Design Example Report

Title	***180 W Power Factor Corrected Power Supply Using HiperPFS™ -2 (PFS7326H) and HiperTFS™-2 (TFS7703H)***
Specification	90 VAC – 264 VAC Input; 180 W (12 V at 0 – 14.2 A, 12 V at 0 – 0.83 A) Main Output plus Standby
Application	PC 80+ Gold Supply
Author	Applications Engineering Department
Document Number	DER-428
Date	October 30, 2014
Revision	7.1

Summary and Features

- Integrated PFC input stage, and 2-switch forward main converter + flyback standby output stages for a very low component count design
- Continuous mode PFC using low cost ferrite core
- +12 V main output converter uses forward diode self-driven (no SR controller) synchronous rectifier
- System efficiency at 115 VAC meets > 87%-90%-87% for 100%-50%-20% load
- System efficiency at 230 VAC meets > 88%-92%-88% for 100%-50%-20% load
- Self-driven SR offers better performance and lower cost than Schottky diode rectification
- PF >0.91 at 230 VAC 20% load

Power Integrations

5245 Hellyer Avenue, San Jose, CA 95138 USA.

Tel: +1 408 414 9200 Fax: +1 408 414 9201

www.powerint.com

Table of Contents

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

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 180 W (12 V / 14.2 A, 12 V / 0.83 A) reference design for an 80+ PC Gold power supply, 90-264 VAC input range. A 66 kHz operating frequency is used for the 12 V main converter, as well as a self-driven synchronous rectifier to replace the output forward diode. This maximizes efficiency while retaining simplicity.

The design is based on the PFS7326H for the PFC front end and a TFS7703H IC for the main and standby output stages.

This unit has a rated full power of 180 W. However, the main channel is capable of delivering 150% peak load.

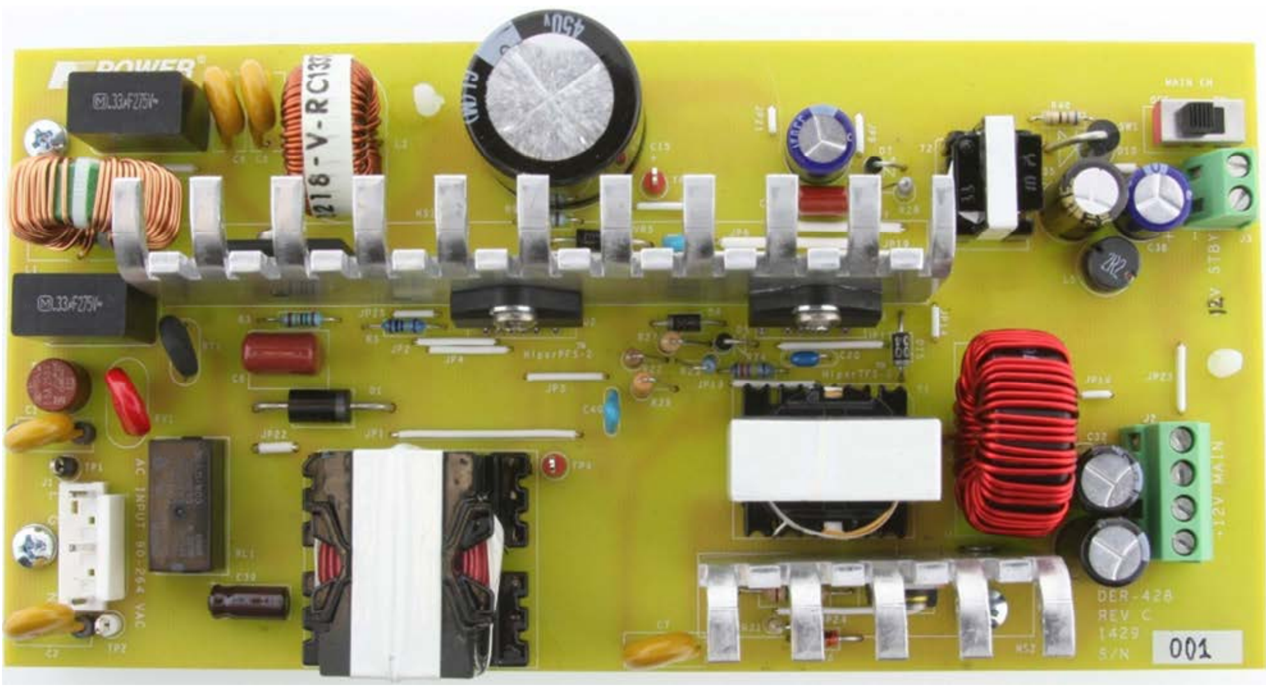


Figure 1 – DER-428 Photograph, Top View.
Dimensions - 3.80” W X 7.64” L X 1.40” H (96.5 mm X 194 mm X 35.6 mm)

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

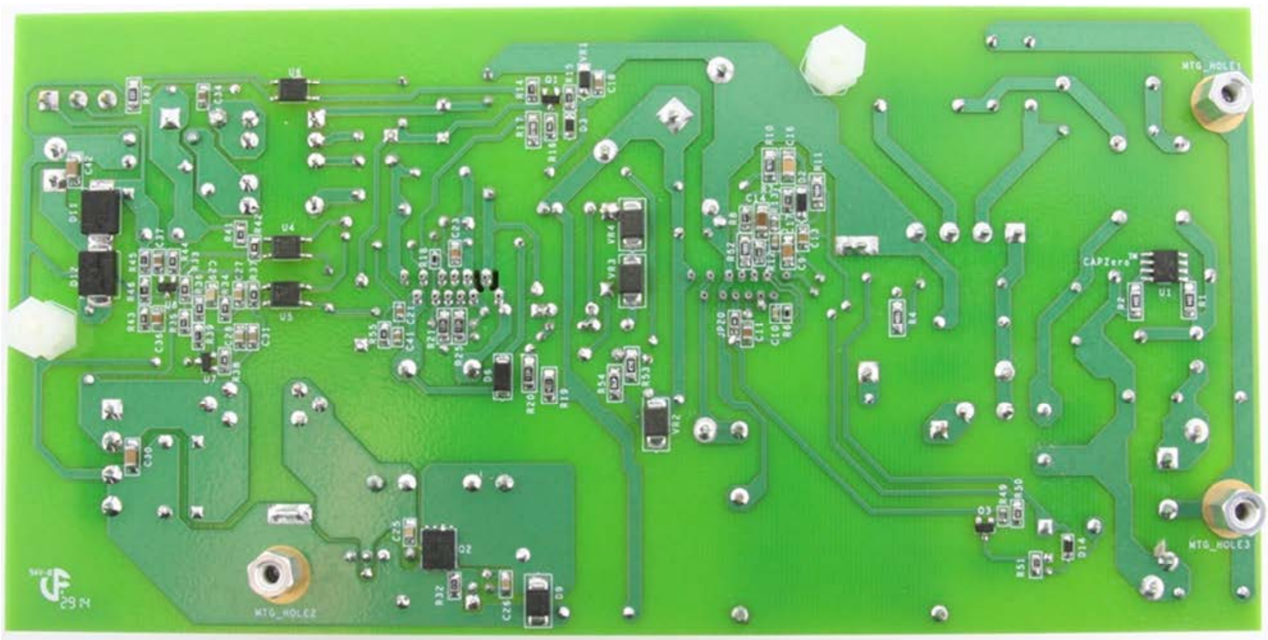


Figure 2 – DER-428 Photograph, Bottom View.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		264	VAC	3 Wire input.
Frequency	f_{LINE}	47	50/60	64	Hz	
Power Factor	PF	0.97				Full load, 230 VAC
	PF	0.91				20% Load, 230 VAC
Main Converter Output						
Output Voltage 1	V_{O1}	11.40	12.00	12.6	V	±5%
Output Ripple 1	$V_{RIPPLE1}$			120	mV P-P	20 MHz bandwidth
Output Current 1	I_{O1}	0.42	14.2	14.2	A	Regulates at no load
Output Voltage 2	V_{O2}	11.4	12.0	12.6	V	±5%
Output Ripple 2	$V_{RIPPLE2}$			120	mV P-P	20 MHz bandwidth
Output Current 2	I_{O2}	0		0.83	A	
Total Output Power						
Continuous Output Power	P_{OUT}		180		W	
Efficiency						
Total system at Full Load	η_{Main}		89.0		%	115 VAC, 100% Load
			91.0			230 VAC, 100% Load
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950 / UL1950 Class II				
Ambient Temperature	T_{AMB}	0		50	^{o}C	See thermal section for conditions

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

3 Schematic

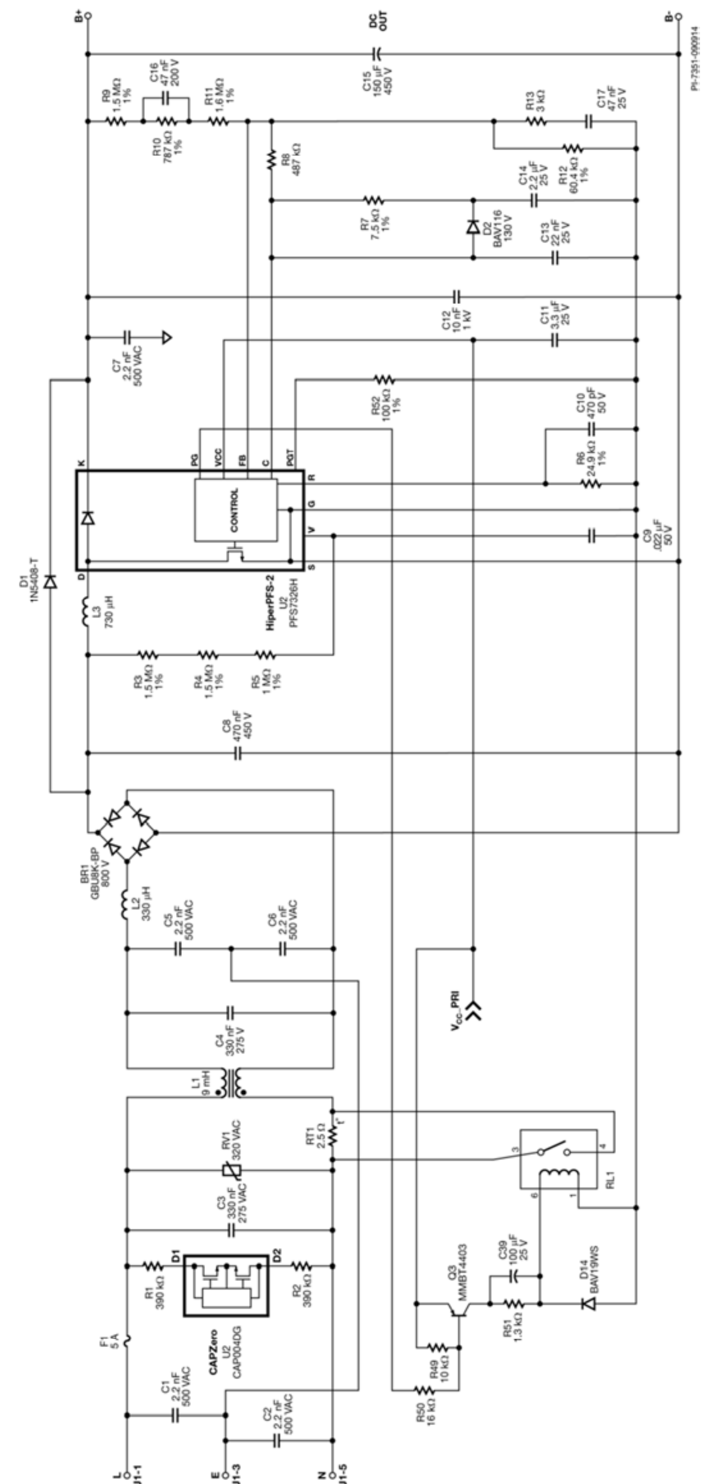


Figure 3 – Schematic DER-428 80+ Gold Power Supply Application Circuit - Input Filter, PFC Power Stage.

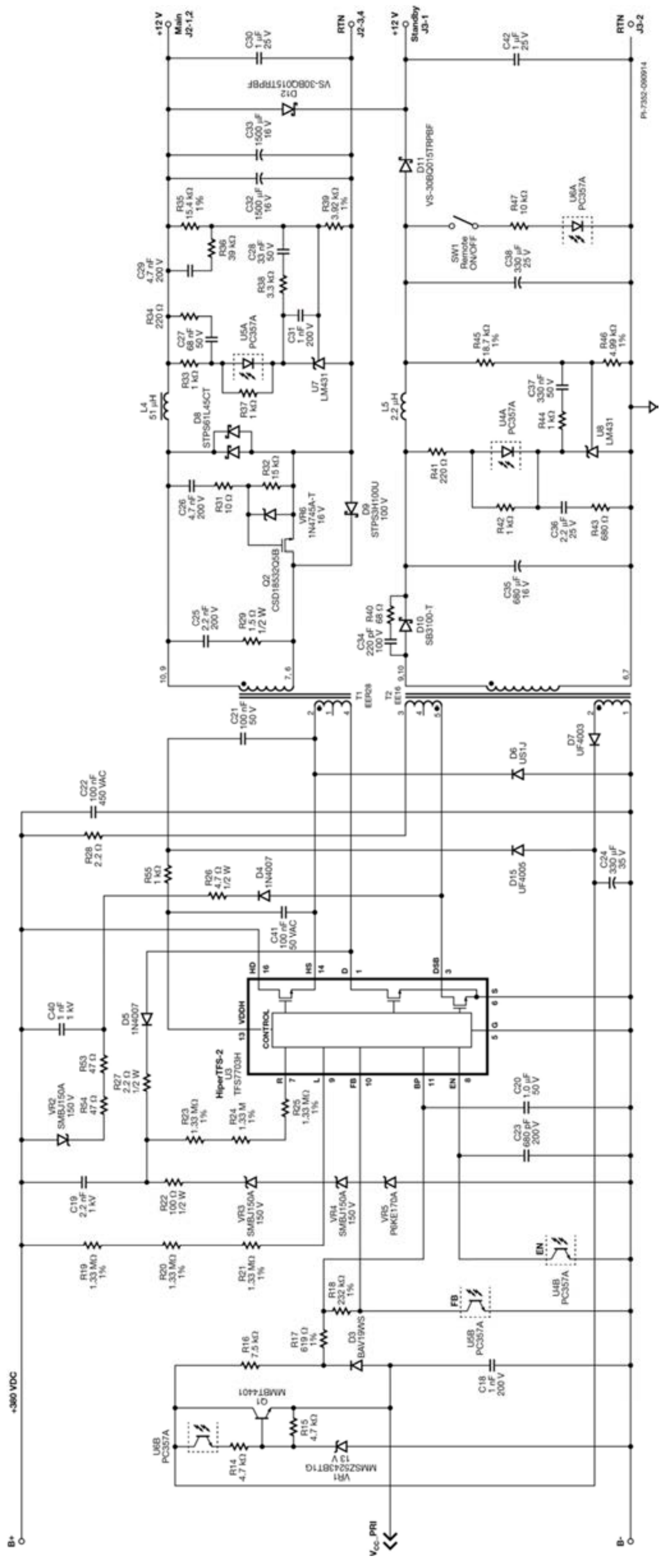


Figure 4 – Schematic of DER-428 80+ Gold Power Supply Application Circuit, Main and Standby Output Stages.

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

4 Circuit Description

4.1 *Input Filter / Boost Converter*

The schematic in Figure 3 shows the input EMI filter and PFC stage. The power factor corrector utilizes the PFS7326H.

4.1.1 *EMI Filtering / Inrush Limiting*

Capacitors C3 and C4 are used to control differential mode noise. Resistors R1 and R2 along with U1 discharge C3 and C4 when AC power is removed. Inductor L1 controls common mode EMI. The heat sink for U2, U3, and BR1 is connected to the PFS source pin source to eliminate the heat sink as a source of radiated/capacitively coupled noise.

Thermistor RT1 provides inrush limiting. Relay RL1 shorts thermistor RT1 to increase efficiency during steady-state operation. The relay is activated by the PG output of U1 via Q3, R49-51, and C39. Capacitor C39 shunts R51 to provide pull-in current when the relay is first turned on. Resistor R51 supplies reduced holding current to RL1 after C39 charges, reducing the steady-state relay power consumption. Diode D14 provides a discharge path for the RL1 coil current when Q3 turns off.

Capacitors C1-2 and C5-7 filter common mode EMI. Inductor L2 filters differential mode EMI.

4.1.2 *Main PFC Stage*

Components R9-12 provide output voltage feedback, with C16-17 and R23 providing fast dv/dt feedback to the U2 FB pin for rapid undershoot and overshoot response of the PFC circuit. Frequency compensation is provided by C13, C14, R7, and R8. Resistors R3-5 (filtered by C9) provide input voltage information to U2. Resistor R6 (filtered by C10) programs U2 for “full” mode. For more information about HiperPFS-2 operating modes, please refer to the HiperPFS-2 data sheet.

Capacitor C11 bypasses the U2 Vcc supply. Diode D1 charges the PFC output capacitor (C15) when AC is first applied, routing the inrush current away from PFC inductor L3 and the internal output diode of U2. Capacitor C12 is used to shrink the high frequency loop around components U2 and C15 to reduce EMI and drain voltage overshoot. The incoming AC is rectified by BR1 and filtered by C8. Capacitor C8 was selected as a low-loss polypropylene type to provide the high instantaneous current through L3 during U2 on-time.

4.2 *Output DC-DC Converters and Bias Supply*

The schematic in Figure 4 depicts a 12 V, 170 W 2-switch forward converter and a 12 V, 10 W flyback standby converter implemented using the TFS7703H.

4.2.1 *Primary Bias Supply*

Components D3, Q1, C18, R14-15 and VR2 regulate the bias supply voltage for U2 and U3. The unregulated bias supply is generated from a primary-referred winding on standby converter transformer T2. The output of this winding is rectified and filtered by D7 and C24. The bias supply is switched on via the output of optocoupler U6 in order to turn on U2 and the forward converter section of U3.

4.2.2 *Main and Standby DC-DC Converters*

Components C40, R53-54, and VR2 form a turn-off clamping circuit that limits the drain voltage of U3 for the standby drain. Zener diode VR2 provides a defined clamp voltage and maintains a maximum voltage (150 V) on clamp capacitor C40.

The low-side drain of the main output forward converter is clamped by D5, R22, R27, C19, and VR3-VR5. This clamping scheme is described as “clamp to ground” and enables a wider operating duty cycle for the main forward converter. This in turn allows the turns ratio of main transformer T1 to be dropped (lower peak output voltage), enabling use of lower voltage rating (lower voltage drop) components for synchronous rectifier MOSFET Q2 and catch diode D8.The wider duty cycle (longer on time) also results in more efficient utilization of synchronous MOSFET Q2. These changes all contribute to increased efficiency for the 12 V main output forward converter.

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 D4 and D5. 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 hold-up time. Use of a clamp to ground snubber for the main converter instead of the usual clamp to rail scheme allows this advantage to be exploited even further.

The BYPASS (BP) pin along with C20 provides a decoupled regulated 5.85 V for the HiperTFS controller. The value for C20 (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 +12 V standby output and primary-side bias voltage will begin to rise. The output of the bias/auxiliary supply winding is rectified by diode D7 and filtered by capacitor C24. Output of the bias winding is used to supply power via resistors R16-17 to the HiperTFS-2 BP pin during standby-only operation. Additional current is provided via Q1 and D3 by the primary bias supply when remote-on switch SW1 activates U6A and U6B and drives Q1 into an ON state. The value of R16 is selected to maintain the minimum 700 μA required into BP pin to inhibit the internal HiperTFS high voltage current source and thus reduce no-load consumption. Zener diode VR1 provides a voltage reference for Q1 to regulate the emitter voltage to 12.4 V for a stable 6 mA into BP pin.

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

The ENABLE (EN) pin is the feedback pin for the flyback standby controller section. Prior to start-up a resistor connected from EN to BP can be detected by the controller to select one of several internal current limits for standby section. In this case there is no resistor, which selects the minimum internal current limit for the standby controller. The FEEDBACK (FB) pin resistor R18 can also be used to select one of three main current limits at start-up in the same manner as the EN pin. Three different values can be used for R18 to select one of the three current limit configurations for the Main section. The circuit presented here uses an open circuit at the EN pin for a standby I_{LIM} of 500 mA and 232 kΩ for R18, setting a main I_{LIM} of 3.1 A.

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 C21 is the filtering and charge storage capacitor for the U3 high-side driver. During start-up the high-side MOSFET HS pin of U3 is briefly pulled to Source for 12 ms to precharge C21 using an internal current source. The nominal voltage on C21 during normal operation is shunt regulated to approximately 12 V. Components D15, C41, and R55 provide an efficient alternate source of current to power the high-side driver of U3, so that the internal high voltage supply for the high-side driver is turned off. This increases efficiency at light load.

Resistors R23-25 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 under-voltage and over-voltage 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 R19-R21 are used to translate the input voltage into a current for the L pin.

4.2.3 *Output Rectification*

Diode D10 is the output rectifier for the standby flyback converter. A low ESR capacitor, C35, provides filtering with low ripple. Inductor L5 and capacitor C38 form a post-filter to further reduce output switching ripple and noise.

Self-driven synchronous rectifier MOSFET Q2 rectifies the main output during on-time. Diode D8 is the output catch diode, providing a current discharge path for the main output inductor L4 during the off-time. A capacitive voltage divider consisting of C26 and the input capacitance of Q2 drives the Q2 gate. Zener diode VR3 clamps the gate voltage and provides a discharge path for C26, while R31 damps the gate drive waveform. Snubber components C25 and R29 reduce the amplitude of leakage spikes for Q2 and D8.

Inductor L4 together with capacitors C32-33 forms an output filter for switching output ripple and noise.

4.2.4 *Output Feedback*

In the standby output secondary control circuit, resistor R45 and R46 form a voltage divider. The output voltage of the power supply is divided and fed to the input terminal of error amplifier U8. The cathode terminal voltage of U4A is controlled by the amplifier inside U8 to maintain the divider voltage to 2.5 V ±2%. Change in cathode terminal voltage results in a change of the current through optocoupler LED inside U4A, which in turn changes the current through the transistor inside U4B. Capacitor C23 provides strong noise rejection for the EN pin. When the current sinking from the EN pin exceeds the EN pin threshold current, the next switching cycle is inhibited, and when the output voltage falls below the feedback threshold, a conduction cycle is allowed to occur. By adjusting the number of enabled cycles, output regulation is maintained. As the load reduces, the number of enabled cycles decreases, lowering the effective switching frequency and scales the switching losses with load. This provides almost constant efficiency down to very light loads, ideal for meeting energy efficiency requirements. Components C37, R41, and R44 compensate/shape the frequency response of the standby control loop, while C36 and R43 provide feedback during startup before the closure of the main control loop. This feedback optimally shapes the output voltage profile and prevents turn-on overshoot.

In the main output secondary control circuit, resistors R35 and R39 are employed to provide the output voltage feedback signal for the U7 error amplifier. In a similar manner, U7 controls the optocoupler U5 used to adjust the operating duty cycle through the current sink from the FB pin, with the main difference being the FB pin current controls the duty cycle of the main converter in a linear manner versus the whole cycle on/off control employed by the standby converter. Components C27-28, C31, R33-34, and R38 compensate the main 12 V control loop, while C29 and R36 comprise a soft-finish network to eliminate turn-on overshoot for the +12 V main output.

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

5 PCB Layout

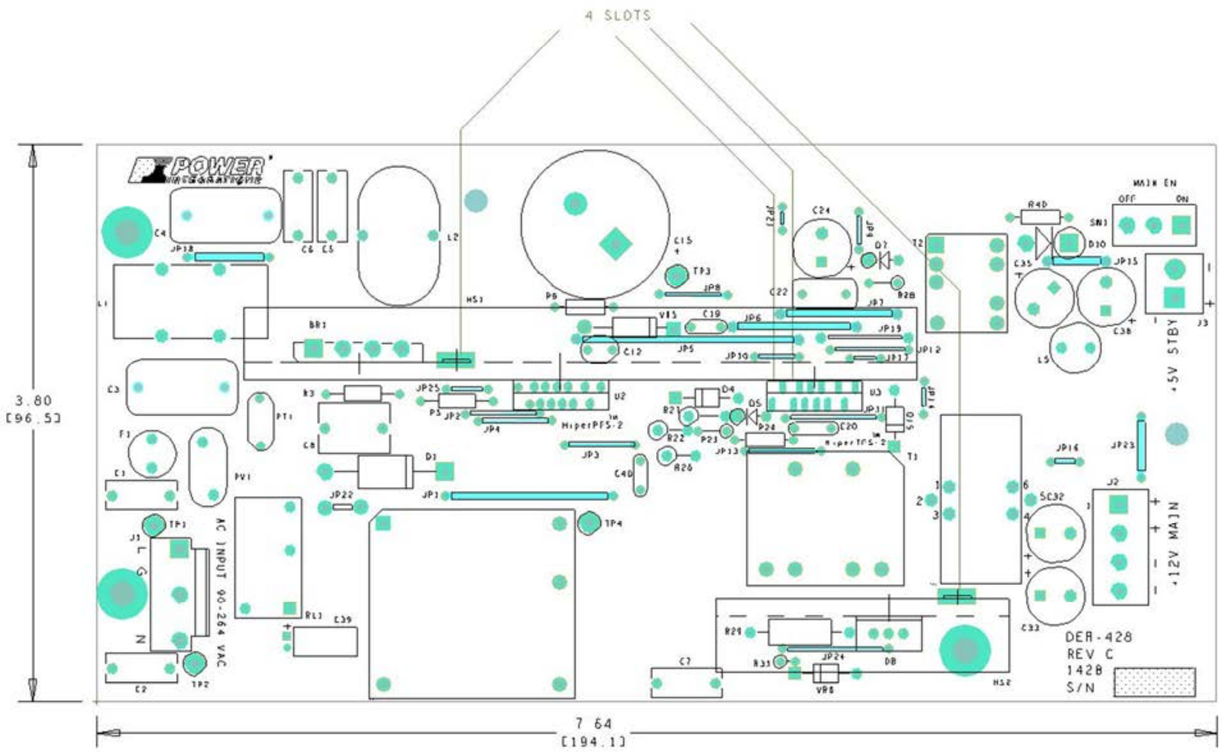


Figure 5 – Printed Circuit Layout, Top Side.

