Design Example Report

Title	***300 W Forward Power Supply Using HiperPFS™-3 PFS7528H and HiperTFS™-2 TFS7706H***
Specification	90 VAC – 264 VAC Input; 280 W (61 V (Nom.) at 0 – 4.59 A) CV/CC Output; 20 W (5 V / 4 A) Standby Output
Application	Battery Charger
Author	Applications Engineering Department
Document Number	DER-484
Date	October 26, 2017
Revision	1.2

Summary and Features

- Integrated forward power stage and flyback standby for a very low component count design
- 90-264 VAC input range with PFC
- >87% full load efficiency
- Compact size
- >0.96 PF at 20% load
- Low no-load input power
- Excellent CV regulation
- Excellent CC regulation

PATENT INFORMATION
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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.

1 Introduction

This engineering report describes a 61 V (nominal), 280 W power supply reference design operating from 90-264 VAC. A 5 V, 4 A standby output is also provided. The power supply main output is designed with a constant voltage/ constant current characteristic for use in battery charger applications.

The design is based on the PFS7528H and TFS7707H, with the main forward stage operating at 66 kHz.

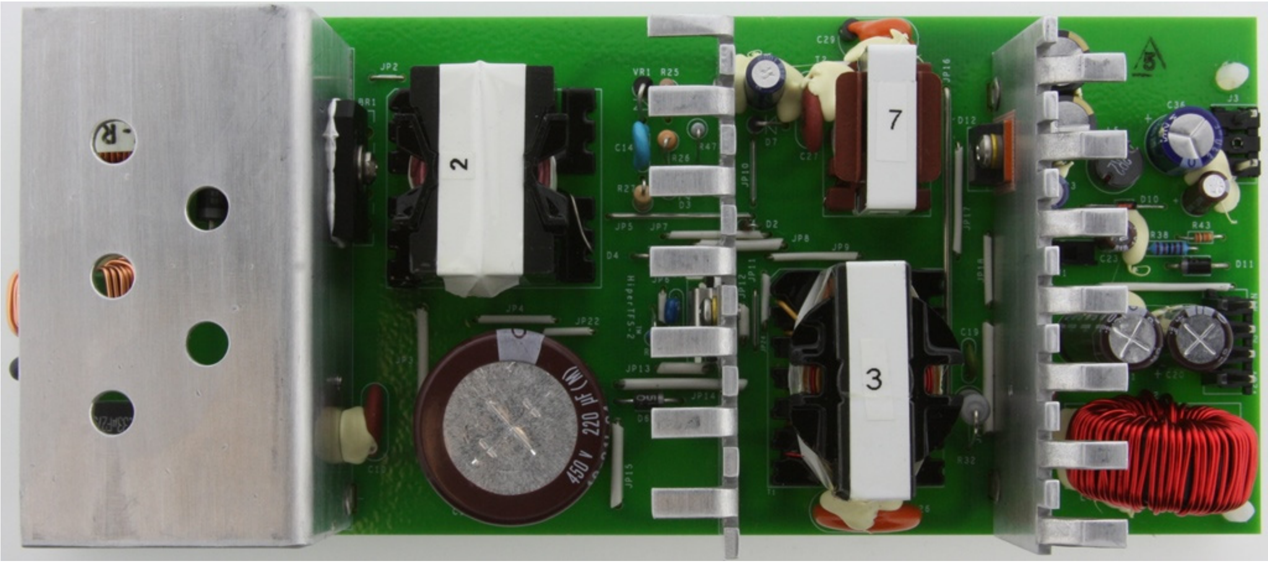


Figure 1 – DER-484 Photograph, Top View.

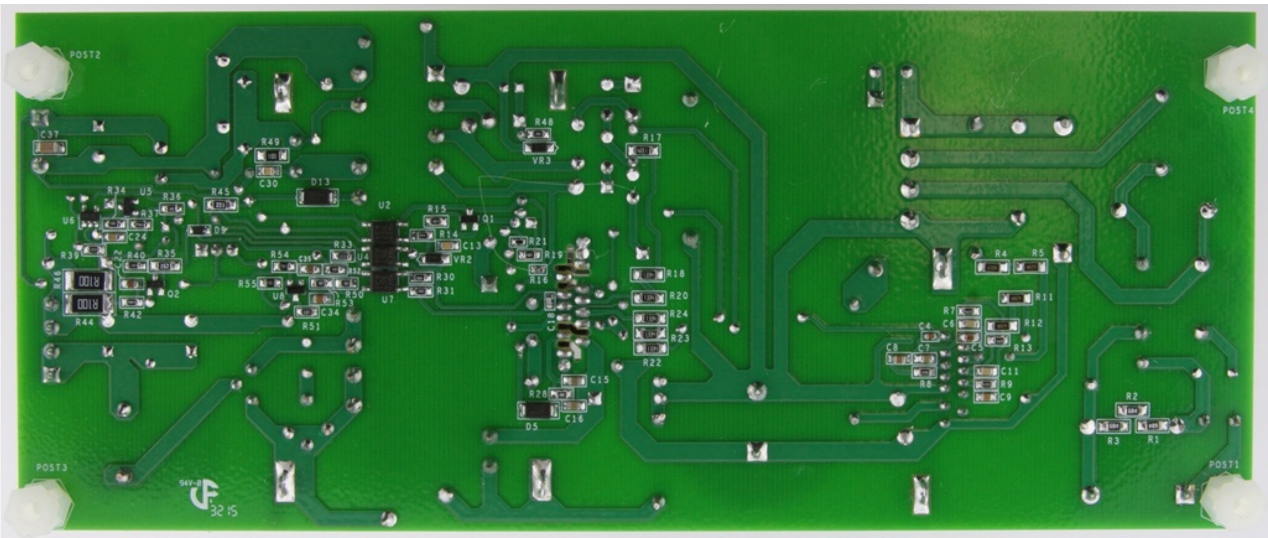


Figure 2 – DER-484 Photograph, Bottom View.

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. Detailed customer specification is shown below.

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_O	0	61		V	61 VDC (nominal – otherwise defined by battery load).
Output Current	I_O		4.59		A	Nominal Current Limit Setting for Design.
Standby Converter Output						
Output Voltage	V_O	4.75	5.00	5.25	V	5 VDC ±5%
Output Current	I_O	0		4	A	
Output Ripple (Optional)				50	mV P-P	20 MHz BW
Total Output Power						
Continuous Output Power	P_{OUT}		300		W	61 V / 4.59 A + 5 V / 4 A
Peak Output Power	$P_{OUT(PK)}$			N/A	W	
Efficiency						
Total system at Full Load	η_{Main}	85	87.8		%	Measured at 115 VAC, Full Load
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950 / UL1950 Class II				
Ambient Temperature	T_{AMB}	0		60	^{o}C	See Thermal Section for Conditions

3 Schematic

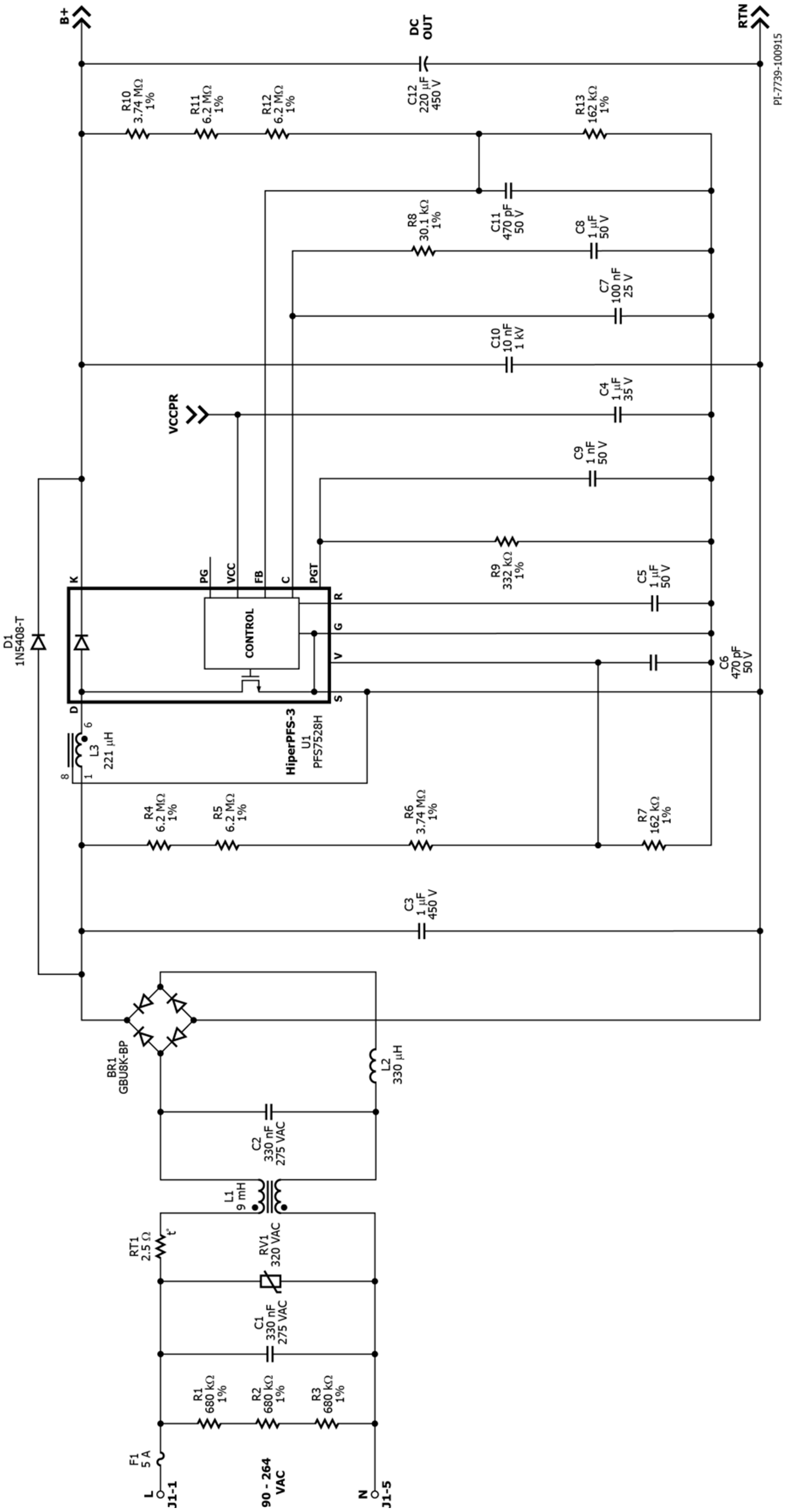


Figure 3 – Schematic Battery Charger Application Circuit - Input Filter, PFC Stage.

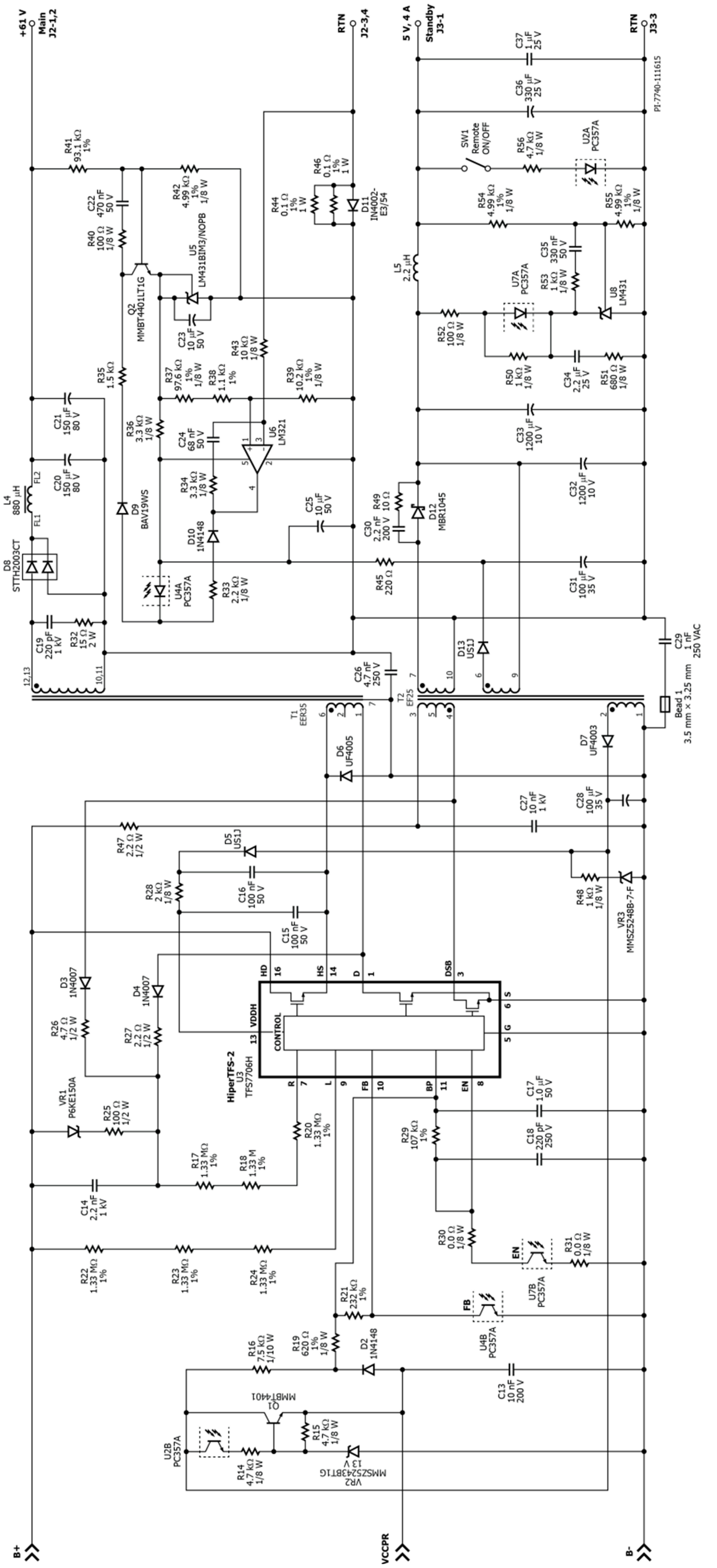


Figure 4 – Schematic Battery Charger Application Circuit - Forward Stage, Standby Supply, Bias Supplies and Output Voltage/Current Control.

4 Circuit Description

The schematic in Figures 3 and 4 shows a 2-switch forward power supply with flyback standby utilizing the TFS7706H, powered via a PFC front end utilizing the PFS7528H. The secondary control circuitry provides CV/CC control for use in battery charger applications

4.1 Input Filter / Boost Converter

The PFC input stage shown in Figure 3 is designed around the Power Integrations PFS7528H integrated PFC controller. This design provides a regulated output voltage of 385 VDC nominal, maintaining a high input power factor and overall efficiency over line and load, while remaining low in cost.

4.1.1 Input EMI Filter and Rectifier

Fuse F1 provides protection to the primary side circuitry and isolates it from the AC supply in the event of a fault. Diode bridge BR1 rectifies the AC input. Capacitors C1, C2, C26 and C29 in conjunction with inductors L1 and L2 constitute the EMI filter for attenuating both common mode and differential mode conducted noise. Film capacitor C3 provides input decoupling charge storage to reduce input ripple current at the switching frequencies and harmonics.

Resistors R1-R3 discharge the EMI filter capacitors after line voltage has been removed from the circuit.

Metal oxide varistor (MOV) RV1 protects the circuit during line surge events by effectively clamping the input voltage seen by the power supply.

4.1.2 PFS7528H Boost Converter

The boost converter stage consists of the boost inductor L3 and the PFS7528H IC (U1). This converter stage operates as a PFC boost converter, thereby maintaining a sinusoidal input current to the power supply while regulating the output DC voltage.

During start-up, diode D1 provides an inrush current path to the PFC output filter/bulk capacitor C12, bypassing the switching inductor L3 and switch U1 in order to prevent a resonant interaction between the switching inductor and output capacitor.

NTC thermistor RT1 limits inrush current of the supply when line voltage is first applied. Capacitor C10 provide a short, high-frequency return path to RTN for improved EMI results and to reduce U1 MOSFET drain voltage overshoot during turn-off. Capacitor C4 decouples and bypasses the U1 VCC pin. Capacitor C12 serves as output filter and energy storage for the PFC output.

Resistor R9 programs the output voltage level [via the POWER GOOD THRESHOLD (PGT) pin] below which the POWER GOOD (PG) pin will go into a high-impedance state.

Capacitor C5 on the REF pin of U1 is a noise decoupler for the internal reference and also programs the output power for either full mode, 100% of rated power [C10 = 1 μF] or efficiency mode, 80% [C10 = 0.1 μF] of rated power.

4.1.3 Input Feed Forward Sense Circuit

The input voltage of the power supply is sensed by the IC U1 using resistors R4-R7. Capacitor C6 bypasses the V pin on IC U1.

4.1.4 Output Feedback

Resistors R10-R13 constitute a voltage divider that provides a scaled voltage proportional to the output voltage as feedback to the controller IC U1, setting the PFC output voltage at 385 V. Capacitor C11 decouples the U1 FB pin.

Resistor R8 and capacitor C8 establish the control loop dominant pole, while C7 attenuates high-frequency noise.

4.2 Main Forward Converter / Standby

The schematic in Figure 4 depicts a 61 V, 280 W Forward DC-DC converter with constant voltage/ constant current output implemented using the TFS7706H.

Integrated circuit U3 incorporates the control circuitry, drivers and output MOSFETs necessary for a 2-switch forward converter and a flyback standby converter.

Components D3-4, C14, R25-27, and VR1 form a shared turn-off clamping circuit that limits the voltage at the U3 standby drain and establishes a higher-than-B+ reset voltage for T1 to allow a maximum duty cycle above 50%. Zener VR1 provides a defined clamp voltage and maintains a maximum voltage (150 V) on clamp capacitor C14 for higher light/no-load efficiency. The high side drain is clamped by D6.

Diode D5 provides biasing for the main converter high-side driver in U3, filtered and current limited by C15-16 and R28.

Most of the leakage and magnetizing energy associated with the main and standby converters is returned back to the B+ supply due to the slow recovery aspect of blocking diodes D3 and D4. During the main converter off-time, the main transformer is reset by a substantially higher voltage than V_{IN}, hence the main converter can operate above 50% duty cycle, lowering RMS switch currents without penalizing holdup time.

The BYPASS (BP) pin along with C17 provides a decoupled regulated 5.85 V for the HiperTFS controller. The value for C17 (1 μF) also selects the operating frequency of the main converter at 66 kHz. At start-up the bypass capacitor is charged from a current source internal to U3. When the BP pin voltage reaches 5.8 V, the standby converter can begin switching and both the secondary and primary-side bias voltages will begin to rise.

Output of the primary bias winding on T2 is used to supply power via resistors R16 and R19 to the HiperTFS BP pin during standby-only operation. Additional current is provided via a regulator consisting of Q1, R14-15, VR2, and C13 by the primary bias supply when remote-on switch SW1 activates U2A and U2B. The value of R19 is selected to satisfy the maximum current requirement of U3. The value of R16 is selected to maintain the minimum 700 μA required into the BP pin to inhibit the internal HiperTFS high voltage current source and thus reduce no-load consumption.

The ENABLE (EN) pin is the feedback pin for the flyback standby controller section. Prior to start-up a resistor (R29) connected from EN to BP can be detected by the controller to select the internal current limit for standby section. The circuit presented here uses a 107 kΩ resistor (R29) at the EN pin to program a standby I_{LIM} of 750 mA (maximum). A capacitor (C18) is placed between EN and G to filter high frequency noise and help prevent pulse bunching, especially at maximum output power.

The FEEDBACK (FB) pin uses a 232 kΩ pull-up resistor (R21) to the BP pin, which selects the maximum primary current limit option for the U1 main forward converter. The FB pin provides feedback for the main converter. An increase in current sinking from FB pin to ground will reduce the operating duty cycle.

Capacitor C15 is the filtering and charge storage capacitor for the U1 high-side driver. During start-up the high-side MOSFET HS pin of U3 is briefly pulled to Source for 12 ms to precharge C5 using an internal current source. The nominal voltage on C5 during normal operation is internally shunt regulated to approximately 12 V. Components D5, C16, and R28 provide an efficient alternate source of current from the primary VCC supply, so that the internal high voltage supply for the high-side driver is turned off. This increases efficiency at light load and prevents main converter from pulse skipping, especially at light output loads.

Resistors R17-18 and R20 are used to translate the maximum available OFF time reset voltage into a current for the R pin and compare with the L pin current to compute the maximum allowable duty cycle to prevent saturation and to also determine the maximum allowable duty factor as a function of peak on-time flux.

The LINE-SENSE (L) pin provides an input bulk voltage line-sense function. This information is used by the undervoltage and overvoltage detection circuits for both the Main and standby sections. This pin can also be pulled down to Source to implement a remote-ON/OFF for both the standby and main supplies simultaneously. Resistors R22-R24 are used to translate the input voltage into a current for the L pin.

Components R56, SW1, and U2 (on the standby converter secondary output) provide remote start. When SW1 is closed, the output transistor of U2 turns on regulator Q1 on the primary side of the supply, providing operating current to the main converter via the BP pin of U3. Opening SW1 turns off U2, shutting down the main converter function of U3, as well as U1.

4.3 Primary Bias Supply

The standby supply utilizes built-in capability of the U3 TFS2 device. Components D7 and C28 provide a 15 V (nominal) flyback bias supply for U1 and U3, generated from a primary-referred winding on standby transformer T2. Components R48 and VR3 clamp the primary VCC output voltage when the 5V standby supply is heavily loaded.

4.4 Main Output Rectification

The output of transformer T1 is rectified and filtered by D8, L4, and C20-21. Output rectifier D8 is a 300V ultrafast rectifier chosen for high efficiency. A snubber consisting of R32 and C19 helps limit the peak voltage excursion on the output rectifier.

4.5 Output Current and Voltage Control

Output current is sensed via resistors R44-45. These resistors are clamped by diode D11 to avoid damage to the current control circuitry during an output short circuit. Components R36 and U5 provide a voltage reference for current sense amplifier U6. Capacitor C25 stabilizes U6. The reference voltage for current sense amplifier U6 is divided down by R37-39. The default current limit setting is 4.589 A, as programmed by R44-45 and R37-39. Voltage from the current sense resistors is applied to the inverting input of U6 via R43. Opamp U6 drives optocoupler U4 through D10 and R33. Components R33-34, R43, and C24 are used for frequency compensation of the current loop.

Components Q2, R40-42, and C22 are used for output constant voltage control when the current limit is not engaged. Transistor Q2 drives optocoupler U4 via D9 and R35. Components R35, R40-42, and C22 affect the voltage control loop frequency compensation.

4.6 Standby Output

A 5 V, 4 A standby output is provided via a triple insulated winding on standby transformer T2. The standby 5 V output is available externally. The 5 V standby winding is rectified and filtered by D12, C32-33, and C36. Components L5 and C36 provide additional filtering to remove high frequency ripple and noise. Snubber C30 and R49 helps limit the peak voltage excursion on D12. The 5 V output is divided down by R54-55, and is applied to the reference input of error amplifier U8, which controls the standby section of U3 via R52 and U7. Resistor R50 provides bias current to U8, while C34 and R51 comprise a soft-finish network to eliminate output voltage overshoot at start-up. Components R52-53, and C35 compensate the standby control loop.

4.7 Secondary Bias Supply

Bias for the secondary control circuitry is supplied from a triple insulated winding on standby transformer T2. This winding is DC stacked on the 5 V standby output to improve regulation for the secondary bias supply. Otherwise, the bias voltage can vary considerably depending on the 5 V standby load, which can be any value form 0 A to 4 A. The standby supply is rectified and filtered by D13 and C31, with additional filtering by R45 and C25.

5 PCB Layout

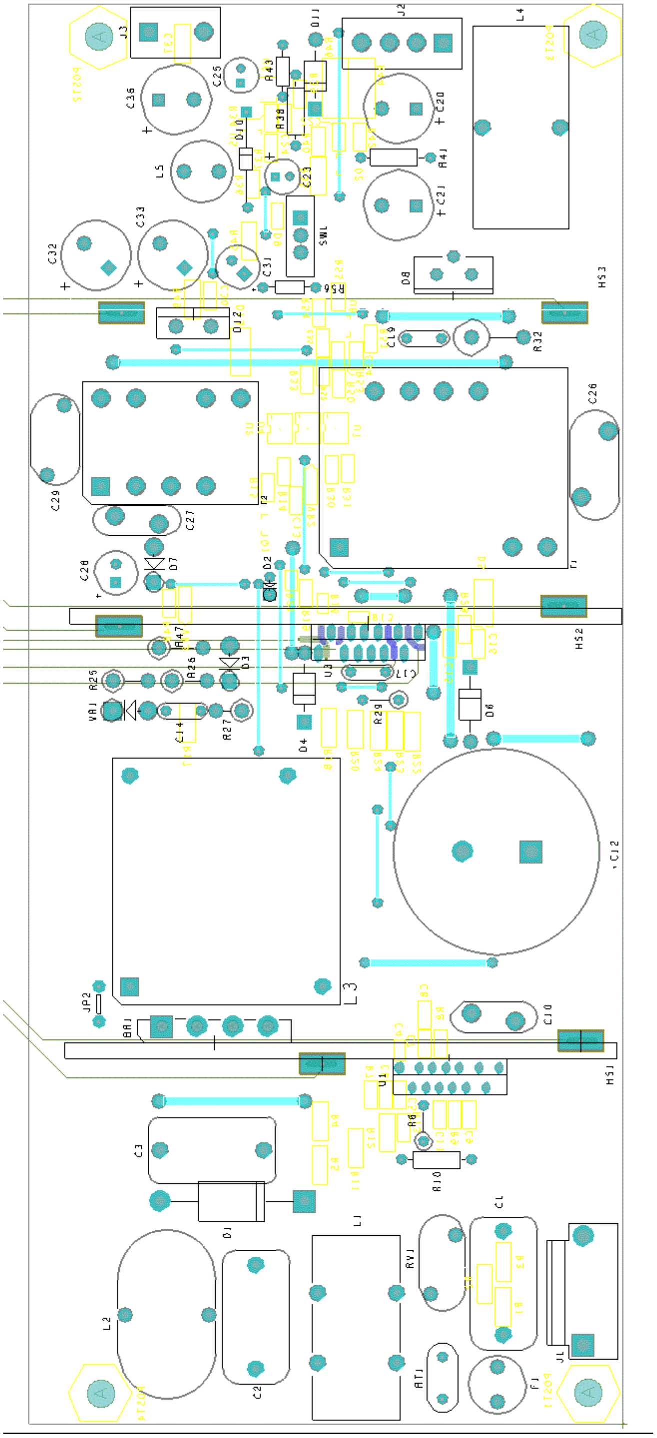


Figure 5 – Printed Circuit Layout, Showing Top Side Components with Bottom Side Traces.

