CONFIDENTIAL

Title	***80 plus Gold Single Output PC Main Supply using HiperPLC PLC810PG***
Specification	90-132 VAC / 180-265 VAC Input, 12 V, 30 A (365 W) Main Output 12 V, 1.3 A (15 W) Standby
Application	PC Gold / Climate Savers 3
Author	JY
Document Number	DER210
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Revision	1.0

Summary and Features

- Meets efficiency requirements for 80 plus GOLD
  - Meet at 230 VAC and 115 VAC input
  - Output current shunt losses included
  - Fan loss at 100% load included (fan off at 20 and 50% load).
- Lossless capacitive sensing of LLC converter current
- PLC810PG Integrated PFC and LLC controller
  - Continuous current mode PFC for reduced differential mode EMI and filter component costs
  - Frequency and phase synchronized PFC and LLC switching
    - Edge collision avoidance technology reduces noise sensitivity and EMI
    - PFC output capacitor ripple cancellation for reduced capacitor size and cost

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

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1 Introduction

This document is an engineering report describing a single output 380 W PC power supply that exceeds the efficiency requirements of 80 PLUS GOLD. By meeting the most technical challenging efficiency level this design can also be used to demonstrate the capability of the PLC810PG to meet both 80 PLUS SILVER and GOLD in both single and multiple output configurations.

The design uses the PLC810PG controller IC, part of the HiperPLC family. This integrates a continuous conduction mode boost controller, resonant LLC half bridge controller and high side driver for the upper MOSFET of the half bridge.

The switching frequencies of the two stages (PFC and LLC) are synchronized (locked) and the controller prevents coincident switching of the two stages (collision) to reduce EMI and simplify layout by reducing noise generation. In addition synchronization reduces the ripple current in the PFC output capacitor allowing a smaller and lower cost capacitor to be used.

The document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, and performance data.