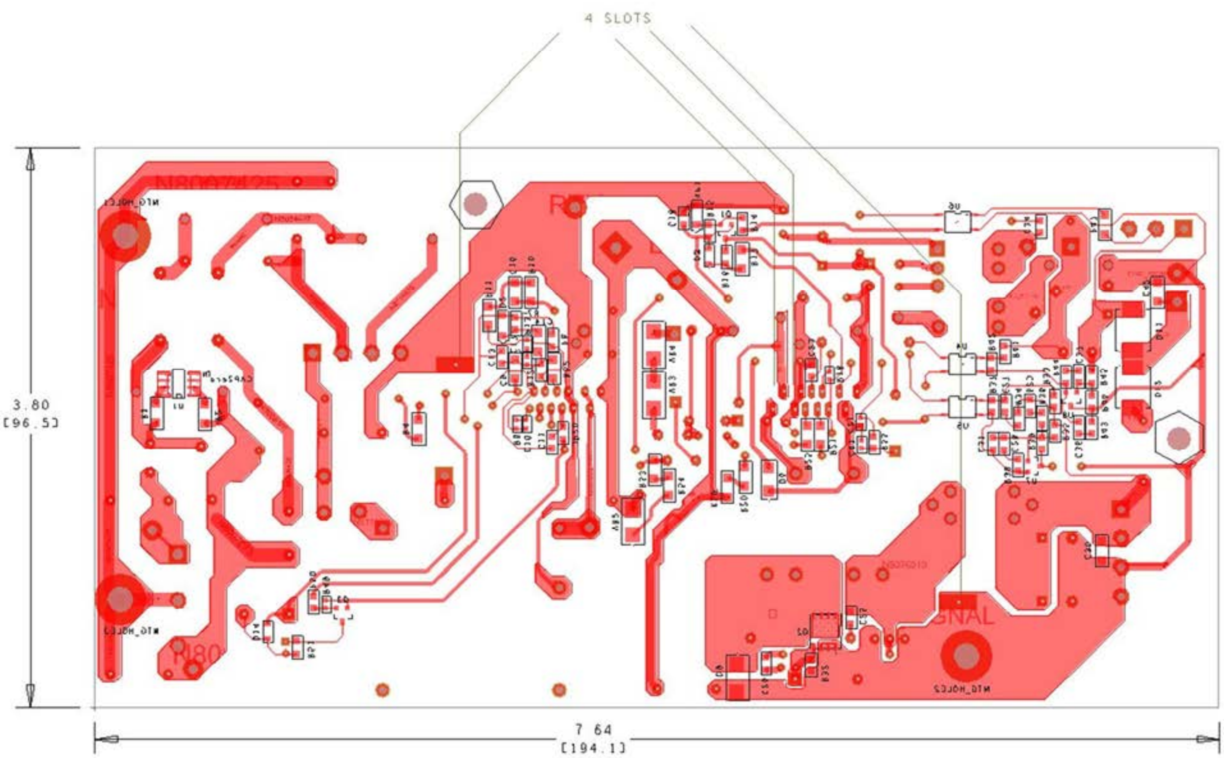


Figure 6 – Printed Circuit Layout, Bottom Side.

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

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	4	BEAD1 BEAD2 BEAD3 BEAD4	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	5	C1 C2 C5 C6 C7	2.2 nF, 500 VAC, Ceramic, Y1	VY1222M47Y5UG63V0	Vishay
4	2	C3 C4	330 nF, 275 VAC, Film, X2	ECQ-U2A334ML	Panasonic
5	1	C8	470 nF, 450 V, METALPOLYPRO	ECW-F2W474JAQ	Panasonic
6	1	C9	22 nF, 50 V, Ceramic, X7R, 1206, FT-CAP	C1206X223K5RACTU	Kemet
7	1	C10	470 pF 50 V, Ceramic, X7R, 0603	C1608C0G1H471J080AA	TDK
8	1	C11	3.3 µF, 25 V, Ceramic, X7R, 0805	C2012X7R1E335K	TDK
9	1	C12	10 nF, 1 kV, Disc Ceramic, X7R	SV01AC103KAR	AVX
10	1	C13	22 nF, 25 V, Ceramic, X7R, 0805	C0805C223K3RACTU	Kemet
11	1	C14	2.2 uF, 25 V, Ceramic, X7R, 1206	TMK316B7225KL-T	Taiyo Yuden
12	1	C15	150 µF, 450 V, Electrolytic, (25 x 25)	LGL2W151MELA25	Nichicon
13	1	C16	47 nF, 200 V, Ceramic, X7R, 1206	12062C473KAT2A	AVX
14	1	C17	47 nF 25 V, Ceramic, X7R, 0603	CC0603KRX7R8BB473	Yageo
15	2	C18 C31	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
16	1	C19	2.2 nF, 1 kV, Ceramic, SL, 0.2" L.S.	DEBB33A222KA2B	Murata
17	1	C20	1.0 µF, 50 V, Ceramic, X7R	FK20X7R1H105K	TDK
18	2	C21 C41	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
19	1	C22	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
20	1	C23	680 pF 200 V X7R Multi-Layer Ceramic ±10 %	C0805C681K2RACAUTO	Kemet
21	1	C24	330 µF, 35 V, Electrolytic, Low ESR, 68 mW, (10 x 16)	ELXZ350ELL331MJ16S	Nippon Chemi-Con
22	1	C25	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
23	1	C26	2.7 nF, 100 V, Ceramic, X7R, 0805	08051C272KAT2A	AVX
24	1	C27	68 nF, 50 V, Ceramic, X7R, 0805	C0805C683K5RACTU	Kemet
25	1	C28	33 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB333	Yageo
26	1	C29	4.7 nF, 200 V, Ceramic, X7R, 0805	08052C472KAT2A	AVX
27	2	C30 C42	1 µF, 25 V, Ceramic, X7R, 1206	C3216X7R1E105K	TDK
28	2	C32 C33	1500 µF, 16 V, Electrolytic, Gen. Purpose, (10 x 20)	EEU-FR1C152	Panasonic
29	1	C34	220 pF, 100 V, Ceramic, X7R, 0805	08051C221KAT2A	AVX
30	1	C35	680 µF, 16 V, Electrolytic, Radial, Low ESR, 26 mΩ, (10 x 16)	EEU-FM1C681	Panasonic
31	1	C36	2.2 µF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
32	1	C37	330 nF, 50 V, Ceramic, X7R, 0805	GRM219R71H334KA88	Murata
33	1	C38	330 µF, 25 V, Electrolytic, Low ESR, 90 mΩ, (10 x 12.5)	ELXZ250ELL331MJC5S	Nippon Chemi-Con
34	1	C39	100 µF, 16 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG160ELL101ME11D	Nippon Chemi-Con
35	1	C40	1 nF, 1 kV, Disc Ceramic	DEBE33A102ZC1B	Murata
36	2	CLIP_LCS_PFS1 CLIP_LCS_PFS2	Heat sink Hardware, Clip LCS_II/PFS	EM-285V0	Kang Yang
37	1	D1	1000 V, 3 A, Recitifier, DO-201AD	1N5408-T	Diodes, Inc.
38	1	D2	130 V, 5%, 250 mW, SOD-123	BAV116W-7-F	Diodes, Inc.
39	2	D3 D14	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
40	2	D4 D5	1000 V, 1 A, Rectifier, DO-41	1N4007-E3/54	Vishay
41	1	D6	Diode Ultrafast, SW 600 V, 1 A, SMA	US1J-13-F	Diodes, Inc.
42	1	D7	200 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	UF4003-E3	Vishay

43	1	D8	45 V, 30 A, Dual Schottky, TO-220AB	STPS61L45CT	ST Micro
44	1	D9	100 V, 3 A, Schottky, DO-214AA	STPS3H100U	ST
45	1	D10	100 V, 3 A, Schottky, DO-201AD	SB3100DICT-ND	Diodes, Inc.
46	2	D11 D12	DIODE, SCHOTTKY, 15 V, 3 A, SMC, DO-214AB	VS-30BQ015TRPBF	Vishay
47	1	D15	600 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	UF4005-E3	Vishay
48	1	F1	5 A, 250 V, Slow, TR5	37215000411	Wickman
49	1	HS1	FAB, HEAT SINK, PRI, DER-383		Custom
50	1	HS2	FAB, HEAT SINK, SEC, Gold, DER-428		Custom
51	1	J1	5 Position (1 x 5) header, 0.156 pitch, Vertical	0026604050	Molex
52	1	J2	4 Position (1 x 4) header, 5 mm (0.196) pitch, Vertical	1711042	Phoenix Contact
53	1	J3	2 Position (1 x 2) header, 5 mm (0.196) pitch, Vertical	1715022	Phoenix Contact
54	1	JP1	Wire Jumper, Insulated, TFE, #18 AWG, 1.2 in	C2052A-12-02	Alpha
55	3	JP2 JP4 JP8	Wire Jumper, Non insulated, #22 AWG, 0.5 in	298	Alpha
56	1	JP3	Wire Jumper, Insulated, #24 AWG, 0.5 in	C2003A-12-02	Gen Cable
57	1	JP5	Wire Jumper, Insulated, TFE, #18 AWG, 1.6 in	C2052A-12-02	Alpha
58	1	JP6	Wire Jumper, Insulated, TFE, #18 AWG, 0.9 in	C2052A-12-02	Alpha
59	1	JP7	Wire Jumper, Insulated, TFE, #18 AWG, 0.7 in	C2052A-12-02	Alpha
60	5	JP9 JP14 JP16 JP17 JP25	Wire Jumper, Insulated, #24 AWG, 0.3 in	C2003A-12-02	Gen Cable
61	1	JP10	Wire Jumper, Insulated, #24 AWG, 0.4 in	C2003A-12-02	Gen Cable
62	2	JP11 JP24	Wire Jumper, Insulated, #24 AWG, 0.8 in	C2003A-12-02	Gen Cable
63	2	JP12 JP13	Wire Jumper, Insulated,# 24 AWG, 0.6 in	C2003A-12-02	Gen Cable
64	2	JP15 JP23	Wire Jumper, Insulated, TFE, #18 AWG, 0.5 in	C2052A-12-02	Alpha
65	1	JP18	Wire Jumper, Insulated, TFE, #18 AWG, 0.6 in	C2052A-12-02	Alpha
66	1	JP19	Wire Jumper, Insulated, TFE, #22 AWG, 0.6 in	C2004-12-02	Alpha
67	1	JP20	0 R, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEY0R00V	Panasonic
68	1	JP21	Wire Jumper, Insulated, #24 AWG, 0.2 in	C2003A-12-02	Gen Cable
69	1	JP22	Wire Jumper, Insulated, TFE, #18 AWG, 0.4 in	C2052A-12-02	Alpha
70	1	L1	9 mH, 5 A, Common Mode Choke	T22148-902S P.I. Custom	Fontaine Technologies
71	1	L2	330 μH, 3.3 A, Vertical Toroidal	2218-V-RC	Bourns
72	1	L3	Custom, DER-428 PFC Inductor, 730 μH, PQ32/20, Vertical, 12 pins		
73	1	L4	51 μH, Inductor Toroidal, Sendust		
74	1	L5	2.2 μH, 6.0 A	RFB0807-2R2L	Coilcraft
75	2	POST-CRKT_BRD_6-32_HEX1 POST-CRKT_BRD_6-32_HEX2	Post, Circuit Board, Female, Hex, 6-32, snap, 0.375L, Nylon	561-0375A	Eagle Hardware
76	1	Q1	NPN, Small Signal BJT, GP SS, 40 V, 0.6 A, SOT-23	MMBT4401LT1G	Diodes, Inc.
77	1	Q2	MOSFET, 60 V, 23A, 3.2 mOhm, N-Channel, 8VSON	CSD18532Q5B	Texas Instruments
78	1	Q3	PNP, Small Signal BJT, 40 V, 0.6 A, SOT-23	MMBT4403-7-F	Diodes, Inc.
79	2	R1 R2	390 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ394V	Panasonic
90	2	R3 R9	1.5 MΩ, 1%, 1/4 W, Metal Film	RNF14FTD1M50	Stackpole
81	1	R4	1.50 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1504V	Panasonic
82	1	R5	1 MΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-1M00	Yageo
83	1	R6	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic
84	1	R7	7.50 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF7501V	Panasonic

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

85	1	R8	487 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4873V	Panasonic
86	1	R10	787 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF7873V	Panasonic
87	1	R11	1.60 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1604V	Panasonic
88	1	R12	60.4 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF6042V	Panasonic
89	1	R13	3 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ302V	Panasonic
90	2	R14 R15	4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
91	1	R16	7.5 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ752V	Panasonic
92	1	R17	619 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF6190V	Panasonic
93	1	R18	232 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2323V	Panasonic
94	4	R19 R20 R21 R25	1.33 M, 1%, 1/4 W, Thick Film, 1206	RC1206FR-071M33L	Yageo
95	1	R22	100 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-100R	Yageo
96	2	R23 R24	1.33 MΩ, 1%, 1/4 W, Metal Film	MF1/4DCT52R1334F	KOA
97	1	R26	4.7 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-4R7	Yageo
98	1	R27	2.2 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-2R2	Yageo
99	1	R28	2.2 Ω, 5%, 1/2 W, Metal Film, Fusible/Flame Proof	NFR25H0002208JR500	Vishay
100	1	R29	1.5 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-1R5	Yageo
101	1	R31	10 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-10R	Yageo
102	1	R32	15 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ153V	Panasonic
103	5	R33 R37 R42 R44 R55	1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
104	2	R34 R41	220 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ221V	Panasonic
105	1	R35	15.4 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1542V	Panasonic
106	1	R36	39 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ393V	Panasonic
107	1	R38	3.3 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ332V	Panasonic
108	1	R39	3.92 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF3921V	Panasonic
109	1	R40	68 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-68R	Yageo
110	1	R43	680 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ681V	Panasonic
111	1	R45	18.7 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1872V	Panasonic
112	1	R46	4.99 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4991V	Panasonic
113	1	R47	10 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ103V	Panasonic
114	1	R49	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
115	1	R50	16 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ163V	Panasonic
116	1	R51	1.3 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ132V	Panasonic
117	1	R52	100 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1003V	Panasonic
118	2	R53 R54	47 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ470V	Panasonic
119	1	RL1	Relay, SPST-NO, 5A 12VDC, PC MNT	G6B-1114P-US-DC12	OMRON
120	1	RT1	NTC Thermistor, 2.5 Ohms, 5 A	SL10 2R505	Ametherm
121	1	RTV1	Thermally conductive Silicone Grease	120-SA	Wakefield
122	1	RV1	320 V, 23 J, 10 mm, RADIAL	V320LA10P	Littlefuse
123	5	SCREW1 SCREW2 SCREW3 SCREW4 SCREW5	SCREW MACHINE PHIL 6-32 X 1/4 SS	PMSSS 632 0025 PH	Building Fasteners
124	1	SCREW6	SCREW MACHINE PHIL 6-32 X 5/16 SS	PMSSS 632 0031 PH	Building Fasteners
125	1	SCREW7	SCREW MACHINE PHIL 4-40 X 1/4 SS	PMSSS 440 0025 PH	Building Fasteners
126	3	STDOFF1 STDOFF2 STDOFF3	Standoff Hex,6-32, 0.375L, F/F, AL	2209	Keystone Elect
127	1	SW1	SLIDE MINI SPDT PC MNT AU	1101M2S3CBE2	C&K Components
128	1	T1	XFMR, EER28, Vertical, Custom		

129	1	T2	XFMR, EE16 Vertical, Custom.		
130	1	TO220PAD1	THERMAL PAD TO-220 .009" SP1000	1009-58	Bergquist
131	1	TP1	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
132	1	TP2	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
133	2	TP3 TP4	Test Point, RED, THRU-HOLE MOUNT	5010	Keystone
134	1	U1	CAPZero, SO-8C	CAP004DG	Power Integrations
135	1	U2	HiperPFS-2, ESIP16/13	PFS7326H	Power Integrations
136	1	U3	HiperTFS-2, ESIP16/12	TFS7703H	Power Integrations
137	3	U4 U5 U6	Optocoupler, 80 V, CTR 80-160%, 4-Mini Flat	PC357N1TJ00F	Sharp
138	2	U7 U8	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semi
139	1	VR1	13 V, 5%, 500 mW, SOD-123	MMSZ5243BT1G	ON Semi
140	3	VR2 VR3 VR4	150 V, 5 W, 5%, DO214AC (SMB)	SMBJ150A	Littlefuse
141	1	VR5	170 V, 5 W, 5%, TVS, DO204AC (DO-15)	P6KE170A	Littlefuse
142	1	VR6	16 V, 5%, 1 W, DO-41	1N4745A-TR	Vishay
143	6	WASHER1 WASHER2 WASHER3 WASHER4 WASHER5 WASHER6	Washer Flat #6, SS, Zinc Plate, 0.267 OD x 0.143 ID x 0.032 Thk	620-6Z	Olander
144	1	WASHER7	Washer Nylon Shoulder #4	3049	Keystone
145	1	WASHER8	WASHER FLAT #4 Zinc, OD 0.219, ID 0.125, Thk 0.032, Yellow Chromate Finish	5205820-2	Tyco

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

7 Magnetics

7.1 *PFC Choke (L3) Specification*

7.1.1 *Electrical Diagram*

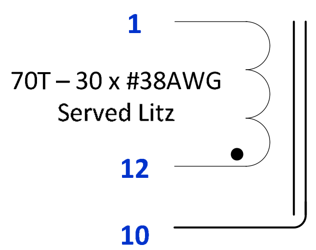


Figure 7 – Inductor Electrical Diagram.

7.1.2 *Electrical Specifications*

Inductance	Pins 1- 12, measured at 100 kHz, 0.4 V_{RMS}.	730 µH ±5%
Resonant Frequency	Pins 1- 12	1300 kHz (Min.)

7.1.3 *Materials*

Item	Description
[1]	Core: TDK-PC44PQ32/20Z or equivalent, gapped for A_{LG} of 154 nH/T$^{2.}$
[2]	Bobbin: PQ32/20, Phenolic, Vertical, 12pins (6/6). TDK BPQ32/20-112CPFR or equivalent.
[3]	Magnet wire: Served Litz wire 30 x #38 AWG, Single Coated Solderable..
[4]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 9.0mm 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*

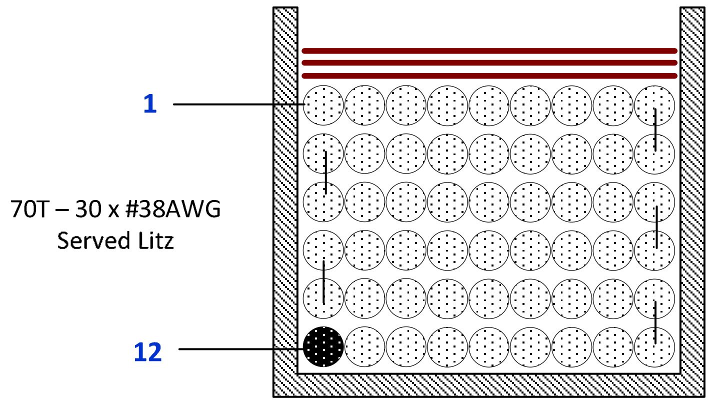


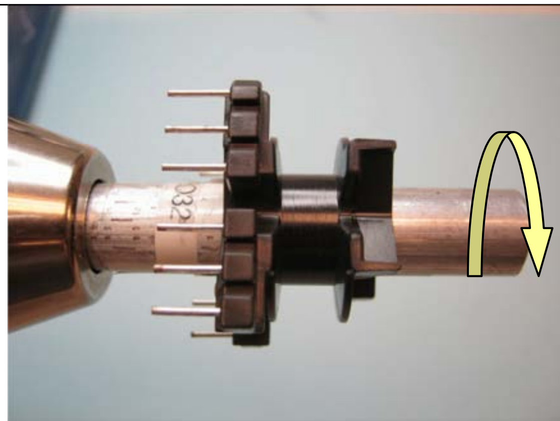
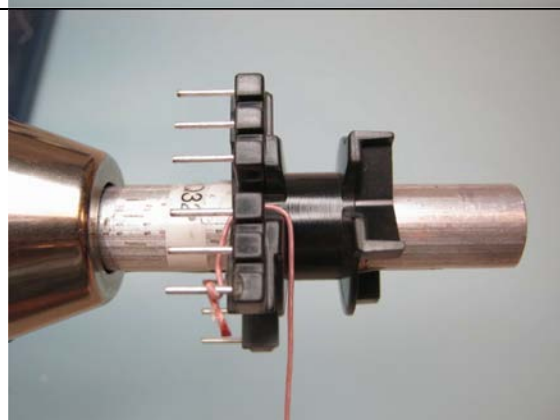
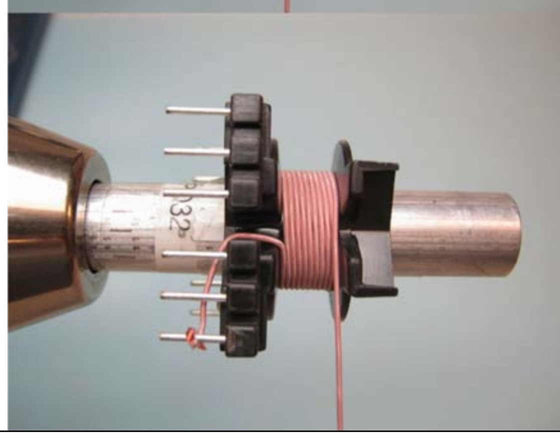
Figure 8 – Transformer Build Diagram.

7.1.5 *Winding Instructions*

Assembly Step	Instructions
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 12, wind 70 turns of wire item [3] in ~ 7 layers, 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] to secure the winding.
Final Assembly	Grind core to get specified inductance. Assemble core halves in bobbin. Attach 100 mm length of bus wire [6] to pin 10 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, 8, 9, 11.** Varnish item [7].

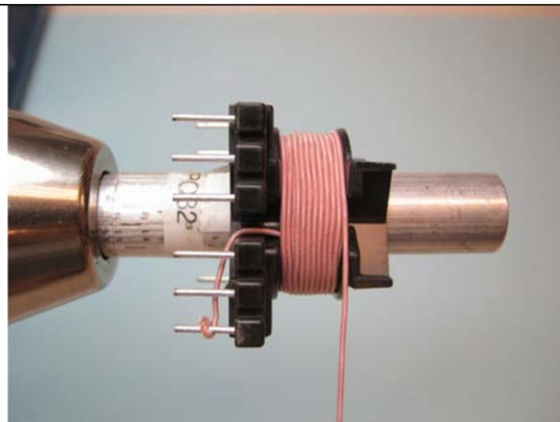
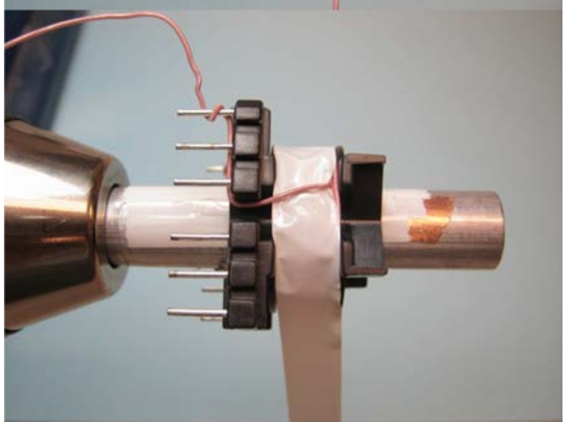
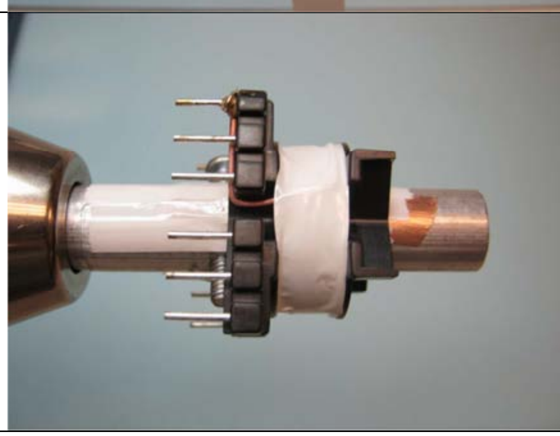
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

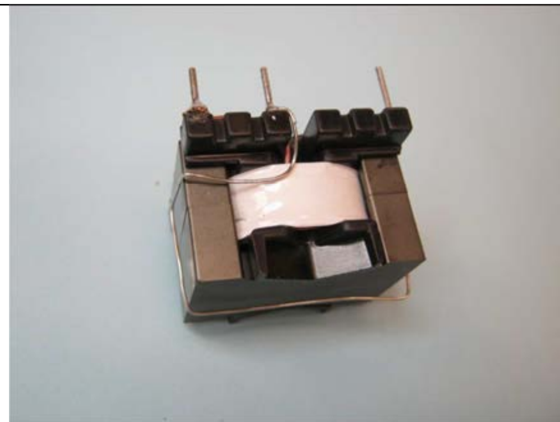
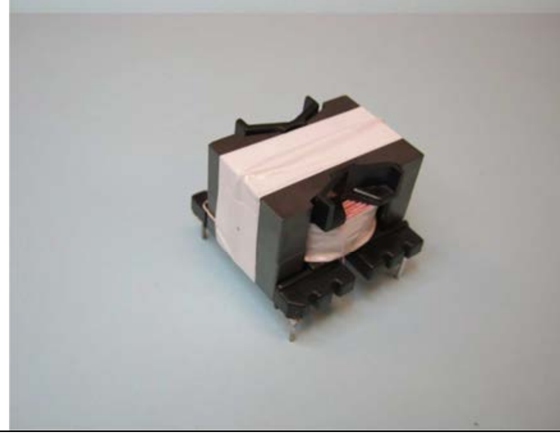
7.1.6 *Winding Illustrations*

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 12, wind 70 turns of wire item [3] in ~ 7 layers, and finish at pin 1. Route start and finish leads on bobbin bottom as shown in pictures.

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

	 	
Insulation		Place 3 layers of tape item [5]

Final Assembly	  	Grind core to get specified inductance. Assemble core halves in bobbin. Attach 100mm length of bus wire [6] to pin 10 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: 2,3,4,5,8,9,11. Varnish item [7].

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

7.2 *Main Transformer (T1) Specification*

7.2.1 *Electrical Diagram*

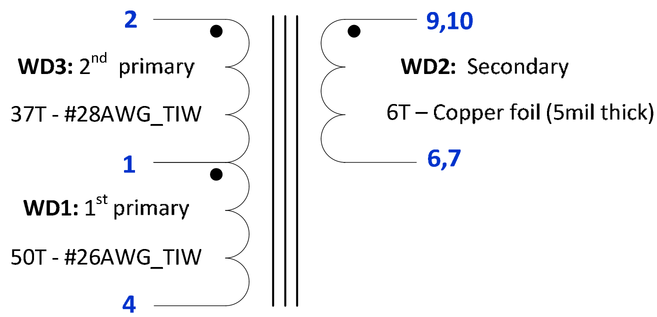


Figure 9 – Main 12 V Transformer Schematic.

