Design Example Report

Title	*70 W Universal Input Non-PFC Flyback Charger Supply Using TOPSwitch™-JX TOP266EG*
Specification	90 VAC – 264 VAC Input; 23 V / 3.04 A Main Output (CV/CC)
Application	Battery Charger
Author	Applications Engineering Department
Document Number	DER-566
Date	August 10, 2016
Revision	1.1

Summary and Features

- High power flyback design with very low component count
- 90-264 VAC universal input (no PFC)
- 132 kHz operation for small magnetics size (PQ26/25)
- High full load efficiency (85% / 115 V, 87% / 230 V)
- Wide output range 10 V – 23 V

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5245 Hellyer Avenue, San Jose, CA 95138 USA.
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Important Notes:
Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. 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 23 V (nominal), 70 W flyback reference design for a power supply operating from 90 VAC to 264 VAC. The power supply output is designed with a constant voltage / constant current characteristic for use in battery charger applications.

The design is based on the TOP266EG operating from universal input, with no PFC input stage. It can run at maximum power without fan at 90 VAC, room temperature.

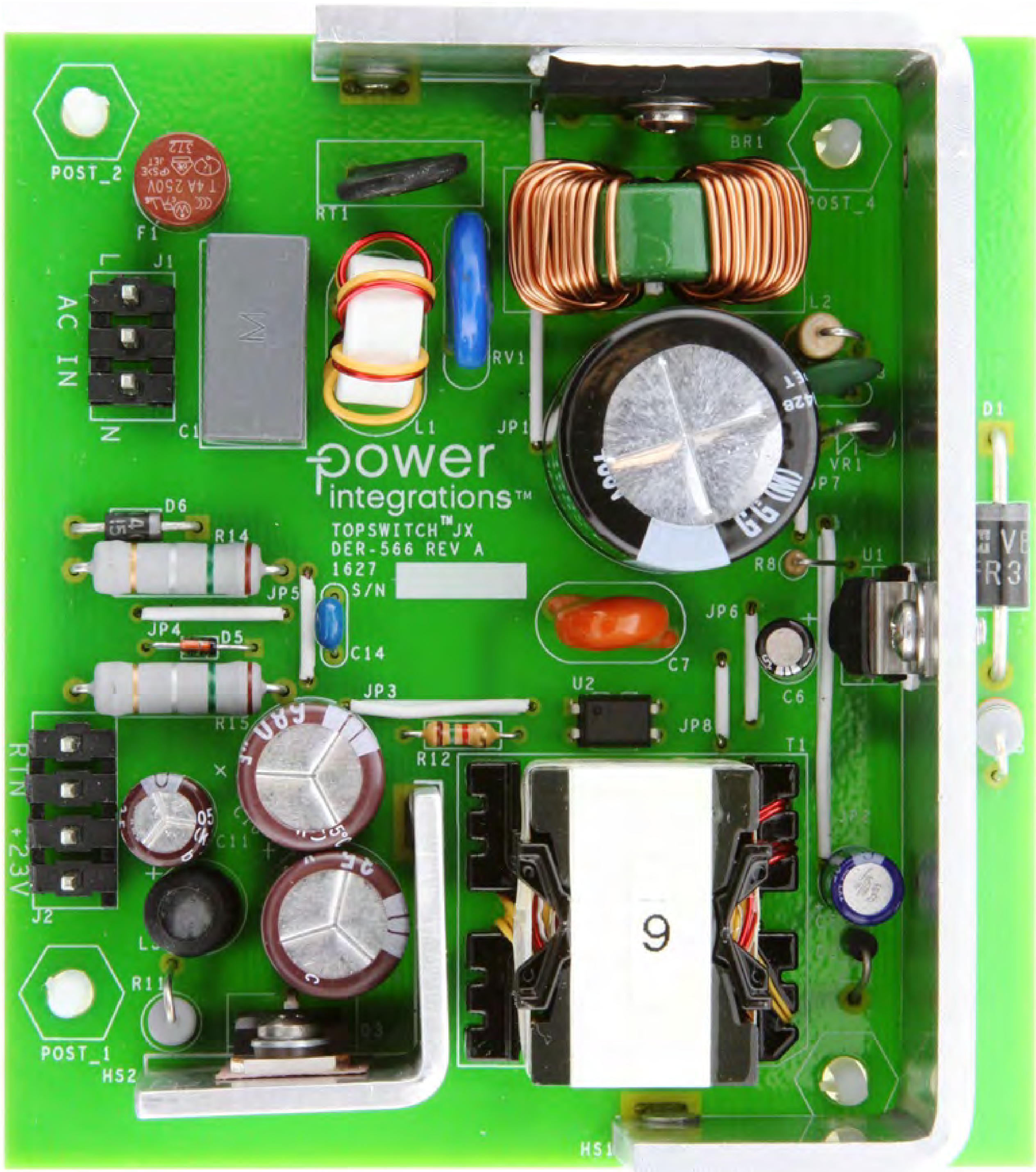

Figure 1 – DER-566 Photograph, Top View.

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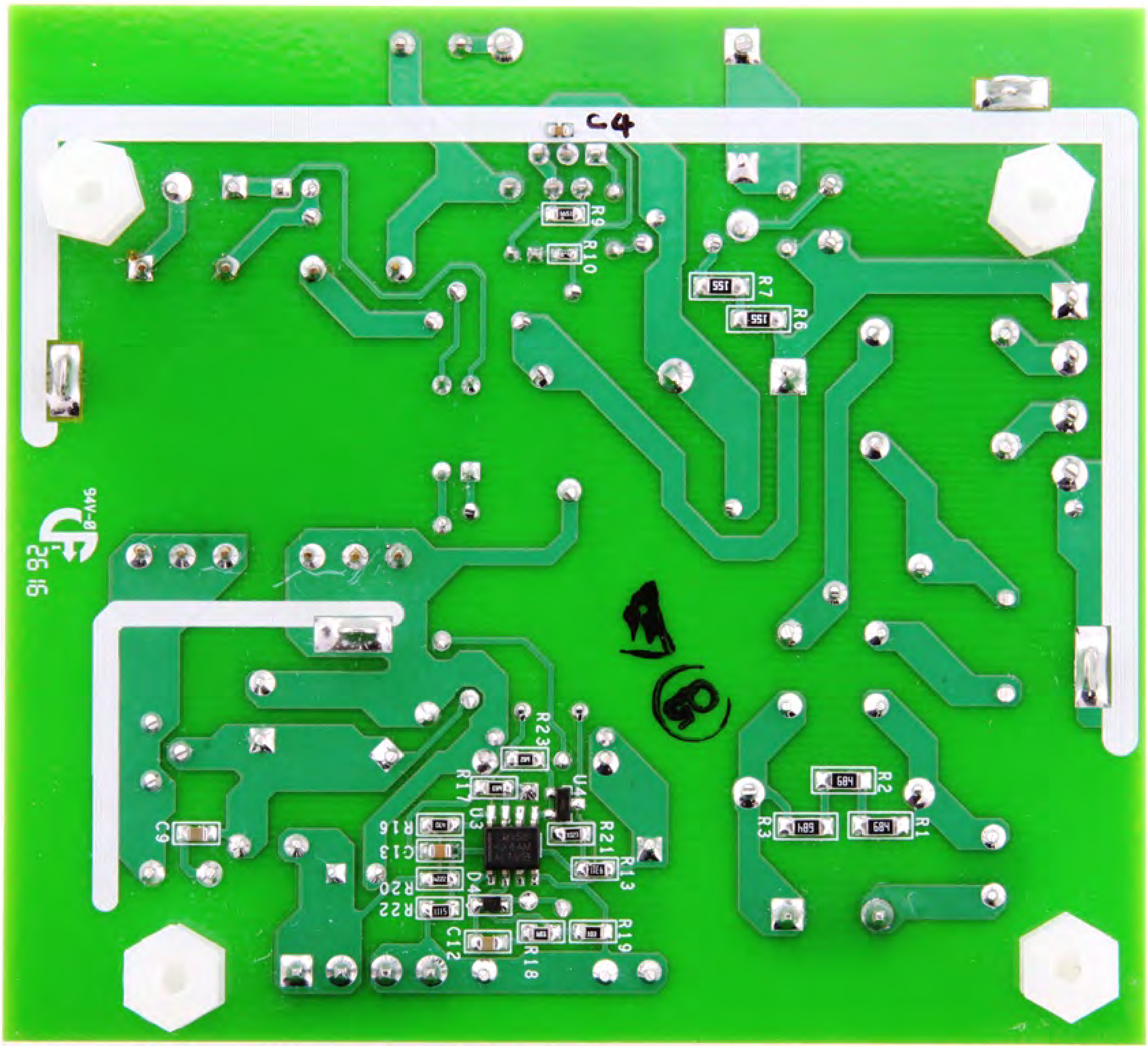

Figure 2 – DER-566 Photograph, Bottom View.

2 Power Supply Specification

The table below represents the specification for the design detailed in this report. Actual performance is listed in the results section.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		264	VAC	2 Wire Input.
Frequency	f_{LINE}	47	50/60	64	Hz	
Main Converter Output						
Output Voltage	V_{OUT}	10		23	V	23 VDC (nominal – otherwise defined by battery load).
Output Current	I_{OUT}		3.04		A	Nominal Current Limit Setting for Design.
Total Output Power						
Continuous Output Power	P_{OUT}		70		W	
Peak Output Power	$P_{OUT(PK)}$			N/A	W	
Efficiency						
Total system at Full Load	η_{Main}		85/87		%	Measured at 115/230 VAC, Full Load.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950 / UL1950 Class II				
Ambient Temperature	T_{AMB}	0	25		°C	See Thermal Section for Conditions.

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3 Schematic

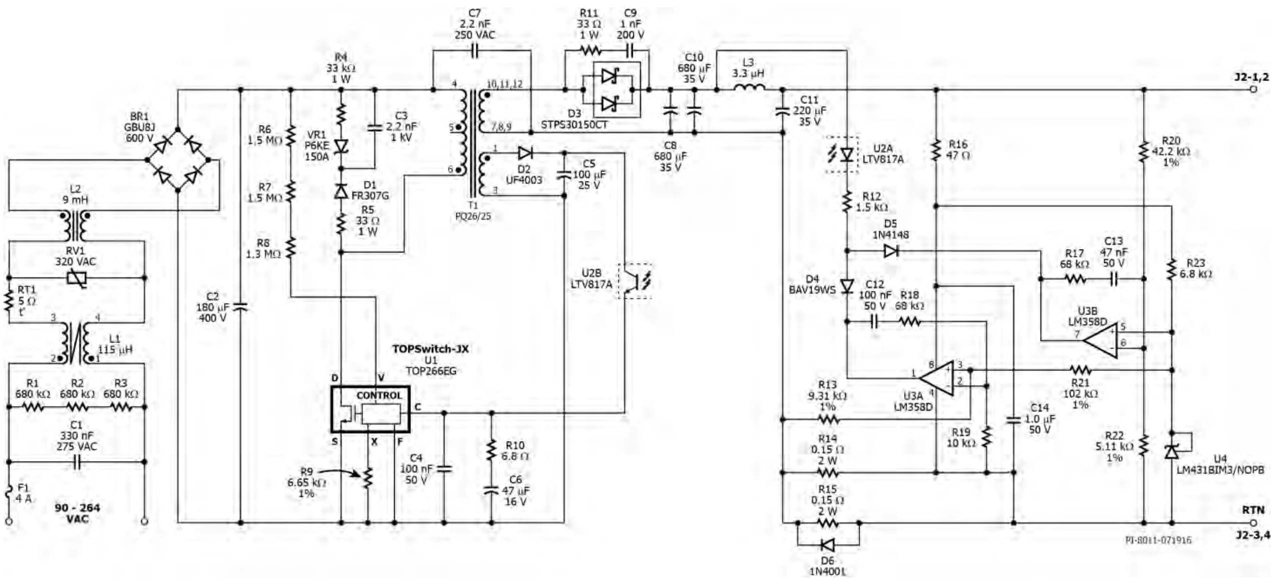

Figure 3 – Schematic - Flyback Battery Charger Application Circuit - Input Filter, DC/DC Stage, Output Voltage/Current Control.

4 Circuit Description

4.1 General Topology

The schematic in Figure 3 shows a 23 V, 70 W universal input flyback power supply utilizing the TOP266EG. The secondary control circuitry provides CV/CC control for use in battery charger applications

4.2 EMI Filtering / Rectification

Capacitor C1 is used to control differential mode noise. Resistors R1-3 discharge C1 when AC power is removed. Inductors L1 and L2 primarily control common mode EMI, and to some extent, differential mode EMI. The heat sink for U1 is connected to primary return to eliminate the heat sink as a source of radiated/capacitive coupled noise. Thermistor RT1 provides inrush limiting. Capacitor C7 filters common mode EMI. Capacitor C2 and BR1 provide a ~126-370 VDC B+ supply from the 90 VAC to 264 VAC input.

4.3 Main Flyback Converter

The schematic in Figure 3 depicts a 23 V, 70 W flyback DC-DC converter with constant voltage/ constant current output implemented using the TOP266EG. For greater detail on TOPSwitch-JX operation, consult the data sheet at www.power.com .

Integrated circuit U1 incorporates the control circuitry, drivers and output MOSFETs necessary for a flyback converter.

Components D1, C3, R4-5, and VR1 form a turn-off clamping circuit that limits the peak drain voltage of U1. Zener VR1 provides a defined clamp voltage and maintains a maximum voltage (150 V) on clamp capacitor C3 for higher light/no-load efficiency.

Resistors R6-8 set the start-up voltage for U1 at 100.5 VDC. Resistor R9 scales the U1 current limit to 100% of rated value. The F pin of U1 is grounded to the source to set the nominal operating frequency to 132 kHz.

Primary bias is provided from a winding on T1 rectified and filtered by D2 and C5.

Components C4, C6, and R10 act as bypass, start-up energy storage, and compensation for U1.

4.4 Output Rectification

The output of transformer T1 is rectified and filtered by D3 and C8, C10, L3, and C11. Output rectifier D3 is a 150 V Schottky rectifier chosen for high efficiency. A snubber consisting of R11 and C9 helps limit the peak voltage excursion on the output rectifier.

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4.5 Output Current and Voltage Control

Output current is sensed via resistors R14-15. These resistors are clamped by diode D6 to avoid damage to the current control circuitry during an output short-circuit. Components R23 and U4 provide a voltage reference for current sense and voltage sense amplifiers U3A and U3B. The reference voltage for current sense amplifier U3A is divided down by R13 and R21. The default current limit setting is 3.04 A, as programmed by R14-15, R13, and R21. The inverting input of U3A is referenced to ground via R19. Opamp U3A drives optocoupler U2 through D4 and R12. Components R12, R18-19, and C12 are used for frequency compensation of the current loop.

Opamp U3B is used for output constant voltage control when the current limit is not engaged. Resistors R20 and R22 sense the output voltage. A reference voltage is applied to the non-inverting input of U3B from U4. Opamp U3B drives optocoupler U2 via D5 and R12. Components R12, R17 and C13 affect the frequency compensation of the voltage control loop.

