Design Example Report

Title	***18 W USB PD Power Supply Using InnoSwitch™ 3-CP INN3264C-H201 and Cypress CCG3PA CYPD3175***
Specification	85 VAC – 264 VAC Input; 5 V / 3 A, 9 V / 2 A USB PD Output
Application	Mobile Phone Charger
Author	Applications Engineering Department
Document Number	DER-628
Date	September 24, 2018
Revision	1.0

Summary and Features

- InnoSwitch3-CP is industry first AC/DC IC with isolated, safety rated integrated feedback
- Highly integrated USB PD controller CCG3PA - CYPD3175
- 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 V5 2016
  - At least 1.6% efficiency margin
- <30 mW no-load input power
- Integrated thermal protection
- Primary sensed output overvoltage protection
- Line undervoltage / overvoltage protection

Power Integrations
5245 Hellyer Avenue, San Jose, CA 95138 USA.
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

Table of Contents

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.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

1 Introduction

This document is an engineering report describing a 5 V / 3.0 A or 9 V / 2 A output USB Type-C and USB PD charger using the InnoSwitch3 and Cypress CCG3PA 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 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.

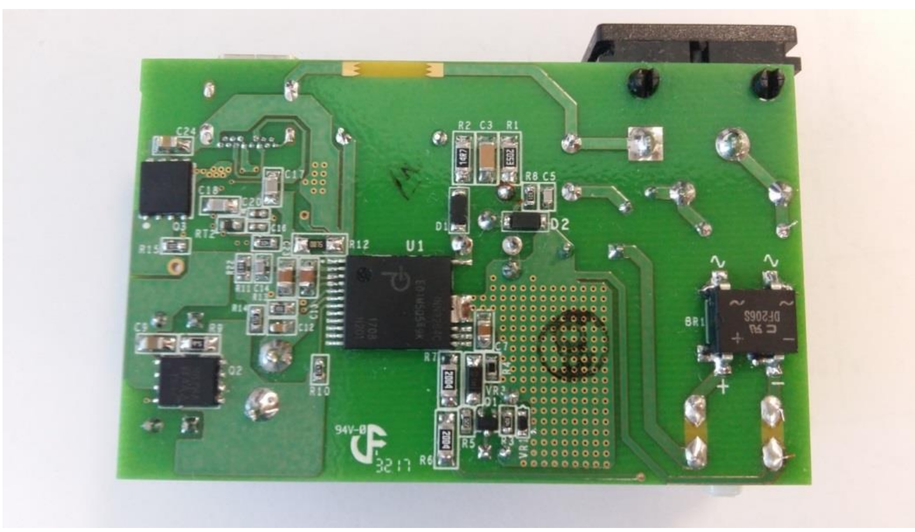


Figure 2 – Populated Circuit Board Photograph, Bottom.

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}	85		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)			12	15	mW	Measured at 230 VAC.
5 V Output						
Output Voltage	V_{OUT}		5		V	±3%
Output Ripple Voltage	V_{RIPPLE}			150	mV	At End of Cable. Cable Needs a Resistance of 60 mΩ.
Output Current	I_{OUT}	3.0			A	20 MHz Bandwidth.
9 V Output						
Output Voltage	V_{OUT}		9		V	±5%
Output Ripple Voltage	V_{RIPPLE}			150	mV	At End of Cable. Cable Needs a Resistance of 100 mΩ.
Output Current	I_{OUT}	2.0			A	At End of Cable. Cable Needs a Resistance of 100 mΩ.
Continuous Output Power	P_{OUT}			27	W	
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC60950 / UL1950 Class II				
Ambient Temperature	T_{AMB}	0		40	ºC	Free Convection, Sea Level.

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

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

3 Schematic

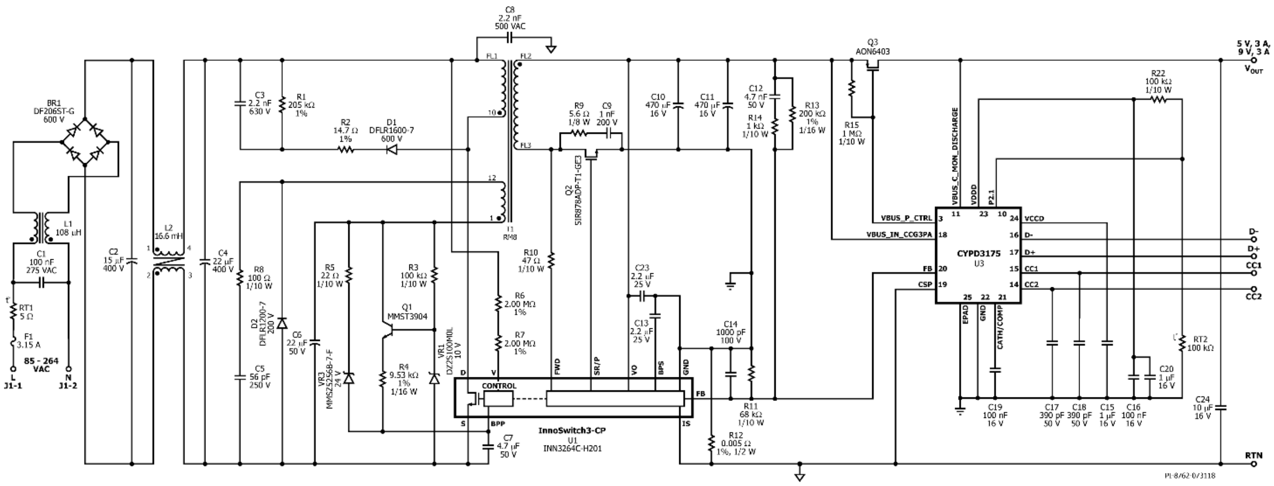


Figure 3 – Schematic.

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 with capacitor C1 and C8 provides attenuation for EMI. Bridge rectifier BR1 rectifies the AC line voltage and provides a full wave rectified DC across the filter consisting of C2, L2, and C4. The inductor L2 and capacitors C2, C4 form a pi-filter. This filter provides differential and common mode noise filtering. Thermistor RT1 limits the inrush current when the power supply is connected to the input AC supply.

4.2 InnoSwitch3-CP IC Primary

One end of the transformer primary is connected to the rectified DC bus; the other is connected to the drain terminal of the MOSFET inside the InnoSwitch3-CP IC (U1). Resistors R6 and R7 provide Input voltage sense protection for undervoltage and overvoltage conditions.

A low cost RCD clamp formed by diode D1, resistors R1 and R2, and capacitor C3 limits the peak Drain voltage of U1 at the instant of turn off of the MOSFET 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 C6. Resistor R4 limits the current being supplied to the BPP pin of the InnoSwitch3-CP IC (U1). A linear regulator comprising of resistor R3, BJT Q1 and Zener diode VR1 prevent any change in current through R4. The RC network comprising resistor R8 and capacitor C5 offer damping to the high frequency ringing in the voltage across diode D2 which reduces radiated EMI.

Zener diode VR3 offers primary sensed output overvoltage protection. In a flyback converter, output of the auxiliary winding tracks the output voltage of the converter. In case of overvoltage at output of the converter, the auxiliary winding voltage increases and causes breakdown of VR3 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 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 C10 and C11. High

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

frequency ringing during switching transients that would otherwise create radiated EMI is reduced via a RC snubber, R9 and C9.

The gate of Q2 is turned on by secondary-side controller inside IC U1, based on the winding voltage sensed via resistor R10 and fed into the FWD pin of the IC.

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. Capacitor C13 connected to the BPS pin of InnoSwitch3-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 MOSFET, the forward voltage that appears across the secondary winding is used to charge the decoupling capacitor C13 via resistor R10 and an internal regulator inside the InnoSwitch IC. This allows output current regulation to be maintained down to ~3.0 V. Below this level the unit enters auto-restart protection.

Output current is sensed by monitoring the voltage drop across resistor R12 between the IS and GND pins with a threshold of approximately 35.9 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 R14 and capacitor C12 form a phase lead network that ensure stable operation and minimize output voltage overshoot and undershoot during transient load conditions. Capacitor C14 provides noise filtering of the signal at the FB pin.

4.4 USB Type-C and PD Interface

In this design, CCG3PA CYPD3175-24QXIT (U3) is the USB Type-C and PD controller. Output of the InnoSwitch3-CP powers the CCG3PA directly to its VBUS input pin.

Resistors R13 and R11 form the feedback divider network to sense the output of InnoSwitch3-CP. CCG3PA directly alters the FB pin current in order to change the output voltage and CC threshold respectively.

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 make 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 VBUS MONITOR DISCHARGE pin.

5 PCB Layout

PCB copper thickness is 2.0 oz.

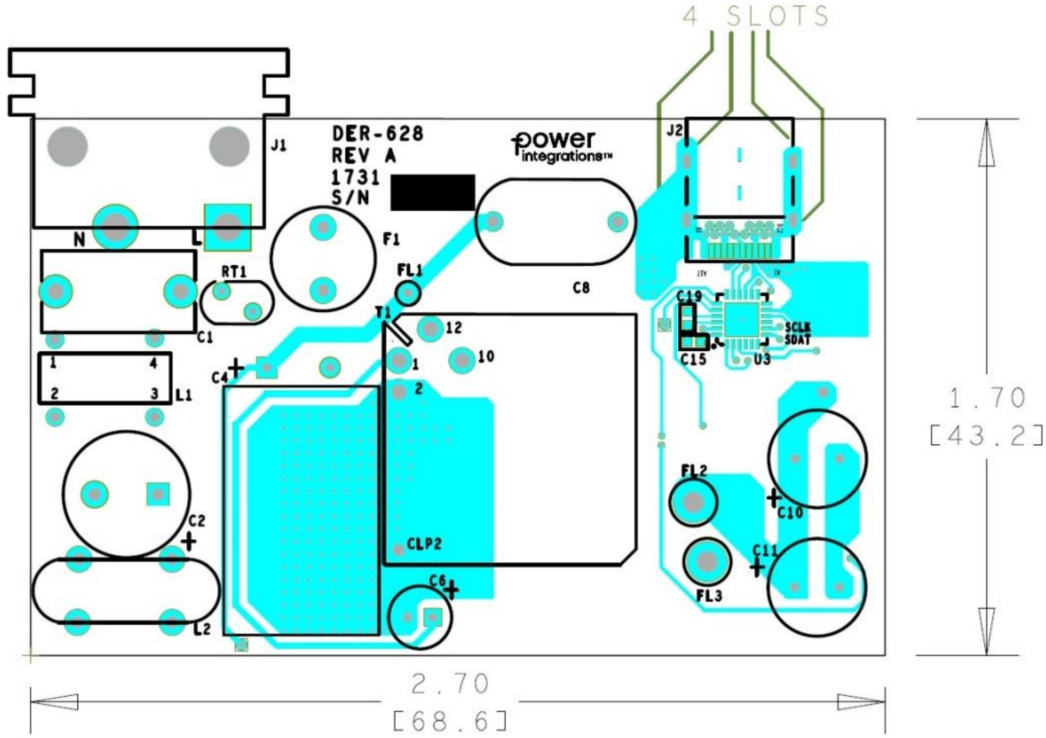


Figure 4 – Printed Circuit Layout, Top.

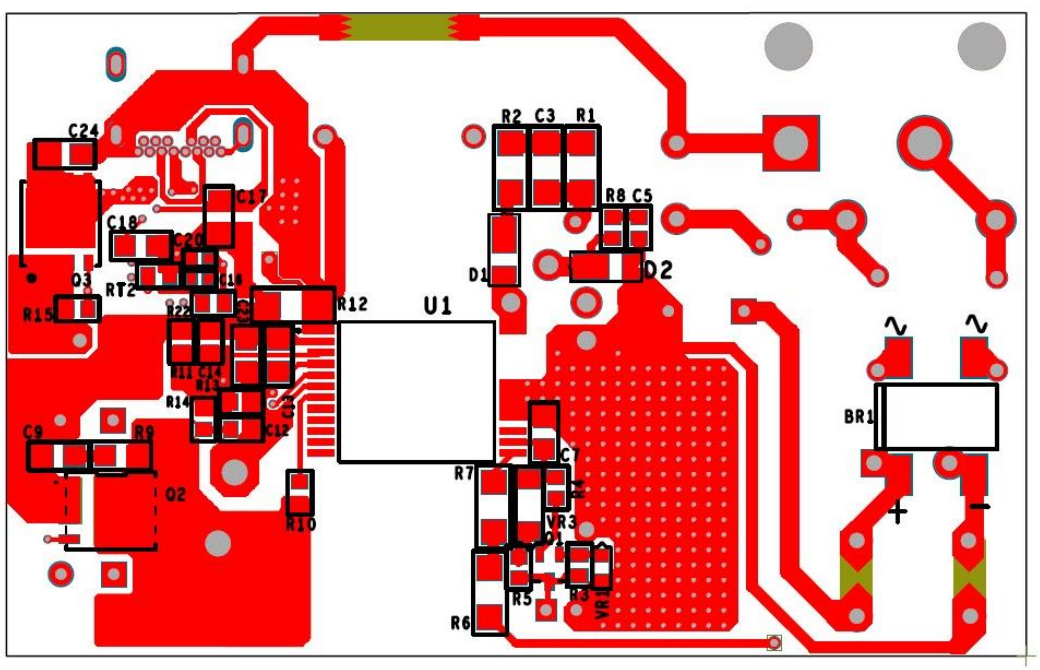


Figure 5 – Printed Circuit Layout, Bottom.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	600 V, 2 A, Bridge Rectifier, SMD, DFS	DF206ST-G	Comchip
2	1	C1	100 nF, 275VAC, Film, X2	LE104-M	OKAYA
3	1	C2	15 μF, 400 V, Electrolytic, (10 x 16)	UVC2G150MPD	Nichicon
4	1	C3	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
5	1	C4	22 μF, 400 V, Electrolytic, (12.5 x 20)	UCS2G220MHD	Nichicon
6	1	C5	56 pF, 250 V, Ceramic, NPO, 0603	GQM1875C2E560JB12D	Murata
7	1	C6	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
8	1	C7	4.7 μF, 50 V, Ceramic, X5R, 0805	CL21A475KBQNNNE	Samsung
9	1	C8	2.2 nF, 500 VAC, Ceramic, Y1	VY1222M47Y5UG63V0	Vishay
10	1	C9	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
11	1	C10	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
12	1	C11	470 μF, 16 V, Al Organic Polymer, 12 mΩ, (8 x 11.5)	RNE1C471MDN1	Nichicon
13	1	C12	4.7 nF 50 V, Ceramic, X7R, 0603	GRM188R71H472KA01D	Murata
14	1	C13	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
15	1	C14	1000 pF, 100 V, Ceramic, NPO, 0603	C1608C0G2A102J	TDK
16	1	C15	1 μF 16 V, Ceramic, X5R, 0402	C1005X5R1C105M	TDK
17	1	C16	100 nF 16 V, Ceramic, X7R, 0402	L05B104KO5NNNC	Samsung
18	1	C17	390 pF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB391	Yageo
19	1	C18	390 pF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB391	Yageo
20	1	C19	100 nF 16 V, Ceramic, X7R, 0402	L05B104KO5NNNC	Samsung
21	1	C20	1 μF 16 V, Ceramic, X5R, 0402	C1005X5R1C105M	TDK
22	1	C23	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
23	1	C24	10 μF, 16 V, Ceramic, X5R, 0805	GRM21BR61C106KE15L	Murata
24	1	D1	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
25	1	D2	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
26	1	F1	3.15 A, 250V,Fast, TR5	37013150410	Wickman
27	1	FL1	Flying Lead , Hole size 30mils	N/A	N/A
28	1	FL2	Flying Lead , Hole size 70mils	N/A	N/A
29	1	FL3	Flying Lead , Hole size 70mils	N/A	N/A
30	1	J1	CONN, AC Recept Panel, R/A, PCB pins	770W-X2/10	Qualtek
31	1	J2	Connector, "Certified", USB - C, USB 3.1, For 0.062" PCB Material!, Superspeed+, Receptacle Connector, 24 Position, SMT, Right Angle, TH	632723300011	Wurth
32	1	L1	Custom, 108 μH, constructed on Core 35T0375-10H from PI# 30-00275-00		Power Integrations
33	1	L2	16.6 mH, xA, Ferrite Toroid, 4 Pin, Output		
34	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-323	MMST3904-7-F	Diodes, Inc.
35	1	Q2	100 V, 40 A, N-Channel, PowerPAK SO-8	SIR878ADP-T1-GE3	Vishay
36	1	Q3	MOSFET, P-CH, 30 V, 21 A, 8DFN	AON6403	Alpha & Omega Semi
37	1	R1	RES, 205 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2053V	Panasonic
38	1	R2	RES, 14.7 Ω, 1%, 1/4 W,Thick Film, 1206	ERJ-8ENF14R7V	Panasonic
39	1	R3	RES, 100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
40	1	R4	RES, 9.53 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF9531V	Panasonic
41	1	R5	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
42	1	R6	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
43	1	R7	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
44	1	R8	RES, 100 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ101V	Panasonic
45	1	R9	RES, 5.6 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ5R6V	Panasonic
46	1	R10	RES, 47 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470V	Panasonic
47	1	R11	RES, 68 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ683V	Panasonic

48	1	R12	RES, 0.005 Ω, 0.5 W, 1%, 0805	PMR10EZPFU5L00	Rohm
49	1	R13	RES, 200 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2003V	Panasonic
50	1	R14	RES, 1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
51	1	R15	RES, 1 MΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ105V	Panasonic
52	1	R22	RES, 100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
53	1	RT1	NTC Thermistor, 5 Ω, 1 A	MF72-005D5	Cantherm
54	1	RT2	NTC Thermistor, 100 kΩ, 3%, 0603	NCP18WF104E03RB	Murata
55	1	T1	Bobbin, RM8, Vertical, 12 pins	BRM08-1112CP-W-P5.0	MH&W
56	1	U1	InnoSwitch3-CP, InSOP24A	INN3264C-H201	Power Integrations
57	1	U3	USB Type-C and Power Delivery Controller	CYPD3175-24LQXQ	Cypress
58	1	VR1	10 V, 5%, 150 mW, SSMINI-2	DZ2S100M0L	Panasonic
59	1	VR3	DIODE ZENER 30 V 500 mW SOD123	MMSZ5256B-7-F	Diodes, Inc.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

7 Transformer Specification

7.1 Electrical Diagram

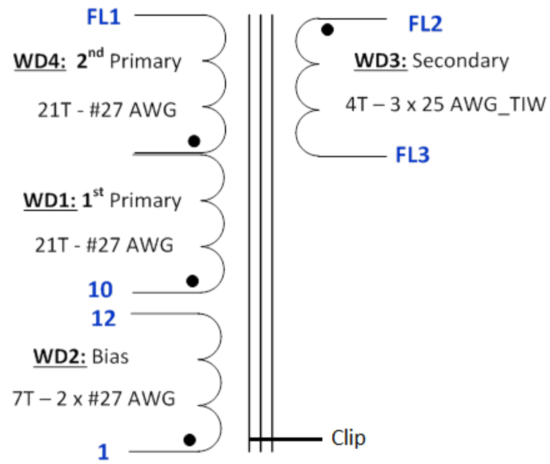


Figure 6 – Transformer Electrical Diagram.

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}.	645 µH ±5%
Resonant Frequency	Pins 10 - FL1, all other windings open.	2,000 kHz (Min.)
Primary Leakage Inductance	Pins 10 - FL1, with FL1 - FL2 shorted, measured at 100 kHz, 0.4 V_{RMS}.	10 µH (Max.)

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: #27 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.

7.4 Transformer Build Diagram

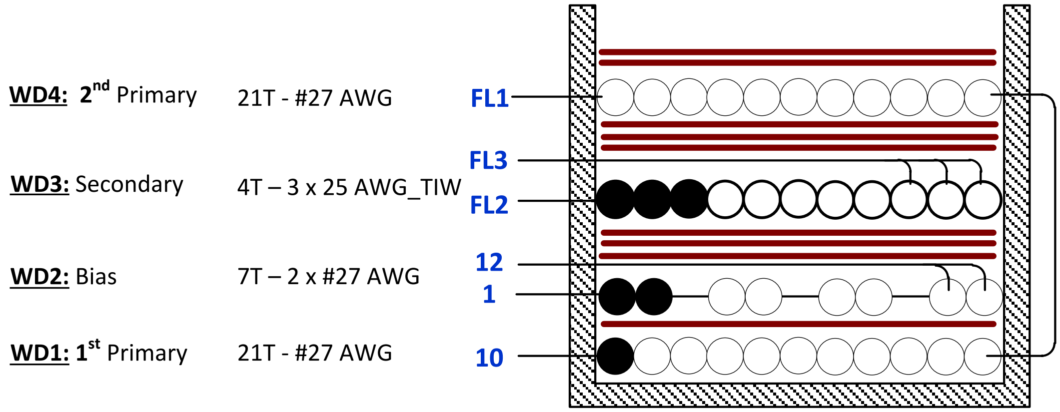


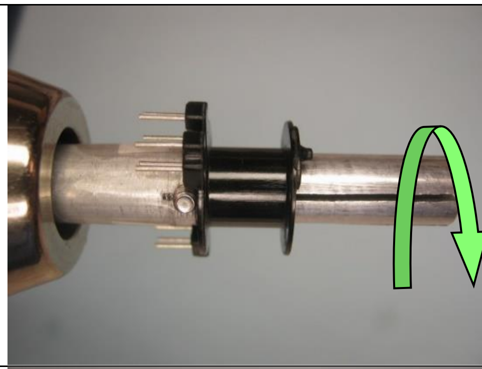
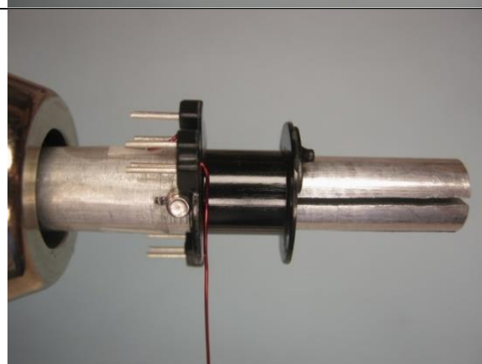
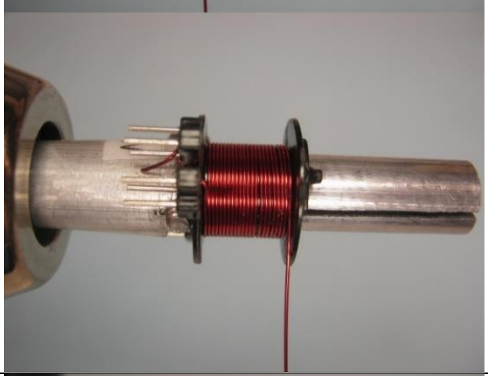
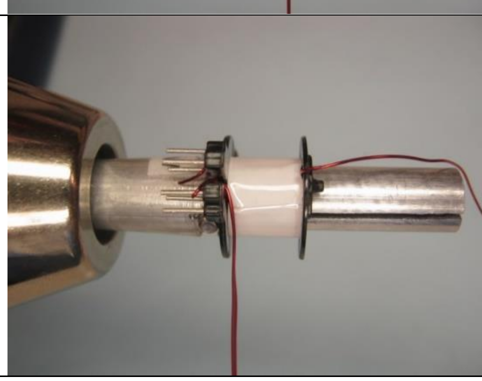
Figure 7 – Transformer Build Diagram.