7.2.2 *Electrical Specifications*

Electrical Strength	1 second, 60 Hz, from pins 2-4 to pins 6-10.	3000 VAC
Primary Inductance	Pins 2-4, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	50.0 mH ±25%
Resonant Frequency	Pins 2-4, all other windings open	160 kHz (Min.)
Primary Leakage Inductance	Pins 2-4, with pins 6-10 shorted, measured at 100 kHz, 0.4 V_{RMS}.	17 µH max

7.2.3 *Materials*

Item	Description
[1]	Core Pair: EER28, TDK PC95 material; or equivalent, ungapped.
[2]	Bobbin: EER28-Vertical, 10 pins (5/5), PI#: 25-00019-00; or equivalent.
[3]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 16.7 mm wide.
[4]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 24.0 mm wide.
[5]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 20.0 mm wide.
[6]	Copper Foil, 0.005” (0.13 mm) thick, 15.2 mm wide, 307 mm long.
[7]	Triple Insulated Wire, Furukawa Tex-E or equivalent, #26 AWG.
[8]	Triple Insulated Wire, Furukawa Tex-E or equivalent, #28 AWG
[9]	Tinned Solid Copper Bus Wire, #20 AWG.
[10]	Varnish: Dolph BC-359, or equivalent.

7.2.4 *Build Diagram*

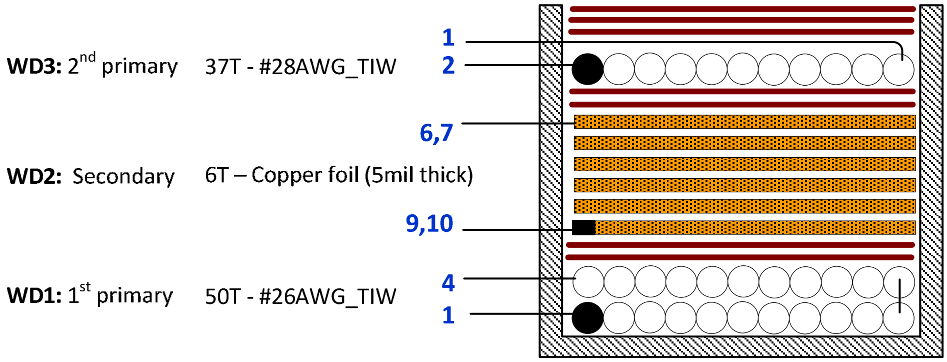


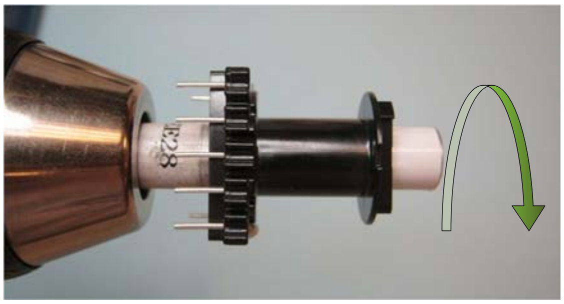
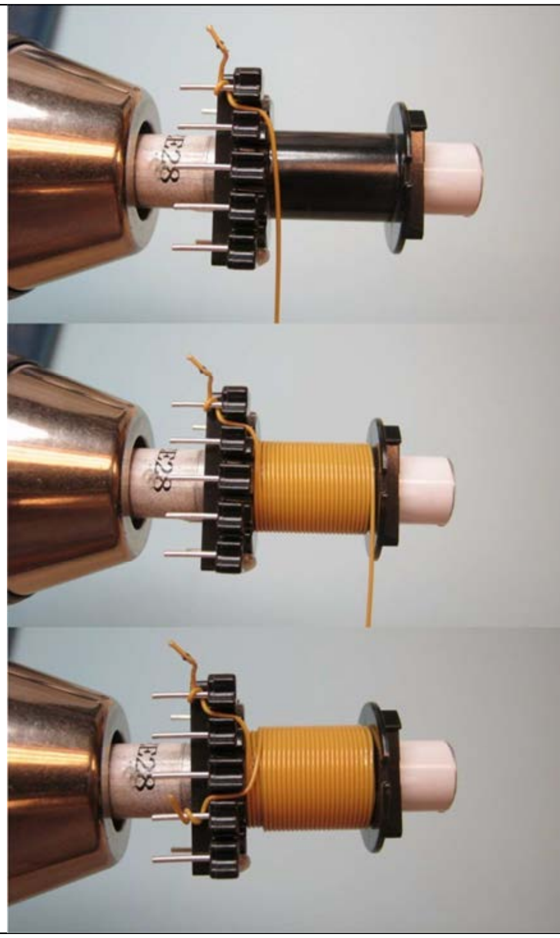
Figure 10 – Main Transformer Build Diagram.

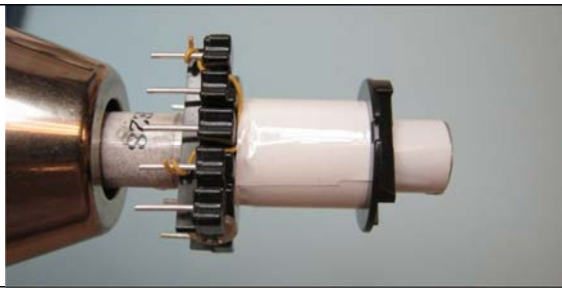
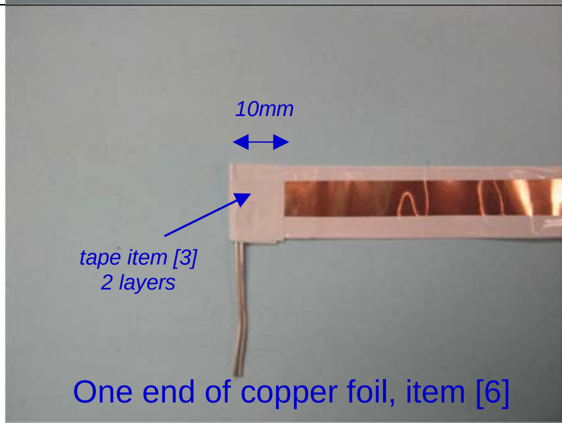
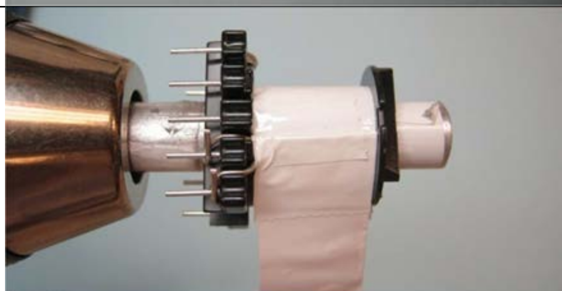
7.2.5 *Winding Instructions*

Assembly Step	Instructions
Preparation	Place bobbin item [2] on the mandrel with pin side on the left side. Winding direction is clockwise direction.
1st Primary (WD1)	Starting at pin 1, wind 50T of triple insulated wire item [7] in two layers. Finish at pin 4.
Insulation	Apply 2 layers of tape item [3] for insulation.
Secondary (WD2)	Using items [3], [4], [6], and [9], construct a 307 mm long cuffed foil assembly per Figure3 and picture below. Starting at pins 9 and 10, wind 6 turns of foil, finishing at pins 6 and 7.
Insulation	Apply 2 layers of tape item [3] for insulation.
2nd Primary (WD3)	Starting at pin 2, wind 37 turns of triple insulated wire item [8]. Finish at pin 1.
Insulation	Apply 3 layers of tape [3] for insulation and secure the windings.
Final Assembly	Wrap bottom core half using 2 layers of tape item [5] 48.0mm long, per illustration. Assemble bobbin and core halves, secure cores with tape. **Pull pins 3, 5, and 8. Cut pin 1 short.** Dip varnish item [10].

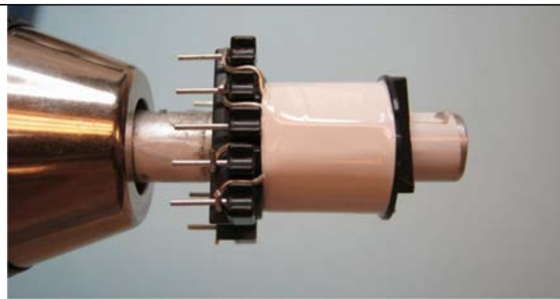
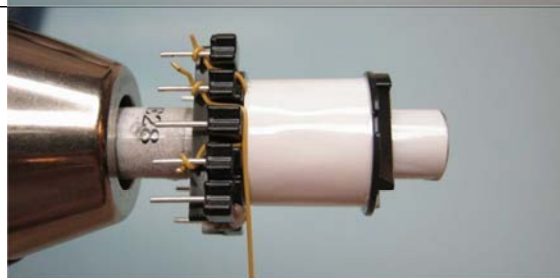
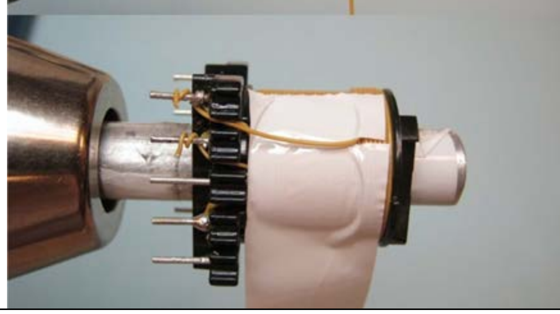
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

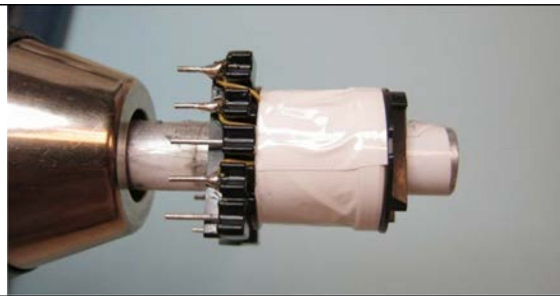
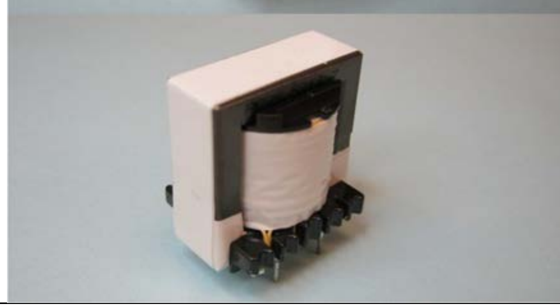
7.2.6 *Winding Illustrations*

Preparation		Place bobbin item [2] on the mandrel with pin side on the left side. Winding direction is clock wise direction.
1st Primary (WD1)		Starting at pin 1, wind 50T of triple insulated wire item [7] in two layers. Finish at pin 4.

Insulation		Apply 2 layer of tape item [3] for insulation.
Secondary (WD2)		Using items [3], [4], [6], and [9], construct a 307 mm long cuffed foil assembly per Figure 3 and picture beside.
		Starting at pins 9 and 10, wind 6 turns of foil, finishing at pins 6 and 7.

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

Insulation		Apply 2 layer of tape item [3] for insulation.
2nd Primary (WD3)	   	Starting at pin 2, wind 37 turns of triple insulated wire item [8]. Finish at pin 1.

Insulation		Apply 3 layers of tape [3] for insulation and to secure the windings.
Final Assembly	 *Place bottom core half in center of tape…* *… then wrap around*   	Wrap bottom core half using 2 layers of tape item [5] 48.0mm long, per illustration. Assemble bobbin and core halves, secure cores with tape. **Pull Pins 3, 5, and 8. Cut Pin 1 short.** Dip varnish item [10].

Note: Use of triple insulated wire in primary allows smaller core and simplifies and lowers cost of assembly.

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

7.2.7 *Secondary Foil Assembly Construction Details*

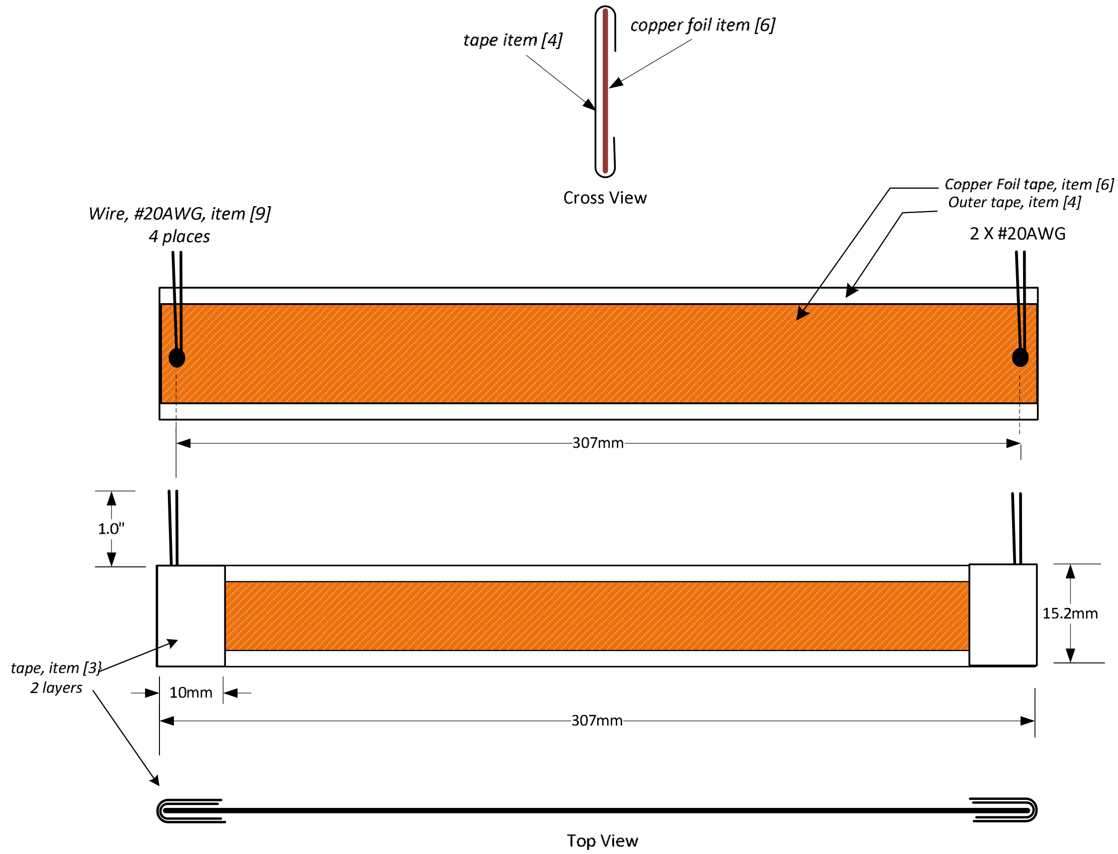


Figure 11 – Output Foil Assembly Drawing.

7.3 *Standby Transformer (T2)*

7.3.1 *Electrical Diagram*

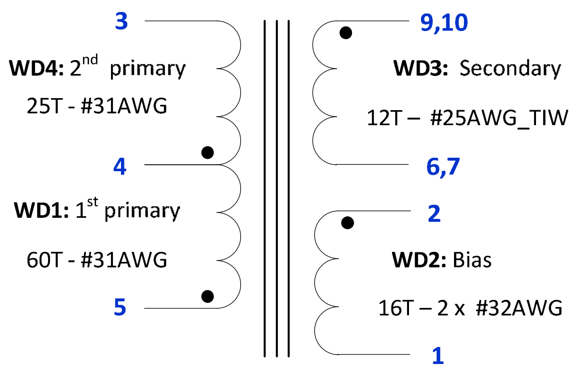


Figure 12 – Standby transformer Electrical Diagram.

7.3.2 *Electrical Specifications*

Electrical Strength	1 second, 60 Hz, from pins 1-5 to pins 6-10.	3000 VAC
Primary Inductance	Pins 3-5, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	838 µH ±10%
Resonant Frequency	Pins 3-5, all other windings open.	1.4 MHz (Min.)
Primary Leakage Inductance	Pins 3-5, with pins 6-10 shorted, measured at 100 kHz, 0.4 V_{RMS}.	15 µH (Max)

7.3.3 *Materials*

Item	Description
[1]	Core: EE16, TDK PC44 material or equivalent, gapped for ALG 116 nH/T^2.
[2]	Bobbin: EE16, Vertical, 10 pins (5/5). Yih Hwa YW-527-00B.
[3]	Tape: 3M 1350 F1 or equivalent, 8.4 mm wide.
[4]	Magnet wire: #31AWG, solderable double coated.
[5]	Magnet wire: #32AWG, solderable double coated.
[6]	Triple Insulated Wire: Furukawa Tex-E or equivalent, #25 AWG.
[7]	Varnish: Dolph BC-359, or equivalent.

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

7.3.4 *Build Diagram*

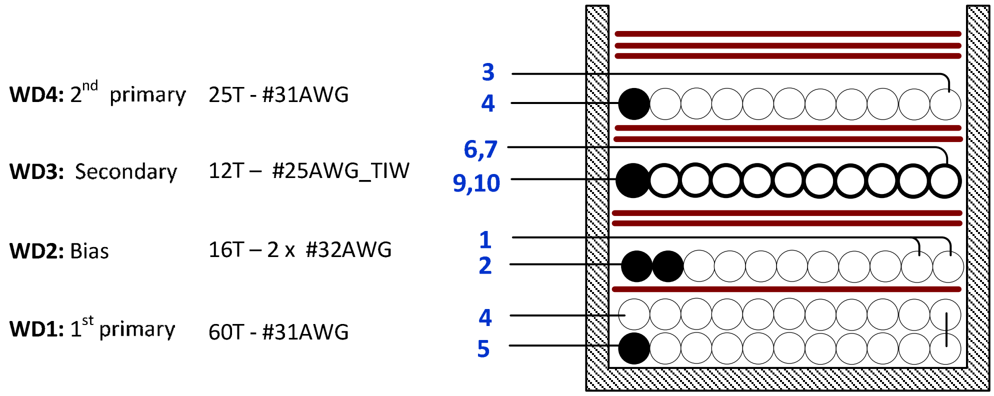
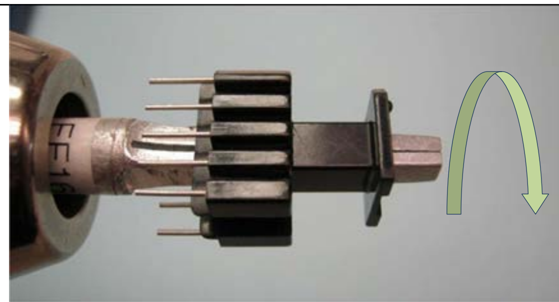
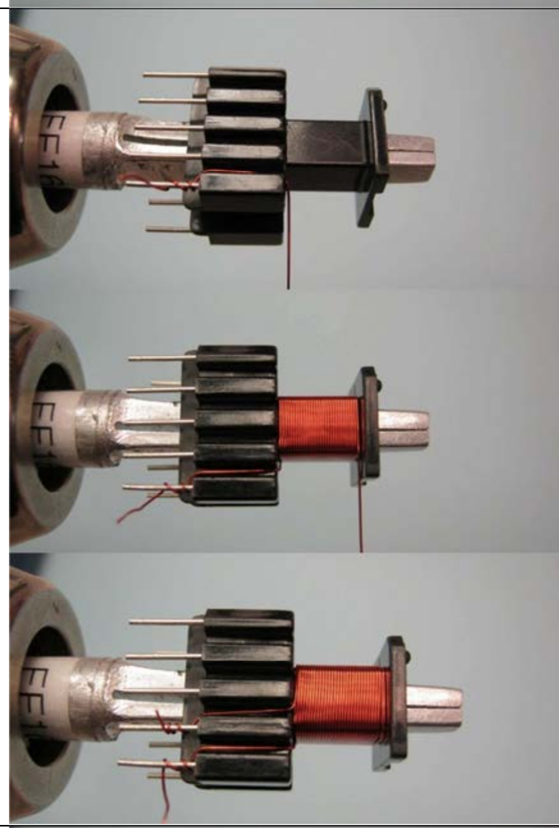
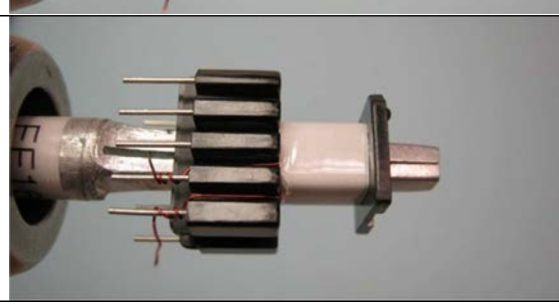


Figure 13 – Build Diagram for Standby Transformer.

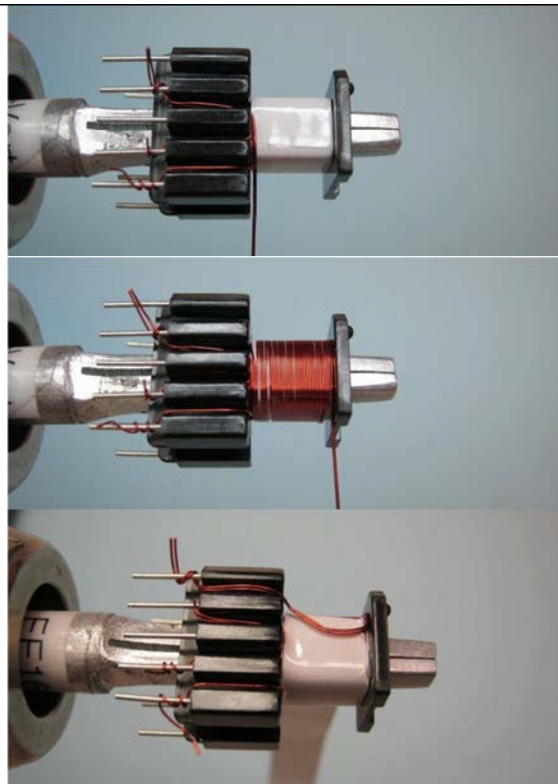
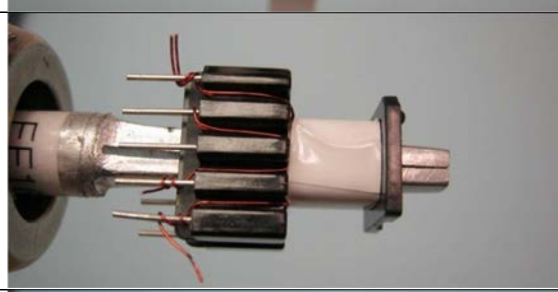
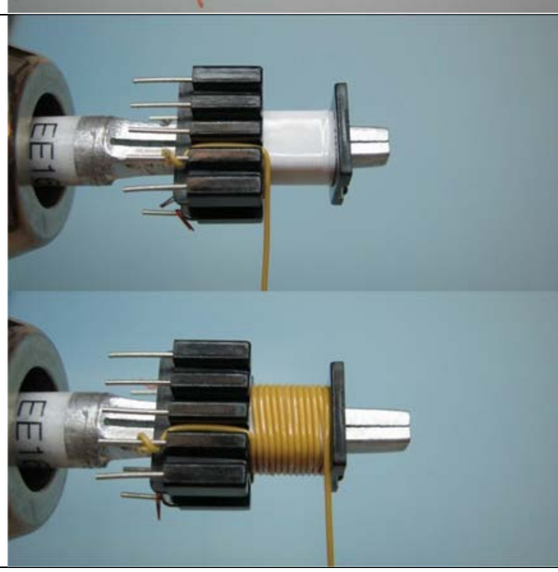
7.3.5 *Winding Instructions*

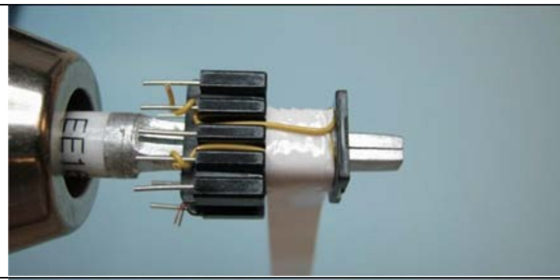
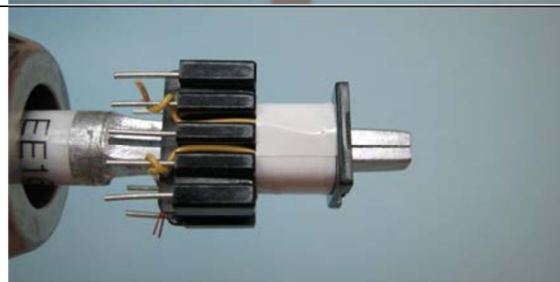
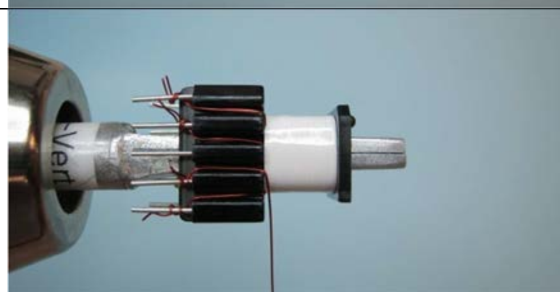
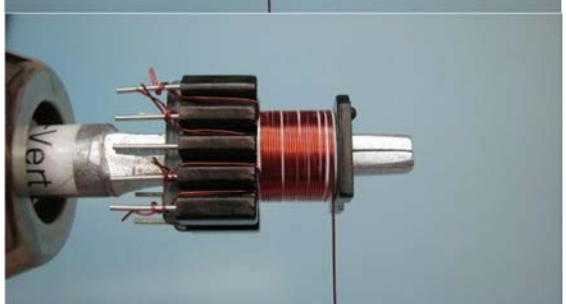
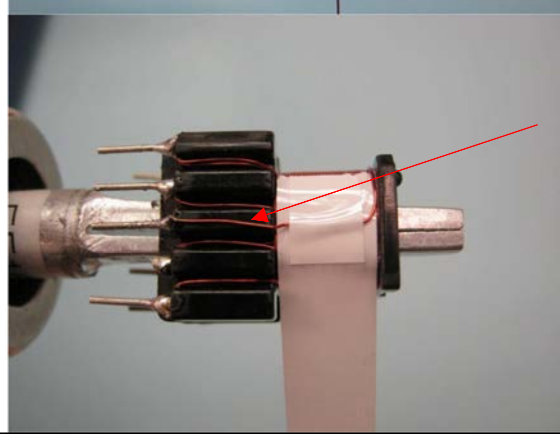
Assembly Step	Instructions
Preparation	Place bobbin item [2] on the mandrel with pin side is on the left. Winding direction is clockwise direction.
1st Primary (WD1)	Starting at Pin 5, wind 60 turns of wire item [4] in two layers. Finish at Pin 4.
Insulation	Apply 1 layer of tape item [3].
Bias (WD2)	Starting at pin 2, wind 16 bifilar turns of wire item [5] in a 1 layer. Finish at pin 1.
Insulation	Apply 2 layers of tape item [3].
Secondary (WD3)	Starting at pin 9, 10, wind 12 turns of triple insulated wire item [6] in 1 layer. Finish at pins 6, 7.
Insulation	Apply 2 layers of tape item [3].
2nd Primary (WD4)	Starting at pin 4, wind 25 turns of wire item [4] in 1 layer. Finish at pin 3. Bring finish wire out of slot to terminate, (see picture below).
Insulation	Apply 3 layers of tape item [3] for finish wrap.
Final Assembly	Grind core gap to specified inductance coefficient. Assemble bobbin and core halves, secure cores with tape. **Pull pin 8, cut short pin 4**. Dip varnish item [7].

