load, (26.4 V_{MAX}).
V_{DRAIN}, 10 V, 10 µs / div.

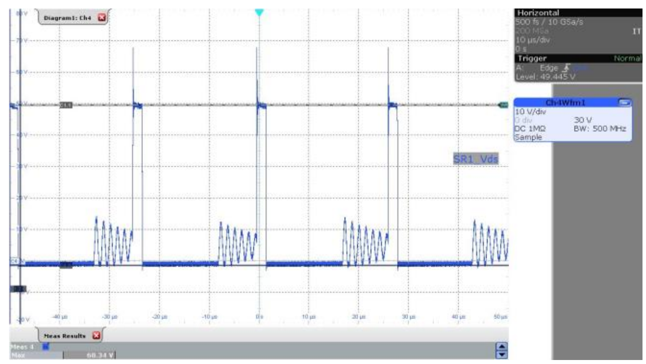

Figure 62 – SR1 FET Voltage Waveform.
265 VAC, 5.0 V, 3.0 A Load, (68.3 V_{MAX}).
V_{DRAIN}, 10 V, 10 µs / div.

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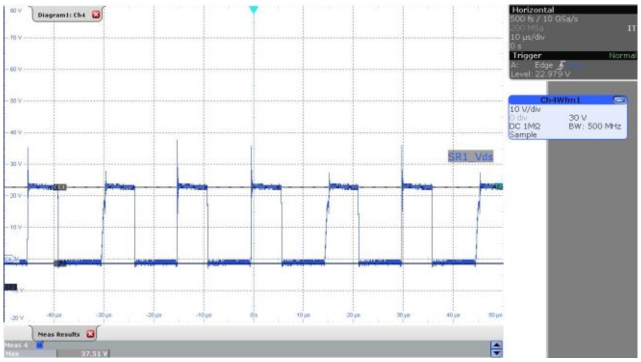

Figure 63 – SR1 FET Voltage Waveforms.
85 VAC, 9.0 V, 3.0 A Load, (37.5 V_{MAX}).
V_{DRAIN}, 10 V, 10 μs / div.

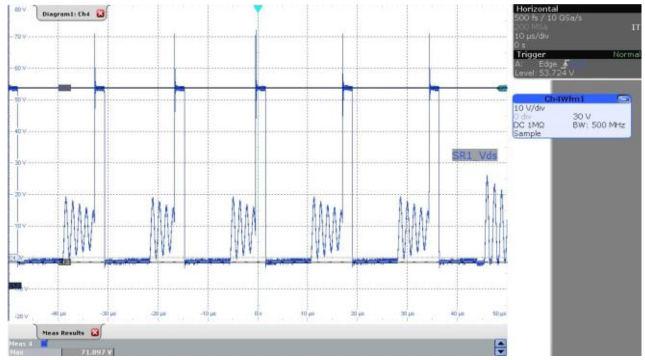

Figure 64 – SR1 FET Voltage Waveforms.
265 VAC, 9.0 V, 3.0 A Load, (71.8 V_{MAX}).
Upper: I_{DRAIN}, 4 A / div.
Lower: V_{DRAIN}, 10 V, 10 μs / div.

13.2.4 Output Voltage and Current Start-up

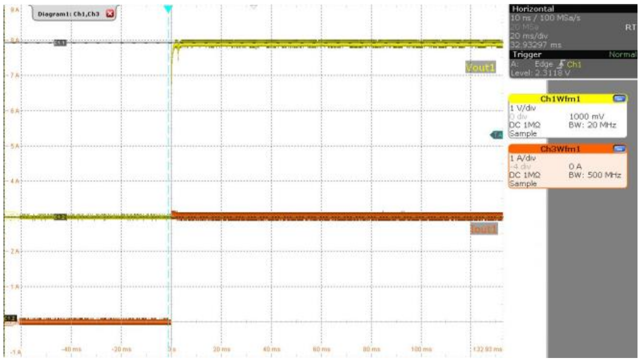

Figure 65 – Output1 Voltage and Current Waveforms.
85 VAC Input, 5 V, 3 A Load .
Upper: V_{OUT}, 1 V, 20 ms / div.
Lower: I_{OUT}, 1 A.

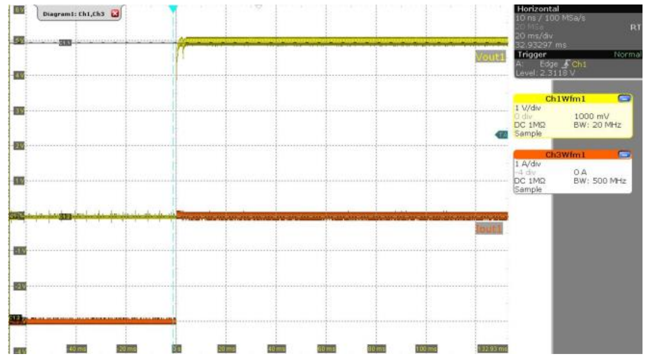

Figure 66 – Output1 Voltage and Current Waveforms.
265 VAC Input, 5 V, 3 A Load.
Upper: V_{OUT}, 1 V, 20 ms / div.
Lower: I_{OUT}, 1 A.

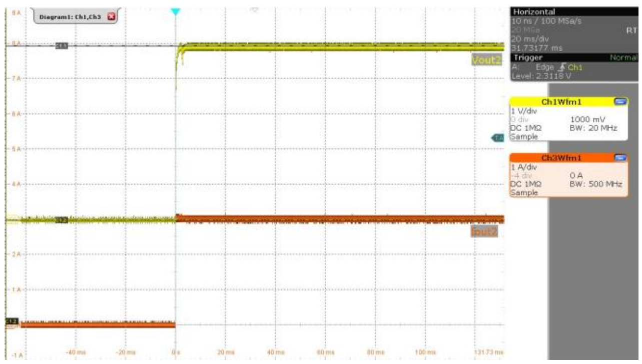

Figure 67 – Output2 Voltage and Current Waveforms.
85 VAC Input, 5 V, 3 A Load .
Upper: V_{OUT}, 1 V, 20 ms / div.
Lower: I_{OUT}, 1 A.

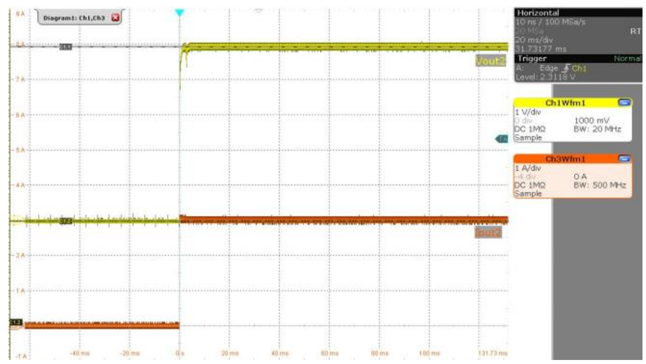

Figure 68 – Output2 Voltage and Current Waveforms.
265 VAC Input, 5 V, 1.7 Ω Load.
Upper: V_{OUT}, 1 V, 20 ms / div.
Lower: I_{OUT}, 1 A.

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13.3 Output Ripple Measurements

13.3.1 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). Ripple measurement done at the end of a 100 mΩ cable.