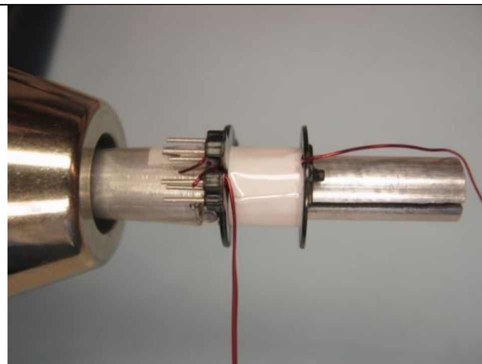
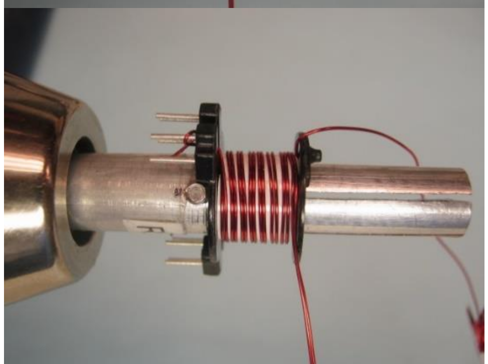
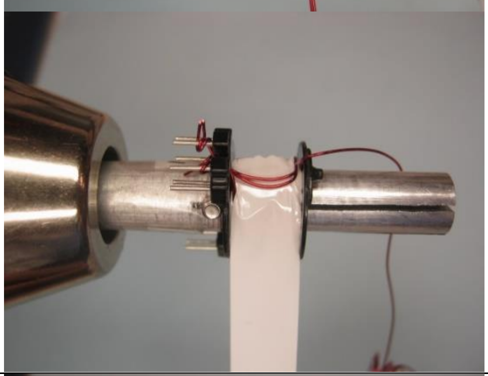
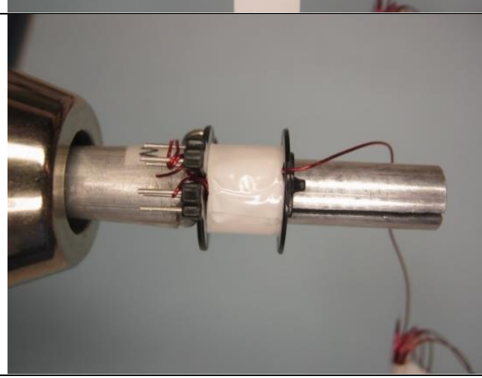
7.5 Transformer Construction

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 21 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 7 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 4 turns in 1 layer, from left to right, 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].
WD1 2nd Primary	Use wire hanging from WD1; continue winding 21 turns from right to left. At the last turn, leave ~1" of wire floating and mark as FL1.
Insulation	2 layers of tape Item [5] for insulation and secure the windings.
Finish	Gap cores to get 645 μH and secure with clips Item [6]. Varnish with Item [7].

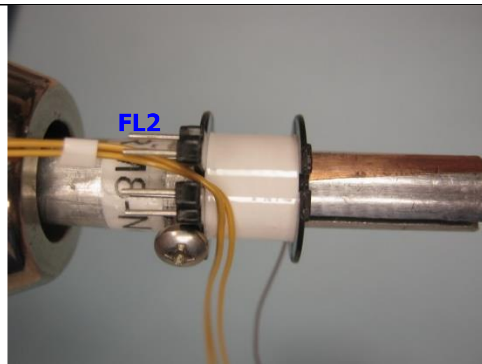
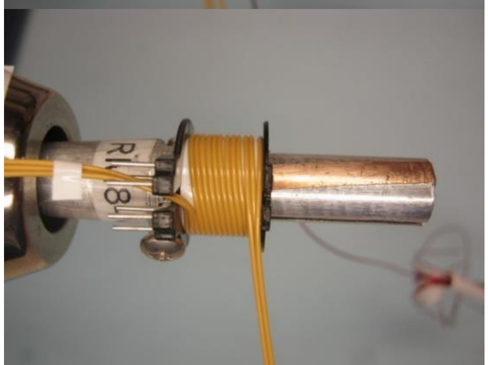
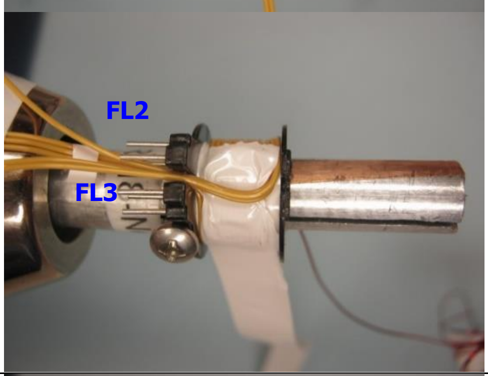
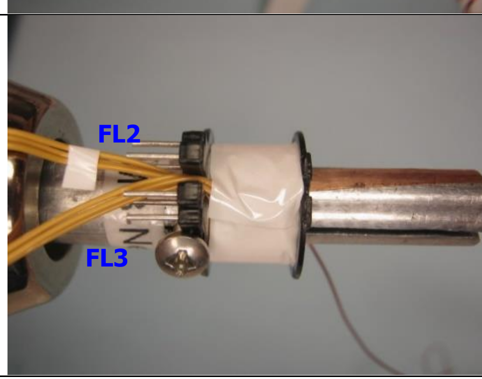
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

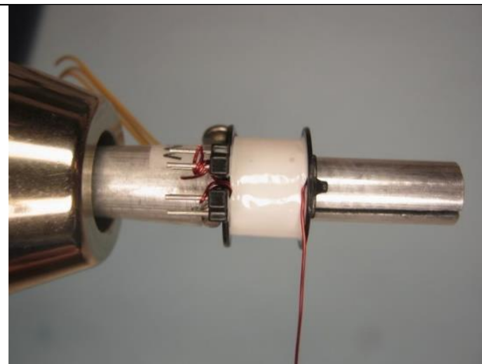
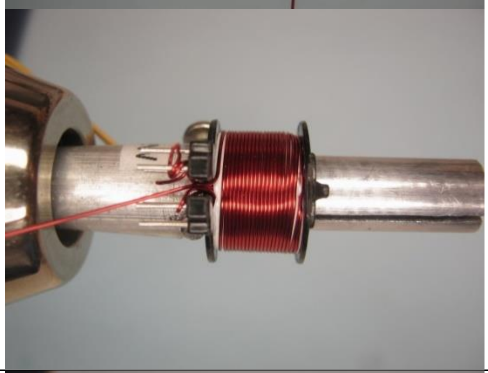
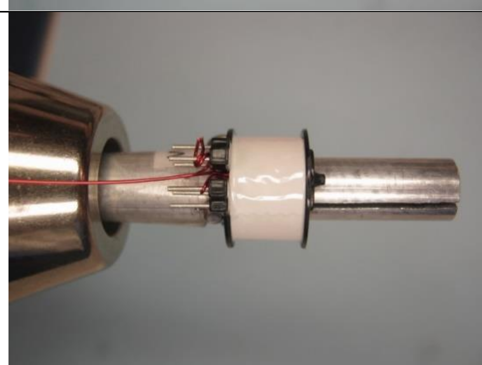
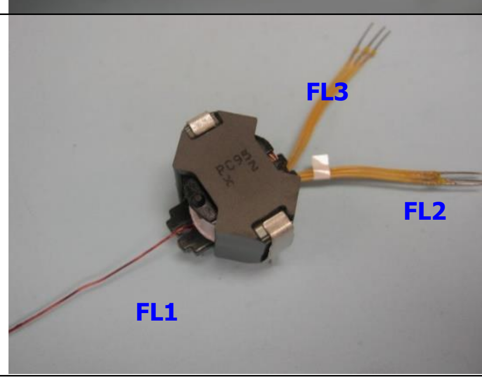
7.6 Winding Illustrations

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 21 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 7 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].

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

WD3 Secondary	  	Start on the secondary side of the bobbin, use 3 wires Item [4], leave ~1” floating, and mark as FL2. Wind 4 turns in 1 layer, from left to right, 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].

WD1 **2nd Primary**	 	Use wire hanging from WD1; continue winding 21 turns from right to left. At the last turn, leave ~1" of wire floating and mark as FL1.
Insulation		2 layers of tape Item [5] for insulation and secure the windings.
Finish		Gap cores to get 645 μH and secure with clips Item [6]. Varnish with Item [7].

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

8 Common Mode Choke Specifications

8.1 *108 μH Common Mode Choke (L1)*

8.1.1 *Electrical Diagram*

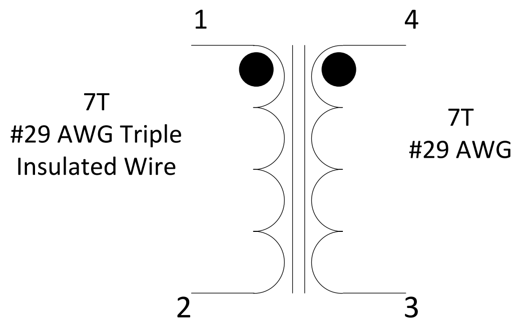


Figure 8 – Inductor Electrical Diagram.

8.1.2 *Electrical Specifications*

Inductance	Pins 1 - 2 measured at 100 kHz, 0.4 V_{RMS}.	108 μH ±20%
Primary Leakage Inductance	Pins 1 - 2, with 3 - 4 shorted.	0.5 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: #29 AWG.
[3]	Triple Insulated Wire #29 AWG.

8.1.4 *Illustrations*

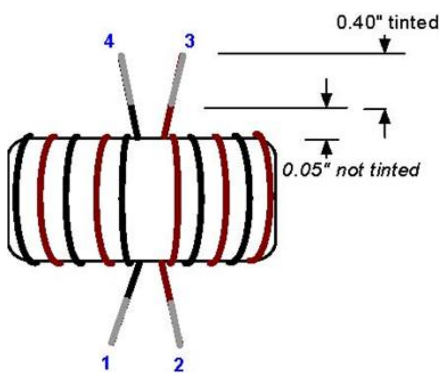


Figure 9 – CMM L1 Top View.

Figure 10 – CMM L1 Front View.

8.2 16.6 mH Common Mode Choke (L3)

8.2.1 *Electrical Diagram*

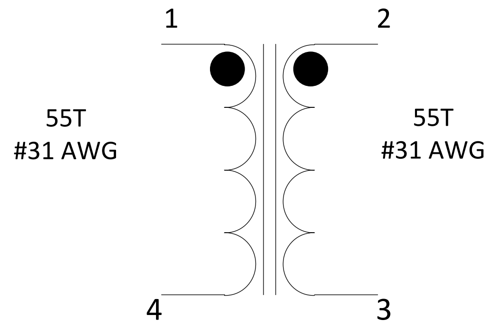


Figure 11 – Inductor Electrical Diagram.

8.2.2 *Electrical Specifications*

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

8.2.3 *Materials List*

Item	Description
[1]	Toroid: FERRITE INDUCTOR TOROID T14 x 8 x 5.5. PI Part number: #32-00286-00.
[2]	Divider: Cable Tie, Panduit, PLT.7M-M,75-00082-00.
[3]	Magnet Wire: #31 AWG Heavy Nyleze.
[4]	Epoxy: Devcon, 14270, 5 min Epoxy; or Equivalent.

8.2.4 *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 55 turns in 2 layers in 1 section of toroid, 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.

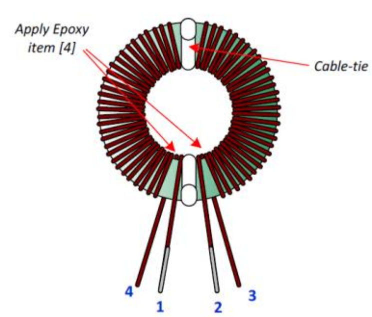


Figure 12 – CMC L3 Side View.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

9 Transformer Design Spreadsheet

9.1 *Output: 5 V / 3 A*

1	ACDC_InnoSwitch3-CP_Flyback_081518; Rev.1.3; Copyright Power Integrations 2018	INPUT	OUTPUT	UNITS	InnoSwitch3-CP Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**				
3	VAC_MIN		85	V	Minimum AC line voltage
4	VAC_MAX		265	V	Maximum AC input voltage
5	VAC_RANGE		UNIVERSAL		AC line voltage range
6	FLINE		60	Hz	AC line voltage frequency
7	CAP_INPUT	37.0	37.0	uF	Input capacitance
9	**SETPOINT 1**				
10	VOUT1	9.00	9.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	2.00	2.00	A	Output current 1
12	POUT1		18.00	W	The output power required exceeds the device capability; reselect the device
13	EFFICIENCY1	0.88	0.88		Converter efficiency for output 1
14	Z_FACTOR1	0.50	0.50		Z-factor for output 1
16	**SETPOINT 2**				
17	VOUT2	5.00	5.00	V	Output voltage 2
18	IOUT2	3.00	3.00	A	Output current 2
19	POUT2		15.00	W	Output power 2
20	EFFICIENCY2	0.88	0.88		Converter efficiency for output 2
21	Z_FACTOR2	0.50	0.50		Z-factor for output 2
72	PERCENT_CDC	0%	0%		Percentage (of output voltage) cable drop compensation desired at full load
73	CDC_SCALING_SETPOINT	2	2		Select the setpoint number for the voltage used for cable drop compensation (typically the 5V output)
77	**PRIMARY CONTROLLER SELECTION**				
78	ENCLOSURE	ADAPTER	ADAPTER		Power supply enclosure
79	ILIMIT_MODE	INCREASED	INCREASED		Device current limit mode
80	VDRAIN_BREAKDOWN	650	650	V	Device breakdown voltage
81	DEVICE_GENERIC	INN32X4	INN32X4		Device selection
82	DEVICE_CODE		INN3264C		Device code
83	PDEVICE_MAX		15	W	Device maximum power capability
84	RDSON_25DEG		3.68	Ω	Primary MOSFET on-time resistance at 25°C
85	RDSON_100DEG		5.70	Ω	Primary MOSFET on-time resistance at 100°C
86	ILIMIT_MIN		0.864	A	Primary MOSFET minimum current limit
87	ILIMIT_TYP		0.950	A	Primary MOSFET typical current limit
88	ILIMIT_MAX		1.036	A	Primary MOSFET maximum current limit
89	VDRAIN_ON_MOSFET		1.28	V	Primary MOSFET on-time voltage drop
90	VDRAIN_OFF_MOSFET		538.31	V	Peak drain voltage on the primary MOSFET during turn-off
94	**WORST CASE ELECTRICAL PARAMETERS**				
95	FSWITCHING_MAX	86555	86555	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
96	VOR	95.0	95.0	V	Voltage reflected to the primary winding (corresponding to setpoint 1) when the primary MOSFET turns off
97	VMIN		86.63	V	Valley of the minimum input AC voltage
98	KP		0.851		Measure of continuous/discontinuous mode of operation
99	MODE_OPERATION		CCM		Mode of operation
100	DUTYCYCLE		0.527		Primary MOSFET duty cycle

101	TIME_ON		7.71	us	Primary MOSFET on-time
102	TIME_OFF		5.47	us	Primary MOSFET off-time
103	LPRIMARY_MIN		612.8	uH	Minimum primary magnetizing inductance
104	LPRIMARY_TYP		645.1	uH	Typical primary magnetizing inductance
105	LPRIMARY_TOL		5.0		Primary magnetizing inductance tolerance
106	LPRIMARY_MAX		677.4	uH	Maximum primary magnetizing inductance
108	**PRIMARY CURRENT**				
109	IAVG_PRIMARY		0.225	A	Primary MOSFET average current
110	IPEAK_PRIMARY		0.983	A	Primary MOSFET peak current
111	IPEDESTAL_PRIMARY		0.124	A	Primary MOSFET current pedestal
112	IRIPPLE_PRIMARY		0.983	A	Primary MOSFET ripple current
113	IRMS_PRIMARY		0.384	A	Primary MOSFET RMS current
115	**SECONDARY CURRENT**				
116	IPEAK_SECONDARY		10.320	A	Secondary MOSFET peak current
117	IPEDESTAL_SECONDARY		1.302	A	Secondary MOSFET pedestal current
118	IRMS_SECONDARY		4.609	A	Secondary MOSFET RMS current
119	IRIPPLE_CAP_OUT		3.500	A	Output capacitor ripple current
123	**TRANSFORMER CONSTRUCTION PARAMETERS**				
124	**CORE SELECTION**				
125	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
126	CORE NAME		PC95RM08Z		Core code
127	AE		64.0	mm^2	Core cross sectional area
128	LE		38.0	mm	Core magnetic path length
129	AL		5290	nH	Ungapped core effective inductance per turns squared
130	VE		2430	mm^3	Core volume
131	BOBBIN NAME		B-RM08-V		Bobbin name
132	AW		30.0	mm^2	Bobbin window area
133	BW		8.8	mm	Bobbin width
134	MARGIN		0.0	mm	Bobbin safety margin
136	**PRIMARY WINDING**				
137	NPRIMARY		42		Primary winding number of turns
138	BPEAK		2672	Gauss	Peak flux density
139	BMAX		2447	Gauss	Maximum flux density
140	BAC		1223	Gauss	AC flux density
141	ALG		366	nH	Typical gapped core effective inductance per turns squared
142	LG		0.205	mm	Core gap length
143	LAYERS_PRIMARY		2		Primary winding number of layers
144	AWG_PRIMARY		27		Primary wire gauge
145	OD_PRIMARY_INSULATED		0.418	mm	Pimary wire insulated outer diameter
146	OD_PRIMARY_BARE		0.361	mm	Primary wire bare outer diameter
147	CMA_PRIMARY		524.5	Cmils/A	The primary winding wire CMA is higher than 500 mil^2/Amperes: Decrease the primary layers or wire thickness
149	**SECONDARY WINDING**				
150	NSECONDARY	4	4		Secondary winding number of turns
151	AWG_SECONDARY		20		Secondary wire gauge
152	OD_SECONDARY_INSULATED		1.118	mm	Secondary wire insulated outer diameter
153	OD_SECONDARY_BARE		0.812		Secondary wire bare outer diameter
154	CMA_SECONDARY		220.9	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 REQURED		80.00	V	Required line brown-in threshold
164	RLS		4.00	MΩ	Connect two 2 MOhm resistors to the V-pin for the

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

					required UV/OV threshold
165	BROWN-IN ACTUAL		80.16	V	Actual brown-in threshold using standard resistors
166	BROWN-OUT ACTUAL		72.50	V	Actual brown-out threshold using standard resistors
168	**LINE OVERVOLTAGE**				
169	OVERVOLTAGE_LINE		334.21	V	The device voltage stress will be higher than 90% of the breakdown voltage when overvoltage is trigerred
171	**BIAS WINDING**				
172	VBIAS	7.00	7.00	V	The rectified bias voltage maybe too low to supply the BP pin: Increase the rectified bias voltage to a value higher than 10V
173	VF_BIAS		0.70	V	Bias winding diode forward drop
174	VREVERSE_BIASDIODE		69.22	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		44.55	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
183	SRFET	SiR878AD P	SiR878AD P		Secondary rectifier (Logic MOSFET)
184	VBREAKDOWN_SRFET		100	V	Secondary rectifier breakdown voltage
185	RDSON_SRFET		18.0	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
187	**FEEDBACK COMPONENTS**				
188	RFB_UPPER		100.00	kΩ	Upper feedback resistor (connected to the output terminal)
189	RFB_LOWER		34.00	kΩ	Lower feedback resistor required to obtain the output for cable drop compensation
190	CFB_LOWER		330	pF	Lower feedback resistor decoupling capacitor
194	**SETPOINTS ANALYSIS**				
195	TOLERANCE CORNER				
196	USER_VAC	115	115	V	Input AC RMS voltage corner to be evaluated
197	USER_ILIMIT	TYP	0.950	A	Current limit corner to be evaluated
198	USER_LPRIMARY	TYP	645.1	uH	Primary inductance corner to be evaluated
200	**SETPOINT SELECTION**				
201	SETPOINT	2	2		Select the setpoint which needs to be evaluated
202	FSWITCHING		62051.7	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
203	VOR		53.2	V	Voltage reflected to the primary winding when the primary MOSFET turns off
204	VMIN		141.87	V	Valley of the minimum input AC voltage
205	KP		1.110		Measure of continuous/discontinuous mode of operation
206	MODE_OPERATION		DCM		Mode of operation
207	DUTYCYCLE		0.254		Primary MOSFET duty cycle
208	TIME_ON		4.09	us	Primary controller's maximum on-time
209	TIME_OFF		12.03	us	Primary controller's minimum off-time
211	**PRIMARY CURRENT**				
212	IAVG_PRIMARY		0.113	A	Primary MOSFET average current
213	IPEAK_PRIMARY		0.895	A	Primary MOSFET peak current
214	IPEDESTAL_PRIMARY		0.000	A	Primary MOSFET current pedestal
215	IRIPPLE_PRIMARY		0.895	A	Primary MOSFET ripple current
216	IRMS_PRIMARY		0.260	A	Primary MOSFET RMS current
218	**SECONDARY CURRENT**				
219	IPEAK_SECONDARY		9.395	A	Secondary MOSFET peak current
220	IPEDESTAL_SECONDARY		0.000	A	Secondary MOSFET pedestal current
221	IRMS_SECONDARY		4.449	A	Secondary MOSFET RMS current
222	IRIPPLE_CAP_OUT		3.285	A	Output capacitor ripple current