7.3.6 *Winding Illustrations*

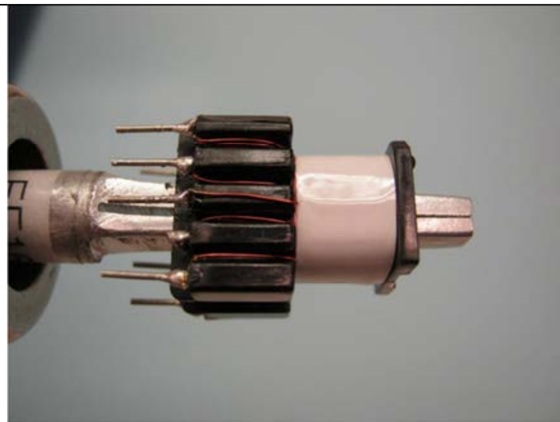
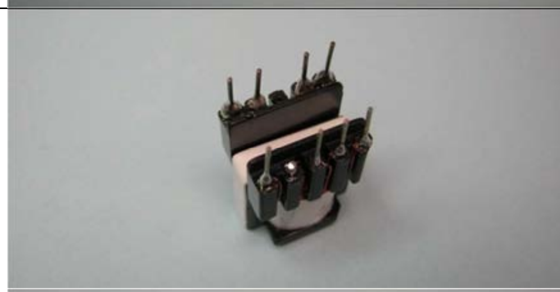
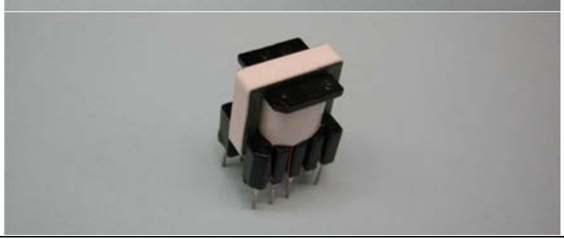
Preparation		Place bobbin item [2] on the mandrel with pin side is on the left. Winding direction is clockwise direction.
1st Primary (WD1)		Starting at Pin 5, wind 60 turns of wire item [4] in two layers. Finish at Pin 4.
Insulation		Apply 1 layer of tape item [3].

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

Bias (WD2)		Starting at pin 2, wind 16 bifilar turns of wire item [5] in a 1 layer. Finish at pin 1.
Insulation		Apply 2 layers of tape item [3].
Secondary (WD3)		Starting at pin 9, 10, wind 12 turns of triple insulated wire item [6] in 1 layer. Finish at pins 6, 7.

		
Insulation		Apply 2 layers of tape item [3].
2nd Primary (WD4)	 	Starting at pin 4, wind 25 turns of wire item [4] in 1 layer.
		Finish at pin 3. Bring finish wire out of slot to terminate, (see picture beside). *(Place a piece small tape to keep wire in place, not moving).*

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

Insulation		Apply 3 layers of tape item [3] for finish wrap.
Final Assembly	 	Grind core gap to specified inductance coefficient. Assemble bobbin and core halves, secure cores with tape. **Pull pin 8, cut short pin 4**. Dip varnish item [6].

7.4 *Main Output Inductor (L4) Specification*

7.4.1 *Electrical Diagram*

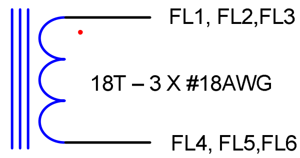


Figure 14 – Inductor Electrical Diagram.

7.4.2 *Electrical Specifications*

Inductance	Pins FL1, FL2, FL3 to FL4, FL5, FL6 measured at 100 kHz, 0.4 $V_{RMS.}$	51 µH, ±15%

7.4.3 *Materials*

Item	Description
[1]	Sendust Toroidal Core, 125µ: Magnetics, Inc. 77930-A7 or equivalent.
[2]	Magnet wire: #18 AWG Solderable Double Coated.

7.4.4 *Construction Detail*

Figure 15 – Finished Part, Front View. Tin Leads to within ~ 1/2" of Toroid Body.

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

8 PFC Design Spreadsheet

Hiper_PFS-II_Boost_092713; Rev.1.2; Copyright Power Integrations 2013	INPUT	INFO	OUTPUT	UNITS	Hiper_PFS-II_Boost_092713_Rev1-2.xls; Continuous Mode Boost Converter Design Spreadsheet
Enter Applications Variables					
Input Voltage Range			**Universal**		Input voltage range
VACMIN			90	V	Minimum AC input voltage
VACMAX			265	V	Maximum AC input voltage
VBROWNIN			76.69	V	Expected Minimum Brown-in Voltage
VBROWNOUT			68.33	V	Specify brownout voltage.
VO			385.00	V	Nominal Output voltage
PO	205.00		205.00	W	Nominal Output power
fL			50	Hz	Line frequency
TA Max			40	deg C	Maximum ambient temperature
n			0.93		Enter the efficiency estimate for the boost converter at VACMIN
KP	0.420		0.42		Ripple to peak inductor current ratio at the peak of VACMIN
VO_MIN			365.75	V	Minimum Output voltage
VO_RIPPLE_MAX			20	V	Maximum Output voltage ripple
tHOLD-UP		*Warning*	20	ms	!!! Warning. Expected hold-up time is smaller than specified value. Please use larger Output capacitance
VHOLD-UP_MIN			310	V	Minimum Voltage Output can drop to during hold-up
I_INRUSH			40	A	Maximum allowable inrush current
Forced Air Cooling	**Yes**		**Yes**		Enter "Yes" for Forced air cooling. Otherwise enter "No"
PFS Parameters					
PFS Part Number	**Auto**		**PFS7326H**		Selected PFS device
MODE	**FULL**		**FULL**		Mode of operation of PFS. For full mode enter "FULL" otherwise enter "EFFICIENCY" to indicate efficiency mode
R_RPIN			24.9	k-ohms	R pin resistor value
C_RPIN			0.47	nF	R pin capacitor value
IOCP min			6.8	A	Minimum Current limit
IOCP typ			7.2	A	Typical current limit
IOCP max			7.5	A	Maximum current limit
RDSON			0.62	ohms	Typical RDSon at 100 'C
RV1			1.50	Mohms	Line sense resistor 1
RV2			1.50	Mohms	Line sense resistor 2
RV3			1.00	Mohms	Line sense resistor 3
C_VCC			3.30	uF	Supply decoupling capacitor
R_VCC			15.00	ohms	VCC resistor
C_V			22.00	nF	V pin decoupling capacitor
C_C			22	nF	Feedback C pin decoupling capacitor
Power good Vo lower threshold VPG(L)			333	V	Power good Vo lower threshold voltage
PGT set resistor			103.79	kohm	Power good threshold setting resistor
FS_PK			63.1	kHz	Estimated frequency of operation at crest of input voltage (at VACMIN)
FS_AVG			51.2	kHz	Estimated average frequency of operation over line cycle (at VACMIN)
IP			3.96	A	MOSFET peak current
PFS_IRMS			1.98	A	PFS MOSFET RMS current
PCOND_LOSS_PFS			2.43	W	Estimated PFS conduction losses
PSW_LOSS_PFS			0.96	W	Estimated PFS switching losses

PFS_TOTAL			3.39	W	Total Estimated PFS losses
TJ Max			100	deg C	Maximum steady-state junction temperature
Rth-JS			3.00	degC/W	Maximum thermal resistance (Junction to heatsink)
HEATSINK Theta-CA			9.30	degC/W	Maximum thermal resistance of heatsink
Basic Inductor Calculation					
LPFC			733	uH	Value of PFC inductor at peak of VACMIN and Full Load
LPFC (0 Bias)			733	uH	Value of PFC inductor at No load. This is the value measured with LCR meter
LP_TOL	5.00		5	%	Tolerance of PFC Inductor Value
LPFC_RMS			2.35	A	Inductor RMS current (calculated at VACMIN and Full Load)
Inductor Construction Parameters					
Core Type	**Ferrite**		**Ferrite**		Enter "Sendust", "Pow Iron" or "Ferrite"
Core Material	**Auto**		**PC44**		Select from 60u, 75u, 90u or 125 u for Sendust cores. Fixed at PC44 or equivalent for Ferrite cores. Fixed at 52 material for Pow Iron cores.
Core Geometry	**Auto**		**PQ**		Select from Toroid or EE for Sendust cores and from EE, or PQ for Ferrite cores
Core	**PQ32/20**		**PQ32/20**		Core part number
AE			170	mm^2	Core cross sectional area
LE			55.5	mm	Core mean path length
AL			6530	nH/t^2	Core AL value
VE			9.44	cm^3	Core volume
HT			5.12	mm	Core height/Height of window
MLT			67.1	cm	Mean length per turn
BW			8.98	mm	Bobbin width
NL			70		Inductor turns
LG			1.77	mm	Gap length (Ferrite cores only)
ILRMS			2.35	A	Inductor RMS current
Wire type	**LITZ**		**LITZ**		Select between "Litz" or "Regular" for double coated magnet wire
AWG	38		38	AWG	Inductor wire gauge
Filar	30		30		Inductor wire number of parallel strands
OD			0.102	mm	Outer diameter of single strand of wire
AC Resistance Ratio			1.02		Ratio of AC resistance to the DC resistance (using Dowell curves)
J		*Warning*	9.66	A/mm^2	!!! Warning Current density is too high and may cause heating in the inductor wire. Reduce J
BP_TARGET	3900		3900	Gauss	Target flux density at selected saturation current level (Ferrite cores only)
BM			2437	Gauss	Maximum operating flux density
BP		*Warning*	4850	Gauss	!!! Warning Peak flux density is too high, use a larger core or increase KP
LPFC_CORE_LOSS			0.06	W	Estimated Inductor core Loss
LPFC_COPPER_LOSS			3.14	W	Estimated Inductor copper losses
LPFC_TOTAL LOSS			3	W	Total estimated Inductor Losses
FIT		*Warning*	96.22%	%	!!! Warning. Windings may not fit on this inductor. Use bigger core or reduce KP or reduce wire gauge if possible
Layers			6.2		Estimated layers in winding
Inductor saturation current	6.000		6	A	Design inductor refer to this saturation current. Default IOCP_MAX
Critical Parameters					
IRMS			2.45	A	AC input RMS current
IO_AVG			0.53	A	Output average current
Output Diode (DO)					
Part Number	**Auto**		**INTERNAL**		PFC Diode Part Number

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

Type			SPECIAL		Diode Type - Special - Diodes specially catered for PFC applications, SiC - Silicon Carbide type, UF - Ultrafast recovery type
Manufacturer			PI		Diode Manufacturer
VRRM			600	V	Diode rated reverse voltage
IF			3	A	Diode rated forward current
TRR			31	ns	Diode Reverse recovery time
VF			1.47	V	Diode rated forward voltage drop
PCOND_DIODE			0.78	W	Estimated Diode conduction losses
PSW_DIODE			0.71	W	Estimated Diode switching losses
P_DIODE			1.49	W	Total estimated Diode losses
TJ Max			100	deg C	Maximum steady-state operating temperature
Rth-JS			3.85	degC/W	Maximum thermal resistance (Junction to heatsink)
HEATSINK Theta-CA			9.30	degC/W	Maximum thermal resistance of heatsink
Output Capacitor					
CO	**150**		**150.00**	uF	Minimum value of Output capacitance
VO_RIPPLE_EXPECTED			12.2	V	Expected ripple voltage on Output with selected Output capacitor
T_HOLD-UP_EXPECTED			19.1	ms	Expected hold-up time with selected Output capacitor
ESR_LF			1.11	ohms	Low Frequency Capacitor ESR
ESR_HF			0.44	ohms	High Frequency Capacitor ESR
IC_RMS_LF			0.38	A	Low Frequency Capacitor RMS current
IC_RMS_HF			1.08	A	High Frequency Capacitor RMS current
CO_LF_LOSS			0.16	W	Estimated Low Frequency ESR loss in Output capacitor
CO_HF_LOSS			0.52	W	Estimated High frequency ESR loss in Output capacitor
Total CO LOSS			0.67	W	Total estimated losses in Output Capacitor
Input Bridge (BR1) and Fuse (F1)					
I^2t Rating			10.53	A^2s	Minimum I^2t rating for fuse
Fuse Current rating			3.84	A	Minimum Current rating of fuse
VF			0.90	V	Input bridge Diode forward Diode drop
IAVG			2.39	A	Input average current at 70 VAC.
PIV_INPUT BRIDGE			375	V	Peak inverse voltage of input bridge
PCOND_LOSS_BRIDGE			3.97	W	Estimated Bridge Diode conduction loss
CIN			0.68	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
Feedback Components					
R1			1.5	Mohms	Feedback network, first high voltage divider resistor
R3			1.6	Mohms	Feedback network, third high voltage divider resistor
R2			787	kohms	Feedback network, second high voltage divider resistor
C1			47	nF	Feedback network, loop speedup capacitor
R4			60.4	kohms	Feedback network, lower divider resistor
R6			487	kohms	Feedback network - pole setting resistor
R7			6.81	kohms	Feedback network - zero setting resistor
C2			47	nF	Feedback component- noise suppression capacitor
R5			3.00	kohms	Damping resistor in serise with C3
C3			2.2	uF	Feedback network - compensation capacitor
D1			BAV116		Feedback network - capacitor failure detection Diode
Loss Budget (Estimated at VACMIN)					
PFS Losses			3.39	W	Total estimated losses in PFS
Boost diode Losses			1.49	W	Total estimated losses in Output Diode

Input Bridge losses			3.97	W	Total estimated losses in input bridge module
Inductor losses			3.19	W	Total estimated losses in PFC choke
Output Capacitor Loss			0.67	W	Total estimated losses in Output capacitor
Total losses			12.71	W	Overall loss estimate
Efficiency			0.94		Estimated efficiency at VACMIN. Verify efficiency at other line voltages
CAPZero component selection recommendation					
CAPZero Device			CAP004DG		(Optional) Recommended CAPZero device to discharge X-Capacitor with time constant of 1 second
Total Series Resistance (R1+R2)			0.78	k-ohms	Maximum Total Series resistor value to discharge X-Capacitors
EMI filter components recommendation					
CIN			680.00	nF	Metallized polyester film capacitor after bridge, ratio with Po
CX2			470.00	nF	X capacitor after differencial mode choke and before bridge, ratio with Po
LDM_calc			220.49	uH	estimated minimum differencial inductance to avoid <10kHz resonance in input current
CX1			470.00	nF	X capacitor before common mode choke, ratio with Po
LCM			10.00	mH	typical common mode choke value
LCM_leakage			30.00	uH	estimated leakage inductance of CM choke, typical from 30~60uH
CY1 (and CY2)			220.00	pF	Typical Y capacitance for common mode noise suppression
LDM_Actual			190.49	uH	cal_LDM minus LCM_leakage, utilizing CM leakage inductance as DM choke.
Note: CX2 can be placed between CM choke and DM choke depending on EMI design requirement.					

In this design, the spreadsheet generated a warning concerning inductor wire fit, current density, and flux density. The wire fits in the actual inductor. The actual inductor has only a modest temperature rise, even with no airflow, and also does not saturate under brownout conditions. The spreadsheet also generated a warning regarding hold-up time. The hold-up time was adequate with the capacitor value chosen.

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

9 HiperTFS-2 Transformer Design Spreadsheet (Main + Standby)

HiperTFS2_Two-switch_Forward_051313; Rev.1.0; Copyright Power Integrations 2013	**INPUT**	**INFO**	**OUTPUT**	**UNIT**	**HiperTFS2_051313_Rev1-0.xls; Two-switch Forward Transformer Design Spreadsheet**
Hiper-TFS MAIN OUTPUT (TWO-SWITCH FORWARD STAGE)					
OUTPUT VOLTAGE AND CURRENT					
VMAIN	12.00			V	Main output voltage
IMAIN	14.20			A	Main output current
VOUT2				V	Output2 voltage - enter zero if none
IOUT2				A	Output2 current - enter zero if none
POST REGULATED OUTPUT					
Post Regulator	NONE	*Info*			!!!! Info. No Selection for post-regulator - select 'NONE' if not using post-regulator
V_SOURCE	NONE			V	Select source of input voltage for post regulator. Enter None if Post regulator not used.
VOUT3			N/A	V	Enter post regulator output voltage
IOUT3			N/A	A	Enter post regulator output current
n_PR			1		Enter post regulator efficiency (Buck only)
COUPLED-INDUCTOR (LOW POWER) DERIVED OUTPUT					
VOUT4				V	Coupled-Inductor derived (low power) output voltage (typically -12 V)
IOUT4				A	Coupled-Inductor derived (low power) output current
POUT(Main)			170.4	W	Total output power (Main converter)
POUT_PEAK(Main)			170.4	W	Peak Output power (Main converter). If there is no peak power requirement enter value equal to continuous power
POUT(Standby)			10.3	W	Continuous output power from Standby power supply
POUT_PEAK(Standby)			10.0	W	Peak output power from Standby section
POUT(System Total)			180.7	W	Total system continuous output power
POUT_PEAK(System Total)			180.4	W	Total system peak output power
VBIAS	17.00			V	DC bias voltage from main transformer aux winding
INPUT VOLTAGE AND UV/OV					
CIN			154.21	uF	Input Capacitance. To increase CMIN, increase T_HOLD-UP
T_HOLD-UP			20.00	ms	Hold-up time
CIN	150.00		150.00	uF	Select Bulk Capacitor
CIN_ESR			0.44	ohms	Bulk capacitor ESR
IRMS_CIN			0.57	A	RMS current through bulk capacitor
PLOSS_CIN			0.15	W	Bulk capacitor ESR losses
VMIN			300	V	Minimum input voltage to guarantee output regulation
VNOM			380	V	Nominal input voltage
VMAX			420	V	Maximum DC input voltage
RR			3.92	M-ohm	R pin resistor
RL			3.92	M-ohm	Line Sense resistor value (L-pin) - goal seek (VUV OFF) for std 1% resistor series
UV / OV / UVOV					
VUV OFF (min)			181.85	V	Minimum undervoltage On-Off threshold
VUV ON (min)			295.50	V	Minimum undervoltage Off-On threshold (turn-on)
VOV ON (min)			526.73	V	Minimum overvoltage Off-On threshold
VOV OFF (min)			526.73	V	Minimum overvoltage On-Off threshold (turn-off)
VUV OFF (max)			224.96	V	Maximum undervoltage On-Off threshold
VUV ON (max)			326.85	V	Maximum undervoltage Off-On threshold (turn-on)

ENTER DEVICE VARIABLES					
Device	TFS7703		TFS7703		Selected HiperTFS device
Select Frequency mode	h		h		Select Frequency mode. "H" indicates 66 kHz selection, "F" indicates 132 kHz selection
ILIMIT_MIN			3.01	A	Device current limit (Minimum)
ILIMIT_TYP			3.24	A	Device current limit (Typical)
ILIMIT_MAX			3.47	A	Device current limit (Maximum)
fSMIN			62000	Hz	Device switching frequency (Minimum)
fS			66000	Hz	Device switching frequency (Typical)
fSMAX			70000	Hz	Device switching frequency (Maximum)
KI	1.0		1.0		Select Current limit factor (KI=1.0 for default ILIMIT, or select KI=0.9 or KI=0.7)
R(FB)			232.0	k-ohms	Feedback Pin Resistor value
ILIMIT SELECT			3.01	A	Selected current limit
RDS(ON)			5.00	ohms	Rds(on) at 100'C
DVNOM_GOAL	0.50		0.50		Target duty cycle at nominal input voltage (VNOM)
VDS			4.30	V	HiperTFS average on-state Drain to Source Voltage
Main MOSFET losses					
RDSON_LOWER			3.60	ohm	RDSON for low side MOSFET
RDSON_UPPER			1.40	ohm	RDSON for high side MOSFET
PCOND_LOWER			2.08	W	Conduction losses in lower MOSFET
PCOND_UPPER			0.81	W	Conduction losses in upper MOSFET
COSS_LOWER			35.00	pF	COSS for low side MOSFET
COSS_UPPER			110.00	pF	COSS for high side MOSFET
V_Coss upper FET			150.00	V	Voltage across upper MOSFET during turn off
P_Coss lower FET			0.06	W	Switching loss in upper MOSFET
P_Coss upper FET			0.08	W	Switching loss in lower MOSFET
lower FET crossoever loss			0.34	W	Crossover loss in lower MOSFET
TOTAL_MOSFET_LOSS			3.37	W	Total loss in MOSFET (upper + lower)
Clamp Section					
Clamp Selection	CLAMP TO GND				Select either "CLAMP TO RAIL" (default) or "CLAMP TO GND"
VCLAMP	550.00		550.00	V	Asymmetric Clamp Voltage
VDSOP			550.00	V	Maximum Hiper-TFS Drain voltage (at VOVOFF_MAX)
DIODE Vf SELECTION					
VDMAIN	0.24		0.24	V	Main output diodes forward voltage drop
VDOUT2			0.5	V	Secondary output diodes forward voltage drop
VDOUT3			0.5	V	3rd output diodes forward voltage drop
VDB			0.7	V	Bias diode forward voltage drop
TRANSFORMER CORE SELECTION					
Core Type	EER28		EER28		Selected core type
AE			0.821	cm^2	Core Effective Cross Sectional Area
LE			6.4	cm	Core Effective Path Length
AL			2870	nH/T^2	Ungapped Core Effective Inductance
BW			16.7	mm	Bobbin Physical Winding Width
B_HT			4.33	mm	Height of bobbin (to calculate fit)
B_WA			0.72	cm^2	Bobbin Winding area
M			4.5	mm	Bobbin safety margin tape width (2 * M = Total Margin)
LG_MAX			0.002	mm	Maximum zero gap tolerance, default 2um
LMAG_MAX			82.59	mH	Maximum magnetizing inductance of transformer. Do not exceed this value
LMAG			20.11	mH	Actual magnetizing inductance (measured) of transformer
FRES_TRF			121.60	kHz	Measured Primary winding self resonant frequency
C_TRF			85.20	pF	Estimated primary winding capacitance

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

L			3.00		Transformer primary layers (split primary recommended)
NMAIN	6.0		6.0		Main rounded turns
NS2			0.0		2nd output number of turns
NBIAS			5		VBias rounded turns (forward bias winding)
VOUT2 ACTUAL			0.0	V	Approximate Output2 voltage of with NS2 = 0 turns (AC stacked secondary)
VBIAS_ACTUAL			16.7	V	Approximate Forward Bias Winding Voltage at VMIN with NB = 5 turns
TRANSFORMER DESIGN PARAMETERS					
NP			86		Primary rounded turns
BM_MAX			2645	Gauss	Max positive operating flux density at minimum switching frequency
BM PK-PK			4008	Gauss	Max peak-peak operating flux density at minimum switching frequency
BP_MAX			3032	Gauss	Max positive flux density at Vmax (limited by DVMAX clamp)
BP PK-PK			4594	Gauss	Max peak-peak flux density at Vmax (limited by DVMAX clamp)
IMAG			0.141	A	Peak magnetizing current at minimum input voltage
OD_P			0.27	mm	Primary wire outer diameter
AWG_P			30	AWG	Primary Wire Gauge (rounded to maximum AWG value)
TRANSFORMER LOSSES AND FIT ESTIMATE					
Core loss					
Core material	Auto		PC95		Select core material
BAC_pp			3765	gauss	Peak to peak flux density
core_loss_multiplier			2.04E-03		Core Loss constant
f_coeff			1.80		Frequency co-efficient
BAC_coeff			2.56		AC flux density co-efficient
specific core loss			314.52	mW/cc	Core loss per unit volume
core volume			5.25	cm^3	Volume of core
core loss			1.65	W	Core loss
PRI WINDING FIT AND LOSSES					
OD_PRI			0.45	mm	Primary winding diameter
FILAR_PRI			1.00	strands	Number of parallel strands of wire (primary)
MLT_PRI			5.22	cm	Mean length per turn
DCR_PRI			618.00	milli-ohm	DC resistance of primary winding
PCOND_PRI			0.36	W	Conduction loss in primary winding
FILL_PRI			19	%	Fill factor (primary only)
SEC WINDING 1 (lower winding when AC stacked)					
VOUT			12.00	V	Specified voltage for this winding
NS1			6.00	turns	Number of turns
IRMS_SEC1			11.91	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_SEC1			N/A	strands	Number of parallel strands (wire selection only)
SEC1_WIDTH			18.00	mm	Foil Width (Applicable if FOIL winding used)
SEC1_MLT			5.22	cm	Mean length per turn
DCR_SEC1			3.08	milli-ohms	DC resistance of secondary winding
PCOND_SEC1			0.44	W	Conduction loss in secondary winding
FILL_SEC1			19	%	Fill factor (secondary 1 only)
SEC WINDING 2 (upper winding AC stacked)					
VOUT			0.00	V	Specified voltage for this winding
NS2			0.00	turns	Number of turns