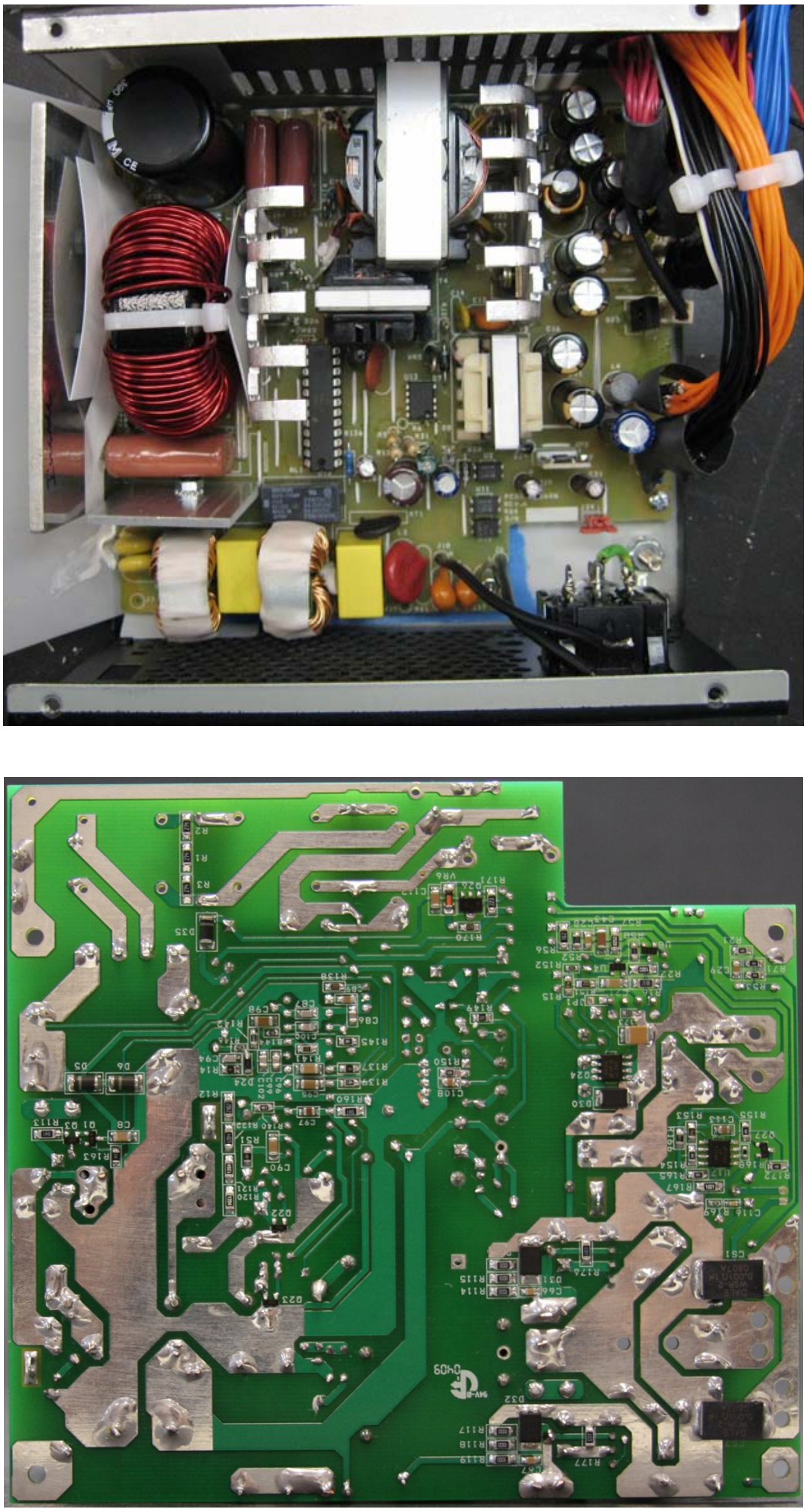

Figure 1 – Populated Circuit Board Photograph.

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2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85		265	VAC	3 Wire input
Frequency	f_{LINE}	47	50/60	64	Hz	
Power Factor	pf	0.9				50% P_{OUT}
No-load Input Power				0.35	W	115 VAC / 230 VAC
Output						
Output Voltage Main 1	$V_{12(1)}$	11.4	12	12.6	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			100	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}			15	A	
Output Voltage Main 2	$V_{12(2)}$	11.4	12	12.6	V	± 5%
Output Ripple Voltage 2	$V_{RIPPLE2}$			100	mV	20 MHz bandwidth
Output Current 2	I_{OUT2}			15	A	
Output Voltage Standby	V_{SB}	11.4	12	12.6		± 5%
Output Ripple Voltage SB	$V_{RIPPLE(SB)}$			100		20 MHz bandwidth
Output Current SB	$I_{OUT(SB)}$			1.3		
Total Output Power						
Continuous Output Power	P_{OUT}			380	W	
Efficiency						
Full Load	η	88			%	Measured at P_{OUT} 25 °C
Required efficiency at 20, 50, 100 % of P_{OUT}	η_{GOLD}	88 / 92 / 88			%	Measured at the PCboard terminals
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950 / UL1950 Class II				
Line Surge Differential Mode (L1-L2) Common mode (L1/L2-PE)		 4			 kV kV	1.2/50 μs surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω Common Mode: 12 Ω
Ring Wave (100 kHz) Differential Mode (L1-L2) Common mode (L1/L2-PE)		 6			 kV kV	500 A short circuit Series Impedance: Differential Mode: 2 Ω Common Mode: 12 Ω
Ambient Temperature	T_{AMB}	0		40	°C	Case external, free convection, sea level