5 PCB Layout

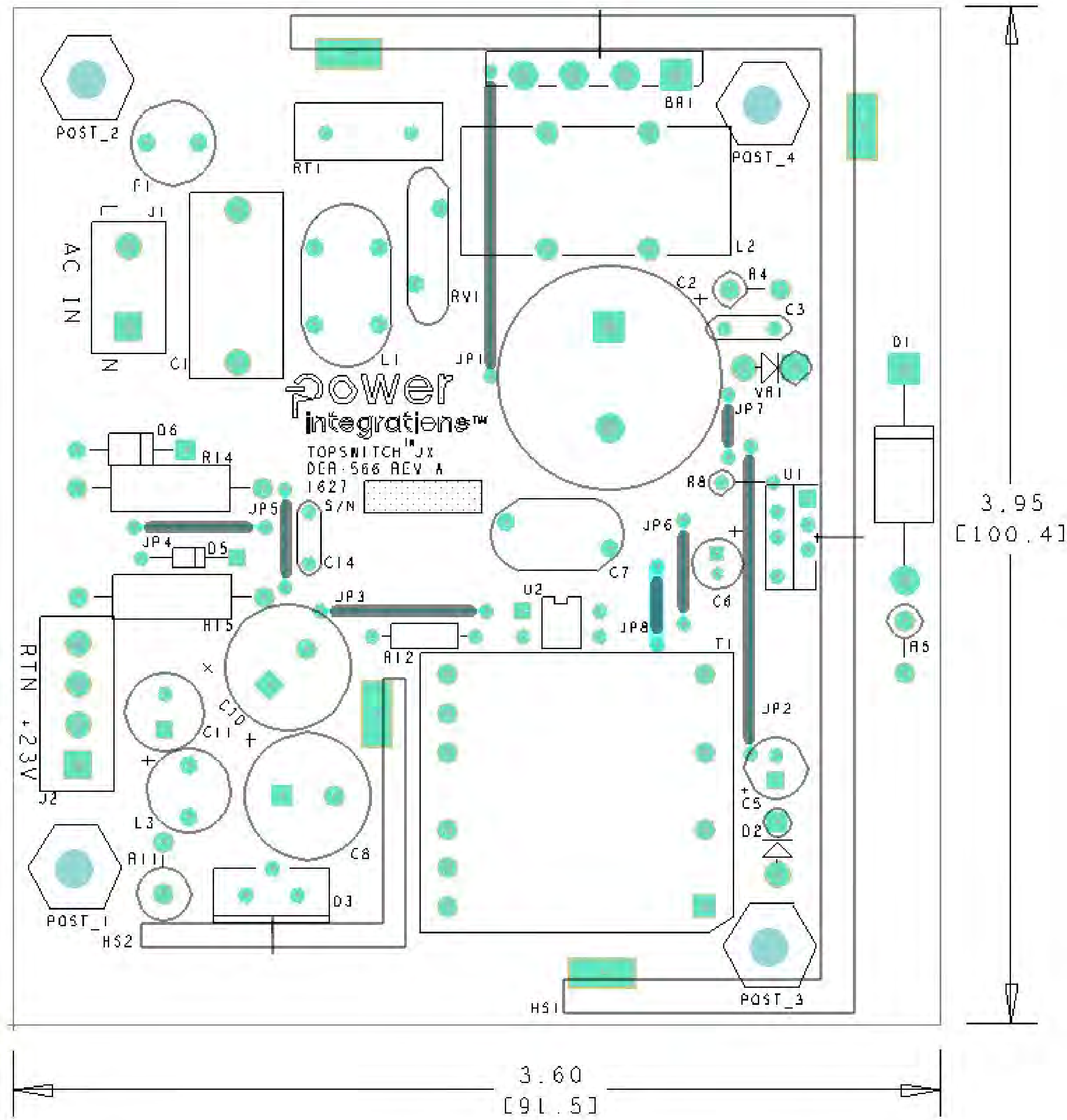

Figure 4 – Printed Circuit Layout, Showing Top Side Components.

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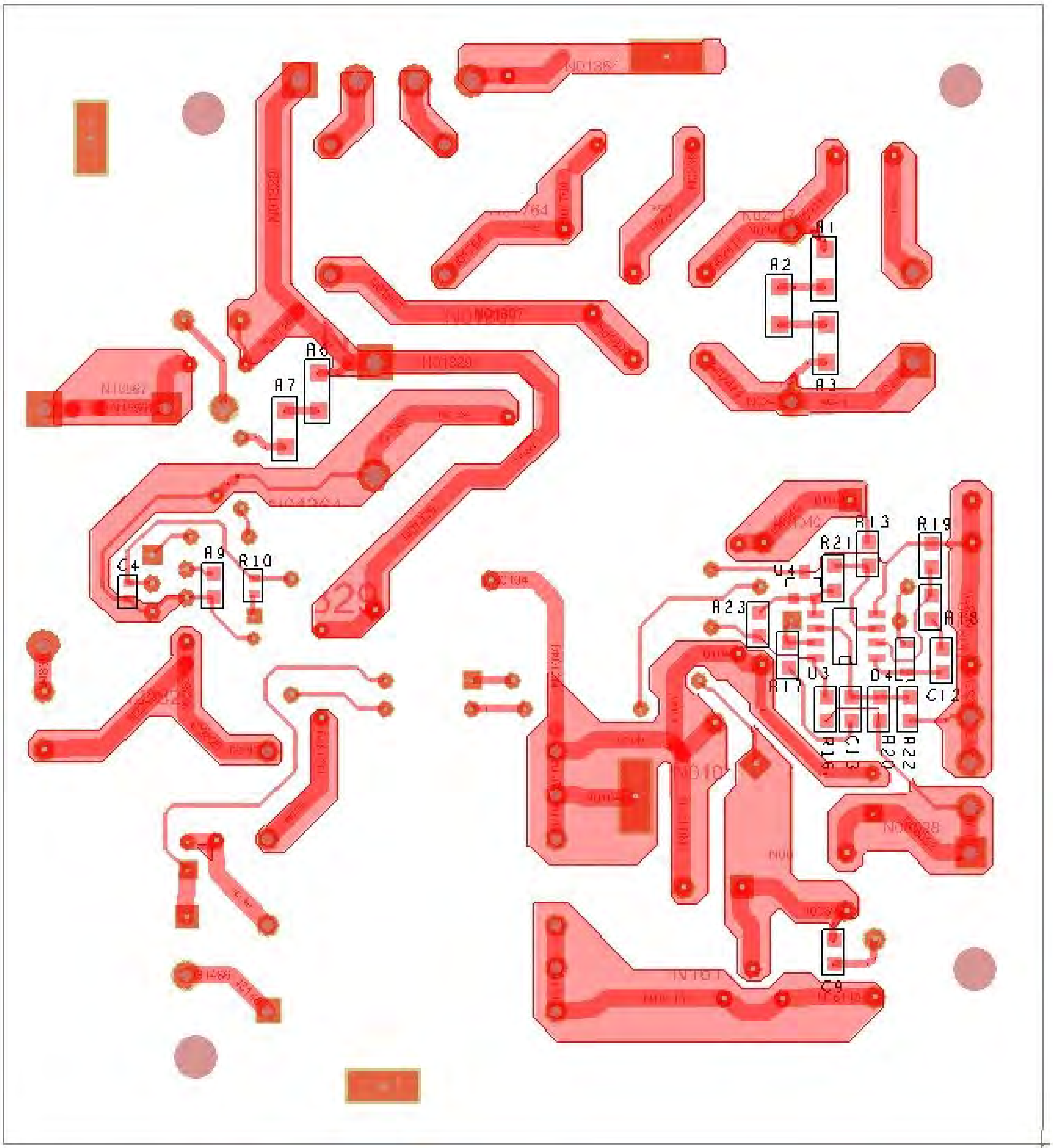

Figure 5 – Printed Circuit Layout, Bottom Side Traces and Components.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	600 V, 8 A, Bridge Rectifier, GBU Case	GBU8J-BP	Micro Commercial
2	1	C1	330 nF, 275 VAC, Film, X2	R46KI333000N1M	Kemet
3	1	C2	CAP, ALUM, 180 μF, 20%, 400V, SNAP, 0.866" Dia (22.00 mm), Height 1.181" (30.00 mm),LS 0.394" (10.00 mm)	LGG2G181MELZ30	Nichicon
4	1	C3	2.2 nF, 1 kV, Disc Ceramic	NCD222K1KVY5FF	NIC
5	1	C4	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
6	1	C5	100 μF, 25 V, Electrolytic, Low ESR, 250 mΩ, (6.3 x 11.5)	ELXZ250ELL101MFB5D	Nippon Chemi-Con
7	1	C6	47 μF, 16 V, Electrolytic, Gen Purpose, (5 x 11.5)	ECA-1CHG470	Panasonic
8	1	C7	2.2 nF, Ceramic, Y1	440LD22-R	Vishay
9	2	C8 C10	680 μF, 35 V, Electrolytic, Very Low ESR, 21 mΩ, (12.5 x 20)	EKZE350ELL681MK20S	Nippon Chemi-Con
10	1	C9	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
11	1	C11	220 μF, 35 V, Electrolytic, Gen. Purpose, (8 x 11)	EKMG350ELL221MHB5D	Nippon Chemi-Con
12	1	C12	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
13	1	C13	47 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H473KA01L	Murata
14	1	C14	1.0 uF, 50 V, Ceramic, X7R	FK20X7R1H105K	TDK
15	1	D1	1000 V,3 A, Fast Recovery Diode, GP DO-201AD	FR307G	Rectron
16	1	D2	200 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	UF4003-E3	Vishay
17	1	D3	150 V, 15 A, Schottky, TO-220AB	STPS30150CT	ST
18	1	D4	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
19	1	D5	75 V, 300 mA, Fast Switching, DO-35	1N4148TR	Vishay
20	1	D6	DIODE, GEN PURP, 50 V, 1 A, DO204AL	1N4001-E3/54	Vishay
21	1	ESIPCLIP M4 METAL1	Heat Sink Hardware, Edge Clip, 20.76 mm L x 8 mm W x 0.015 mm Thk	NP975864	Aavid Thermalloy
22	1	F1	4 A, 250 V, Slow, TR5	37214000411	Wickman
23	1	HS1	MACH, Heat Sink, Primary, DER566		Custom
24	1	HS2	MACH, Heat Sink, Secondary, DER566		Custom
25	1	J1	3 Position (1 x 3) header, 0.156 pitch, Vertical	26-48-1031	Molex
26	1	J2	4 Position (1 x 4) header, 0.156 pitch, Vertical	26-48-1045	Molex
27	2	JP1 JP2	Wire Jumper, Insulated, TFE, #22 AWG, 1.2 in	C2004-12-02	Alpha
28	1	JP3	Wire Jumper, Insulated, TFE, #22 AWG, 0.7 in	C2004-12-02	Alpha
29	1	JP4	Wire Jumper, Insulated, TFE, #22 AWG, 0.6 in	C2004-12-02	Alpha
30	2	JP5 JP6	Wire Jumper, Insulated, TFE, #22 AWG, 0.4 in	C2004-12-02	Alpha
31	1	JP7	Wire Jumper, Insulated, TFE, #22 AWG, 0.3 in	C2004-12-02	Alpha
32	1	JP8	Wire Jumper, Insulated, TFE, #18 AWG, 0.3 in	C2052A-12-02	Alpha
33	1	L1	115 μH, Common Mode Choke, 4 Pin		
34	1	L2	9 mH, 5A, Common Mode Choke	T22148-902S P.I. Custom	Fontaine
35	1	L3	3.3 μH, 5.5 A	RL622-3R3K-RC	JW Miller
36	4	POST-CRKT_BRD_6-32_HEX1 POST-CRKT_BRD_6-32_HEX2 POST-CRKT_BRD_6-32_HEX3 POST-CRKT_BRD_6-32_HEX4	Post, Circuit Board, Female, Hex, 6-32, snap, 0.375L, Nylon	561-0375A	Eagle Hardware

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37	3	R1 R2 R3	RES, 680 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ684V	Panasonic
38	1	R4	RES, 33 kΩ, 5%, 1 W, Metal Oxide	RSF100JB-33K	Yageo
39	2	R5 R11	RES, 33 Ω, 5%, 1 W, Metal Oxide	RSF100JB-33R	Yageo
40	2	R6 R7	RES, 1.5 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ155V	Panasonic
41	1	R8	RES, 1.3 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-1M3	Yageo
42	1	R9	RES, 6.65 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF6651V	Panasonic
43	1	R10	RES, 6.8 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ6R8V	Panasonic
44	1	R12	RES, 1.5 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-521K5	Yageo
45	1	R13	RES, 9.31 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF9311V	Panasonic
46	2	R14 R15	RES, 0.15 Ω, 5%, 2 W, Metal Oxide	MO200J0R15B	Synton-Tech
47	1	R16	RES, 47 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ470V	Panasonic
48	2	R17 R18	RES, 68 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ683V	Panasonic
49	1	R19	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
50	1	R20	RES, 42.2 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4222V	Panasonic
51	1	R21	RES, 102 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1023V	Panasonic
52	1	R22	RES, 5.11 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF5111V	Panasonic
53	1	R23	RES, 6.8 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ682V	Panasonic
54	1	RT1	NTC Thermistor, 5 Ohms, 4.7 A	CL-150	Thermometrics
55	1	RTV1	Thermally conductive Silicone Grease	120-SA	Wakefield
56	1	RV1	320Vad, 84J, 15.5 mm, RADIAL	S14K320	Epcos
57	3	SCREW1 SCREW2 SCREW3	SCREW MACHINE PHIL 4-40 X 1/4 SS	PMSSS 440 0025 PH	Building Fasteners
58	1	T1	Custom Transformer, PQ26/25, Vertical, 12 pins	TBD	
59	1	TO-220 PAD1	THERMAL PAD TO-220 .009" SP1000	1009-58	Bergquist
60	1	U1	TOPSwitch-JX, eSIP-7F	TOP266EG	Power Integrations
61	1	U2	Opto coupler, 35 V, CTR 80-160%, 4-DIP	LTV-817A	Liteon
62	1	U3	DUAL Op Amp, Single Supply, SOIC-8	LM358D	TI
63	1	U4	IC, REG ZENER SHUNT ADJ SOT-23	LM431BIM3/NOPB	National Semi
64	1	VR1	150 V, 5 W, 5%, TVS, DO204AC (DO-15)	P6KE150A	LittleFuse
65	3	WASHER1 WASHER2 WASHER3	WASHER FLAT #4 SS	FWSS 004	Building Fasteners
66	1	WASHER4	Washer, Shoulder, #4, 0.040 Shoulder x 0.140 Dia, Polyphenylene Sulfide PPS	7721-8PPSG	Aavid Thermalloy

7 Magnetics

7.1 Transformer (T1) Specification

7.1.1 Electrical Diagram

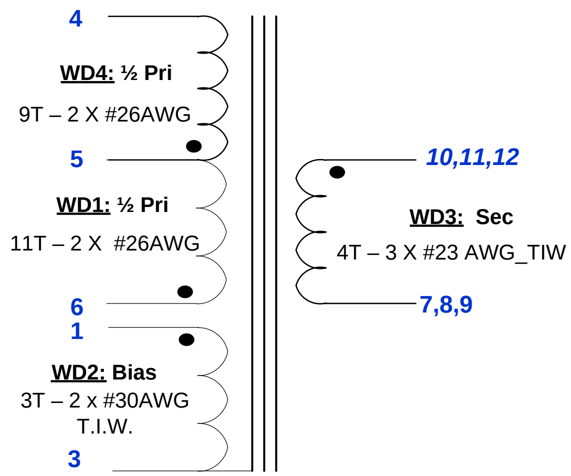

Figure 6 – Transformer Schematic.

7.1.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from pins 1-6 to 10-13.	3000 VAC
Primary Inductance	Pins 4-6 all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	308 μH ±10%
Resonant Frequency	Pins 4-6, all other windings open.	3 MHz (Min.)
Primary Leakage Inductance	Pins 4-6, with pins 7-12 shorted, measured at 100 kHz, 0.4 V_{RMS}.	3 μH (Max.)

7.1.3 Material List

Item	**Description**
[1]	Core Pair PQ26/25: TDK PC44 or equivalent.
[2]	Bobbin: PQ26/25 Vertical, 12 pins, PI Part # 25-00055-00.
[3]	Wire, Triple Insulated, #23 AWG – Furukawa Tex-E or equivalent.
[4]	Wire, Triple Insulated, #30 AWG – Furukawa Tex-E or equivalent.
[5]	Wire, Magnet, Solderable Double Coated, #26 AWG.
[6]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 13 mm wide.
[7]	Tape: Polyester Web, 3M 44 or equivalent, 2.0 mm wide.
[8]	Tape: Copper Foil, 3M 1194 or equivalent, 8 mm wide.
[9]	Varnish: Dolph BC-359, or equivalent.