IRMS_SEC2			0.00	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			18.00	mm	Foil Width (Applicable if FOIL winding used)
SEC2_MLT			5.22	cm	Mean length per turn
DCR_SEC2			0.00	milli-ohms	DC resistance of secondary winding
PCOND_SEC2			0.00	W	Conduction loss in secondary winding
FILL_SEC2			0	%	Fill factor (secondary 1 only)
Total main transformer					
FILL_TOTAL			38	%	Total transformer fill factor
TOTAL_CU_LOSS			0.79	W	Total copper losses in transformer
TOTAL_CORE_LOSS			1.65	W	Total core losses in transformer
TOTAL_TRF_LOSS			2.45	W	Total losses in transformer
DUTY CYCLE VALUES (REGULATION)					
DVMIN			0.63		Duty cycle at minimum DC input voltage
DVNOM			0.50		Duty cycle at nominal DC input voltage
DVMAX			0.45		Duty cycle at maximum DC input voltage
DOVOFF MIN			0.36		Duty cycle at over-voltage DC input voltage (DOVOFF_MIN)
MAXIMUM DUTY CYLE VALUES					
DMAX_UVOFF_MIN			0.76		Max duty cycle clamp at VUVOFF_MIN
DMAX_VMIN			0.65		Max duty clamp cycle at VMIN
DMAX_VNOM			0.56		Max duty clamp cycle at VNOM
DMAX_VMAX			0.51		Max duty clamp cycle at VMAX
DMAX_OVOFFMIN			0.41		Max duty clamp cycle at VOVOFF_MAX
CURRENT WAVESHAPE PARAMETERS					
IP			1.32	A	Maximum peak primary current at maximum DC input voltage
IP_PEAK			1.32	A	Peak primary current at Peak Output Power and max DC input voltage
IPRMS(NOM)			0.76	A	Nominal primary RMS current at nominal DC input voltage
OUTPUT INDUCTOR OUTPUT PARAMETERS					
KDI_ACTUAL			0.38		Current ripple factor of combined Main and Output2 outputs
Core Type	Kool Mu 125u		Kool Mu 125u		Select core type
Core	Auto		77930(O.D)=27.7		Coupled Inductor - Core size
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			4150.0	mm^3	Volume of core
Powder cores (Sendust and Powdered Iron) Cores					
MUR			125.0		Relative permeability of material
H			43.6	AT/cm	Magnetic field strength
MUR_RATIO			0.37		Percent of permeability as compared to permeability at H = 0 AT/cm
LMAIN_ACTUAL			18.9	uH	Estimated inductance of main output at full load
LMAIN_0bias			50.9	uH	Estimated inductance of main output with 0 DC bias
LOUT2			0.0	uH	Estimated inductance of auxiliary output at full load
BM_IND			2474.7	Gauss	DC component of flux density
BAC_IND			463.9	Gauss	AC component of flux density
Turns					

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

INDUCTOR TURNS MULTIPLIER			3.0		Multiplier factor between main number of turns in transformer and inductor (default value = 3)
NMAIN_INDUCTOR	18		18.0		Main output inductor number of turns
NOUT2_INDUCTOR			0.0		Output 2 inductor number of turns
NOUT4_INDUCTOR			N/A		Bias output inductor number of turns (for bias or control circuit VDD supply)
Ferrite Cores					
LMAIN_ACTUAL			N/A	uH	Estimated inductance of main output
LOUT2			N/A	uH	Estimated inductance of aux output
LG			N/A	mm	Gap length of inductor cores
Target BM			N/A	Gauss	Target maximum flux density
BM_IND			N/A	Gauss	Estimated maximum operating flux density
BAC_IND			N/A	Gauss	AC flux density
Turns					
NMAIN_INDUCTOR			N/A		Main output inductor number of turns
NAUX_INDUCTOR			N/A		Aux output inductor number of turns
N_BIAS			N/A		Aux output inductor number of turns
Wire Parameters					
Total number of layers			1.00		Total number of layers for chosen toroid
IRMS_MAIN			14.2	A	RMS current through main inductor windings
IRMS_AUX			0.0	A	RMS current through aux winding
AWG_MAIN			17.0	AWG	Main inductor winding wire gauge
OD_MAIN			1.2	mm	Main winding wire gauge outer diameter
FILAR_MAIN			2.0		Number of parallel strands for main output
RDC_MAIN			6.0	mohm	Resistance of wire for main inductor winding
AC Resistance Ratio (Main)			2.8		Ratio of total resistance (AC + DC) to the DC resistance (using Dowell curves)
CMA_MAIN			288.5	CMA	Cir mils per amp for main inductor winding
J_MAIN			12.1	A/mm^2	Current density in main inductor winding
AWG_AUX			0.0	AWG	Aux winding wire gauge
OD_MAIN			N/A	mm	Auxiliary winding wire gauge outer diameter
FILAR_AUX			2.0		Number of parallel strands for aux output
RDC_AUX			0.0	mohm	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*	0.0	CMA	!!! Info. Low CMA may cause overheating. Verify acceptable temperature rise
J_AUX			0.0	A/mm^2	Current density in auxiliary winding
Estimated Power Loss					
PCOPPER_MAIN			1.2	W	Copper loss in main inductor winding
PCOPPER_AUX			0.0	W	Copper loss in aux inductor windings
PCORE			0.4	W	Total core loss
PTOTAL_IND			1.6	W	Total losses in output choke
SECONDARY OUTPUT PARAMETERS					
ISFWDRMS			11.91	A	Max. fwd sec. RMS current (at DVNOM)
ISFWD2RMS			0.00	A	Max. fwd sec. RMS current (at DVNOM)
ISCATCHRMS			11.99	A	Max. catch sec. RMS current (at DVNOM)
ISCATCH2RMS			0.00	A	Max. catch sec. RMS current (at DVNOM)
IDAVMAINF			8.96	A	Maximum average current, Main rectifier (single device rating)
IDAVMAINC			7.82	A	Maximum average current, Main rectifier (single device rating)
IDAVOUT2F			0.00	A	Maximum average current, Main rectifier (single device rating)
IDAVOUT2C			0.00	A	Maximum average current, Main rectifier (single device

					rating)
IRMSMAIN			1.56	A	Maximum RMS current, Main output capacitor
IRMSOUT2			0.00	A	Maximum RMS current, Out2 output capacitor
PD_LOSS_MAIN			3.41	W	main diode loss
PD_LOSS_OUT2			0.00	W	output 2 diode loss
	% Derating				
VPIVMAINF	100%		38.4	V	Main Forward Diode peak-inverse voltage (at VDSOP)
VPIVMAINC	100%		29.3	V	Main Catch Diode peak-inverse voltage (at VOVOFF_MAX)
VPIVOUT2F	100%		0.0	V	Output2 Forward Diode peak-inverse voltage (at VDSOP)
VPIVOUT2C	100%		0.0	V	Output2 Catch Diode peak-inverse voltage (at VOVOFF_MAX)
VPIVB	100%		32.0	V	Bias output rectifier peak-inverse voltage (at VDSOP)
Hiper-TFS STANDBY SECTION (FLYBACK STAGE)					
ENTER APPLICATION VARIABLES					
VACMIN	85			V	Minimum AC Input Voltage
VACMAX	265			V	Maximum AC Input Voltage
fL	50			Hz	AC Mains Frequency
VO_SB	12.00			V	Output Voltage (at continuous power)
IO_SB	0.83			A	Power Supply Output Current (corresponding to peak power)
IO_SB_PK	0.83				Peak output current
POUT_SB			9.96	W	Continuous Output Power
POUT_SB_TOTAL			10.28	W	Total Standby power (Includes Bias winding power)
POUT_SB_PK	10.32		9.96	W	Peak Standby Output Power
n	0.80				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	LOW		Low 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			0.465	A	Minimum Current Limit
ILIM_TYP			0.500	A	Typical Current Limit
ILIM_MAX			0.535	A	Maximum Current Limit
R(EN)			NONE	k-ohms	Enable pin resistor
fSmin			124000	Hz	Minimum Device Switching Frequency
I^2fmin			29.70	A^2kHz	I^2f (product of current limit squared and frequency is trimmed for tighter tolerance)
VOR			90	V	Reflected Output Voltage (VOR < 135 V Recommended)
VDS			10	V	Hiper-TFS Standby On State Drain to Source Voltage
VD_SB			0.7	V	Output Winding Diode Forward Voltage Drop
KP			0.90		Ripple to Peak Current Ratio (KP < 6)
KP_TRANSIENT			0.69		Transient Ripple to Peak Current Ratio. Ensure KP_TRANSIENT > 0.25
ENTER BIAS WINDING VARIABLES					
VB			16.00	V	Bias Winding Voltage
IB			20.00	mA	Bias winding Load current
PB			0.32	W	Bias winding power
VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
NB			15.78		Bias Winding Number of Turns

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

VZOV			22.00	V	Over Voltage Protection zener diode voltage.
UVLO VARIABLES					
RLS			3.92	M-Ohms	Line sense resistor (from Main converter section)
V_UV_ACTUAL			100	V	Typical DC start-up voltage
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	EE16		EE16		Enter Transformer Core
AE			0.192	cm^2	Core Effective Cross Sectional Area
LE			3.5	cm	Core Effective Path Length
AL			1140	nH/T^2	Ungapped Core Effective Inductance
BW			8.6	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	3.00		3		Number of Primary Layers
NS_SB			12		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN_SB			115.41	V	Minimum DC Input Voltage
VMAX_SB			374.77	V	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX_SB			0.46		Duty Ratio at full load, minimum primary inductance and minimum input voltage
IAVG			0.12	A	Average Primary Current
IP_SB			0.47	A	Minimum Peak Primary Current
IR_SB			0.47	A	Primary Ripple Current
IRMS_SB			0.21	A	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP_SB			838.23	uH	Typical Primary Inductance. +/- 10% to ensure a minimum primary inductance of 762 uH
LP_TOLERANCE			10	%	Primary inductance tolerance
NP_SB			85		Primary Winding Number of Turns
ALG			116	nH/T^2	Gapped Core Effective Inductance
BM			2747	Gauss	Maximum Operating Flux Density, BM<3000 is recommended
BAC			1373	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1654		Relative Permeability of Ungapped Core
LG			0.19	mm	Gap Length (Lg > 0.1 mm)
BWE			25.8	mm	Effective Bobbin Width
OD			0.30	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.25	mm	Bare conductor diameter
AWG			31	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			81	Cmils	Bare conductor effective area in circular mils
CMA			383	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			3.30	A	Peak Secondary Current
ISRMS			1.69	A	Secondary RMS Current
IRIPPLE			1.47	A	Output Capacitor RMS Ripple Current
CMS			338	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			24	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
VOLTAGE STRESS PARAMETERS					
VDRAIN			584	V	Maximum Drain Voltage Estimate (Assumes 20% zener

					clamp tolerance and an additional 10% temperature tolerance)
PIVS			65	V	Output Rectifier Maximum Peak Inverse Voltage
Other Losses					
PCB trace losses			0.24	W	Estimated PCB trace losses
Forward DC-DC System efficiency					
TOTAL_MOSFET_LOSS			3.37	W	HiperTFS losses
TOTAL_TRF_LOSS			2.45	W	Main transformer losses
Output diode losses			3.41	W	Output diode losses
PLOSS_CIN			0.15	W	Bulk capacitor ESR losses
PTOTAL_IND			1.61	W	Output choke losses
Other Losses			0.24	W	Other losses (includes PCB traces, clamp loss, standby loss, magamp loss etc.)
Efficiency			93.8%		Total system efficiency

9.1 *Special Spreadsheet Considerations for Using Synchronous Rectification*

The HiperTFS-2 spreadsheet assumes use of a conventional Schottky rectifier in the output section of the forward converter as a default condition, with a forward voltage drop of 0.5. In addition, the default spreadsheet assumes that the forward and catch diodes have identical voltage drop. For a supply like the DER-428 that utilizes a synchronous rectifier for the forward diode and a 60 A diode (lower drop than standard 30 A diode), the forward synchronous rectifier and the Schottky catch diode have vastly different voltage drops. Because of this, the value for VDMAIN in the spreadsheet must be adjusted in order to obtain a closer estimate for the primary turns needed to attain the desired nominal duty cycle, as the output rectifier voltage drop is a determining factor in the main transformer turns ratio and nominal operating duty cycle.

Instead of the default estimated V_F value of 0.5 V for the main forward converter, an averaged forward voltage drop can be substituted that weights the contribution of the forward synchronous rectifier and the catch diode as a function of duty cycle. This is simply expressed as:

$$V_{FAV} = (D*V_{FF}) + ((1-D)*V_{FC})$$

V_{FAV} is the averaged voltage drop of the main converter output rectifiers, V_{FF} is the voltage drop of the forward rectifier (in this case, a synchronous rectifier with very low forward voltage drop, ~0.09 V), and V_{FC} is the voltage drop for the catch diode, which in the case of the DER-428 is a 45 V, 60 A device with a drop of ~0.39 V. For a nominal duty cycle D of 50%, the V_{FAV} is:

$$V_{FAV} = (0.5)\ (0.09 + 0.39) = 0.24\ V$$

This value, when entered in the spreadsheet as VDMAIN, results in an NP of 86 turns In the case of the DER-428, one more primary turn is used in the actual transformer as compared to the spreadsheet (87t vs. 86t). This turn was added to compensate for a slightly higher B+ voltage.

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

Plausible starting values for V_{FF} and V_{FC} are 0.1 V and 0.5 V, respectively. Starting with the turns ratio generated from this value, the main turns ratio can then be trimmed in circuit (usually by varying N_P) until the desired nominal operating duty cycle is obtained. The average output rectifier voltage drop can then be adjusted in the spreadsheet such that the number of primary turns in the spreadsheet matches the actual transformer.

10 Heat Sinks

10.1 *Primary Heat Sink*

10.1.1 *Primary Heat Sink Sheet Metal*

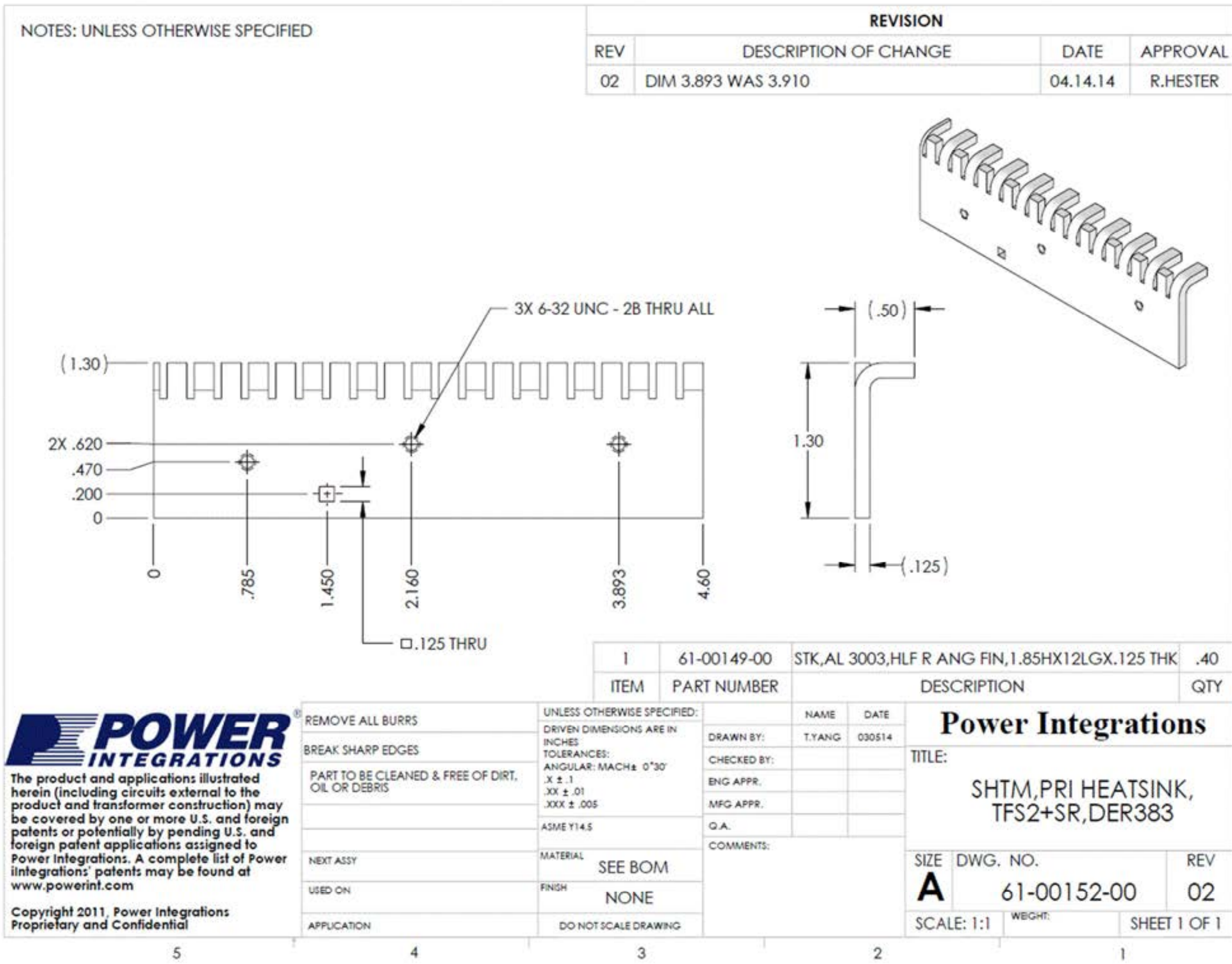


Figure 16 – Primary Heat Sink Sheet Metal Drawing.

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

10.1.2 *Primary Heat Sink with Fasteners*

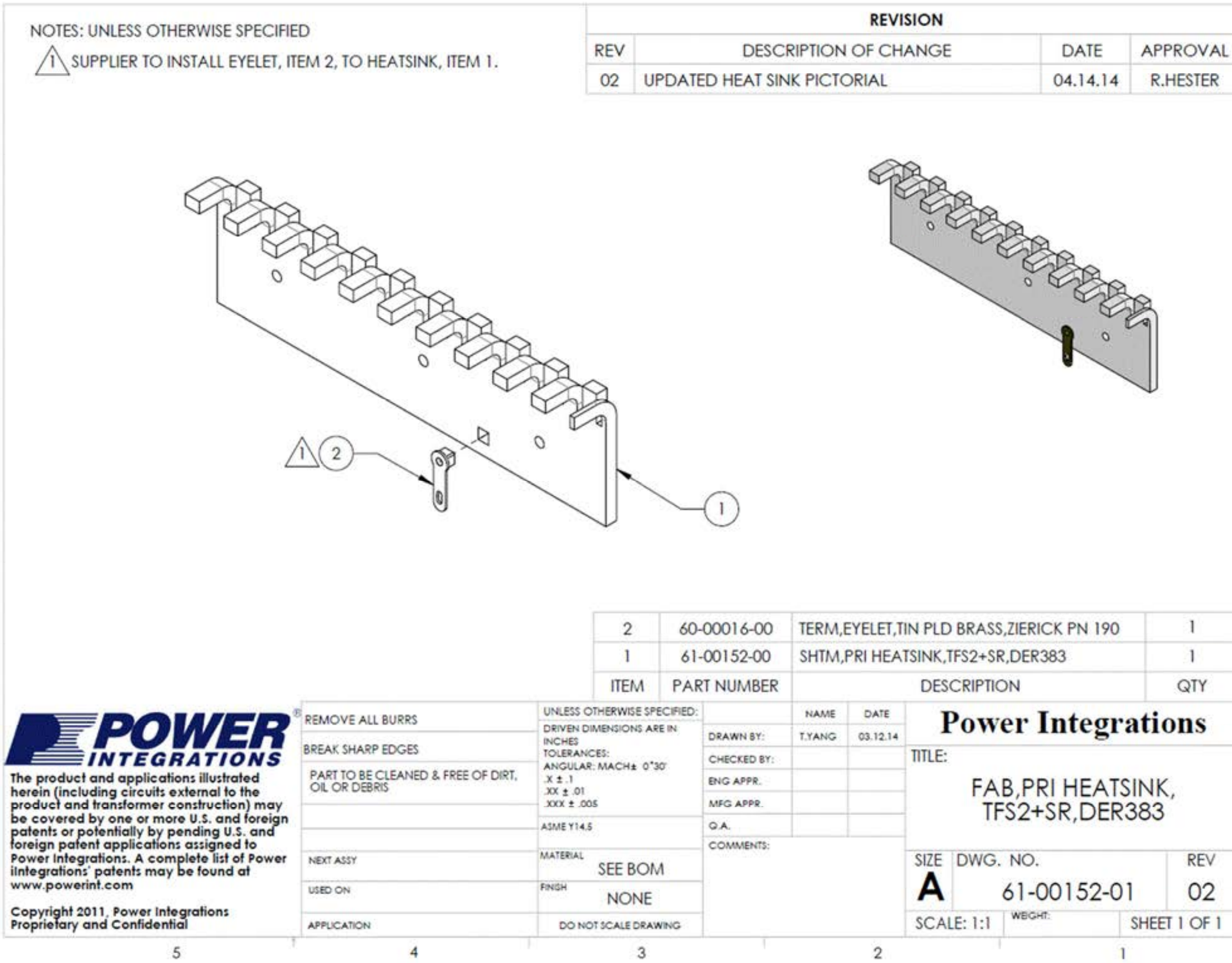


Figure 17 – Finished Primary Heat Sink Drawing with Installed Fasteners.

10.1.3 *Primary Heat Sink Assembly*

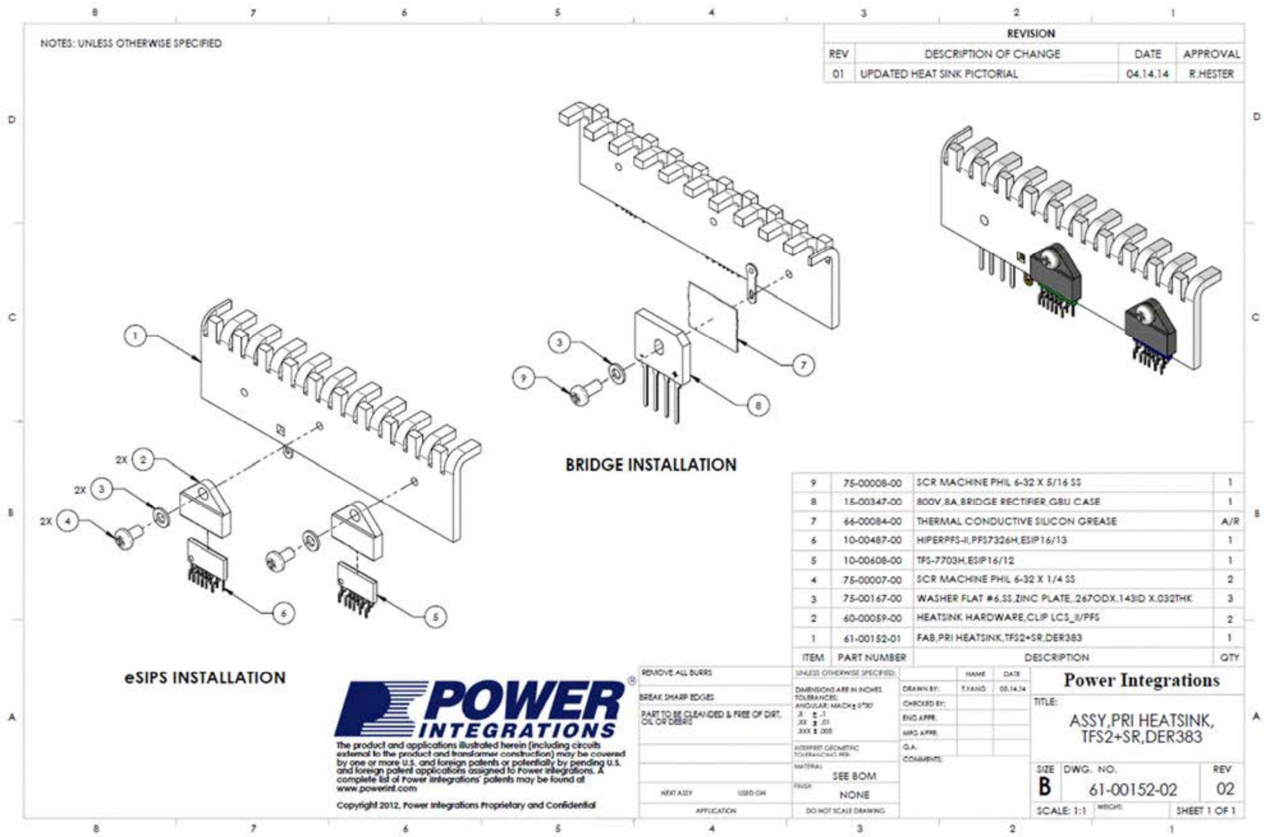


Figure 18 – Primary Heat Sink Assembly.

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

10.2 *Secondary Heat Sink*

10.2.1 *Secondary Heat Sink Sheet Metal*

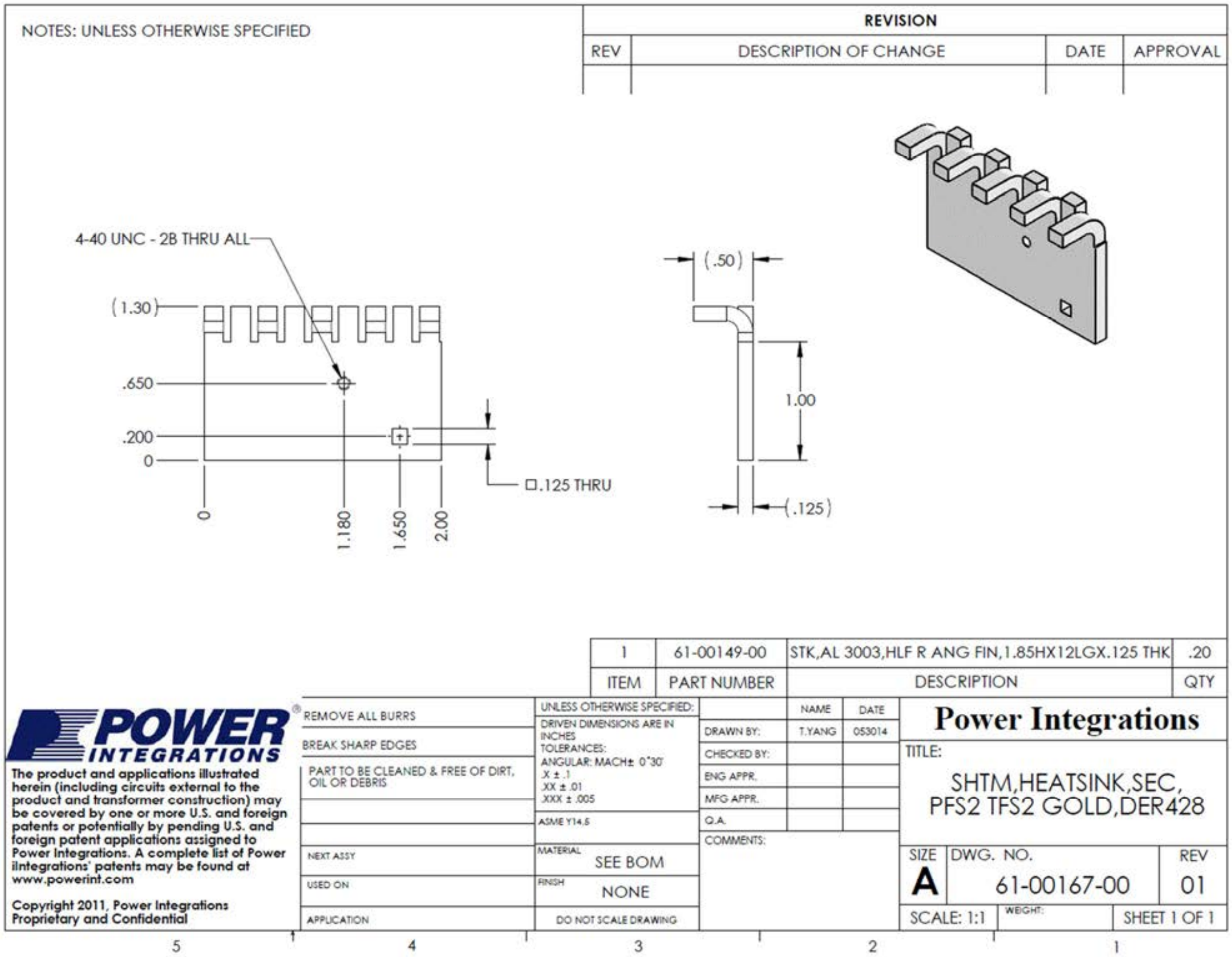


Figure 19 – Secondary Heat Sink Sheet Metal Drawing.