3 Schematic

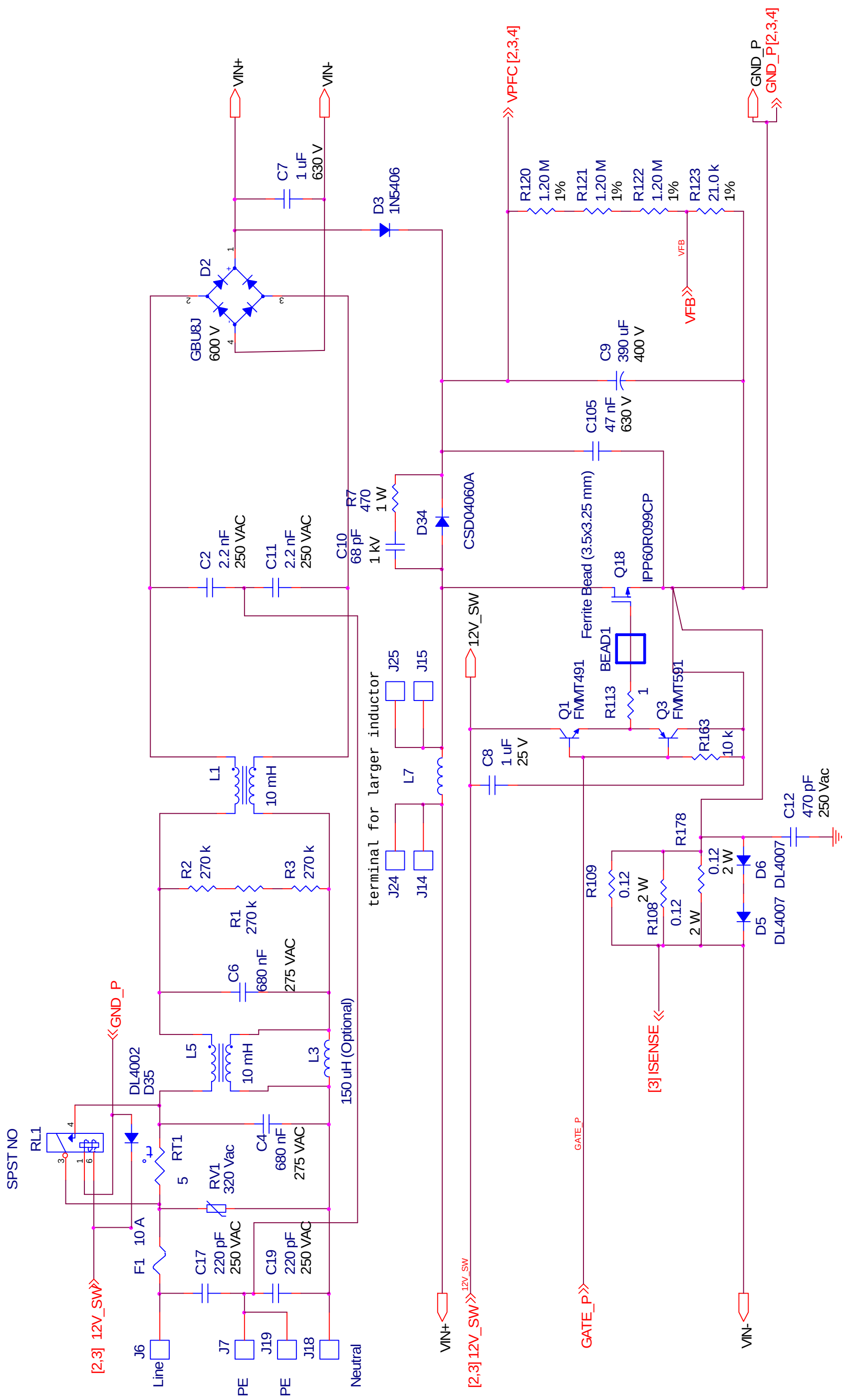

Figure 2 – Input and PFC Stage Schematic

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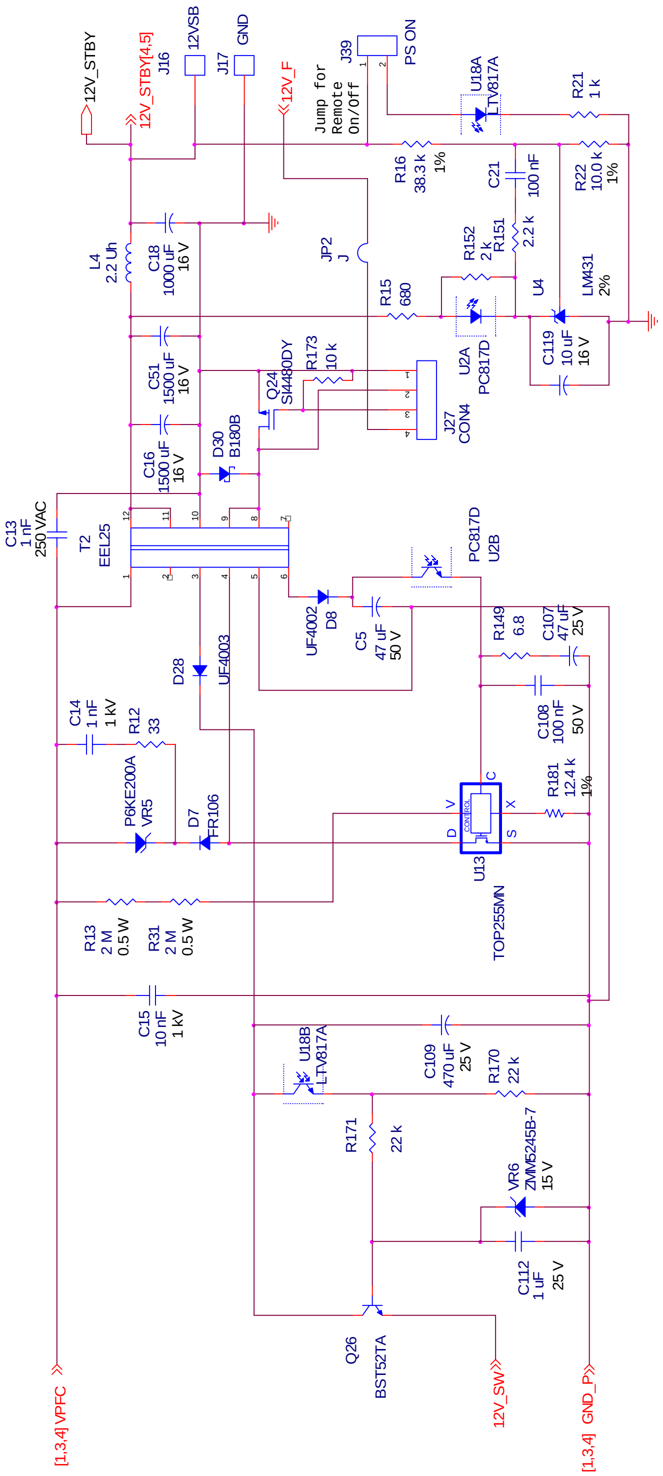