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7.1.4 Build Diagram

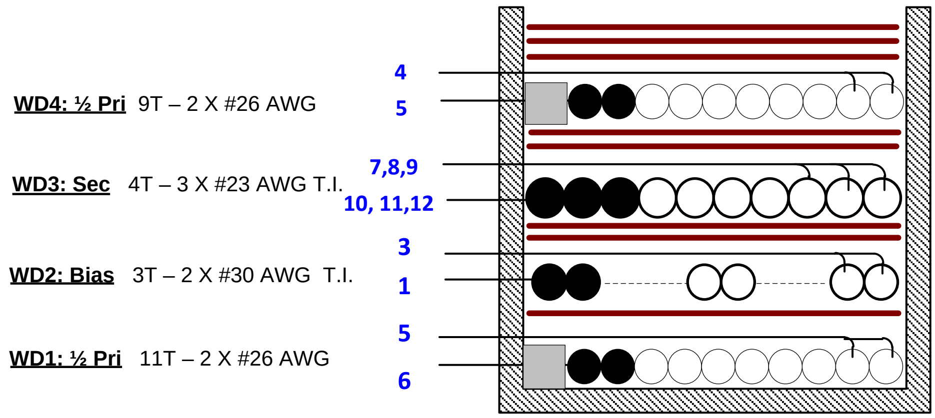
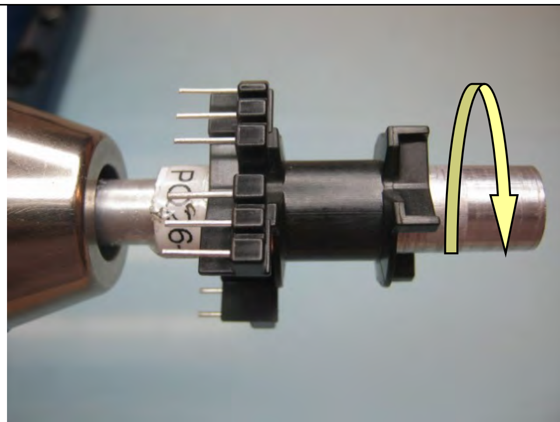
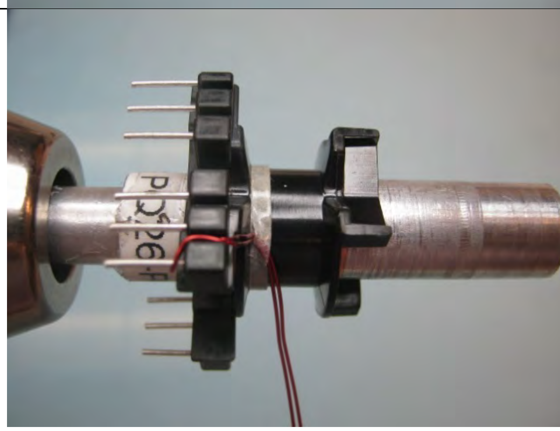
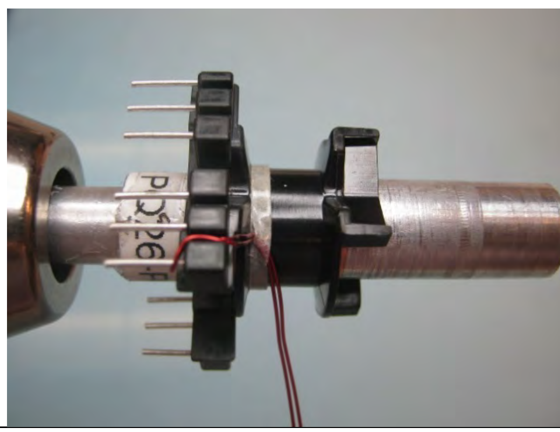


Figure 7 – Transformer Build Diagram.

7.1.5 Winding Instructions

General note	For the purpose of these instructions, bobbin is oriented on winder such that pins are on the left side (see illustration). Winding direction as shown is clockwise.
Margin	Apply 2 mm margin on pin side of bobbin using item [7] Match height of first primary winding.
WD1: ½ Primary	Starting on pin 6, wind 11 bifilar turns of wire item [5] in 1 layer, finish on pin 5.
Insulation	Apply 1 layer of tape item [6].
WD2: Bias	Starting at pin 1, wind 3 bifilar turns of triple insulated wire [4] spaced evenly across bobbin window. Finish on pin 3.
Insulation	Apply 2 layers of tape item [6].
WD3: Secondary	Starting at pins 10, 11, and 12 wind 4 trifilar turns of triple insulated wire item [3] in one layer, finishing at pins 7, 8, and 9.
Insulation	Apply 2 layers of tape item [6].
WD4: ½ Primary	Starting on pin 5, wind 9 bifilar turns of wire item [5] in 1 layer, finishing on pin 4.
Finish Wrap	Apply 3 layers of tape item [6].
Assembly (1)	Assemble gapped and ungapped core halves in bobbin, secure with tape. Using copper tape item [8], apply an outside flux band centered in the bobbin window as shown in illustration. Overlap and solder ends of band to form a shorted turn. Attach wire [5] to copper band and terminate to pin 3.
Assembly (2)	Apply 1 layer of tape item [6] around transformer as shown to insulate flux band. Remove pin 2 and cut pin 5 short. Dip varnish [9].

7.1.6 Winding Illustrations

General Note		For the purpose of these instructions, bobbin is oriented on winder such that pins are on the left side (see illustration). Winding direction as shown is clockwise
WD1: 1st Primary	 	Apply 2 mm margin on pin side of bobbin using item [7] match height of first primary winding. Starting on pin 6, wind 11 bifilar turns of wire item [5] in 1 layer, finish on pin 5.

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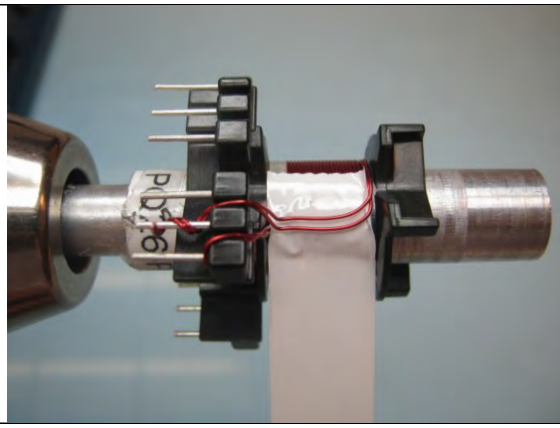
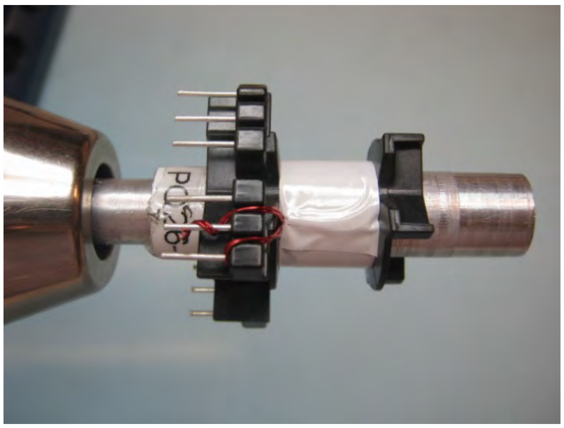
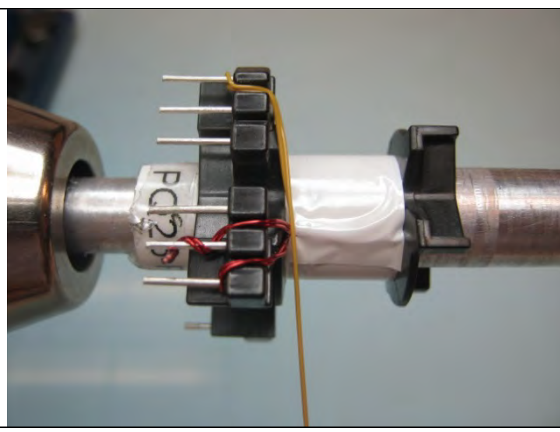
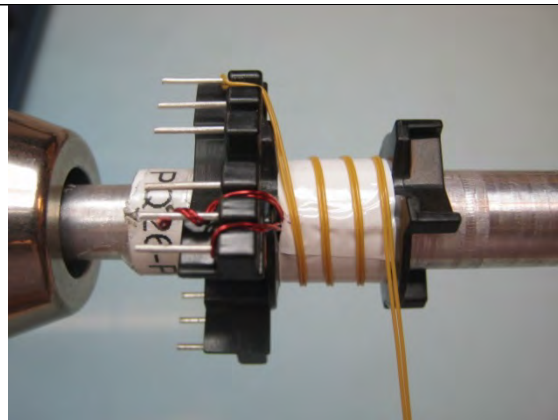
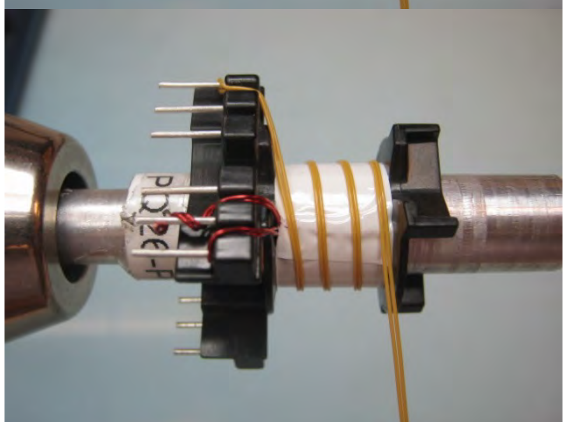
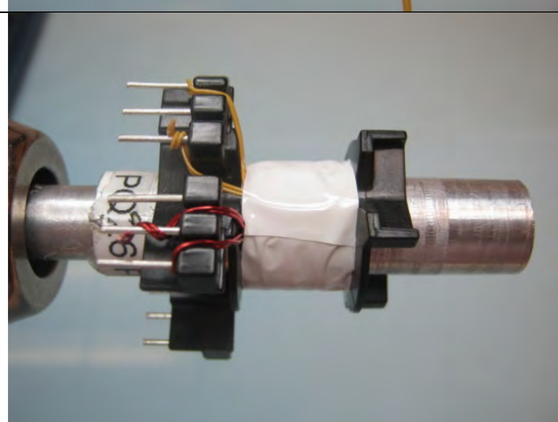
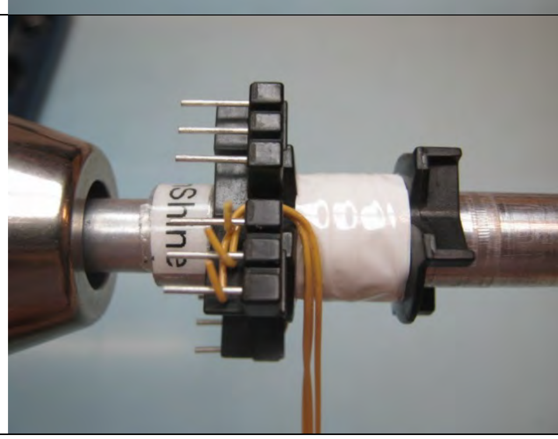
		
Insulation		Apply 1 layer of tape item [6].
WD2: Secondary		Starting at pin 1, wind 3 bifilar turns of triple insulated wire [4] spaced evenly across bobbin window. Finish on pin 3.

	 	
Insulation		Apply 2 layers of tape item [6].
WD3: Secondary		Starting at pins 10, 11, and 12 wind 4 trifilar turns of triple insulated wire item [3] in one layer, finishing at pins 7, 8, and 9.

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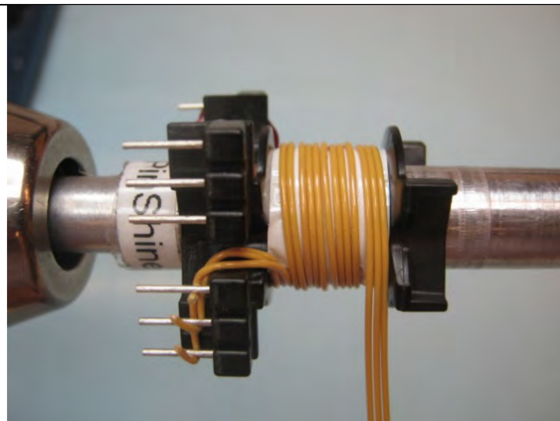
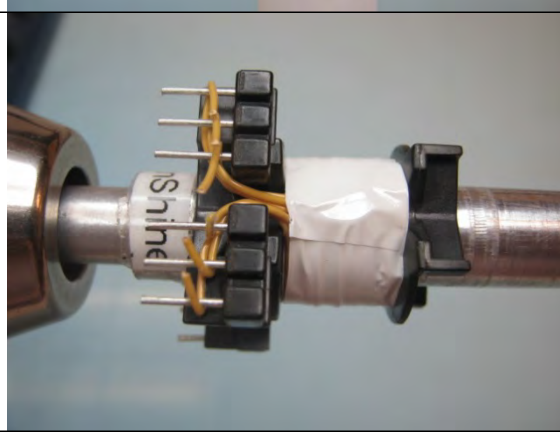
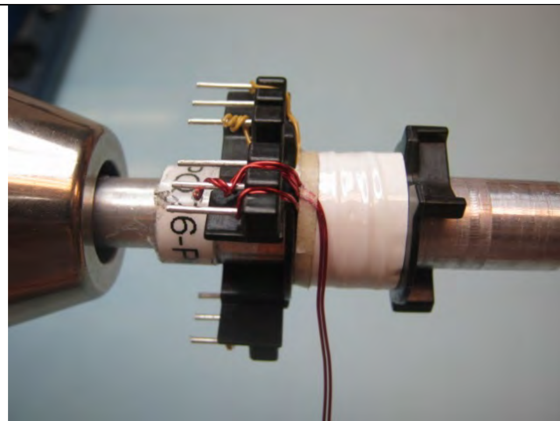
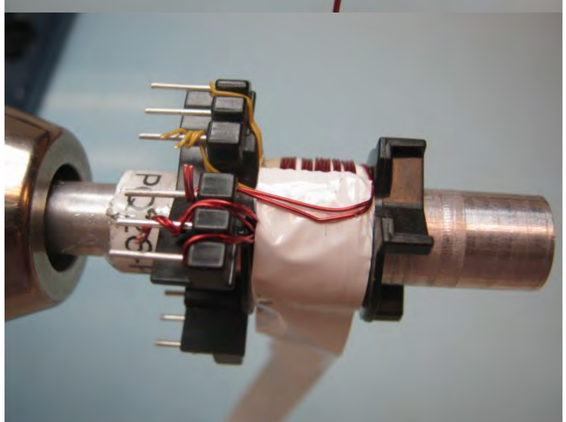
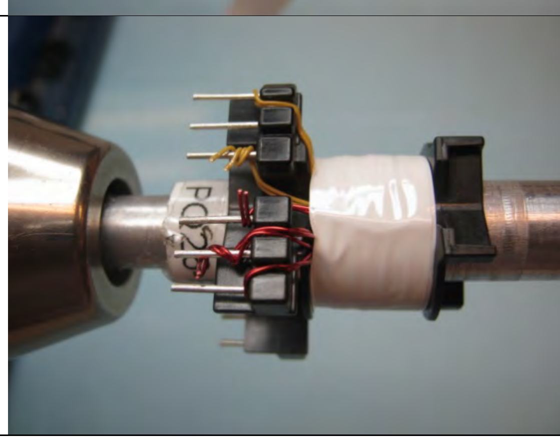
	 	
Insulation		Apply 2 layers of tape item [6].

WD4: ½ Primary	  	Apply 2 mm margin on pin side of bobbin using item [7] match height of second primary winding. Starting on pin 5, wind 9 bifilar turns of wire item [5] in 1 layer, finishing on pin 4.
Finish Wrap		Apply 3 layers of tape item [6].

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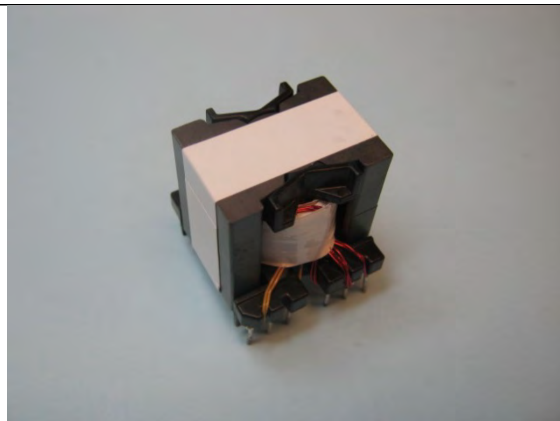
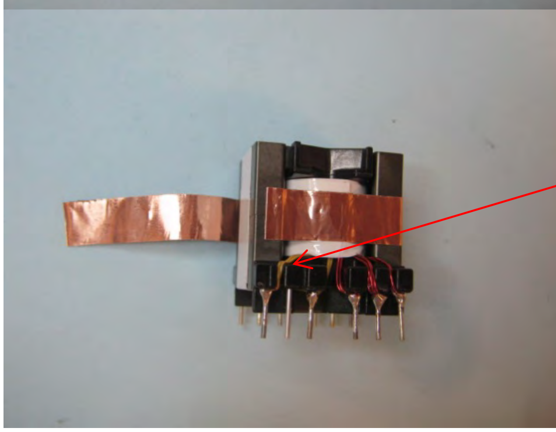
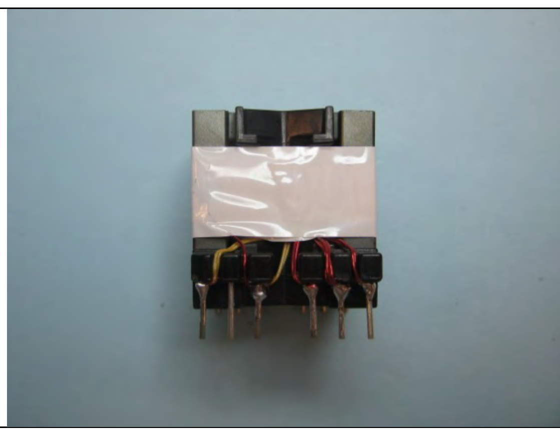
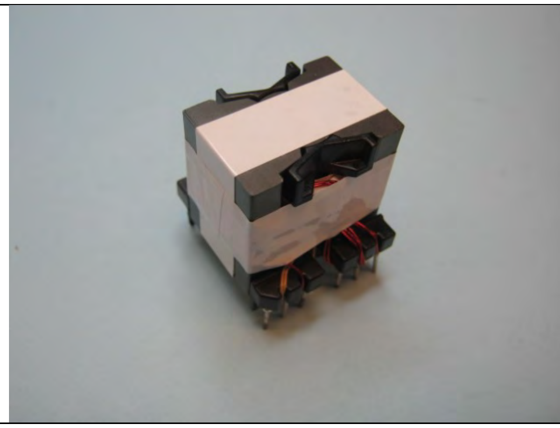
Assembly (1)	 	Assemble gapped and ungapped core halves in bobbin, secure with tape. Using copper tape item [8], apply an outside flux band centered in the bobbin window as shown in illustration. Overlap and solder ends of band to form a shorted turn. Attach wire [5] to copper band and terminate to pin 3.
Assembly (2)		Apply 1 layer of tape item [6] around transformer as shown to insulate flux band. Remove pin 2 and cut pin 5 short. Dip varnish [9].