10.2.2 *Secondary Heat Sink with Fasteners*

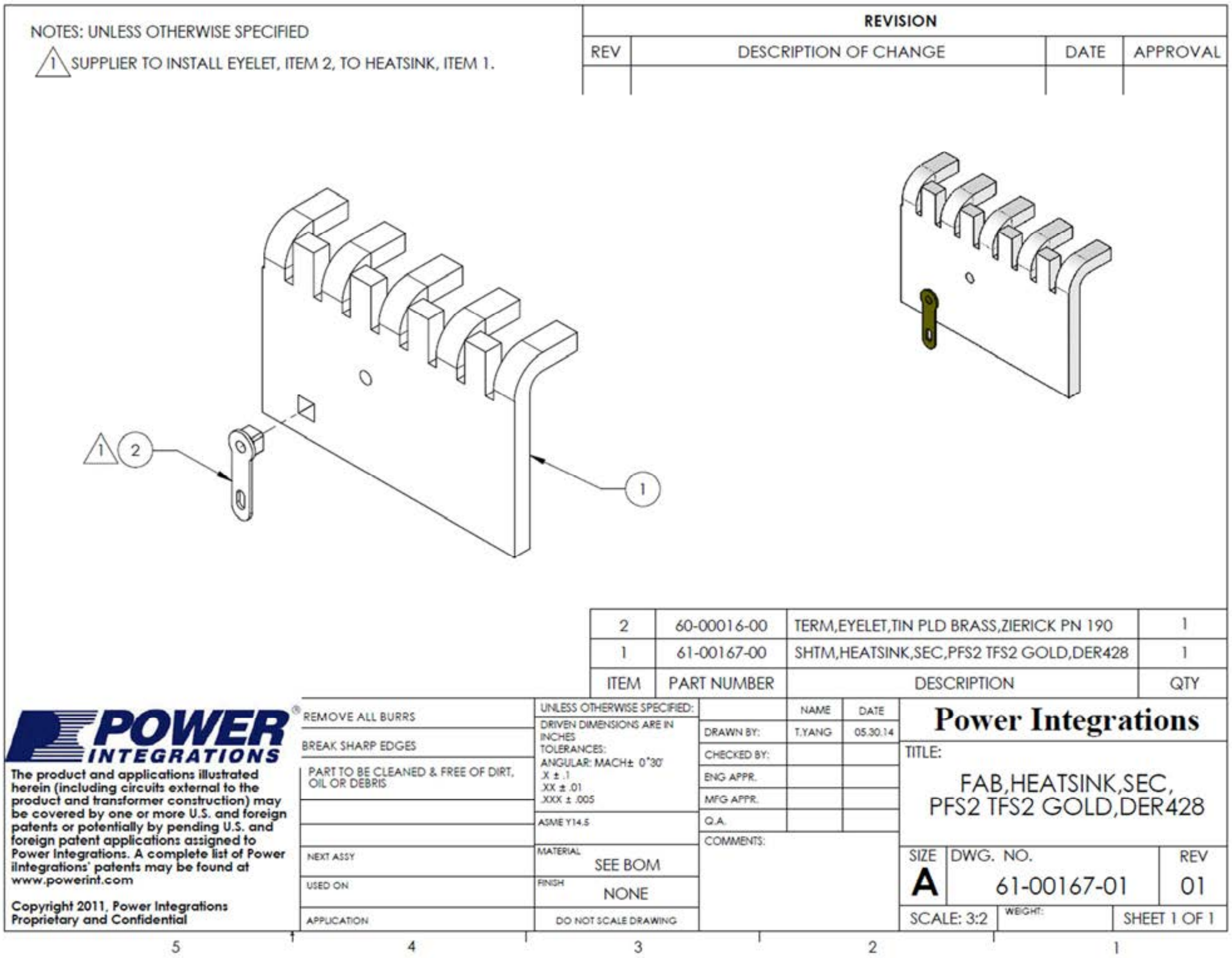


Figure 20 – Finished Secondary Heat Sink with Installed Fasteners.

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

10.2.3 *Secondary Heat Sink Assembly*

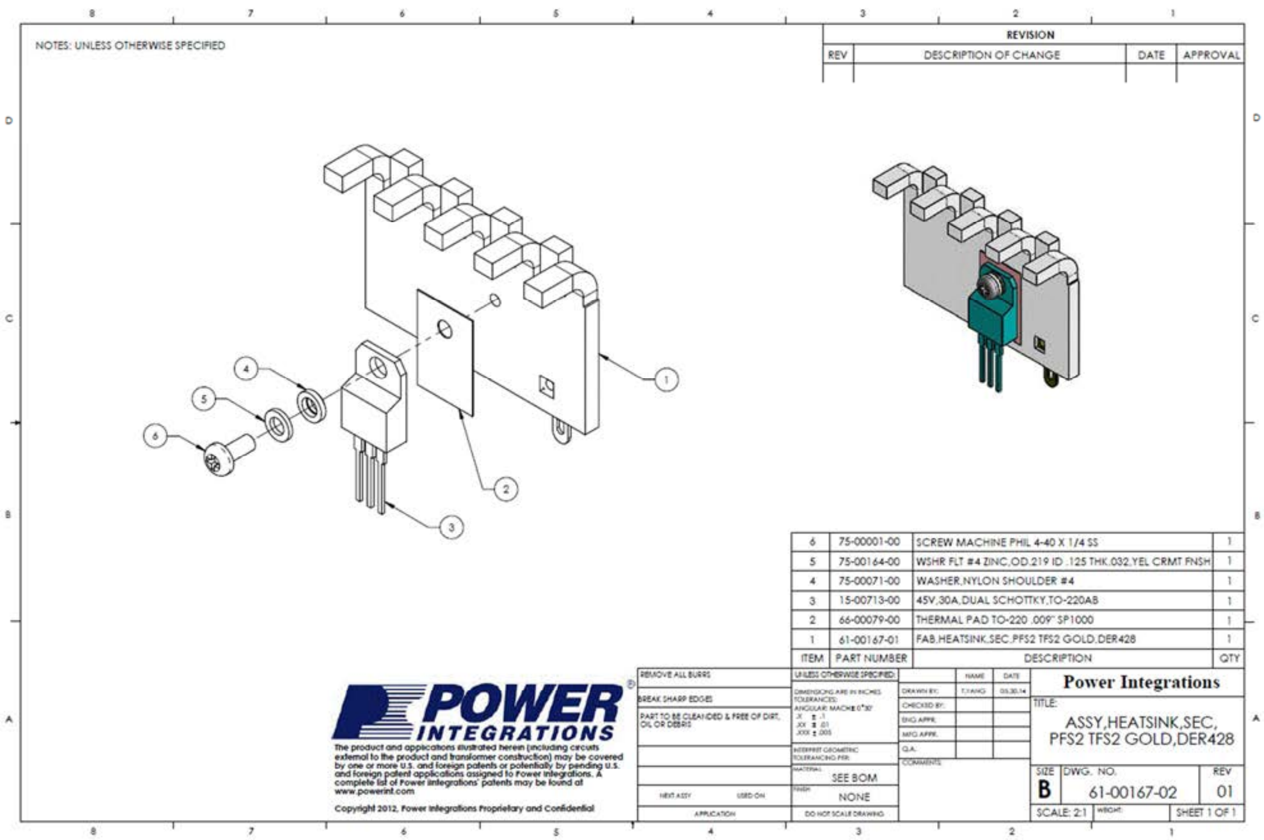


Figure 21 – DER-428 Secondary Heat Sink Assembly.

11 DER-428 Performance Data

All measurements were taken at room temperature. Output voltage measurements were taken at the output connectors.

11.1 *Main Output Stage Efficiency*

To make this measurement, the +12 V main converter stage was supplied by connecting an external 380 VDC source across bulk capacitor C15. The +12 V standby supply was operated with no load.

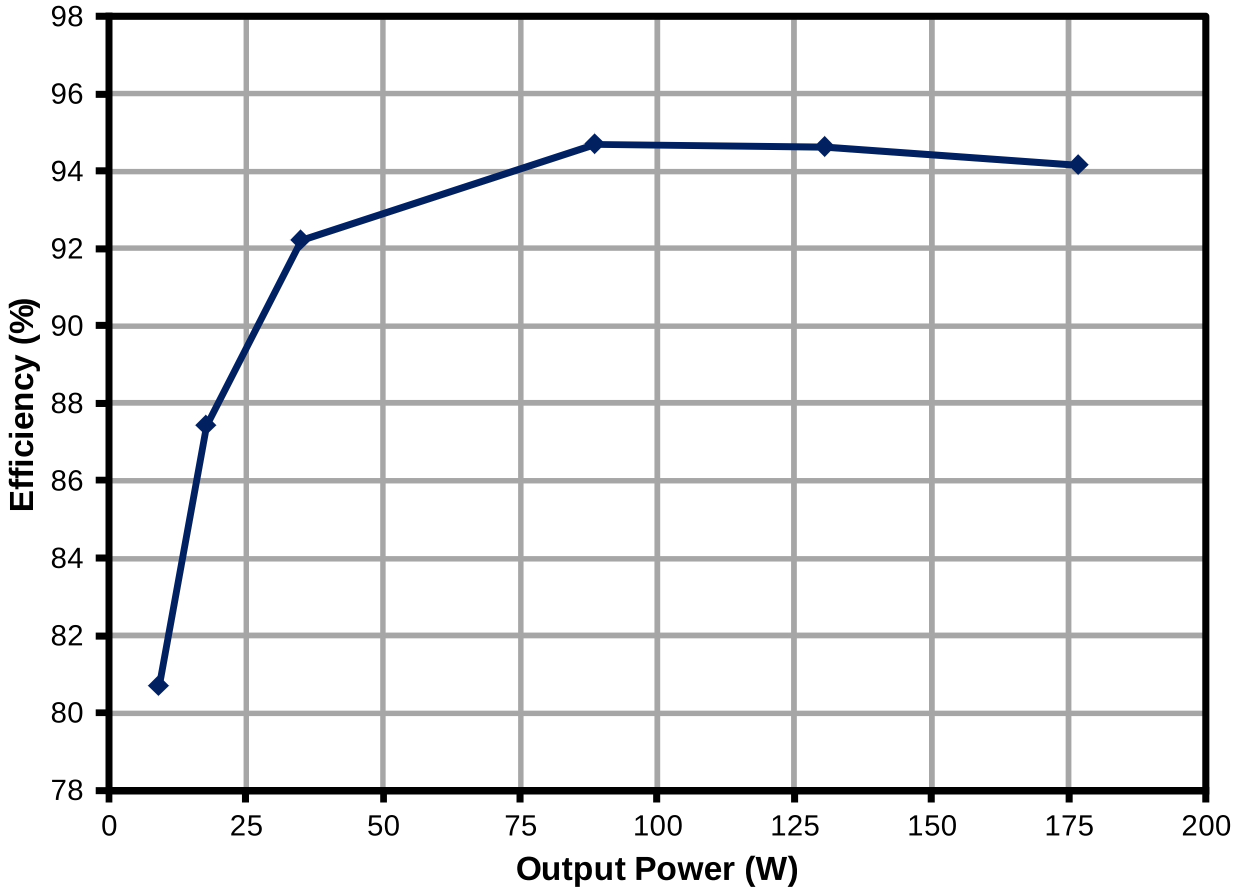


Figure 22 – Main +12 V Forward Stage Efficiency vs. Load, 380 VDC Input.

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

11.2 *Standby Supply Efficiency*

To obtain the data shown below, the standby supply was powered using a 380 V DC source connected across the PFC output bulk capacitor with no AC input. The +12 V main converter and PFC were switched off using the output enable switch.

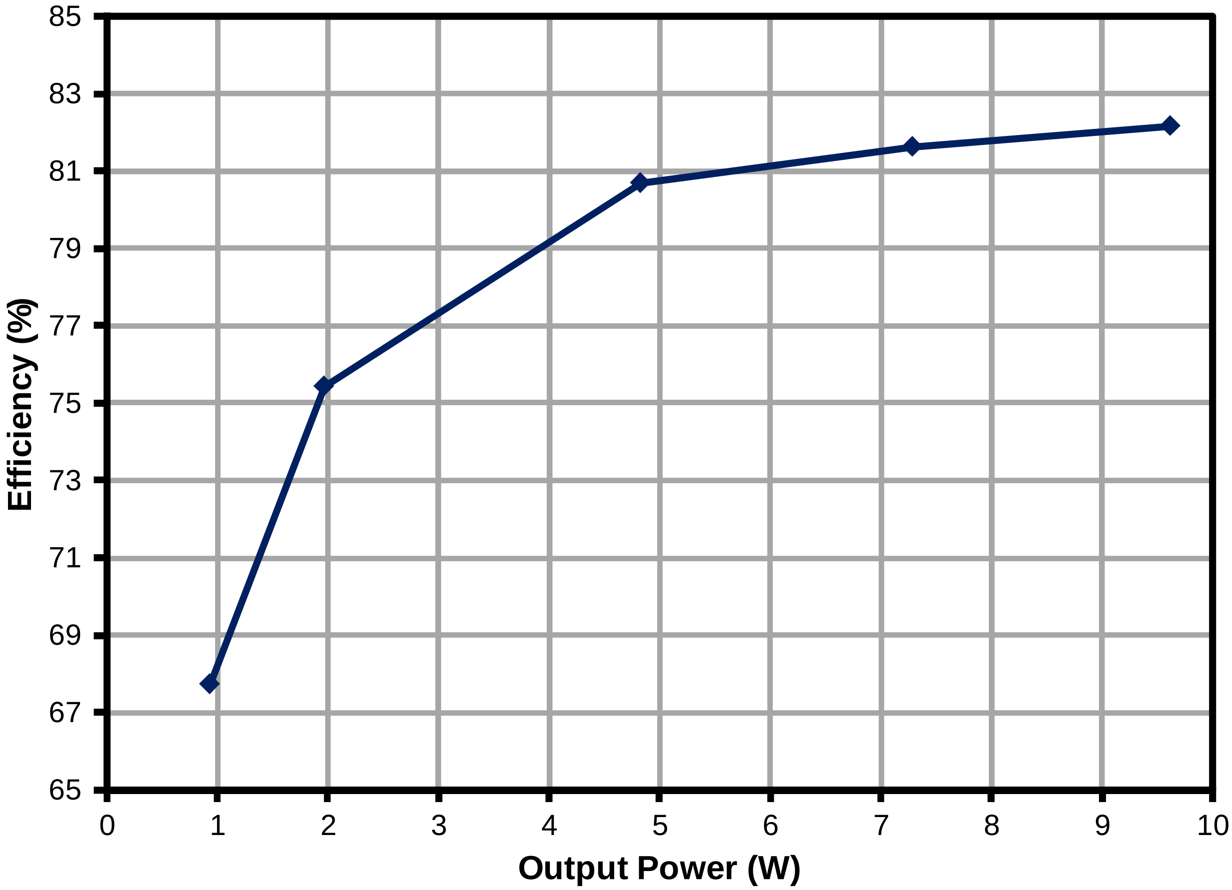


Figure 23 - +12 V Flyback Standby Stage Efficiency vs. Load, 380 VDC Input.

11.3 *Total Efficiency*

Figures below show the total supply efficiency (PFC, main and standby stages). AC input was supplied using a sine wave source. The output was loaded with an electronic load set for constant current.

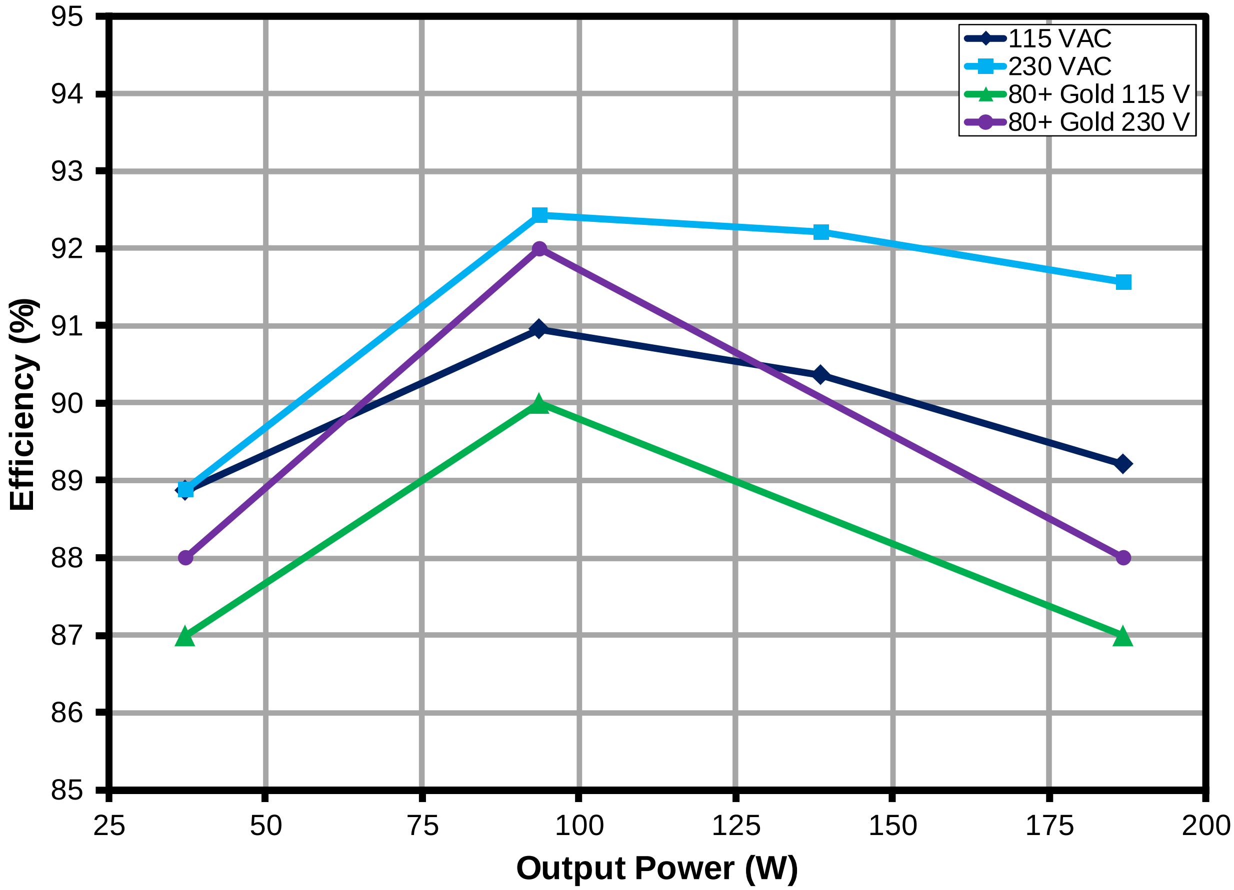


Figure 24 – Total Efficiency vs. Input Voltage, 100% Load.

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

11.4 *Power Factor*

Power factor measurements were made using a sine wave AC source and a Yokogawa WT210 power meter.

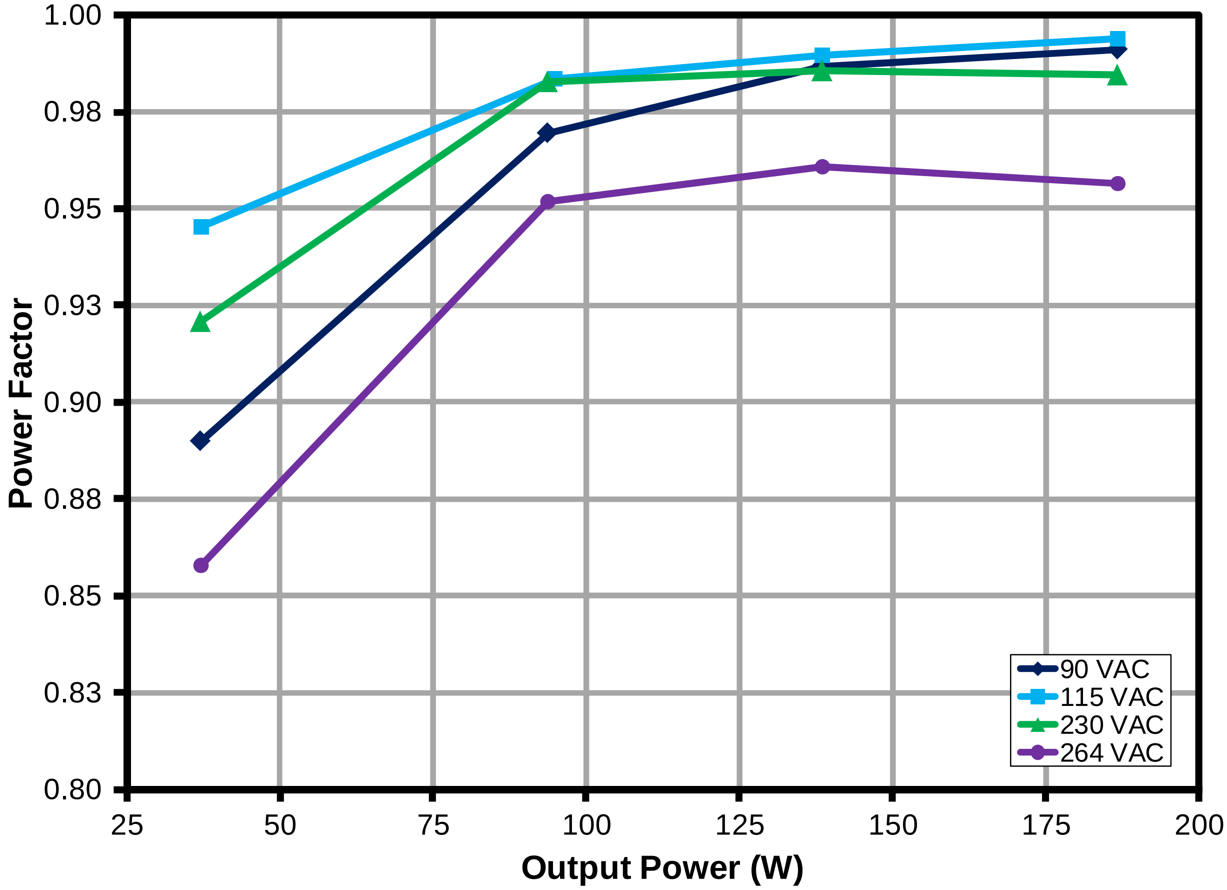


Figure 25 – Power Factor vs. Input Voltage.

11.5 *Input THD vs. Input Voltage*

THD was measured using a Yokogawa WT210 power meter, using a sine wave AC source.

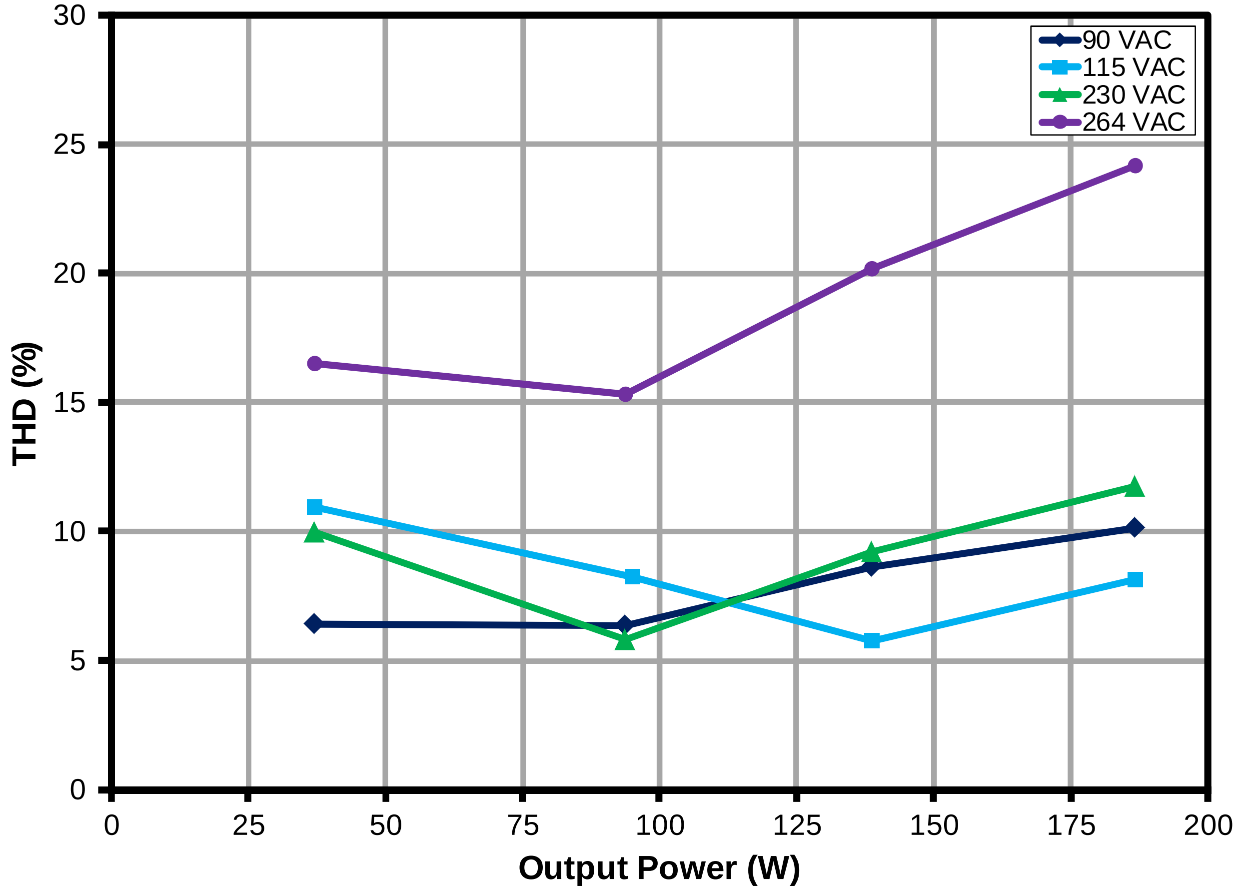


Figure 26 – Input THD vs. Input Voltage.