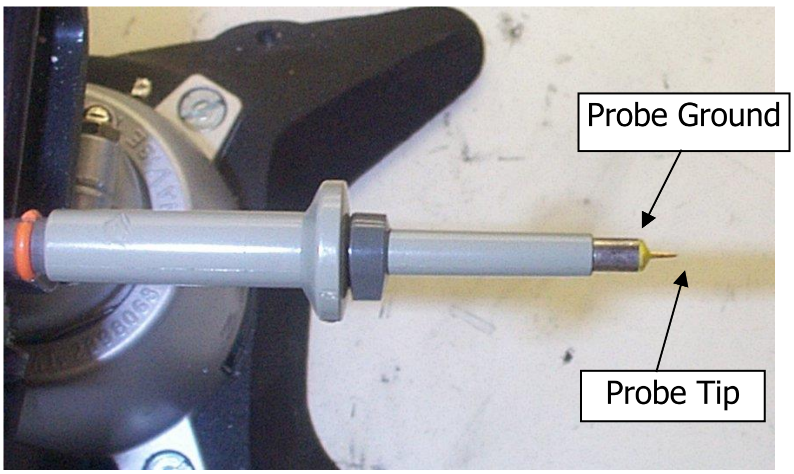

Figure 69 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

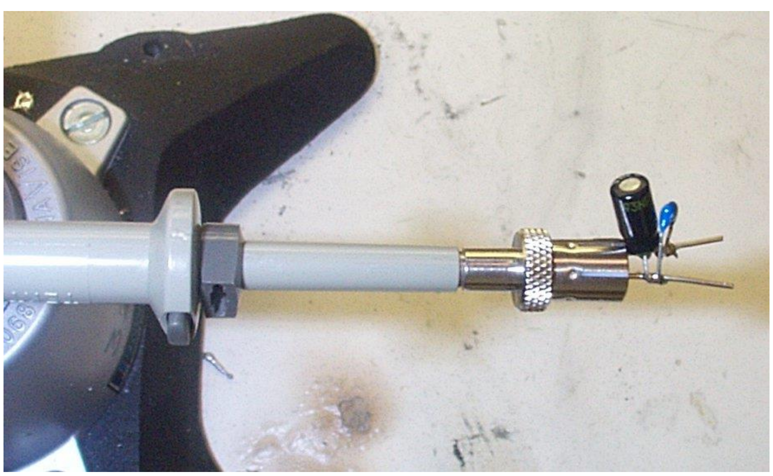

Figure 70 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

13.3.1.1 5 V Output (Measured at End of 100 mΩ Cable)

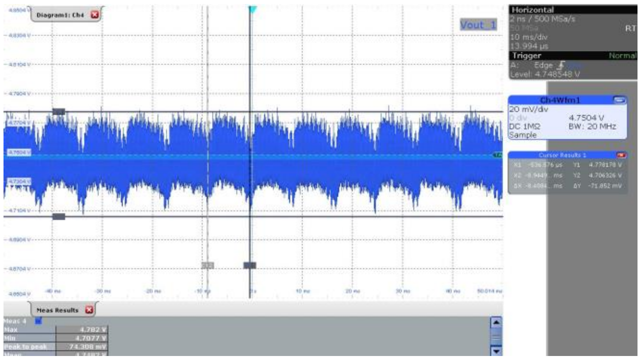

Figure 71 – Output 1 Ripple.(PK-PK – 74.4 mV).
85 VAC Input, 5.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 10 ms / div.

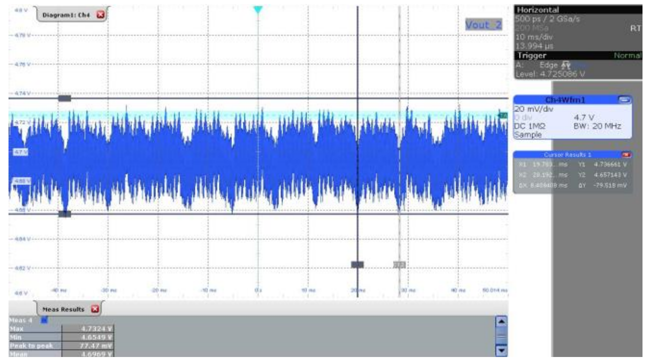

Figure 72 – Output 2 Ripple.(PK-PK – 77.5 mV).
85 VAC Input, 5.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 10 ms / div.

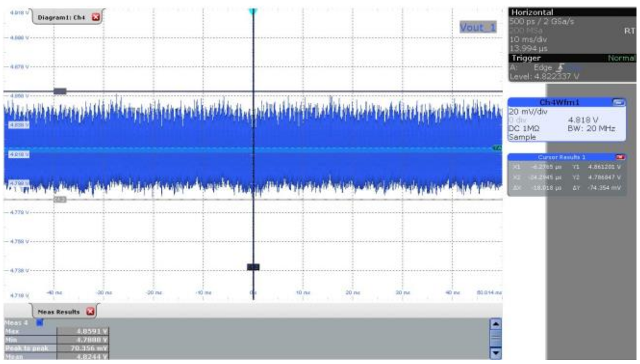

Figure 73 – Output 1 Ripple.(PK-PK – 70.4 mV).
265 VAC Input, 5.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 20 ms / div.

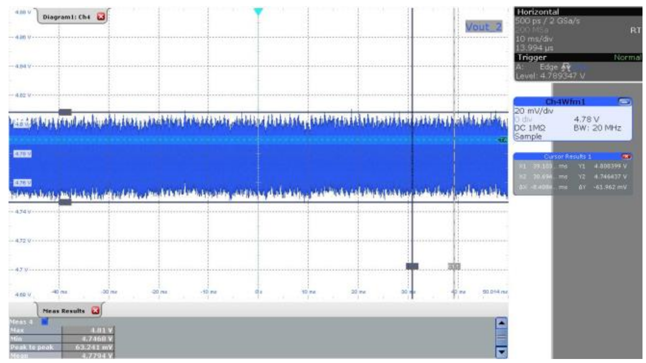

Figure 74 – Output 2 Ripple.(PK-PK – 63.3 mV).
265 VAC Input, 5.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 20 ms / div.

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13.3.1.2 9 V Output (Measured at the end of 100 mΩ Cable)

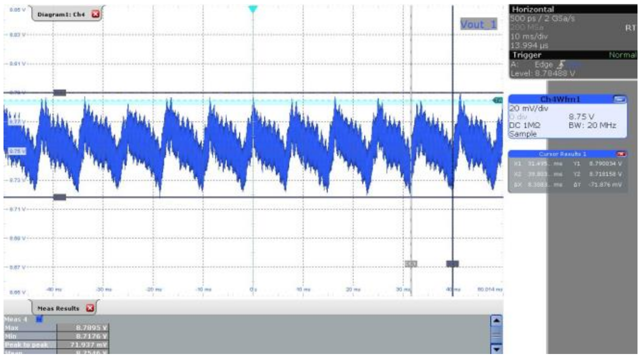

Figure 75 – Output 1 Ripple.(PK-PK – 72 mV).
85 VAC Input, 9.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 10 ms / div.

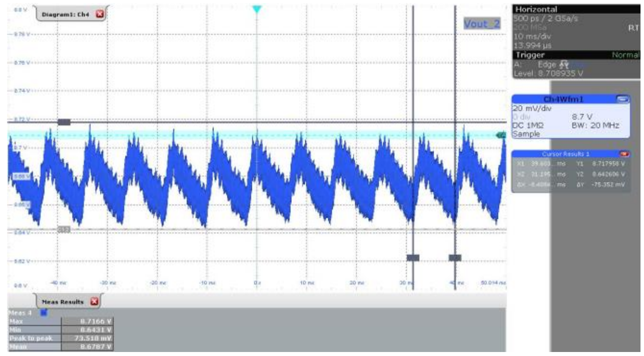

Figure 76 – Output 2 Ripple.(PK-PK – 73.6 mV).
85 VAC Input, 9.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 10 ms / div.

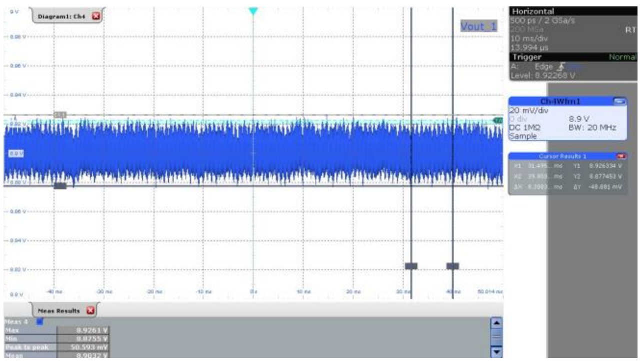

Figure 77 – Output 1 Ripple.(PK-PK – 50.6 mV)
265 VAC Input, 9.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 10 ms / div.

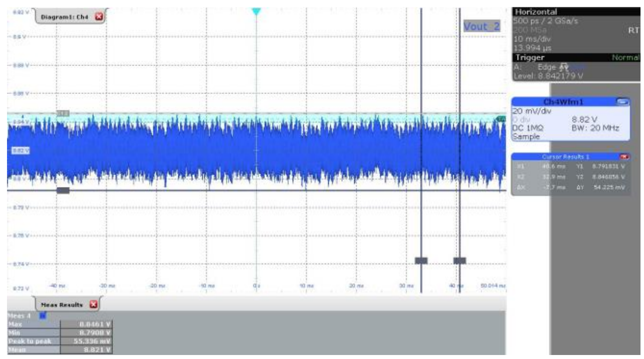

Figure 78 – Output 2 Ripple.(PK-PK – 55.4 mV).
265 VAC Input, 9.0 V, 3 A Load.
V_{OUT}, 20 mV / div., 10 ms / div.