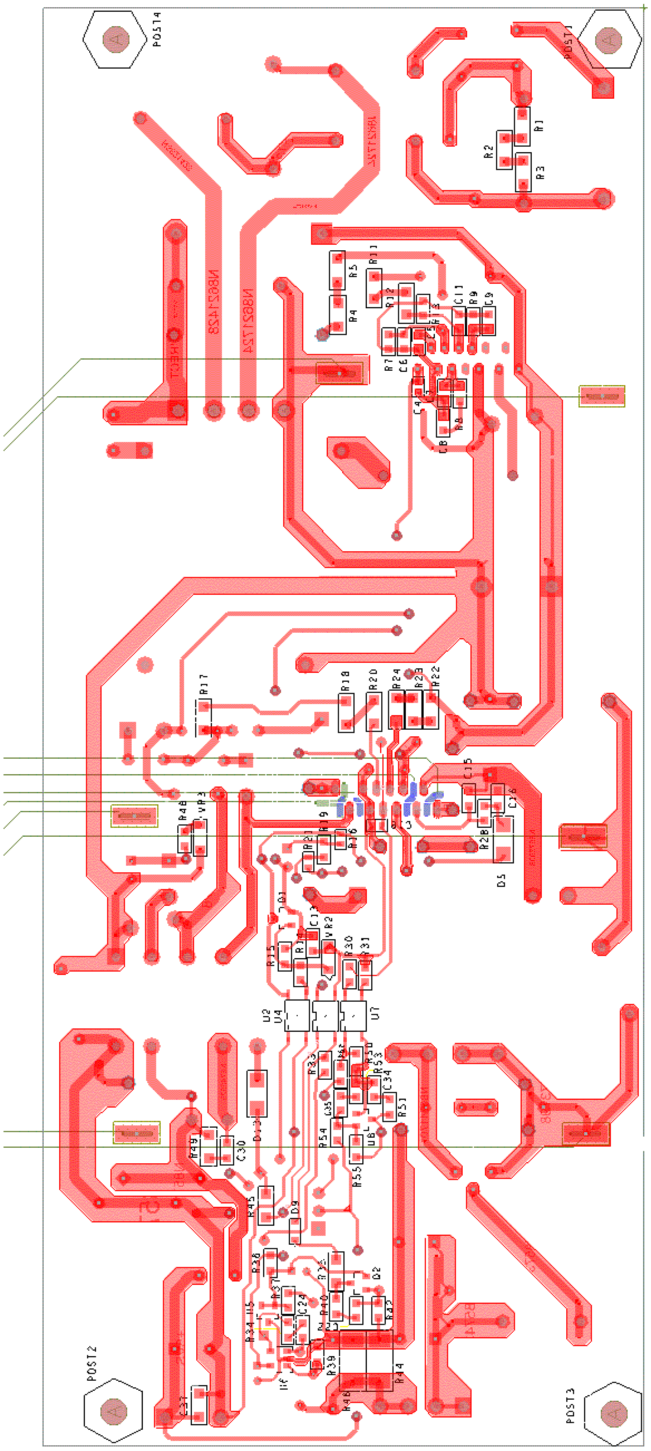


Figure 6 – Printed Circuit Layout, Bottom Side Traces and Components.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BEAD1	3.5 mm D x 3.25 L mm, 21 Ω at 25 MHz, 1.6 mm (.063) hole, Ferrite Bead	2643001501	Fair-Rite
2	1	BR1	800 V, 8 A, Bridge Rectifier, GBU Case	GBU8K-BP	Micro Commercial
3	2	C1 C2	330 nF, 275 VAC, Film, X2	ECQ-U2A334ML	Panasonic
4	1	C3	1.0 μF, 450 V, METALPOLYPRO	ECW-F2W105JA	Panasonic
5	1	C4	1 μf 35 V, Ceramic, X7R, 0603	C1608X7R1V105M	TDK
6	2	C5 C8	1 μF, 50 V, Ceramic, X7R, 0805	C2012X7R1H105M	TDK
7	2	C6 C11	470 pF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB471	Yageo
8	1	C7	100 nF, 25 V, Ceramic, X7R, 0805	08053C104KAT2A	AVX
9	1	C9	1 nF, 50 V, Ceramic, X7R, 0805	08055C102KAT2A	AVX
10	2	C10 C27	10 nF, 1 kV, Disc Ceramic	562R5HKMS10	Vishay
11	1	C12	220 μF, 450 V, Electrolytic, Snap-In, (30 x 30)	EKMQ451VSN221MR30S	United Chemi-con
12	1	C13	10 nF, 200 V, Ceramic, X7R, 0805	08052C103KAT2A	AVX
13	1	C14	2.2 nF, 1 kV, Ceramic, SL, 0.2" L.S.	DEBB33A222KA2B	Murata
14	2	C15 C16	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
15	1	C17	1.0 μF, 50 V, Ceramic, X7R	FK20X7R1H105K	TDK
16	1	C18	220 pF, 250 V, Ceramic, COG, 0603	C1608C0G2E221J	TDK
17	1	C19	220 pF, 1 kV, Disc Ceramic	NCD221K1KVY5FF	NIC
18	2	C20 C21	150 μF, 80 V, Electrolytic, Gen. Purpose, (10 x 33)	UPJ1K151MPD	Nichicon
19	1	C22	470 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H474KA88L	Murata
20	2	C23 C25	10 μF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG500ELL100ME11D	Nippon Chemi-Con
21	1	C24	68 nF, 50 V, Ceramic, X7R, 0805	C0805C683K5RACTU	Kemet
22	1	C26	4.7 nF, Ceramic, Y1	440LD47-R	Vishay
23	2	C28 C31	100 μF, 35 V, Electrolytic, Low ESR, 180 mΩ, (6.3 x 15)	ELXZ350ELL101MF15D	Nippon Chemi-Con
24	1	C29	1 nF, Ceramic, Y1	440LD10-R	Vishay
25	1	C30	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
26	2	C32 C33	1200 μF, 10 V, Electrolytic, Radial	EEU-FM1A122	Panasonic
27	1	C34	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
28	1	C35	330 nF, 50 V, Ceramic, X7R, 0805	GRM219R71H334KA88	Murata
29	1	C36	330 uF, 25 V, Electrolytic, Low ESR, 90 mΩ, (10 x 12.5)	ELXZ250ELL331MJC5S	Nippon Chemi-Con
30	1	C37	1 μF, 25 V, Ceramic, X7R, 1206	C3216X7R1E105K	TDK
31	1	D1	1000 V, 3 A, Rectifier, DO-201AD	1N5408-T	Diodes, Inc.
32	2	D2 D10	75 V, 300 mA, Fast Switching, DO-35	1N4148TR	Vishay
33	2	D3 D4	1000 V, 1 A, Rectifier, DO-41	1N4007-E3/54	Vishay
34	2	D5 D13	Diode Ultrafast, SW 600 V, 1 A, SMA	US1J-13-F	Diodes, Inc.
35	1	D6	600 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	UF4005-E3	Vishay
36	1	D7	200 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	UF4003-E3	Vishay
37	1	D8	300 V, 10 A, Diode ARRAY, GP, 35 ns, TO-220AB	STTH2003CT	ST Miscrs
38	1	D9	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
39	1	D11	100 V, 1 A, Rectifier, DO-41	1N4002-E3/54	Vishay
40	1	D12	45 V, 10 A, Schottky, TO-220AC	MBR1045	Vishay
41	2	ESIPCLIP M4 METAL1 ESIPCLIP M4 METAL2	Heat Sink Hardware, Edge Clip, 20.76 mm L x 8 mm W x 0.015 mm Thk	NP975864	Aavid Thermalloy
42	1	F1	5 A, 250 V, Slow, TR5	37215000411	Wickman
43	1	HOTMELT_V?	Adhesive, Hot Melt, VO	3748 VO-TC	3M
44	1	HS1	FAB, Heat Sink, PFS Bridge, DER484		Custom
45	1	HS2	FAB, Heat Sink, PFS eSIP, DER484		Custom
46	1	HS3	FAB, Heat Sink, PFS Diode, DER484		Custom
47	1	J1	5 Position (1 x 5) header, 0.156 pitch, Vertical	0026604050	Molex

48	1	J2	4 Position (1 x 4) header, 0.156 pitch, Vertical	26-48-1045	Molex
49	1	J3	3 Position (1 x 3) header, 0.156 pitch, Vertical	26-48-1031	Molex
50	2	JP1 JP14	Wire Jumper, Insulated, TFE, #18 AWG, 0.9 in	C2052A-12-02	Alpha
51	1	JP2	Wire Jumper, Non insulated, #22 AWG, 0.2 in	298	Alpha
52	3	JP3 JP19 JP24	Wire Jumper, Insulated, TFE, #18 AWG, 0.8 in	C2052A-12-02	Alpha
53	1	JP4	Wire Jumper, Insulated, #24 AWG, 0.6 in	C2003A-12-02	Gen Cable
54	1	JP5	Wire Jumper, Non insulated, #22 AWG, 1.0 in	298	Alpha
55	2	JP6 JP22	Wire Jumper, Insulated, #24 AWG, 0.3 in	C2003A-12-02	Gen Cable
56	2	JP7 JP17	Wire Jumper, Insulated, #24 AWG, 0.8 in	C2003A-12-02	Gen Cable
57	2	JP8 JP15	Wire Jumper, Insulated, TFE, #18 AWG, 0.6 in	C2052A-12-02	Alpha
58	1	JP9	Wire Jumper, Insulated, #24 AWG, 0.7 in	C2003A-12-02	Gen Cable
59	1	JP10	Wire Jumper, Non insulated, #22 AWG, 0.5 in	298	Alpha
60	1	JP11	Wire Jumper, Non insulated, #22 AWG, 0.4 in	298	Alpha
61	1	JP12	Wire Jumper, Insulated, TFE, #18 AWG, 0.3 in	C2052A-12-02	Alpha
62	1	JP13	Wire Jumper, Insulated, TFE, #18 AWG, 0.4 in	C2052A-12-02	Alpha
63	1	JP16	Wire Jumper, Non Insulated, #18 AWG, 2.3 in	296 SV001	Alpha
64	1	JP18	Wire Jumper, Insulated, #24 AWG, 0.5 in	C2003A-12-02	Gen Cable
65	2	JP20 JP23	Wire Jumper, Non insulated, #22 AWG, 0.3 in	298	Alpha
66	1	JP21	Wire Jumper, Insulated, #24 AWG, 1.0 in	C2003A-12-02	Gen Cable
67	1	L1	9 mH, 5 A, Common Mode Choke	T22148-902S P.I. Custom	Fontaine
68	1	L2	330 μH, 3.3 A, Vertical Toroidal	2218-V-RC VTK-00037	Bourns Premier Magnetics
69	1	L3	Custom, PFC Inductor, 221 μH, PQ32/20, Vertical	BQ32/30-1112CPFR TSD-4013	TDK Premier Magnetics
70	1	L4	Custom, 880 μH, Constructed on core AllStar T28*12*14 from PI #32-00308-00	TSD-4014	Premier Magnetics
71	1	L5	2.2 uH, 6.0 A	RFB0807-2R2L TSD-4015	Coilcraft Premier Magnetics
72	4	POST1 POST2 POST3 POST4	Post, Circuit Board, Female, Hex, 6-32, snap, 0.375L, Nylon	561-0375A	Eagle Hardware
73	2	Q1 Q2	NPN, Small Signal BJT, GP SS, 40 V, 0.6 A, SOT-23	MMBT4401LT1G	Diodes, Inc.
74	3	R1 R2 R3	680 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ684V	Panasonic
75	4	R4 R5 R11 R12	6.2 MΩ, 1%, 1/4 W, Thick Film, 1206	KTR18EZPF6204	Rohm Semi
76	2	R6 R10	3.74 MΩ, 1%, 1/4 W, Metal Film	MFR-25FBF52-3M74	Yageo
77	2	R7 R13	162 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1623V	Panasonic
78	1	R8	30.1 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF3012V	Panasonic
79	1	R9	332 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF3323V	Panasonic
80	2	R14 R15	4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
81	1	R16	7.5 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ752V	Panasonic
82	6	R17 R18 R20 R22 R23 R24	1.33 MΩ, 1%, 1/4 W, Thick Film, 1206	RC1206FR-071M33L	Yageo
83	1	R19	620Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ621V	Panasonic
84	1	R21	232 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2323V	Panasonic
85	1	R25	100 Ω, 5%, 1/2 W, Carbon Film	CF12JT100R	Stackpole
86	1	R26	4.7 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-4R7	Yageo
87	1	R27	2.2 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-2R2	Yageo
88	1	R28	2 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ202V	Panasonic
89	1	R29	107 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-107K	Yageo
90	2	R30 R31	0 Ω 5%, 1/8 W, Thick Film, 0805	ERJ-6GEY0R00V	Panasonic
91	1	R32	15 Ω, 5%, 2 W, Metal Oxide	RSF200JB-15R	Yageo
92	1	R33	2.2 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ222V	Panasonic
93	2	R34 R36	3.3 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ332V	Panasonic
94	1	R35	1.5 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ152V	Panasonic
95	1	R37	97.6 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF9762V	Panasonic

96	1	R38	1.1 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-1K10	Yageo
97	1	R39	10.2 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1022V	Panasonic
98	2	R40 R52	100 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ101V	Panasonic
99	1	R41	93.1 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-93K1	Yageo
100	3	R42 R54 R55	4.99 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4991V	Panasonic
101	1	R43	10 kΩ, 5%, 1/8 W, Carbon Film	CF18JT10K0	Stackpole
102	2	R44 R46	0.1 Ω, 1%, 1 W, Thick Film, 2512	RL2512FK-070R1L	Yageo
103	1	R45	220 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ221V	Panasonic
104	1	R47	2.2 Ω, 5%, 1/2 W, Metal Film, Fusible/Flame Proof	NFR25H0002208JR500	Vishay
105	3	R48 R50 R53	1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
106	1	R49	10 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ100V	Panasonic
107	1	R51	680 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ681V	Panasonic
108	1	R56	4.7 kΩ, 5%, 1/8 W, Carbon Film	CF18JT4K70	Stackpole
109	1	RT1	NTC Thermistor, 2.5 Ohms, 5 A	SL10 2R505	Ametherm
110	3	RTV1 RTV2 RTV3	Thermally conductive Silicone Grease	120-SA	Wakefield
111	1	RV1	320 V, 23 J, 10 mm, RADIAL	V320LA10P	Littlefuse
112	3	SCREW1 SCREW3 SCREW4	SCREW MACHINE PHIL 4-40 X 1/4 SS	PMSSS 440 0025 PH	Building Fasteners
113	2	SCREW2 SCREW5	SCREW MACHINE PHIL 4-40X 3/16 SS	67413609	MSC Industrial
114	2	SPACER_CER1 SPACER_CER2	SPACER RND, Steatite C220 Ceramic	CER-2	Richco
115	1	SW1	SWITCH SLIDE SPDT 30 V, .2 A PC MNT	EG1218	E-Switch
116	1	T1	Transformer, EER35, Vertical, 14 Custom	TSD-4016	Premier Magnetics
117	1	T2	Transformer, EF25/13/7, Vertical, Custom	TSD-4017	Premier Magnetics
118	2	TO-220 PAD1 TO-220 PAD2	THERMAL PAD TO-220 .009" SP1000	1009-58	Bergquist
119	1	U1	HiperPFS-3, eSIP16/13	PFS7528H	Power Integrations
120	3	U2 U4 U7	Optocoupler, 80 V, CTR 80-160%, 4-Mini Flat	PC357N1TJ00F	Sharp
121	1	U3	HiperTFS-2, ESIP16/12	TFS7706H	Power Integrations
122	1	U5	IC, REG ZENER SHUNT ADJ SOT-23	LM431BIM3/NOPB	National Semi
123	1	U6	OP AMP SINGLE LOW PWR SOT23-5	LM321MF	National Semi
124	1	U8	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semi
125	1	VR1	150 V, 5 W, 5%, TVS, DO204AC (DO-15)	P6KE150A	LittleFuse
126	1	VR2	13 V, 5%, 500 mW, SOD-123	MMSZ5243BT1G	ON Semi
127	1	VR3	Diode Zener 18 V 500 MW SOD123	MMSZ5248B-7-F	Diodes, Inc.
128	1	WASHER1	WASHER FLAT #4 SS	FWSS 004	Building Fasteners
129	4	WASHER2 WASHER3 WASHER4 WASHER5	WASHER FLAT #4 Zinc, OD 0.219, ID 0.125, Thk 0.032, Yellow Chromate Finish	5205820-2	Tyco
130	2	WASHER6 WASHER7	Washer, Shoulder, #4, 0.032 Shoulder x 0.116" Dia, Polyphenylene Sulfide PPS	7721-7PPSG	Aavid Thermalloy

7 Magnetics

7.1 PFC Boost Inductor (L3) Specification

7.1.1 Electrical Diagram

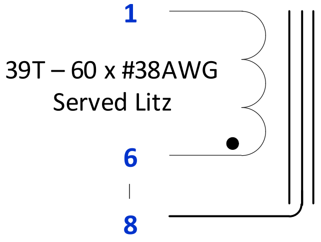


Figure 7 – PFC Inductor Schematic Diagram.

7.1.2 Electrical Specification

Inductance	Pins 1-6, measured at 100 kHz, 0.4 V_{RMS}.	221 µH ±5%
Resonant Frequency	Pins 1-6.	1300 kHz (Min.)

7.1.3 Material List

Item	**Description**
[1]	Core: TDK-PC44PQ32/30Z or equivalent, gapped for A_{LG} of 145 nH/T^2.
[2]	Bobbin: PQ32/30, Phenolic, Vertical, 12 pins (6/6). TDK BPQ32/30-112CPFR or equivalent.
[3]	Magnet wire: Served Litz wire 60 x #38 AWG, Single Coated Solderable.
[4]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 17.6 mm wide.
[5]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 13 mm wide.
[6]	Tinned Bus Wire: #24 AWG.
[7]	Varnish: Dolph BC-359 or equivalent.

7.1.4 Build Diagram

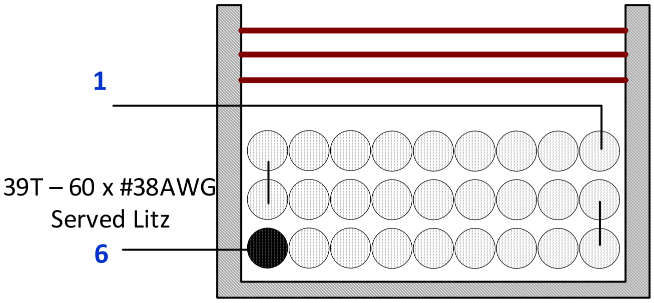
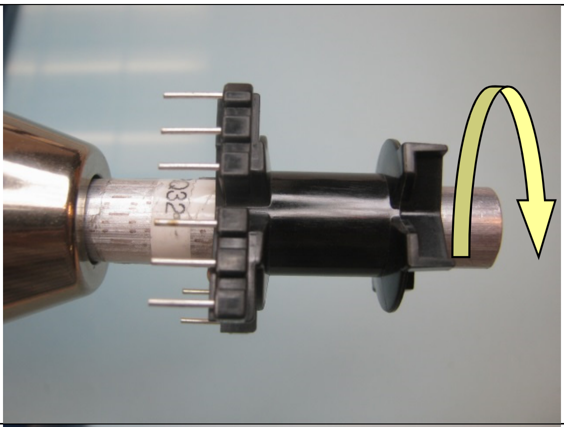
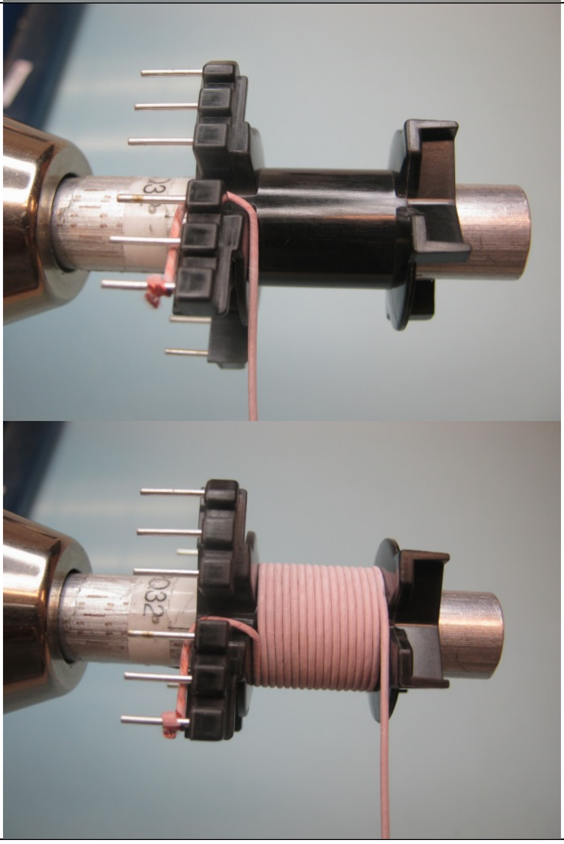
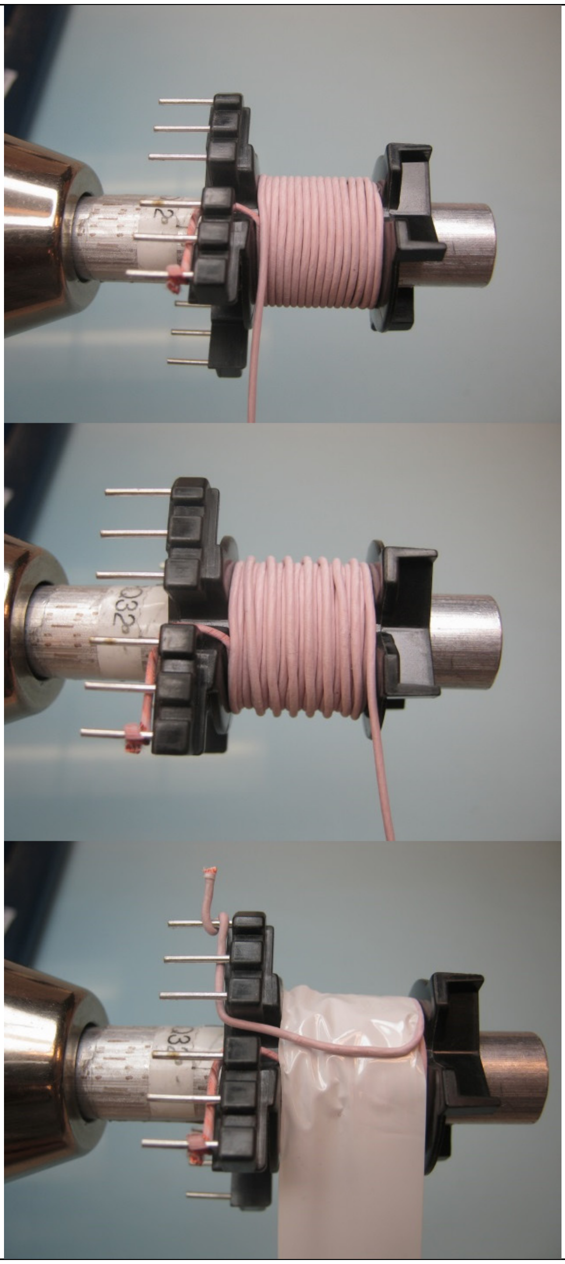
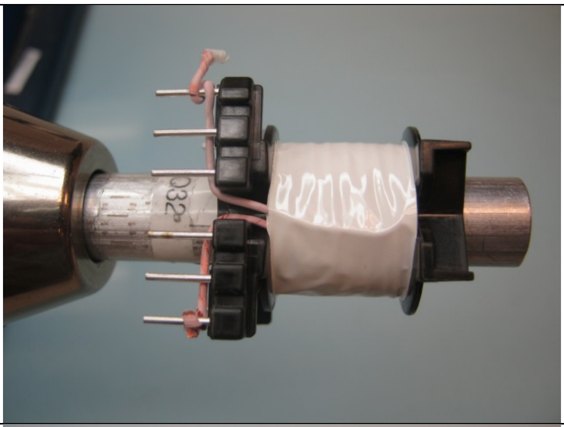
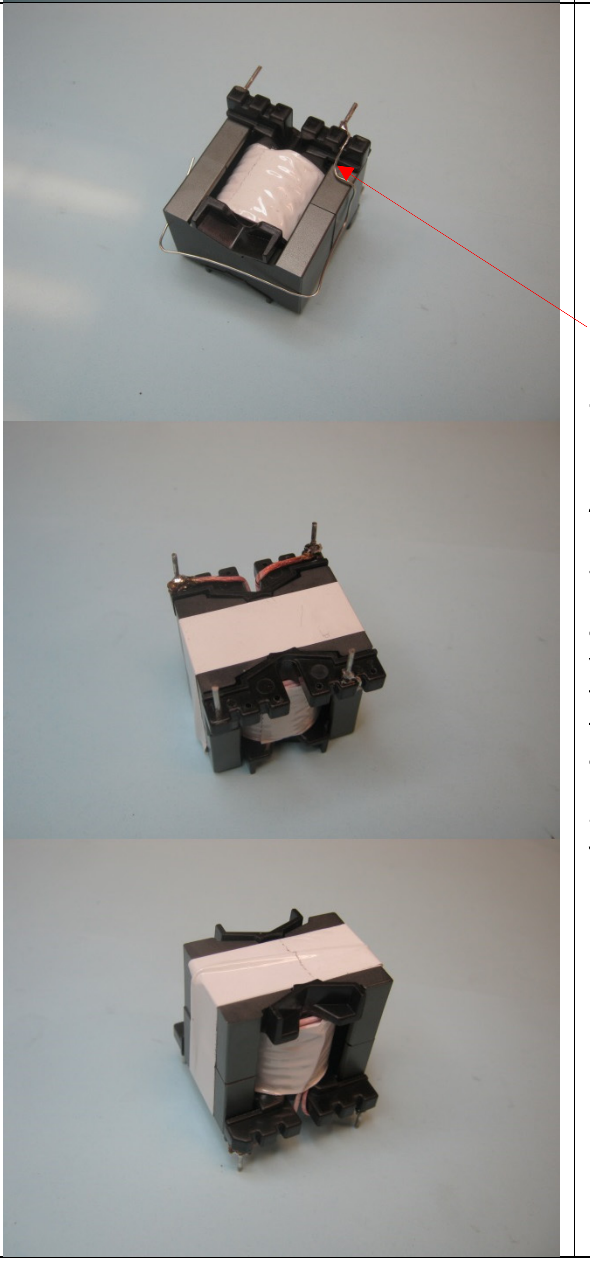


Figure 8 – PFC Inductor Build Diagram.

7.1.5 Winding Illustrations

Winding Preparation		Place the bobbin item [2] on the mandrel with the pin side is on the left side. Winding direction is clockwise direction.
Winding		Start at pin 6, wind 39 turns of wire item [3] in 2 ½ layers, spread wire evenly on last layer, and finish at pin 1. Route start and finish leads on bobbin bottom as shown in pictures.

Insulation		Place 3 layers of tape item [5]
Final Assembly		Grind core to get specified inductance. Assemble core halves in bobbin. Attach bus wire item [6] to pin 8 of bobbin [2].Bend as shown in pictures. Position wire in in center of core as shown. Secure wire and core halves with three layers of tape [5], trapping wire [6] against core halves. Remove pins: 2, 3, 4, 5, 7, 9, 10, 11. Varnish item [7].

7.2 Main Transformer (T1) Specification

7.2.1 Electrical Diagram

Figure 9 – Main Forward Transformer Schematic.

7.2.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from pins 1-6 to 10-13.	3000 VAC
Primary Inductance	Pins 1-6 all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	23 mH ±20%
Resonant Frequency	Pins 1-6, all other windings open.	150 kHz (Min.)
Primary Leakage Inductance	Pins 1-6, with pins 10-13 shorted, measured at 100 kHz, 0.4 V_{RMS}.	10 μH (Max.)

7.2.3 Material List

Item	Description
[1]	Core Pair EER35: TDK PC95 or equivalent.
[2]	Bobbin: EER35 Vertical, 14 pins, PI Part # 25-00029-00, Ying Chin YC-3508 or equivalent.
[3]	Wire, Triple Insulated, #23 AWG – Furukawa Tex-E or equivalent.
[4]	Wire, Magnet, Solderable Double Coated, #25 AWG.
[5]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 26 mm wide.
[6]	Tape: Polyester Web, 3M 44 or equivalent, 3 mm wide.
[7]	Tape: Copper Foil, 3M 1194 or equivalent, 13 mm wide.
[8]	Transformer Varnish: Dolph BC-359, or equivalent.

7.2.4 Build Diagram

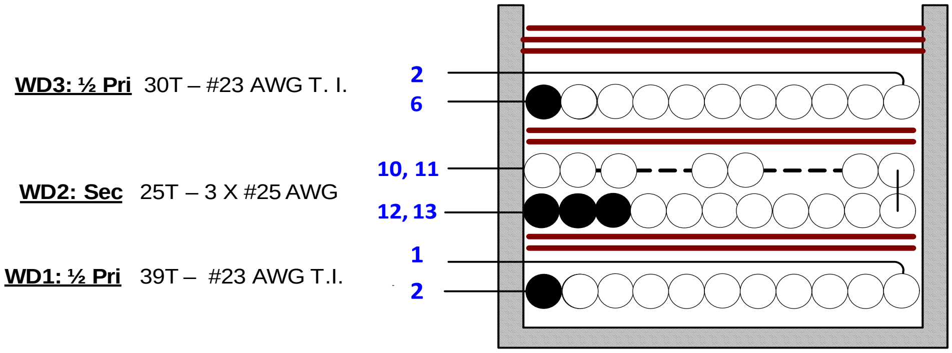
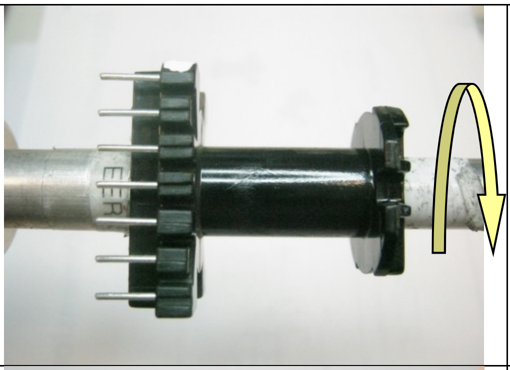
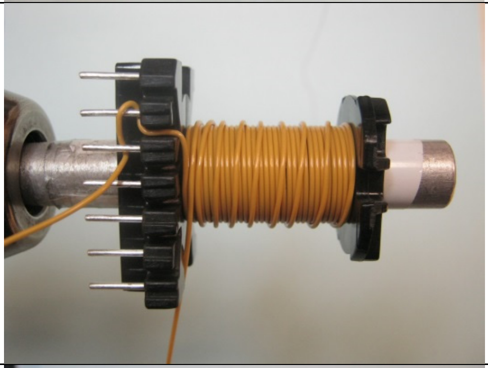
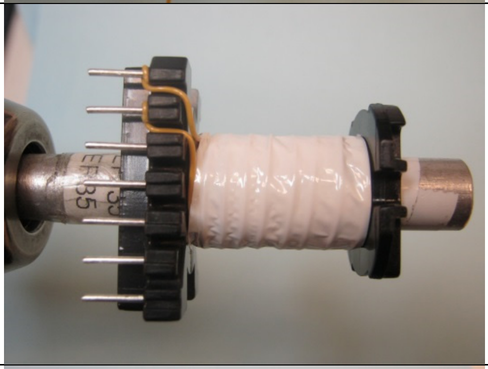
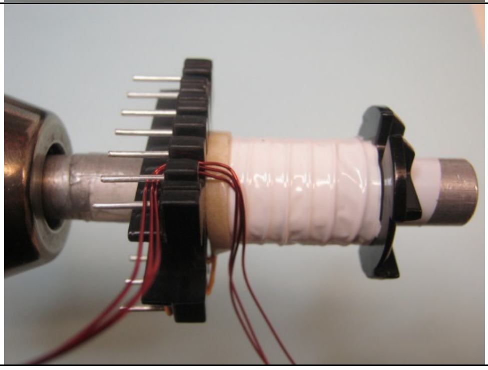


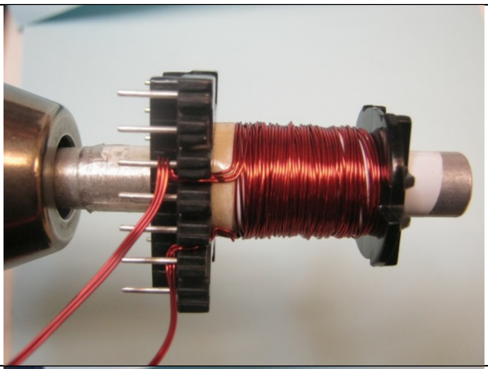
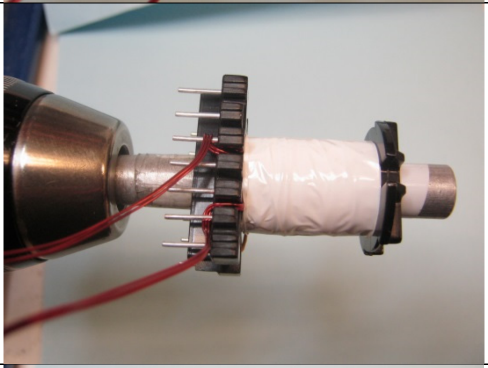
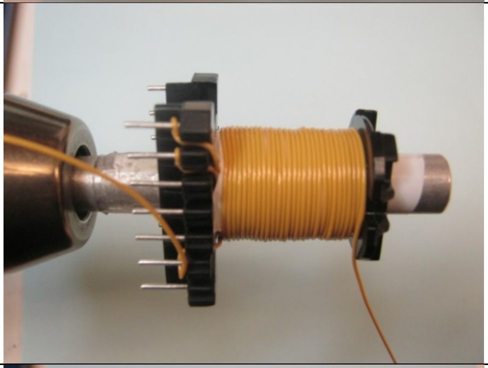
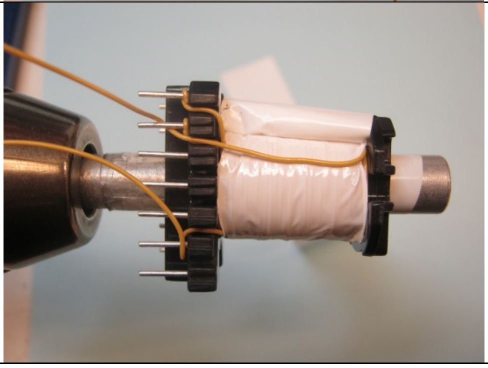
Figure 10 – Transformer Build Diagram.