9.2 *Output: 9 V / 2 A*

1	**ACDC_InnoSwitch3-CP_Flyback_081518; Rev.1.3; Copyright Power Integrations 2018**	**INPUT**	**OUTPUT**	**UNITS**	**InnoSwitch3-CP Flyback Design Spreadsheet**
2	**APPLICATION VARIABLES**				
3	VAC_MIN		85	V	Minimum AC line voltage
4	VAC_MAX		265	V	Maximum AC input voltage
5	VAC_RANGE		UNIVERSAL		AC line voltage range
6	FLINE		60	Hz	AC line voltage frequency
7	CAP_INPUT	37.0	37.0	uF	Input capacitance
9	**SETPOINT 1**				
10	VOUT1	9.00	9.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	2.00	2.00	A	Output current 1
12	POUT1		18.00	W	The output power required exceeds the device capability; reselect the device
13	EFFICIENCY1	0.88	0.88		Converter efficiency for output 1
14	Z_FACTOR1	0.50	0.50		Z-factor for output 1
16	**SETPOINT 2**				
17	VOUT2	5.00	5.00	V	Output voltage 2
18	IOUT2	3.00	3.00	A	Output current 2
19	POUT2		15.00	W	Output power 2
20	EFFICIENCY2	0.88	0.88		Converter efficiency for output 2
21	Z_FACTOR2	0.50	0.50		Z-factor for output 2
72	PERCENT_CDC	0%	0%		Percentage (of output voltage) cable drop compensation desired at full load
73	CDC_SCALING_SETPOINT	2	2		Select the setpoint number for the voltage used for cable drop compensation (typically the 5V output)
77	**PRIMARY CONTROLLER SELECTION**				
78	ENCLOSURE	ADAPTER	ADAPTER		Power supply enclosure
79	ILIMIT_MODE	INCREASED	INCREASED		Device current limit mode
80	VDRAIN_BREAKDOWN	650	650	V	Device breakdown voltage
81	DEVICE_GENERIC	INN32X4	INN32X4		Device selection
82	DEVICE_CODE		INN3264C		Device code
83	PDEVICE_MAX		15	W	Device maximum power capability
84	RDSON_25DEG		3.68	Ω	Primary MOSFET on-time resistance at 25°C
85	RDSON_100DEG		5.70	Ω	Primary MOSFET on-time resistance at 100°C
86	ILIMIT_MIN		0.864	A	Primary MOSFET minimum current limit
87	ILIMIT_TYP		0.950	A	Primary MOSFET typical current limit
88	ILIMIT_MAX		1.036	A	Primary MOSFET maximum current limit
89	VDRAIN_ON_MOSFET		1.28	V	Primary MOSFET on-time voltage drop
90	VDRAIN_OFF_MOSFET		538.31	V	Peak drain voltage on the primary MOSFET during turn-off
94	**WORST CASE ELECTRICAL PARAMETERS**				
95	FSWITCHING_MAX	86555	86555	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
96	VOR	95.0	95.0	V	Voltage reflected to the primary winding (corresponding to setpoint 1) when the primary MOSFET turns off
97	VMIN		86.63	V	Valley of the minimum input AC voltage
98	KP		0.851		Measure of continuous/discontinuous mode of operation
99	MODE_OPERATION		CCM		Mode of operation
100	DUTYCYCLE		0.527		Primary MOSFET duty cycle
101	TIME_ON		7.71	us	Primary MOSFET on-time
102	TIME_OFF		5.47	us	Primary MOSFET off-time
103	LPRIMARY_MIN		612.8	uH	Minimum primary magnetizing inductance
104	LPRIMARY_TYP		645.1	uH	Typical primary magnetizing inductance

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

105	LPRIMARY_TOL		5.0		Primary magnetizing inductance tolerance
106	LPRIMARY_MAX		677.4	uH	Maximum primary magnetizing inductance
108	**PRIMARY CURRENT**				
109	IAVG_PRIMARY		0.225	A	Primary MOSFET average current
110	IPEAK_PRIMARY		0.983	A	Primary MOSFET peak current
111	IPEDESTAL_PRIMARY		0.124	A	Primary MOSFET current pedestal
112	IRIPPLE_PRIMARY		0.983	A	Primary MOSFET ripple current
113	IRMS_PRIMARY		0.384	A	Primary MOSFET RMS current
115	**SECONDARY CURRENT**				
116	IPEAK_SECONDARY		10.320	A	Secondary MOSFET peak current
117	IPEDESTAL_SECONDARY		1.302	A	Secondary MOSFET pedestal current
118	IRMS_SECONDARY		4.609	A	Secondary MOSFET RMS current
119	IRIPPLE_CAP_OUT		3.500	A	Output capacitor ripple current
123	**TRANSFORMER CONSTRUCTION PARAMETERS**				
124	**CORE SELECTION**				
125	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
126	CORE NAME		PC95RM08Z		Core code
127	AE		64.0	mm^2	Core cross sectional area
128	LE		38.0	mm	Core magnetic path length
129	AL		5290	nH	Ungapped core effective inductance per turns squared
130	VE		2430	mm^3	Core volume
131	BOBBIN NAME		B-RM08-V		Bobbin name
132	AW		30.0	mm^2	Bobbin window area
133	BW		8.8	mm	Bobbin width
134	MARGIN		0.0	mm	Bobbin safety margin
136	**PRIMARY WINDING**				
137	NPRIMARY		42		Primary winding number of turns
138	BPEAK		2672	Gauss	Peak flux density
139	BMAX		2447	Gauss	Maximum flux density
140	BAC		1223	Gauss	AC flux density
141	ALG		366	nH	Typical gapped core effective inductance per turns squared
142	LG		0.205	mm	Core gap length
143	LAYERS_PRIMARY		2		Primary winding number of layers
144	AWG_PRIMARY		27		Primary wire gauge
145	OD_PRIMARY_INSULATED		0.418	mm	Pimary wire insulated outer diameter
146	OD_PRIMARY_BARE		0.361	mm	Primary wire bare outer diameter
147	CMA_PRIMARY		524.5	Cmils/A	The primary winding wire CMA is higher than 500 mil^2/Amperes: Decrease the primary layers or wire thickness
149	**SECONDARY WINDING**				
150	NSECONDARY	4	4		Secondary winding number of turns
151	AWG_SECONDARY		20		Secondary wire gauge
152	OD_SECONDARY_INSULATED		1.118	mm	Secondary wire insulated outer diameter
153	OD_SECONDARY_BARE		0.812		Secondary wire bare outer diameter
154	CMA_SECONDARY		220.9	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 REQURED		80.00	V	Required line brown-in threshold
164	RLS		4.00	MΩ	Connect two 2 MOhm resistors to the V-pin for the required UV/OV threshold
165	BROWN-IN ACTUAL		80.16	V	Actual brown-in threshold using standard resistors
166	BROWN-OUT ACTUAL		72.50	V	Actual brown-out threshold using standard resistors
168	**LINE OVERVOLTAGE**				

169	OVERVOLTAGE_LINE	Warning	334.21	V	The device voltage stress will be higher than 90% of the breakdown voltage when overvoltage is trigerred
171	**BIAS WINDING**				
172	VBIAS	7.00	7.00	V	The rectified bias voltage maybe too low to supply the BP pin: Increase the rectified bias voltage to a value higher than 10V
173	VF_BIAS		0.70	V	Bias winding diode forward drop
174	VREVERSE_BIASDIODE		69.22	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		44.55	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
183	SRFET	SiR878ADP	SiR878ADP		Secondary rectifier (Logic MOSFET)
184	VBREAKDOWN_SRFET		100	V	Secondary rectifier breakdown voltage
185	RDSON_SRFET		18.0	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
187	**FEEDBACK COMPONENTS**				
188	RFB_UPPER		100.00	kΩ	Upper feedback resistor (connected to the output terminal)
189	RFB_LOWER		34.00	kΩ	Lower feedback resistor required to obtain the output for cable drop compensation
190	CFB_LOWER		330	pF	Lower feedback resistor decoupling capacitor
194	**SETPOINTS ANALYSIS**				
195	TOLERANCE CORNER				
196	USER_VAC	115	115	V	Input AC RMS voltage corner to be evaluated
197	USER_ILIMIT	TYP	0.950	A	Current limit corner to be evaluated
198	USER_LPRIMARY	TYP	645.1	uH	Primary inductance corner to be evaluated
200	**SETPOINT SELECTION**				
201	SETPOINT	1	1		Select the setpoint which needs to be evaluated
202	FSWITCHING		71376.5	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
203	VOR		95.0	V	Voltage reflected to the primary winding when the primary MOSFET turns off
204	VMIN		137.92	V	Valley of the minimum input AC voltage
205	KP		1.565		Measure of continuous/discontinuous mode of operation
206	MODE_OPERATION		DCM		Mode of operation
207	DUTYCYCLE		0.307		Primary MOSFET duty cycle
208	TIME_ON		4.30	us	Primary controller's maximum on-time
209	TIME_OFF		9.71	us	Primary controller's minimum off-time
211	**PRIMARY CURRENT**				
212	IAVG_PRIMARY		0.140	A	Primary MOSFET average current
213	IPEAK_PRIMARY		0.914	A	Primary MOSFET peak current
214	IPEDESTAL_PRIMARY		0.000	A	Primary MOSFET current pedestal
215	IRIPPLE_PRIMARY		0.914	A	Primary MOSFET ripple current
216	IRMS_PRIMARY		0.292	A	Primary MOSFET RMS current
218	**SECONDARY CURRENT**				
219	IPEAK_SECONDARY		9.596	A	Secondary MOSFET peak current
220	IPEDESTAL_SECONDARY		0.000	A	Secondary MOSFET pedestal current
221	IRMS_SECONDARY		3.687	A	Secondary MOSFET RMS current
222	IRIPPLE_CAP_OUT		3.098	A	Output capacitor ripple current
224	**MAGNETIC FLUX DENSITY**				
225	BPEAK		2334	Gauss	Peak flux density
226	BMAX		2193	Gauss	Maximum flux density
227	BAC		1097	Gauss	AC flux density (0.5 x Peak to Peak)

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

10 Performance Data

10.1 *Efficiency vs. Load (On Board)*

10.1.1 *Output: 5 V / 3 A*

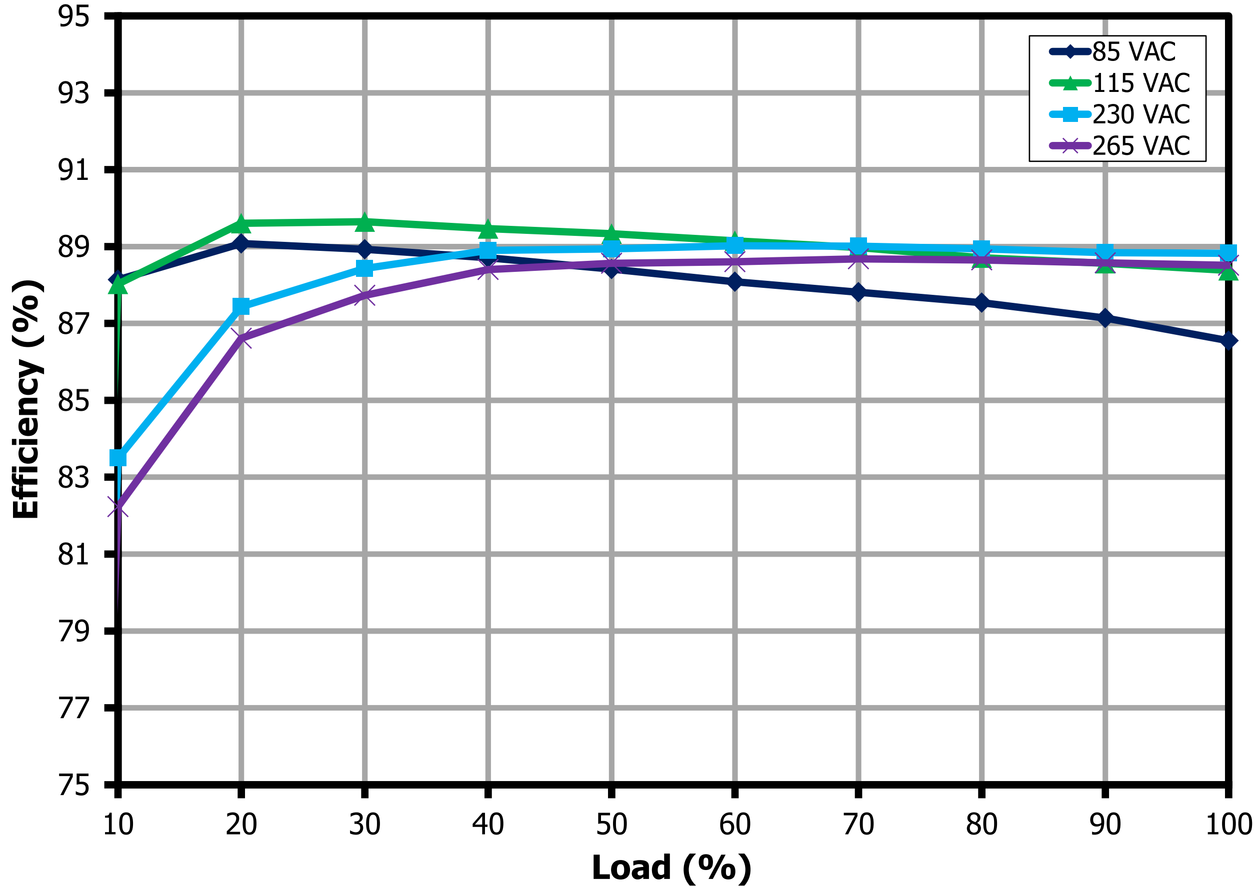


Figure 13 – Efficiency vs. Load, Room Ambient.

10.1.2 *Output: 9 V / 2 A*

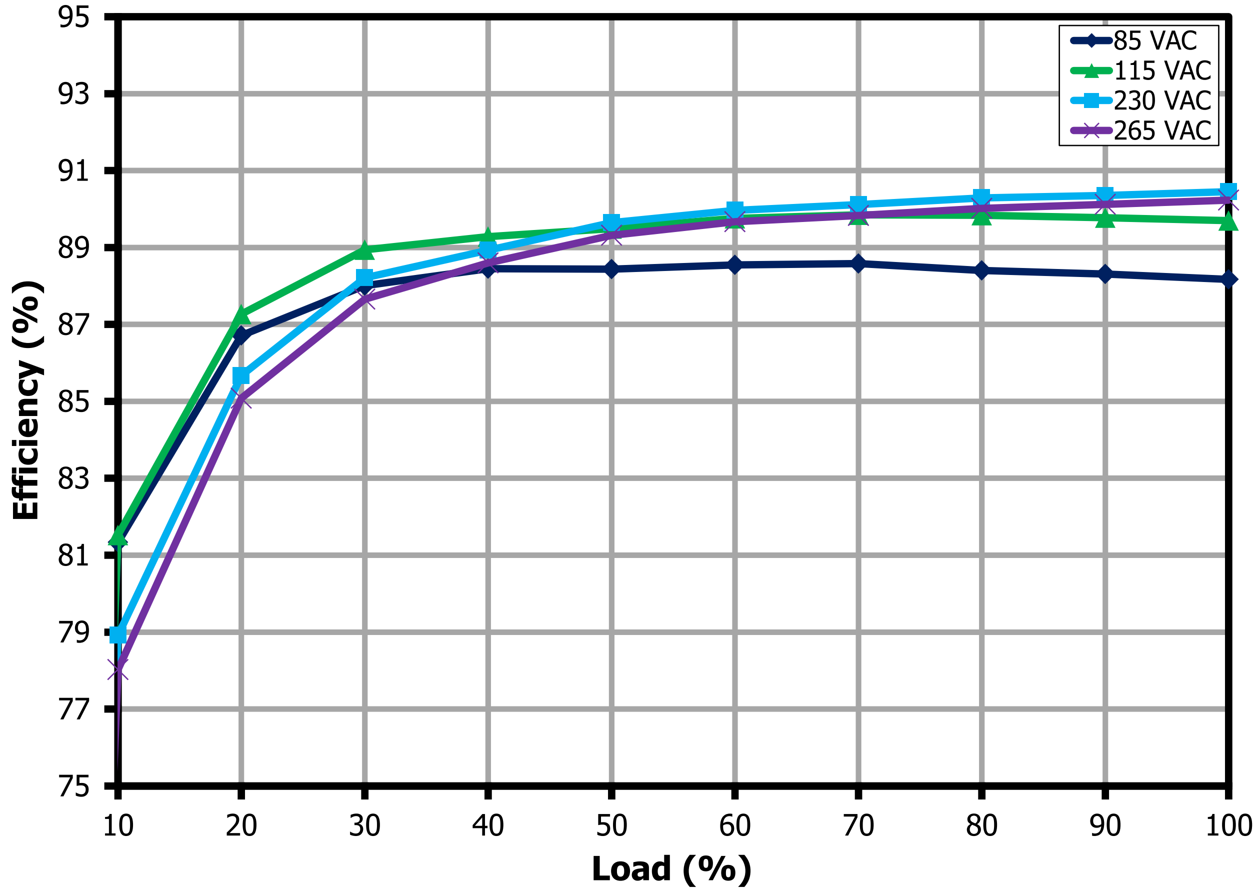


Figure 14 – Efficiency vs. Load, Room Ambient.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

10.2 Efficiency vs. Line (At the Board)

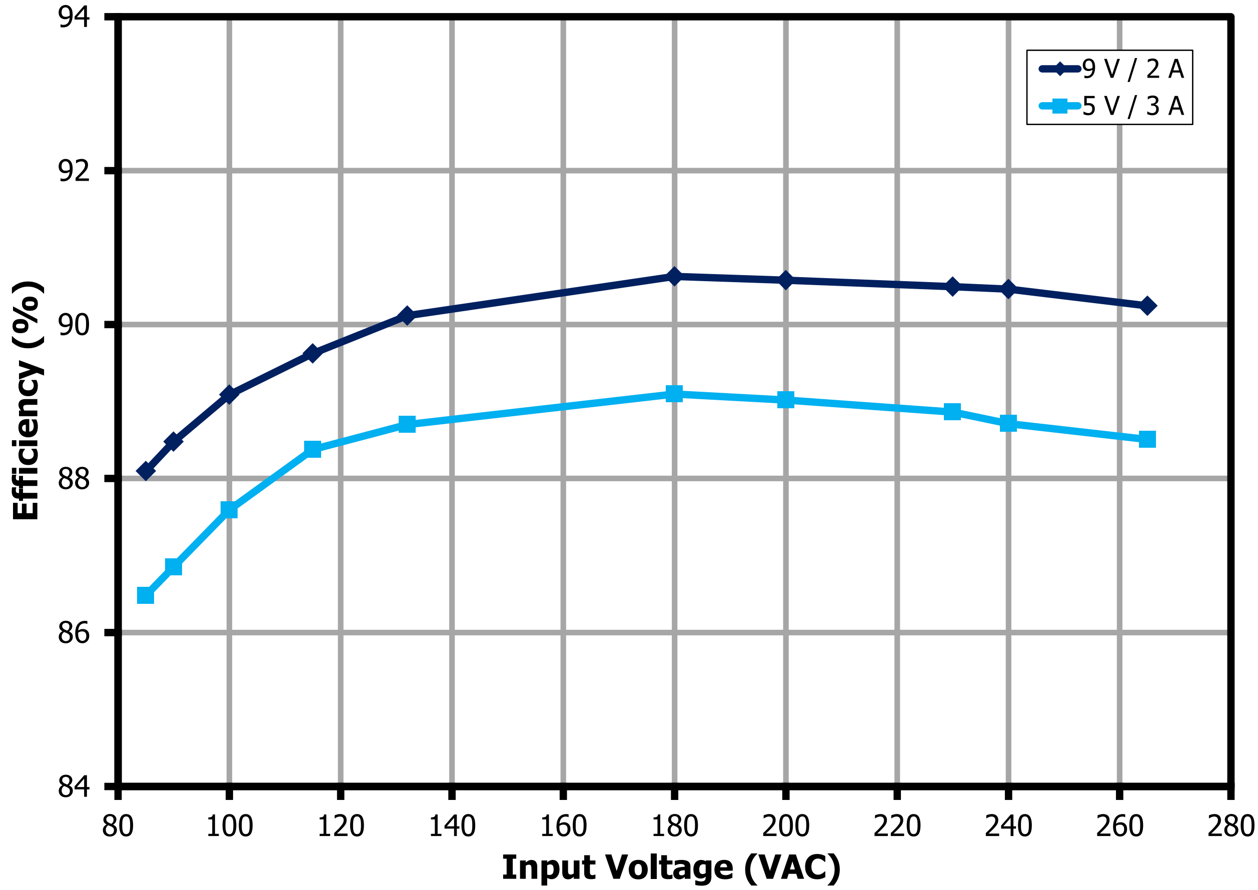


Figure 15 – Efficiency vs. Line, Room Ambient.