14 Conducted EMI

14.1 Test Set-up

14.1.1 Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Hioki 3322 power hitester.
4. Chroma measurement test fixture, model A662003.
5. Resistor load with input voltage set at 230 VAC.

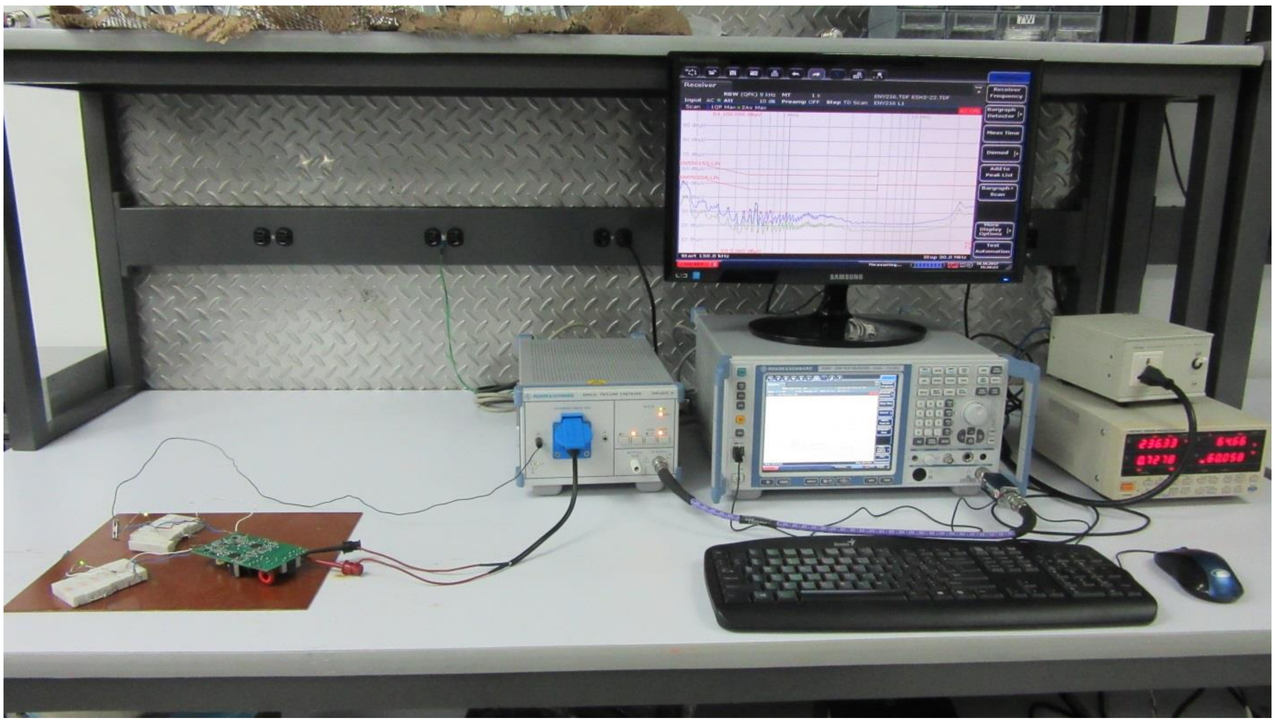

Figure 79 – Conducted EMI Test Set-up.