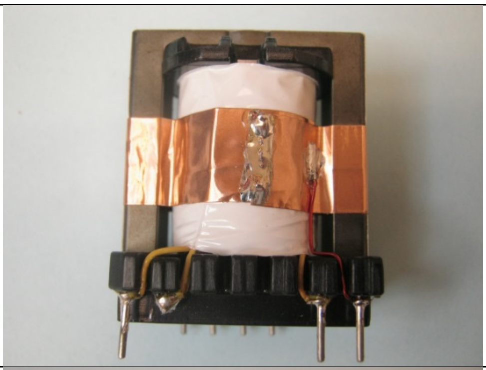
7.2.5 Winding Instructions

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.
WD1: ½ Primary	Starting on pin 2, wind 30 turns of triple insulated wire item [3] in 1 layer, Wind remaining 9 turns back evenly across bobbin window, finish on pin 1.
Insulation	Apply 2 layers of tape item [5].
Margin	Using tape item [6], apply a 3mm margin to pins side of bobbin. Match height of WD2.
WD2: Secondary	Starting at pins 12 & 13, wind 25 trifilar turns of wire item [4] in 2 layers, finishing at pins 10 and 11.
Insulation	Apply 2 layers of tape item [5].
WD3: ½ Primary	Starting on pin 6, wind 30 turns of triple insulated wire item [3] in 1 layer, and finish on pin 2.
Insulation	Apply 3 layers of tape item [5].
Assembly (1)	Assemble gapped core halves in bobbin, secure with tape. Using copper tape item [7], 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 item [4] to copper band and terminate to pin 7.
Assembly (2)	Apply 1 layer of tape item [5] around transformer as shown to insulate flux band. Remove pins 3, 4, 5, 8, 9, and 14. Cut pin 2 short. Dip varnish [9].

7.2.6 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		Starting on pin 2, wind 30 turns of triple insulated wire item [3] in 1 layer, Wind remaining 9 turns back evenly across bobbin window, finish on pin 1.
Insulation		Apply 2 layers of tape item [5].
Margin		Using tape item [6], apply a 3 mm margin to pins side of bobbin. Match height of WD2.

WD2: Secondary		Starting at pins 12 & 13, wind 25 trifilar turns of wire item [4] in 2 layers, finishing at pins 10 & 11.
Insulation		Apply 2 layers of tape item [5].
WD3: ½ Primary		Starting on pin 6, wind 30 turns of triple insulated wire item [3] in 1 layer, and finish on pin 2.
Insulation		Apply 3 layers of tape item [5].

Assembly (1)		Assemble gapped and ungapped core halves in bobbin, secure with tape. Using copper tape item [7], 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 item [4] to copper band and terminate to pin 7.
Assembly (2)		Apply 1 layer of tape item [5] around transformer as shown to insulate flux band. Remove pins 3, 4, 5, 8, 9, and 14. Cut pin 2 short. Dip varnish [8].

7.3 Standby Transformer (T2) Specification

7.3.1 Electrical Diagram

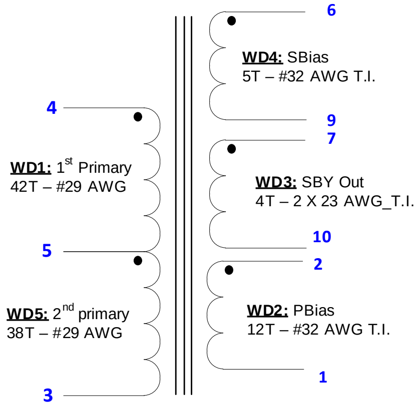


Figure 11 – Transformer Electrical Diagram.

7.3.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from pins 1-5 to 6-10.	3000 VAC
Primary Inductance	Pins 4-3 all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	1074 ·H ±10%
Resonant Frequency	Pins 4-3, all other windings open.	1500 kHz (Min.)
Primary Leakage Inductance	Pins 4-3, with pins 7 and 10 shorted, measured at 100 kHz, 0.4 V_{RMS}.	50 µH (Max.)

7.3.3 Material List

Item	Description
[1]	Core: EF25, TDK PC44 material or equivalent. gap for inductance coefficient (A_L) of 202 nH/T².
[2]	Bobbin, EF25, Vertical, 10 Pins (5/5) Miles-Platts FE0100 w/ 10 pieces TBS601 terminal, PI Part # 25-00012-00.
[3]	Tape, Polyester film, 3M 1350F-1 or equivalent, 16.0 mm wide.
[4]	Tape, Polyester film, 3M 1350F-1 or equivalent, 14.9 mm wide.
[5]	Tape, Polyester web, 3M 44 or equivalent, 1.5 mm wide.
[6]	Wire, Magnet 28 AWG, solderable double coated.
[7]	Wire, Triple Insulated, Furukawa TEX-E or equivalent, #23 AWG.
[8]	Wire, Triple Insulated, Furukawa TEX-E or equivalent, #32 AWG.
[9]	Transformer Varnish, Dolph BC-359 or equivalent.

7.3.4 Build Diagram

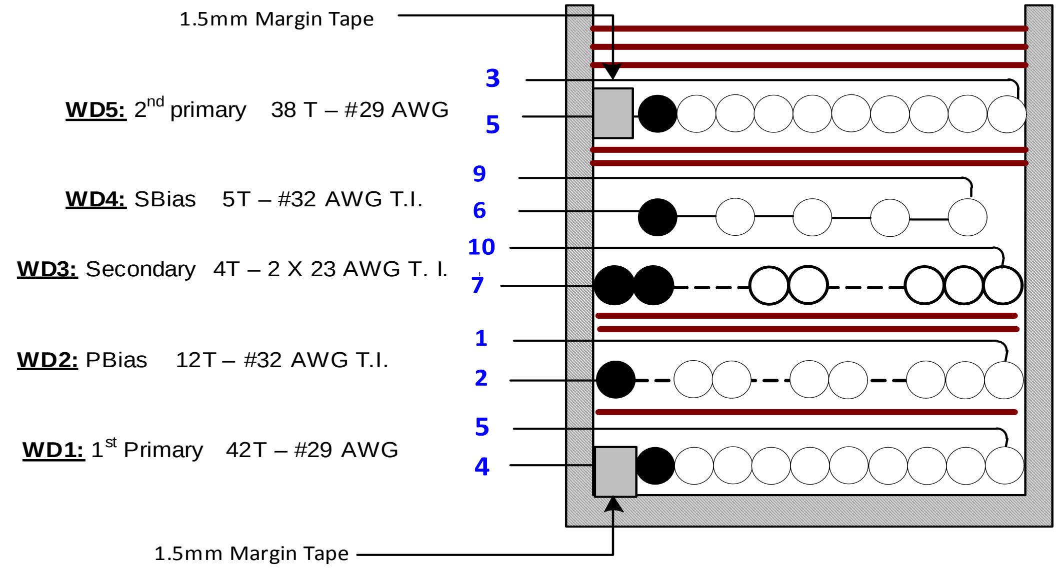
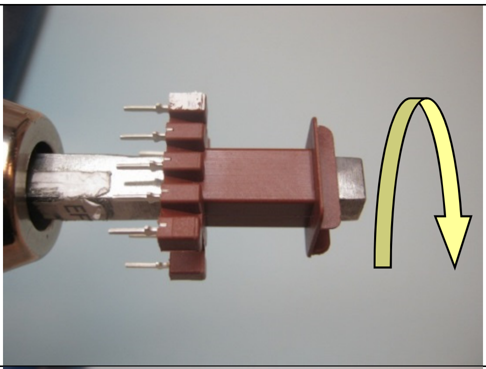
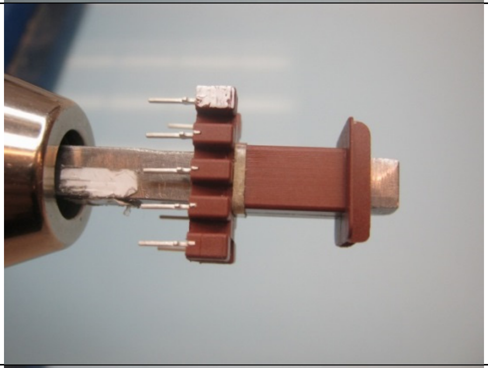
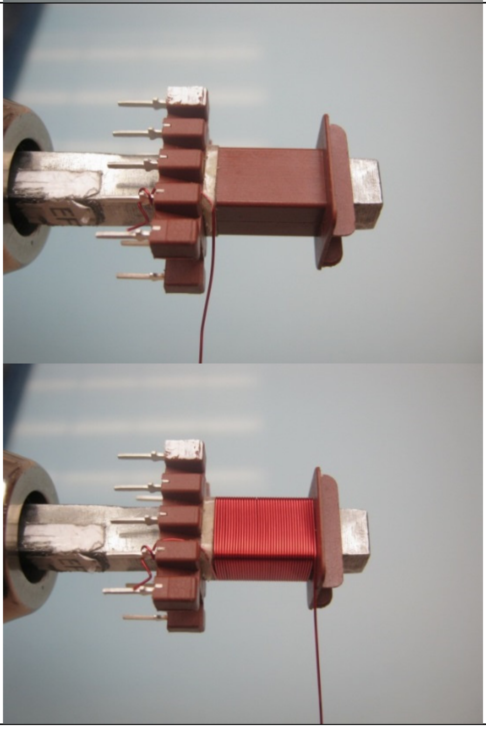


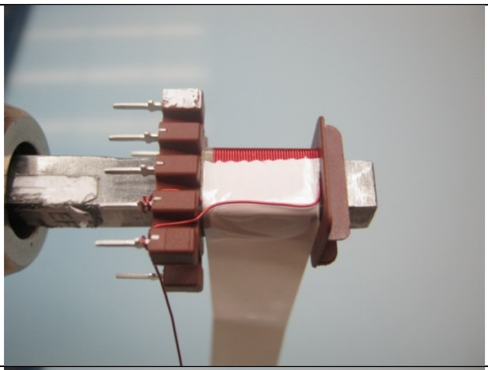
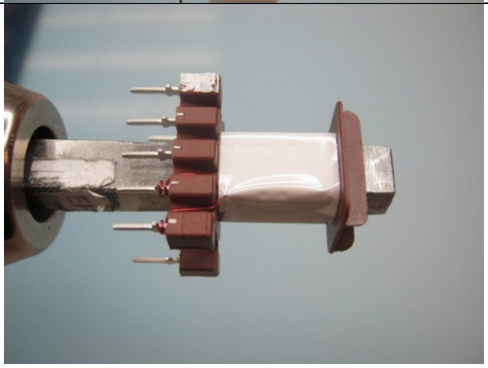
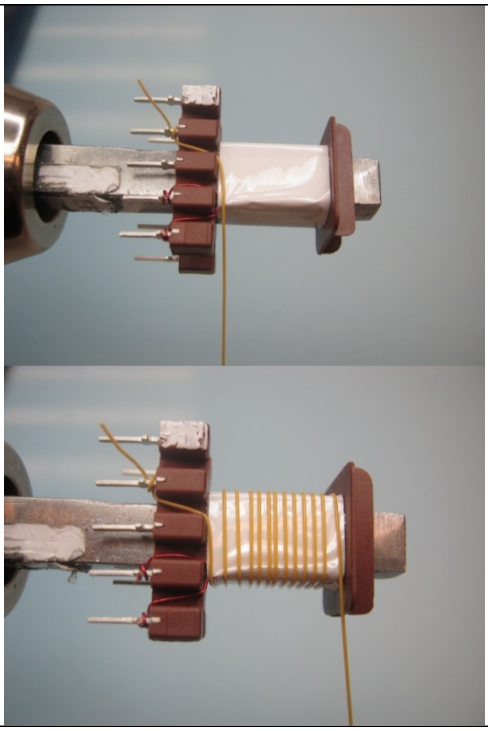
Figure 12 – Transformer Build Diagram.

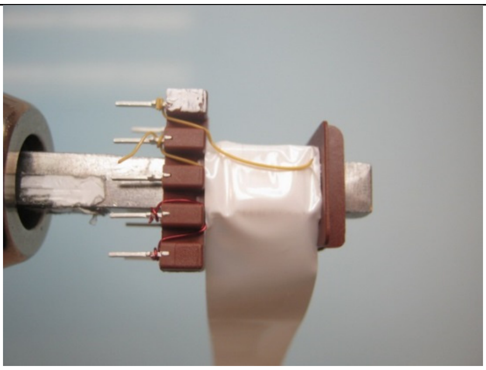
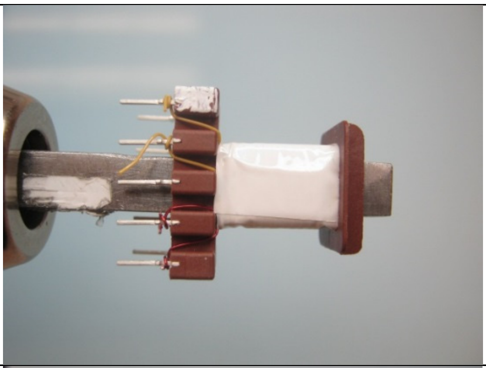
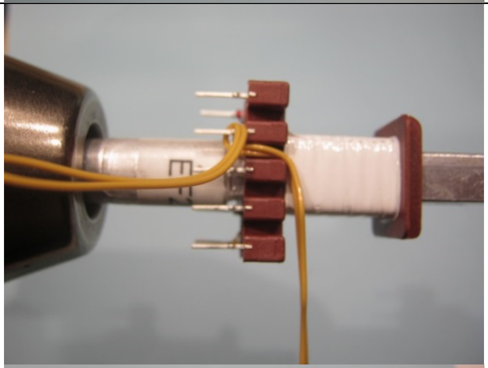
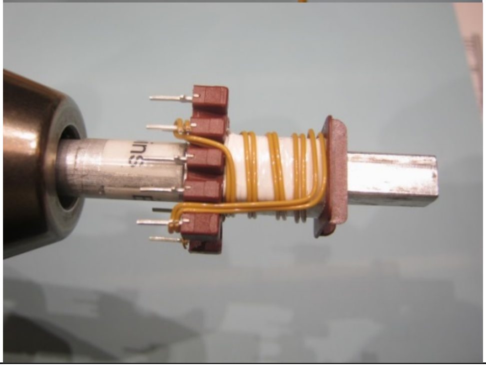
7.3.5 Winding Instructions

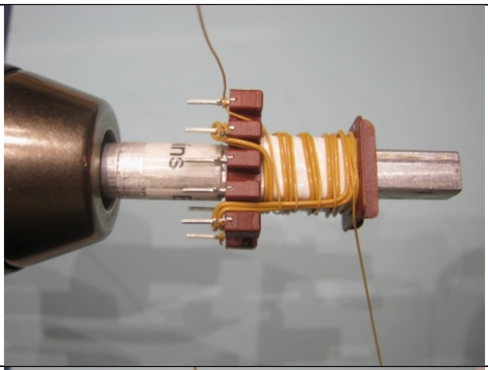
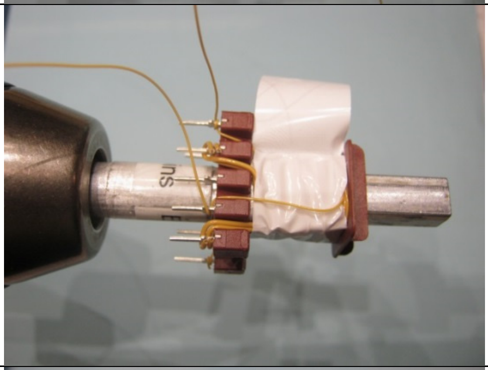
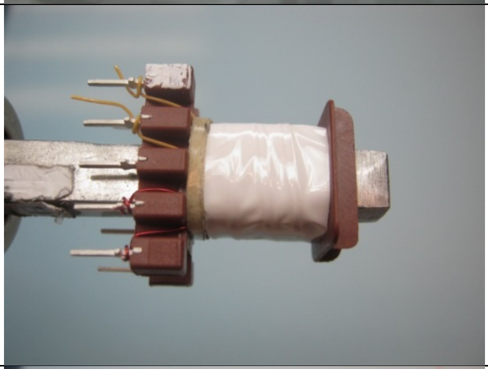
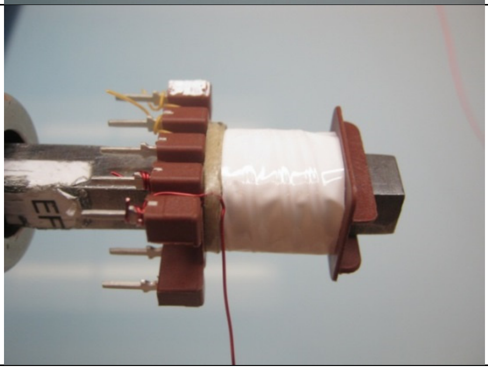
General Note	For the purpose of these instructions, bobbin is oriented on winder such that pin side is on the left side (see illustration). Winding direction as shown is clockwise.
Margin	Apply 1.5 mm margin on pin side of bobbin using tape [5]. Match height of WDG 1.
WD1: 1st Primary	Starting at pin 4, wind 42 turns of wire item [6] in 1 layer. Finish at pin 5.
Insulation	Use 1 layer of tape item [3] for insulation.
WD2: PBias	Starting at pin 2, wind 12 turns of triple insulated wire item [8] in one layer. Finish at pin 1.
Insulation	Use 2 layers of tape item [3] for insulation.
WD3: Secondary	Starting at pin 9, wind 4 bifilar turns of triple insulated wire item [7] in one layer. Finish at pin 10.
WD4: SBias	Starting on pin 6, wind 5 turns of triple insulated wire item [8] directly on top of WD3. Space turns evenly across bobbin width, and finish on Pin 9.
Insulation	Use 2 layers of tape item [3] for insulation.
Margin	Apply 1.5 mm margin on pins side of bobbin using tape [5]. Match height of WDG 4.
WD5: 2nd Primary	Starting at pin 5, wind 38 turns of wire item [6] in 1 layer. Finish at pin 3.
Insulation	Use 3 layers of tape item [3] to secure the windings.
Assembly	Grind core halves for specified primary inductance. Wrap one core half with 2 layers of tape item [4] as shown in illustrations. Insert the wrapped core in pin side of bobbin. Secure core halves with tape. Remove pin 8, cut pin 5 short. Dip varnish item [9].

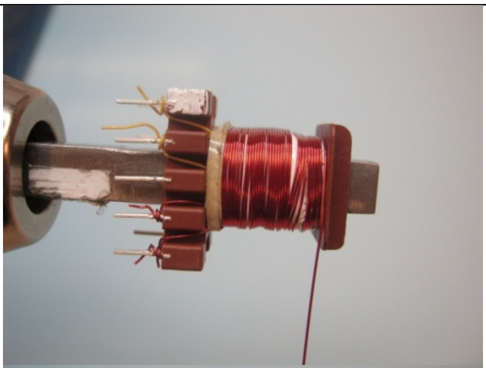
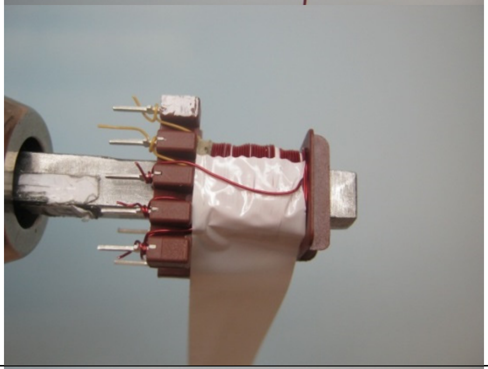
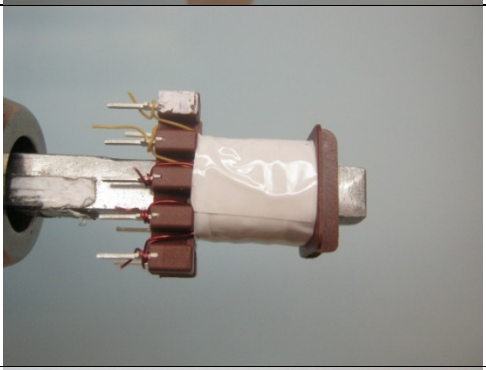
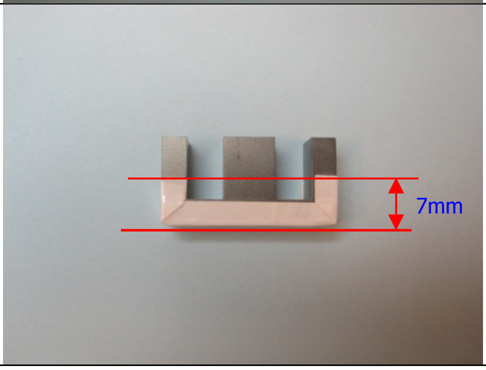
7.3.6 Transformer Illustrations

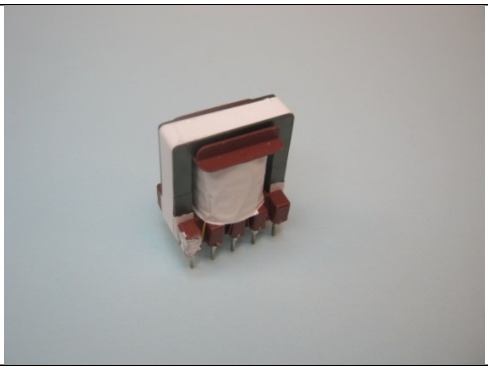
General Note		For the purpose of these instructions, bobbin is oriented on winder such that pin side is on the left side (see illustration). Winding direction as shown is clockwise.
Margin		Apply 1.5 mm margin on pins side of bobbin using tape [5]. Match height of WDG 1 & 2.
WD1: 1st Primary		Starting at pin 4, wind 42 turns of wire item [6] in 1 layer. Finish at pin 5.

		
Insulation		Use 1 layer of tape item [3] for insulation.
WD2: PBias		Starting at pin 2, wind 12 turns of triple insulated wire item [8] in one layer. Finish at pin 1.

		
Insulation		Use 2 layers of tape item [3] for insulation.
WD3: Secondary	 	Starting at pin 7, wind 4 bifilar turns of triple insulated wire item [7] in one layer. Finish at pin 10.

WD4: SBias		Starting on Pin6, wind 5 turns of triple insulated wire item [8] directly on top of WD3. Space turns evenly across bobbin width, and finish on pin 9.
Insulation		Use 2 layers of tape item [3] for insulation.
Margin		Apply 1.5 mm margin on pins side of bobbin using tape [5]. Match height of WDG 4.
WD4: 2nd Primary		Starting at pin 5, wind 38 turns of wire item [6] in 1 layer. Finish at pin 3.

	 	
Insulation		Use 3 layers of tape item [3] to secure the windings.
Assembly	 	Grind core halves for specified primary inductance. Wrap one core half with 2 layers of tape item [4] as shown in illustrations. Insert the wrapped core in pin side of bobbin. Secure core halves with tape. Remove pin 8, cut pin 5 short. Dip varnish item [9].

7.4 Main Output Choke (L4) Specification

7.4.1 Electrical Diagram

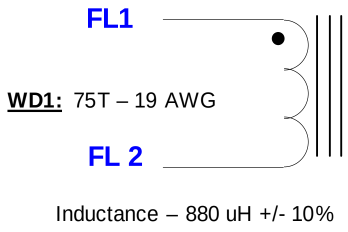


Figure 13 – Output Choke Schematic.

7.4.2 Material List

Item	Description
[1]	Core: Sendust Toroid 125 µ, 27.7 mm diameter, Mag-Inc 77930-A7 or equivalent.
[4]	Wire, Magnet, #19 AWG, solderable double coated.

7.4.3 Winding Illustration

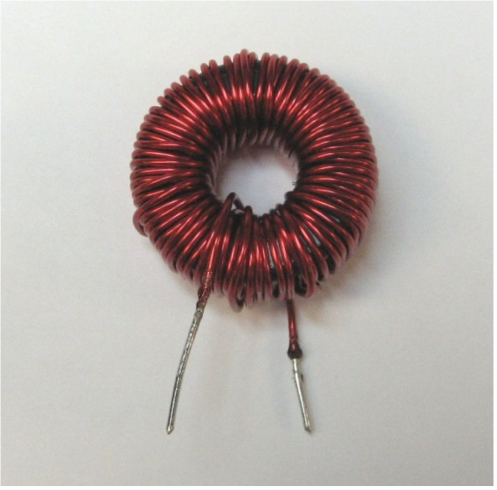


Figure 14 – Finished Output Choke.

8 PFC Design Spreadsheet

Hiper_PFS-3_Boost_041715; Rev.0.7; Copyright Power Integrations 2015	**INPUT**	**INFO**	**OUTPUT**	**UNITS**	**Hiper_PFS-3_Boost_041715_Rev0-7.xls; Continuous Mode Boost Converter Design Spreadsheet**
Enter Application Variables					
Input Voltage Range	Universal		Universal		Input voltage range
VACMIN			90	VAC	Minimum AC input voltage. Spreadsheet simulation is performed at this voltage. To examine operation at other votlages, enter here, but enter fixed value for LPFC_ACTUAL.
VACMAX			265	VAC	Maximum AC input voltage
VBROWNIN			79	VAC	Expected Typical Brown-in Voltage per IC specifications; Line impedance not accounted.
VBROWNOUT			69	VAC	Expected Typical Brown-out voltage per IC specifications; Line impedance not accounted.
VO			385	VDC	Nominal load voltage
PO	341		341	W	Nominal Output power
fL			50	Hz	Line frequency
TA Max			40	°C	Maximum ambient temperature
n			0.93		Enter the efficiency estimate for the boost converter at VACMIN. Should approximately match calculated efficiency in Loss Budget section
VO_MIN			366	VDC	Minimum Output voltage
VO_RIPPLE_MAX			20	VDC	Maximum Output voltage ripple
tHOLDUP	15		15	ms	Holdup time
VHOLDUP_MIN			310	VDC	Minimum Voltage Output can drop to during holdup
I_INRUSH			40	A	Maximum allowable inrush current
Forced Air Cooling	Yes		Yes		Enter "Yes" for Forced air cooling. Otherwise enter "No". Forced air reduces acceptable choke current density and core autopick core size
KP and INDUCTANCE					
KP_TARGET	0.520		0.520		Target ripple to peak inductor current ratio at the peak of VACMIN. Affects inductance value
LPFC_TARGET (0 bias)			220	uH	PFC inductance required to hit KP_TARGET at peak of VACMIN and full load
LPFC_DESIRED (0 bias)			220	uH	LPFC value used for calculations. Leave blank to use LPFC_TARGET. Enter value to hold constant (also enter core selection) while changing VACMIN to examine brownout operation. Calculated inductance with rounded (integral) turns for powder core.
KP_ACTUAL			0.508		Actual KP calculated from LPFC_ACTUAL
LPFC_PEAK			220	uH	Inductance at VACMIN, 90°. For Ferrite, same as LPFC_DESIRED (0 bias)
Basic current parameters					
IAC_RMS			4.07	A	AC input RMS current at VACMIN and Full Power load
IO_DC			0.89	A	Output average current/Average diode current
PFS Parameters					
PFS Part Number	Auto		PFS7528H		If examining brownout operation, over-ride autopick with desired device size
Operating Mode	Full Power		Full Power		Mode of operation of PFS. For Full Power mode enter "Full Power" otherwise enter "EFFICIENCY" to indicate efficiency mode
IOCP min			9.0	A	Minimum Current limit
IOCP typ			9.5	A	Typical current limit
IOCP max			9.9	A	Maximum current limit
IP			7.41	A	MOSFET peak current

IRMS			3.42	A	PFS MOSFET RMS current
RDSON			0.46	Ohms	Typical RDSon at 100 'C
FS_PK			96	kHz	Estimated frequency of operation at crest of input voltage (at VACMIN)
FS_AVG			68	kHz	Estimated average frequency of operation over line cycle (at VACMIN)
PCOND_LOSS_PFS			5.4	W	Estimated PFS conduction losses
PSW_LOSS_PFS			3.1	W	Estimated PFS switching losses
PFS_TOTAL			8.5	W	Total Estimated PFS losses
TJ Max			100	deg C	Maximum steady-state junction temperature
Rth-JS			2.80	°C/W	Maximum thermal resistance (Junction to heatsink)
HEATSINK Theta-CA			3.15	°C/W	Maximum thermal resistance of heatsink
INDUCTOR DESIGN					
Basic Inductor Parameters					
LPFC (0 Bias)			220	uH	Value of PFC inductor at zero current. This is the value measured with LCR meter. For powder, it will be different than LPFC.
LP_TOL			10.0	%	Tolerance of PFC Inductor Value (ferrite only)
IL_RMS			4.00	A	Inductor RMS current (calculated at VACMIN and Full Power Load)
Material and Dimensions					
Core Type	Ferrite		Ferrite		Enter "Sendust", "Pow Iron" or "Ferrite"
Core Material	Auto		PC44/PC95		Select from 60u, 75u, 90u or 125 u for Sendust cores. Fixed at PC44/PC95 for Ferrite cores. Fixed at -52 material for Pow Iron cores.
Core Geometry	Auto		PQ		Toroid only for Sendust and Powdered Iron; EE or PQ for Ferrite cores.
Core	PQ32/30		PQ32/30		Core part number
Ae			161.00	mm^2	Core cross sectional area
Le			74.60	mm	Core mean path length
AL			5140.00	nH/t^2	Core AL value
Ve			12.00	cm^3	Core volume
HT (EE/PQ) / ID (toroid)			5.12	mm	Core height/Height of window; ID if toroid
MLT			67.1	mm	Mean length per turn
BW			18.60	mm	Bobbin width
LG			1.11	mm	Gap length (Ferrite cores only)
Flux and MMF calculations					
BP_TARGET (ferrite only)			3900	Gauss	Target flux density at worst case: IOCP and maximum tolerance inductance (ferrite only) - drives turns and gap
B_OCP (or BP)			3818	Gauss	Target flux density at worst case: IOCP and maximum tolerance inductance (ferrite only) - drives turns and gap
B_MAX			2730	Gauss	peak flux density at AC peak, VACMIN and Full Power Load, nominal inductance
µ_TARGET (powder only)			N/A	%	%µ at peak current vs. zero current, at VACMIN, Full Power Load, divided by permeability at 0 current (powder only)
µ_MAX (powder only)			N/A	%	%µ vs. zero current, at VACMIN Full Power LOAD (powder only)
µ_OCP (powder only)			N/A	%	%µ vs. zero current, at IOCP_typ (powder only)
I_TEST			9.5	A	Current at which B_TEST and H_TEST are calculated, for checking flux at a current other than IOCP or IP; if blank IOCP_typ is used.
B_TEST			3664	Gauss	Flux density at I_TEST and maximum tolerance inductance
µ_TEST (powder only)			N/A	%	relative permeability at I_TEST and typical inductance (powder only)
Wire					
TURNS			39		Inductor turns. To adjust turns, change BP_TARGET (ferrite) or µ_TARGET (powder)
ILRMS			4.00	A	Inductor RMS current