10.3 No-Load Input Power at 5 V_{OUT}

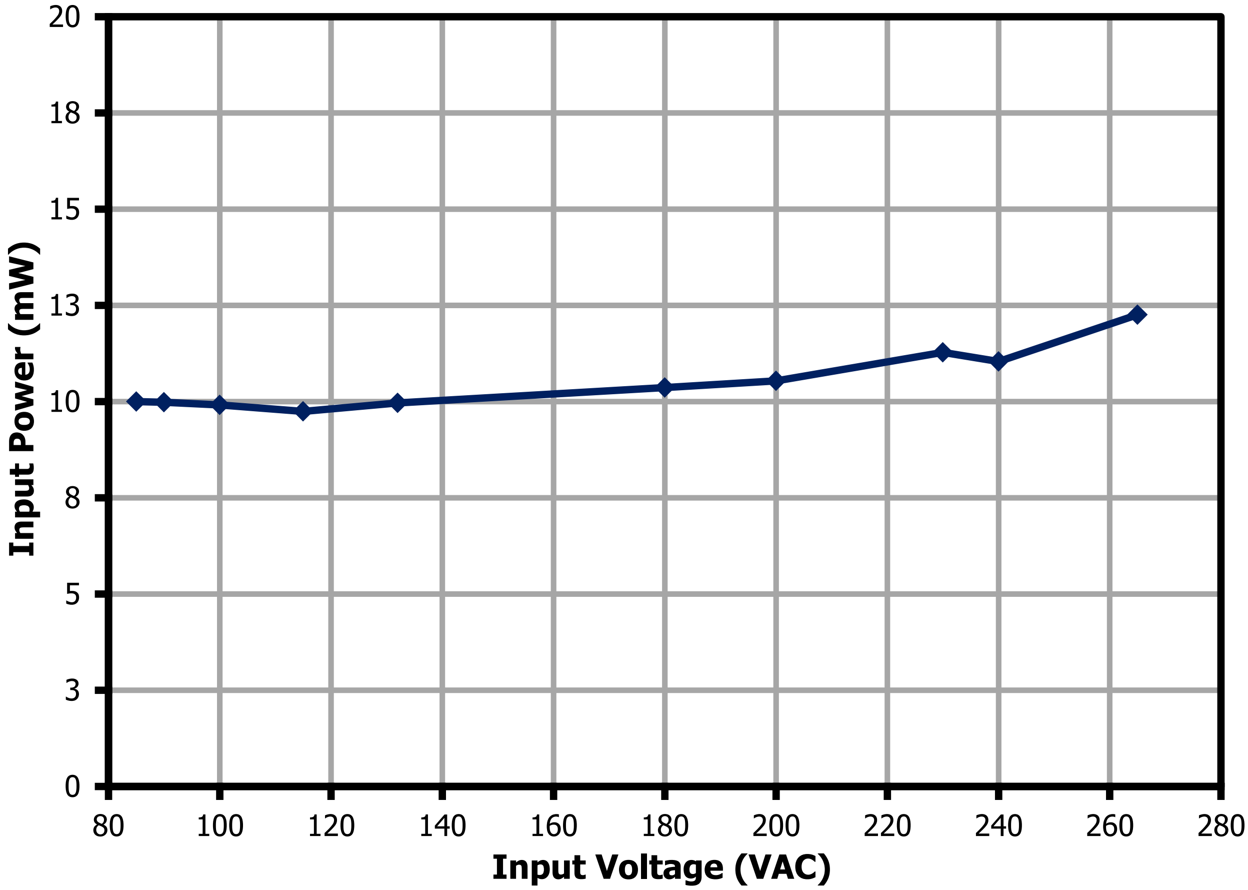


Figure 16 – No-Load Input Power vs. Input Line Voltage, Room Temperature.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

10.4 **Load Regulation (At the Board)**

10.4.1 *Output: 5 V / 3 A*

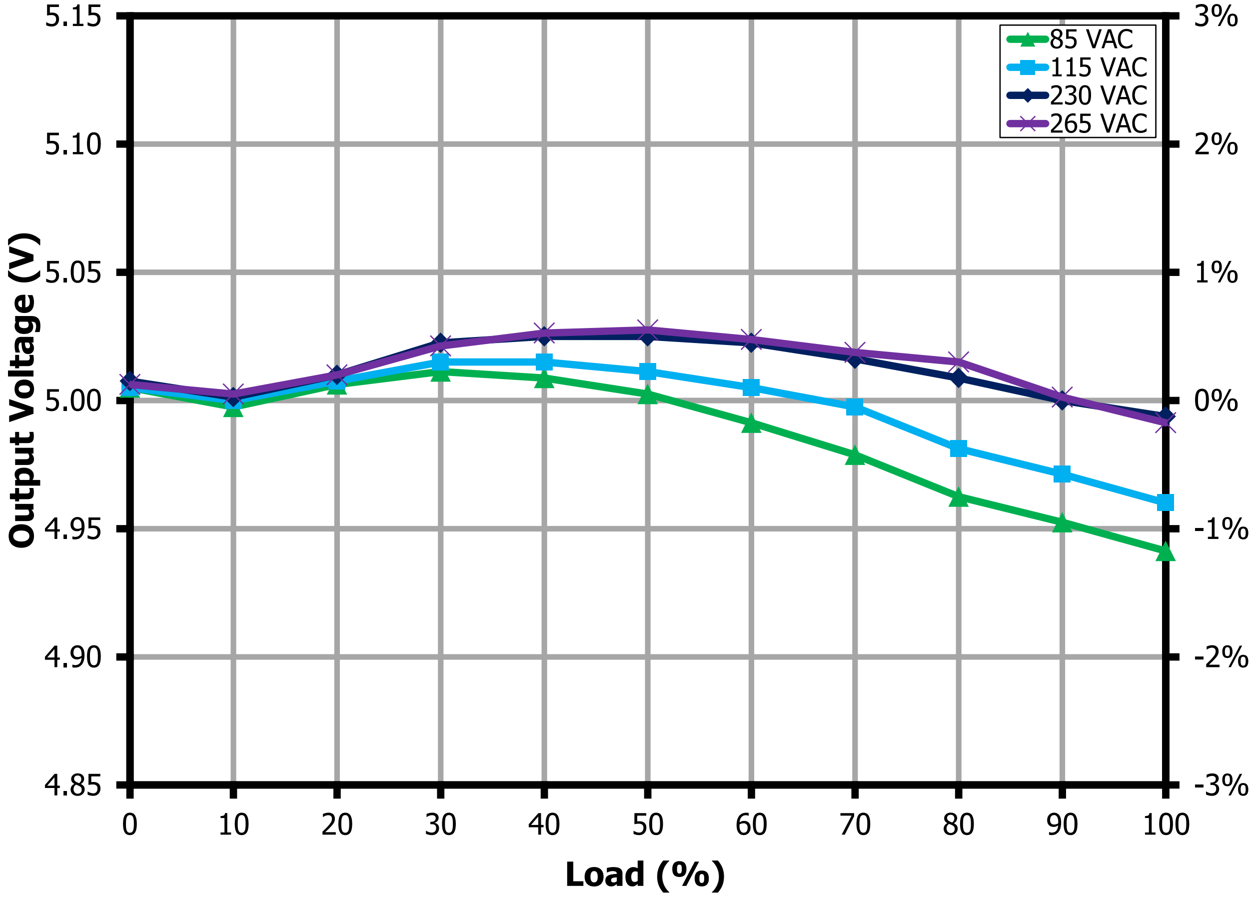


Figure 17 – Output Regulation vs. Percent Load.

10.4.2 *Output: 9 V / 2 A*

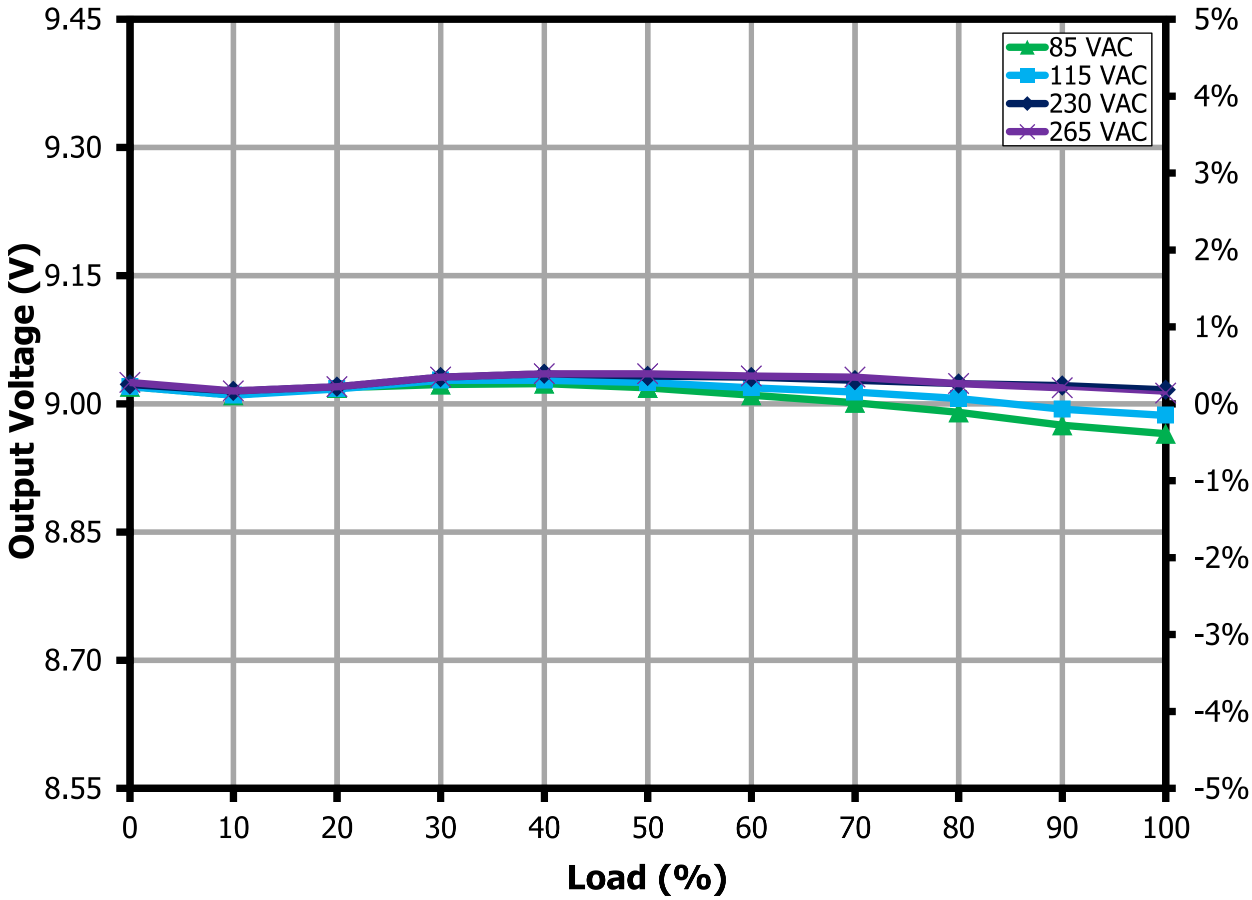


Figure 18 – Output Regulation vs. Percent Load.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

10.5 Line Regulation (At the Board)

10.5.1 *Output: 5 V / 3 A*

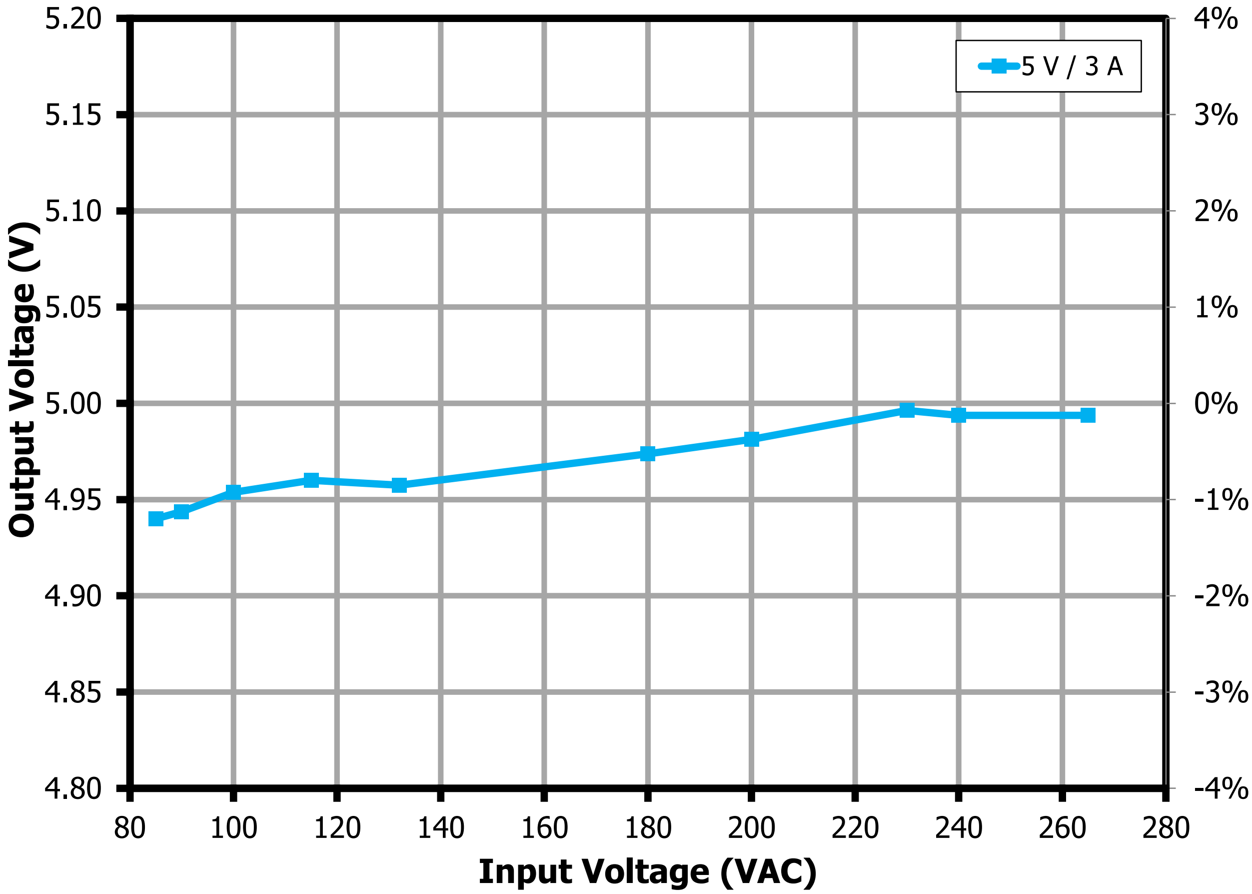


Figure 19 – 5 V Output Regulation vs. Input Line Voltage.

10.5.2 *Output: 9 V / 2 A*

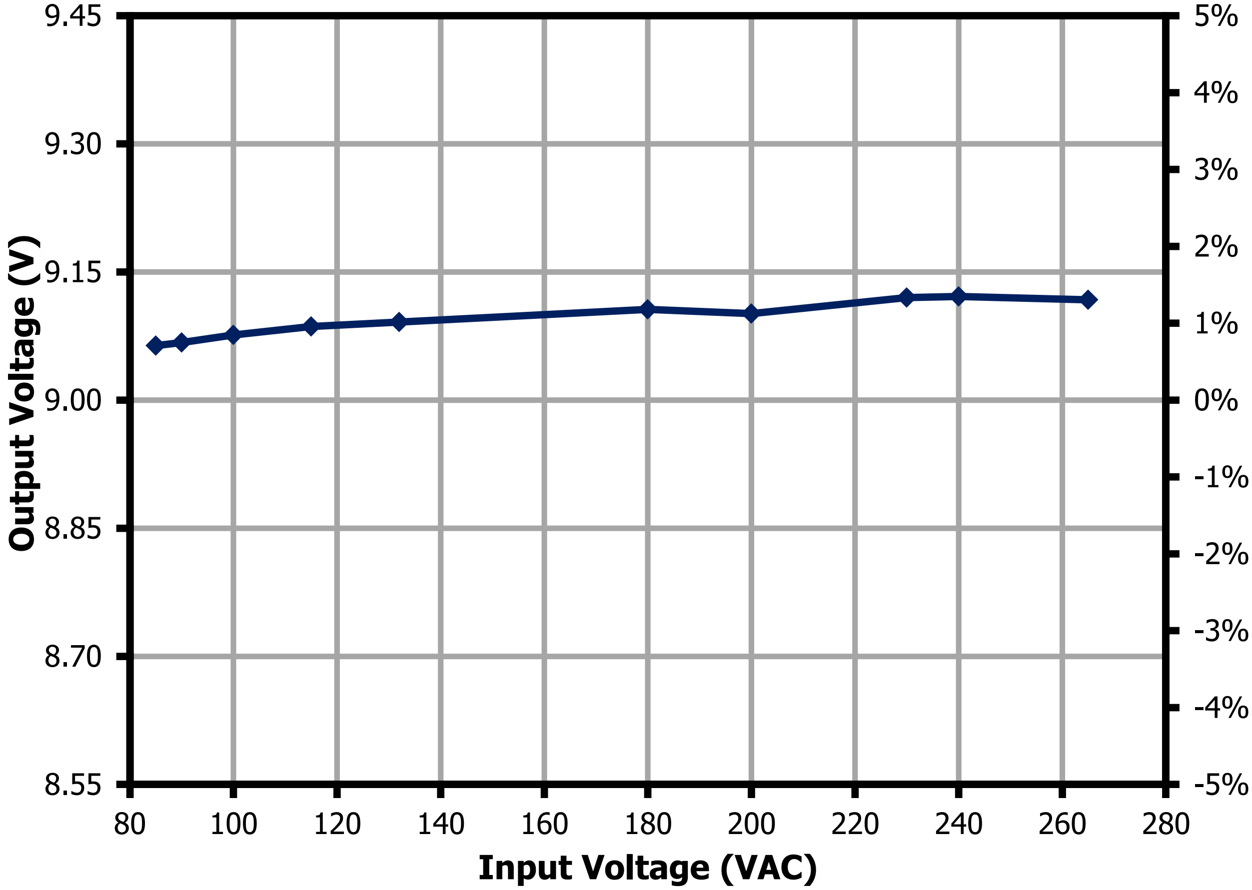


Figure 20 – 9 V Output Regulation vs. Input Line Voltage.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

10.6 Average Efficiency

10.6.1 *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 EISA2007	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	18	81.14%	85.00%	82.69%	85.45%	72.69%	75.45%

10.7 Average and 10% Efficiency (On the Board) at 115 VAC Input

10.7.1 *Output: 5 V*

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	14.87	88.33	89.01
75	11.22	88.79	
50	7.51	89.34	
25	3.76	89.61	
10	1.50	88.01	

10.7.2 *Output: 9 V*

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	18.16	89.64	89.26
75	13.65	89.76	
50	9.01	89.64	
25	4.56	88.00	
10	1.82	81.29	

10.8 Average and 10% Efficiency (On the Board) at 230 VAC Input

10.8.1 *Output: 5 V*

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	14.97	88.80	88.65
75	11.27	88.98	
50	7.54	88.97	
25	3.76	87.87	
10	1.50	83.51	

10.8.2 *Output: 9 V*

% Load	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)
100	18.23	90.43	89.60
75	13.69	90.17	
50	9.02	90.43	
25	4.56	87.36	
10	1.82	78.86	

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

10.9 ***CV/CC***

Note: Over current protection is implemented on the interface IC

10.9.1 *Output: 5 V*

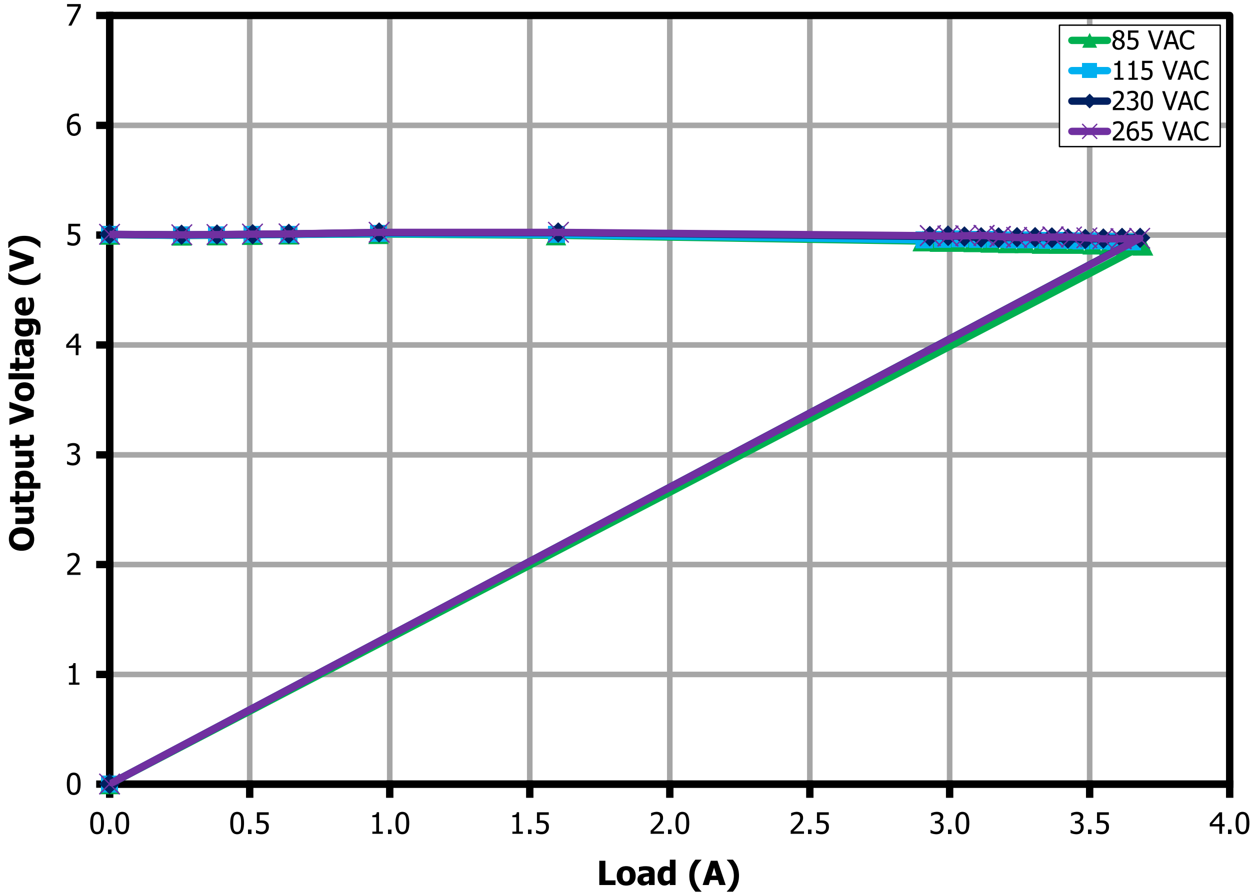


Figure 21 – Output Voltage vs. Output Current, Room Temperature.