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8 High Frequency Common Mode Choke

8.1 Electrical Diagram

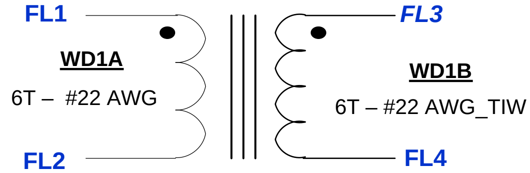

Figure 8 – Choke Schematic.

8.2 Electrical Specifications

Inductance	FL1-FL2 or FL3-FL4 other winding open, measured at 100 kHz, 0.4 V_{RMS}.	115 µH ±20%

8.3 Material List

Item	Description
[1]	Core, Ferrite, Coated, 5000 µ: Fair-Rite 5975001121 or equivalent.
[2]	Wire, Triple Insulated, #22 AWG – Furukawa Tex-E or equivalent.
[3]	Wire, Magnet, Solderable Double Coated, #22 AWG.

8.4 Build Picture

Figure 9 – Finished Choke

8.5 Winding Instructions

Winding & Termination	Using 1 Strand each of items [2] and [3], wind six bifilar turns on core [1]. Trim leads to within 15 mm of core, tin last 10mm of leads. Finished choke should resemble above figure.

9 Transformer Design Spreadsheet

ACDC_TOPSwitchJX_032514; Rev.1.6; Copyright Power Integrations 2014	INPUT	INFO	OUTPUT	UNIT	TOP_JX_032514: TOPSwitch-JX Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	90			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	23.00			Volts	Output Voltage (main)
PO_AVG	70.00			Watts	Average Output Power
PO_PEAK			70.00	Watts	Peak Output Power
Heatsink Type	**External**		External		Heatsink Type
Enclosure	**Open Frame**				Open Frame enclosure assumes sufficient airflow, while Adapter means a sealed enclosure.
n	0.85			%/100	Efficiency Estimate
Z	0.50				Loss allocation factor
VB	16			Volts	Bias Voltage - Verify that VB is > 8 V at no load and VMAX
tC	3.00			ms	Bridge Rectifier Conduction Time Estimate
CIN	180.0		180.0	uFarads	Input Filter Capacitor
ENTER TOPSWITCH-JX VARIABLES					
TOPSwitch-JX	**TOP266E**			Universal / Peak	115 Doubled/230V
Chosen Device		TOP266E	Power Out	86 W / 86 W	119W
KI	1.00				External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN_EXT			2.371	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX_EXT			2.805	Amps	Use 1% resistor in setting external ILIMIT. Includes tolerance over temperature. See Fig 37 of datasheet
Frequency (F)=132kHz, (H)=66kHz	**F**		F		Select 'H' for Half frequency - 66kHz, or 'F' for Full frequency - 132kHz
fS			132000	Hertz	TOPSwitch-JX Switching Frequency: Choose between 132 kHz and 66 kHz
fSmin			119000	Hertz	TOPSwitch-JX Minimum Switching Frequency
fSmax			145000	Hertz	TOPSwitch-JX Maximum Switching Frequency
High Line Operating Mode			FF		Full Frequency, Jitter enabled
VOR	120.00			Volts	Reflected Output Voltage
VDS			10.00	Volts	TOPSwitch on-state Drain to Source Voltage
VD	0.50			Volts	Output Winding Diode Forward Voltage Drop
VDB	0.70			Volts	Bias Winding Diode Forward Voltage Drop
KP	0.65				Ripple to Peak Current Ratio (0.3 < KRP < 1.0 : 1.0< KDP<6.0)
PROTECTION FEATURES					
LINE SENSING					V pin functionality
VUV_STARTUP			100.54	Volts	Minimum DC Bus Voltage at which the power supply will start-up
VOV_SHUTDOWN			490	Volts	Typical DC Bus Voltage at which power supply will shut-down (Max)
RLS			4.4	M-ohms	Use two standard, 2.2 M-Ohm, 5%

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					resistors in series for line sense functionality.
OUTPUT OVERVOLTAGE					
VZ			30	Volts	Zener Diode rated voltage for Output Overvoltage shutdown protection
RZ			5.1	k-ohms	Output OVP resistor. For latching shutdown use 20 ohm resistor instead
OVERLOAD POWER LIMITING					X pin functionality
Overload Current Ratio at VMAX			1.20		Enter the desired margin to current limit at VMAX. A value of 1.2 indicates that the current limit should be 20% higher than peak primary current at VMAX
Overload Current Ratio at VMIN			1.06		Margin to current limit at low line.
ILIMIT_EXT_VMIN			2.15	A	Peak primary Current at VMIN
ILIMIT_EXT_VMAX			2.19	A	Peak Primary Current at VMAX
RIL			6.65	k-ohms	Current limit/Power Limiting resistor.
RPL			N/A	M-ohms	Resistor not required. Use RIL resistor only
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**Custom**		Custom		Core Type
Custom Core (Optional)					If Custom core is used - Enter Part number here
Bobbin		#N/A		P/N:	#N/A
AE	1.2200		1.2200	cm^2	Core Effective Cross Sectional Area
LE	5.3600		5.3600	cm	Core Effective Path Length
AL	4650.0		4650.0	nH/T^2	Ungapped Core Effective Inductance
BW	15.5		15.5	mm	Bobbin Physical Winding Width
M	1.00			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00				Number of Primary Layers
NS	4		4		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			99	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.57		Maximum Duty Cycle (calculated at PO_PEAK)
IAVG			0.83	Amps	Average Primary Current (calculated at average output power)
IP			2.15	Amps	Peak Primary Current (calculated at Peak output power)
IR			1.40	Amps	Primary Ripple Current (calculated at average output power)
IRMS			1.14	Amps	Primary RMS Current (calculated at average output power)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			305	uHenries	Primary Inductance
LP Tolerance			10		Tolerance of Primary Inductance
NP			20		Primary Winding Number of Turns
NB			3		Bias Winding Number of Turns
ALG			730	nH/T^2	Gapped Core Effective Inductance
BM			2624	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			3772	Gauss	Peak Flux Density (BP<4200) at ILIMITMAX and LP_MAX. Note: Recommended values for adapters and external power supplies <=3600 Gauss
BAC			853	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1626		Relative Permeability of Ungapped

					Core
LG			0.18	mm	Gap Length (Lg > 0.1 mm)
BWE			27	mm	Effective Bobbin Width
OD			1.32	mm	Maximum Primary Wire Diameter including insulation
INS			0.09	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			1.23	mm	Bare conductor diameter
AWG			17	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			2048	Cmils	Bare conductor effective area in circular mils
CMA		Warning	1797	Cmils/Amp	!!! DECREASE CMA> (decrease L(primary layers),increase NS,smaller Core)
Primary Current Density (J)			1.10	Amps/mm^2	!!! Info. Primary current density is low. Can increase Primary current density. Reduce primary layers, or use smaller core
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			10.96	Amps	Peak Secondary Current
ISRMS			5.01	Amps	Secondary RMS Current
IO_PEAK			3.04	Amps	Secondary Peak Output Current
IO			3.04	Amps	Average Power Supply Output Current
IRIPPLE			3.98	Amps	Output Capacitor RMS Ripple Current
CMS			1002	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			20	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.81	mm	Secondary Minimum Bare Conductor Diameter
ODS			3.38	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			1.28	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			611	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			96	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB			68	Volts	Bias Rectifier Maximum Peak Inverse Voltage
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1			23.00	Volts	Output Voltage
IO1_AVG			3.04	Amps	Average DC Output Current
PO1_AVG			70.00	Watts	Average Output Power
VD1			0.50	Volts	Output Diode Forward Voltage Drop
NS1			4.00		Output Winding Number of Turns
ISRMS1			5.011	Amps	Output Winding RMS Current
IRIPPLE1			3.98	Amps	Output Capacitor RMS Ripple Current
PIVS1			96	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS1			1002	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			20	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.81	mm	Minimum Bare Conductor Diameter
ODS1			3.38	mm	Maximum Outside Diameter for Triple Insulated Wire

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2nd output					
VO2				Volts	Output Voltage
IO2_AVG				Amps	Average DC Output Current
PO2_AVG			0.00	Watts	Average Output Power
VD2			0.70	Volts	Output Diode Forward Voltage Drop
NS2			0.12		Output Winding Number of Turns
ISRMS2			0.000	Amps	Output Winding RMS Current
IRIPPLE2			0.00	Amps	Output Capacitor RMS Ripple Current
PIVS2			2	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS2			0	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS2			N/A	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS2			N/A	mm	Minimum Bare Conductor Diameter
ODS2			N/A	mm	Maximum Outside Diameter for Triple Insulated Wire
3rd output					
VO3				Volts	Output Voltage
IO3_AVG				Amps	Average DC Output Current
PO3_AVG			0.00	Watts	Average Output Power
VD3			0.70	Volts	Output Diode Forward Voltage Drop
NS3			0.12		Output Winding Number of Turns
ISRMS3			0.000	Amps	Output Winding RMS Current
IRIPPLE3			0.00	Amps	Output Capacitor RMS Ripple Current
PIVS3			2	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS3			0	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS3			N/A	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS3			N/A	mm	Minimum Bare Conductor Diameter
ODS3			N/A	mm	Maximum Outside Diameter for Triple Insulated Wire
Total Continuous Output Power			70	Watts	Total Continuous Output Power

10 Heat Sinks

10.1 Primary Heat Sink

10.1.1 Primary Heat Sink Sheet Metal

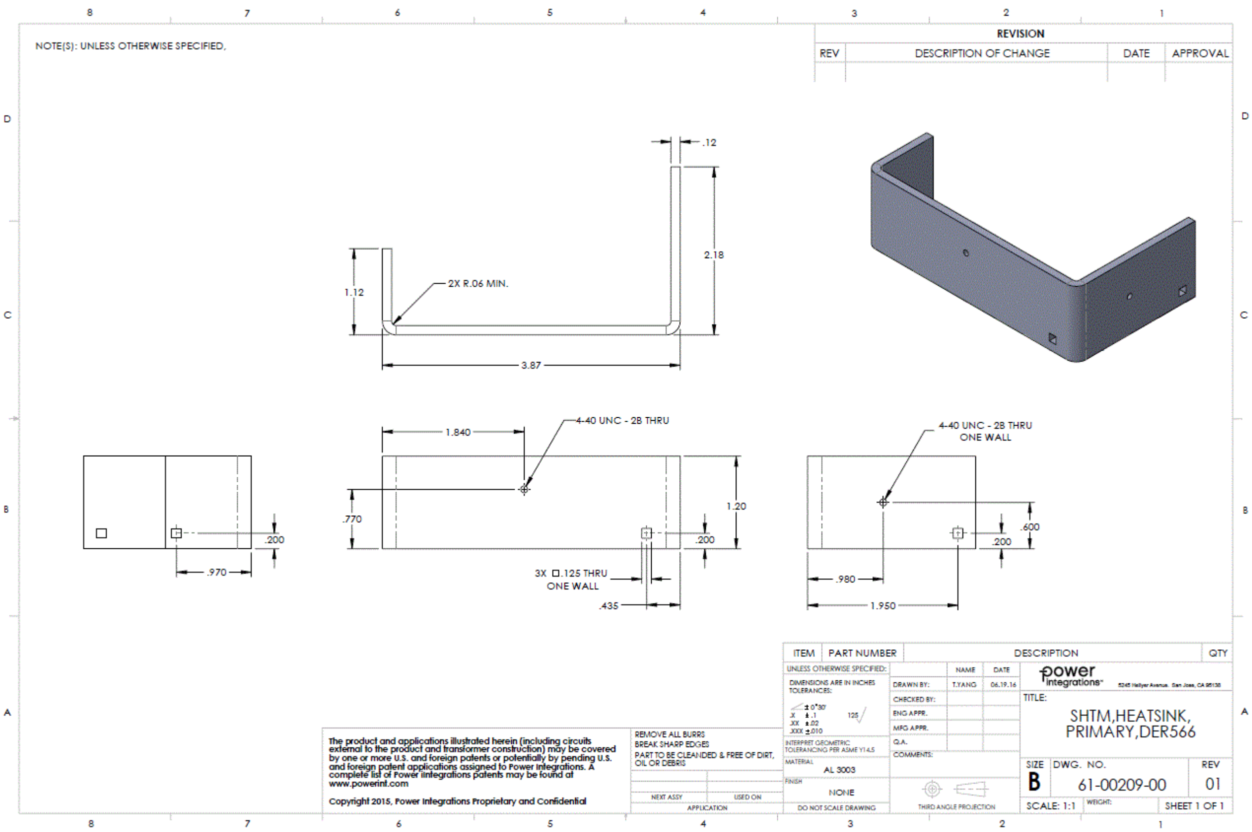

Figure 9 – DER-566 Primary Heat Sink Sheet Metal Drawing.

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10.1.2 Finished Primary Heat Sink with Hardware

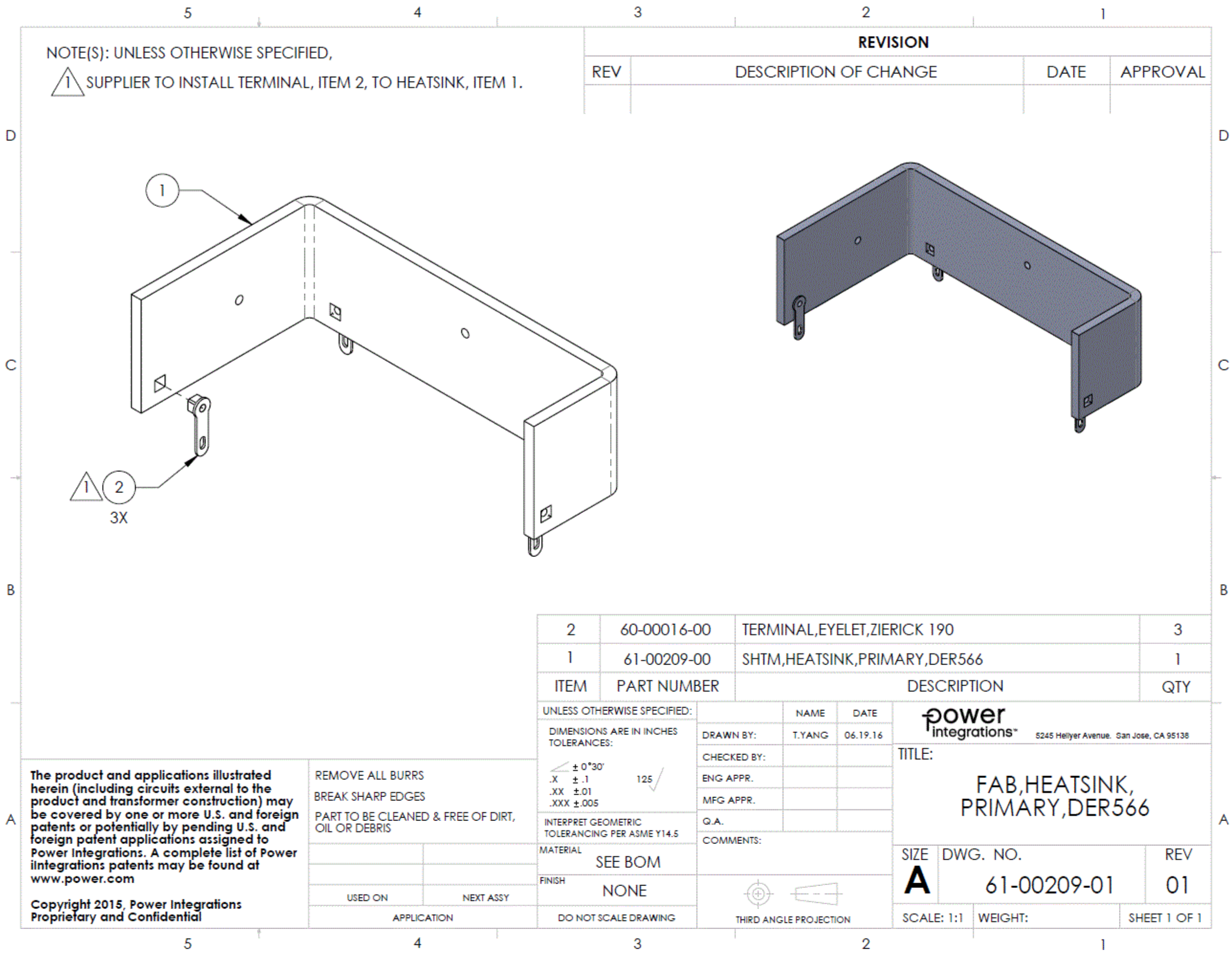

Figure 10 – DER-566 – Finished Primary Heat Sink with Hardware.