Figure 3 – Standby Converter Schematic

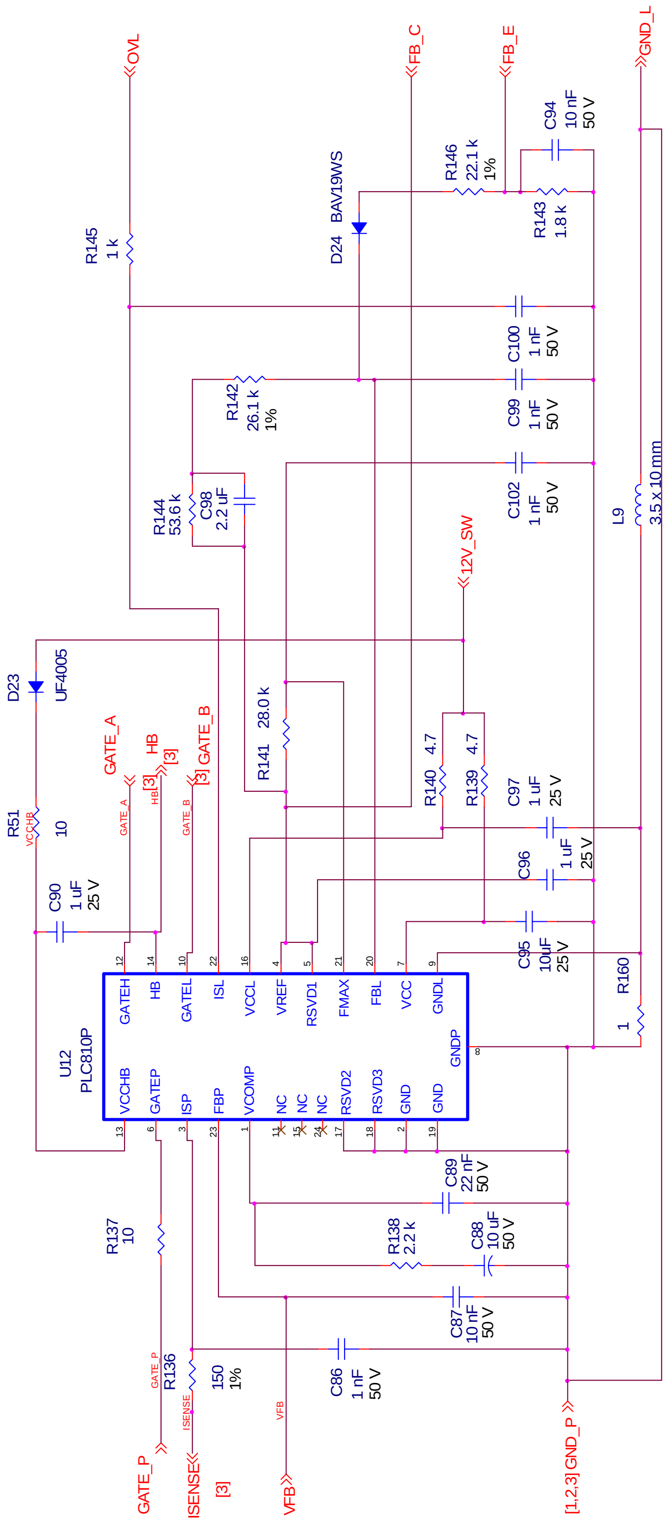

Figure 4 – PLC810PG Controller Schematic