10.9.2 *Output: 9 V*

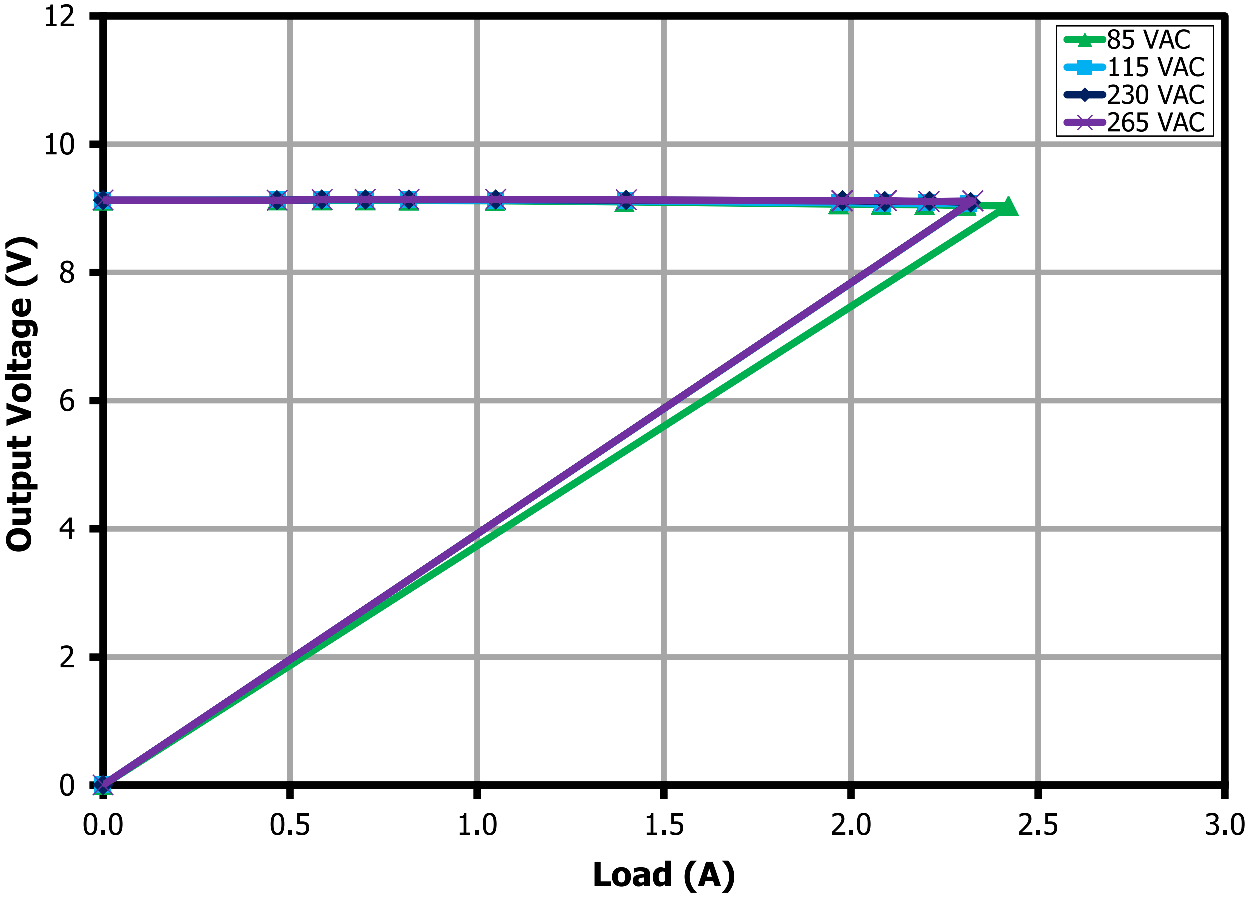


Figure 22 – Output Voltage vs. Output Current, Room Temperature.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

11 Thermal Performance in Open Case

11.1 85 VAC Input 5 V / 3 A

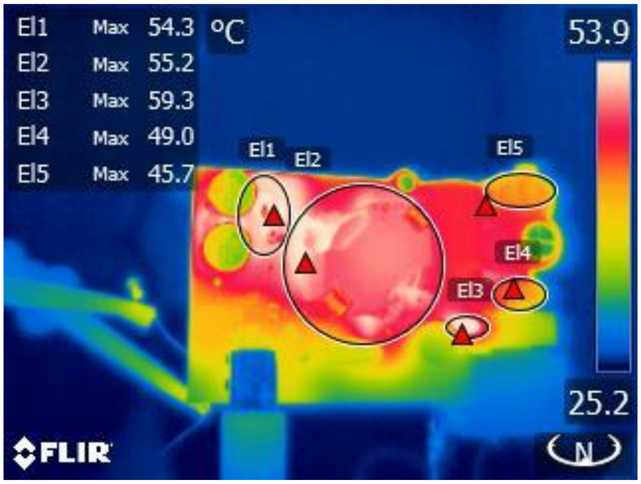


Figure 23 – Top Components, Ambient = 27 ºC.
EI1: SR FET PCB Top, 54.3 ºC.
EI2: Transformer, T2 = 55.2 ºC.
EI3: Thermistor, TH1 = 59.3 ºC.
EI4: CMC, L1 = 49.0 ºC.
EI5: CMC, L2 = 45.7 ºC.

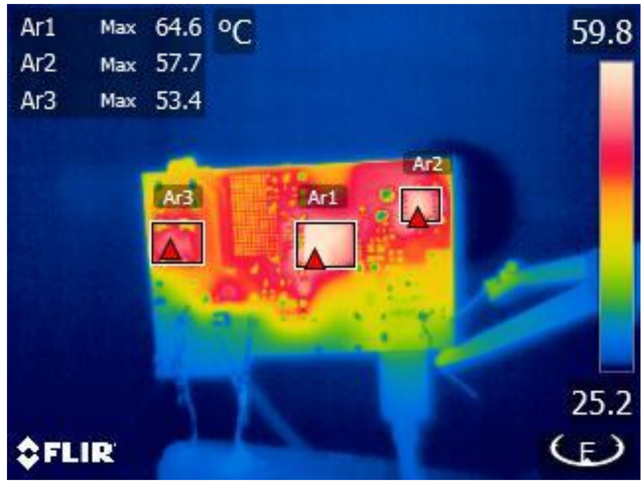


Figure 24 – Bottom Components, Ambient = 27 ºC.
AR1: InnoSwitch3-CP, U1 = 54.6 ºC.
AR2: SR FET, Q2 = 57.7 ºC
AR3: Bridge Diodes, BR1 = 53.4 ºC.

11.2 265 VAC Input 5 V / 3 A

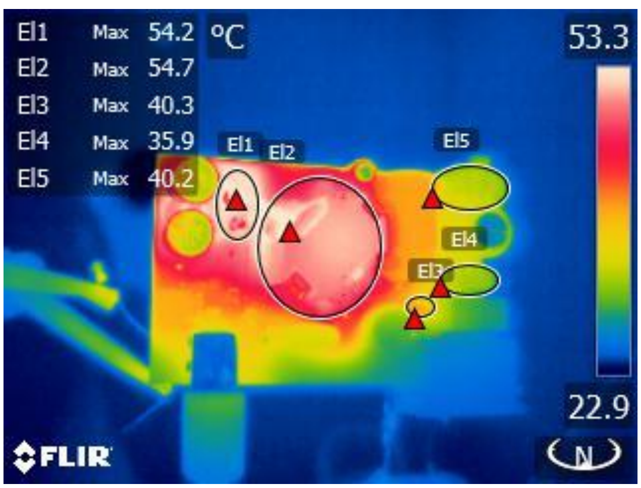


Figure 25 – Top Components, Ambient = 27 ºC.
EI1: SR FET PCB Top, 54.2 ºC.
EI2: Transformer, T2 = 54.7 ºC.
EI3: Thermistor, TH1 = 40.3 ºC
EI4: CMC, L1 = 35.9 ºC.
EI5: CMC, L2 = 40.2 ºC.

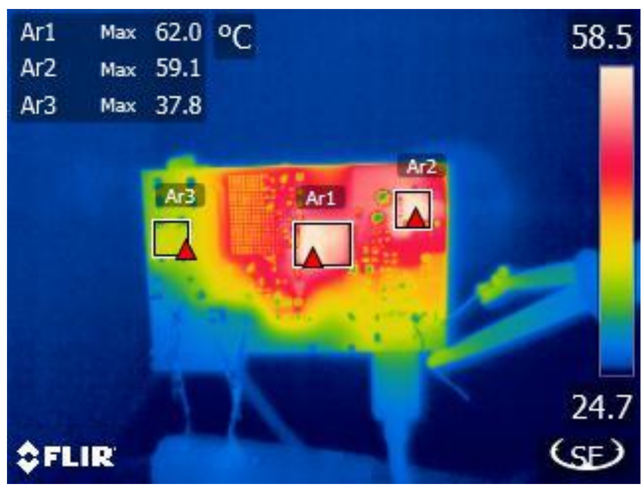


Figure 26 – Bottom Components, Ambient = 27 ºC.
AR1: InnoSwitch3-CP, U1 = 62.0 ºC.
AR2: SR FET, Q2 = 59.1 ºC.
AR3: Bridge Diodes, BR1 = 37.8 ºC.

11.3 85 VAC Input 9 V / 2 A

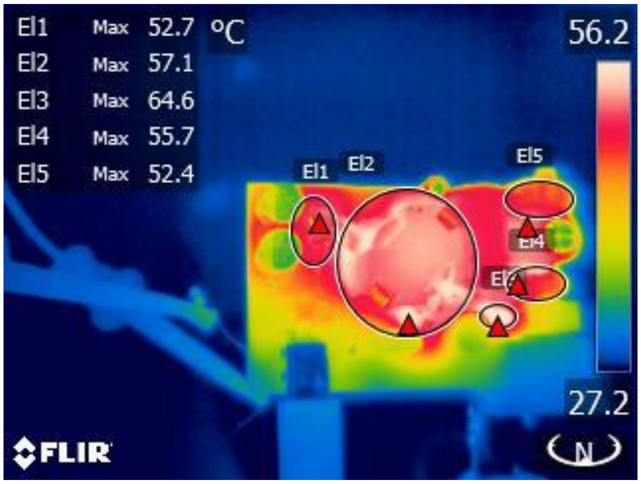


Figure 27 – Top Components, Ambient = 27 ºC.
EI1: SR FET PCB Top, 52.7 ºC.
EI2: Transformer, T2 = 57.1 ºC.
EI3: Thermistor, TH1 = 64.6 ºC.
EI4: CMC, L1 = 55.7 ºC.
EI5: CMC, L2 = 52.4 ºC.

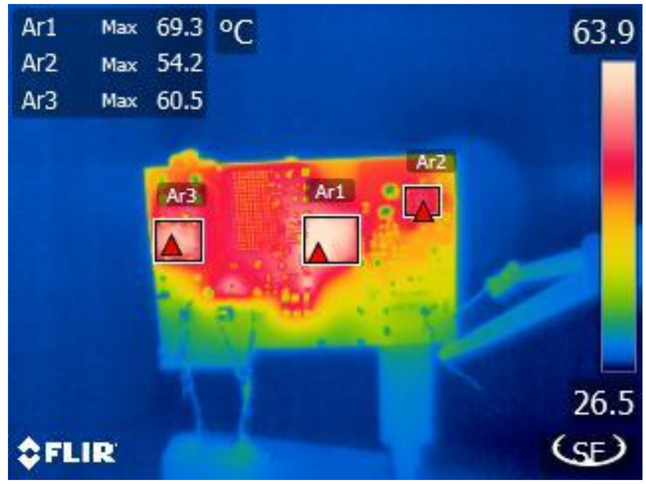


Figure 28 – Bottom Components, Ambient = 27 ºC.
AR1: InnoSwitch3-CP, U1 = 69.3 ºC.
AR2: SR FET, Q2 = 54.2 ºC.
AR3: Bridge Diodes, BR1 = 60.5 ºC.

11.4 265 VAC Input 9 V / 2 A

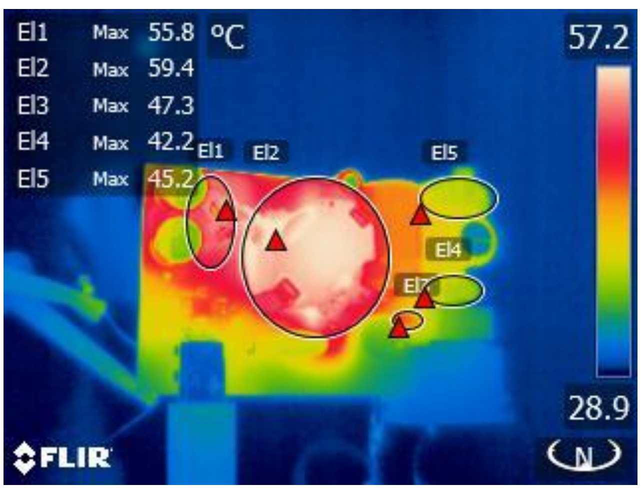


Figure 29 – Top Components, Ambient = 27 ºC.
EI1: SR FET PCB Top, 55.8 ºC.
EI2: Transformer, T2 = 59.4 ºC.
EI3: Thermistor, TH1 = 47.3 ºC.
EI4: CMC, L1 = 42.2 ºC.
EI5: CMC, L2 = 45.2 ºC.

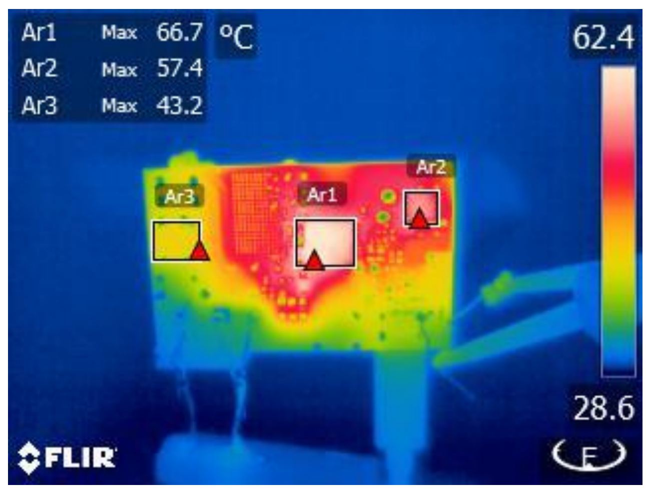


Figure 30 – Bottom Components, Ambient = 27 ºC.
AR1: InnoSwitch3-CP, U1 = 66.7 ºC.
AR2: SR FET, Q2 = 57.4 ºC
AR3: Bridge Diodes, BR1 = 43.2 ºC.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

12 Waveforms

12.1 Load Transient Response (At End of 100 mΩ Cable)

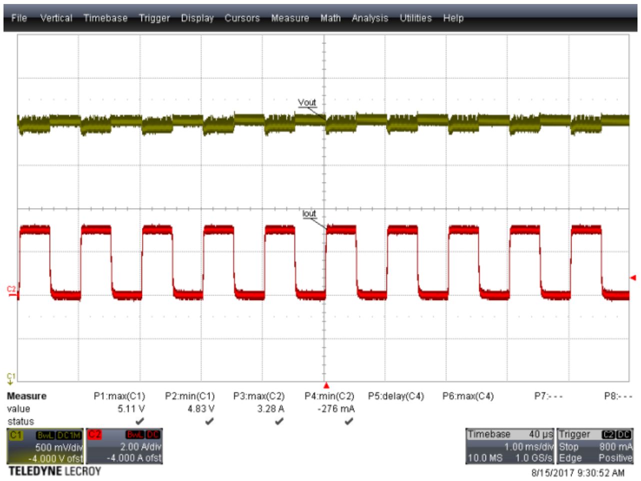


Figure 31 – Transient Response.
85 VAC, 5.0 V, 0 - 3 A Load Step.
V_{MIN} 4.83 V, V_{MAX}: 5.11 V.
Upper: V_{OUT}, 0.5 V / div., 1 ms / div.
Lower: I_{LOAD}, 2 A / div.

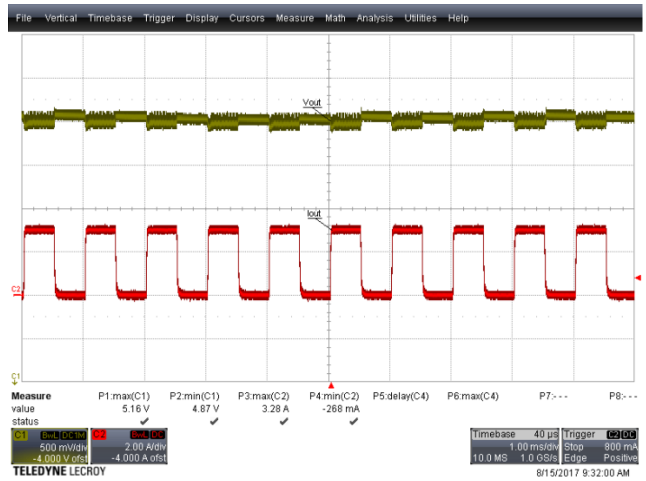


Figure 32 – Transient Response.
265 VAC, 5.0 V, 0 - 3 A Load Step.
V_{MIN} : 4.87 V, V_{MAX}: 5.16 V.
Upper: V_{OUT}, 0.5 V / div., 1 ms / div.
Lower: I_{LOAD}, 2 A / div.

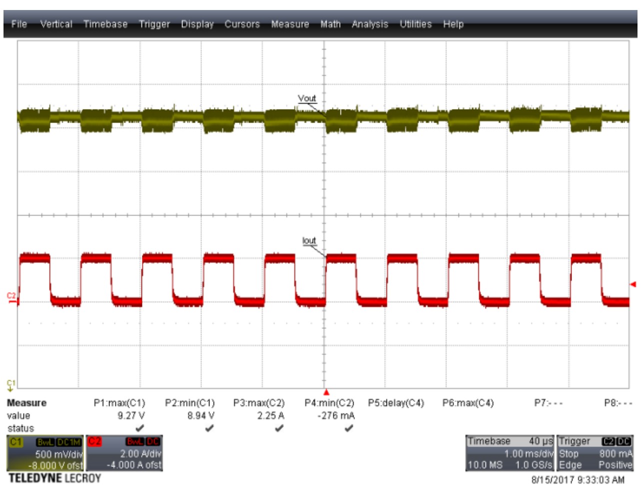


Figure 33 – Transient Response.
85 VAC, 9 V, 0 – 3 A Load Step.
V_{MIN}: 8.94 V, V_{MAX}: 9.27 V.
Upper: V_{OUT}, 0.5 V / div., 1 ms / div.
Lower: I_{LOAD}, 2 A / div.

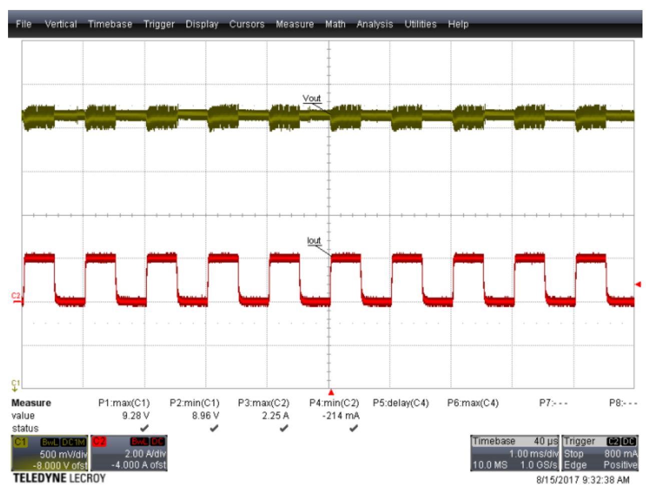


Figure 34 – Transient Response.
265 VAC, 9 V, 0 – 2 A Load Step.
V_{MIN}: 8.96V, V_{MAX}: 9.28 V.
Upper: V_{OUT}, 0.5 V / div., 1 ms / div.
Lower: I_{LOAD}, 2 A / div.

12.2 **Switching Waveforms**

12.2.1 *Drain Voltage and Current*

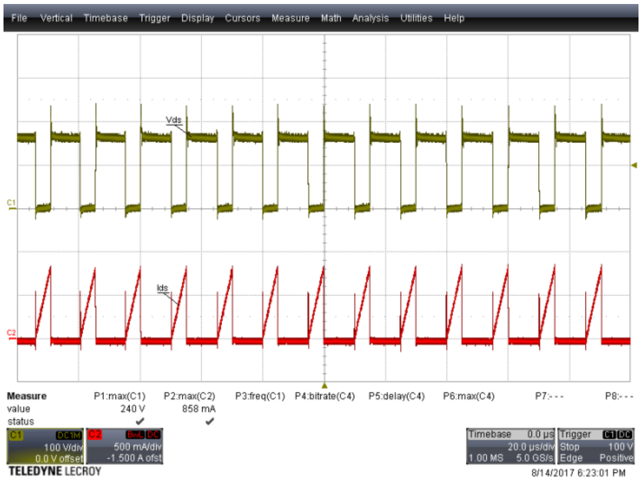


Figure 35 – Drain Voltage and Current Waveforms.
85 VAC, 3.0 V, 5 A Load, (240 V_{MAX}).
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA / div., 20 µs / div.

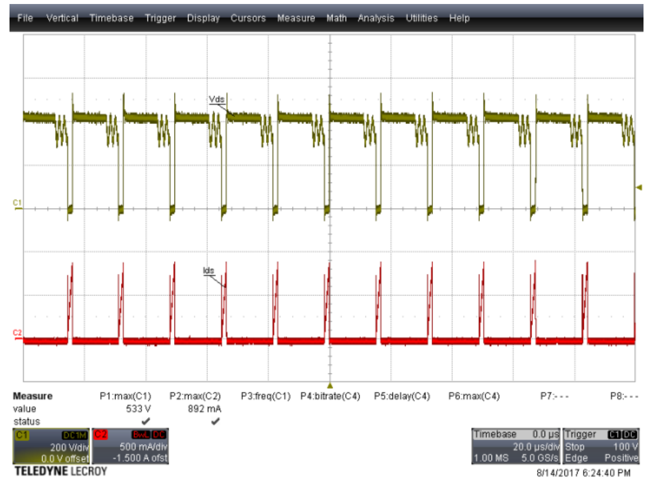


Figure 36 – Drain Voltage and Current Waveforms.
265 VAC, 5 V, 3 A Load, (533 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA / div., 20 µs / div.

Figure 37 – Drain Voltage and Current Waveforms.
85 VAC, 9.0 V, 2 A Load, (262 V_{MAX}).
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA / div., 20 µs / div.