10.1.3 Primary Heat Sink Assembly

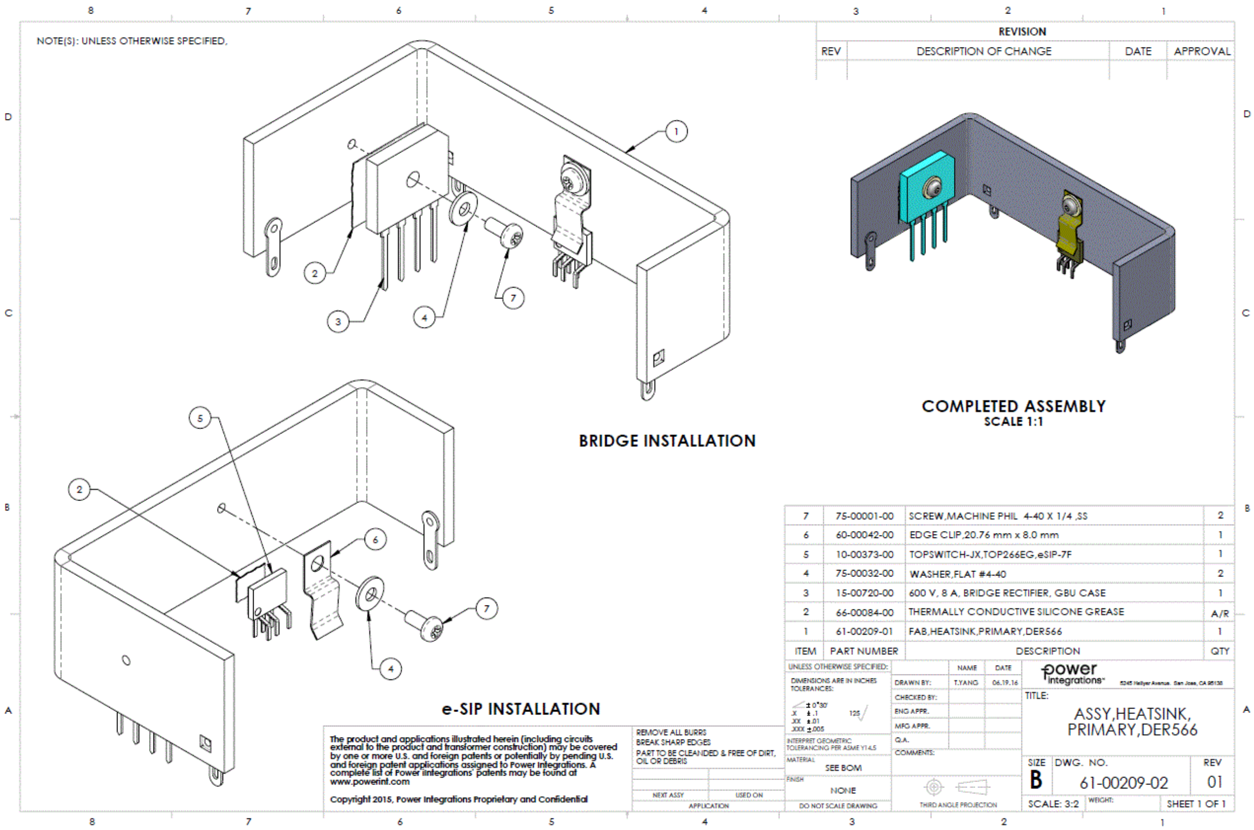

Figure 11 – DER-566 Primary Heat Sink Assembly.

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10.2 Output Rectifier Heat Sink

10.2.1 Output Rectifier Heat Sink Sheet Metal Drawing

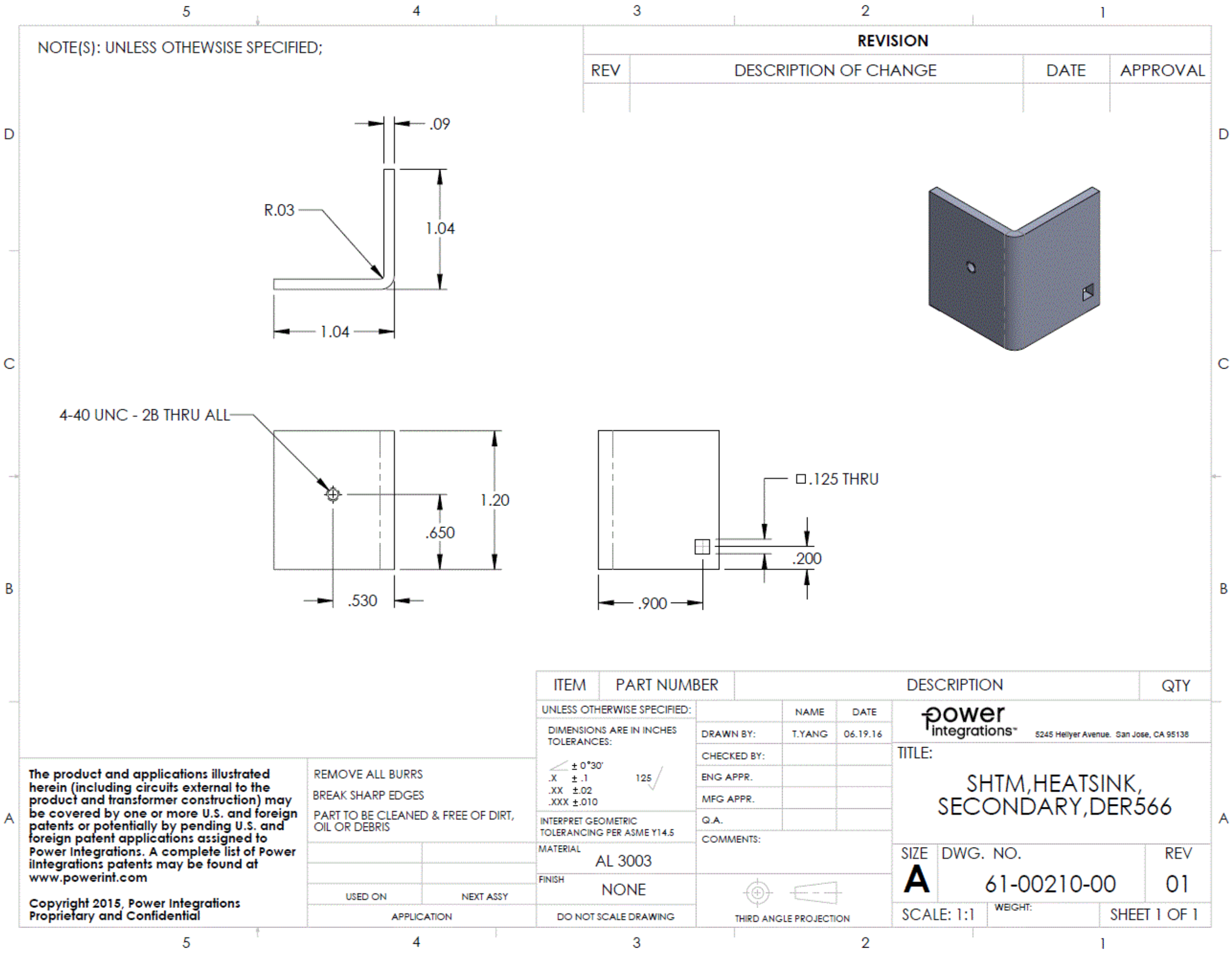

Figure 12 – DER-566 Output Rectifier Heat Sink Sheet Metal Drawing.

10.2.2 Finished Output Rectifier Heat Sink with Hardware

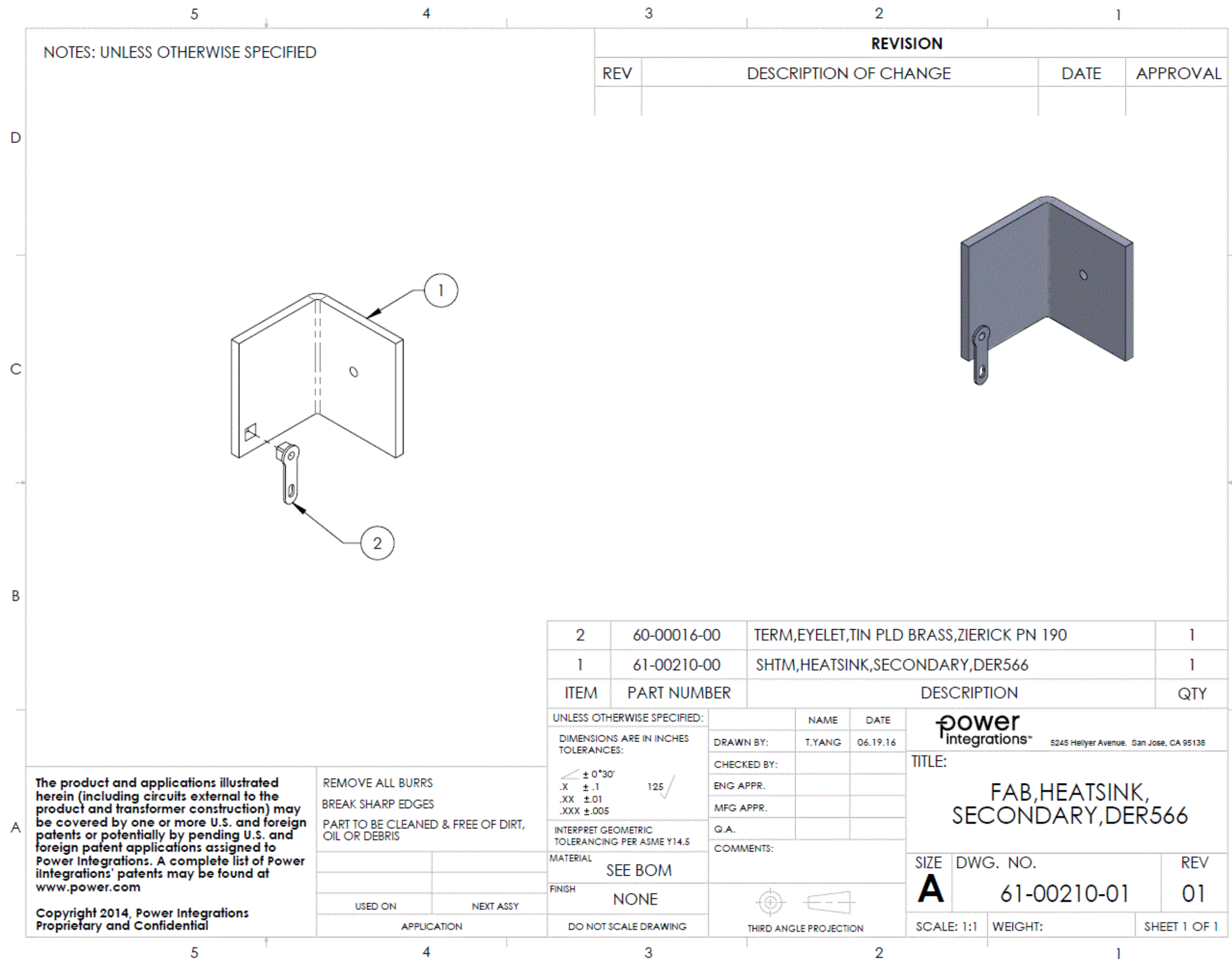

Figure 13 – DER-566 Output Rectifier Heat Sink with Hardware.

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10.2.3 Output Rectifier Heat Sink Assembly

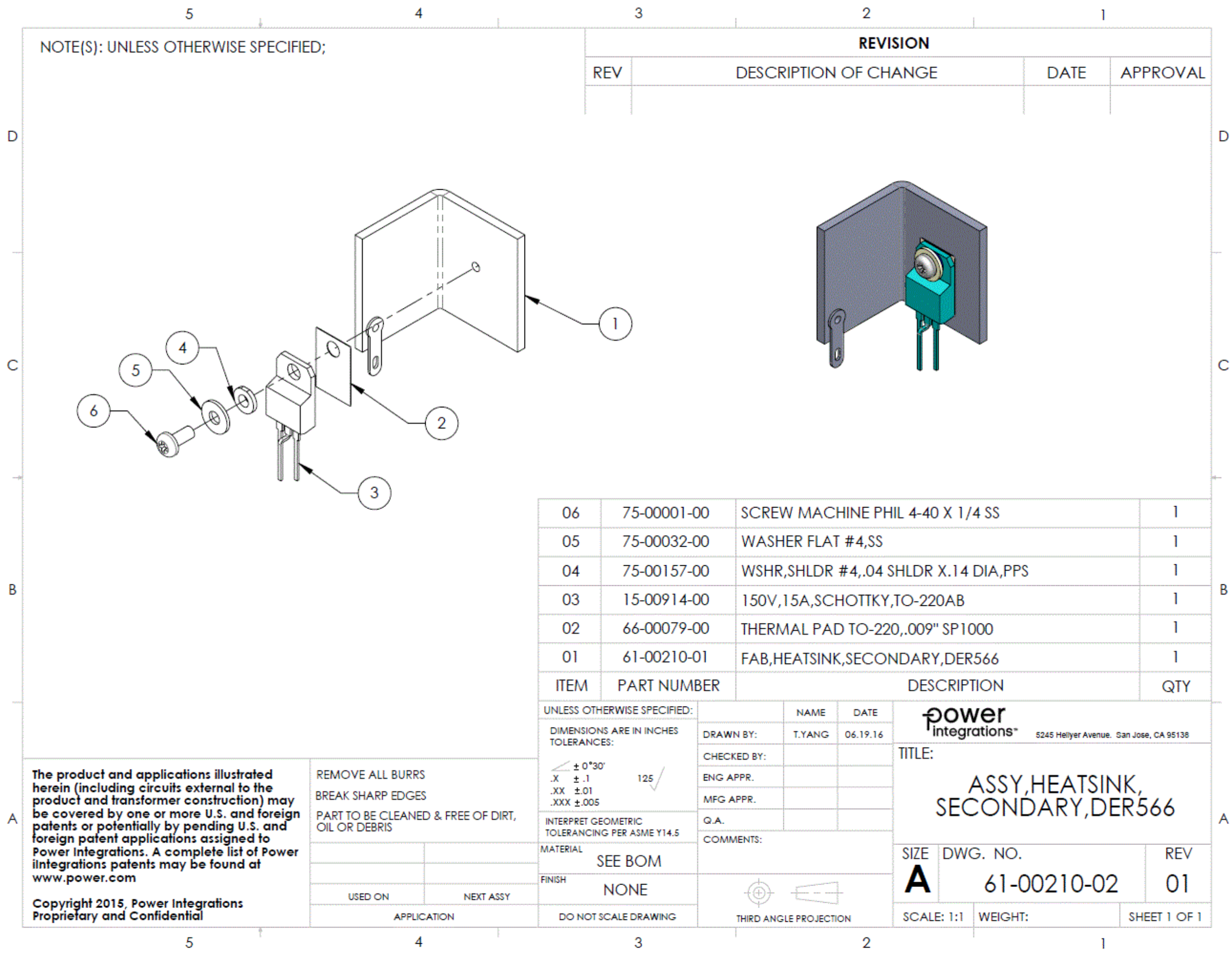

Figure 14 – DER-566 Output Rectifier Heat Sink Assembly.

11 Performance Data

All measurements were taken at room temperature and 60 Hz (input frequency) unless otherwise specified. Output voltage measurements were taken at the output connectors.

11.1 Output Load Considerations for Testing a CV/CC Supply in Battery Charger Applications

Since this power supply has a constant voltage/constant current output and normally operates in CC mode in its intended application (battery charging), some care must be taken in selecting the type/s of output load for testing.

The default setting for most electronic loads is constant current. This setting can be used in testing a CV/CC supply in the CV portion of its load range below the power supply current limit set point. Once the current limit of the DUT is reached, a constant current load will cause the output voltage of the DUT to immediately collapse to the minimum voltage capability of the electronic load.

To test a CV/CC supply in both its CV and CC regions (an example - obtaining a V-I characteristic curve that spans both the CV and CC regions of operation), an electronic load set for constant resistance can be used. However, in an application where the control loop is strongly affected by the output impedance, use of a CR load will give results for loop compensation that are overly optimistic and will likely oscillate when tested with an actual low impedance battery load. For final characterization and tuning the output control loops, a constant voltage load should be used.