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

12 Waveforms

12.1 *Input Current, 100% Load*

Figure 27 – Input Current, 90 VAC, 100% Load, 1 A, 5 ms / div.

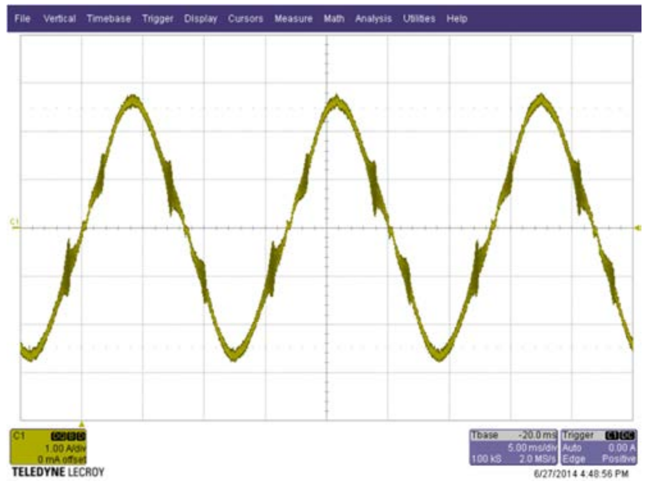


Figure 28 – Input Current, 115 VAC, 100% Load, 1 A, 5 ms / div.

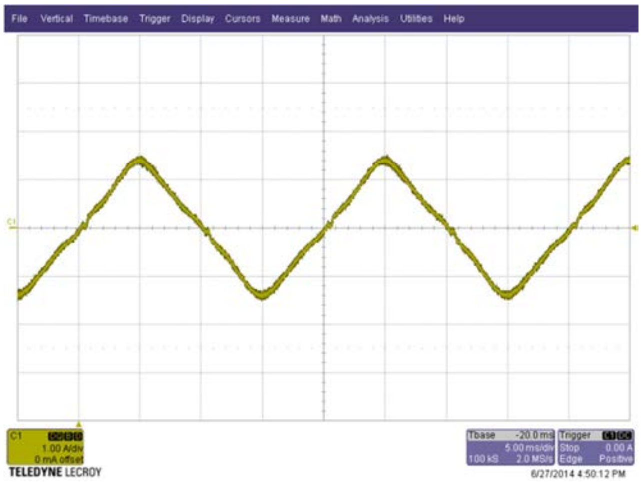


Figure 29 – Input Current, 230 VAC, 100% Load, 1 A, 5 ms / div.

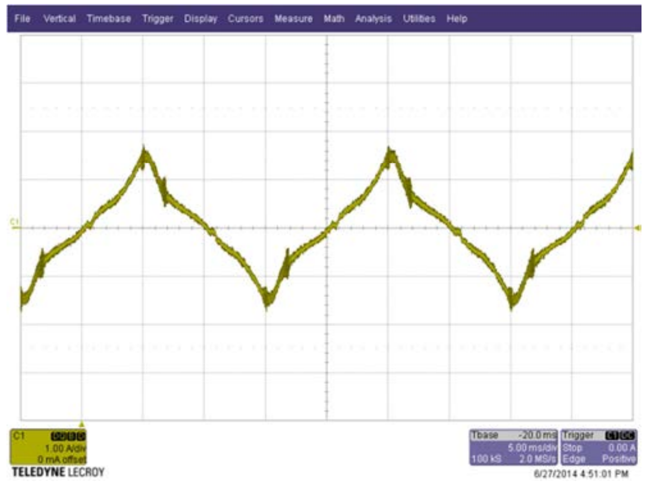


Figure 30 – Input Current, 264 VAC, 100% Load, 1 A, 5 ms / div.

12.2 *Main and Standby Primary Voltage and Current*

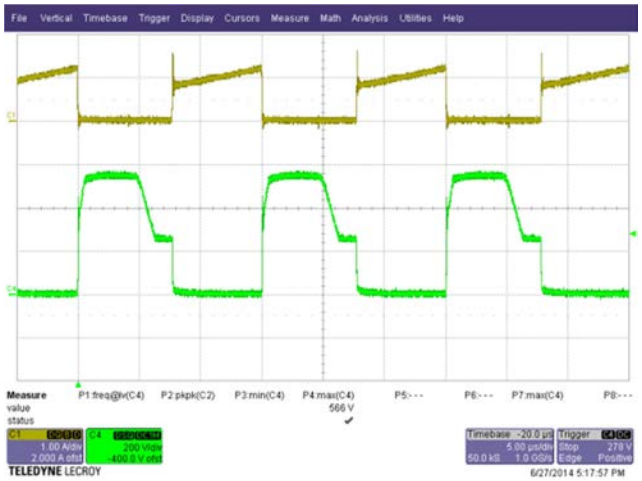


Figure 31 – Main Stage Primary Voltage and Current, 115 VAC (PFC On), 100% Load.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 1 A, 5 µs / div.

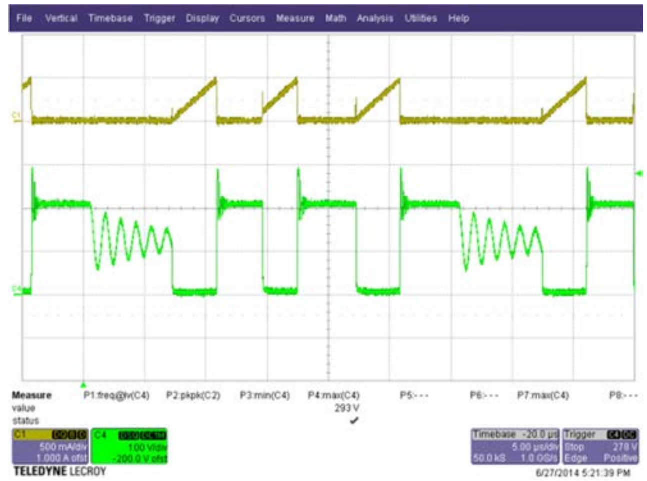


Figure 32 – Standby Stage Primary Voltage and Current, 90 VAC Input (PFC Off), 100% Load.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 0.5 A, 5 µs / div.

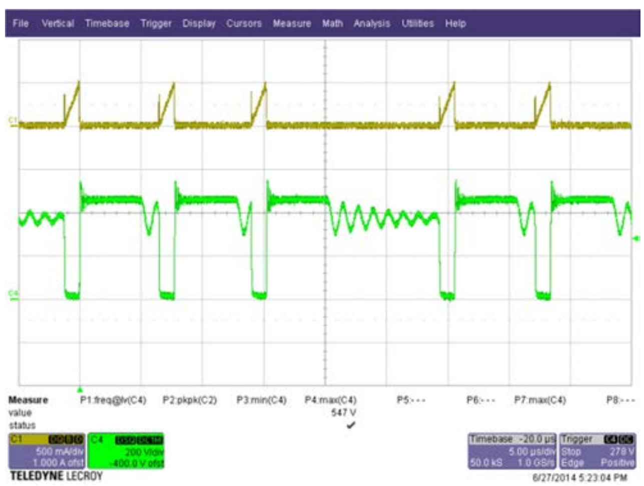


Figure 33 – Standby Stage Primary Voltage and Current, 264 VAC Input (PFC Off), 100% Load.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 0.5 A, 5 µs / div.

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

12.3 *Output Rectifier Voltage Stress Waveforms*

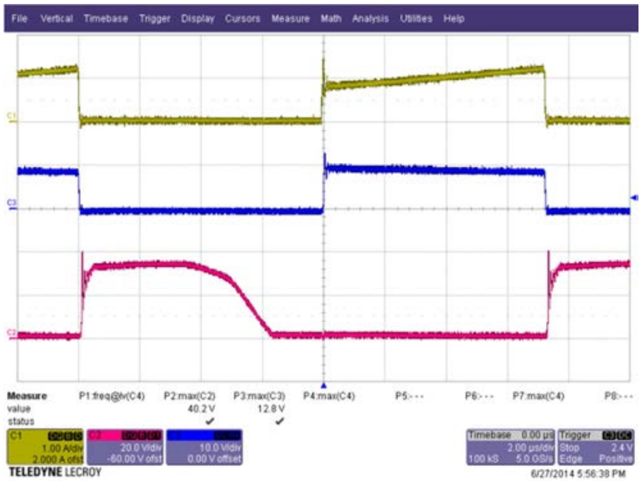


Figure 34 – +12 V Output Synchronous Rectifier (Q2), 100% Load, 115 VAC Input.
Upper: Main Converter Primary Current, 1 A / div.
Middle: Synchronous Rectifier V_{GS}, 10 V / div.
Lower: Synchronous Rectifier V_{DS}, 20 V, 2 µs / div.

Figure 35 – +12 V Output Catch Diode (D8) Reverse Voltage, 100% Load, 115 VAC Input. 20 V, 2 µs / div.

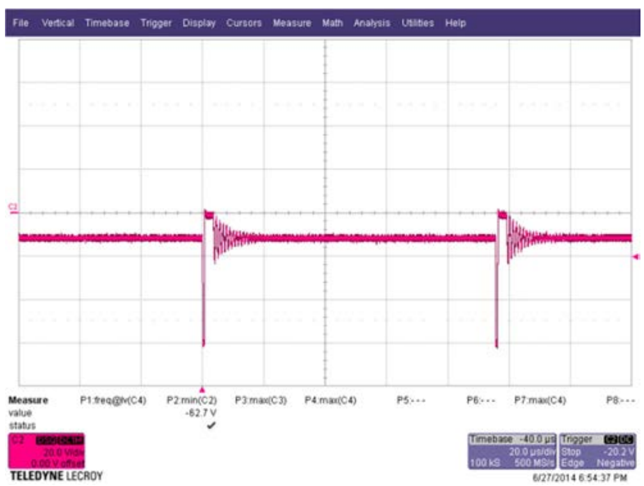


Figure 36 – +12 V Standby Output Rectifier (D10) Reverse Voltage, 100% Load, 230 VAC Input, Main / PFC Disabled. 20 V, 20 µs / div.

12.4 *PFC Inductor + Switch Voltage and Current, 100% Load*

Since the PFC in this power supply utilizes the internal output diode of the HiperPFS-2, the measured drain current cannot be separated from the PFC inductor current.

Figure 37 – PFC Stage 115 VAC 100% Load
Green: AC V_{IN}, 50 V / div.
Yellow: Inductor Current, 2 A / div.
Red: V_{DS}, 200 V / div.; 1 ms / div.
Bottom Zoom in on Top of Sine Wave.
Green: AC V_{IN}, 50 V / div.
Yellow: Inductor Current, 2 A / div.
Red: V_{DS}, 200 V, 20 µs / div.

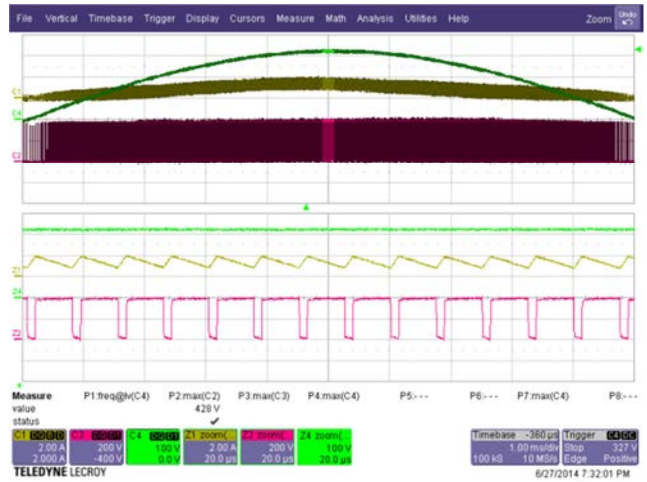


Figure 38 – PFC Stage 230 VAC 100% Load
Green: AC V_{IN}, 100 V / div.
Yellow: Inductor Current, 2 A / div.
Red: V_{DS}, 200 V / div.; 1 ms / div.
Bottom Zoom in on Top of Sine Wave.
Green: AC V_{IN}, 100 V / div.
Yellow: Inductor Current, 2 A / div.
Red: V_{DS}, 200 V, 20 µs / div.

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

12.5 *AC Input Current and PFC Output Voltage During Start-up*

Figure 39 – AC I_{IN} vs. PFC V_{OUT} at Start-up, 100% Load, 115 VAC.
Upper: PFC V_{OUT}, 100 V / div.
Lower: AC I_{IN}, 5 A, 50 ms / div.

Figure 40 – AC I_{IN} vs. PFC V_{OUT} at Start-up, 100% Load, 230 VAC.
Upper: PFC V_{OUT}, 200 V / div.
Lower: AC I_{IN}, 5 A, 50 ms / div.

12.6 *Output Voltage Start-Up Waveforms*

Figure 41 – +12 V Main Start-up. 115 VAC, 100% Load, 2 V, 500 µs / div.

Figure 42 – +12 V Main Start-up. 115 VAC, No-Load, 2 V, 500 µs / div.

Figure 43 – 12 V Standby Start-up. 230 VAC, 100% Load, 2 V, 5 ms / div.

Figure 44 **–** +12 V Standby Start-up. 230 VAC, No-Load, 2 V, 5 ms / div.

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

12.7 ***+12 V Main Output Hold-up***

Figure 45 – 12 V Main Hold-up Time, 100% Load, 115 VAC Input.
Upper: 12 V Main V_{OUT}, 2 V / div.
Middle: AC I_{IN}, 2 A / div.
Bottom: B+ Voltage, 200 V / 5 ms / div.
Hold-up Time: 23.9 ms.

12.8 *Output Ripple Measurements*

12.8.1 *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 / 50 V aluminum electrolytic capacitor. The aluminum-electrolytic capacitor is polarized, so always maintain proper polarity across DC outputs.

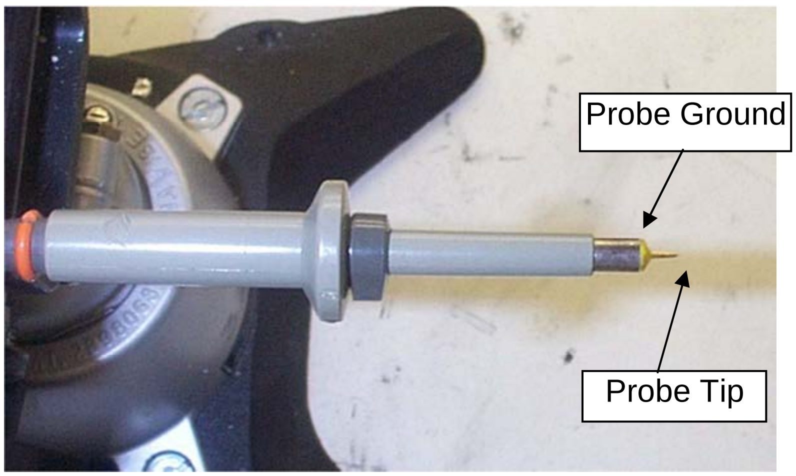


Figure 46 – Oscilloscope Probe Prepared for Ripple Measurement (End Cap and Ground Lead Removed).

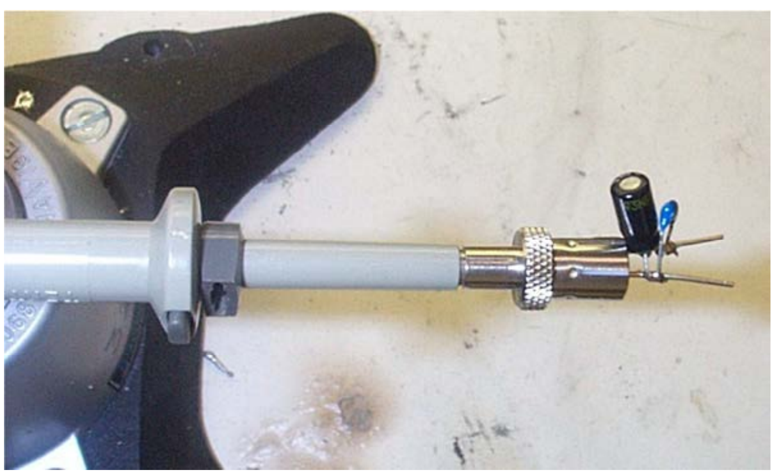


Figure 47 – Oscilloscope Probe with Probe Master 4987BA BNC Adapter (Modified with Wires for Probe Ground for Ripple measurement and Two Parallel Decoupling Capacitors Added).

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

12.8.2 *Ripple Measurements*

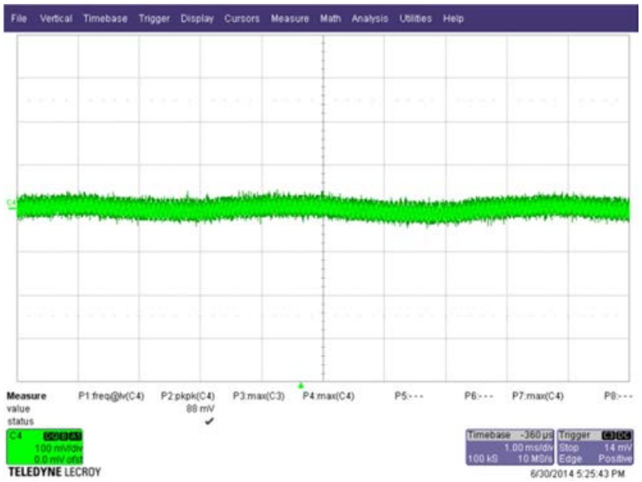


Figure 48 – 12 V Main Output Ripple, 100% Load, 115 VAC Input. 100 mV, 1 ms / div.

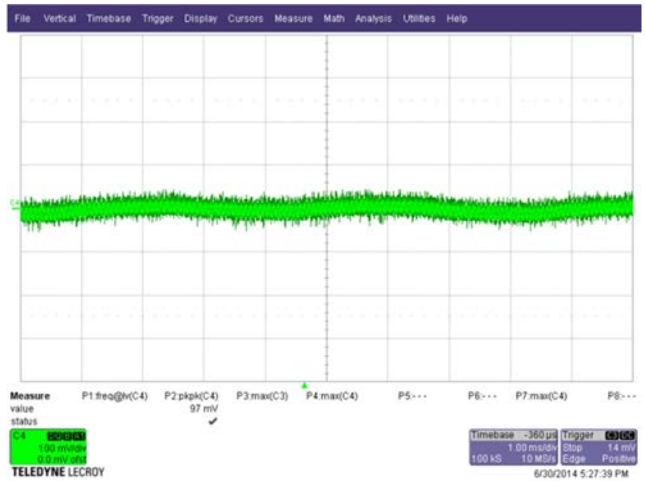


Figure 49 – 12 V Standby Output Ripple, 100% Load, 115 VAC Input, Main Output Enabled. 100 mV, 1 ms / div.

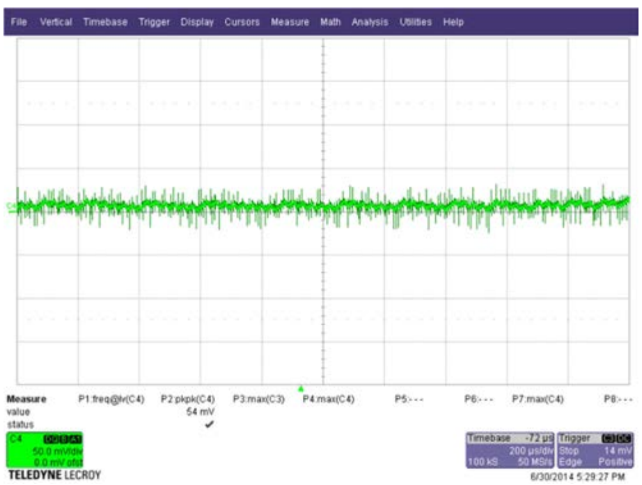


Figure 50 – 12 V Standby Output Ripple, 100% Load, 115 VAC Input, Main Output / PFC Disabled. 50 mV, 200 µs / div.

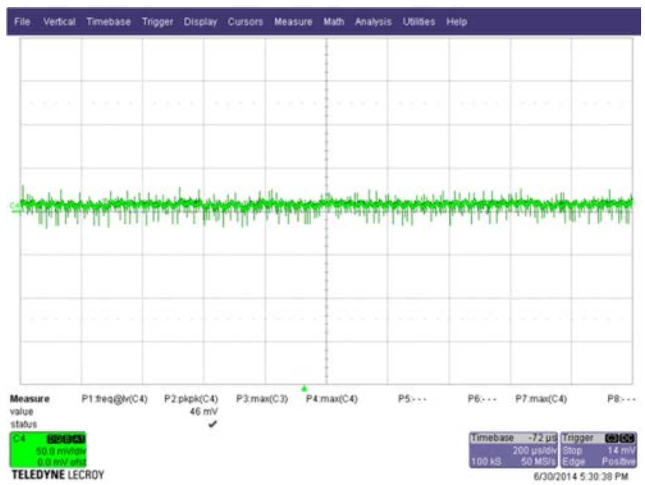


Figure 51 – 12 V Standby Output Ripple, 100% Load, 230 VAC Input, Main Output / PFC Disabled. 50 mV, 200 µs / div.

12.9 ***Main and Standby Output Transient Response***

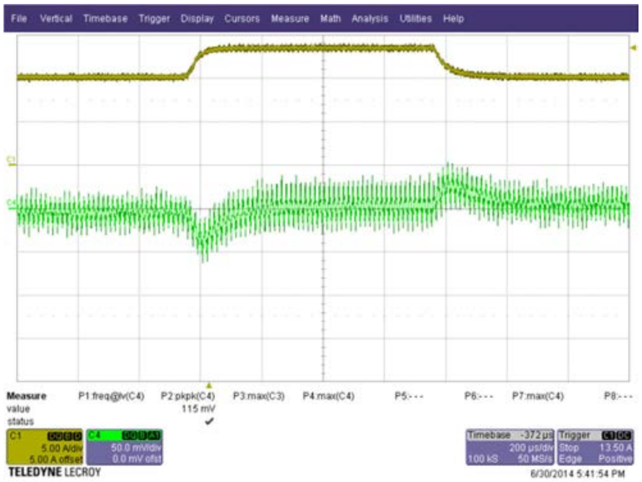


Figure 52 – +12 V Main Output Transient Response, 75%-100%-75% Load Step, 115 VAC Input.
Upper: 12 V I_{OUT}, 5 A / div.
Lower: +12 V Voltage, 50 mV, 200 µs / div.

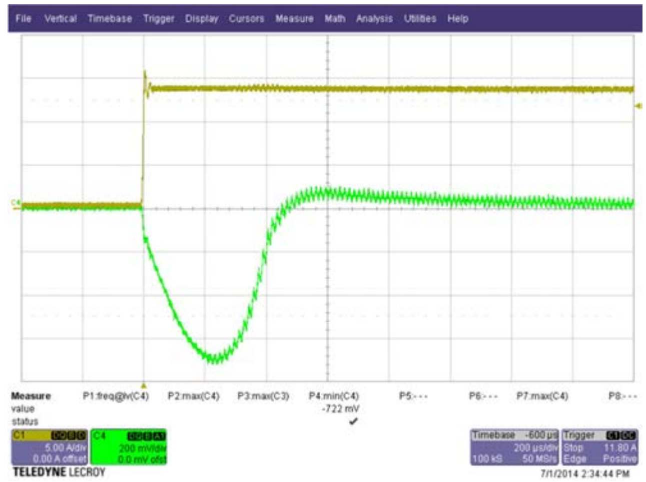


Figure 53 – +12 V Main Output Transient Response, 3%-100% Load Step, 115 VAC Input.
Upper: +12 V I_{OUT}, 5 A/div.
Lower: +12 V Output, 200 mV, 200 µs / div.

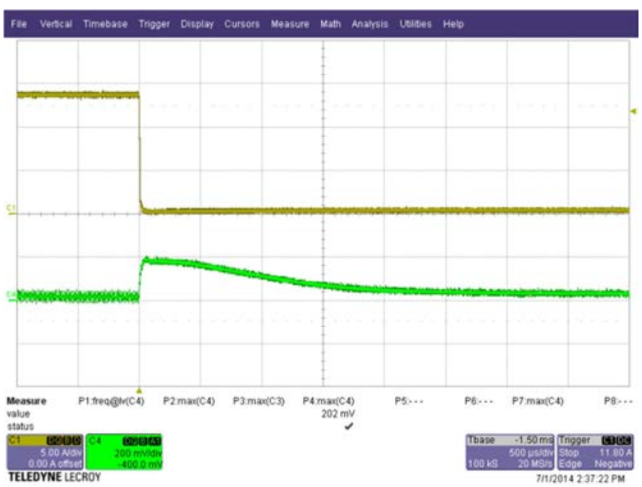


Figure 54 – +12 V Main Output Transient Response, 100%-3% Load Step, 115 VAC Input.
Upper: +12 V I_{OUT}, 5 A / div.
Lower: +12 V Output, 200 mV, 500 µs / div.

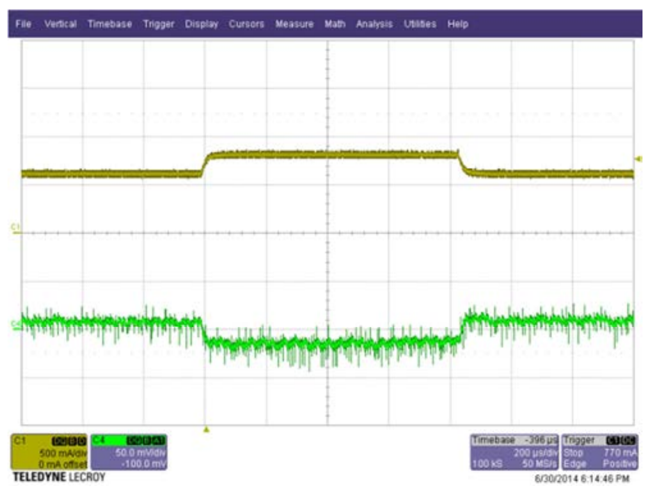


Figure 55 – +12 V Standby Output Transient Response, 75%-100%-75% Load Step, 115 VAC Input, Main Output and PFC Disabled.
Upper: +12 V Standby I_{OUT}, 0.5 A / div.
Lower: +12 V Standby Voltage, 50 mV, 200 µs / div.