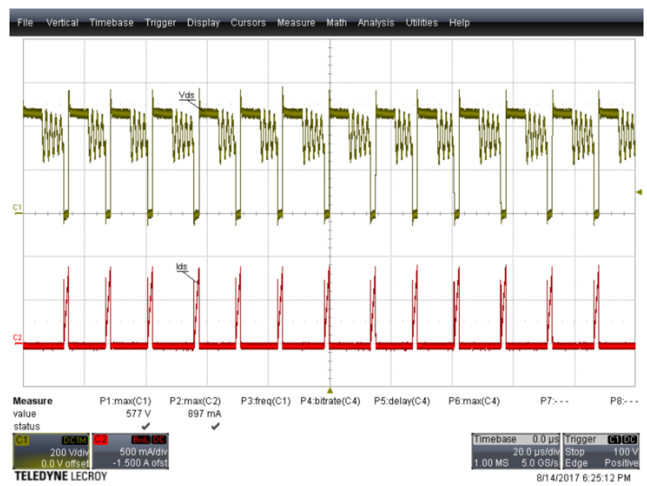


Figure 38 – Drain Voltage and Current Waveforms.
265 VAC, 9.0 V, 2 A Load, (577 V_{MAX}).
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA / div., 20 µs / div.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

12.2.2 *SR FET Voltage*

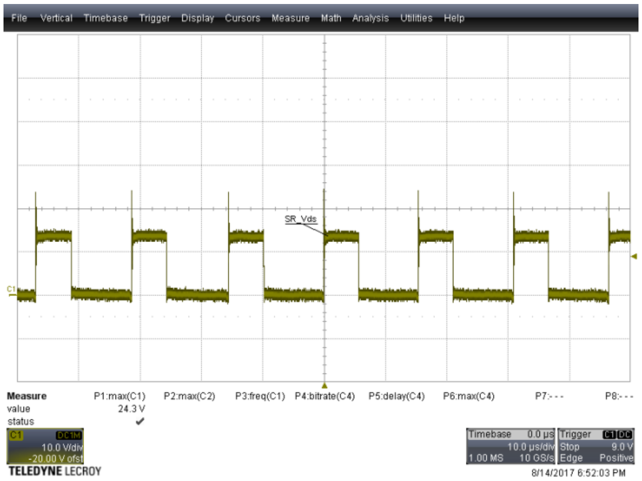


Figure 39 – SR FET Voltage Waveforms.
85 VAC, 9 V, 2 A Load, (24.3 V_{MAX}).
SR_V_{DRAIN}, 10 V / div., 10 µs / div.

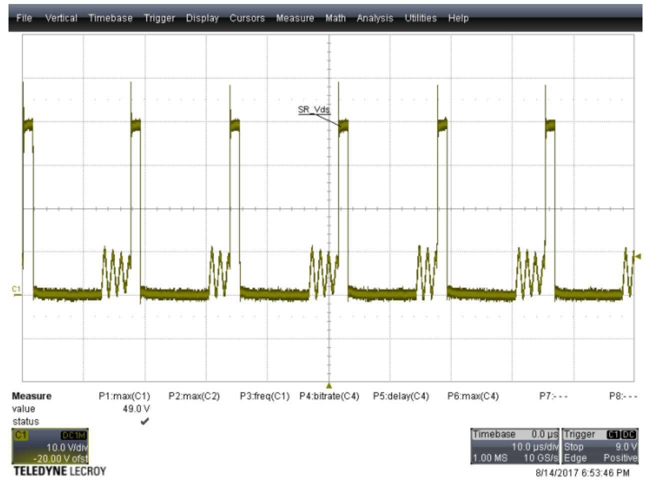


Figure 40 – SR FET Voltage Waveforms.
265 VAC, 9 V, 2 A Load, (49.0 V_{MAX}).
SR_V_{DRAIN}, 10 V / div., 10 µs / div.

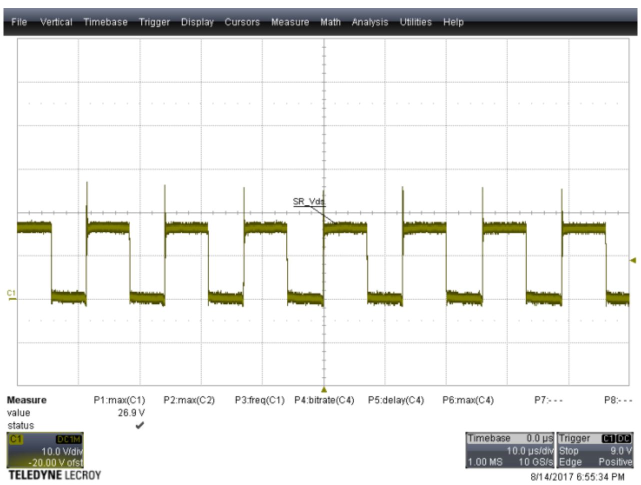


Figure 41 – SR FET Voltage Waveforms.
85 VAC, 9 V, 2 A Load, (26.9 V_{MAX}).
SR_V_{DRAIN}, 10 V / div., 10 µs / div.

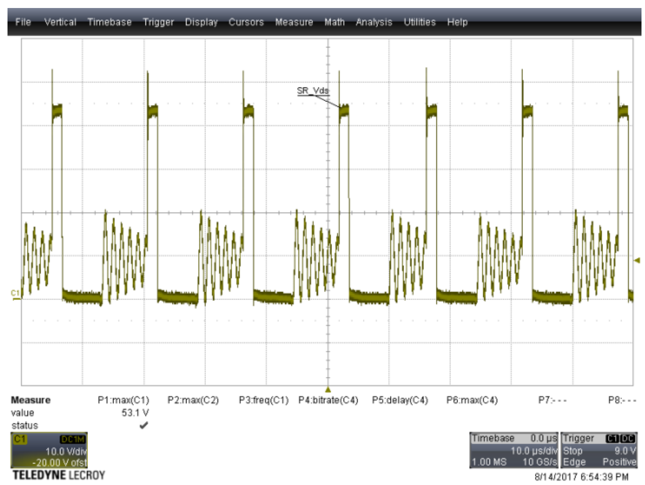


Figure 42 – SR FET Voltage Waveforms.
265 VAC, 9 V, 2 A Load, (53.1 V_{MAX}).
SR_V_{DRAIN}, 10 V / div., 10 µs / div.

12.2.3 *Output Voltage and Current Start-up (On the Board)*

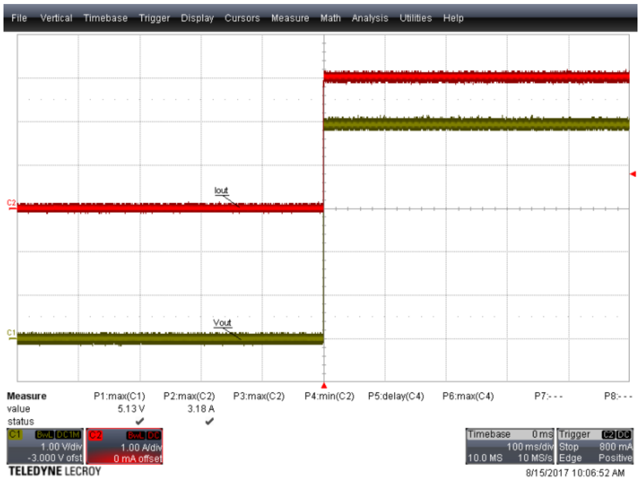


Figure 43 – Output Voltage and Current Waveforms.
85 VAC, 5 V, 3 A Load,
Upper: I_{OUT}, 1 A / div., 100 ms / div.
Lower: V_{OUT}, 1 V / div.

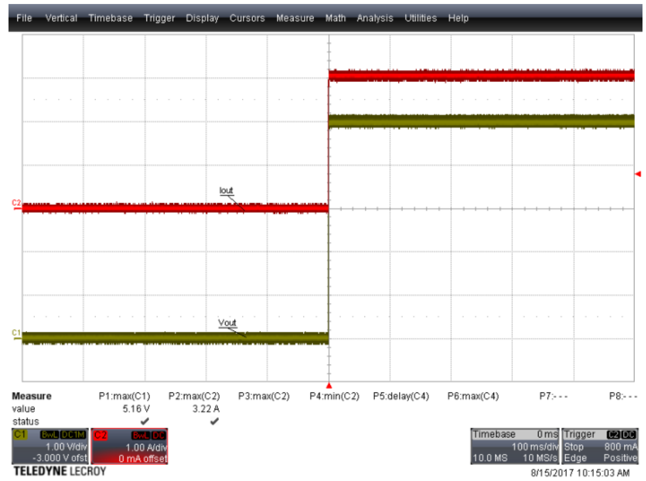


Figure 44 – Output Voltage and Current Waveforms.
265 VAC, 5 V, 3 A Load,
Upper: I_{OUT}, 1 A / div., 100 ms / div.
Lower: V_{OUT}, 1 V / div.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

12.3 ***Output Ripple Measurements***

12.3.1 *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).

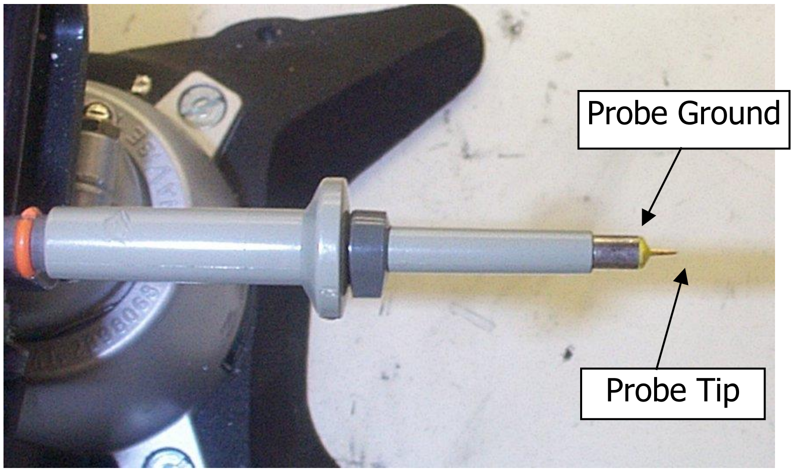


Figure 45 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

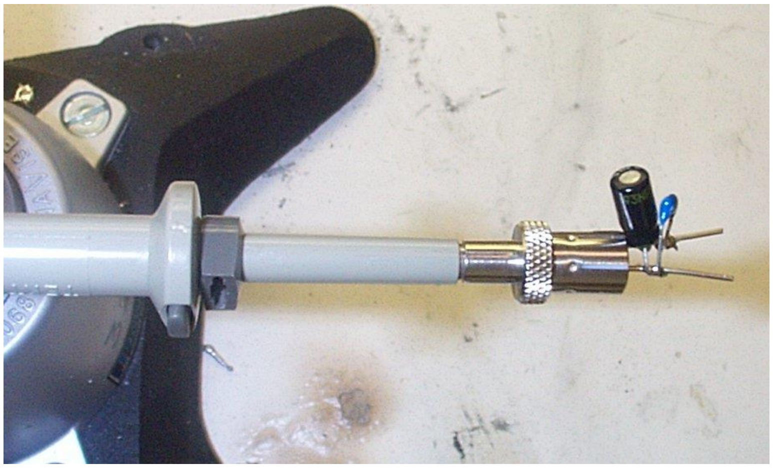


Figure 46 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

12.3.2 *Ripple Amplitude vs. Line*

12.3.2.1 5 V Ripple waveforms (Full Load)

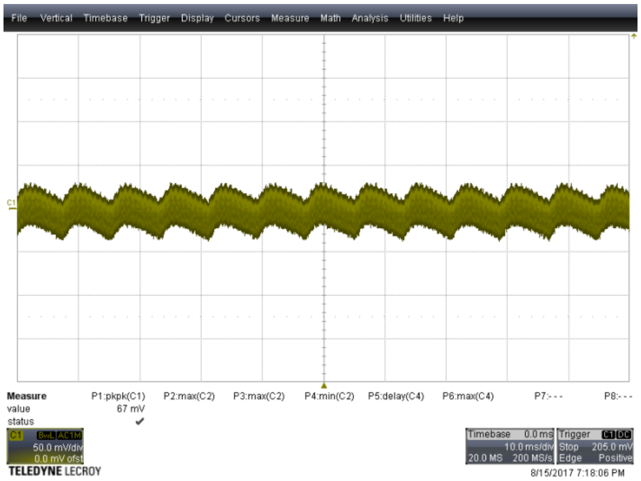


Figure 47 – Output Ripple (PK-PK – 67 mV).
85 VAC Input 5.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

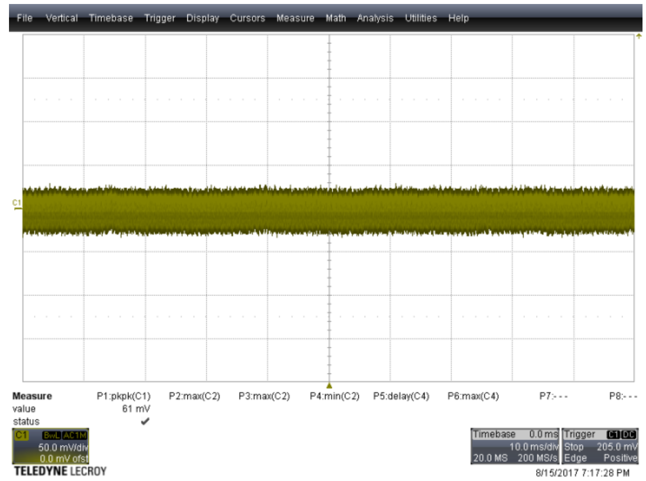


Figure 48 – Output Ripple (PK-PK – 61 mV).
265 VAC Input 5.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

12.3.2.2 5 V Ripple waveforms (No-Load)

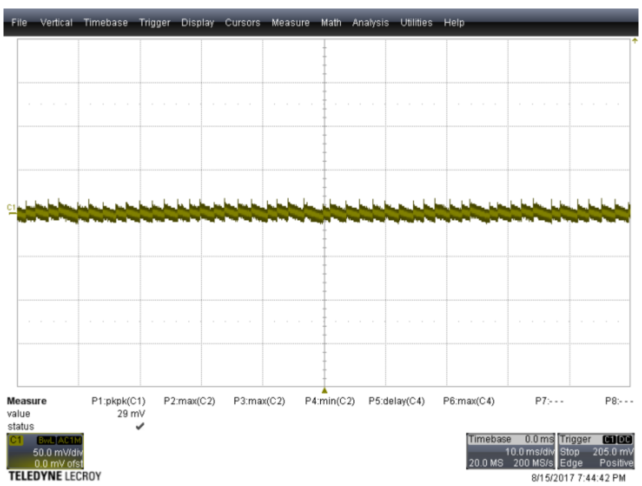


Figure 49 – Output Ripple (PK-PK – 29 mV).
85 VAC Input, 5.0 V, 0 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

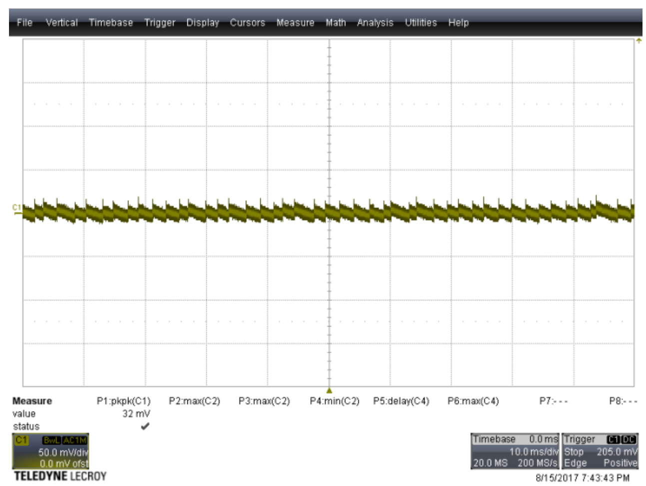


Figure 50 – Output Ripple (PK-PK – 32 mV).
265 VAC Input 5.0 V, 0 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

12.3.2.3 9 V Ripple waveforms (Full Load)

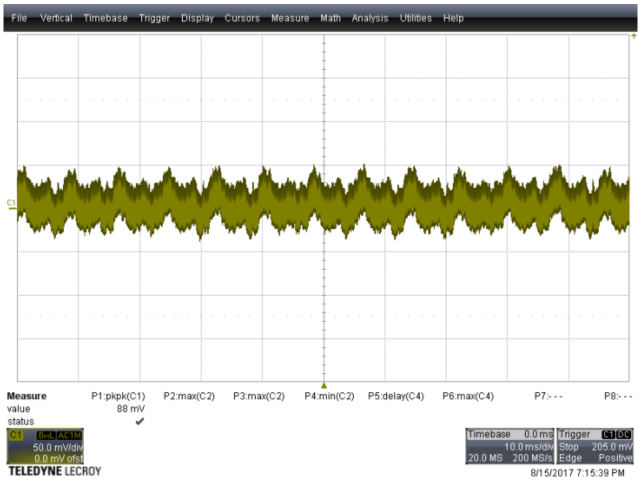


Figure 51 – Output Ripple (PK-PK – 88 mV).
85 VAC Input 9.0 V, 2 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

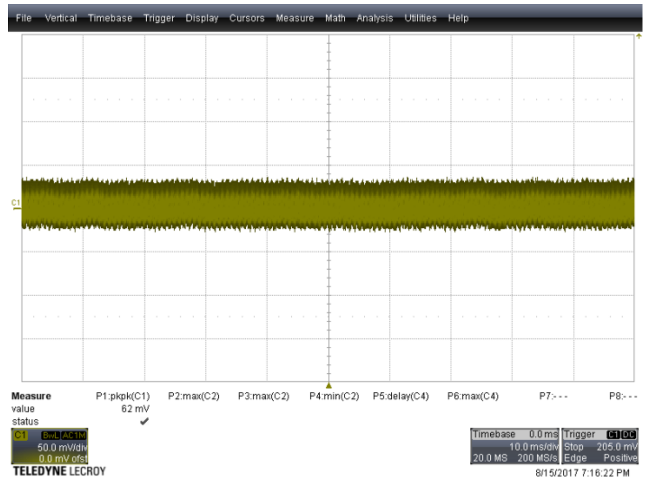


Figure 52 – Output Ripple (PK-PK – 62 mV).
265 VAC Input 9.0 V, 2 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

12.3.2.4 9 V Ripple waveforms (No-Load)

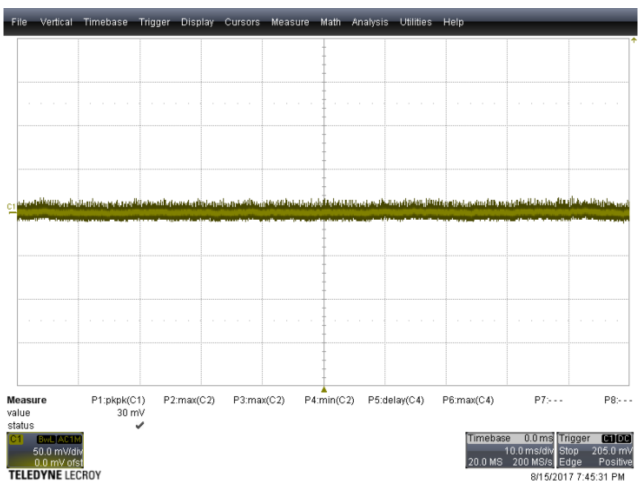


Figure 53 – Output Ripple (PK-PK – 30 mV).
85 VAC Input, 9.0 V, 0 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

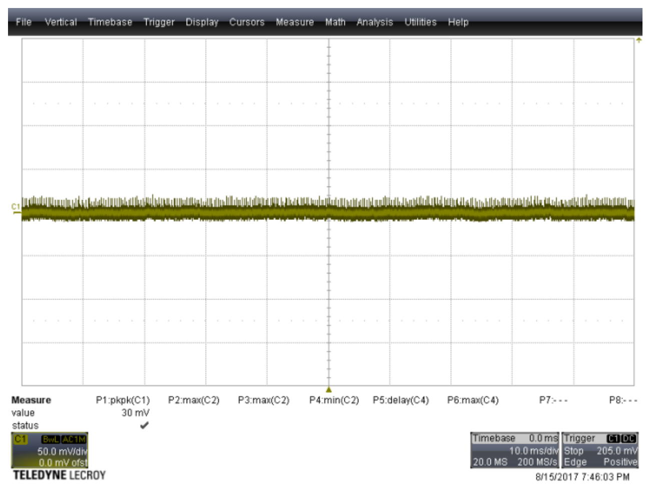


Figure 54 – Output Ripple (PK-PK – 30 mV).
265 VAC Input 9.0 V, 0 A Load.
V_{OUT}, 50 mV / div., 10 ms / div.