Having said this, many electronic loads incorporate a constant voltage setting, but the output impedance of the load in this setting may not be sufficiently low to successfully emulate a real-world battery (impedance on the order of tens of milliohms). Simulating this impedance can be crucial in properly setting the compensation of the current control loop in order to prevent oscillation in a real-life application.

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11.2 Efficiency

To make this measurement, the supply was powered with an AC source.

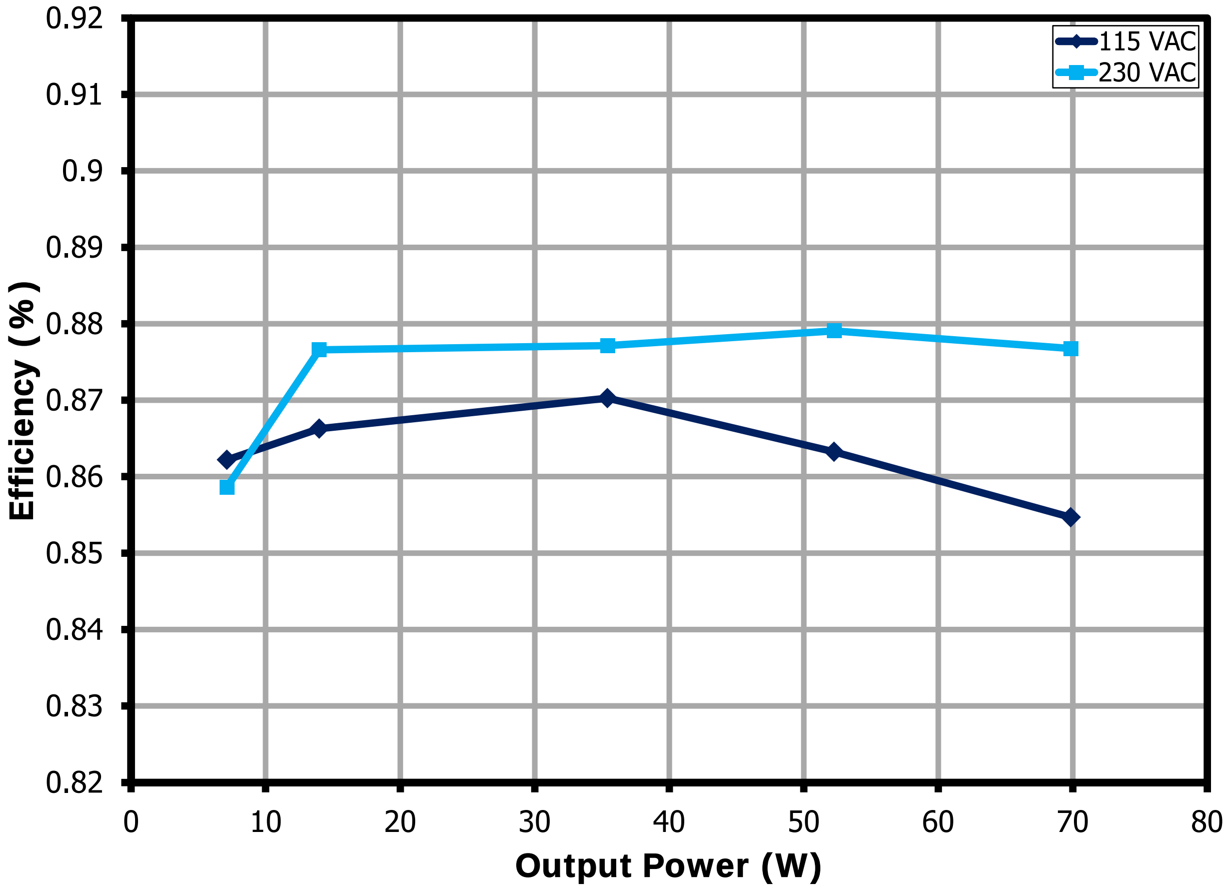

Figure 15 – Efficiency vs. Output Power, 115 / 230 VAC Input.

11.3 No-Load Input Power

No-load input power was measured using a Yokogawa WT210 power analyzer. The power meter was set up to record Watt-Hours, with a 20 min integration time.

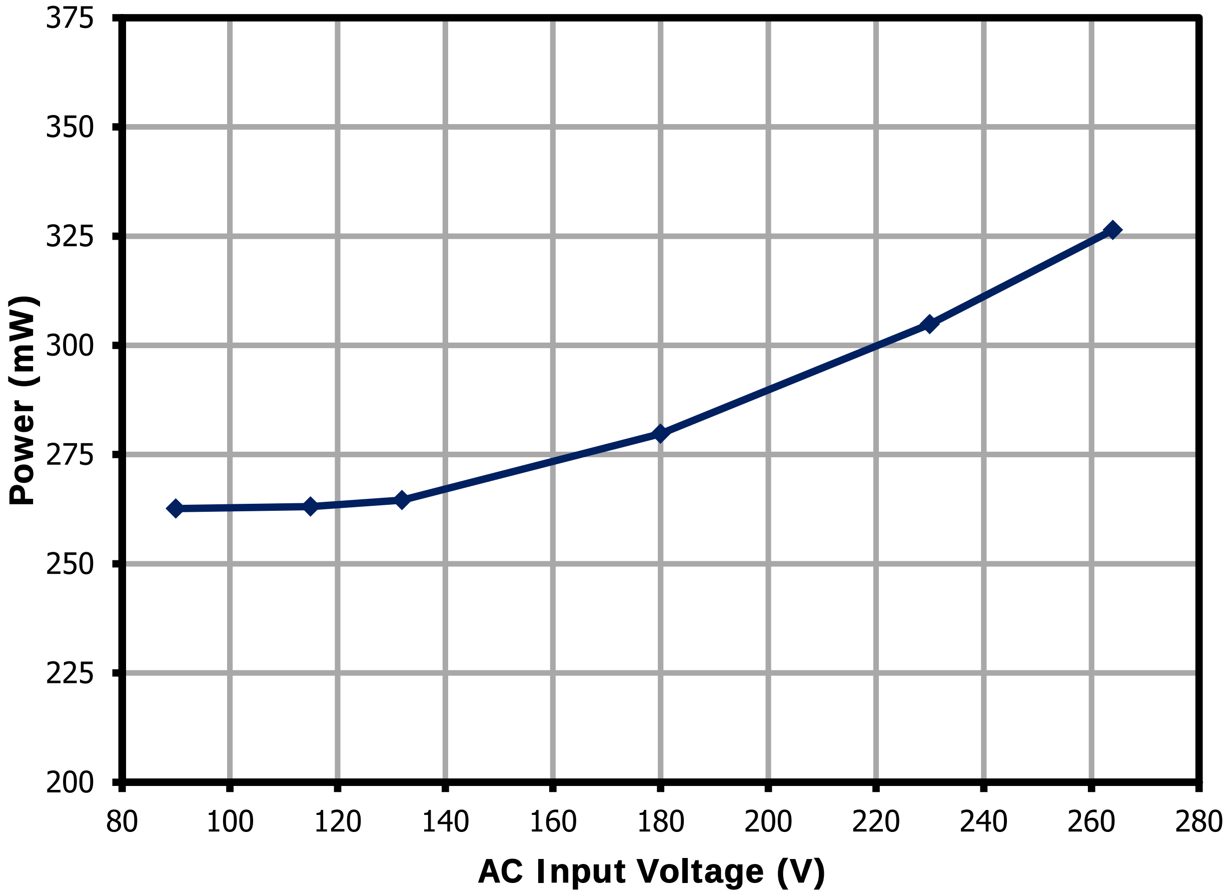

Figure 16 – No-Load Input Power vs. Input Voltage.

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11.4 Main Output V-I Characteristic

The main output V-I characteristic showing the transition from constant voltage mode to constant current mode was measured using a Chroma electronic load set for constant resistance. This setting allows proper operation of the DUT in both CV and CC mode. The measurements cut off at 10 V, as this is the minimum output voltage specified.

11.4.1 Main Output V-I Characteristic, Constant Resistance Load

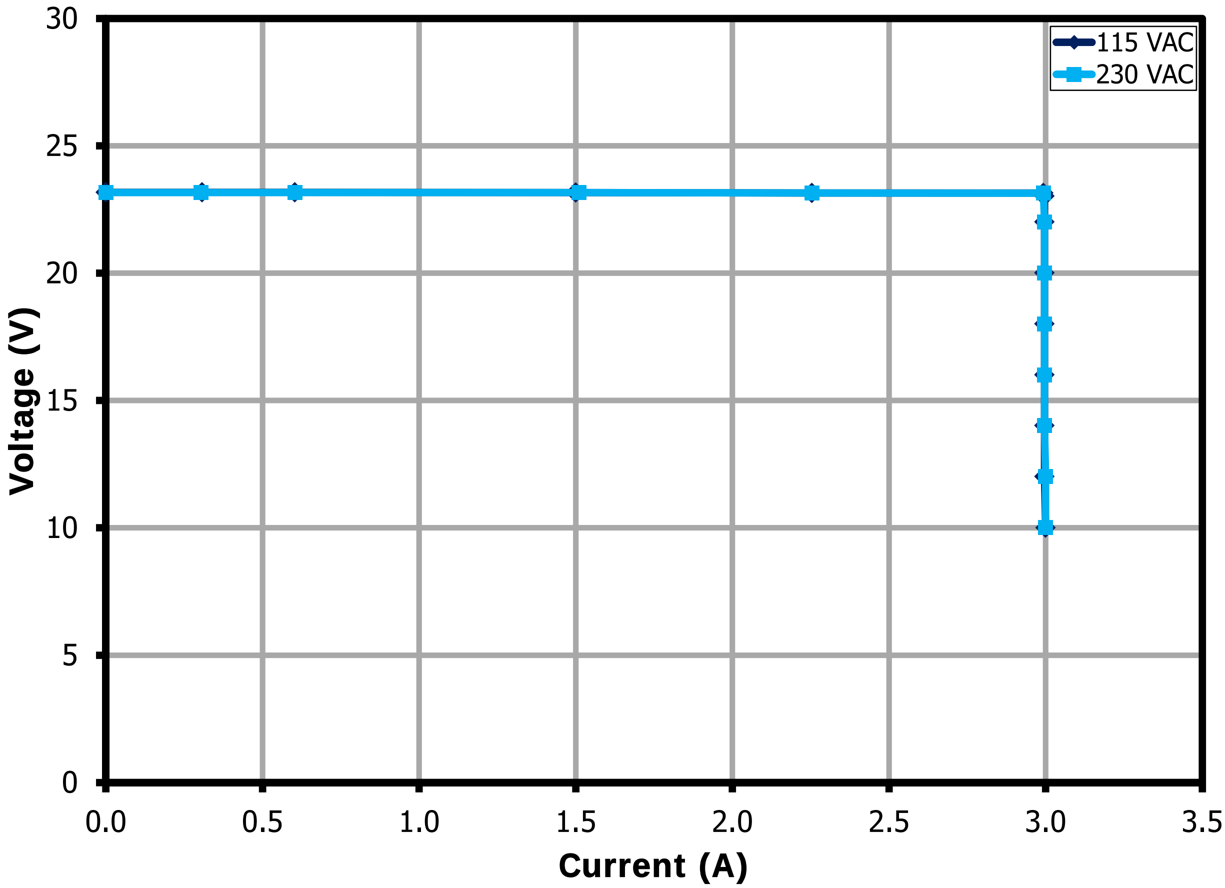

Figure 17 – V-I Characteristic with CR Load.

12 Waveforms

12.1 Primary Voltage and Current

The main stage primary current was measured by inserting a current sensing loop in series with the DRAIN pin of U1.

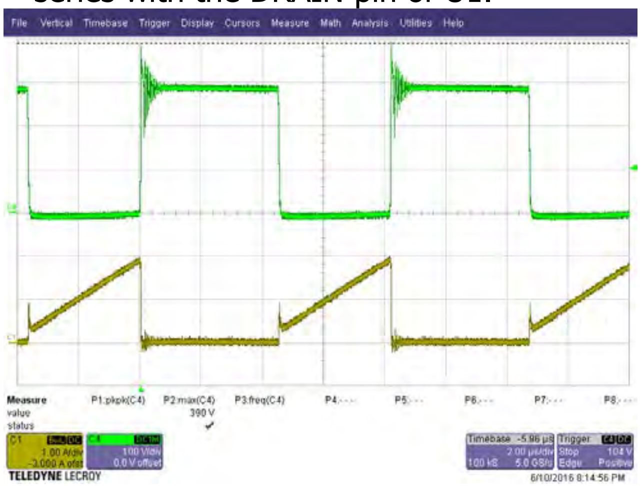

Figure 18 – Primary Voltage and Current, 115 VAC Input, 100% Load.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 1 A / div. 2 µs / div.

Figure 19 – Primary Voltage and Current, 230 VAC Input, 100% Load.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A /, 2 µs / div.

12.2 Output Rectifier Peak Reverse Voltage

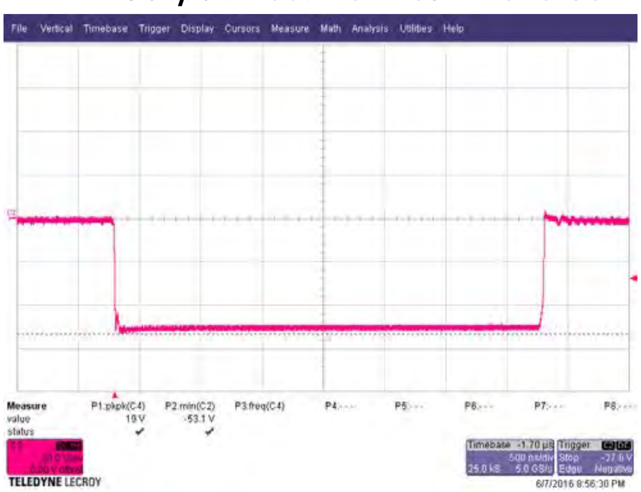

Figure 20 – Output Rectifier (D3) Reverse Voltage, 115 VAC input, 100% Load.
20 V, 500 ns / div.

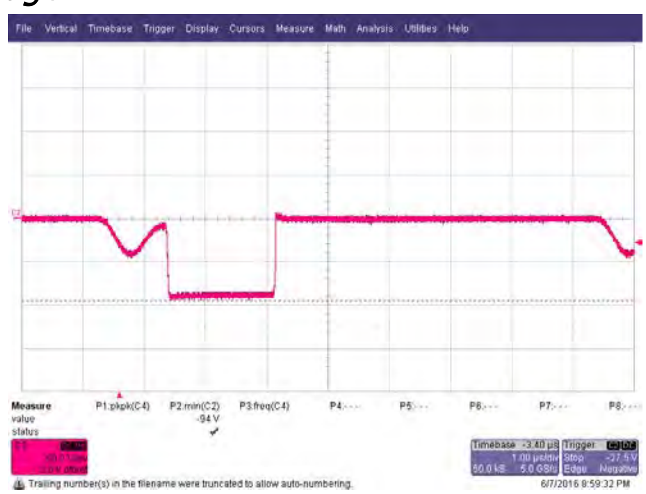

Figure 21 – Output Rectifier (D3) Reverse Voltage, 264 VAC, 100% Load.
50 V, 1 µs / div.

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12.3 Start-up Output Voltage / Current and Using Constant Current and Constant Voltage Output Loads

Figures 22-27 show the power supply output voltage/current start-up profiles. Figures 22-23 show the start-up into a constant current load, set to 2.8 A, comfortably below the supply current limit set point. This shows the start-up behavior of the supply in constant voltage mode. Figures 24-27 show the start-up behavior into a constant voltage load, showing the start-up behavior of the supply in constant current mode for two voltage set points.

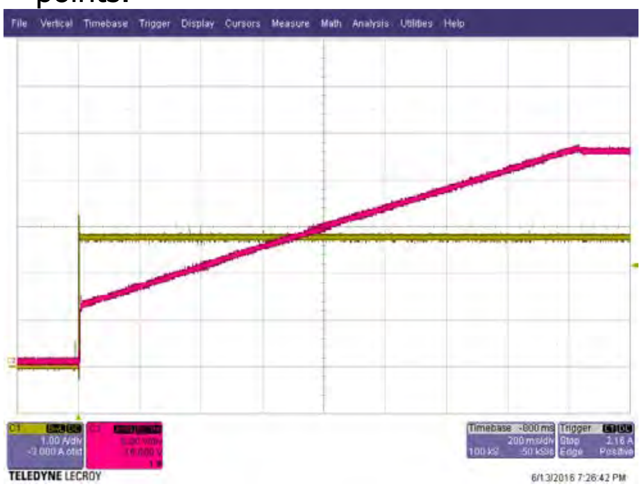

Figure 22 – Output Start-up, Constant Voltage Mode, 115 VAC, Chroma CC Load, 2.8 A Setting.
Upper: V_{OUT}, 5 V / div.
Lower: I_{OUT}, 1 A, 200 ms / div.