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14.2 EMI Test Result

14.2.1 Floating Outputs

14.2.1.1 Outputs (5 V / 3 A; 5 V / 3 A)

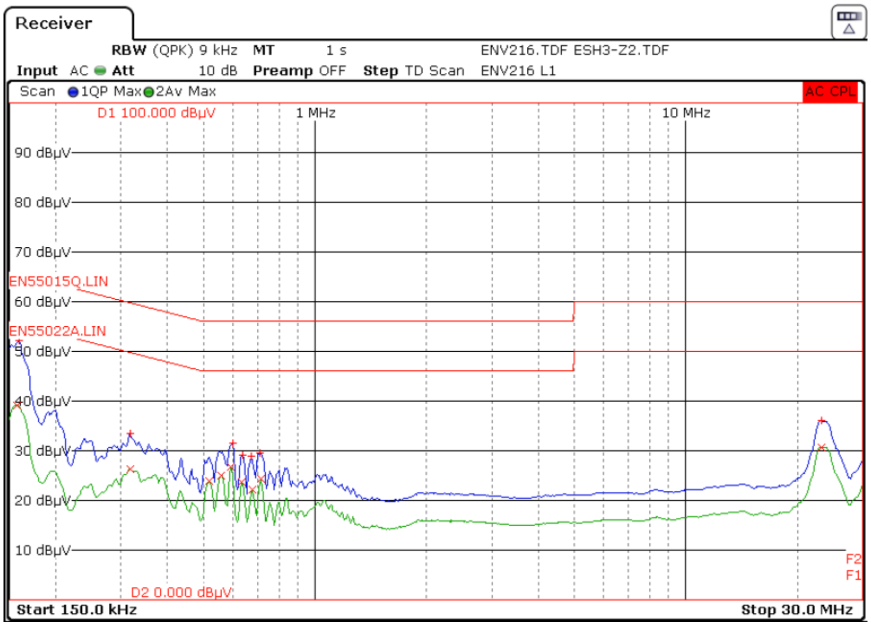

Figure 80 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

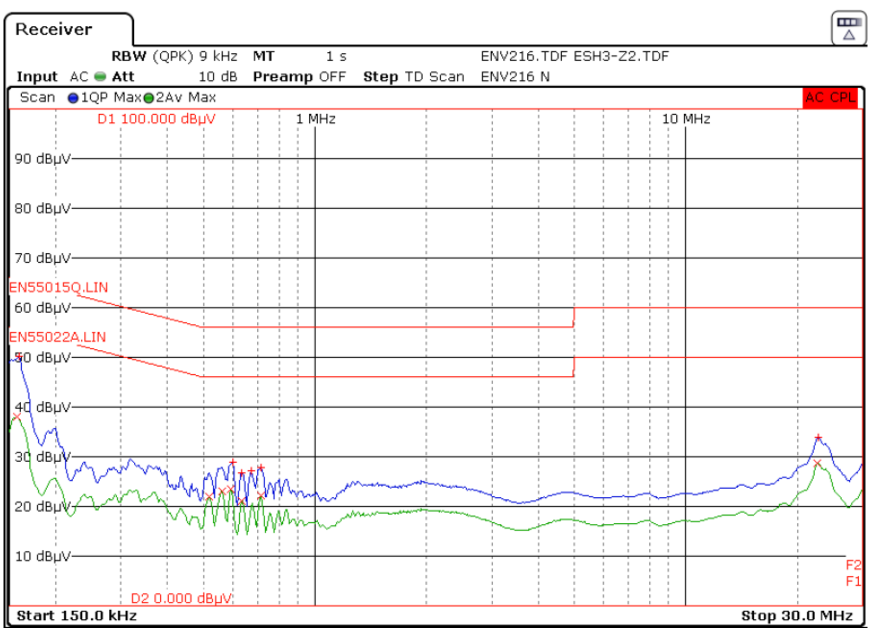

Figure 81 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

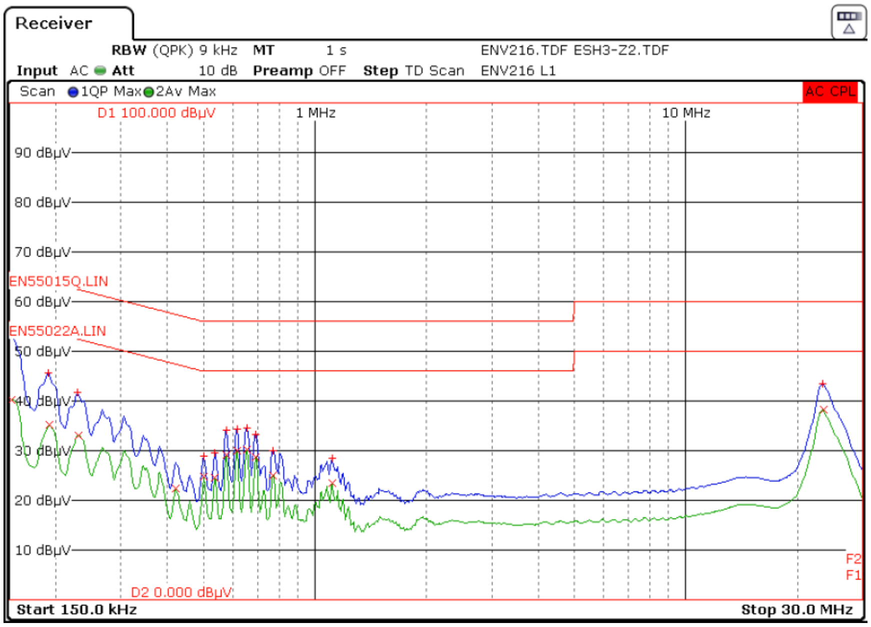

Figure 82 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

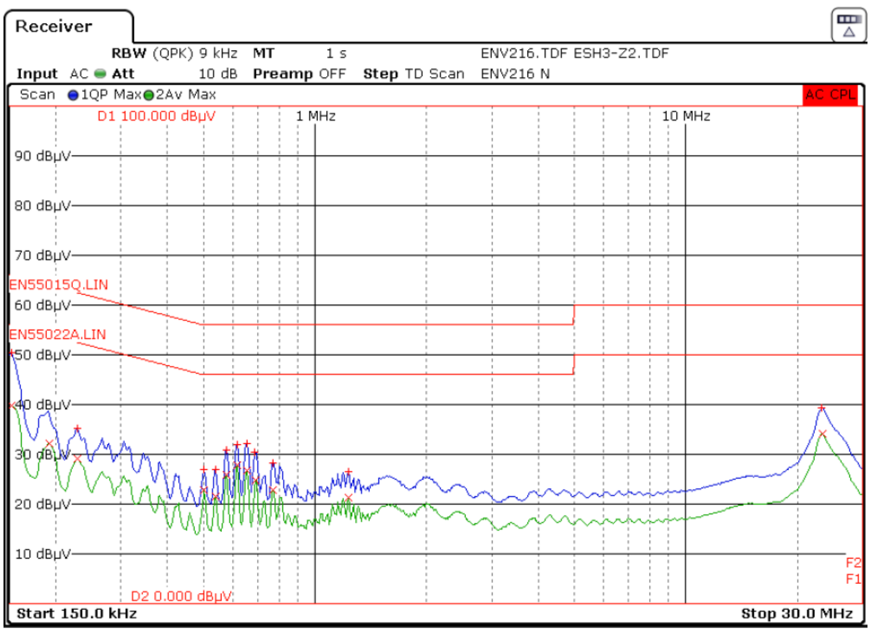

Figure 83 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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14.2.1.2 Outputs (9 V / 3 A; 9 V / 3 A)