13 Conducted EMI

13.1 Floating Output

13.1.1 *Output: 5 V / 3 A*

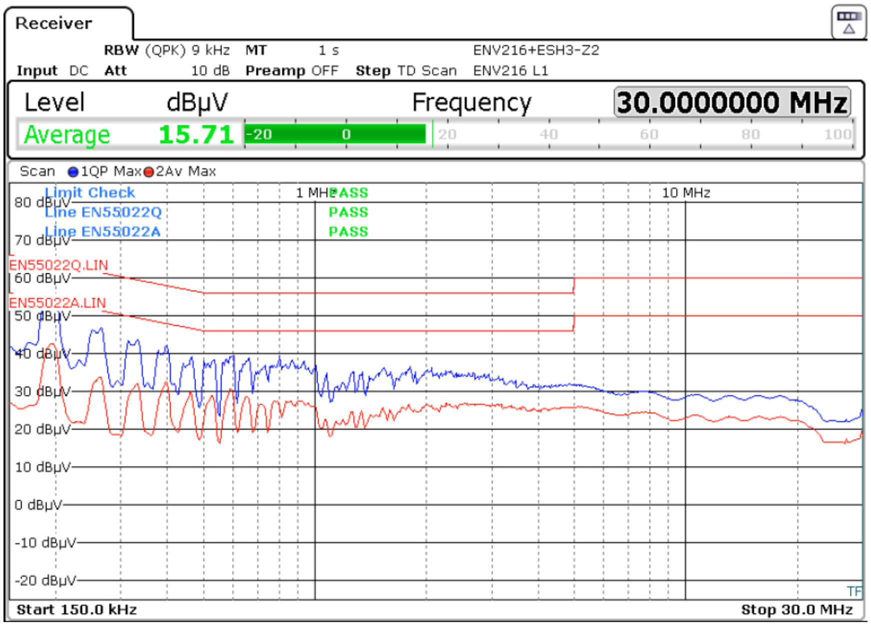


Figure 55 – Floating Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

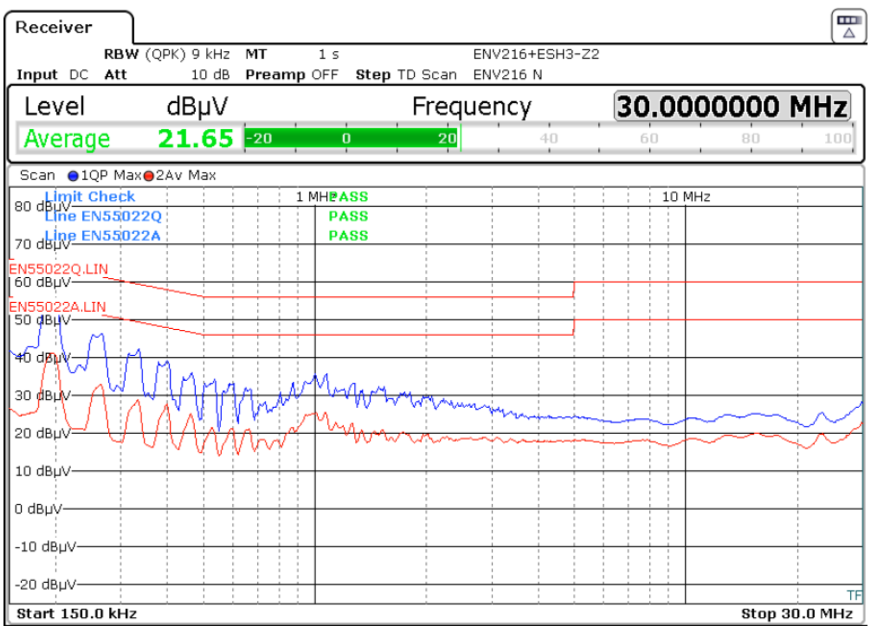


Figure 56 – Floating Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

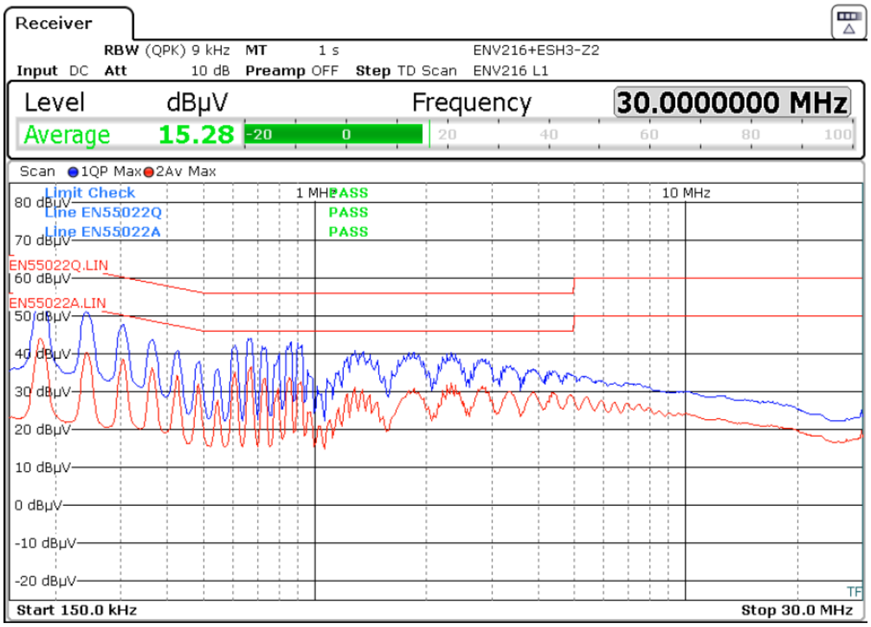


Figure 57 – Floating Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

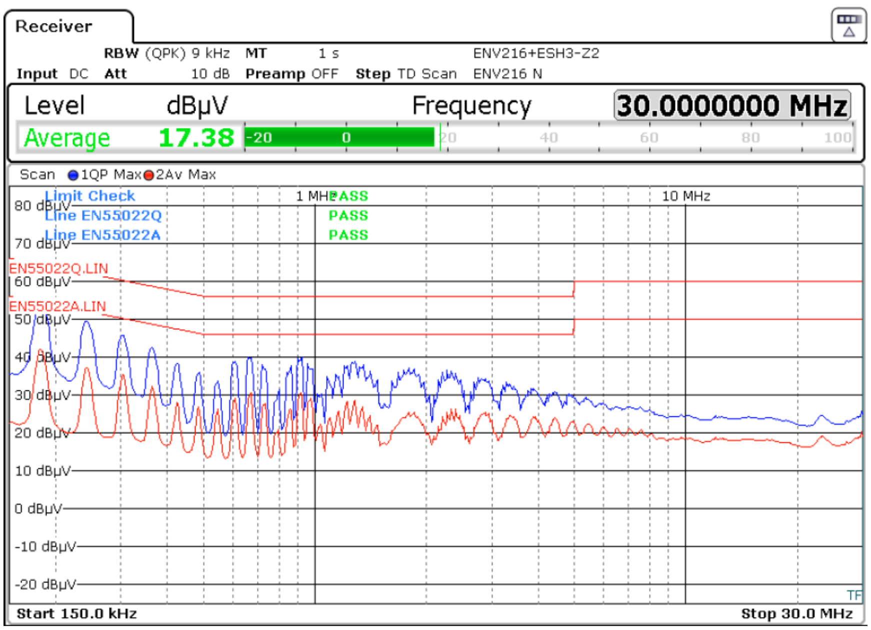


Figure 58 – Floating Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

13.1.2 *Output: 9 V / 2 A*

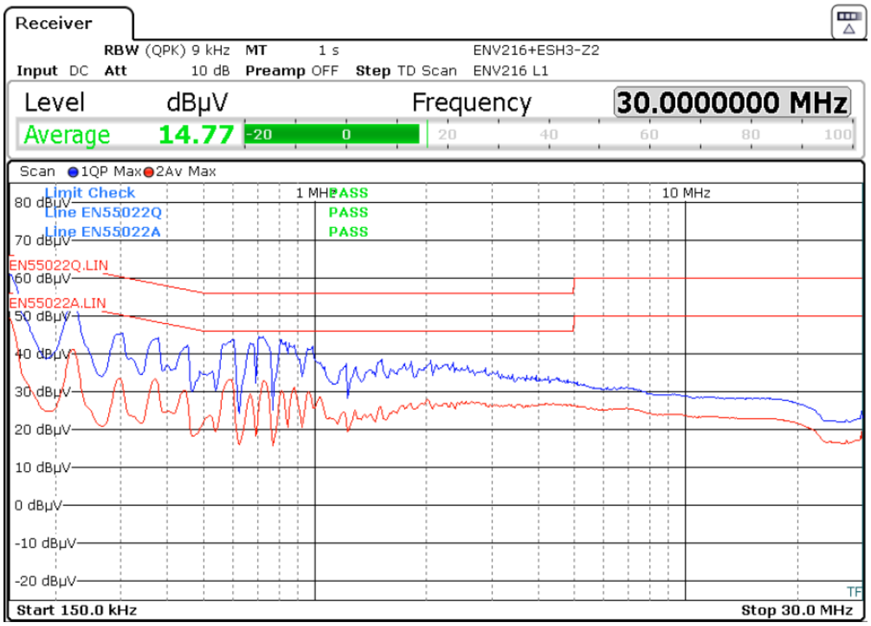


Figure 59 – Floating Ground EMI, 9 V / 2 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

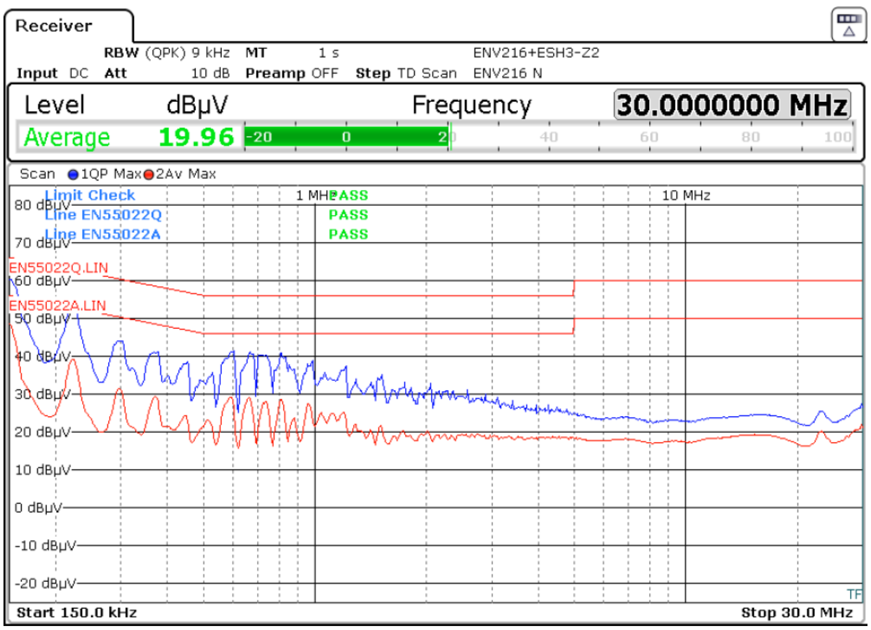


Figure 60 – Floating Ground EMI, 9 V / 2 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

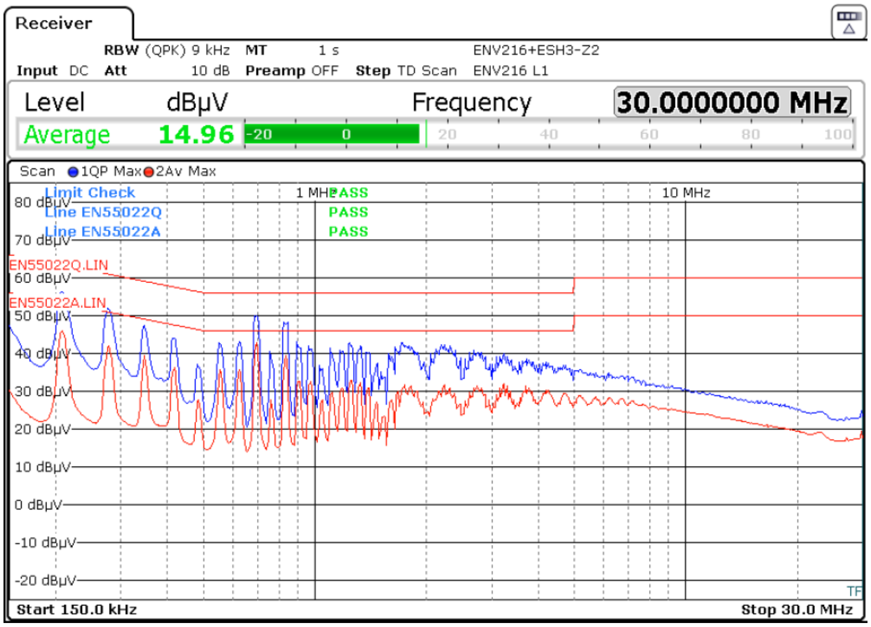


Figure 61 – Floating Ground EMI, 9 V / 2 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

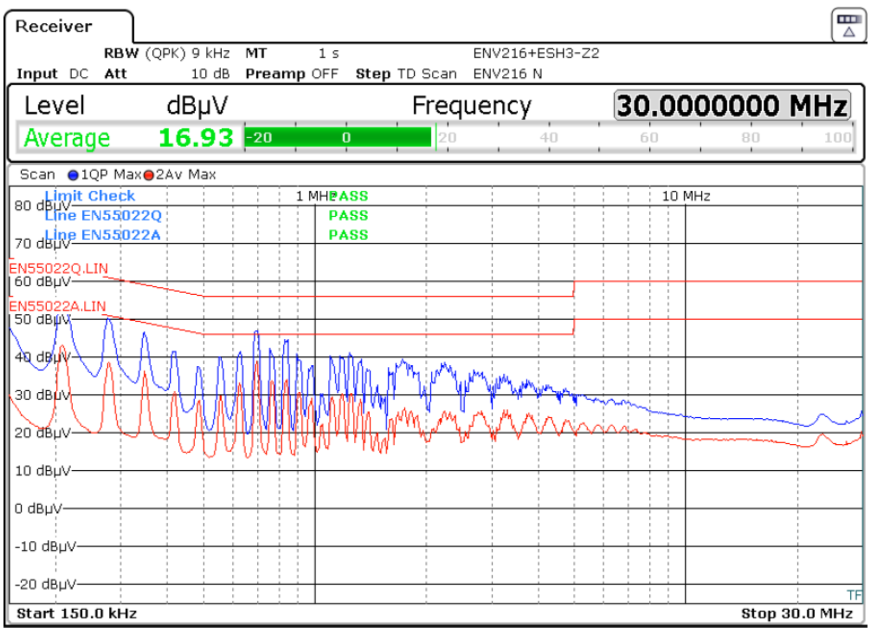


Figure 62 – Floating Ground EMI, 9 V / 2 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

13.2 ***Artificial Hand***

13.2.1 *Output: 5 V / 3 A*

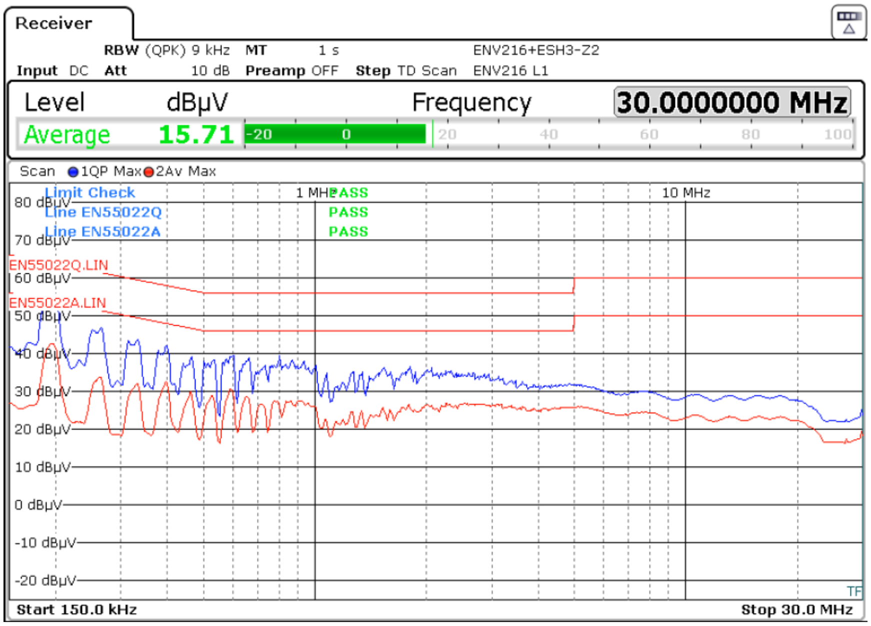


Figure 63 – Artificial Hand EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

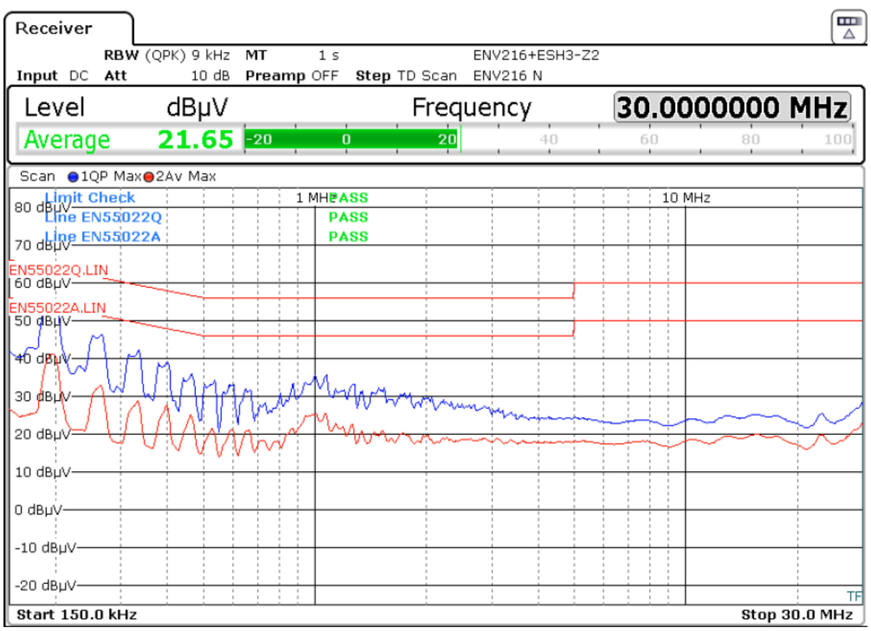


Figure 64 – Artificial Hand EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

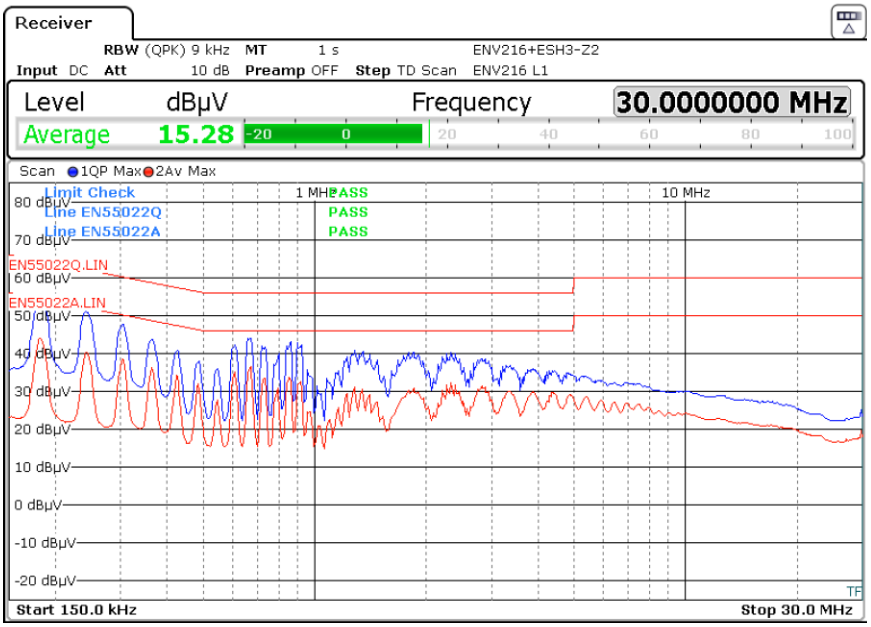


Figure 65 – Artificial Hand EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

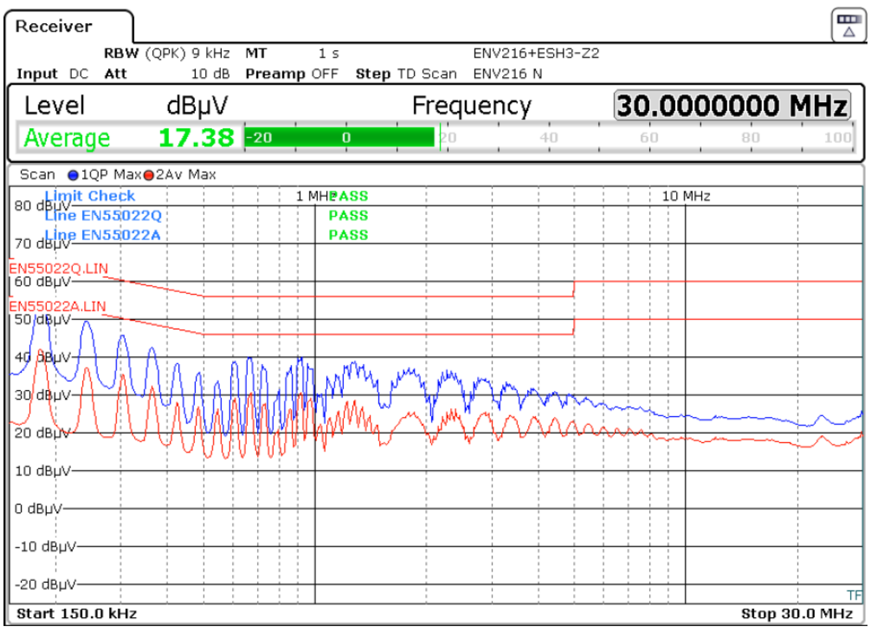


Figure 66 – Artificial Hand EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

13.2.2 *Output: 9 V / 2 A*

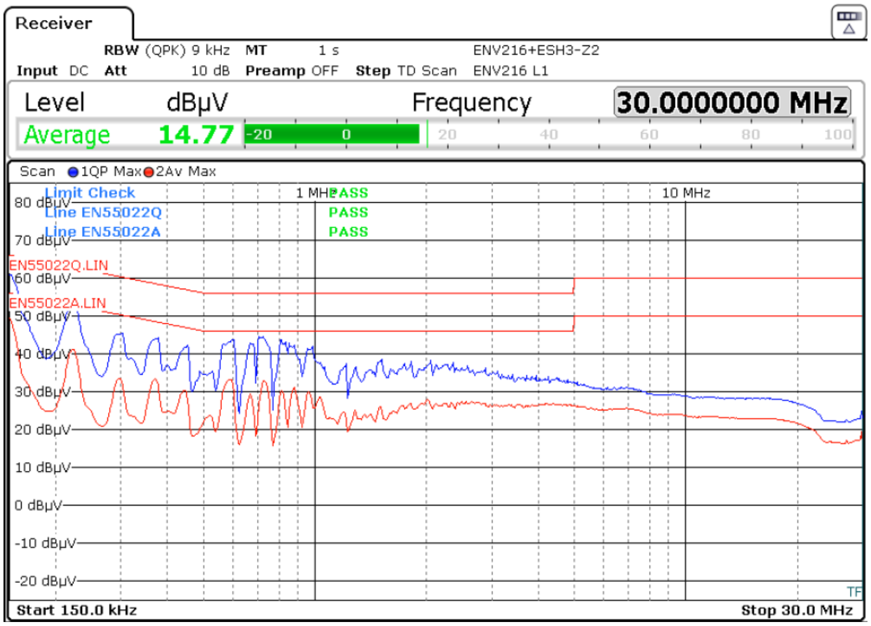


Figure 67 – Artificial Hand EMI, 9 V / 2 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