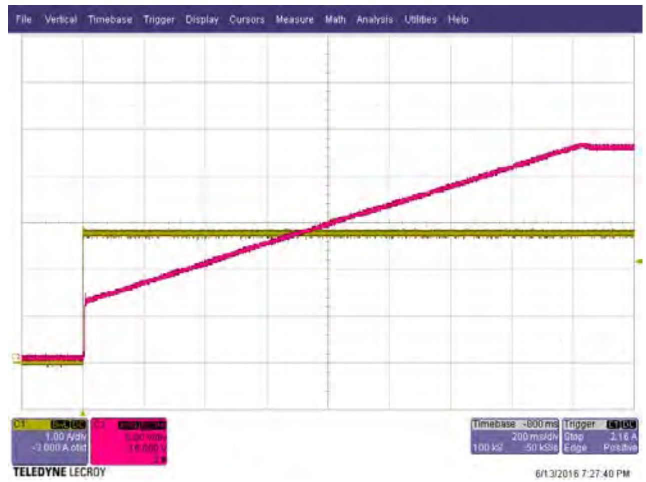

Figure 23 – Main Output Start-up, Constant Voltage Mode, 230 VAC, Chroma CC Load, 2.8 A Setting.
Upper: V_{OUT}, 5 V / div.
Lower: I_{OUT}, 1 A, 200 ms / div.

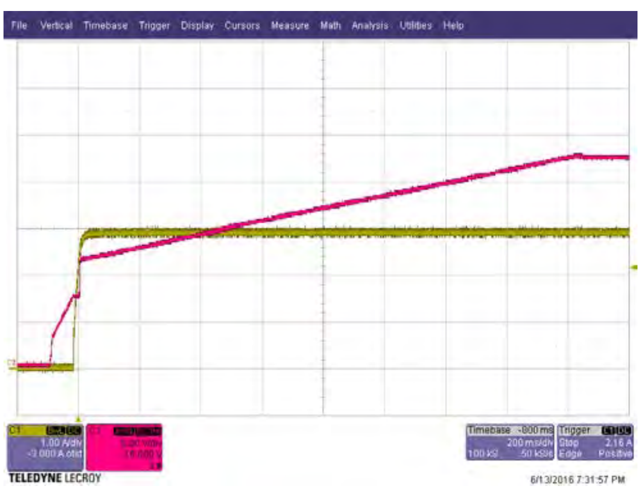

Figure 24 – Output Start-up, Constant Current Mode, 115 VAC, Chroma CV Load, 22 V Setting.
Upper: Main V_{OUT}, 5 V / div.
Lower: Main I_{OUT}, 1A, 200 ms / div.

Figure 25 – Output Start-up, Constant Current Mode. 230 VAC, Chroma CV Load, 22 V Setting.
Upper: Main V_{OUT}, 5 V / div.
Lower: Main V_{OUT} 1 A, 200 ms / div.

Figure 26 – Output Start-up, Constant Current Mode, 115 VAC, Chroma CV Load, 10 V Setting.
Upper: Main V_{OUT}, 2 V / div.
Lower: Main I_{OUT}, 1 A, 20 ms / div.

Figure 27 – Output Start-up, Constant Current Mode. 230 VAC, Chroma CV Load, 10 V Setting.
Upper: Main V_{OUT}, 2 V / div.
Lower: Main I_{OUT} 1 A, 20 ms / div.

12.4 Load Transient Response, Voltage Mode 50% -75% -50% Load Step

32 cycles of averaging were used on load transient waveforms to filter out ripple and better view actual output voltage excursion due to load transient.

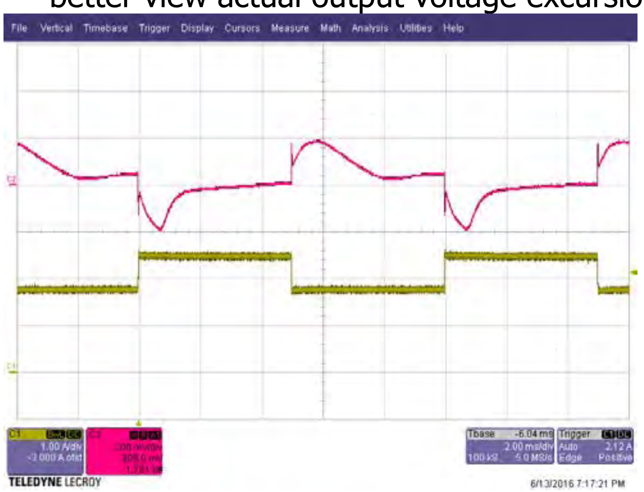

Figure 28 – Output Transient Response, CV Mode, 50%-75%-50% Load Step, 115VAC 115 VAC Input.
Upper: V_{OUT}, 200 mV / div.
Lower: Main Output I_{LOAD}, 1 A, 2 ms / div.

Figure 29 – Output Transient Response, CV Mode, 50%-75%-50% Load Step, 230 VAC Input.
Upper: V_{OUT}, 200 mV / div.
Lower: Main Output I_{LOAD}, 1 A, 2 ms / div.

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12.5 Output Ripple Measurements

12.5.1 Ripple Measurement Technique

For DC output ripple measurements a modified oscilloscope test probe is used to reduce spurious signals. Details of the probe modification are provided in the figures below.

Tie two capacitors in parallel across the probe tip of the 4987BA probe adapter. Use a 0.1 μF / 50 V ceramic capacitor and 1.0 μF / 100 V aluminum electrolytic capacitor. The aluminum-electrolytic capacitor is polarized, so always maintain proper polarity across DC outputs.

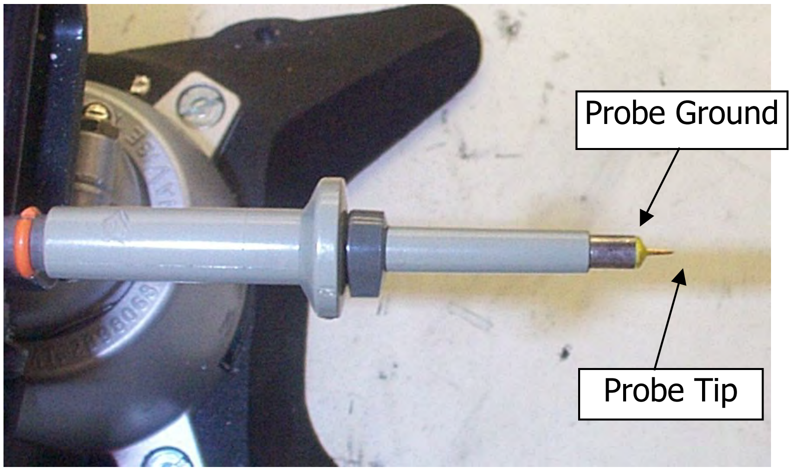

Figure 30 – Oscilloscope Probe Prepared for Ripple Measurement (End Cap and Ground Lead Removed).

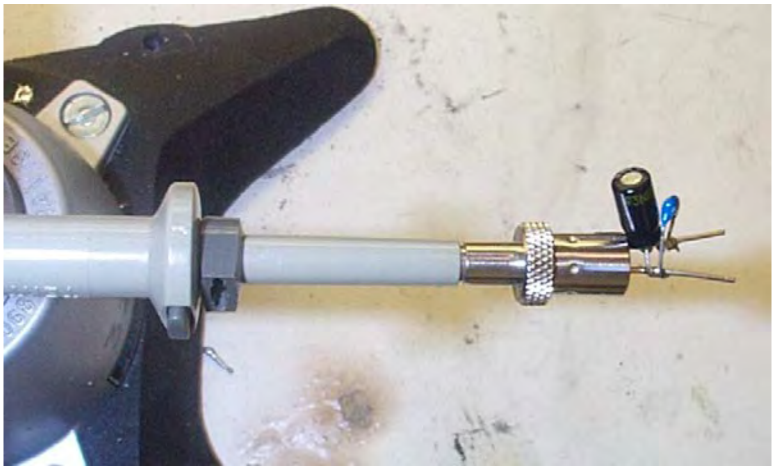

Figure 31 – Oscilloscope Probe with Probe Master 4987BA BNC Adapter (Modified with Wires for Probe Ground for Ripple measurement and Two Parallel Decoupling Capacitors Added).

12.5.2 Output Ripple Measurements

Measurements were taken for output ripple voltage and current with the supply operating in constant voltage mode with a constant current load, and for with the supply operating in CC mode. CC mode measurements were taken using a Chroma electronic load set in CV mode at 22 V, and 10 V CV settings. Output ripple voltage/current measurements were made using AC coupled voltage and current probes.

Figure 32 – Main Output Voltage Ripple, 115 VAC, CV Mode, Using Chroma CC Load, 2.8 A Setting.
Upper: Output V_{RIPPLE}, 200 mV / div.
Lower: I_{OUT} Ripple, 50 mA, 5 ms / div.

Figure 33 – Output Voltage and Current Ripple in CV Mode, 230 VAC, Chroma CC Load, 2.8 A Setting.
Upper: Output V_{RIPPLE}, 200 mV / div.
Lower: I_{OUT} Ripple, 50 mA, 5 ms / div.

Figure 34 – Main Output Voltage and Current Ripple in Constant Current Mode, 115 VAC, Chroma CV Load, 22 V Setting.
Upper: Main Output V_{RIPPLE}, 200 mV / div.
Lower:, I_{OUT} Ripple, 50 mA, 5 ms /div.

Figure 35 – Main Output Voltage and Current Ripple in Constant Current Mode, 230 VAC, Chroma CV Load, 22 V Setting.
Upper: Main Output V_{RIPPLE}, 200 mV / div.
Lower: I_{OUT} Ripple, 50 mA, 5 ms /div.

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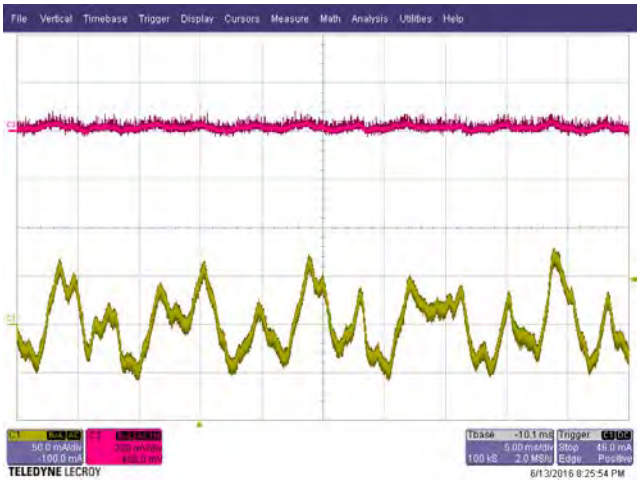

Figure 36 – Main Output Voltage and Current Ripple in Constant Current Mode, 115 VAC, Chroma CV Load, 10 V Setting.
Upper: Main Output V_{RIPPLE}, 200 mV / div.
Lower: I_{OUT} Ripple, 50 mA, 5 ms /div.

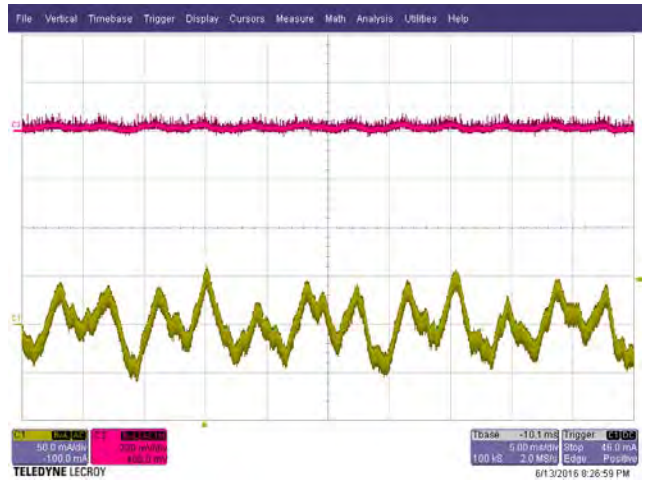

Figure 37 – Main Output Voltage and Current Ripple in Constant Current Mode, 230 VAC, Chroma CV Load, 10 V Setting.
Upper: Main Output V_{RIPPLE}, 200 mV / div.
Lower: I_{OUT} Ripple, 50 mA, 5 ms /div.

13 Temperature Profiles

The board was operated at room temperature, with output set at maximum using a Chroma electronic load with constant resistance setting. A constant resistance allows the output load to be set for maximum power output without having the main output drift into current limit and collapsing the output voltage, as can happen when a constant current load is used. The unit was allowed to thermally stabilize (~1 hr) before measurements were made.

13.1 Spot Temperature Measurements

Position	Temperature (°C)		
	90 VAC	**115 VAC**	**230 VAC**
AMB	21	21	21
L2 (CM Choke)	57.1	50.6	41.7
BR1	71.2	57.4	44.8
D1 (Primary Snubber)	58.9	47.9	53.8
R4 (Primary Snubber)	66.6	53.8	40.2
VR1 (Primary Snubber)	61	50.7	40.8
U1	84.1	65.8	53.6
T1	64.1	65.2	72.8
D3 (Output Rectifier)	75	72.5	75.6
R11 (Secondary Snubber)	70.4	73.7	93.5
R14/15 (Current Sense)	62.8 / 63.1	62.7 / 61.3	64.6 / 62.6

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13.1.1 115 VAC, 60 Hz, 100% Load Overall Temperature Profile

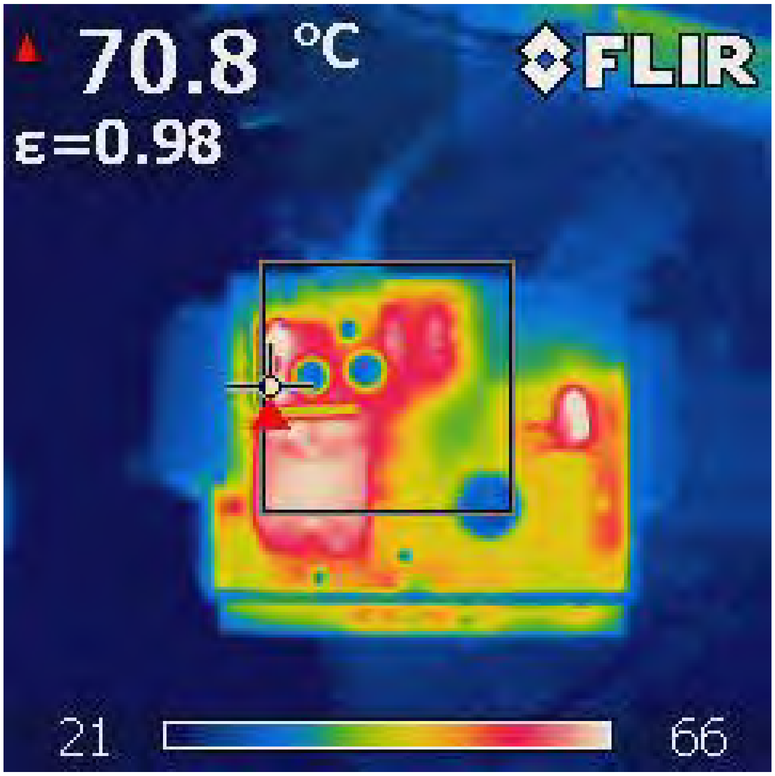

Figure 38 – Top View Thermal Picture, 115 VAC.

14 Gain-Phase

14.1 Main Output Constant Voltage Mode Gain-Phase

For these measurements the electronic load was set to constant current mode, with the output current just below the current limit (~3 A), in order to determine the characteristics of the voltage regulation loop. Measurements were taken at 90 VAC, 115 VAC, and 230 VAC. To get the phase margin, the displayed phase measurement is subtracted from 180°.