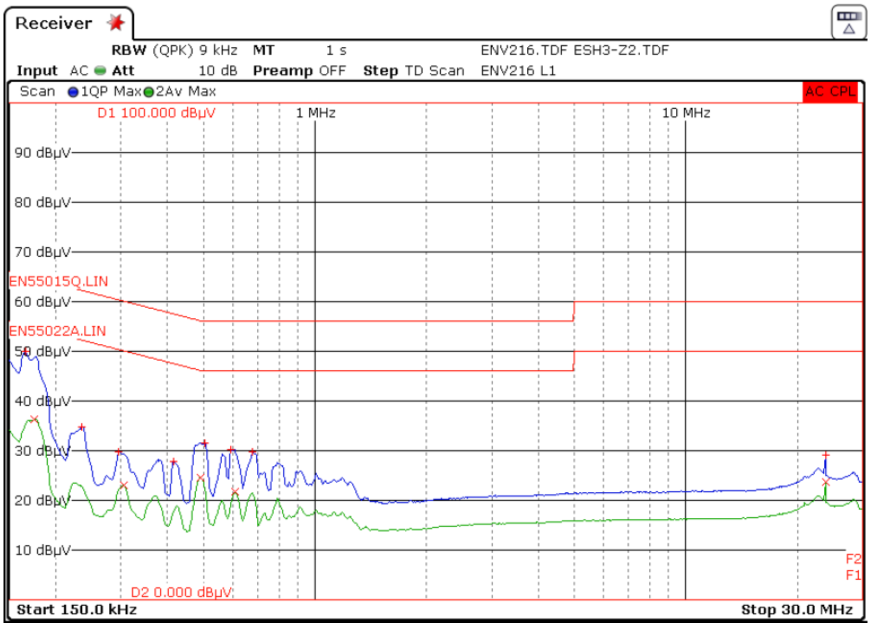

Figure 84 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

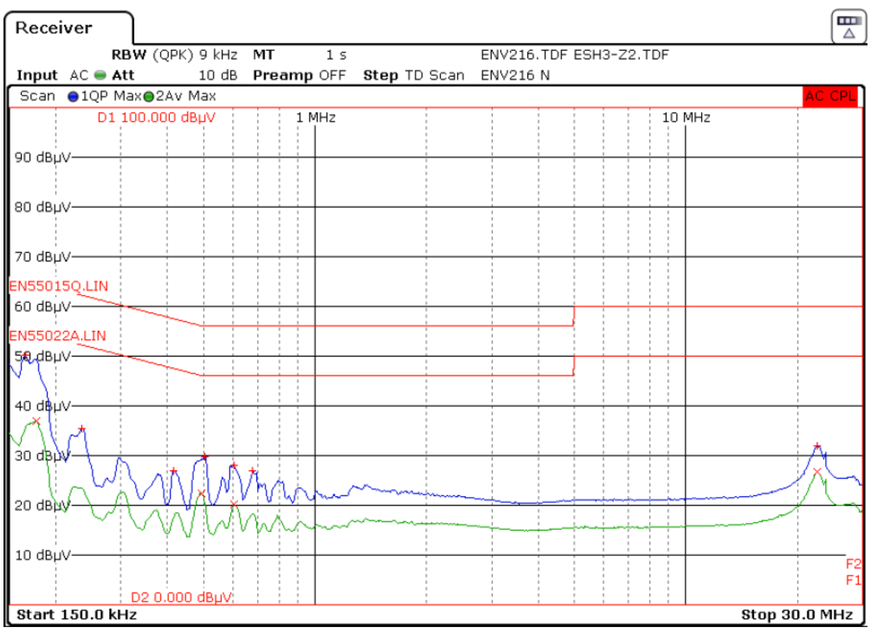

Figure 85 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

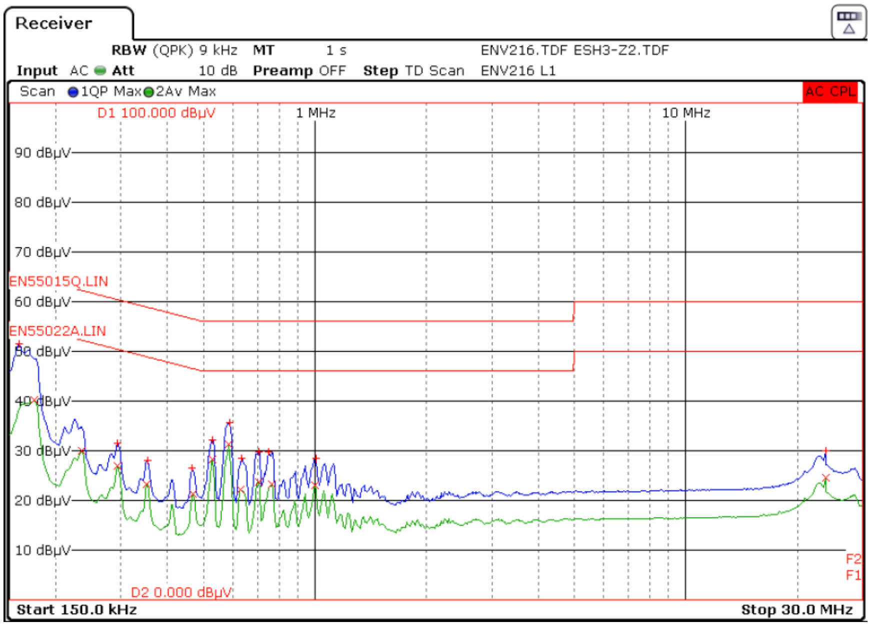

Figure 86 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

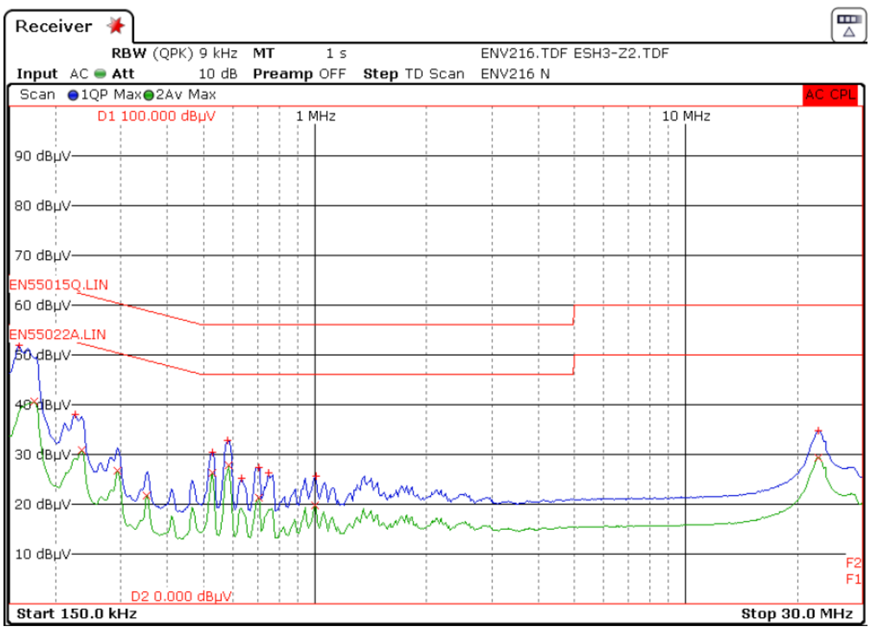

Figure 87 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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14.2.2 Artificial Hand