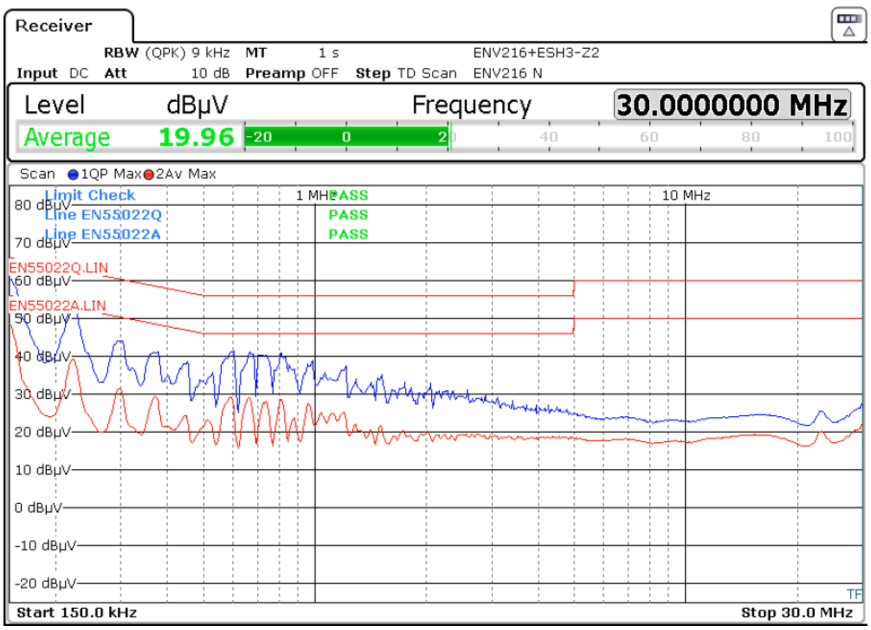


Figure 68 – Artificial Hand EMI, 9 V / 2 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

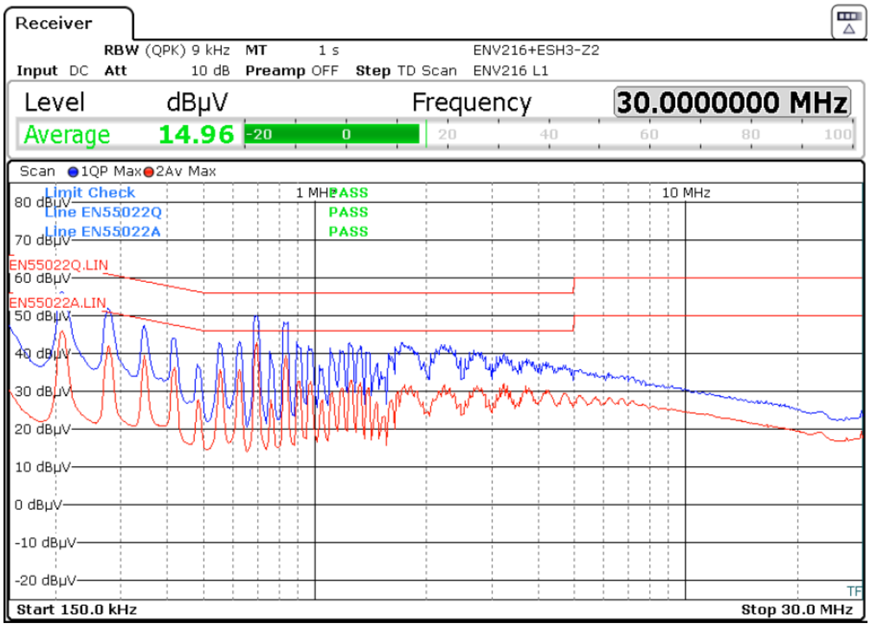


Figure 69 – Artificial Hand EMI, 9 V / 2 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

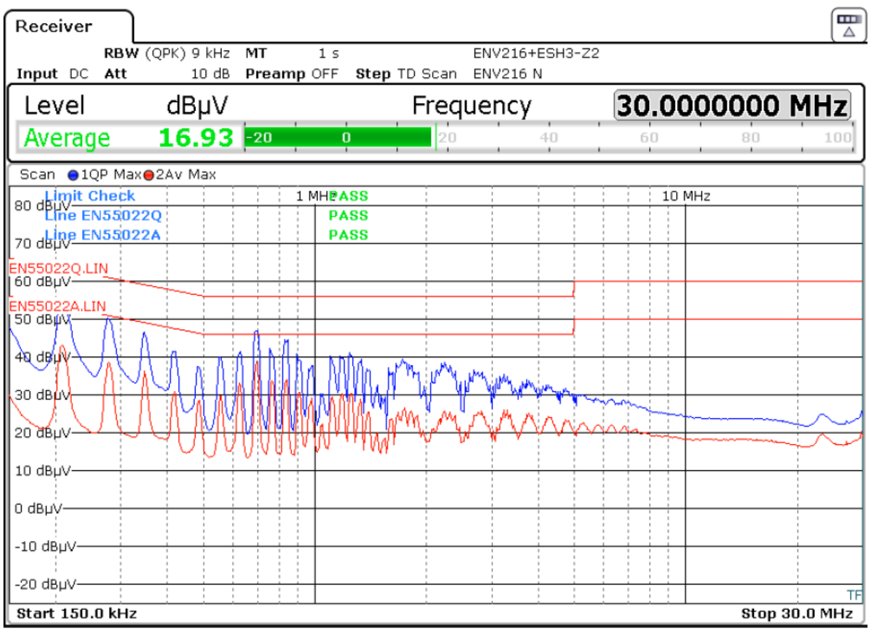


Figure 70 – Artificial Hand EMI, 9 V / 2 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

13.3 ***Earth Ground***

13.3.1 *Output: 5 V / 3 A*

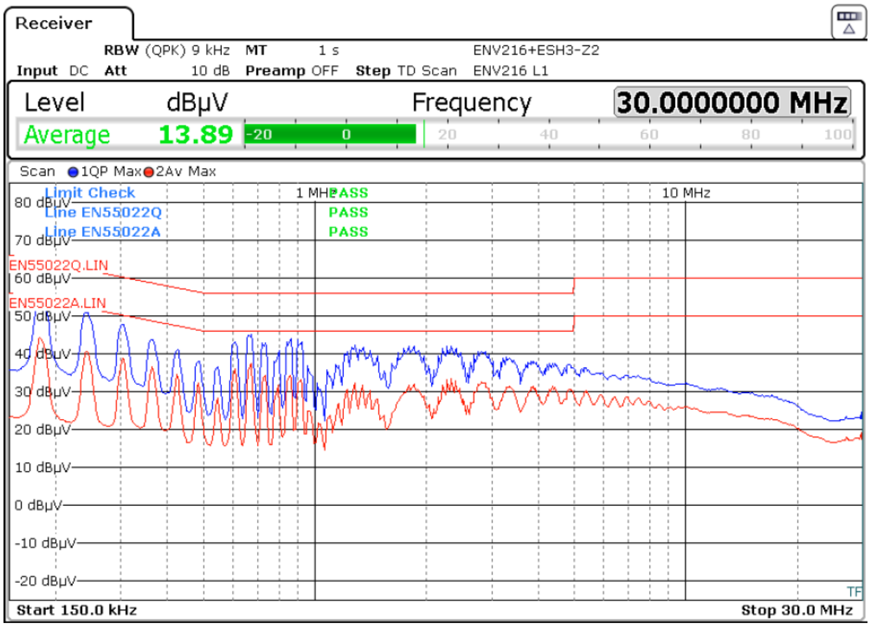


Figure 71 – Earth Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

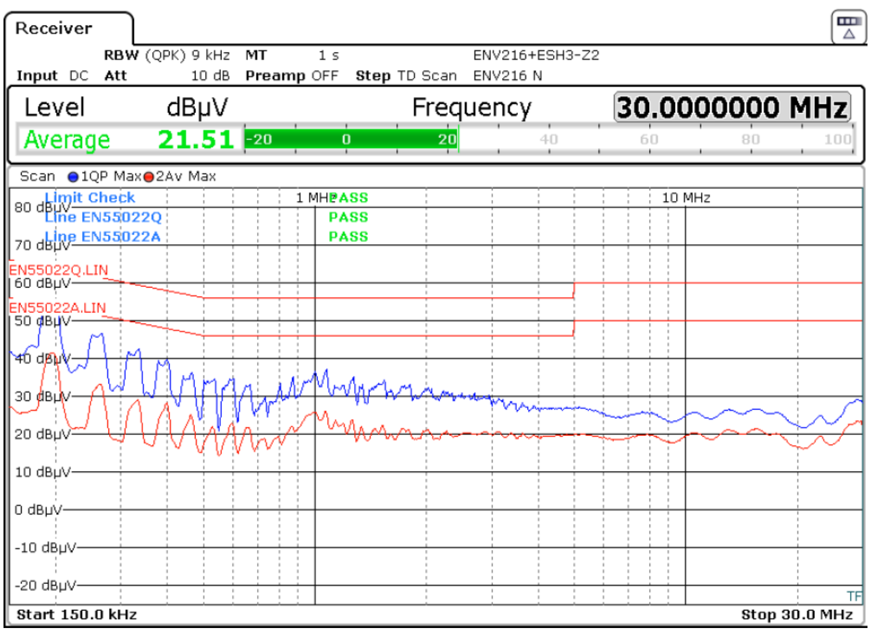


Figure 72 – Earth Ground EMI, 5 V / 3 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

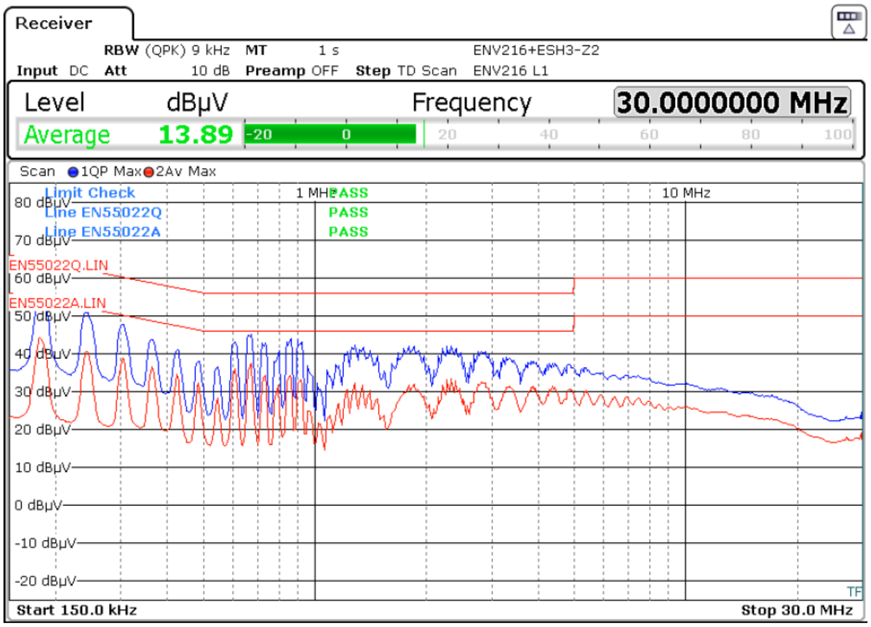


Figure 73 – Earth Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

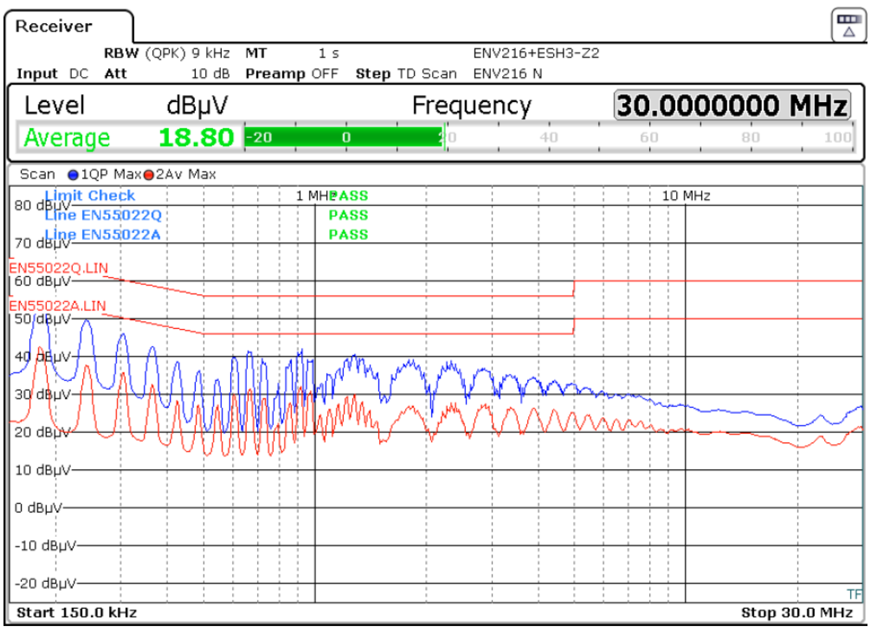


Figure 74 – Earth Ground EMI, 5 V / 3 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

13.3.2 *Output: 9 V / 2 A*

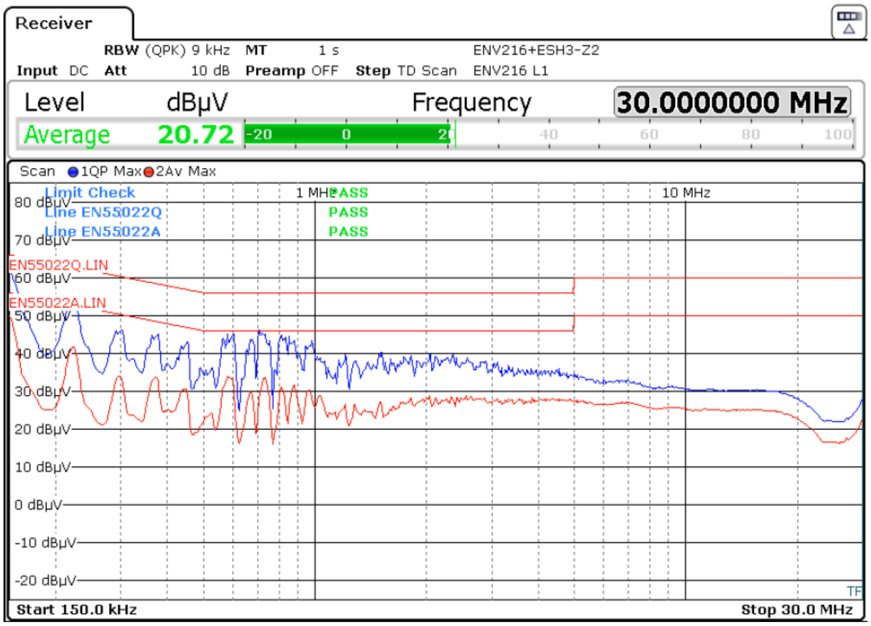


Figure 75 – Earth Ground EMI, 9 V / 2 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Line).

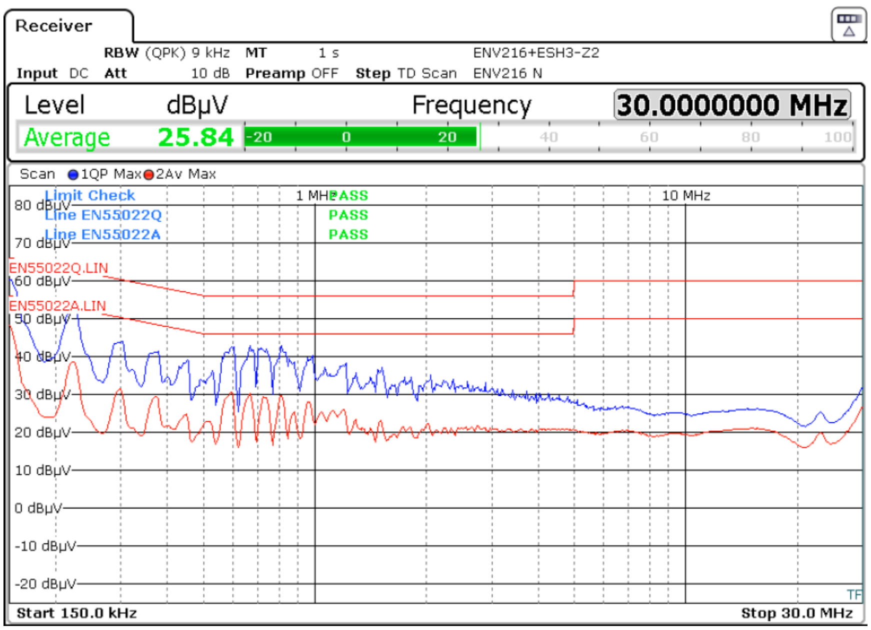


Figure 76 – Earth Ground EMI, 9 V / 2 A Load 115 VAC, 60 Hz, and EN55022 B Limits (Neutral).

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

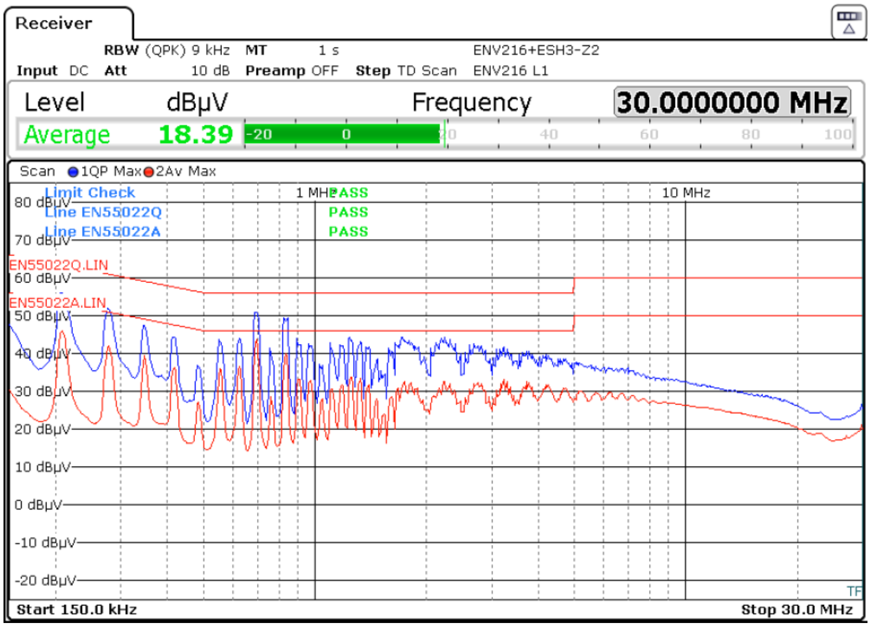


Figure 77 – Earth Ground EMI, 9 V / 2 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Line).

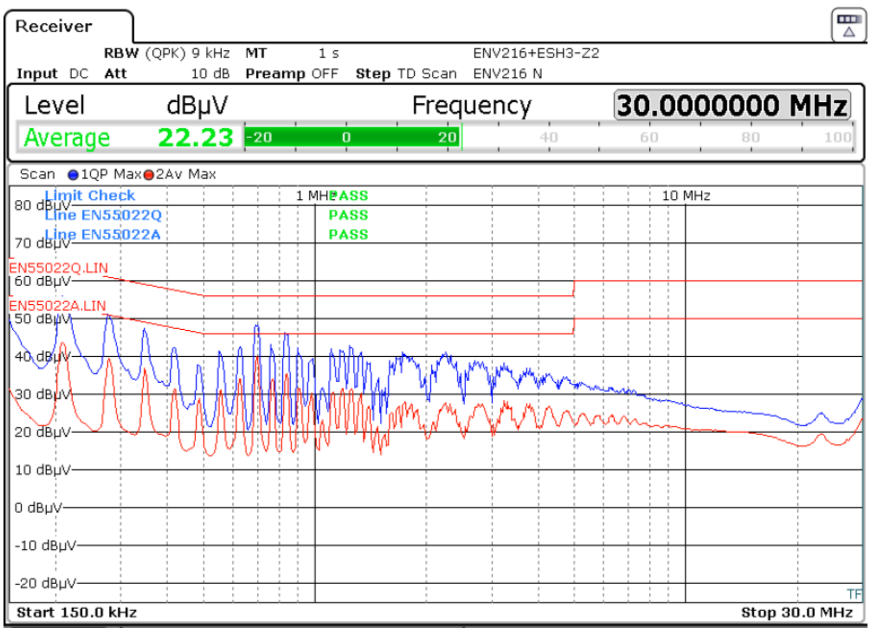


Figure 78 – Earth Ground EMI, 9 V / 2 A Load 230 VAC, 60 Hz, and EN55022 B Limits (Neutral).

14 Revision History

Date	Author	Revision	Description & Changes	Reviewed
24-Sep-18	CS	1.0	Initial Release	Apps & Mktg

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

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

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95138, USA.
Main: +1-408-414-9200
Customer Service:
Worldwide: +1-65-635-64480
Americas: +1-408-414-9621
e-mail: usasales@power.com

China (Shanghai)
Rm 2410, Charity Plaza, No. 88,
North Caoxi Road,
Shanghai, PRC 200030
Phone: +86-21-6354-6323
e-mail: chinasales@power.com

CHINA (SHENZHEN)
17/F, Hivac Building, No. 2, Keji
Nan 8th Road, Nanshan District,
Shenzhen, China, 518057
Phone: +86-755-8672-8689
e-mail: chinasales@power.com

GERMANY (AC-DC/LED Sales)
Lindwurmstrasse 114
D-80337 München
Germany
Phone: +49-89-5527-39100
e-mail: eurosales@power.com

GERMANY (Gate Driver Sales)
HellwegForum 1
59469 Ense
Germany
Tel: +49-2938-64-39990
e-mail: igbt-driver.sales@
power.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
e-mail: indiasales@power.com

ITALY
Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni (MI) Italy
Phone: +39-024-550-8701
e-mail: eurosales@power.com

JAPAN
Yusen Shin-Yokohama 1-chome Bldg.
1-7-9, Shin-Yokohama, Kohoku-ku
Yokohama-shi,
Kanagawa 222-0033 Japan
Phone: +81-45-471-1021
e-mail: japansales@power.com

KOREA
RM 602, 6FL
Korea City Air Terminal B/D,
159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728 Korea
Phone: +82-2-2016-6610
e-mail: koreasales@power.com

SINGAPORE
51 Newton Road,
#19-01/05 Goldhill Plaza
Singapore, 308900
Phone: +65-6358-2160
e-mail:
singaporesales@power.com

TAIWAN
5F, No. 318, Nei Hu Rd.,
Sec. 1
Nei Hu District
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
e-mail: taiwansales@power.com

UK
Building 5, Suite 21
The Westbrook Centre
Milton Road
Cambridge
CB4 1YG
Phone: +44 (0) 7823-557484
e-mail: eurosales@power.com