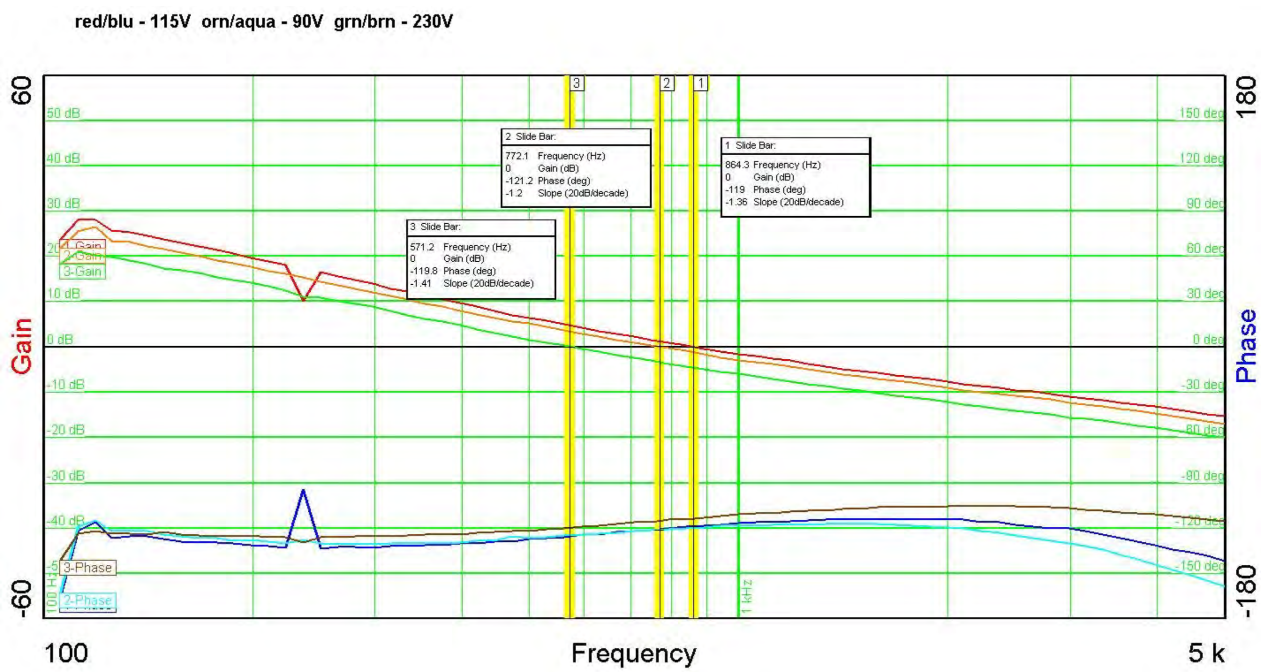

Figure 39 – Main Output Gain-Phase, Voltage Loop, Chroma Constant Current Load Set to 3 ADC.
Orn/Aqua – 90 VAC Gain and Phase Crossover Frequency – 772 Hz, Phase Margin – 59°.
Red/Blu – 115 VAC Gain and Phase Crossover Frequency – 864 Hz, Phase Margin – 61°.
Grn/Brn – 230 VAC Gain and Phase Crossover Frequency – 571 Hz, Phase Margin – 60°.

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14.2 Main Output Constant Current Mode Gain-Phase

Current loop gain-phase was tested using a Chroma electronic load set to constant voltage mode at two set points - 22 V and 10 V, obtaining the gain-phase measurements for two widely separated points on the V-I characteristic curve. Using a CV load maximizes the CC loop gain (worst case for control loop) and simulates operating while charging a low impedance load like a battery. Using the constant resistance setting for the electronic load will yield overly optimistic results for gain-phase measurements and for determining component values for frequency compensation. Measurements were taken at 90 VAC, 115 VAC, and 230 VAC for each output voltage setting. To get the phase margin, the displayed phase measurement is subtracted from 180°.

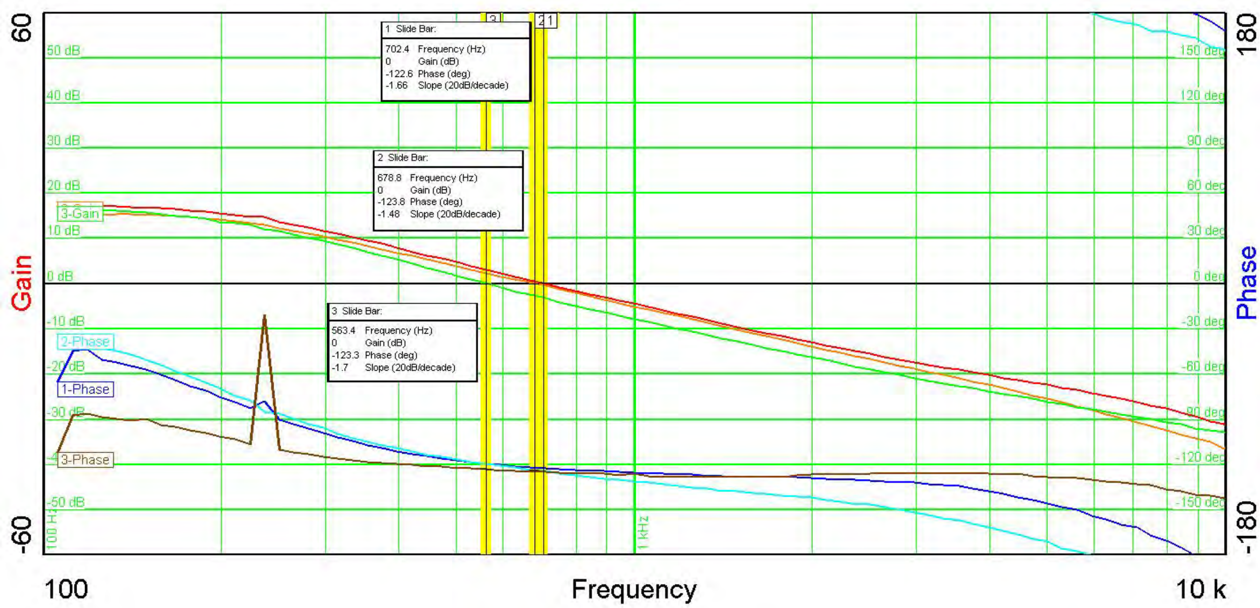

Figure 40 – Main Output Gain-Phase, Current Loop, Chroma Constant Voltage Load Set to 22 VDC.
Orn/Aqua – 90 VAC Gain and Phase Crossover Frequency – 679 Hz, Phase Margin – 56°.
Red/Blu – 115 VAC Gain and Phase Crossover Frequency – 702 Hz, Phase Margin – 57°.
Grn/Brn – 230 VAC Gain and Phase Crossover Frequency – 563 Hz, Phase Margin – 57°.

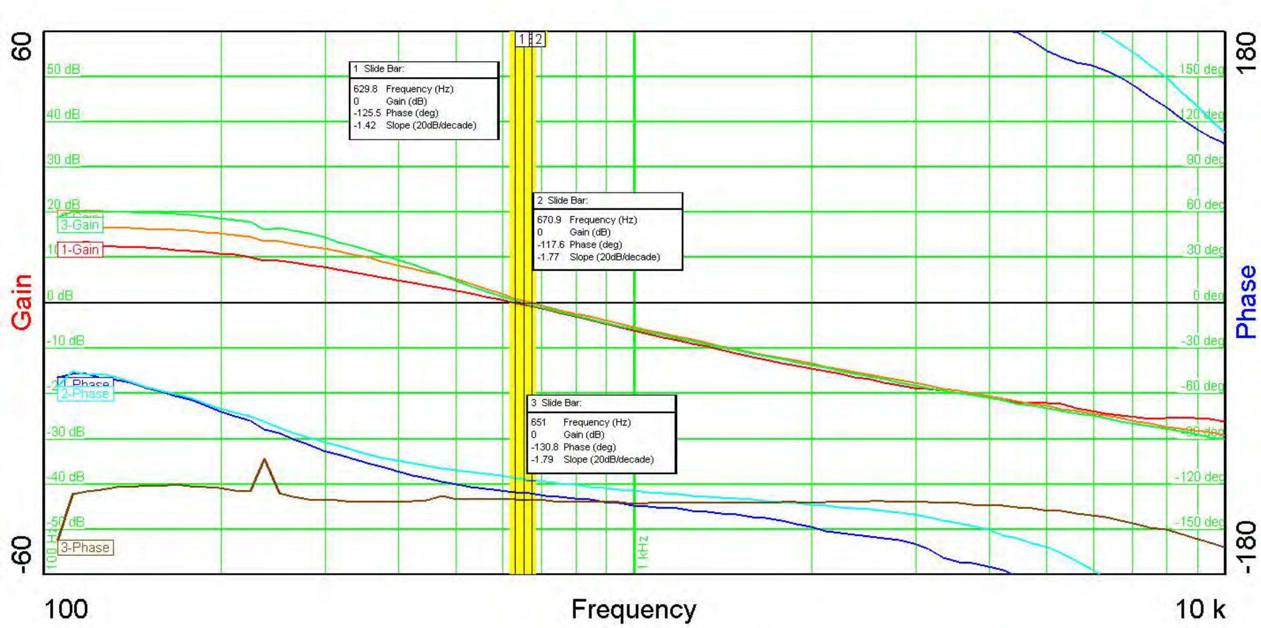

Figure 41 – Main Output Gain-Phase, Current Loop, Chroma Constant Voltage Load Set to 10 VDC.
Orn/Aqua – 90 VAC Gain and Phase Crossover Frequency – 671 Hz, Phase Margin – 62°.
Red/Blu – 115 VAC Gain and Phase Crossover Frequency – 630 Hz, Phase Margin – 54.5°.
Grn/Brn – 230 VAC Gain and Phase Crossover Frequency – 651 Hz, Phase Margin – 49°.

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15 Conducted EMI

Conducted EMI tests were performed using a 9Ω floating resistive load. An actual 2-wire input cord was used for EMI measurements.

Figure 42 – EMI Set-up with Floating Resistive Load.

15.1 Conducted EMI Scan

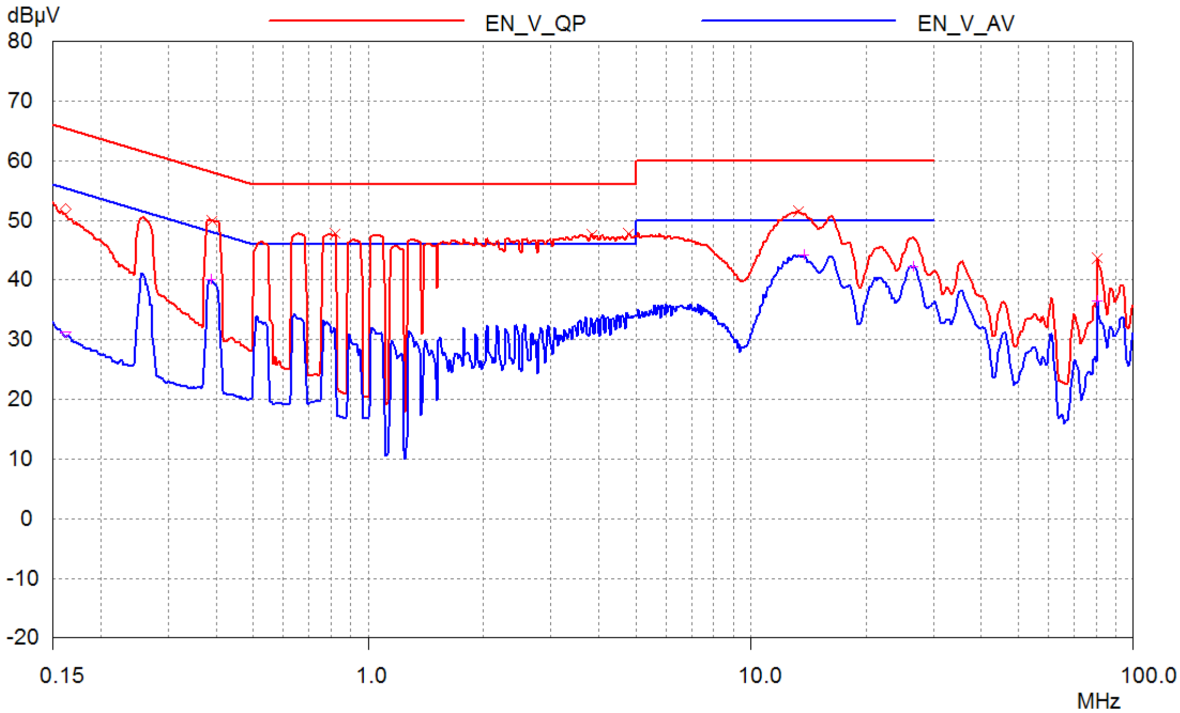

Figure 43 – Conducted EMI, 115 VAC, 9 Ω Floating Resistive Load.

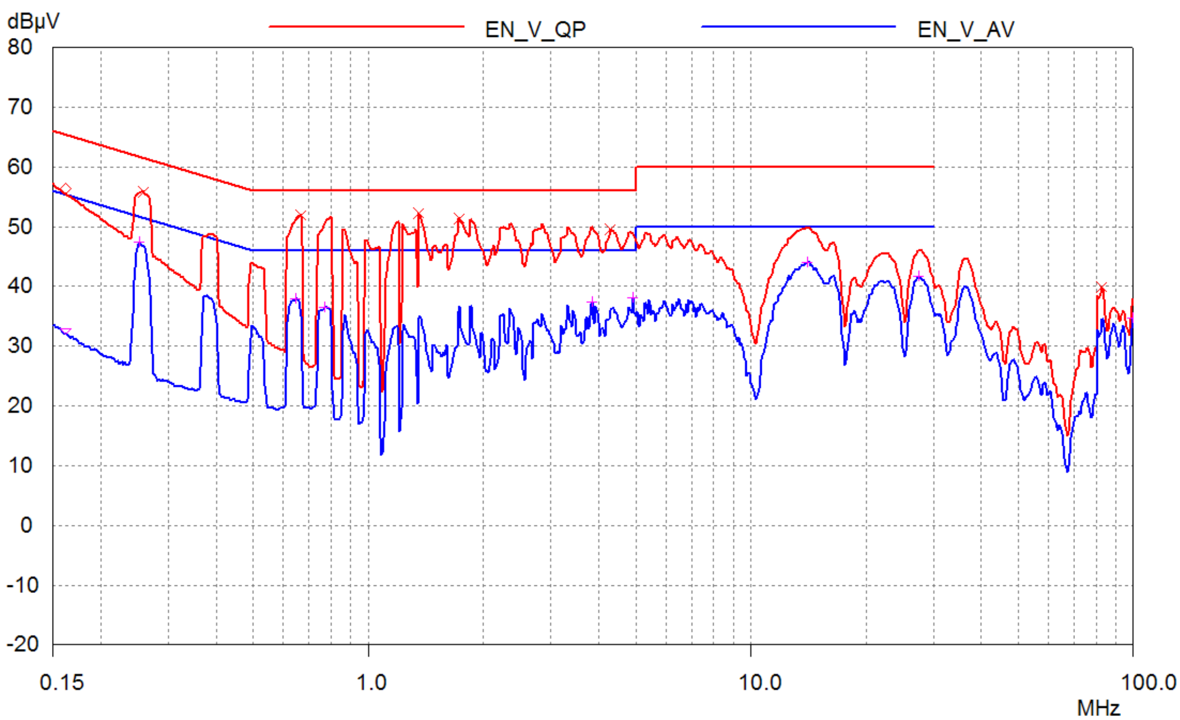

Figure 44 – Conducted EMI, 230 VAC, 9 Ω Floating Resistive Load.

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16 Revision History

Date	Author	Revision	Description & changes	Reviewed
02-Aug-16	RH	1.0	Initial Release.	Apps & Mktg
10-Aug-16	RH	1.1	Text Updates.	

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

Patent Information

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95138, USA.
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
e-mail: usasales@power.com

GERMANY
Lindwurmstrasse 114
80337, Munich
Germany
Phone: +49-895-527-39110
Fax: +49-895-527-39200
e-mail: eurosales@power.com

JAPAN
Kosei Dai-3 Building
2-12-11, Shin-Yokohama,
Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033
Japan
Phone: +81-45-471-1021
Fax: +81-45-471-3717
e-mail: japansales@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
Fax: +886-2-2659-4550
e-mail:
taiwansales@power.com

CHINA (SHANGHAI)
Rm 2410, Charity Plaza, No. 88,
North Caoxi Road,
Shanghai, PRC 200030
Phone: +86-21-6354-6323
Fax: +86-21-6354-6325
e-mail: chinasales@power.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
Fax: +91-80-4113-8023
e-mail: indiasales@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
Fax: +82-2-2016-6630
e-mail: koreasales@power.com

UK
Cambridge Semiconductor,
a Power Integrations company
Westbrook Centre, Block 5,
2nd Floor
Milton Road
Cambridge CB4 1YG
Phone: +44 (0) 1223-446483
e-mail: eurosales@power.com

CHINA (SHENZHEN)
17/F, Hivac Building, No. 2, Keji
Nan 8th Road, Nanshan District,
Shenzhen, China, 518057
Phone: +86-755-8672-8689
Fax: +86-755-8672-8690
e-mail: chinasales@power.com

ITALY
Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni (MI)
Italy
Phone: +39-024-550-8701
Fax: +39-028-928-6009
e-mail: eurosales@power.com

SINGAPORE
51 Newton Road,
#19-01/05 Goldhill Plaza
Singapore, 308900
Phone: +65-6358-2160
Fax: +65-6358-2015
e-mail: singaporesales@power.com