14.2.2.1 Outputs (5 V / 3 A; 5 V / 3 A)

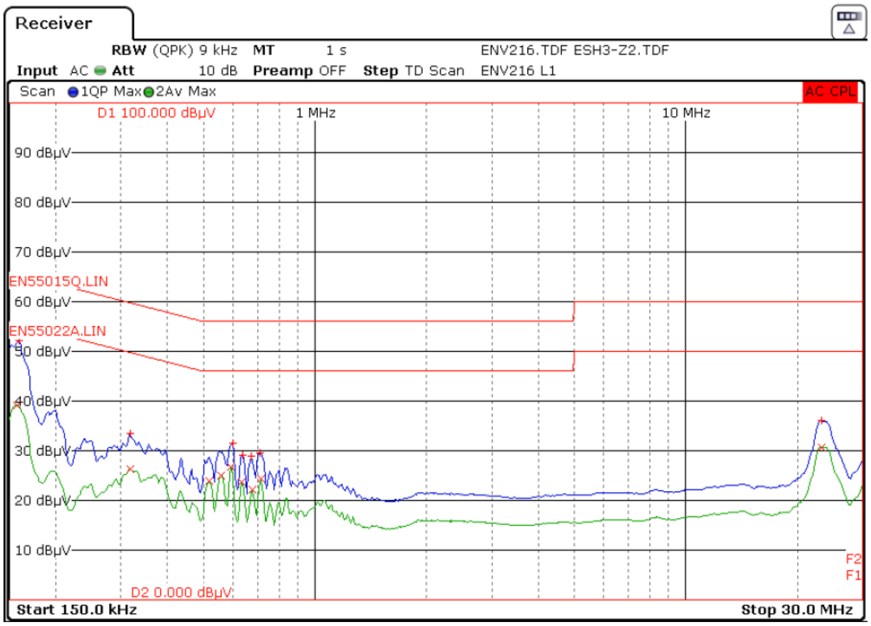

Figure 88 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

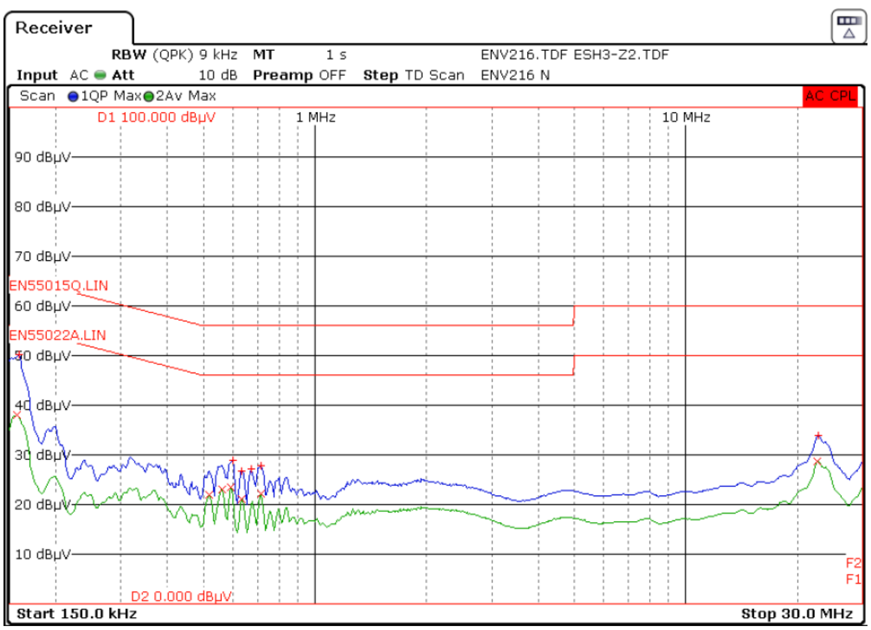

Figure 89 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

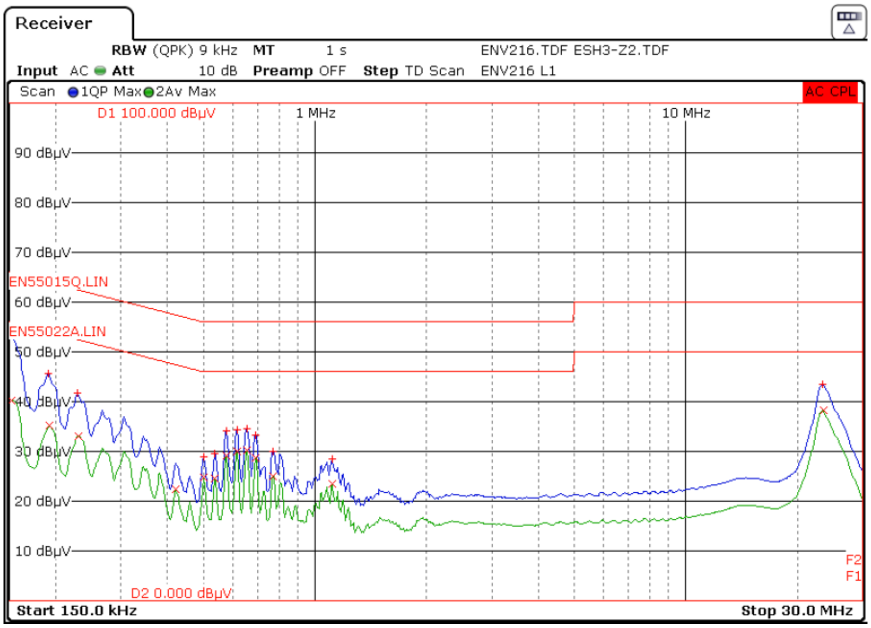

Figure 90 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

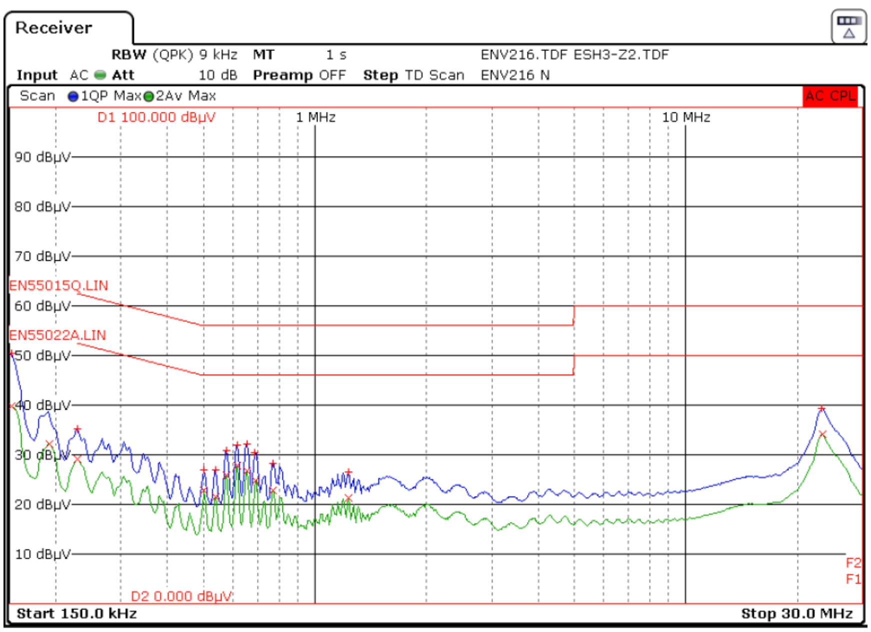

Figure 91 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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14.2.2.2 Outputs (9 V / 3 A; 9 V / 3 A)

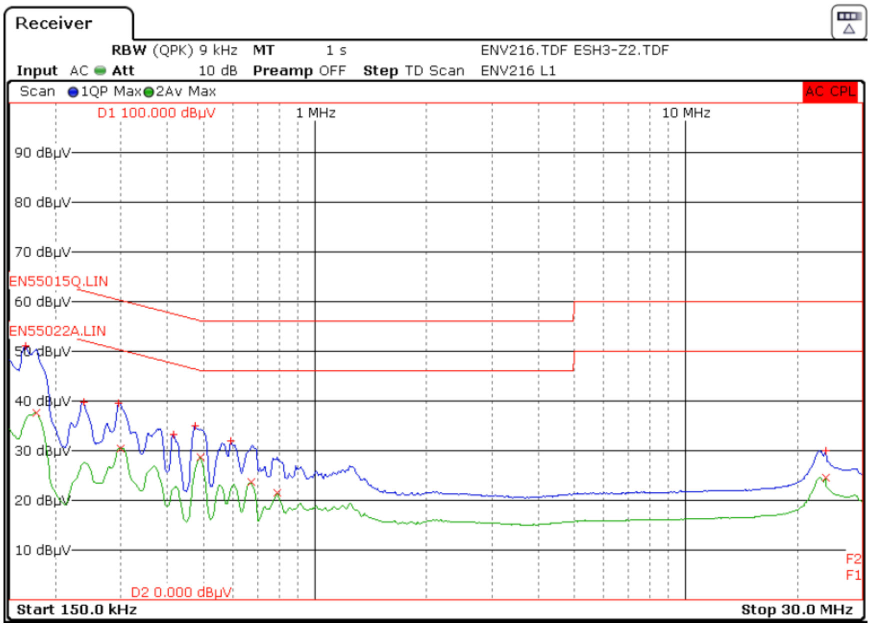

Figure 92 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

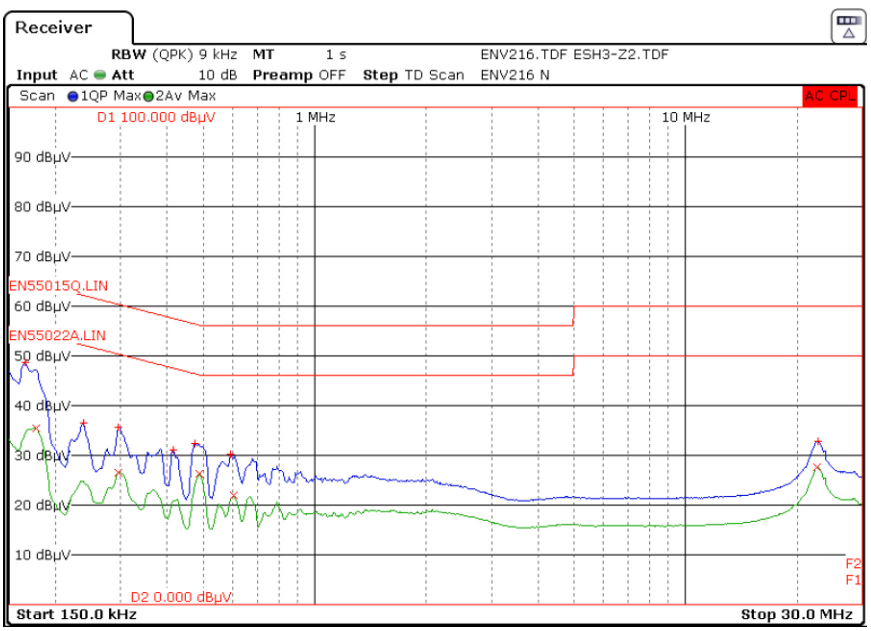

Figure 93 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

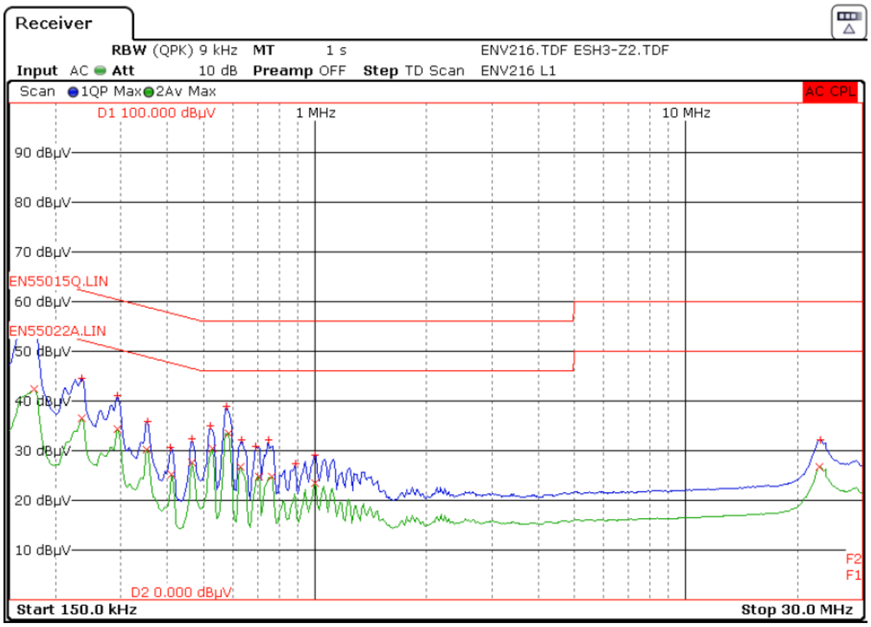

Figure 94 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

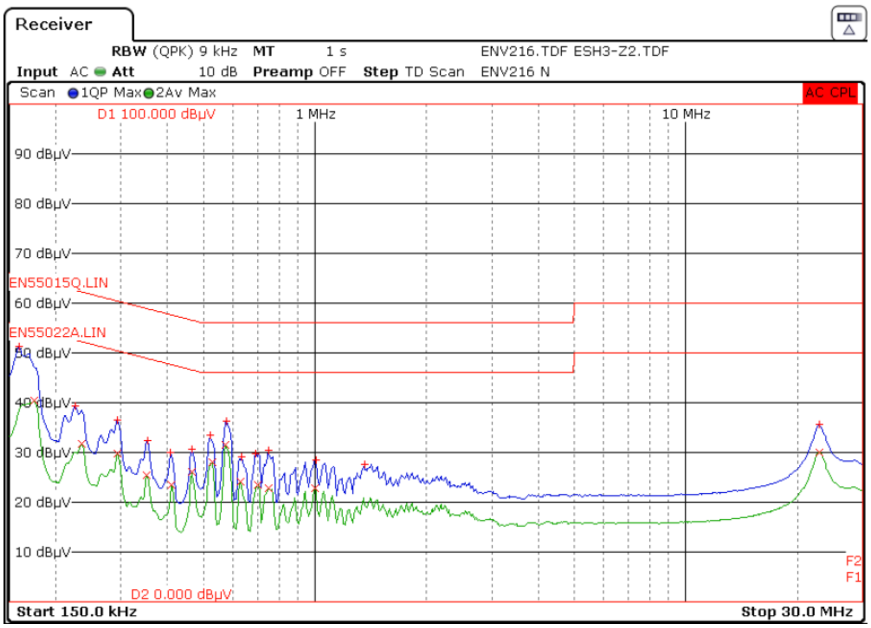

Figure 95 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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14.2.3 Earth Ground