Wire type	Litz		Litz		Select between "Litz" or "Magnet" for double coated magnet wire
AWG	38		38	AWG	Inductor wire gauge
Filar	60		60		Inductor wire number of parallel strands. Leave blank to auto-calc for Litz
OD (per strand)			0.102	mm	Outer diameter of single strand of wire
OD bundle (Litz only)			1.10	mm	Will be different than OD if Litz
DCR			0.12	ohm	Choke DC Resistance
P AC Resistance Ratio			1.11		Ratio of total Cu loss including HF ACR loss vs. assuming only DCR (uses Dowell equations)
J		Warning	8.22	A/mm^2	Current density is high, if copper loss is high use thicker wire, more strands, or larger core
FIT			50%	%	Percentage fill of winding window for EE/PQ core. Full window approx. 90%
Layers			2.1		Estimated layers in winding
Loss calculations					
BAC-p-p			1419	Gauss	Core AC peak-peak flux excursion at VACMIN, peak of sine wave
LPFC_CORE_LOSS			0.81	W	Estimated Inductor core Loss
LPFC_COPPER_LOSS			2.20	W	Estimated Inductor copper losses
LPFC_TOTAL_LOSS			3.00	W	Total estimated Inductor Losses
Built-in PFC Diode					
PFC Diode Part Number			INTERNAL1		PFC Diode Part Number
Type			SPECIAL		PFD Diode Type
Manufacturer			PI		Diode Manufacturer
VRRM			530	V	Diode rated reverse voltage
IF			3	A	Diode rated forward current
Qrr					high temperature
VF			1.47	V	Diode rated forward voltage drop
PCOND_DIODE			1.30	W	Estimated Diode conduction losses
PSW_DIODE			0.29	W	Estimated Diode switching losses
P_DIODE			1.59	W	Total estimated Diode losses
TJ Max			100	deg C	Maximum steady-state operating temperature
Rth-JS			3.00	degC/W	Maximum thermal resistance (Junction to heatsink)
HEATSINK Theta-CA			3.15	degC/W	Maximum thermal resistance of heatsink
Output Capacitor					
Output Capacitor	220		220	uF	Minimum value of Output capacitance
VO_RIPPLE_EXPECTED			13.8	V	Expected ripple voltage on Output with selected Output capacitor
T_HOLDUP_EXPECTED			16.8	ms	Expected holdup time with selected Output capacitor
ESR_LF			0.75	ohms	Low Frequency Capacitor ESR
ESR_HF			0.30	ohms	High Frequency Capacitor ESR
IC_RMS_LF			0.61	A	Low Frequency Capacitor RMS current
IC_RMS_HF			1.53	A	High Frequency Capacitor RMS current
CO_LF_LOSS			0.28	W	Estimated Low Frequency ESR loss in Output capacitor
CO_HF_LOSS			0.70	W	Estimated High frequency ESR loss in Output capacitor
Total CO LOSS			0.98	W	Total estimated losses in Output Capacitor
Input Bridge (BR1) and Fuse (F1)					
I^2t Rating			15.45	A^2*s	Minimum I^2t rating for fuse
Fuse Current rating			6.36	A	Minimum Current rating of fuse
VF			0.90	V	Input bridge Diode forward Diode drop
IAVG			3.96	A	Input average current at 70 VAC.
PIV_INPUT BRIDGE			375	V	Peak inverse voltage of input bridge
PCOND_LOSS_BRIDGE			6.60	W	Estimated Bridge Diode conduction loss
CIN			1.0	uF	Input capacitor. Use metallized polypropylene or film foil type with high ripple current rating
RT			9.37	ohms	Input Thermistor value

D_Precharge			1N5407		Recommended precharge Diode
PFS3 small signal components					
C_REF			1.0	uF	REF pin capacitor value
RV1			4.0	MOhms	Line sense resistor 1
RV2			6.0	MOhms	Line sense resistor 2
RV3			6.0	MOhms	Typical value of the lower resistor connected to the V-PIN. Use 1% resistor only!
RV4			161.6	kOhms	Description pending, could be modified based on feedback chain R1-R4
C_V			0.495	nF	V pin decoupling capacitor (RV4 and C_V should have a time constant of 80us) Pick the closest available capacitance.
C_VCC			1.0	uF	Supply decoupling capacitor
C_C			100	nF	Feedback C pin decoupling capacitor
Power good Vo lower threshold VPG(L)			333	V	Vo lower threshold voltage at which power good signal will trigger
PGT set resistor			333.0	kohm	Power good threshold setting resistor
Feedback Components					
R1			4.0	Mohms	Feedback network, first high voltage divider resistor
R2			6.0	Mohms	Feedback network, second high voltage divider resistor
R3			6.0	Mohms	Feedback network, third high voltage divider resistor
R4			161.6	kohms	Feedback network, lower divider resistor
C1			0.495	nF	Feedback network, loop speedup capacitor. (R4 and C1 should have a time constant of 80us) Pick the closest available capacitance.
R5			24.9	kohms	Feedback network: zero setting resistor
C2			1000	nF	Feedback component- noise suppression capacitor
Loss Budget (Estimated at VACMIN)					
PFS Losses			8.49	W	Total estimated losses in PFS
Boost diode Losses			1.59	W	Total estimated losses in Output Diode
Input Bridge losses			6.60	W	Total estimated losses in input bridge module
Inductor losses			3.00	W	Total estimated losses in PFC choke
Output Capacitor Loss			0.98	W	Total estimated losses in Output capacitor
EMI choke copper loss			0.50	W	Total estimated losses in EMI choke copper
Total losses			20.66	W	Overall loss estimate
Efficiency			0.94		Estimated efficiency at VACMIN, full load.
CAPZero component selection recommendation					
CAPZero Device			CAP005DG		(Optional) Recommended CAPZero device to discharge X-Capacitor with time constant of 1 second
Total Series Resistance (R1+R2)			0.48	k-ohms	Maximum Total Series resistor value to discharge X-Capacitors
EMI filter components recommendation					
CIN_RECOMMENDED			1000	nF	Metallized polyester film capacitor after bridge, ratio with Po
CX2			680	nF	X capacitor after differencial mode choke and before bridge, ratio with Po
LDM_calc			151	uH	estimated minimum differencial inductance to avoid <10kHz resonance in input current
CX1			470	nF	X capacitor before common mode choke, ratio with Po
LCM			10	mH	typical common mode choke value
LCM_leakage			30	uH	estimated leakage inductance of CM choke, typical from 30~60uH
CY1 (and CY2)			220	pF	typical Y capacitance for common mode noise suppression
LDM_Actual			121	uH	cal_LDM minus LCM_leakage, utilizing CM leakage inductance as DM choke.
DCR_LCM	0.10		0.10	Ohms	total DCR of CM choke for estimating copper loss
DCR_LDM	0.10		0.10	Ohms	total DCR of DM choke(or CM #2) for estimating

					copper loss
Note: CX2 can be placed between CM chock and DM choke depending on EMI design requirement.					

Note: If PFC inductor winding current density is higher than 6 A / mm^2 for forced air cooling, a “warning” will be generated by the design spreadsheet. Need for a larger wire cross section should be determined based on thermal test results. With sufficient cooling, higher current densities can be used safely. In the case of this design, the temperature rise as shown in Section 16 is acceptable.

10 Main / Standby Design Spreadsheet

HiperTFS2_Two-switch_Forward_041114; Rev.2.0; Copyright Power Integrations 2013	**INPUT**	**INFO**	**OUTPUT**	**UNIT**	**HiperTFS2_041114_Rev2-0.xls; Two-switch Forward Transformer Design Spreadsheet**
Hiper-TFS MAIN OUTPUT (TWO-SWITCH FORWARD STAGE)					
OUTPUT VOLTAGE AND CURRENT					
VMAIN	61.00		61.00	V	Main output voltage
IMAIN	4.59		4.59	A	Main output current
VOUT2			0.00	V	Output2 voltage - enter zero or leave blank if none
IOUT2			0.00	A	Output2 current - enter zero or leave blank if none
Post Regulated Output					
Post Regulator	**NONE**		NONE		Select post regulator from Mag-Amp, Buck, or NONE
V_SOURCE	**NONE**		NONE	V	Select source of input voltage for post regulator. Enter None if Post regulator not used.
VOUT3			0.00	V	Enter post regulator output voltage. Enter zero or leave blank if none
IOUT3			0.00	A	Enter post regulator output current. Enter zero or leave blank if none
n_PR			1.00		Enter post regulator efficiency (Buck only)
Coupled Inductor (Low Power) derived output					
VOUT4			0.00	V	Output choke derived (low power) output voltage (typically -12 V)
IOUT4			0.00	A	Output choke derived (low power) output current
System Power					
POUT(Main)			280.0	W	Total output power (Main converter)
POUT_PEAK(Main)	280.0		280.0	W	Peak Output power (Main converter). If there is no peak power requirement enter value equal to continuous power
POUT(Standby)			20.3	W	Continuous output power from Standby power supply
POUT_PEAK(Standby)			20.3	W	Peak output power from Standby section below
POUT(System Total)			**300.3**	**W**	**Total system continuous output power**
POUT_PEAK(System Total)			300.3	W	Total system peak output power
INPUT VOLTAGE AND UV/OV					
CIN_MIN			37	uF	Minimum Input Capacitance to meet holdup time. To increase CMIN, increase T_HOLDUP
T_HOLDUP	1.0		1.0	ms	Holdup time
CIN_ACTUAL	**220**		220	uF	Select Actual Bulk Capacitor
CIN_ESR			0.30	Ω	Bulk capacitor ESR
IRMS_CIN			0.90	A	RMS current through bulk capacitor
PLOSS_CIN			0.24	W	Bulk capacitor ESR losses
VMIN	360		360	V	Minimum input voltage to guarantee output regulation at full load
VNOM	385		385	V	Nominal input voltage
VMAX			420	V	Maximum DC input voltage
RR			3.97	MΩ	R pin resistor
RL			3.97	MΩ	Line Sense resistor value (L-pin) - goal seek (VUV OFF) for std 1% resistor series
UV and OV thresholds					
Clamp Section					
Clamp Selection	**CLAMP TO RAIL**				Select either "CLAMP TO RAIL" (default) or "CLAMP TO GND"
VCLAMP			150	V	Asymmetric Clamp Zener Voltage

VDSOP			570	V	Estimated Maximum Hiper-TFS Drain voltage (at VOVOFF_MAX)
DUTY CYCLE VALUES (REGULATION)					
DVMIN			0.51		Duty cycle at minimum DC input voltage
DVNOM_GOAL	0.48		0.48		Target duty cycle at nominal input voltage (VNOM)
DVNOM			0.47		Duty cycle at nominal DC input voltage
DVMAX			0.43		Duty cycle at maximum DC input voltage
DOVOFF MIN			0.39		Duty cycle at over-voltage DC input voltage (DOVOFF_MIN)
Maximum Duty Cycle values					
DMAX_UVOFF_MIN			0.65		Max duty cycle clamp at VUVOFF_MIN
DMAX_VMIN			0.59		Max duty clamp cycle at VMIN
DMAX_VNOM			0.56		Max duty clamp cycle at VNOM
DMAX_VMAX			0.52		Max duty clamp cycle at VMAX
DMAX_OVOFFMIN			0.46		Max duty clamp cycle at VOVOFF_MAX
DEVICE VARIABLES					
Device	**TFS7706**		TFS7706		Selected HiperTFS device
Select Frequency mode	**66**		66	kHz	Select Frequency mode.
ILIMIT_MIN			4.05	A	Device current limit (Minimum)
ILIMIT_TYP			4.36	A	Device current limit (Typical)
ILIMIT_MAX			4.67	A	Device current limit (Maximum)
fSMIN			62,000	Hz	Device switching frequency (Minimum)
fS			66,000	Hz	Device switching frequency (Typical)
fSMAX			70,000	Hz	Device switching frequency (Maximum)
KI	0.9		0.9		Select Current limit factor (KI=1.0 for default ILIMIT, or select KI=0.9 or KI=0.7)
R(FB)			1740	kΩ	Feedback Pin Resistor value
ILIMIT SELECT			3.65	A	Selected current limit
RDS(ON)			3.06	Ω	Sum of Rds(on) of high and low-side MOSFETs at 100°C
VDS			4.39	V	HiperTFS full-load average on-state Drain to Source Voltage (sum for both MOSFETs)
Main MOSFET losses					
MAIN TRANSFORMER					
Transformer core selection					
Core Type	**EER35**		EER35		Selected core type
AE			1.07	cm^2	Core effective cross sectional area
LE			9.08	cm	Core Effective Path Length
AL			2770	nH/T^2	Ungapped Core Effective Inductance
BW			26.1	mm	Bobbin Physical Winding Width
B_HT			5.52	mm	Height of bobbin (to calculate fit)
B_WA			1.44	cm^2	Bobbin Winding area
M			4.5	mm	Bobbin safety margin tape width (2 * M = Total Margin)
Primary Inductance					
LMAG_MAX			105.3	mH	Max LMAG to hit min zero-load resonant frequency, calculated from C_PRI. Do not exceed.
LMAG			12.7	mH	Estimated magnetizing inductance of transformer; may be lower than LMAG_MAX due to minimum gap size of 0.05 mm. Enter actual value.
GAP			0.00	mm	gap calculatedfrom LMAG
FRES_SYS	173		173	kHz	Total XFMR + system resonant frequency; enter value along with actual LMAG
C_SYS			67	pF	Estimated total XFMR + Sys parasitic cap reflected to primary, calc'd from LMAG and FRES
Diode Vf Selection					
Turns					

NMAIN			25	turns	Main rounded turns
NS2			N/A	turns	2nd output number of turns
VOUT2 ACTUAL			0.0	V	Approximate Output2 voltage with NS2 = 0 turns (AC stacked secondary). VDMAIN and VDOUT2 affect this.
NP			69	turns	Primary rounded turns. NMAIN and DVNOM_GOAL affect this.
HI SIDE BIAS WINDING (optional)	**No**		No		Can be used to eliminate pulse skipping at light load 132 kHz when zero transformer gap; better efficiency than adding gap
VBIAS				V	DC bias voltage from main transformer optional aux winding
NBIAS				turns	VBias rounded turns
VBIAS_ACTUAL				V	Vbias not used
Flux calculations					
BM_MAX			2299	Gauss	Peak positive flux density at nominal switching frequency
BM PK-PK			3483	Gauss	Peak-peak flux density at nominal conditions. Used to calculate core losses
BP_MAX			2938	Gauss	Max transient positive flux density at Vmax (limited by DVMAX clamp)
BP PK-PK			4452	Gauss	Max transient peak-peak flux density at Vmax (limited by DVMAX clamp)
TRANSFORMER LOSSES AND FIT ESTIMATE					
Core loss					
Core material	**PC95**		PC95		Core material
core_loss_multiplier			23.97		Core Loss coefficient
f_coeff			1.56		Core Loss Frequency co-efficient
BAC_coeff			2.89		Core Loss AC flux density co-efficient
specific core loss			105	mW/cc	Core loss per unit volume
core volume			9.72	cm^3	Volume of core
core loss			1.02	W	Core loss
Primary Winding Fit and losses					
L			3.0	layers	Transformer primary layers (split primary recommended)
OD_PRI			0.57	mm	Primary winding diameter
FILAR_PRI			1.0	strands	Number of parallel strands of wire (primary)
MLT_PRI			6.14	cm	Mean length per turn
DCR_PRI			372	mΩ	DC resistance of primary winding
PCOND_PRI			0.54	W	Conduction loss in primary winding
FILL_PRI			12	%	Fill factor (primary only)
Secondary Winding 1 (lower winding when AC stacked)					
VOUT			61.0	V	Specified voltage for this winding
NS1			25.0	turns	Number of turns
IRMS_SEC1			4.0	A	RMS current through winding
Foil/Wire	**WIRE**		WIRE	foil/wire	Select FOIL or WIRE for winding
OD/Thickness			0.36576	mm	Wire diameter or Foil thickness
FILAR_SEC1	3		3.00	strands	Number of parallel strands (wire selection only)
SEC1_WIDTH			N/A	mm	Foil Width (Applicable if FOIL winding used)
SEC1_MLT			6.14	cm	Mean length per turn
DCR_SEC1			107.62	mΩ	DC resistance of secondary winding
PCOND_SEC1			1.68	W	Conduction loss in secondary winding
FILL_SEC1			5	%	Fill factor (secondary 1 only)
Secondary Winding 2 (upper winding when AC stacked)					
VOUT			0.0	V	Specified voltage for this winding
NS2			0.0	turns	Number of turns
IRMS_SEC2			0.0	A	RMS current through winding
Foil/Wire	**FOIL**		FOIL	foil/wire	Select FOIL or WIRE for winding
OD/Thickness			0.125	mm	Wire diameter or Foil thickness
FILAR_SEC2			N/A	strands	Number of parallel strands (wire selection

					only)
SEC2_WIDTH			18.0	mm	Foil Width (Applicable if FOIL winding used)
SEC2_MLT			6.14	cm	Mean length per turn
DCR_SEC2			0.00	mΩ	DC resistance of secondary winding
PCOND_SEC2			0.00	W	Conduction loss in secondary winding
FILL_SEC2			0	%	Fill factor (secondary 1 only)
Fill Factor and losses of main transformer					
FILL_TOTAL			18	%	Total transformer fill factor
TOTAL_CU_LOSS			2.22	W	Total copper losses in transformer
TOTAL_CORE_LOSS			1.02	W	Total core losses in transformer
TOTAL_TRF_LOSS			3.24	W	Total losses in transformer
CURRENT WAVESHAPE PARAMETERS					
IP			2.30	A	Peak primary current at Full Load, VNOM
IP_PEAK			2.30	A	Peak primary current at Peak Load and VNOM
IPRMS(NOM)			1.21	A	Primary RMS current at Full Load, VNOM
IMAG			0.22	A	Peak magnetizing current at VMIN
OUTPUT INDUCTOR					
KDI_ACTUAL		Warning	0.50		!!! Warning. KDI_ACTUAL too high. Increase NMAIN_INDUCTOR
Turns					
POWDER TURNS MULTIPLIER	3.00		3.0		Powder only. Multiplier factor between main number of turns in transformer and inductor (default value = 3 for 66kHz or 4 for 132kHz).
NMAIN_INDUCTOR			75.0	turns	Main output inductor number of turns - affected by powder turns multiplier or ferrite Target BM
NOUT2_INDUCTOR				turns	Output 2 inductor number of turns
NOUT4_INDUCTOR			N/A	turns	Output 4 number of turns (low power)
Inductance and flux					
LMAIN_ACTUAL			229.4	uH	Estimated inductance of main output at full load
LOUT_2			0.0	uH	Estimated inductance of auxiliary output at full load
BM_IND			2385	gauss	DC component of flux density
BAC_IND			575	gauss	AC component of flux density
Core Selection					
Core Type	**Kool Mu 125u**		Kool Mu 125u		Select core type
Core	**Auto**		77930(O.D)= 27.7		Output choke core size - verify on bench
AE			65.4	mm^2	Core Effective Cross Sectional Area
LE			63.5	mm	Core Effective Path Length
AL			157.0	nH/T^2	Ungapped Core Effective Inductance
BW			44.3	mm	Bobbin Physical Winding Width
VE			4150	mm^3	Volume of core
Powder cores (Sendust and Powdered Iron) Cores					
MUR			125		Relative permeability of material at 0 bias
H			60.2	AT/cm	Magnetic field strength
MUR_RATIO			0.26		Ratio of permeability at full load divided by initial permeability
LMAIN_0bias			883.1	uH	Estimated inductance of main output with 0 DC bias
Ferrite Cores					
LG			N/A	mm	Gap length of inductor cores
Target BM			N/A	Gauss	Target maximum flux density
Choke wires					
Total number of layers			1.67	layers	Total number of layers for chosen toroid
IRMS_MAIN			4.60	A	RMS current through main inductor

					windings
IRMS_AUX			0.00	A	RMS current through aux winding
AWG_MAIN			19	AWG	Main inductor winding wire gauge
OD_MAIN			0.98	mm	Main winding wire gauge outer diameter
FILAR_MAIN	1.00		1	strands	Number of parallel strands for main output
RDC_MAIN			77.34	mΩ	Resistance of wire for main inductor winding
AC Resistance Ratio (Main)			6.94		Ratio of total resistance (AC + DC) to the DC resistance (using Dowell curves)
CMA_MAIN			281	CMA	Cir mils per amp for main inductor winding
J_MAIN			6.09	A/mm^2	Current density in main inductor winding
AWG_AUX			0	AWG	Aux winding wire gauge
OD_AUX			N/A	mm	Auxiliary winding wire gauge outer diameter
FILAR_AUX			2	strands	Number of parallel strands for aux output
RDC_AUX			0.00	mΩ	Resistance of wire for aux inductor winding
AC Resistance Ratio (Aux)			0.00		Ratio of total resistance (AC + DC) to the DC resistance (using Dowell curves)
CMA_AUX		Info	0	CMA	!!! Info. Low CMA may cause overheating. Verify acceptable temperature rise
J_AUX			0.00	A/mm^2	Current density in auxiliary winding
Choke Losses					
PCOPPER_MAIN			1.64	W	Copper loss in main inductor winding
PCOPPER_AUX			0.00	W	Copper loss in aux inductor windings
PCORE			0.62	W	Total core loss
PTOTAL_IND			2.26	W	Total losses in output choke
SECONDARY OUTPUT DIODE PARAMETERS					
Main Output					
ISFWDRMS			3.95	A	Full load forward diode RMS current at nominal input voltage
ISCATCHRMS			4.16	A	Freewheeling diode RMS current at nominal input voltage
IDAVMAINF			2.33	A	Worst case average current of forward rectifier at VMIN (single device rating)
IDAVMAINC			2.60	A	Worst case average current of freewheeling diode at VMAX(single device rating)
IRMSMAIN			0.66	A	Maximum RMS current, Main output capacitor
PD_LOSS_MAIN			2.30	W	Conduction loss of forward diode
Second Output					
ISFWD2RMS			0.00	A	Full load forward diode RMS current at nominal input voltage
ISCATCH2RMS			0.00	A	Freewheeling diode RMS current at nominal input voltage
IDAVOUT2F			0.00	A	Worst case average current of forward rectifier at VMIN (single device rating)
IDAVOUT2C			0.00	A	Worst case average current of freewheeling diode at VMAX(single device rating)
IRMSOUT2			0.00	A	Maximum RMS current, Main output capacitor
PD_LOSS_OUT2			0.00	W	Conduction loss of forward diode
Diode Derating					
VPIVMAINF	1.00		206.5	V	Main Forward Diode peak-inverse voltage (at VDSOP), including derating
VPIVMAINC	1.00		152.2	V	Main Catch Diode peak-inverse voltage (at VOVOFF_MAX), including derating
VPIVOUT2F	1.00		0.0	V	Output2 Forward Diode peak-inverse voltage (at VDSOP), including derating
VPIVOUT2C	1.00		0.0	V	Output2 Catch Diode peak-inverse voltage (at VOVOFF_MAX), including derating
VPIVB	1.00		N/A	V	Bias output rectifier peak-inverse voltage (at VDSOP), including derating
Hiper-TFS STANDBY SECTION (FLYBACK STAGE)					

ENTER APPLICATION VARIABLES					
VACMIN	90		90	V	Minimum AC Input Voltage
VACMAX			265	V	Maximum AC Input Voltage
fL			50	Hz	AC Mains Frequency
VO_SB			5.0	V	Output Voltage (at continuous power)
IO_SB	4.00		4.00	A	Power Supply Output Current (corresponding to peak power)
IO_SB_PK			4.00	A	Peak output current
POUT_SB			20.00	W	Continuous Output Power
POUT_SB_TOTAL			20.32	W	Total Standby power (Includes Bias winding power)
POUT_SB_PK			20.32	W	Peak Standby Output Power
n	0.75		0.75		Efficiency Estimate at output terminals. Under 0.7 if no better data available
Z			0.50		Z Factor. Ratio of secondary side losses to the total losses in the power supply. Use 0.5 if no better data available
tC			3.00	ms	Bridge Rectifier Conduction Time Estimate
ENTER Hiper-TFS STANDBY VARIABLES					
Select Current Limit	**INC**		Increased Current Limit		Enter "LOW" for low current limit, "RED" for reduced current limit (sealed adapters), "STD" for standard current limit or "INC" for increased current limit (peak or higher power applications)
ILIM_MIN			0.70	A	Minimum Current Limit
ILIM_TYP			0.75	A	Typical Current Limit
ILIM_MAX			0.80	A	Maximum Current Limit
R(EN)			107	kΩ	Enable pin resistor
fSmin			124,000	Hz	Minimum Device Switching Frequency
I^2fmin			66.8	A^2kHz	I^2f (product of current limit squared and frequency is trimmed for tighter tolerance)
VOR	110		110	V	Reflected Output Voltage (VOR < 135 V Recommended)
VDS			10.0	V	Hiper-TFS Standby On State Drain to Source Voltage
VD_SB			0.5	V	Output Winding Diode Forward Voltage Drop
KP			0.39		Ripple to Peak Current Ratio (KP < 6)
KP_TRANSIENT			0.26		Transient Ripple to Peak Current Ratio. Ensure KP_TRANSIENT > 0.25
ENTER BIAS WINDING VARIABLES					
VB			16.0	V	Bias Winding Voltage
IB			20.0	mA	Bias winding Load current
PB			0.32	W	Bias winding power
VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
NB			12.1	turns	Bias Winding Number of Turns
VZOV			22	V	Over Voltage Protection zener diode voltage.
UVLO VARIABLES					
RLS			3.97	MΩ	Line sense resistor (from Main converter section)
V_UV_ACTUAL			101	V	Typical DC start-up voltage
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**EF25**		**EF25**		Enter Transformer Core
AE			0.518	cm^2	Core Effective Cross Sectional Area
LE			5.78	cm	Core Effective Path Length
AL			2000	nH/T^2	Ungapped Core Effective Inductance
BW			15.6	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00		2		Number of Primary Layers

NS_SB	4		4		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN_SB			78	V	Minimum DC Input Voltage
VMAX_SB			375	V	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX_SB			0.62		Duty Ratio at full load, minimum primary inductance and minimum input voltage
IAVG			0.40	A	Average Primary Current
IP_SB			0.70	A	Minimum Peak Primary Current
IR_SB			0.27	A	Primary Ripple Current
IRMS_SB			0.51	A	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP_SB			1247	uH	Typical Primary Inductance. +/- 10% to ensure a minimum primary inductance of 1133 uH
LP_TOLERANCE			10	%	Primary inductance tolerance
NP_SB			80	turns	Primary Winding Number of Turns
ALG			195	nH/T^2	Gapped Core Effective Inductance
BM			2415	Gauss	Maximum Operating Flux Density, BM<3000 is recommended
BAC			469	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1776		Relative Permeability of Ungapped Core
LG			0.30	mm	Gap Length (Lg > 0.1 mm)
BWE			31.2	mm	Effective Bobbin Width
OD			0.39	mm	Maximum Primary Wire Diameter including insulation
INS			0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.33	mm	Bare conductor diameter
AWG			28	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			161	Cmils	Bare conductor effective area in circular mils
CMA			314	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			14.0	A	Peak Secondary Current
ISRMS			8.07	A	Secondary RMS Current
IRIPPLE			7.01	A	Output Capacitor RMS Ripple Current
CMS			1614	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			18	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
VOLTAGE STRESS PARAMETERS					
VDRAIN			626	V	Maximum Drain Voltage Estimate (Assumes 20% zener clamp tolerance and an additional 10% temperature tolerance)
PIVS			24	V	Output Rectifier Maximum Peak Inverse Voltage
Forward DC-DC System efficiency					
P_MOSFET_MAIN_TOTAL			5.25	W	HiperTFS losses
P_XFMR_LOSS			3.2	W	Main transformer losses
P_MAIN_OUT_DIODE			2.3	W	Output diode losses
P_CIN_ESR			0.24	W	Bulk capacitor ESR losses
P_IND_MAIN			2.3	W	Output choke losses
OTHER_LOSSES			0.13	W	Other losses (includes PCB traces, clamp loss, magamp loss etc.)
EFFICIENCY_STDBY			75.0%		Estimated efficiency of flyback power supply
EFFICIENCY_MAIN			95.4%		Estimated Forward efficiency

EFFICIENCY_SYSTEM			93.7%		Estimated System efficiency (forward + standby)
Other Losses					
Detailed Mosfet Loss Information					

Note: PIXls for TFS2 generates a "warning" message if the output inductor KDI_ACTUAL is ≥ 0.5. This is still rather continuous, and the only real consequence of less continuous operation is slightly higher peak primary current, somewhat higher AC loss in the output inductor, and slightly higher ripple current in the output capacitors than would be the case in a more continuous design (lower KDI_ACTUAL). None of these factors posed significant issues in this design. A more continuous design would require more inductor turns or a larger core.