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

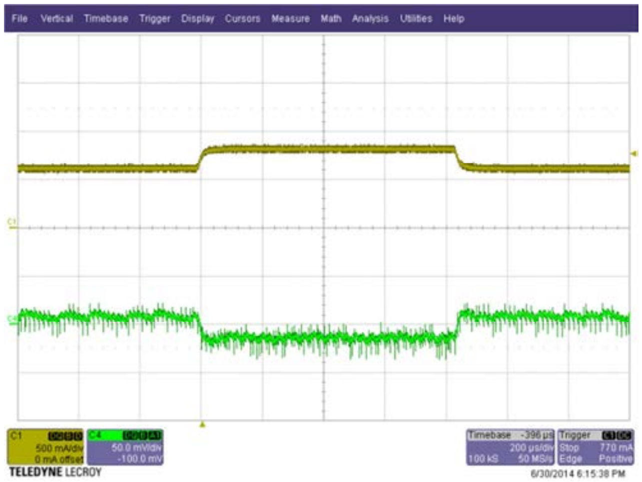


Figure 56 – +12 V Standby Output Transient Response, 75%-100%-75% Load Step, 230 VAC Input, Main Output and PFC Enabled.
Upper: +12 V Standby I_{OUT}, 0.5 A / div.
Lower: +12 V Standby Voltage, 50 mV, 200 µs / div.

13 Thermal Profile

The DER-428 supply was operated at room temperature, maximum load with no forced airflow (no fan) for thermal measurements. An actual design with case and fan would result in lower component operating temperatures and allow smaller heat sink size.

		Temperature (°C) 100% Load	
Component		**115 VAC**	**230 VAC**
Ambient Temperature		25	26
Input Bridge	BR1	92.5	70
HiperPFS-2 IC	U2	85.5	71.1
PFC Inductor	L3	69.5	49
HiperTFS-2 IC	U3	86.3	75.3
Main Transformer	T1	91.8	90.6
Main Output Choke	L4	76.4	84
Main Synchronous Rectifier	Q2	86.6	88
Main Catch Diode	D8	84.1	83.8
Standby Transformer	T2	32.5	35.6

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

13.1 *Thermal Pictures, 115 VAC, 60 Hz, 100% Load, Room Temperature, No Cooling Fan*

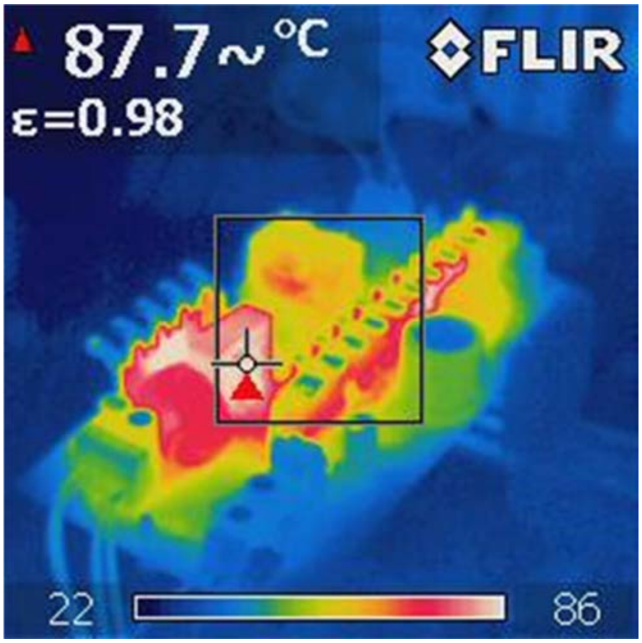


Figure 57 – DER-428 Thermal Picture, Oblique View from Output End of Board, 115 VAC, 60 Hz, 100% Load, Room Temperature, No Cooling Fan.

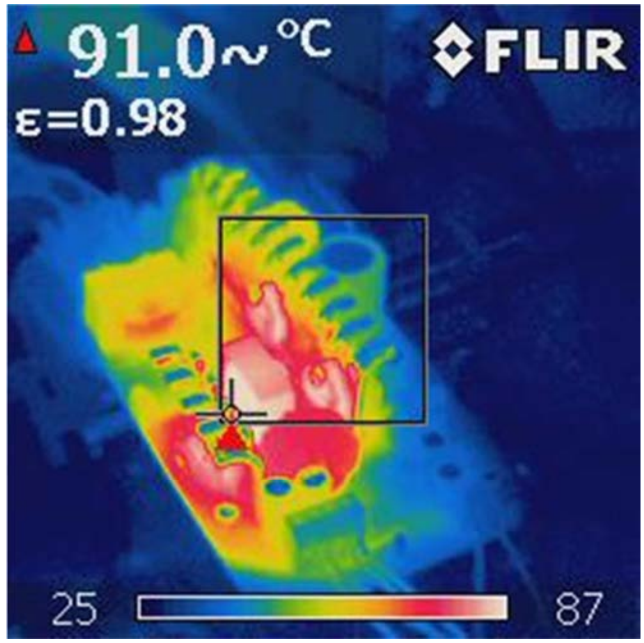


Figure 58 – DER-428 Thermal Picture, 2nd Oblique View from Output End of Board, 115 VAC, 60 Hz, 100% Load, Room Temperature, No Cooling Fan.

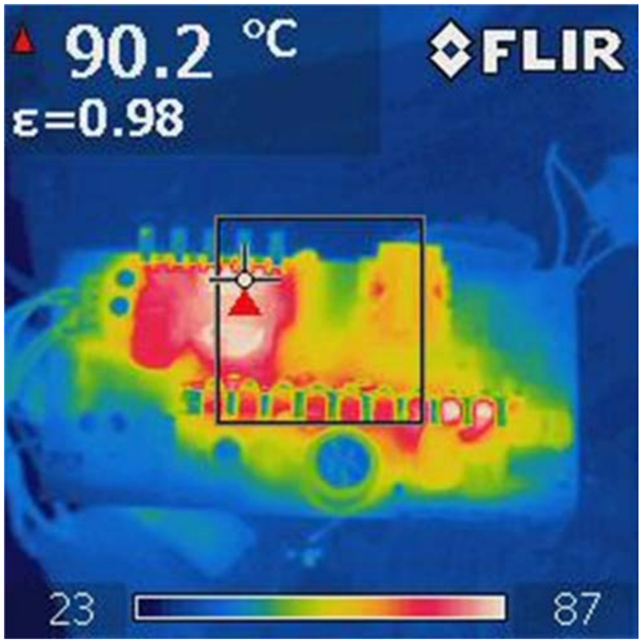


Figure 59 – DER-428 Thermal Picture, Top View , 115 VAC, 60 Hz, 100% Load, Room Temperature, No Cooling Fan.

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

13.2 *Thermal Pictures, 230 VAC, 50 Hz, 100% Load, Room Temperature, No Cooling Fan*

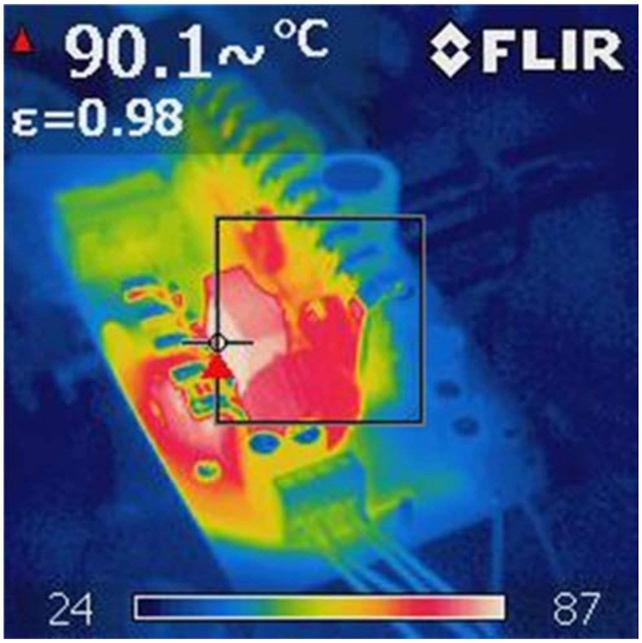


Figure 60 – DER-428 Thermal Picture, Oblique View from Output End of Board, 230 VAC, 50 Hz, 100% Load, Room Temperature, No Cooling Fan.

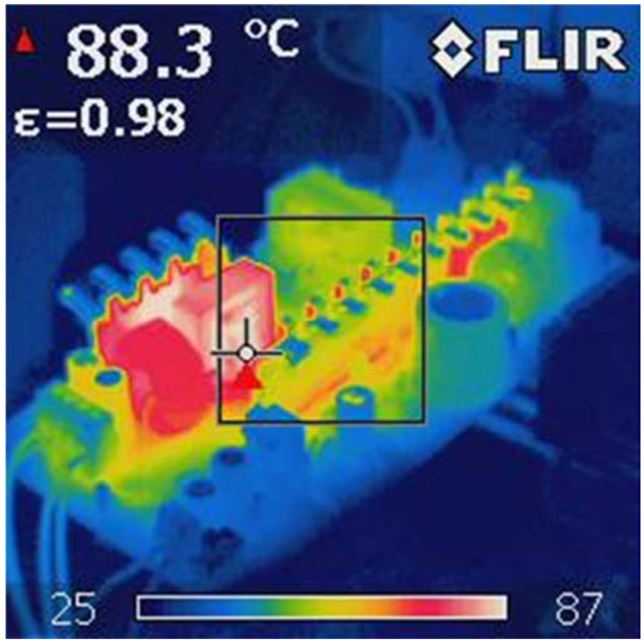


Figure 61 – DER-428 Thermal Picture, 2nd Oblique View from Output End of Board, 230 VAC, 50 Hz, 100% Load, Room Temperature, No Cooling Fan.

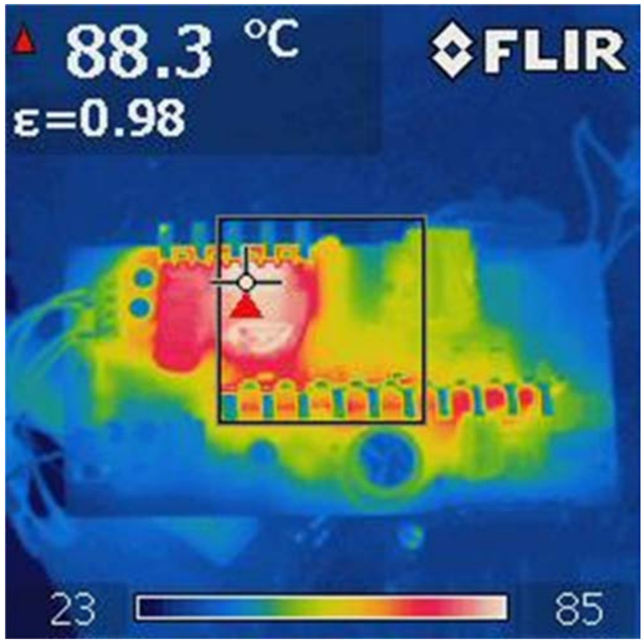


Figure 62 – DER-428 Thermal Picture, Top View, 230 VAC, 60 Hz, 100% Load, Room Temperature, No Cooling Fan.

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

14 Main Output Gain-Phase

The +12 V Main converter control loop gain-phase was measured at 115 VAC input, maximum load.

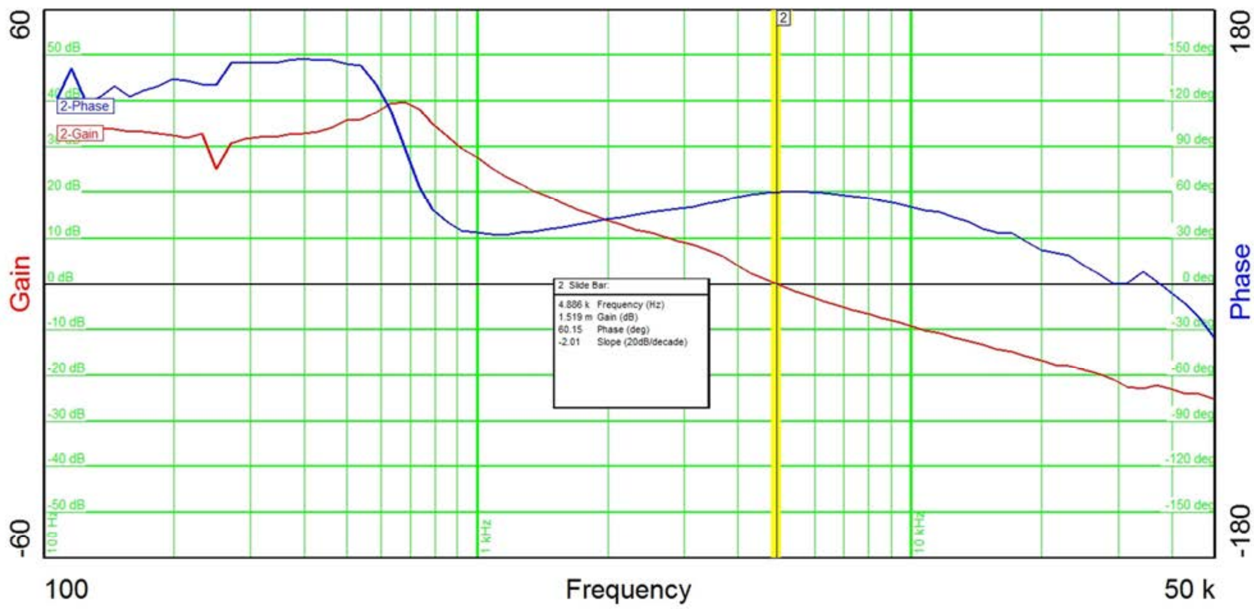


Figure 63 – +12 V Main Converter Gain-Phase, 100% Load. Crossover Frequency – 4.9 kHz, Phase Margin – 60°.

15 Conducted EMI

Conducted EMI tests were performed using the setup shown in the picture below, with the power supply and its resistive load box placed on a large copper ground plane.

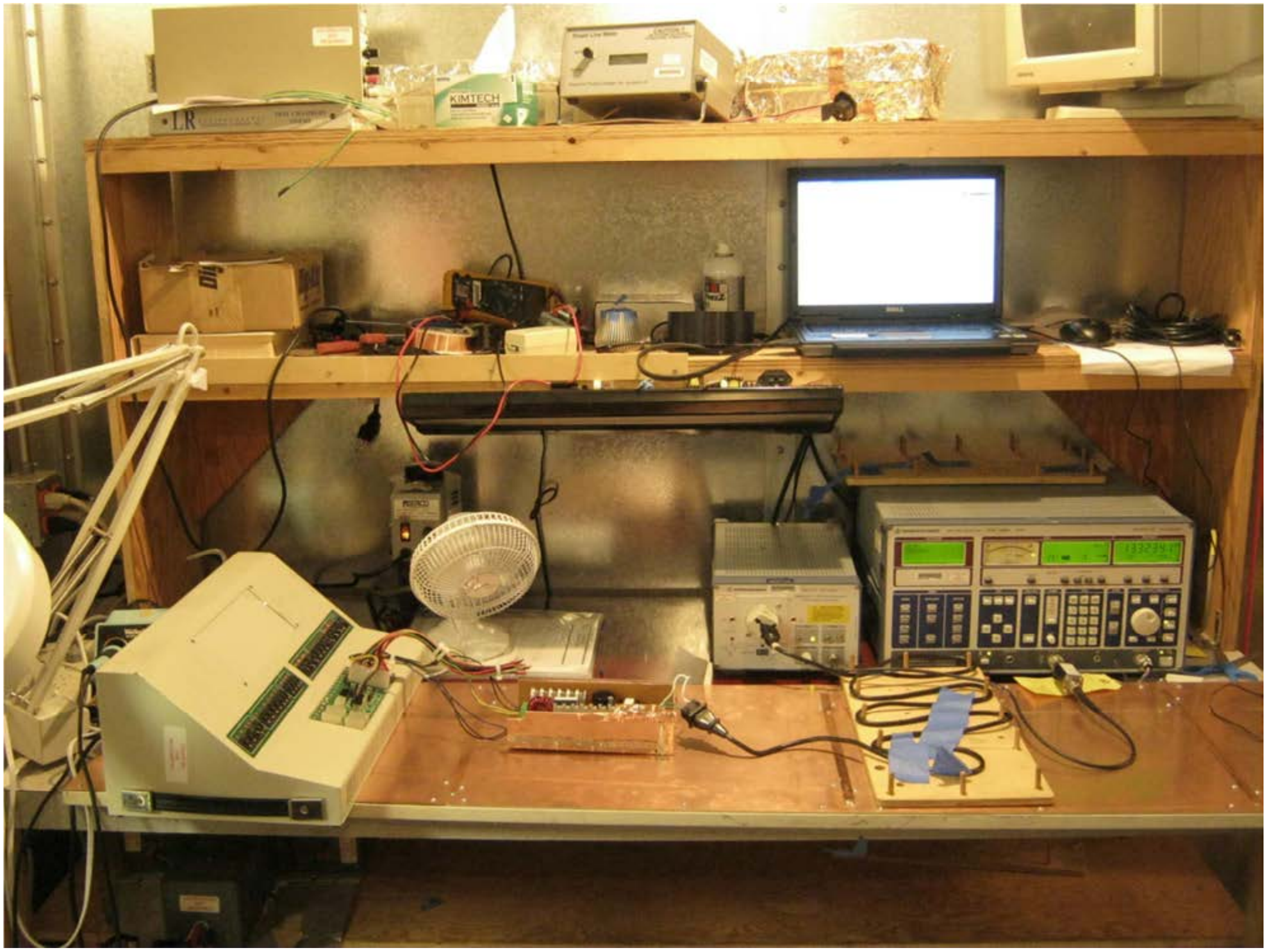


Figure 64 – EMI Test Set-up.

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

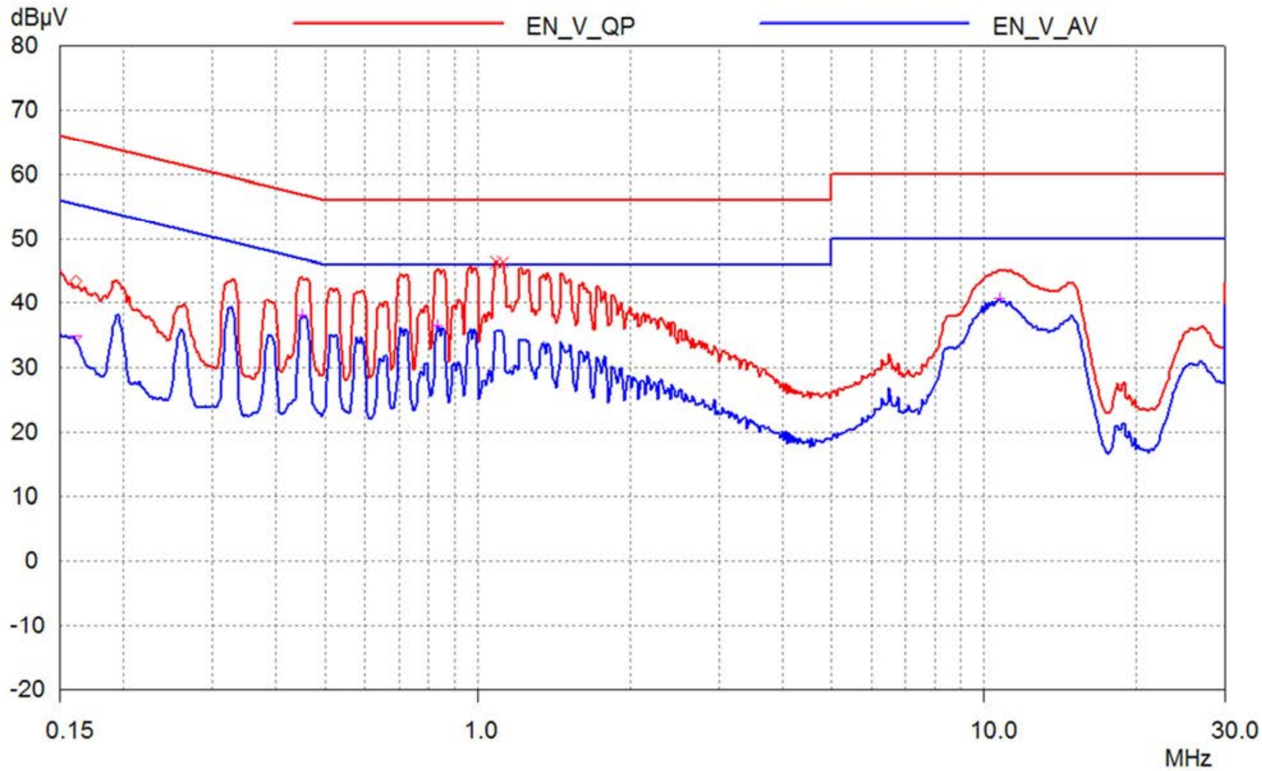


Figure 65 – Conducted EMI, 115 VAC, 100% Load.

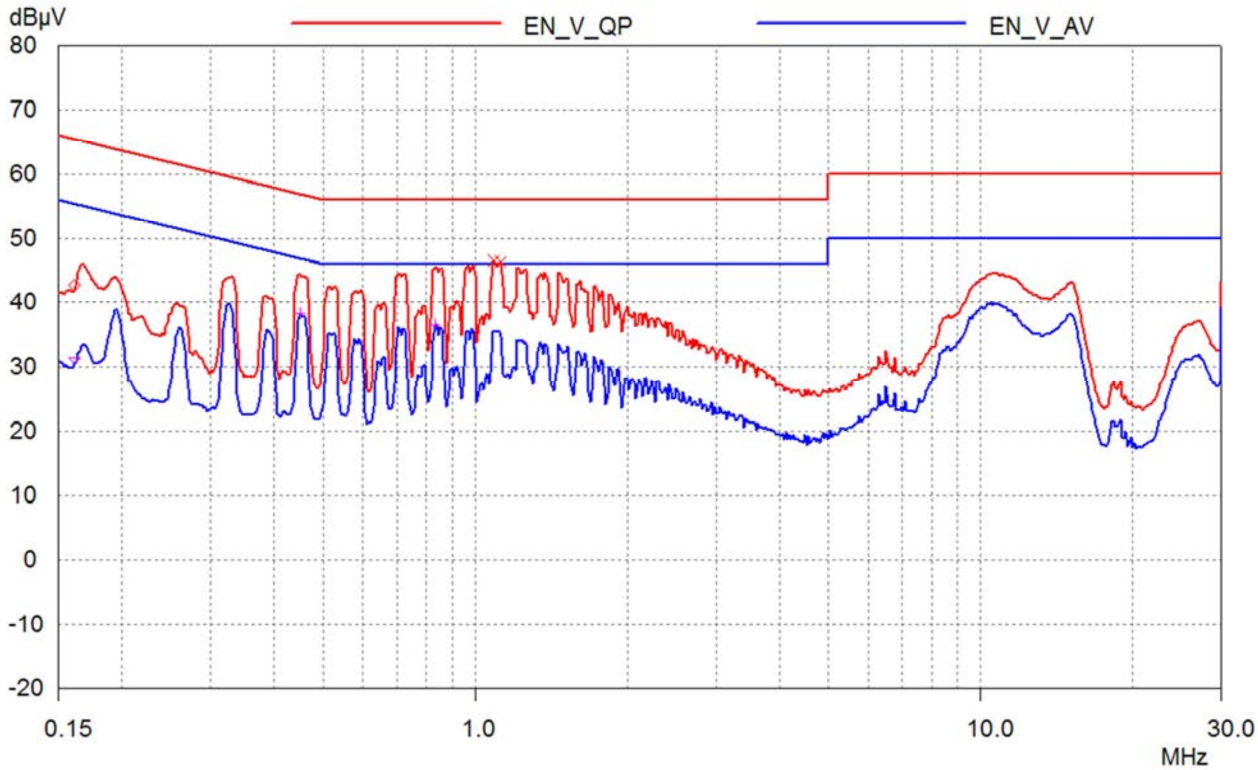


Figure 66 – Conducted EMI, 230 VAC, 100% Load.

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

16 Appendix A – Hold-up Time with 120 μF Bulk Capacitor (C15)

To reduce costs, it may be desirable to use a reduced value bulk capacitor (C15). Figure 69 shows the impact on hold-up time of reducing the C15 value from 150 μF to 120 μF. This appendix only shows the effect of C15 value on hold-up time – other power supply characteristics may be affected by a reduced value C15, and should be checked.

Figure 67 – DER-428 Hold-up Time using 120 µf Bulk Capacitor (C15), 115 VAC Input, 100% Load.
Upper: 12 V Main Output, 2 V / div.
Middle: AC I_{IN} Waveform, 2 A / div.
Lower: B+ Voltage, 200 V, 5 ms / div.
Hold-up Time: 17.79 ms.

17 Revision History

Date	Author	Revision	Description and Changes	Reviewed
25-Sep-14	RH	7	Initial Release	Apps & Mktg
30-Oct-14	KM	7.1	Updated Schematic	

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

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

PATENT INFORMATION

Power Integrations Worldwide Sales Support Locations

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

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

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

TAIWAN
5F, No. 318, Nei Hu Rd.,
Sec. 1
Nei Hu District
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
Fax: +886-2-2659-4550
e-mail:
taiwansales@powerint.com

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

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

KOREA
RM 602, 6FL
Korea City Air Terminal B/D,
159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728 Korea
Phone: +82-2-2016-6610
Fax: +82-2-2016-6630
e-mail: koreasales@powerint.com

EUROPE HQ
1st Floor, St. James's House
East Street, Farnham
Surrey GU9 7TJ
United Kingdom
Phone: +44 (0) 1252-730-141
Fax: +44 (0) 1252-727-689
e-mail:
eurosales@powerint.com

CHINA (SHENZHEN)
3rd Floor, Block A,
Zhongtou International Business
Center, No. 1061, Xiang Mei Rd,
FuTian District, ShenZhen,
China, 518040
Phone: +86-755-8379-3243
Fax: +86-755-8379-5828
e-mail: chinasales@powerint.com

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

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

APPLICATIONS HOTLINE
World Wide +1-408-414-9660

APPLICATIONS FAX
World Wide +1-408-414-9760