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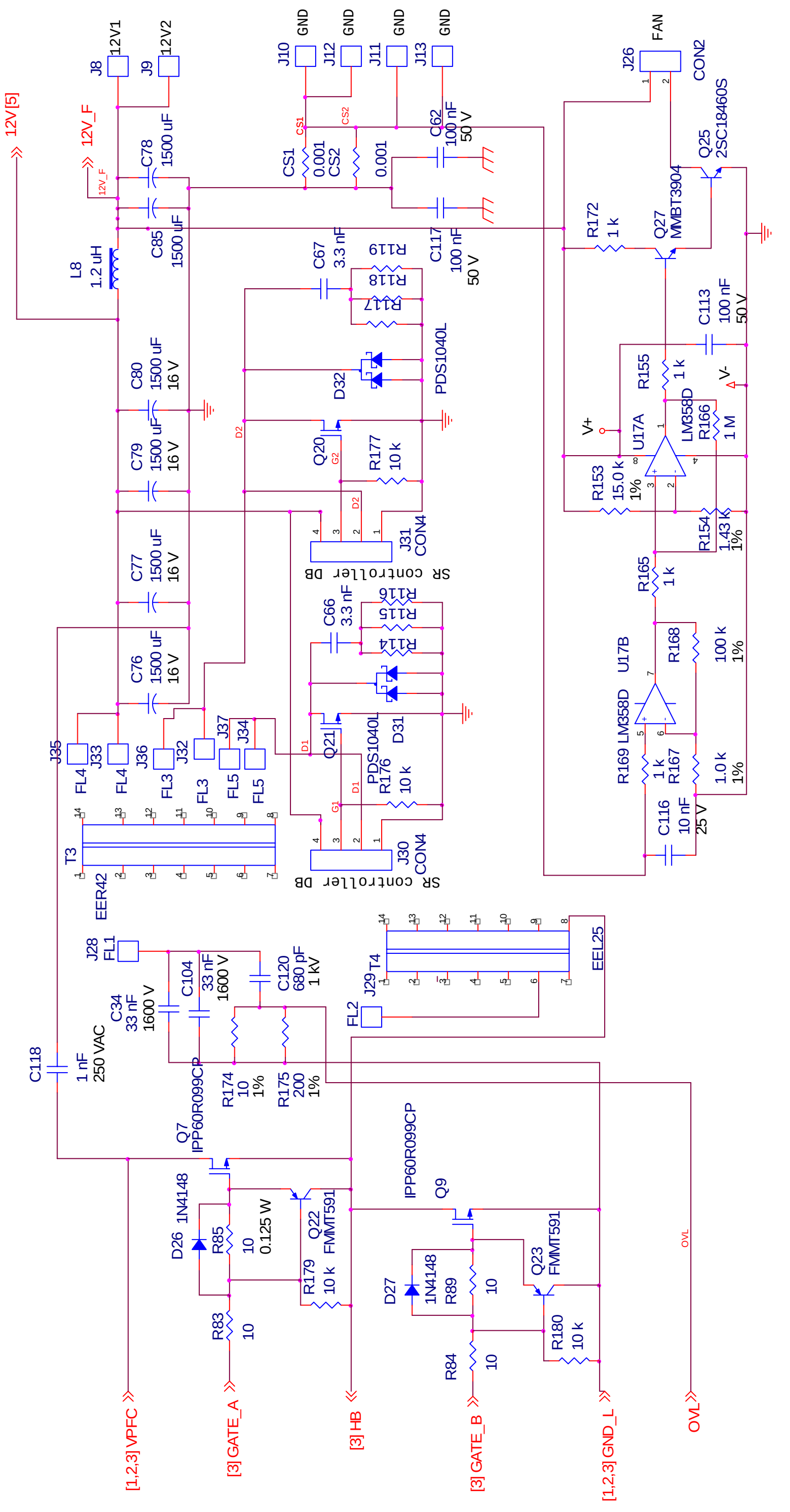