11 Heat Sinks

11.1 Main Primary Heat Sink (U1 and BR1)

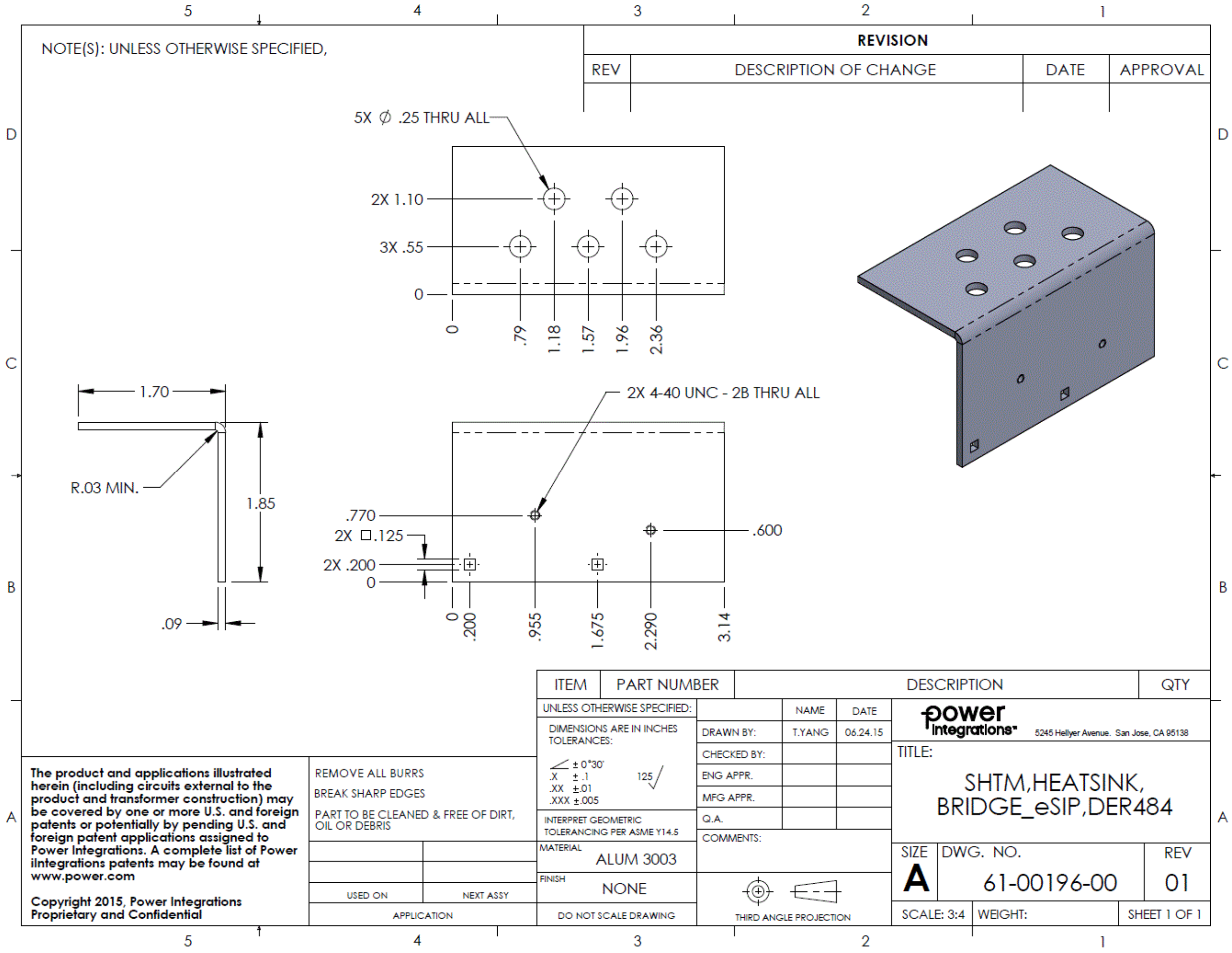
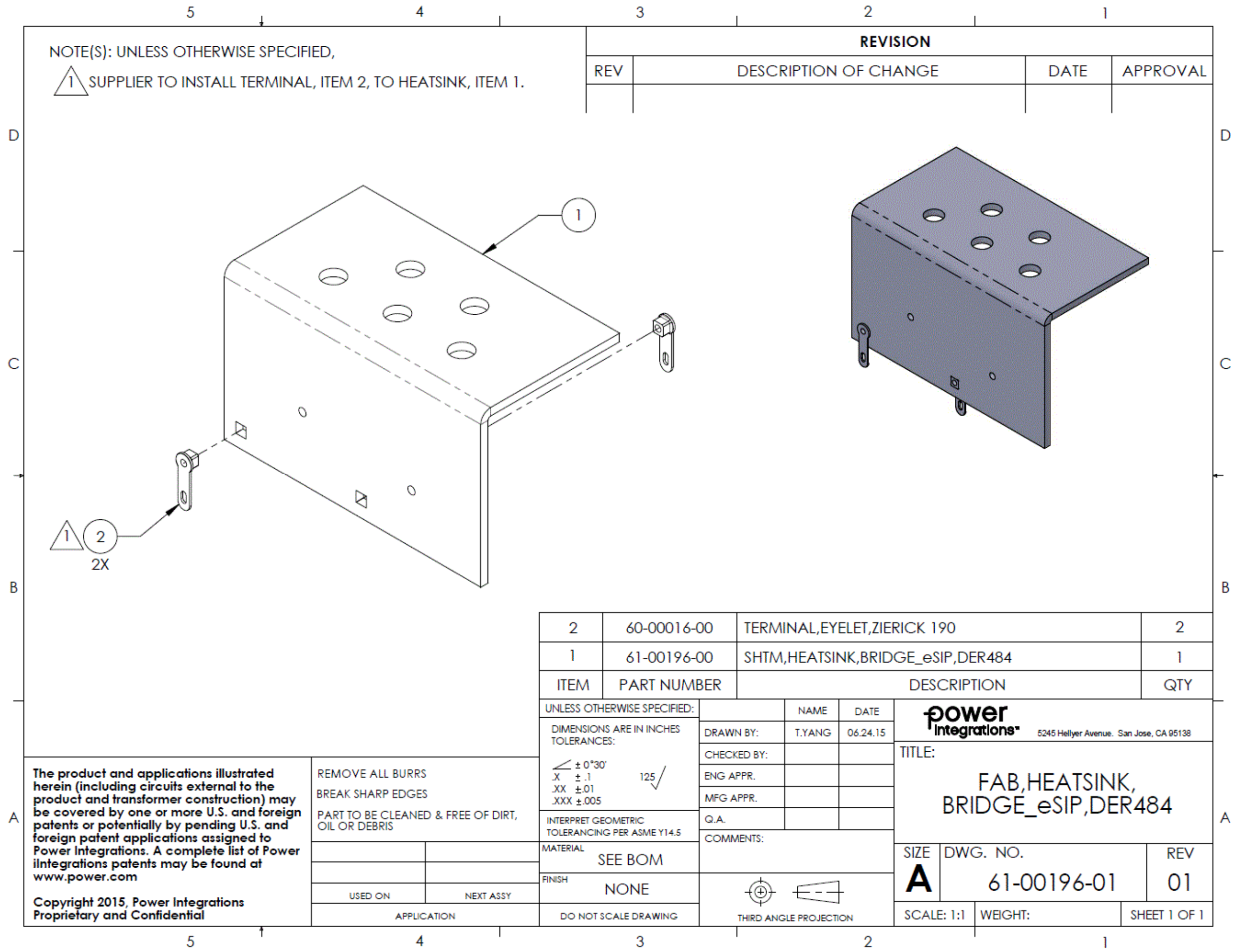


Figure 15 – U1/BR1 Heat Sink Sheet Metal.



NOTE(S): UNLESS OTHERWISE SPECIFIED,
1 SUPPLIER TO INSTALL TERMINAL, ITEM 2, TO HEATSINK, ITEM 1.

ITEM	PART NUMBER	DESCRIPTION	QTY
2	60-00016-00	TERMINAL,EYELET,ZIERICK 190	2
1	61-00196-00	SHTM,HEATSINK,BRIDGE_eSIP,DER484	1

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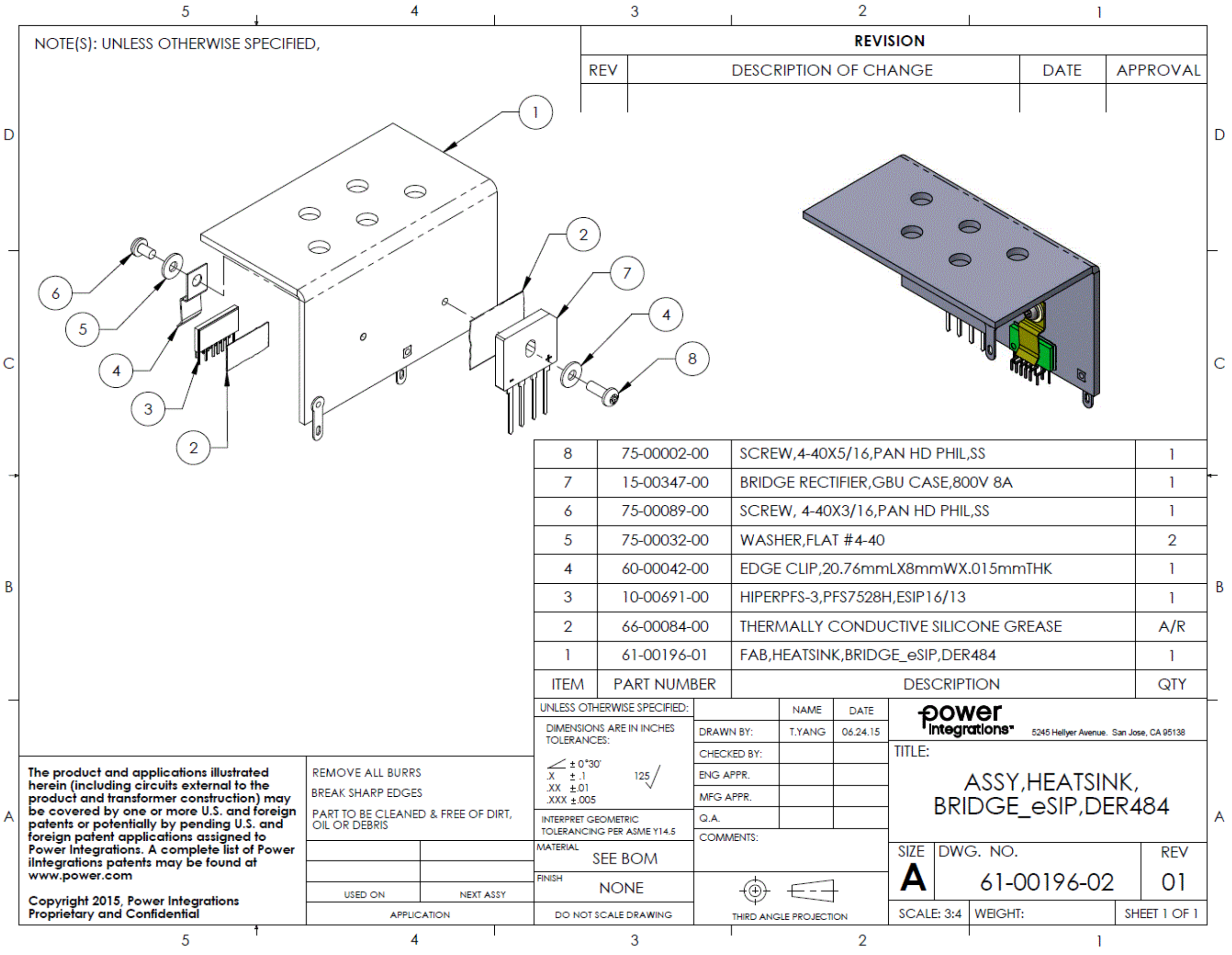
Figure 16 – U1/BR1 Completed Heat Sink.



NOTE(S): UNLESS OTHERWISE SPECIFIED,

REVISION			
REV	DESCRIPTION OF CHANGE	DATE	APPROVAL

ITEM	PART NUMBER	DESCRIPTION	QTY
8	75-00002-00	SCREW,4-40X5/16,PAN HD PHIL,SS	1
7	15-00347-00	BRIDGE RECTIFIER,GBU CASE,800V 8A	1
6	75-00089-00	SCREW, 4-40X3/16,PAN HD PHIL,SS	1
5	75-00032-00	WASHER,FLAT #4-40	2
4	60-00042-00	EDGE CLIP,20.76mmLX8mmWX.015mmTHK	1
3	10-00691-00	HIPERPFS-3,PFS7528H,ESIP16/13	1
2	66-00084-00	THERMALLY CONDUCTIVE SILICONE GREASE	A/R
1	61-00196-01	FAB,HEATSINK,BRIDGE_eSIP,DER484	1

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APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
∠ ± 0°30'
.X ± .1
.XX ± .01
.XXX ± .005
125 √
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5
MATERIAL SEE BOM
FINISH NONE
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	T.YANG	06.24.15
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

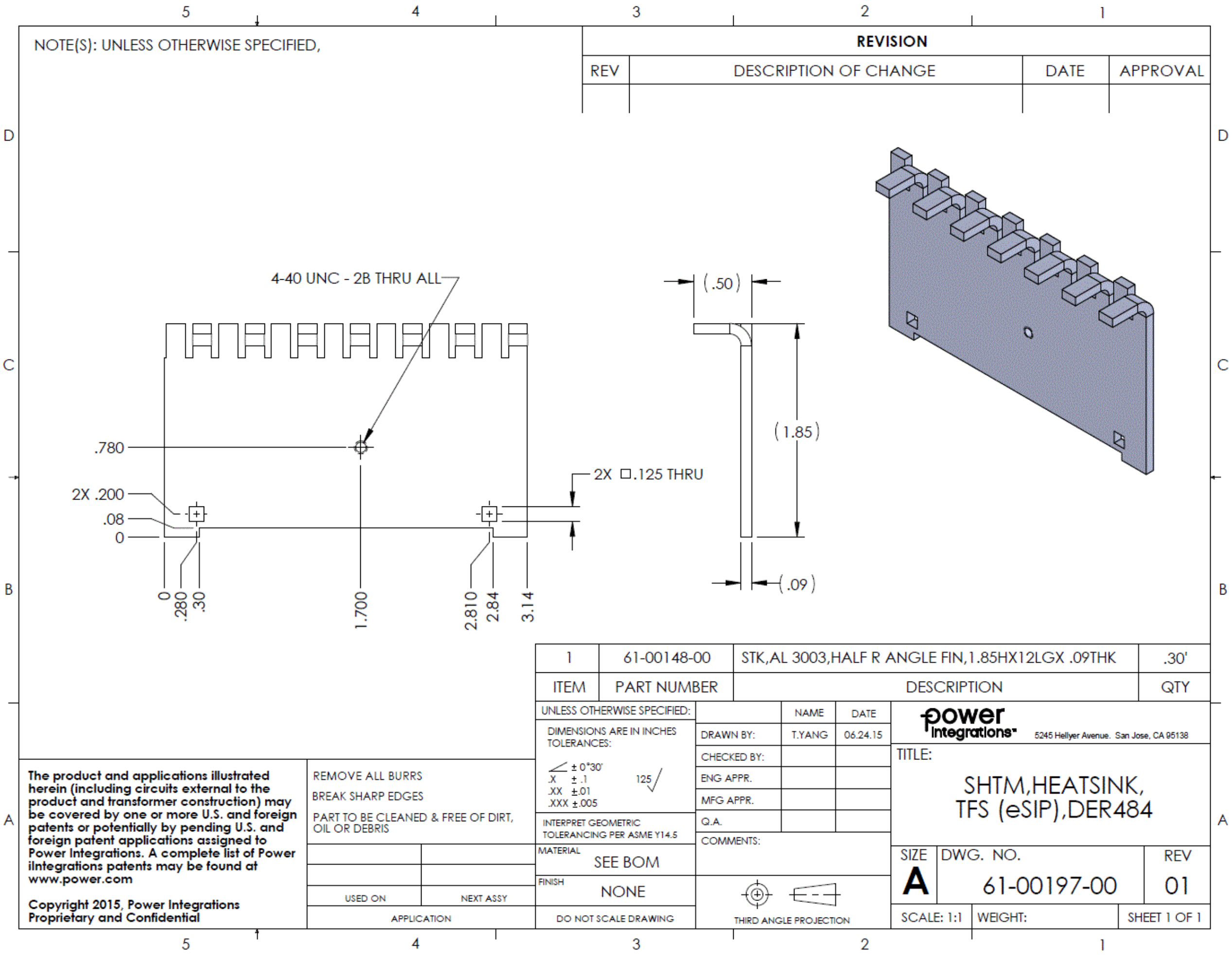
COMMENTS:
THIRD ANGLE PROJECTION

Power Integrations 5245 Hellyer Avenue. San Jose, CA 95138
TITLE:
ASSY,HEATSINK,
BRIDGE_eSIP,DER484

SIZE A | DWG. NO. 61-00196-02 | REV 01
SCALE: 3:4 | WEIGHT: | SHEET 1 OF 1

Figure 17 – U1/BR1 Heat Sink Assembly.

11.2 Primary Heat Sink #2 (U2)



ITEM	PART NUMBER	DESCRIPTION	QTY
1	61-00148-00	STK,AL 3003,HALF R ANGLE FIN,1.85HX12LGX .09THK	.30'

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
∠ ± 0°30'
.X ± .1
.XX ±.01
.XXX ±.005
125√
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5
MATERIAL SEE BOM
FINISH NONE
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	T.YANG	06.24.15
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
THIRD ANGLE PROJECTION

power integrations 5245 Hellyer Avenue. San Jose, CA 95138
TITLE: SHTM,HEATSINK, TFS (eSIP),DER484
SIZE A
DWG. NO. 61-00197-00
REV 01
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

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Figure 18 – U2 Heat Sink Sheet Metal.

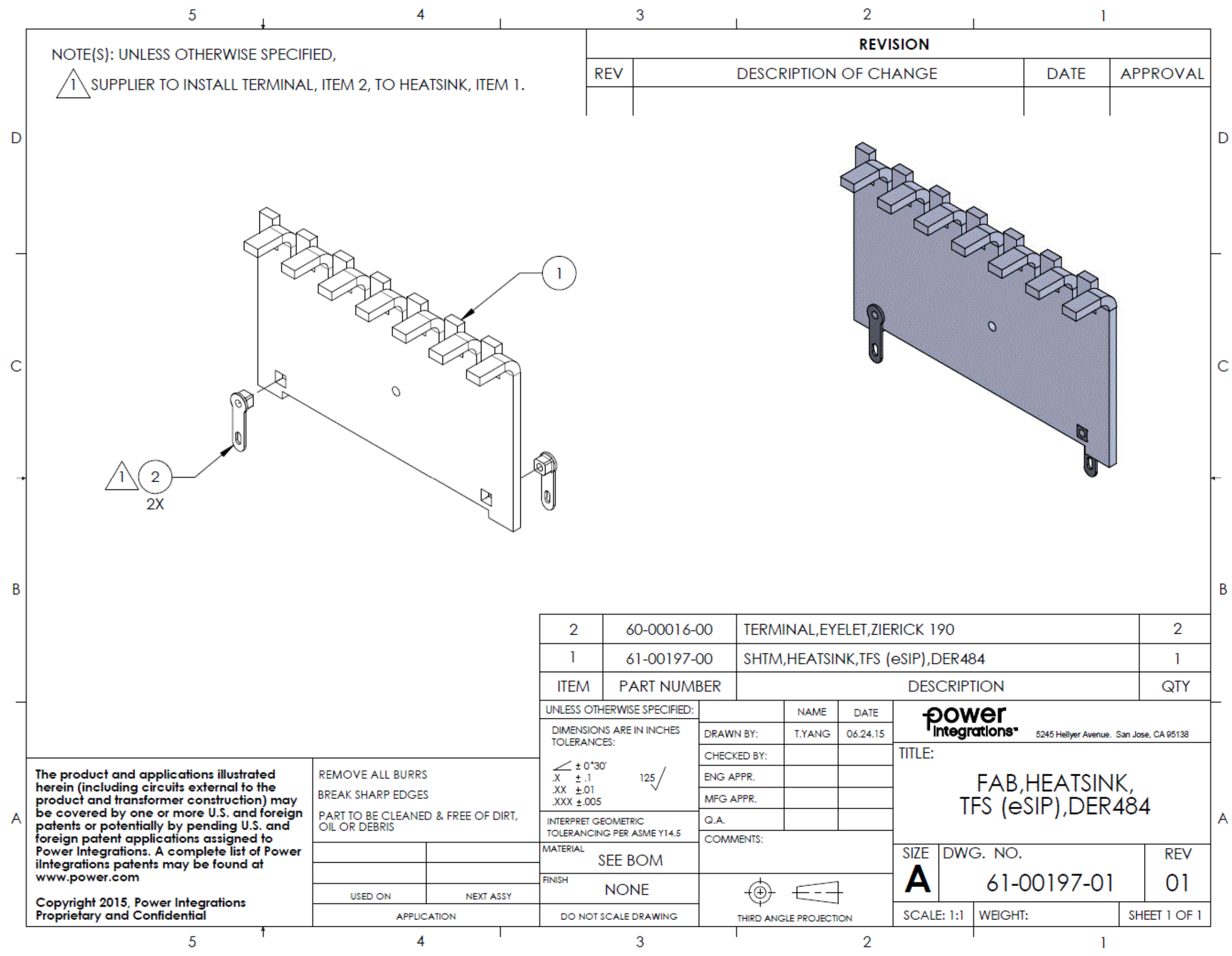
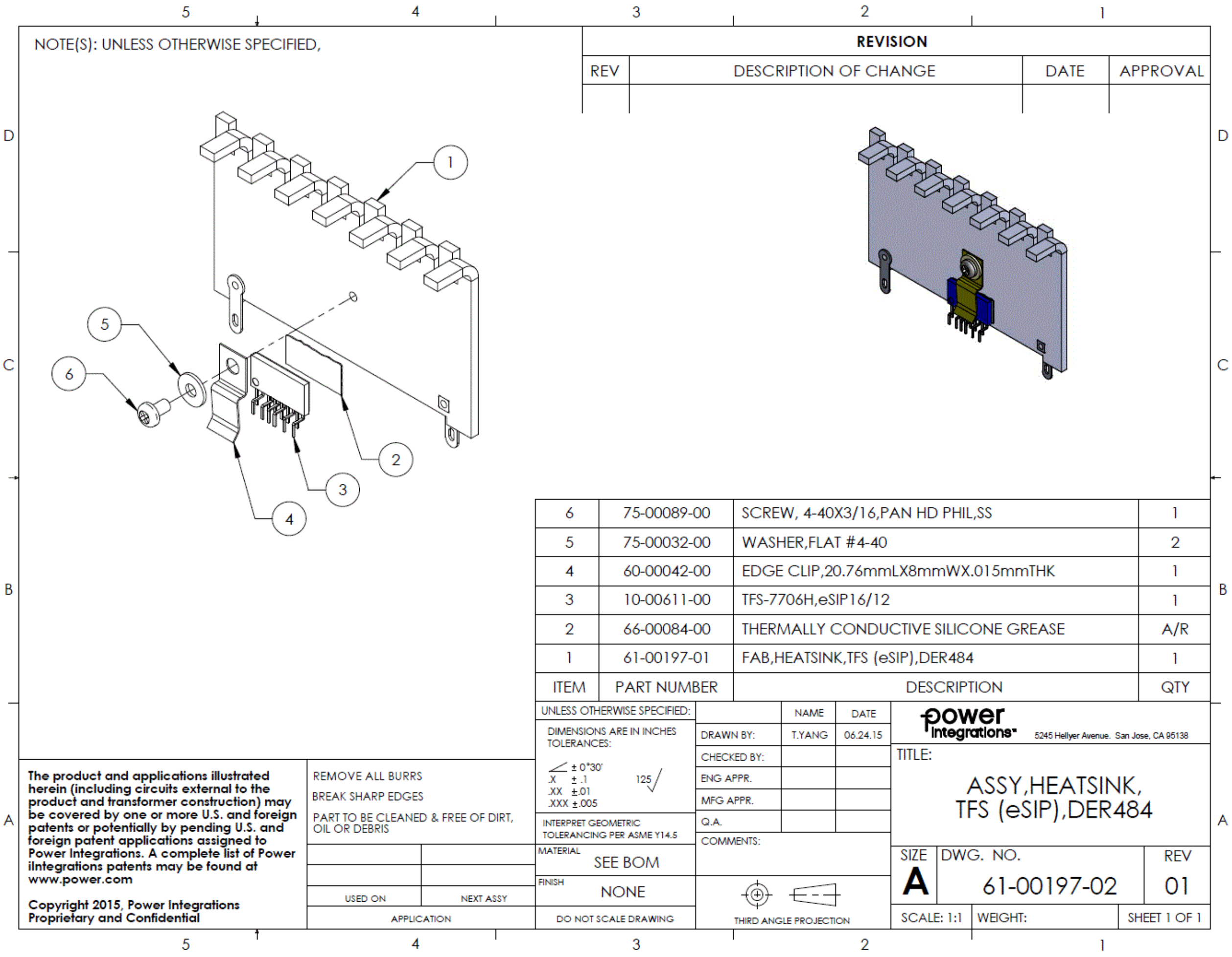


Figure 19 – U2 Completed Heat Sink.



NOTE(S): UNLESS OTHERWISE SPECIFIED,

REVISION			
REV	DESCRIPTION OF CHANGE	DATE	APPROVAL

ITEM	PART NUMBER	DESCRIPTION	QTY
6	75-00089-00	SCREW, 4-40X3/16,PAN HD PHIL,SS	1
5	75-00032-00	WASHER,FLAT #4-40	2
4	60-00042-00	EDGE CLIP,20.76mmLX8mmWX.015mmTHK	1
3	10-00611-00	TFS-7706H,eSIP16/12	1
2	66-00084-00	THERMALLY CONDUCTIVE SILICONE GREASE	A/R
1	61-00197-01	FAB,HEATSINK,TFS (eSIP),DER484	1

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USED ON | NEXT ASSY

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES

TOLERANCES:

∠ ± 0°30'

.X ± .1

.XX ±.01

.XXX ±.005

125√

INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5

MATERIAL SEE BOM

FINISH NONE

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	T.YANG	06.24.15
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

THIRD ANGLE PROJECTION

power integrations™ 5245 Hellyer Avenue. San Jose, CA 95138

TITLE: ASSY,HEATSINK, TFS (eSIP),DER484

SIZE A

DWG. NO. 61-00197-02

REV 01

SCALE: 1:1

WEIGHT:

SHEET 1 OF 1

Figure 20 – U2 Heat Sink Assembly.