14.2.3.1 Outputs (5 V / 3 A; 5 V / 3 A)

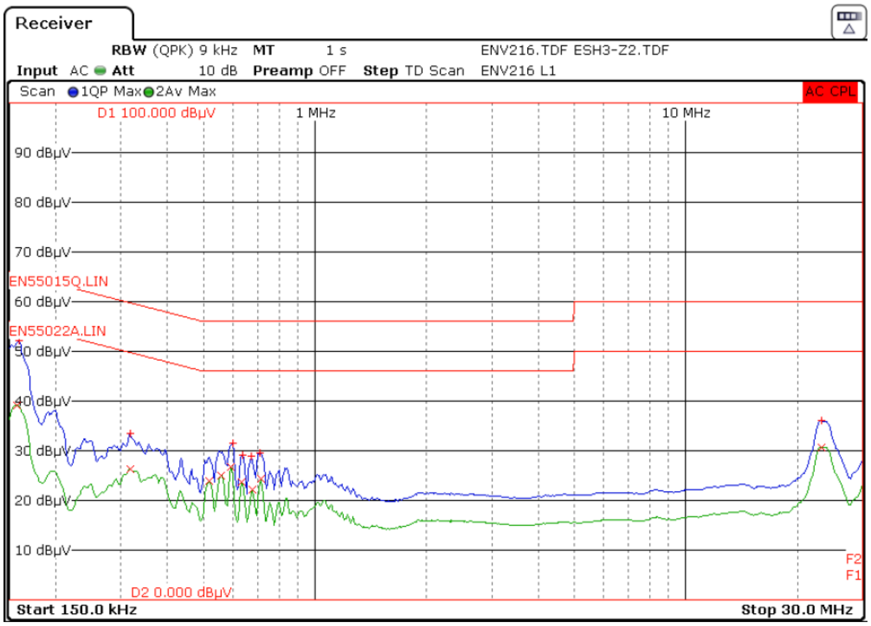

Figure 96 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

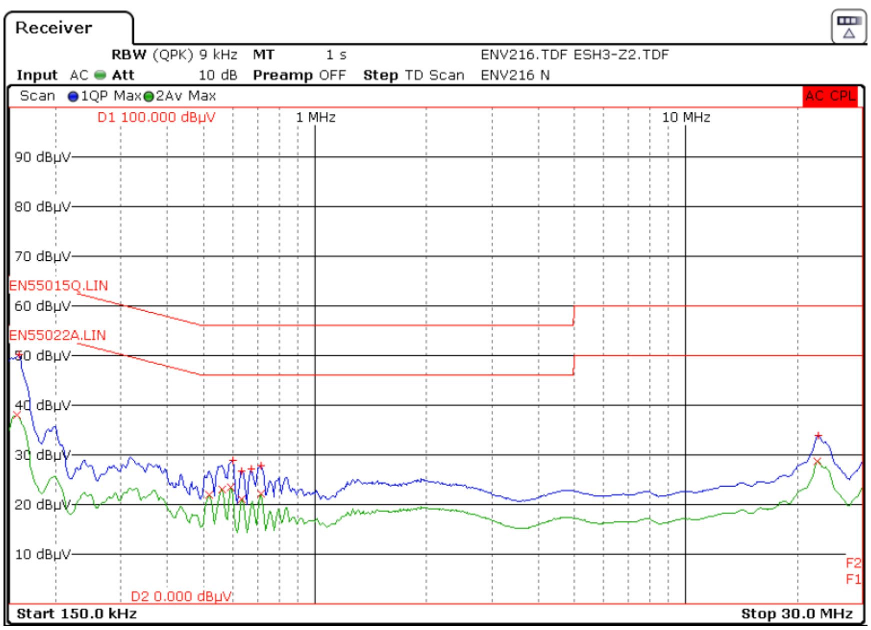

Figure 97 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

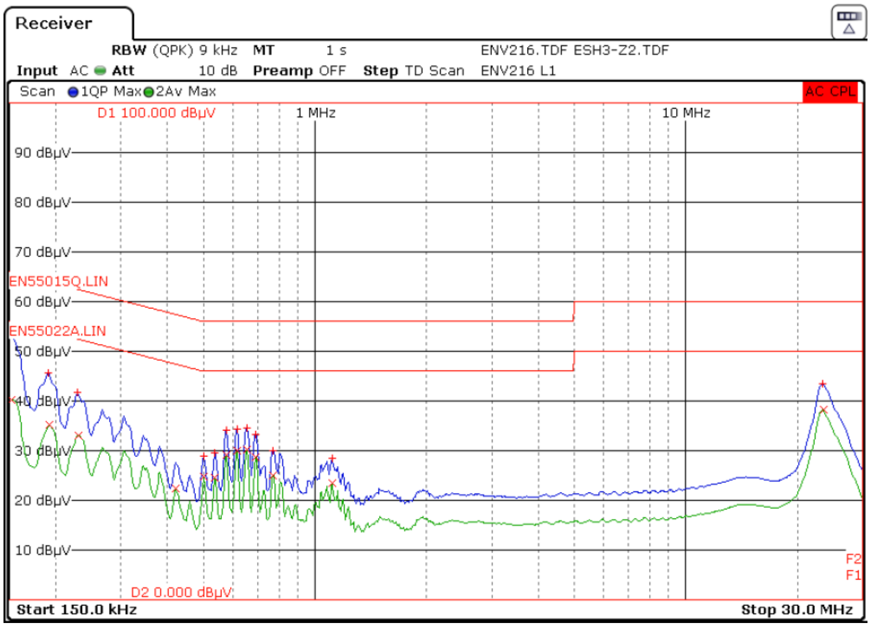

Figure 98 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

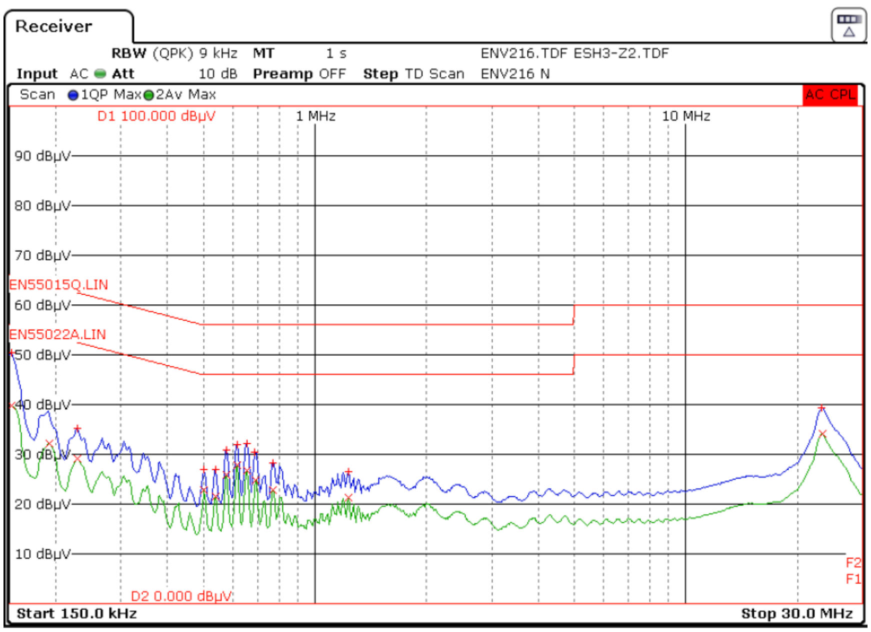

Figure 99 – Conducted EMI, 5 V / 3 A; 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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14.2.3.2 Outputs (9 V / 3 A; 9 V / 3 A)