Figure 5 – LLC Power Stage and Fan Controller

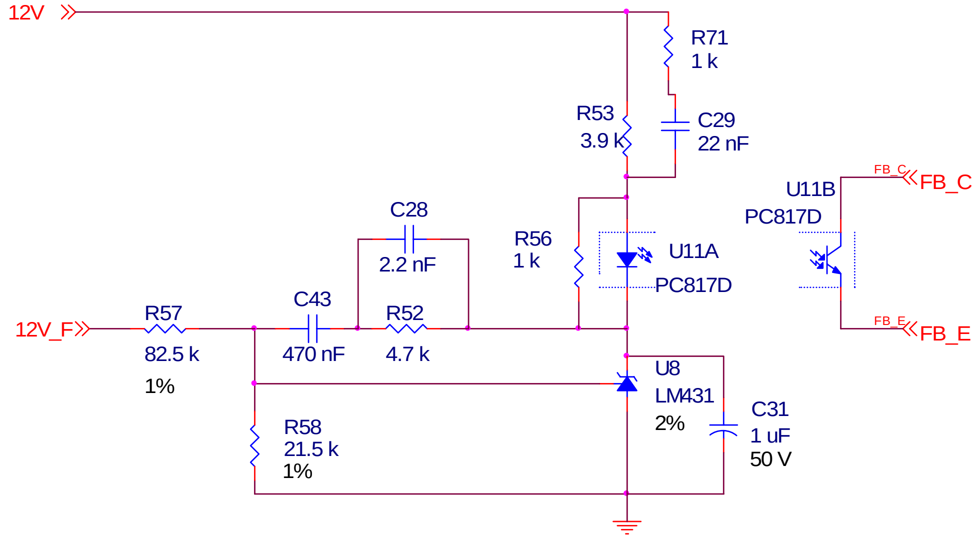

Figure 6 – LLC Secondary Side Feedback Section Schematic

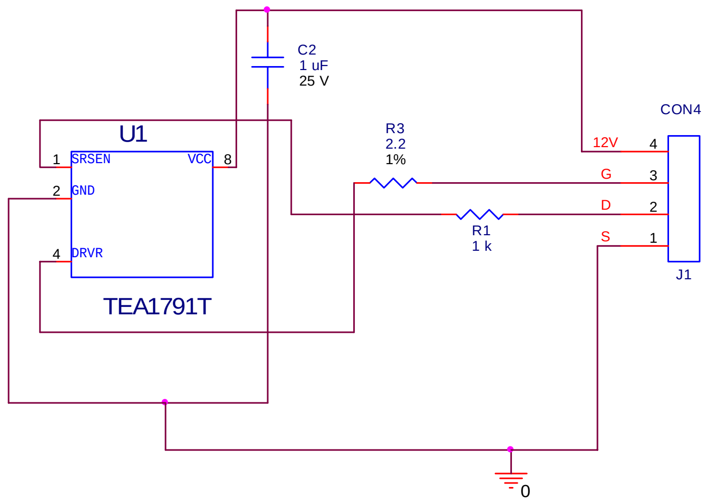

Figure 7 – Synchronous Rectifier Daughter Board Schematic

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4 Circuit Description

The design uses PLC810PG as the core controller and includes input filtering circuit, standby supply, PFC, LLC, synchronous rectification and feedback circuit.

4.1 Input EMI Filtering and Inrush Current Limiting

Capacitors C17 and C19 are connected directly across the input line, neutral and PE to filter common mode noise at frequencies greater than 30MHz. Common mode chokes L5 and L1 eliminate EMI at low frequencies and the mid-band (~10 MHz), respectively. Capacitors C2 and C11 can filter the resonant noise at mid-band. C4 and C6 are used to filter the differential EMI. Resistors R1, R2 and R3 are used to discharge the capacitors for safety requirement when AC input is removed. An optional inductor L3 can be used to eliminate the differential mode EMI.