11.3 Secondary Heat Sink

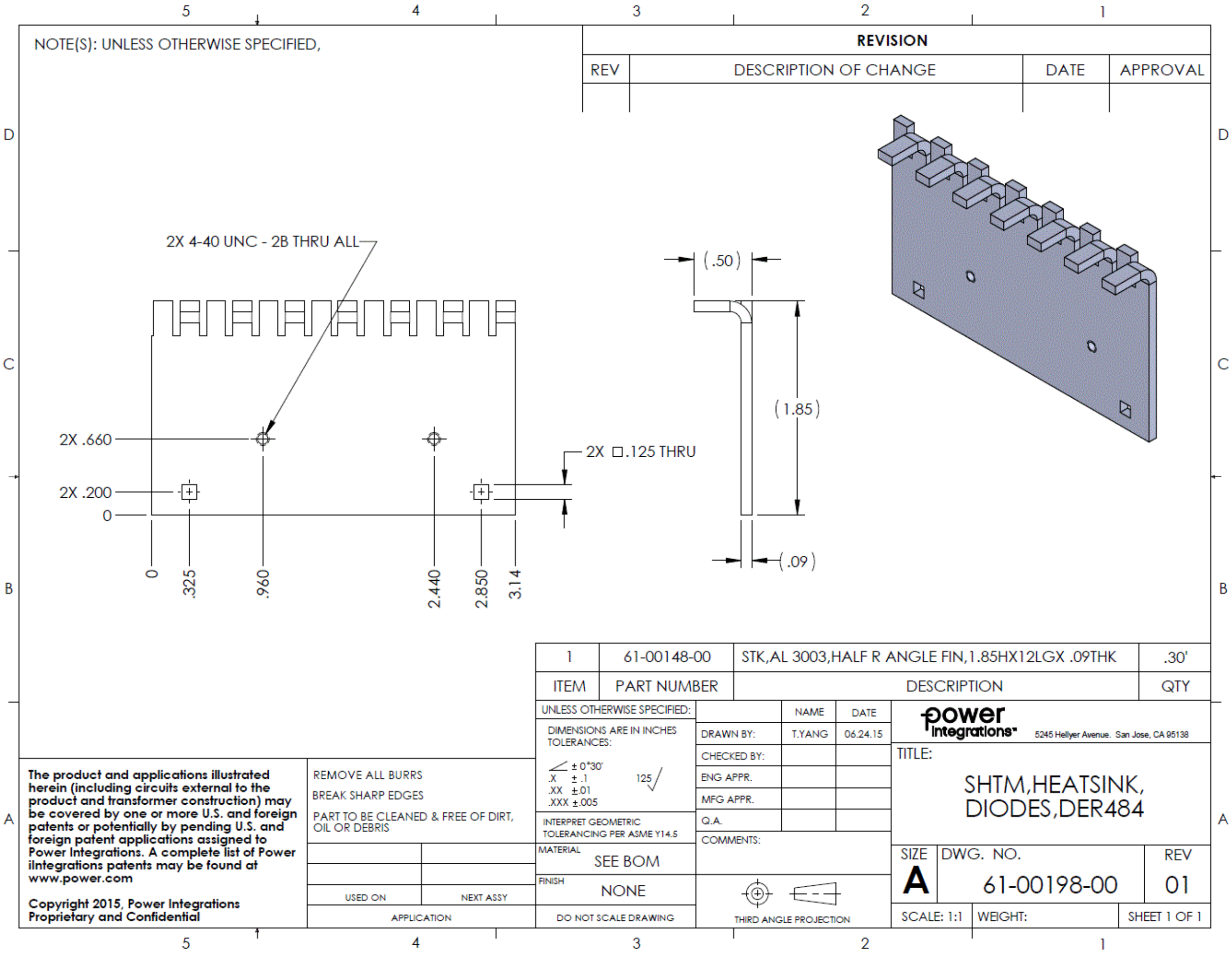
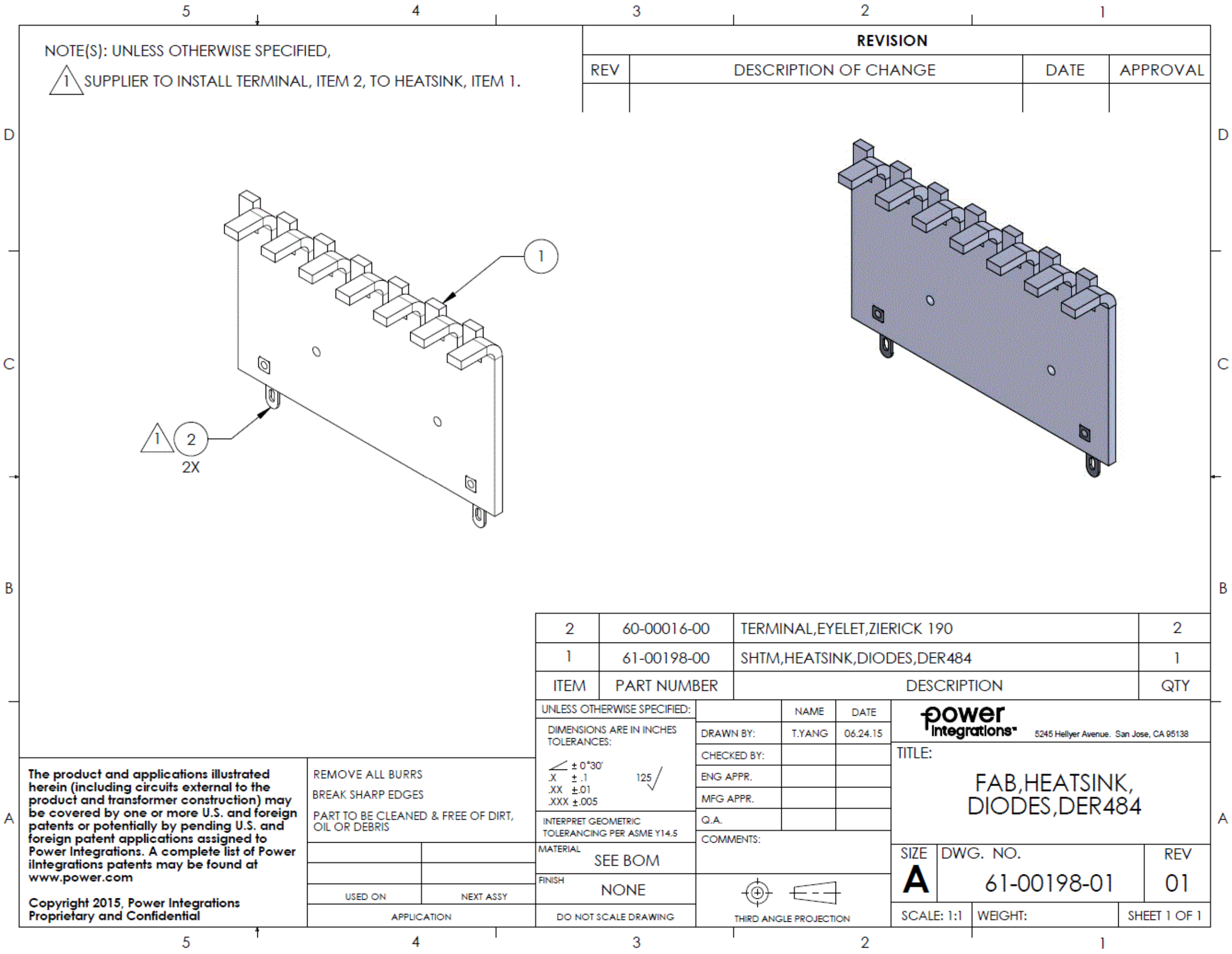
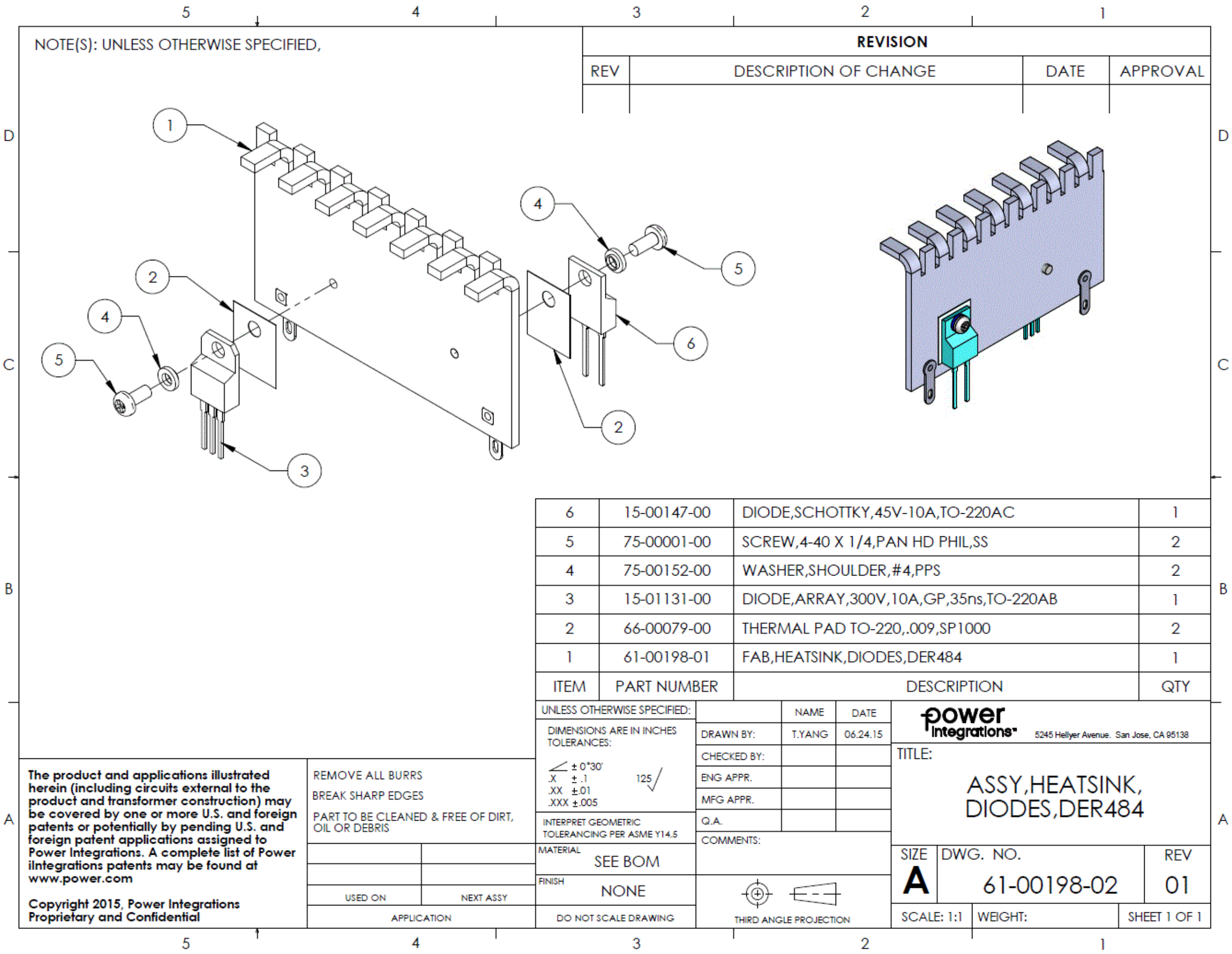


Figure 21 – Secondary Heat Sink Sheet Metal.



ITEM	PART NUMBER	DESCRIPTION	QTY
2	60-00016-00	TERMINAL,EYELET,ZIERICK 190	2
1	61-00198-00	SHTM,HEATSINK,DIODES,DER484	1

Figure 22 – Secondary Heat Sink (Completed).



NOTE(S): UNLESS OTHERWISE SPECIFIED,

REVISION			
REV	DESCRIPTION OF CHANGE	DATE	APPROVAL

ITEM	PART NUMBER	DESCRIPTION	QTY
6	15-00147-00	DIODE,SCHOTTKY,45V-10A,TO-220AC	1
5	75-00001-00	SCREW,4-40 X 1/4,PAN HD PHIL,SS	2
4	75-00152-00	WASHER,SHOULDER,#4,PPS	2
3	15-01131-00	DIODE,ARRAY,300V,10A,GP,35ns,TO-220AB	1
2	66-00079-00	THERMAL PAD TO-220,.009,SP1000	2
1	61-00198-01	FAB,HEATSINK,DIODES,DER484	1

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BREAK SHARP EDGES
PART TO BE CLEANED & FREE OF DIRT, OIL OR DEBRIS

USED ON | NEXT ASSY
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
∠ ± 0°30'
.X ± .1
.XX ± .01
.XXX ± .005
125√
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5
MATERIAL: SEE BOM
FINISH: NONE
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	T.YANG	06.24.15
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

THIRD ANGLE PROJECTION

power integrations 5245 Hellyer Avenue. San Jose, CA 95138

TITLE:
ASSY,HEATSINK, DIODES,DER484

SIZE: A
DWG. NO.: 61-00198-02
REV: 01
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

Figure 23 – Secondary Heat Sink Assembly.

12 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.

12.1 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.

12.2 Efficiency

To make this measurement, the supply was powered with an AC source. The figure shown includes the efficiency of the main forward stage combined with that of the standby/bias flyback supply.

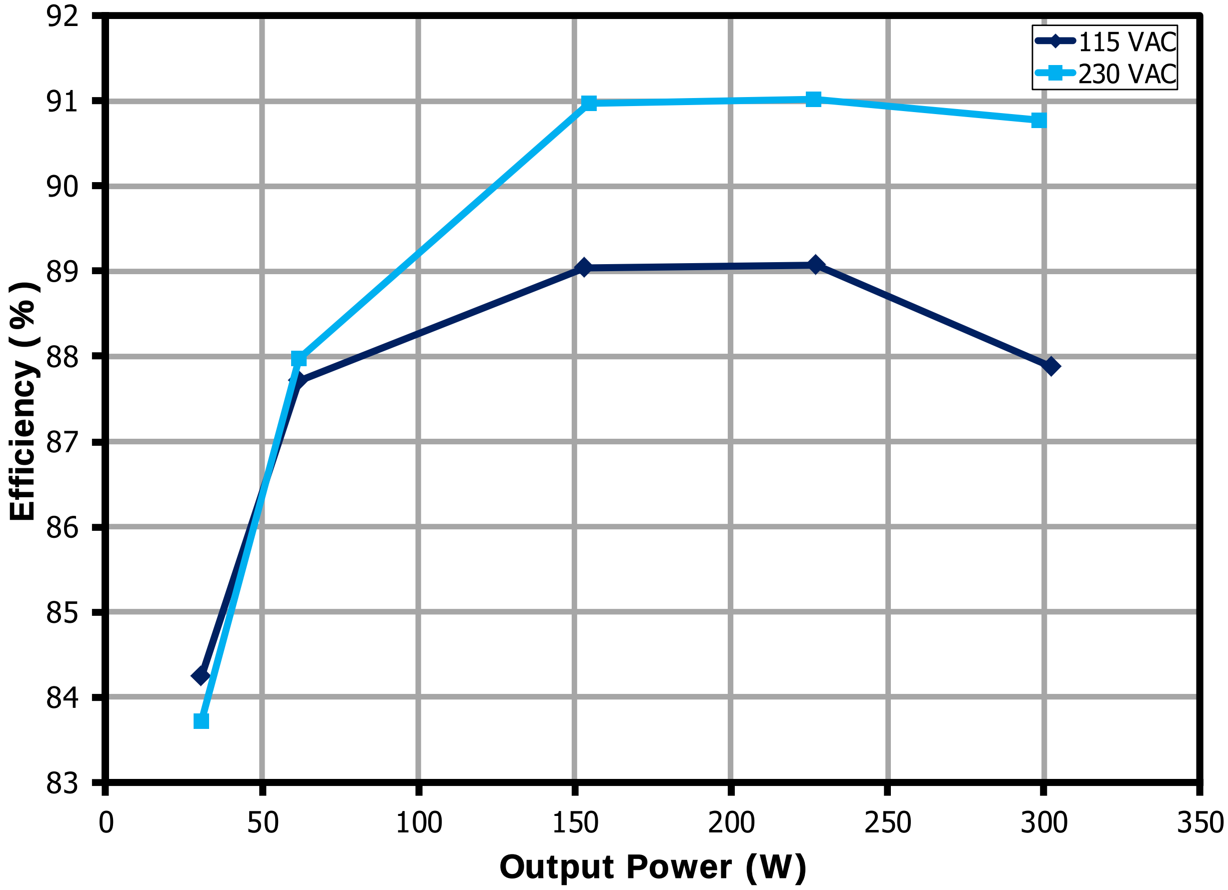


Figure 24 – Efficiency vs. Output Power.

12.3 No-Load Input Power

No-load input power was measured with no load on the main and standby outputs and with the main enable switch turned off, such that only the standby supply remained active.

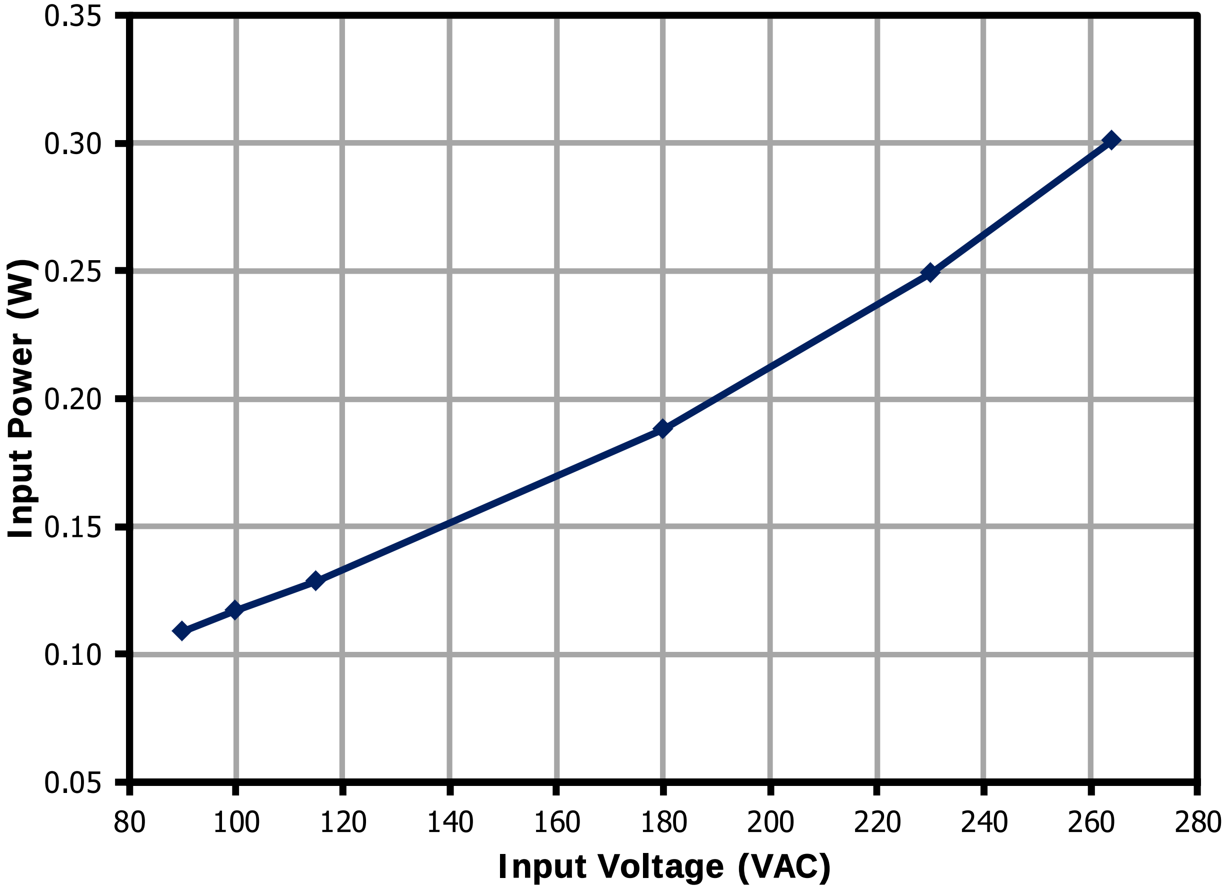


Figure 25 – No-Load Input Power vs. Input Voltage.

12.4 Power Factor

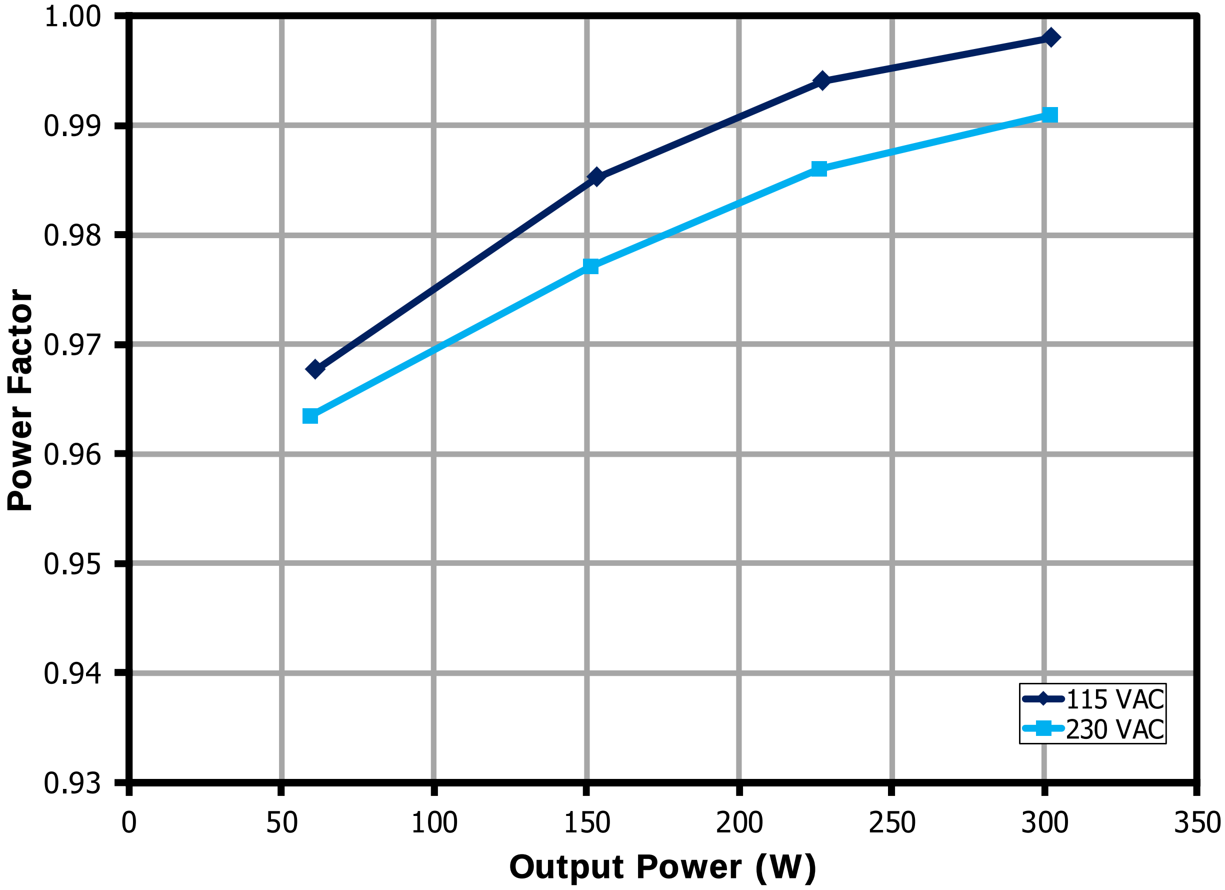


Figure 26 – Power Factor vs. Output Power.

12.5 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 3.2 V, as this is the minimum load voltage attainable by the electronic load in CR mode.

12.5.1 V-I Characteristic, Constant Resistance Load

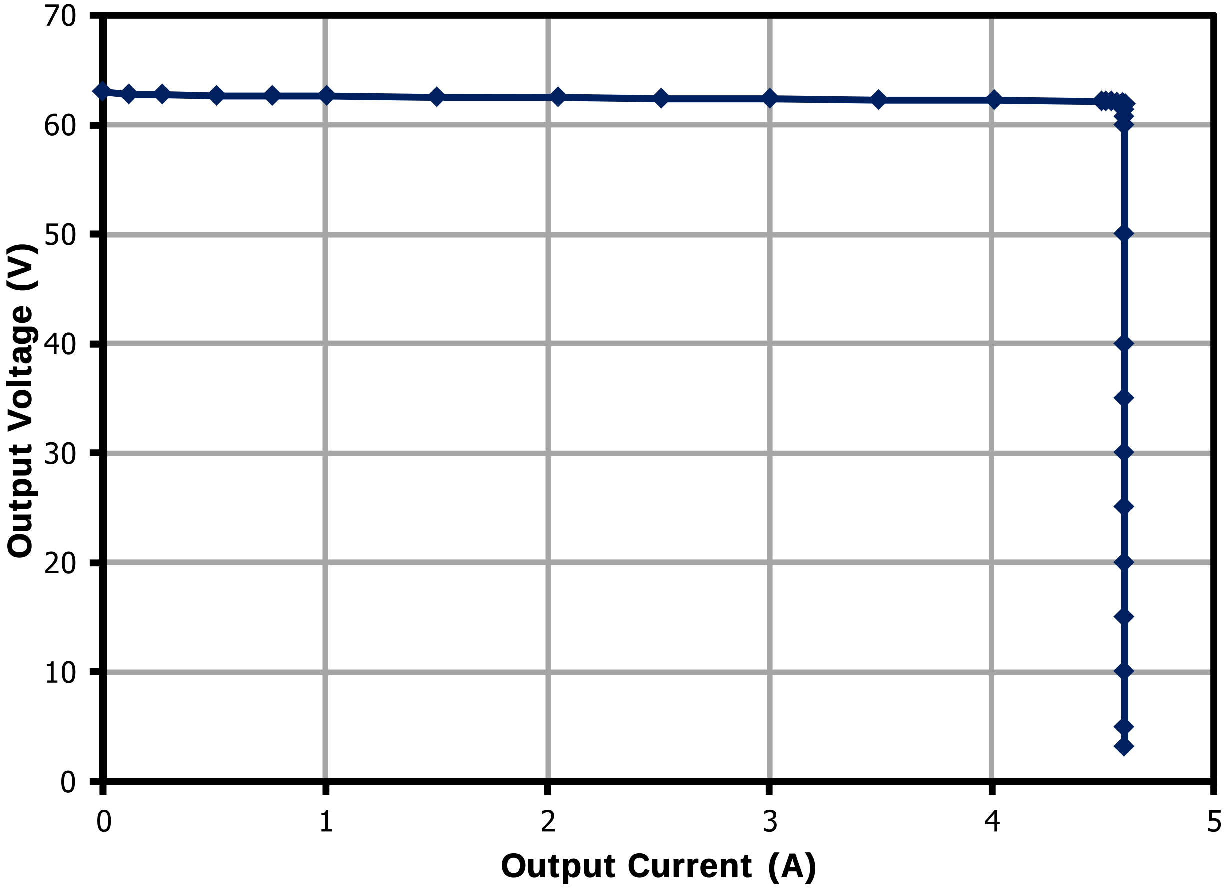


Figure 27 – V-I Characteristic with CR Load.

12.5.2 Main Output V-I Characteristic, Constant Voltage Load

The main output V-I characteristic in constant current mode was measured using a Chroma electronic load set for constant voltage mode. The minimum operating voltage of the load in CV mode is ~0.37 V.

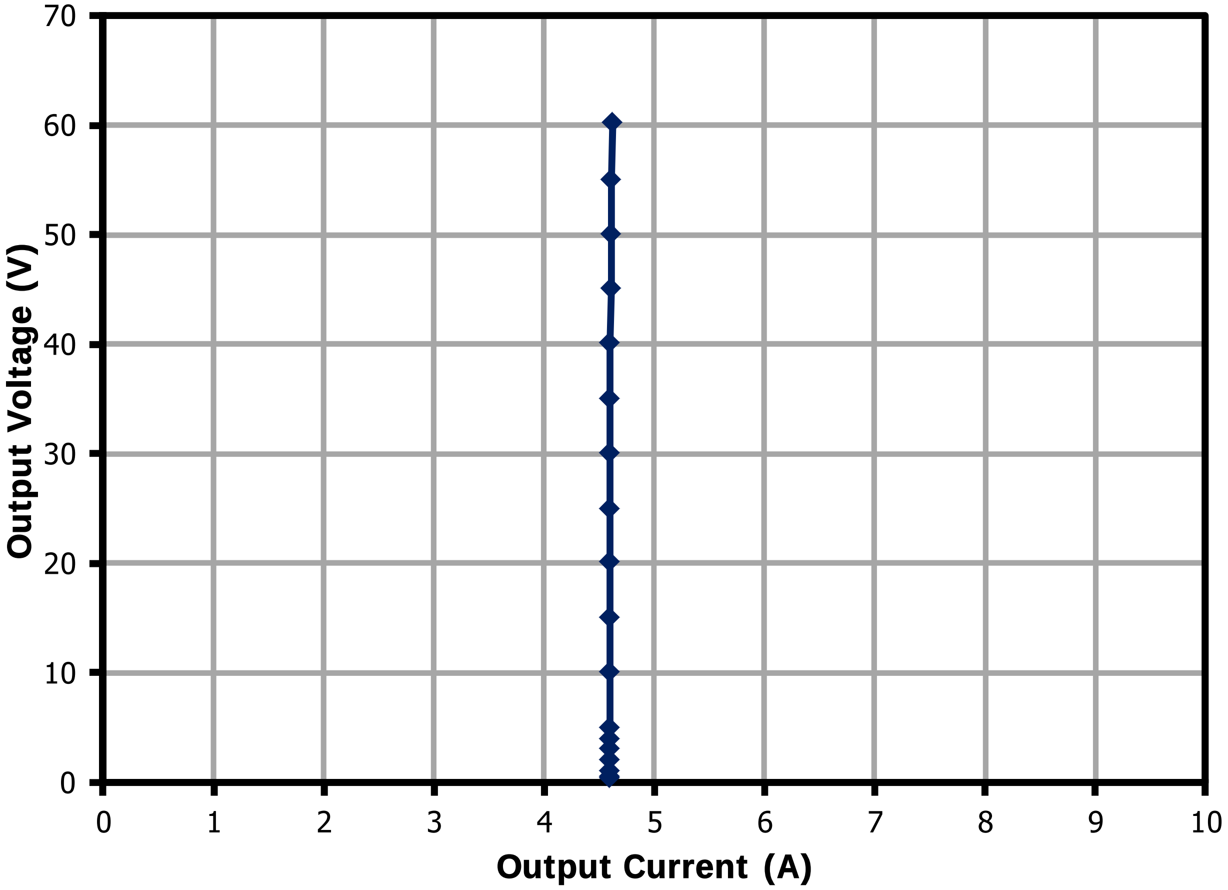
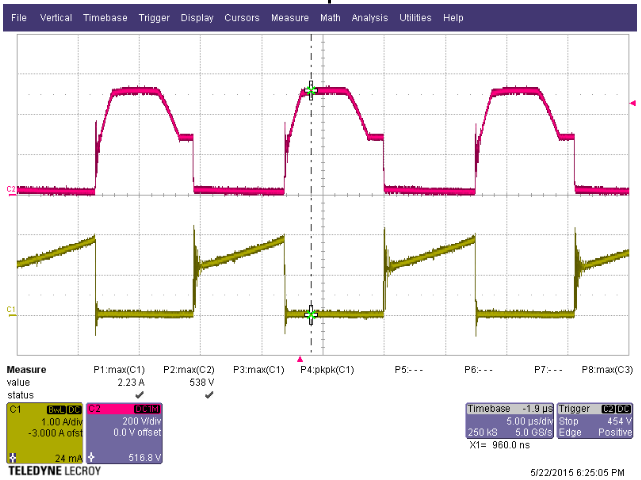


Figure 28 – V-I Characteristic with CV Load.

13 Waveforms

13.1 Primary Voltage and Current, Main and Standby Converters

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



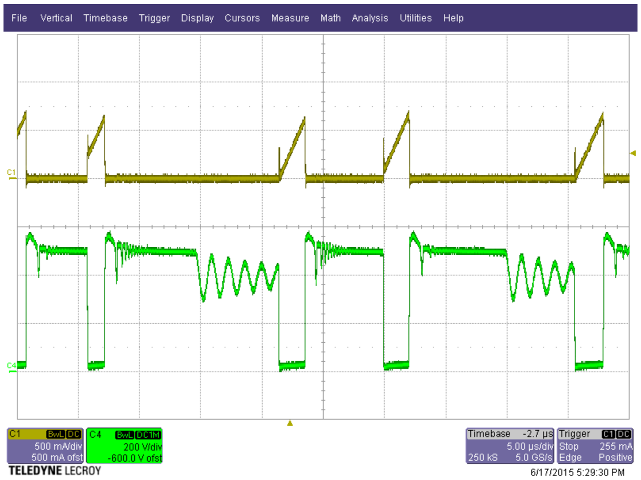


Figure 29 – Main Stage Primary Voltage and Current, 115 VAC Input, 100% Load.
Upper: D Pin Voltage, 200 V / div.
Lower: I_{DRAIN}, 1 A / div., 5 µs / div.

Figure 30 – Standby Primary Voltage and Current, 115 VAC Input, 100% Load Enable Switch "On".
Upper: I_{DRAIN}, 0.5 A /div.
Lower: DSB Pin Voltage, 200 V, 5 µs / div.

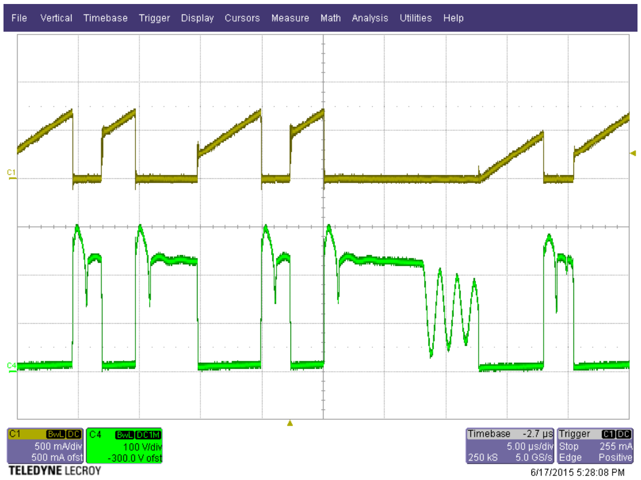


Figure 31 – Standby Primary Voltage and Current, 90 VAC Input, 100% Load, Enable Switch "Off".
Upper: I_{DRAIN}, 0.5 A / div.
Lower: DSB Pin Voltage, 100 V, 5 µs / div.