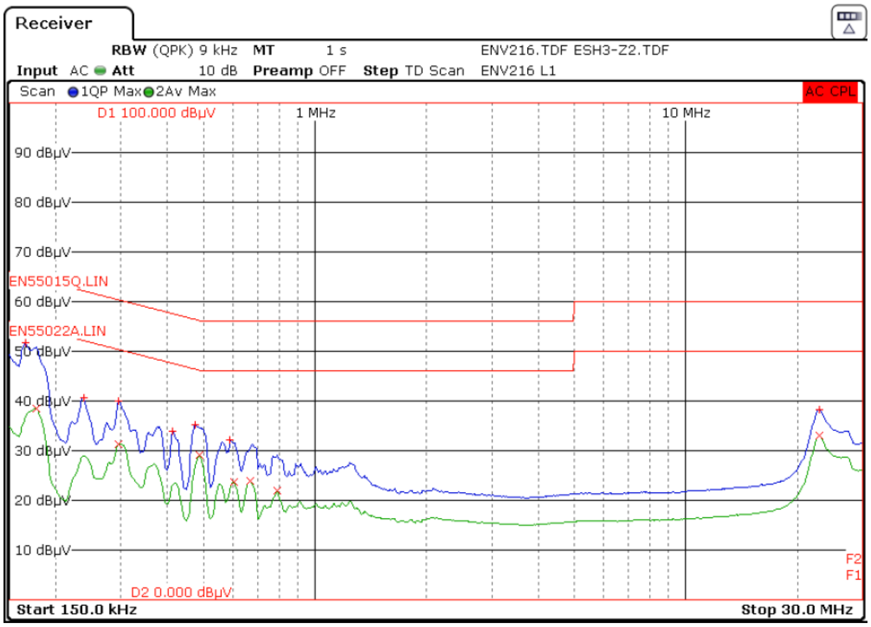

Figure 100 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

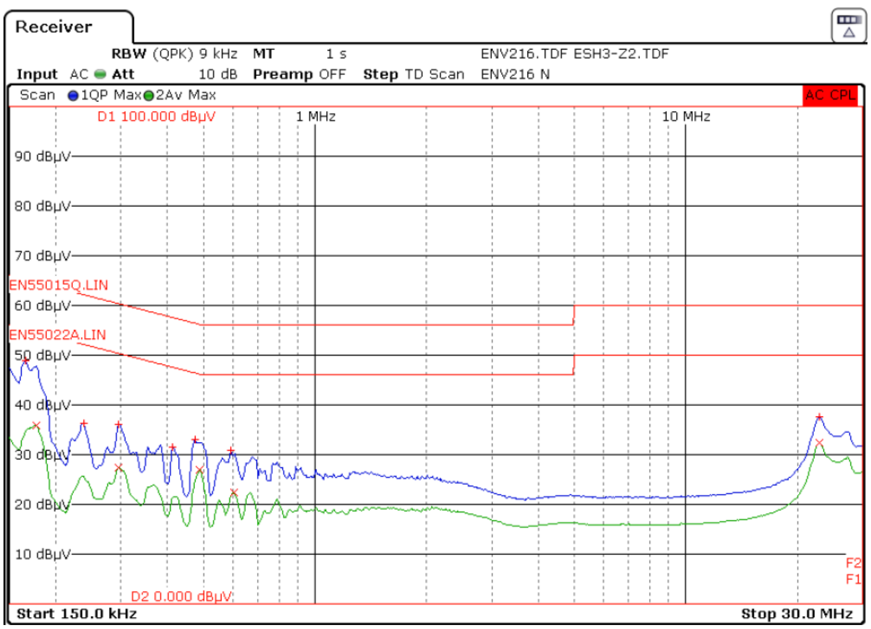

Figure 101 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

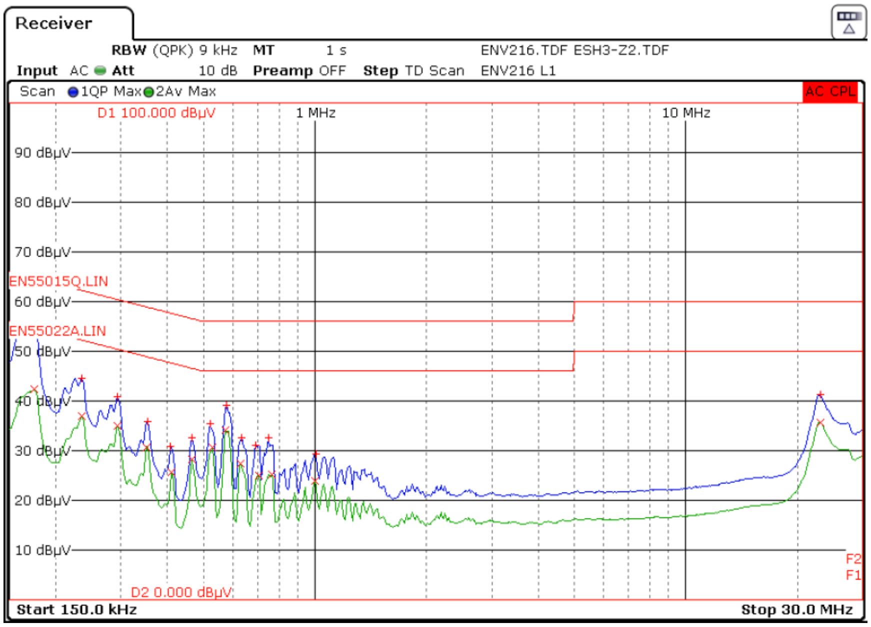

Figure 102 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

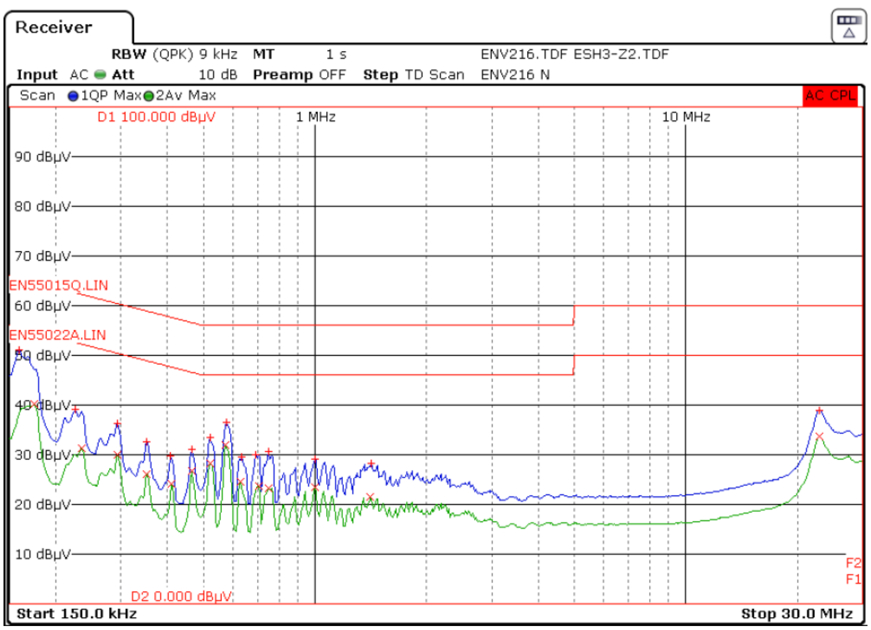

Figure 103 – Conducted EMI, 9 V / 3 A; 9 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

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15 Line Surge

The unit was subjected to ±2000 V, common mode surge and ±1000 V differential surge using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

15.1 Differential Surge

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

15.2 Common Mode Surge

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2000	230	L1 to PE	0	Pass
-2000	230	L1 to PE	0	Pass
+2000	230	L1 to PE	90	Pass
-2000	230	L1 to PE	90	Pass
+2000	230	L1 to PE	180	Pass
-2000	230	L1 to PE	180	Pass
+2000	230	L1 to PE	270	Pass
-2000	230	L1 to PE	270	Pass

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2000	230	L2 to PE	0	Pass
-2000	230	L2 to PE	0	Pass
+2000	230	L2 to PE	90	Pass
-2000	230	L2 to PE	90	Pass
+2000	230	L2 to PE	180	Pass
-2000	230	L2 to PE	180	Pass
+2000	230	L2 to PE	270	Pass
-2000	230	L2 to PE	270	Pass

Note: Output ground (RTN1) connected to PE.

16 Revision History

Date	Author	Revision	Description and Changes	Reviewed
16-Oct-18	CS	1.0	Initial Release.	Apps & Mktg

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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 http://www.power.com/ip.htm.

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