13.2 AC Input Voltage and Current

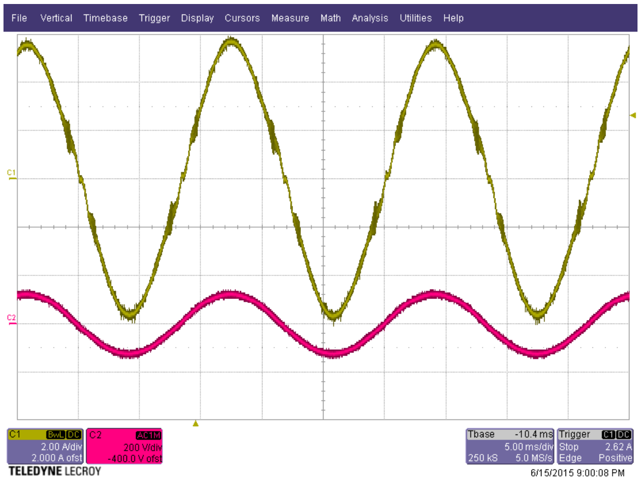


Figure 32 – AC Input Voltage and Current, 90 VAC, 100% Load.
Upper: AC I_{IN}, 2 A / div.
Lower: AC V_{IN}, 200 V / 5 ms / div.

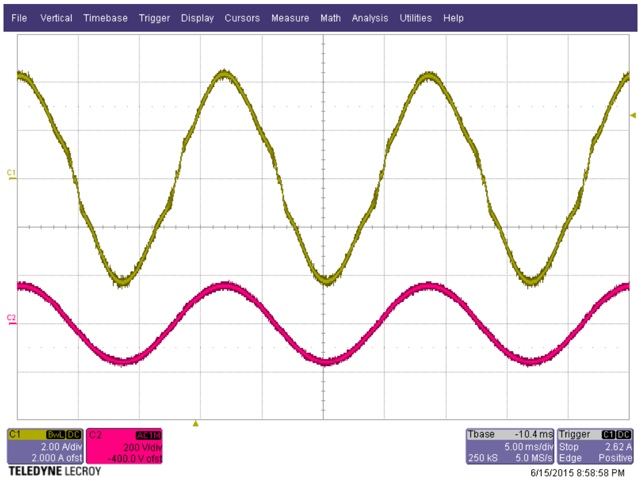


Figure 33 – AC Input Voltage and Current, 115 VAC, 100% Load.
Upper: AC I_{IN}, 2 A / div.
Lower: AC V_{IN}, 200 V / 5 ms / div.

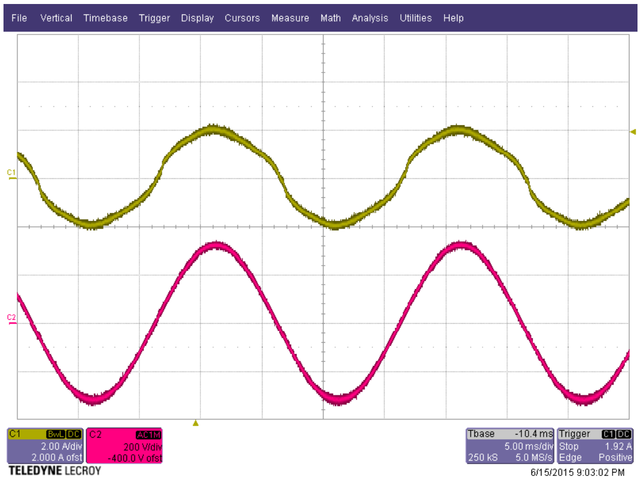


Figure 34 – AC Input Voltage and Current, 230 VAC, 100% Load.
Upper: AC I_{IN}, 2 A / div.
Lower: AC V_{IN}, 200 V / 5 ms / div.

13.3 PFC Stage Inductor Current / Drain Voltage Waveforms

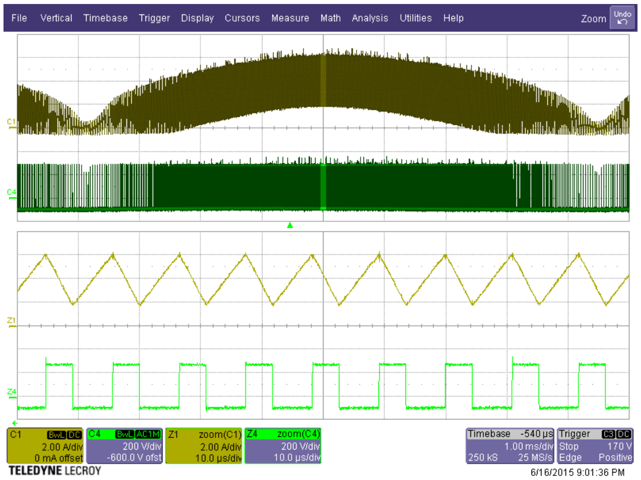


Figure 35 – PFC Inductor Current / Drain Voltage, 115 VAC, 100% Load.
Upper: $I_{INDUCTOR}$, 2 A / div.
Lower: V_{DRAIN}, 200 V / div., 1 ms / div.
Zoom Upper: $I_{INDUCTOR}$, 2 A / div.
Zoom Lower: V_{DRAIN}, 200 V / div., 20 µs / div.

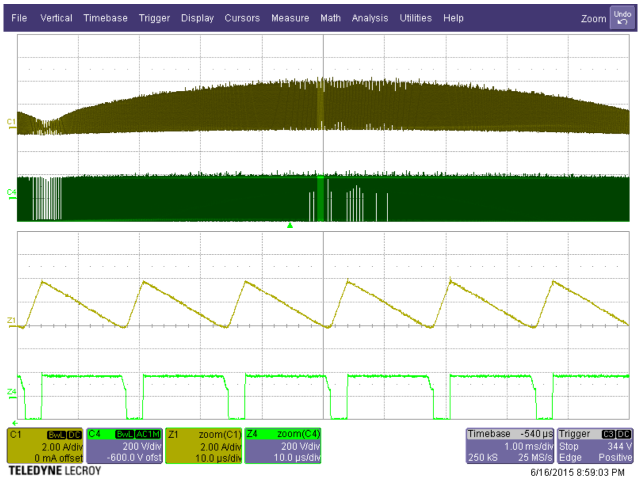


Figure 36 – PFC Inductor Current / Drain Voltage, 230 VAC, 100% Load.
Upper: $I_{INDUCTOR}$, 2 A / div.
Lower: V_{DRAIN}, 200 V / div., 1 ms / div.
Zoom Upper: $I_{INDUCTOR}$, 2 A / div.
Zoom Lower: V_{DRAIN}, 200 V / div., 20 µs / div.

13.4 Output Rectifier Peak Reverse Voltage

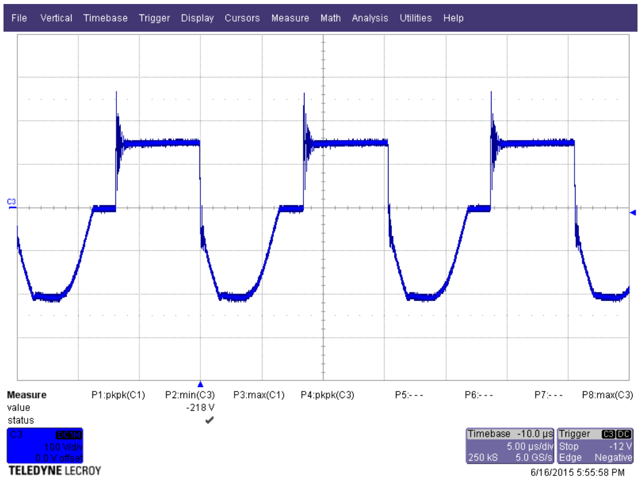


Figure 37 – Output Forward Rectifier (D19) Reverse Voltage, 115 VAC input, 100% Load. 100 V, 5 µs / div.

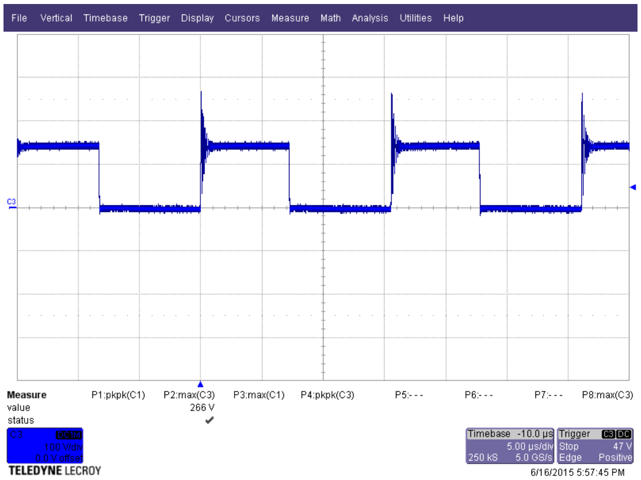


Figure 38 – Output Catch Rectifier (D19) Reverse Voltage, Leading Edge Spike, 115 VAC, 100% Load. 100 V, 5 µs / div.

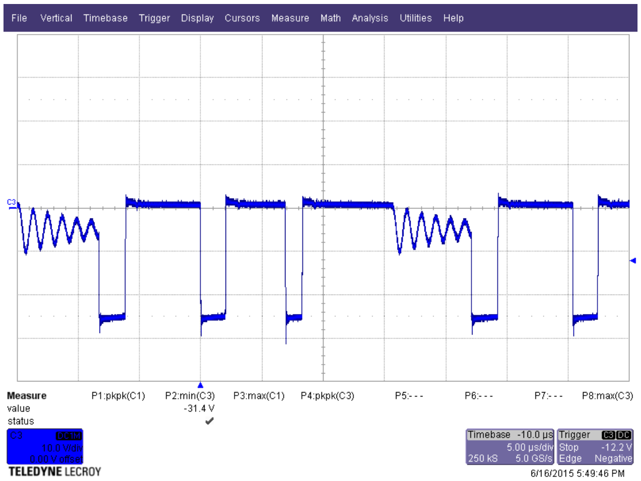


Figure 39 – Standby Output Rectifier (D18) Reverse Voltage, 115 VAC, 100% Load. 10 V, 5 µs / div.

13.5 Main Start-up Output Voltage / Current and Transformer Primary Current Using Constant Voltage and Constant Voltage Output Loads

13.5.1 Main and Standby Start-Up, Supply Started via AC Input

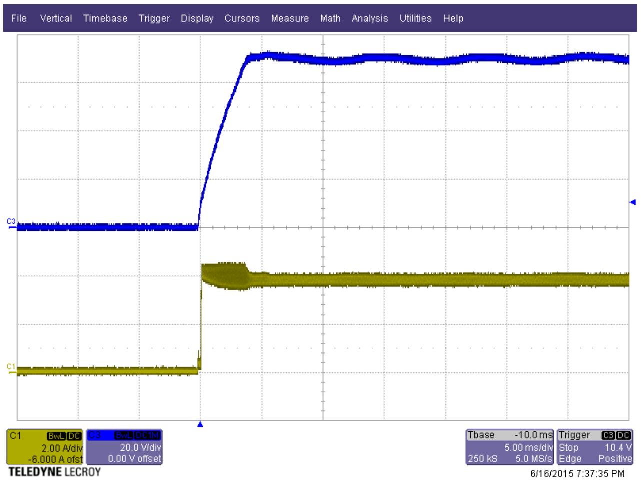


Figure 40 – Main Output Start-up, CV Mode, 115 VAC, Chroma CC Load, 4.3 A Setting.
Upper: Main V_{OUT}, 10 V / div.
Lower: Main I_{OUT}, 2 A, 2 ms / div.

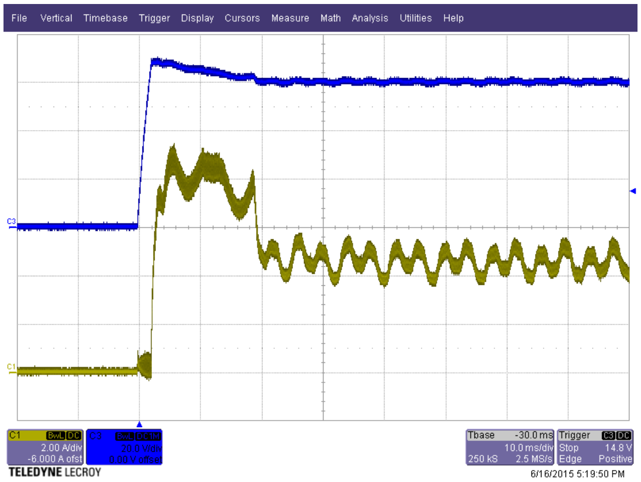


Figure 41 – Main Output Start-up, CC Mode, 115 VAC, Chroma CV Load, 60 V Setting.
Upper: Main V_{OUT}, 20 V / div.
Lower: Main I_{OUT}, 2 A, 10 ms / div.

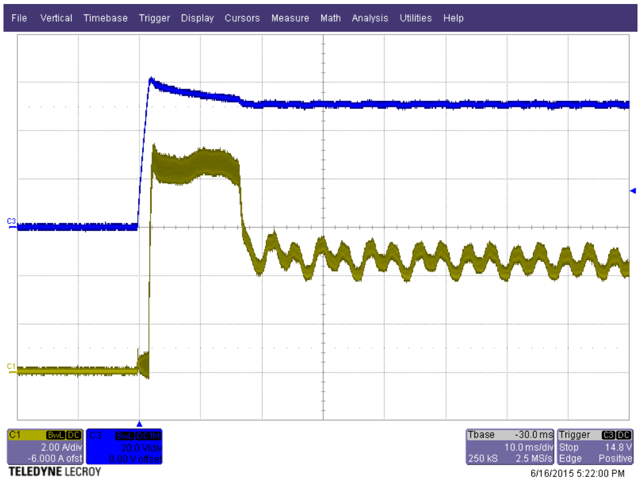


Figure 42 – Main Output Start-up, CC Mode, 115 VAC, Chroma CV Load, 50 V Setting.
Upper: Main V_{OUT}, 20 V.
Lower: Main I_{OUT}, 2 A, 10 ms / div.

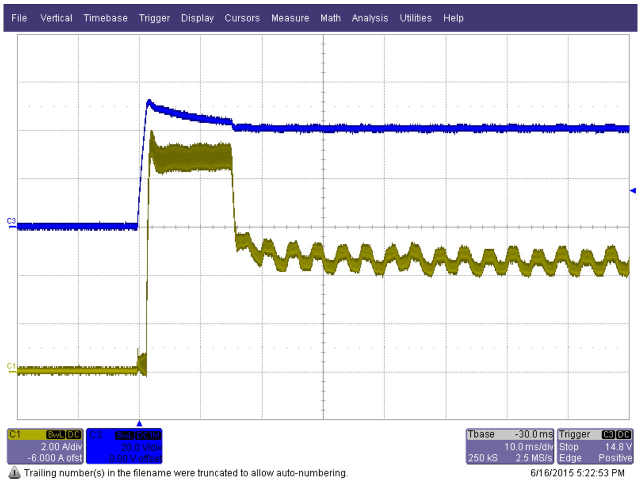
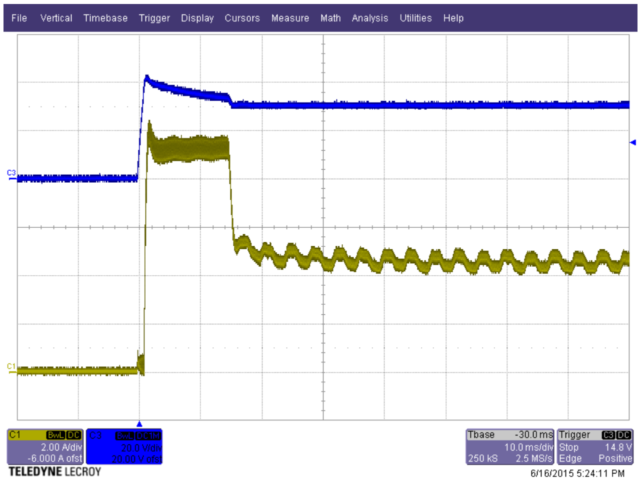


Figure 43 – Main Output Start-up, CC Mode, 115 VAC, Chroma CV Load, 45 V Setting.
Upper: Main V_{OUT}, 20 V.
Lower: Main I_{OUT}, 2 A, 10 ms / div.



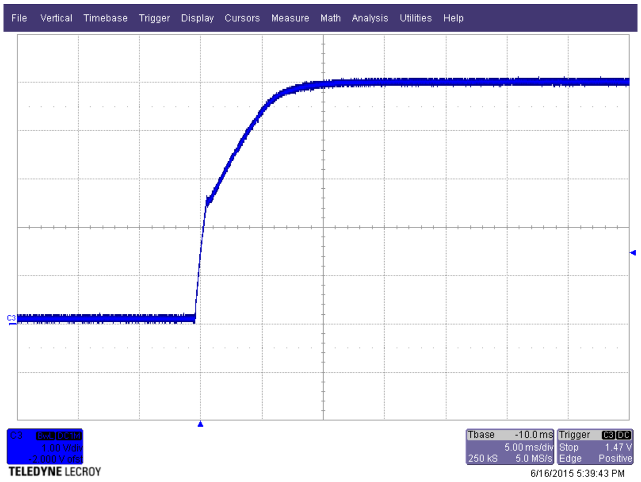


Figure 44 – Main Output Start-up, CC Mode. 115 VAC, Chroma CV Load, 30 V Setting.
Upper: Main V_{OUT}, 20 V.
Lower: Main I_{OUT}, 2 A, 10 ms / div.

Figure 45 – Standby Start-up, 100% Load, 115 VAC Input, 1 V / 5 ms / div.

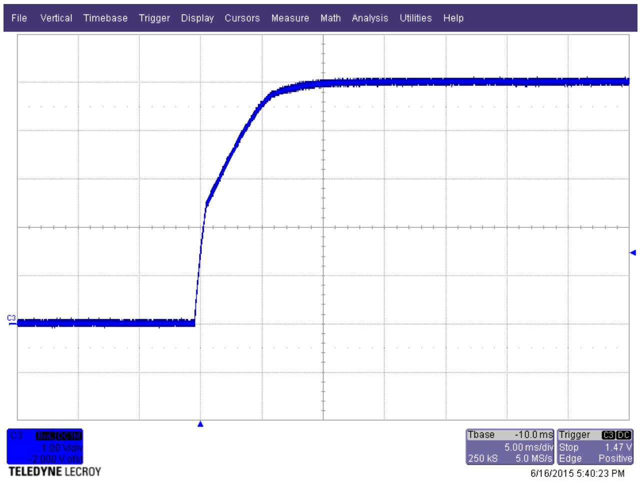


Figure 46 – Standby Start-up, No-Load, 115 VAC Input, 1 V / 5 ms / div.

13.5.2 Main Output Start-Up Using Enable Switch

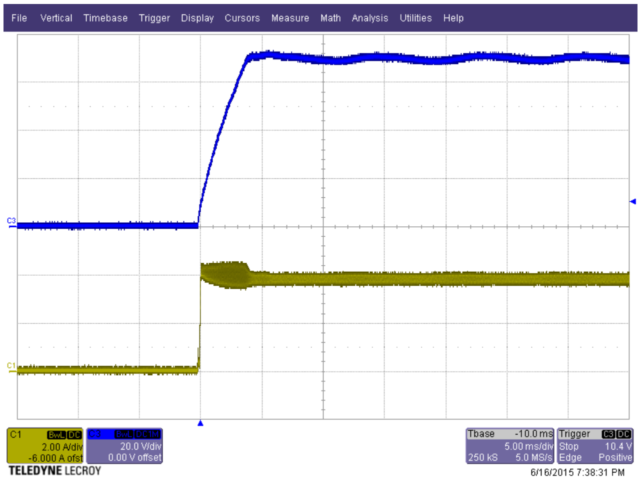


Figure 47 – Main Output Start-up, CV Mode, 115 VAC, Chroma CC Load, ~4.2 A Setting.
Upper: Main V_{OUT}, 20 V.
Lower: Main I_{OUT}, 2 A, 10 ms / div.

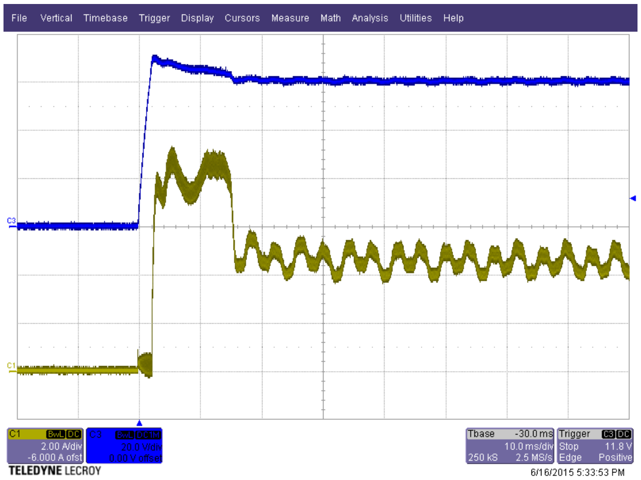


Figure 48 – Main Output Start-up, CC Mode, 115 VAC, Chroma CV Load, 60 V Setting.
Upper: Main V_{OUT}, 20 V.
Lower: Main I_{OUT}, 2 A, 10 ms / div.

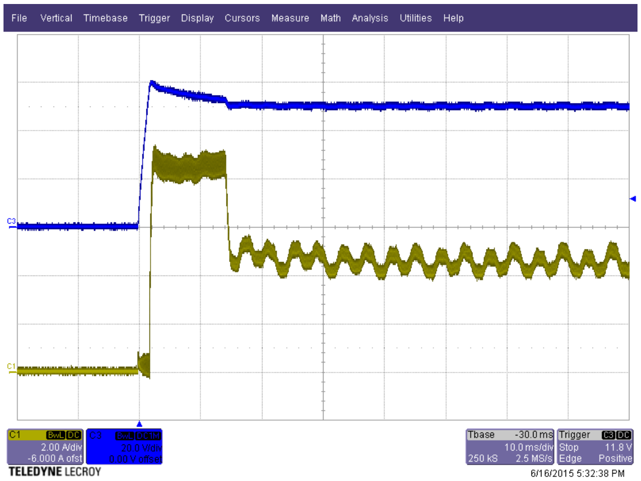


Figure 49 – Main Output Start-up, CC Mode, 115 VAC, Chroma CV Load, 50 V Setting.
Upper: Main V_{OUT} 10 V / div.
Lower: Main I_{OUT}, 2 A**,** 10 ms / div.

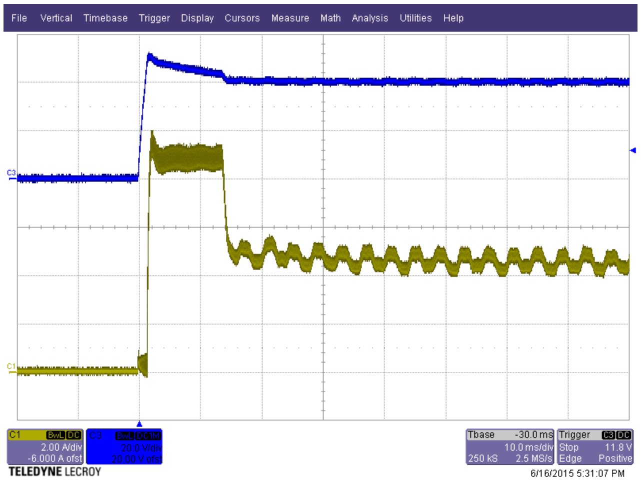


Figure 50 – Main Output Start-up, CC Mode, 115 VAC, Chroma CV Load, 40 V Setting.
Upper: Main V_{OUT} 10 V / div
Lower: Main I_{OUT}, 2 A**,** 10 ms / div.

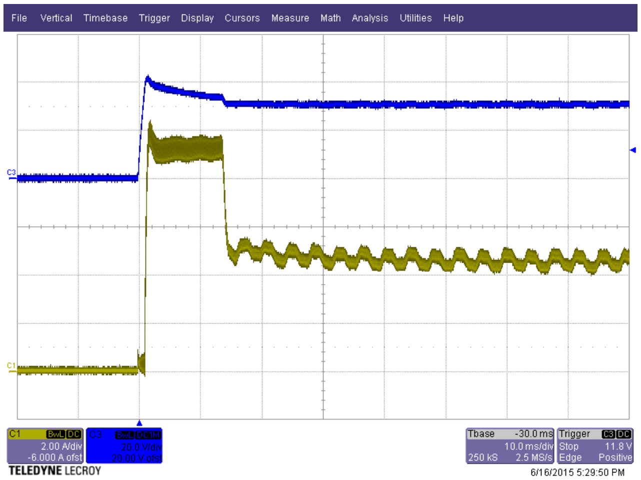
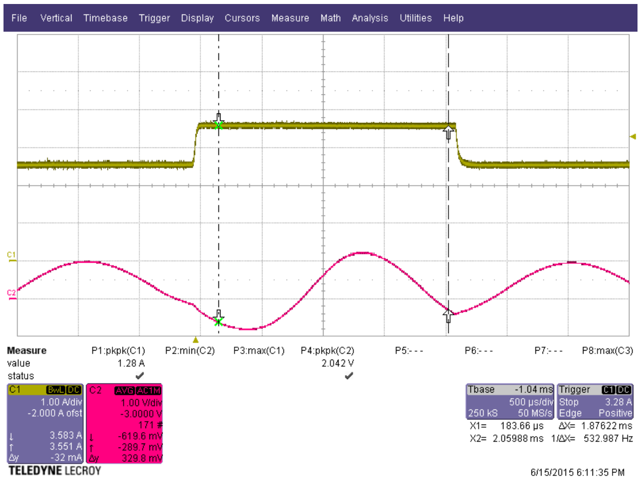


Figure 51 – Main Output Start-up, CC Mode,
115 VAC, Chroma CV Load,
30 V Setting.
Upper: Main V_{OUT} 10 V / div.
Lower: Main I_{OUT}, 2 A**,** 10 ms / div.

13.6 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.



Measure	P1:pkpk(C1)	P2:min(C2)	P3:max(C1)	P4:pkpk(C2)	P5:- - -	P6:- - -	P7:- - -	P8:max(C3)
value	1.28 A			2.042 V				
status	✓			✓				

C1 BwL DC 1.00 A/div -2.000 A ofst ↓ 3.583 A ↑ 3.551 A Δy -32 mA

C2 AVG AC1M 1.00 V/div -3.0000 V 171 # ↓ -619.6 mV ↑ -289.7 mV Δy 329.8 mV

Tbase -1.04 ms 500 µs/div 250 kS 50 MS/s

Trigger C1 DC Stop 3.28 A Edge Positive

X1= 183.66 µs ΔX= 1.87622 ms

X2= 2.05988 ms 1/ΔX= 532.987 Hz

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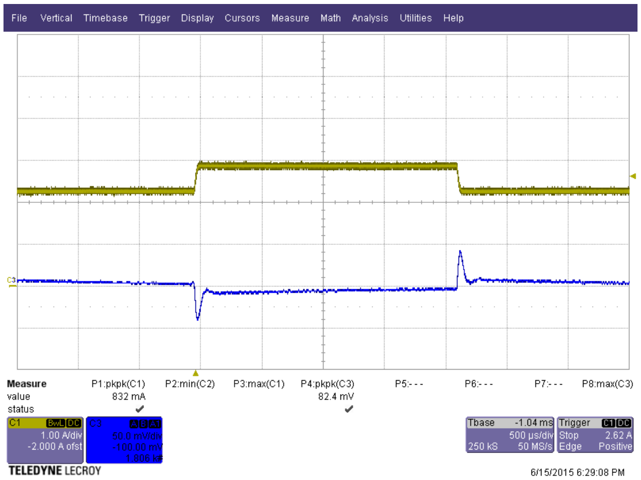
Figure 52 – Main Output Transient Response,
CV Mode, 50%-75%-50% Load Step,
115 VAC Input.
Upper: V_{OUT}, 200 mV / div.
Lower: Main Output I_{LOAD}, 1 A,
500 µs / div.



Measure	P1:pkpk(C1)	P2:min(C2)	P3:max(C1)	P4:pkpk(C3)	P5:- - -	P6:- - -	P7:- - -	P8:max(C3)
value	832 mA			82.4 mV				
status	✓			✓				

C1 BwL DC 1.00 A/div -2.000 A ofst

C3 A B A1 50.0 mV/div -100.00 mV 1.806 k#

Tbase -1.04 ms 500 µs/div 250 kS 50 MS/s

Trigger C1 DC Stop 2.62 A Edge Positive

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Figure 53 – Standby Output Transient Response,
CV Mode, 50%-75%-50% Load Step,
115 VAC Input.
Upper: V_{OUT}, 50 mV / div.
Lower: Main Output I_{LOAD}, 1 A,
500 µs / div.

14 Output Ripple Measurements

14.1 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 10 μF / 100 V aluminum electrolytic capacitor. The electrolytic capacitor is polarized, so always maintain proper polarity across DC outputs.

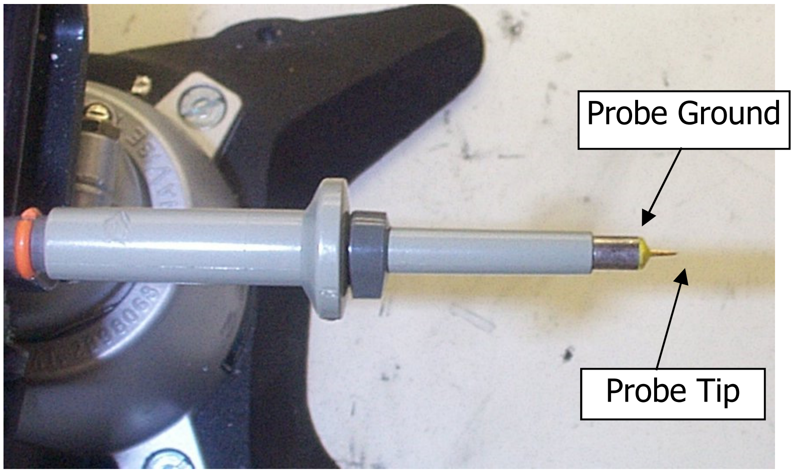

Figure 54 – Oscilloscope Probe Prepared for Ripple Measurement (End Cap and Ground Lead Removed).

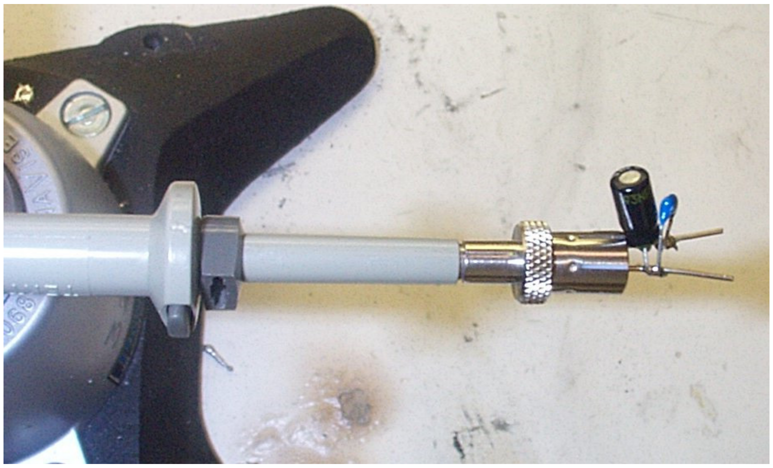

Figure 55 – Oscilloscope Probe with Probe Master 4987BA BNC Adapter (Modified with Wires for Probe Ground for Ripple measurement and Two Parallel Decoupling Capacitors Added).

14.2 Output Ripple Measurements

Measurements were taken for output ripple voltage with the main supply operating in constant voltage mode with a constant current load, and for both output ripple voltage and current with the main supply operating in CC mode. CC mode measurements were taken using a Chroma electronic load set in CV mode at 59 V, 50 V, and 40 V, and 30 V CV settings. Output ripple voltage/current measurements were made using AC coupled voltage and/or current probes.

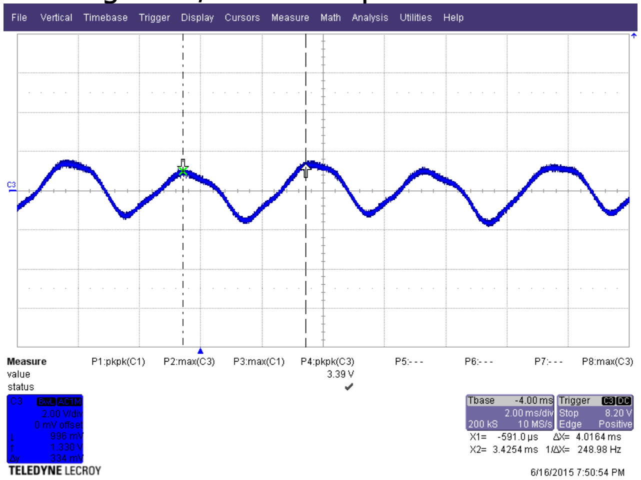

Figure 56 – Main Output Voltage Ripple, 115 VAC, CV Mode, 100% Load Using Chroma CR Load – 200 mV, 5 ms / div.

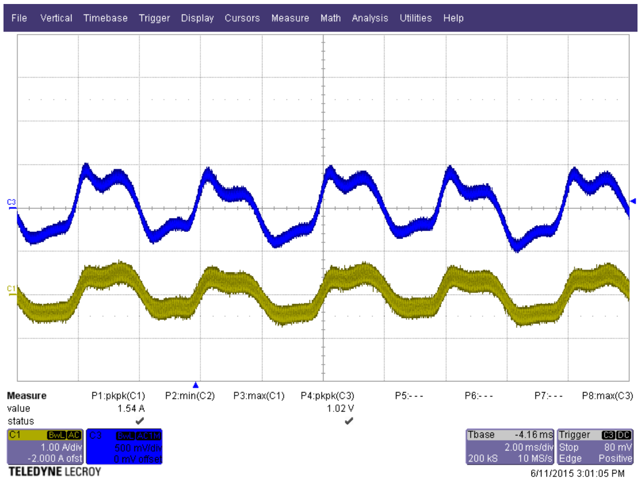

Figure 57 – Output Voltage and Current Ripple in CC Mode, 115 VAC, Chroma CV Load, 59 V Setting.
Upper: Main V_{OUT} Ripple, 1 V / div.
Lower: I_{OUT} Ripple, 1 A, 2 ms / div.

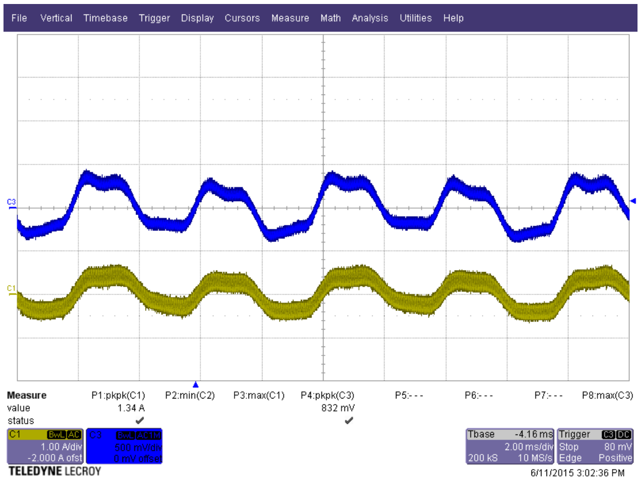

Figure 58 – Main Output Voltage and Current Ripple in CC Mode, 115 VAC, Chroma CV Load, 50 V Setting.
Upper: Main V_{OUT} Ripple, 1 V / div.
Lower: I_{OUT} Ripple, 1 A, 2 ms / div.

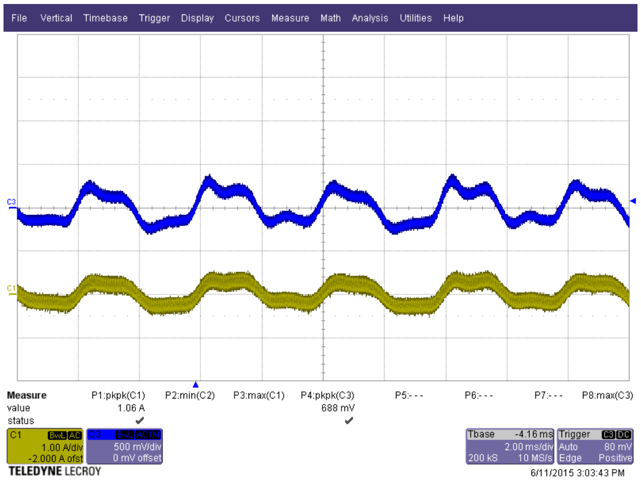

Figure 59 – Main Output Voltage and Current Ripple in CC Mode, 115 VAC, Chroma CV Load, 40 V Setting.
Upper: Main V_{OUT} Ripple, 1 V / div.
Lower: I_{OUT} Ripple, 1 A, 2 ms /div.

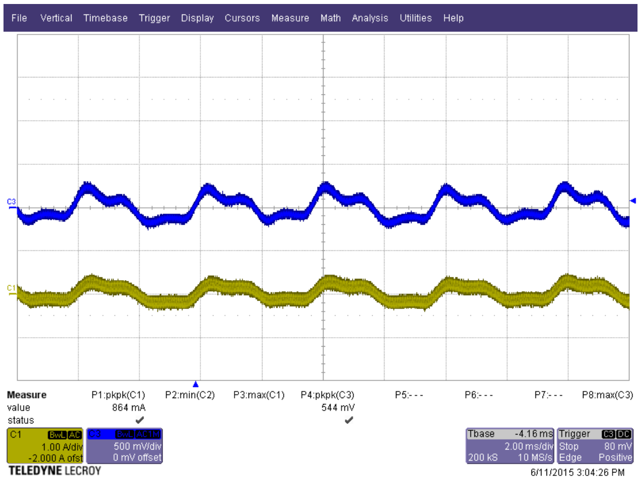

Figure 60 – Main Output Voltage and Current Ripple in CC Mode, 115 VAC, Chroma CV Load, 30 V Setting.
Upper: Main V_{OUT} Ripple, 1 V / div.
Lower: I_{OUT} Ripple, 1 A, 2 ms / div.

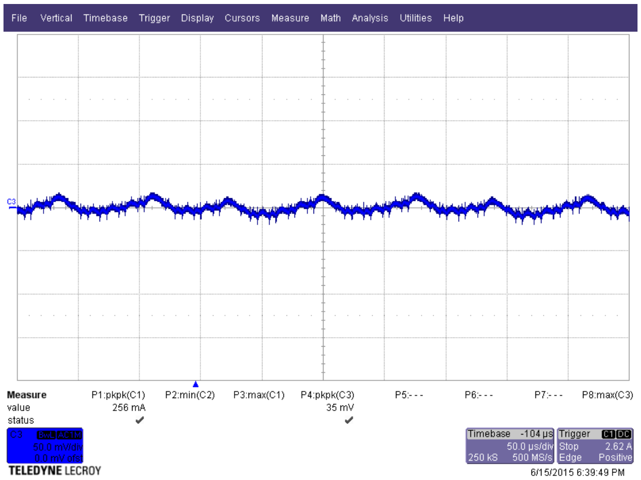

Figure 61 – Standby Output Voltage Ripple, 100% Load, 90 VAC with 100% Load on Main Output, Enable Switch "Off" – 100 mV, 100 µs / div.

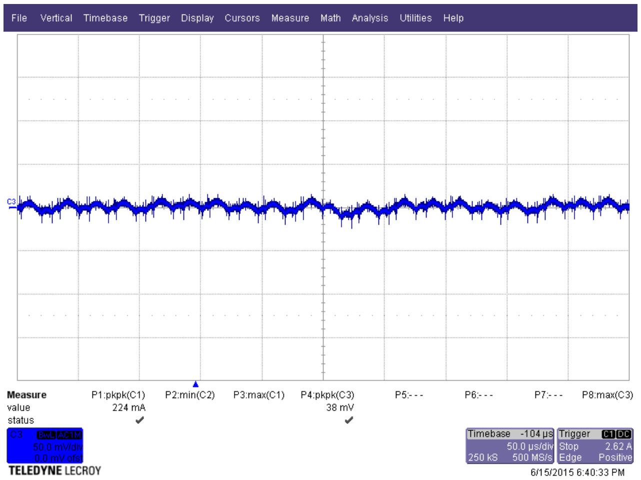

Figure 62 – Standby Output Voltage Ripple, 100% Load, 115 VAC, Main Output/PFC Enabled with ON/OFF Switch – 100 mV, 100 µs / div.

15 Temperature Profiles

The board was operated at room temperature, with output set at maximum using a Chroma electronic load with constant resistance for the main output and constant current mode for the standby output. The constant resistance load for the main output allows the main 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 before measurements were made.

This supply requires airflow, especially to reduce the temperature of the primary heat sink cooling the PFS3 (U10) and bridge rectifier BR1. An actual customer application will be sensitive to fan size, speed an placement. Figure 62 shows the fan placement for the measurements taken below. The fan location was offset somewhat to favor the heat sink for U10 and BR1.

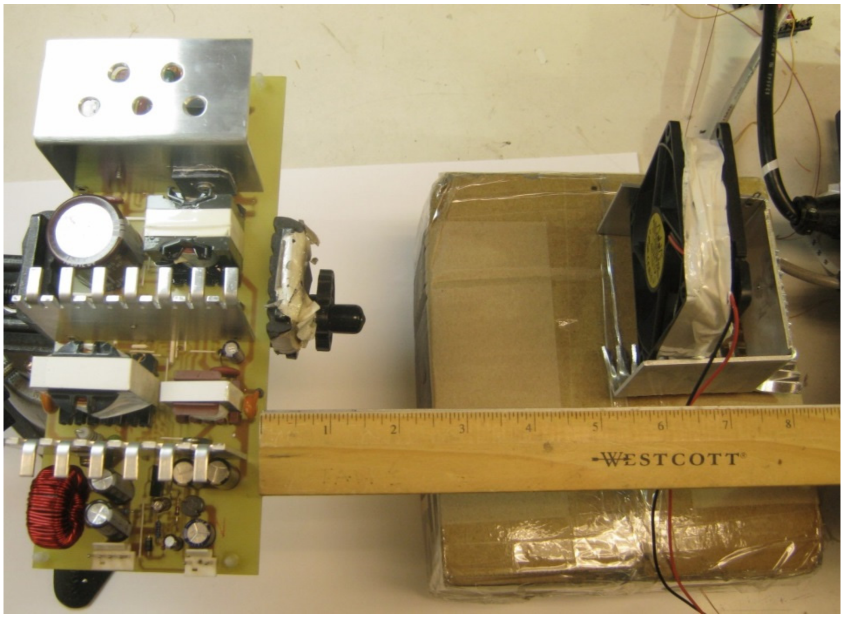

Figure 63 – Fan Set-Up for Thermal Measurements.

15.1 Spot Temperature Measurements

Position	Temperature (°C)		
	90 VAC	115 VAC	230 VAC
T1 (Main)	59.7	57.5	59.5
T2 (Standby)	35.7	35.9	35.3
BR1	66.3	53.7	35.4
L2 (CM)	57.4	46.3	35.4
L6 (DM)	37.6	31.4	23
L3 (Main)	63.2	63	63.4
L1 PFC Choke	45.3	39	30.2
U10	73.1	56.1	36.8
U2	36	39.1	38.6
D19 Main (FWD/CTH)	61.6	60.8	61.1
D18 Standby Rectifier	52	52.3	51
Ambient	21	21	21

15.1.1 90 VAC, 60 Hz, 100% Load Overall Temperature Profile

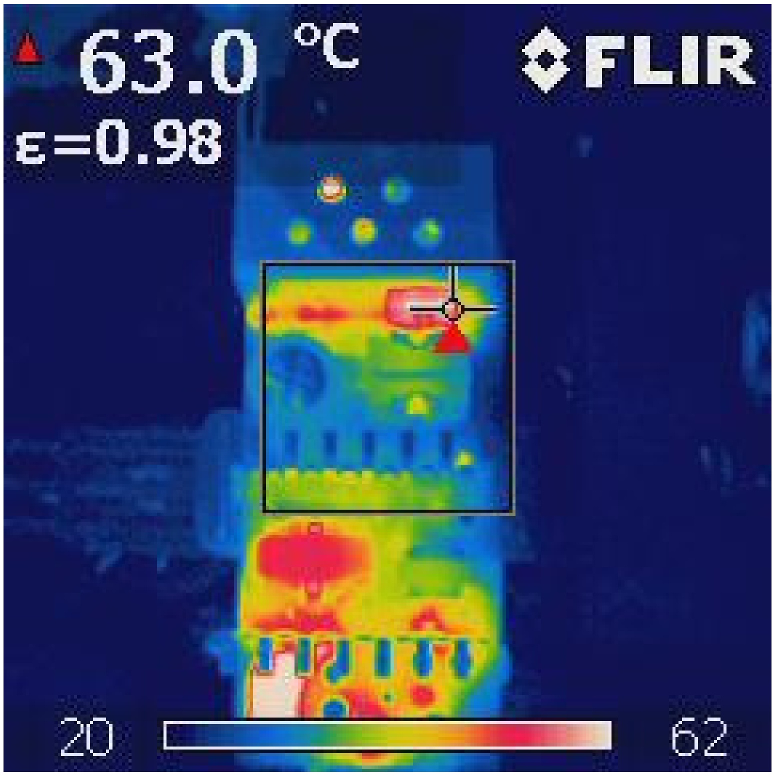

Figure 64 – Top View Thermal Picture, 90 VAC.

16 Gain-Phase

16.1 Main Output Constant Voltage Mode Gain-Phase

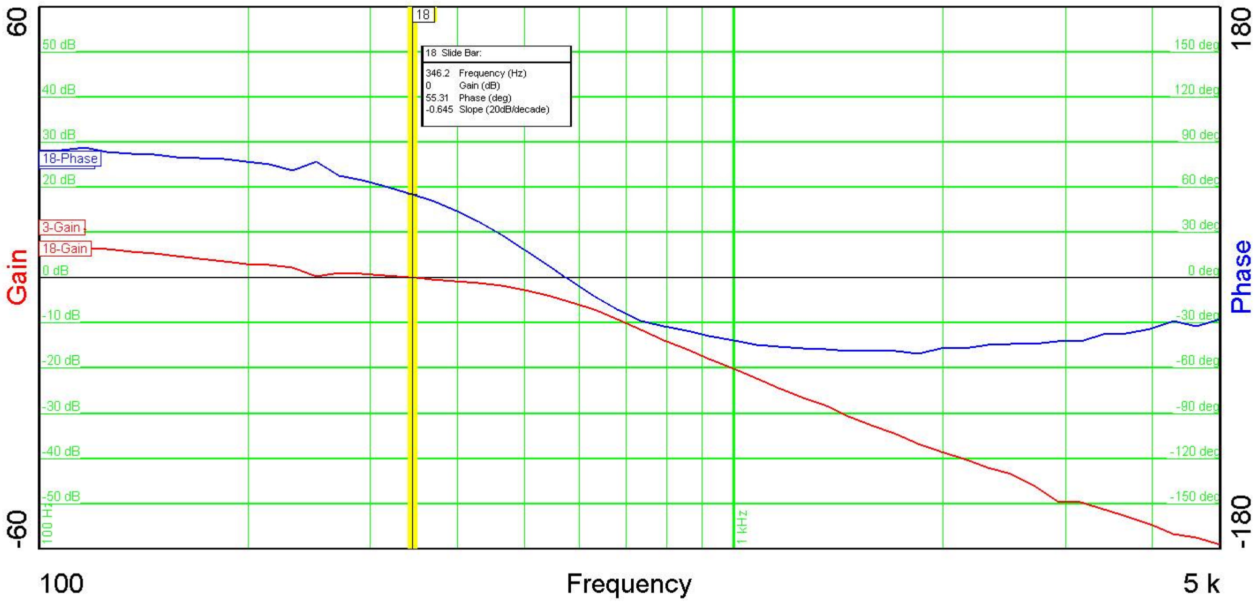

Figure 65 – Main Output Voltage Mode Gain-Phase Plot with Chroma CC Load - Gain Crossover is 346 Hz, Phase Margin is 55.3°.

16.2 Main Output Constant Current Mode Gain-Phase

Gain-phase was tested using a Chroma electronic load set to constant voltage mode at four set points – 59 V, 50 V, 40 V, and 30 V, obtaining the gain-phase measurements for several 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.

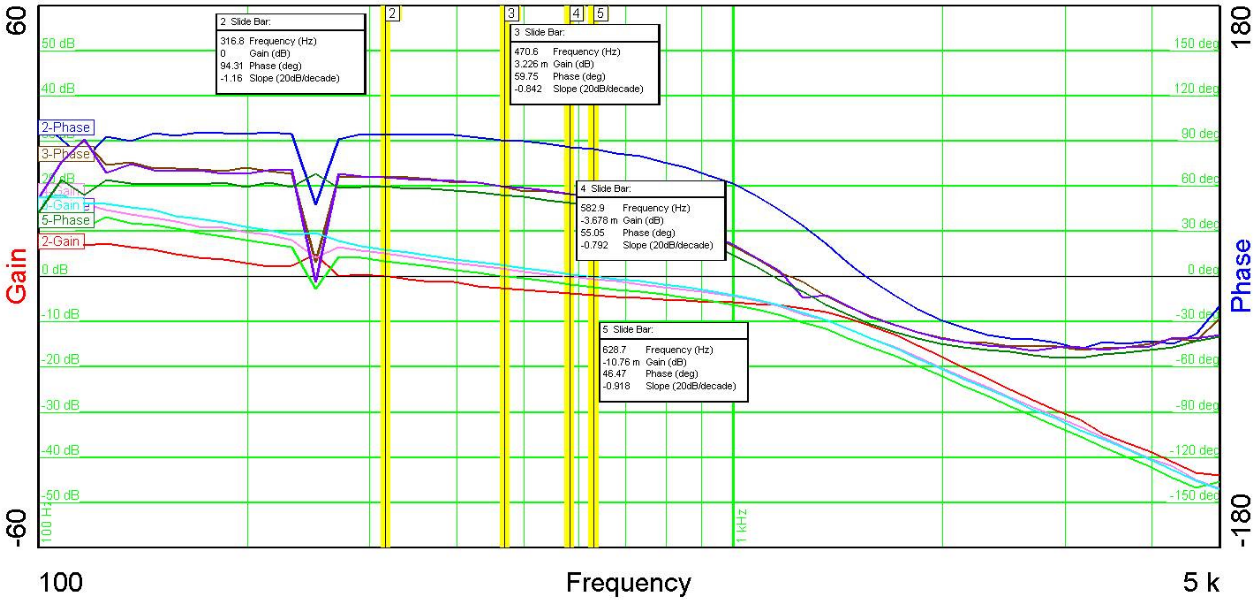

Figure 66 – Main Output Gain-Phase, Constant Current Output, Chroma Constant Voltage Load.
Red/Blue – 59 V Gain and Phase Crossover Frequency – 317 Hz, Phase Margin – 94°.
Brown/Green – 50 V Gain and Phase Crossover Frequency – 471 Hz, Phase Margin – 60°.
Pink/Purple – 40 V Gain and Phase Crossover Frequency – 583 Hz, Phase Margin – 55°.
Aqua/Dark Green – 30 V Gain and Phase Crossover Frequency – 629 Hz, Phase Margin – 46.5°.

17 Conducted EMI

Conducted EMI tests were performed using floating resistive loads (13 Ω main, 1.25 Ω standby). Physical set-up is shown in the figure below.

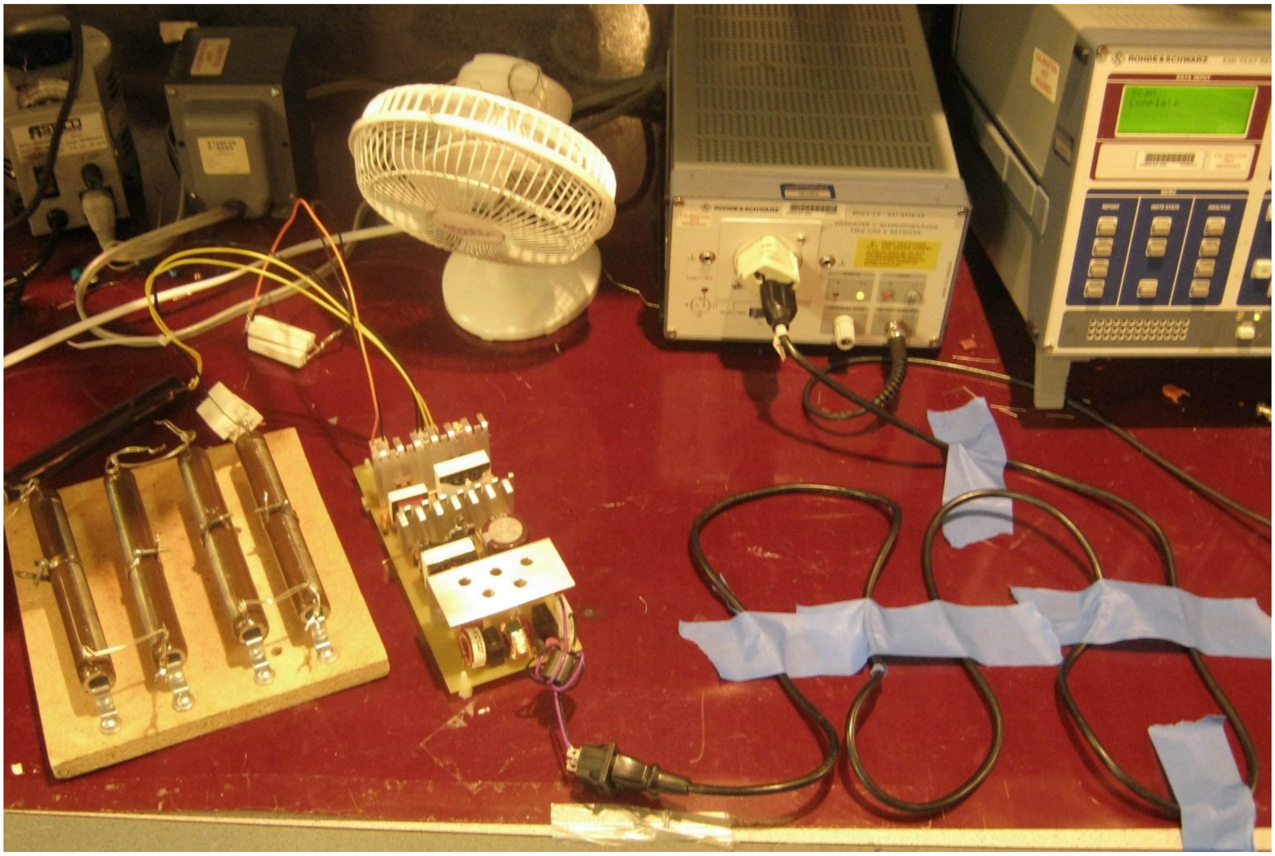

Figure 67 – Physical Setup for Conducted EMI Measurements.

A supplemental common mode choke was added to the AC input cable harness of the supply as shown in Figure 67. This choke consisted of 4 turns on a Fair-Rite 5943000201 toroidal bead. In practice, this choke would be wound into the AC input cord inside the power supply enclosure

Figure 68 – Supplemental CM Choke (4T on Fair-Rite 5943000201).

17.1 Conducted EMI Scan

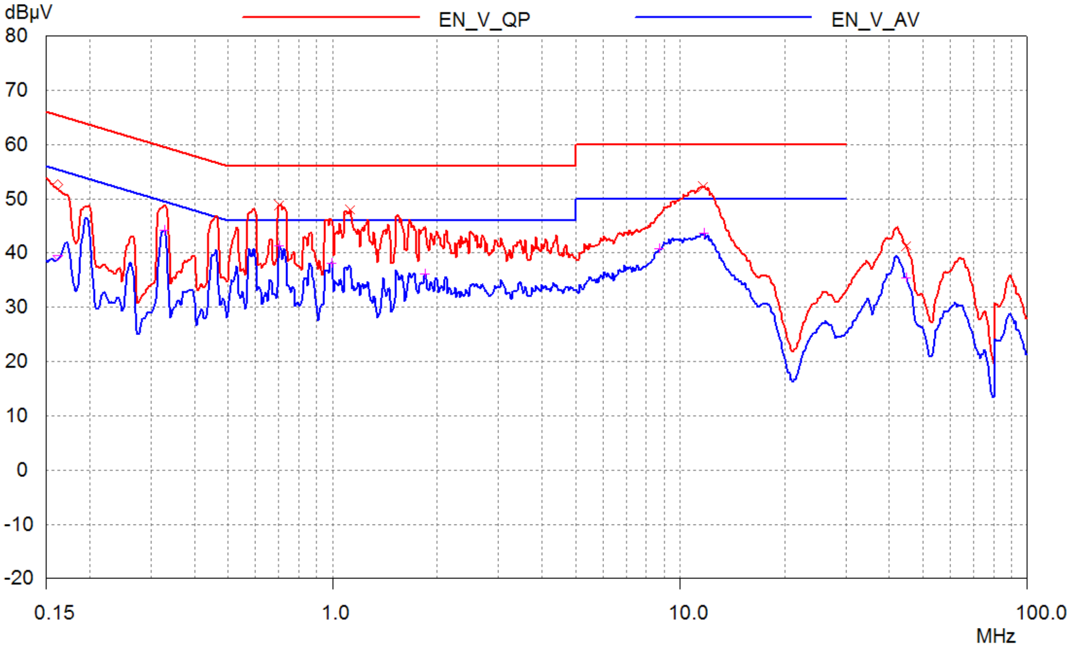

Figure 69 – Conducted EMI, 115 VAC, 13 Ω (Main) and 1.25 Ω (Standby) Floating Resistive Loads.

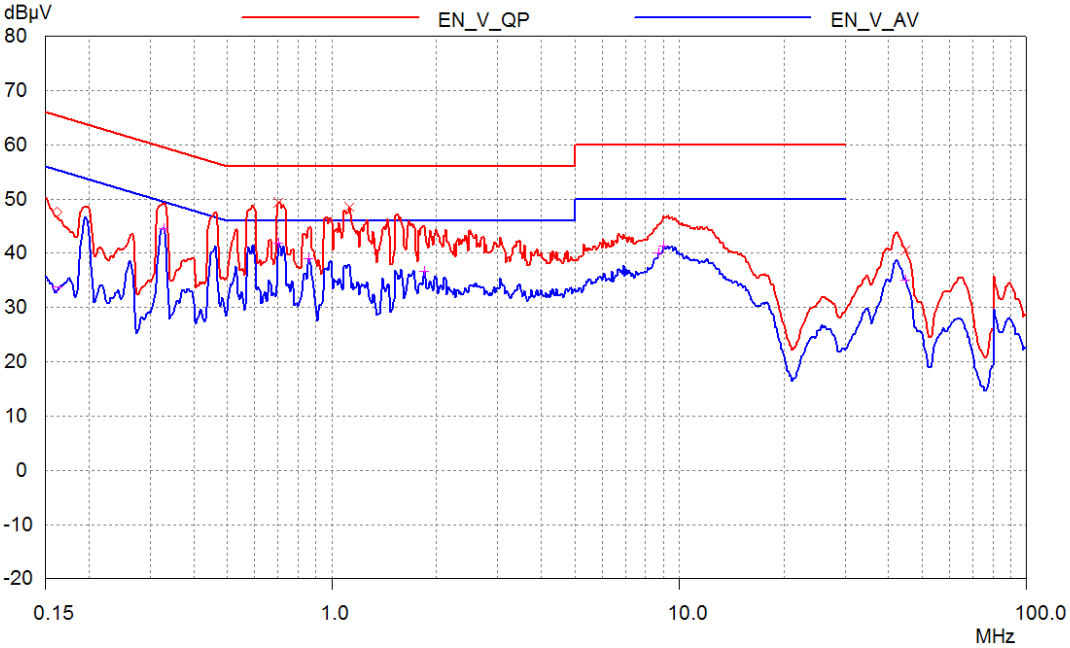

Figure 70 – Conducted EMI, 230 VAC, 13 Ω (Main) and 1.25 Ω (Standby) Floating Resistive Loads**.**

18 Revision History

Date	Author	Revision	Description & changes	Reviewed
06-Oct-15	RH	1.0	Initial Release	Apps & Mktg
16-Nov-15	KM	1.1	Updated Schematic.	
26-Nov-17	KM	1.2	Added Magnetics Supplier for L2, L3 L4, L5, T1 and T2.	

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