A thermistor RT1 is used to limit the inrush current. After startup, it is shorted with the help of a relay RL1 to improve efficiency.

The diode bridge rectifier recitifies the incoming AC voltage.

4.2 PFC Stage

Capacitor C7, Inductor L7, MOSFET Q18, diode D34 and capacitor C9 form a boost converter which realizes PFC in continuous conduction mode. The transistor pair Q1 and Q3 forms a simple gate driver for Q18. Gate resistor R113 is selected to be very low in order to maximize the efficiency. A silicon carbide diode D34 is used for ultra high efficiency due to its zero reverse recovery. While the bulk capacitor C9 can make the loop area large, the addition of C105 can effectively reduce the actual loop area to reduce EMI. Resistors R108, R109 and R178 form a 0.4Ω current sense resistor for PFC over current protection.

4.3 LLC Stage

MOSFETs Q7 and Q9 forms a half bridge which are driven by PLC810PG GATEH and GATEL signals. Components R83 (R84), R85 (R89), D26 (D27) and Q22 (Q23) adjust the turn-on / turn-off speed of upper (lower) switch Q7 (Q9). The switched voltage at the half bridge is applied to inductor T4, transformer T3, capacitors C34 and C104 which are the main resonant components. The transformer T3 is separated with the resonant inductor for the flexibility of transformer design and smaller layout area.

4.4 LLC Output Rectification

The secondary side of LLC is rectified by Q20 and Q21 with synchronous rectification. Low forward drop diodes D31 and D32 are put in parallel with MOSFET body diodes to help reducing power loss at diode conducting portion. Components C66, C67 and R114 – R119 provide RC snubber for the commutation between diode and MOSFET.

Capacitors C76 – C80, and C85 has very low ESR so that the power loss is further reduced. These capacitors and L8 provide output filtering.

4.5 Standby Power

Standby power supply uses TOPSwitch U13 with no current limit setting. A clamping circuit is formed by D7, VR5, R12 and C14. Bias winding, D8 and C5 provides bias voltage. The secondary side use Q24 and D30 for synchronous rectification. Components C16, C51, L4 and C18 form output filter for standby power.

The schematic and layout are designed such that both 5V and 12V standby power can use the same schematic and layout. Synchronous Rectifier controller for stanby by is supplied from 12V Main Output. The layput is designed such that it matches the footprints of the diode and MOSFET for both 5V and 12V.

The shunt regulator U4 and optocoupler are the major components for feedback.

An auxiliary winding with D28 and C109 provide voltage for the PLC810P (U12) controller IC. The voltage is then further regulated by Q26 and VR6. Optocoupler U18 is used for remote on/off control of the auxiliary power for controller IC.

4.6 PLC810 Controller IC

The PFC output voltage is fed back to the FBP pin of U12 via resistors R120-123. Capacitor C87 filters noise. Components C88, C89 and R138 provide frequency compensation for the PFC. The PFC current sense signal is filtered by R136 and C86. The PFC drive signal from the GATEP pin is routed to the main switching FET via resistor R137.

Capacitors C95 and C96 provide supply bypassing for VCC and VCCL of U12. Resistor R160 and ferrite bead L9 provide ground isolation between the PFC and LLC ground systems. Resistors R160 isolates the IC analog and digital supply rails.

Feedback from the LLC output feedback circuit is provided by shunt regulator U8 and optocoupler U11, which develops a feedback voltage across resistor R143. Resistor R146 set the feedback signal current. Capacitor C94 filters the feedback signal. Resistors R142 and R144 set the lower frequency limit for the LLC converter stage. Capacitor C98 is used to provide output soft start. Resistor R141 sets the LLC upper frequency limit. Components C90, R51, and D23 provide bootstrapping for the LLC top side MOSFET drive.

4.7 Capacitive Sensing for LLC

The simplest way of LLC resonant current sensing is using a sense resistor. Lossless sensing can improve efficiency. The capacitive sensing uses only about 1% of the main

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resonant capacitor current by putting C120, R174 and R175 to share a very small portion of resonant current. The voltage drop across R174 and R175 is used for ISL pin of U12.

5 PCB Layout

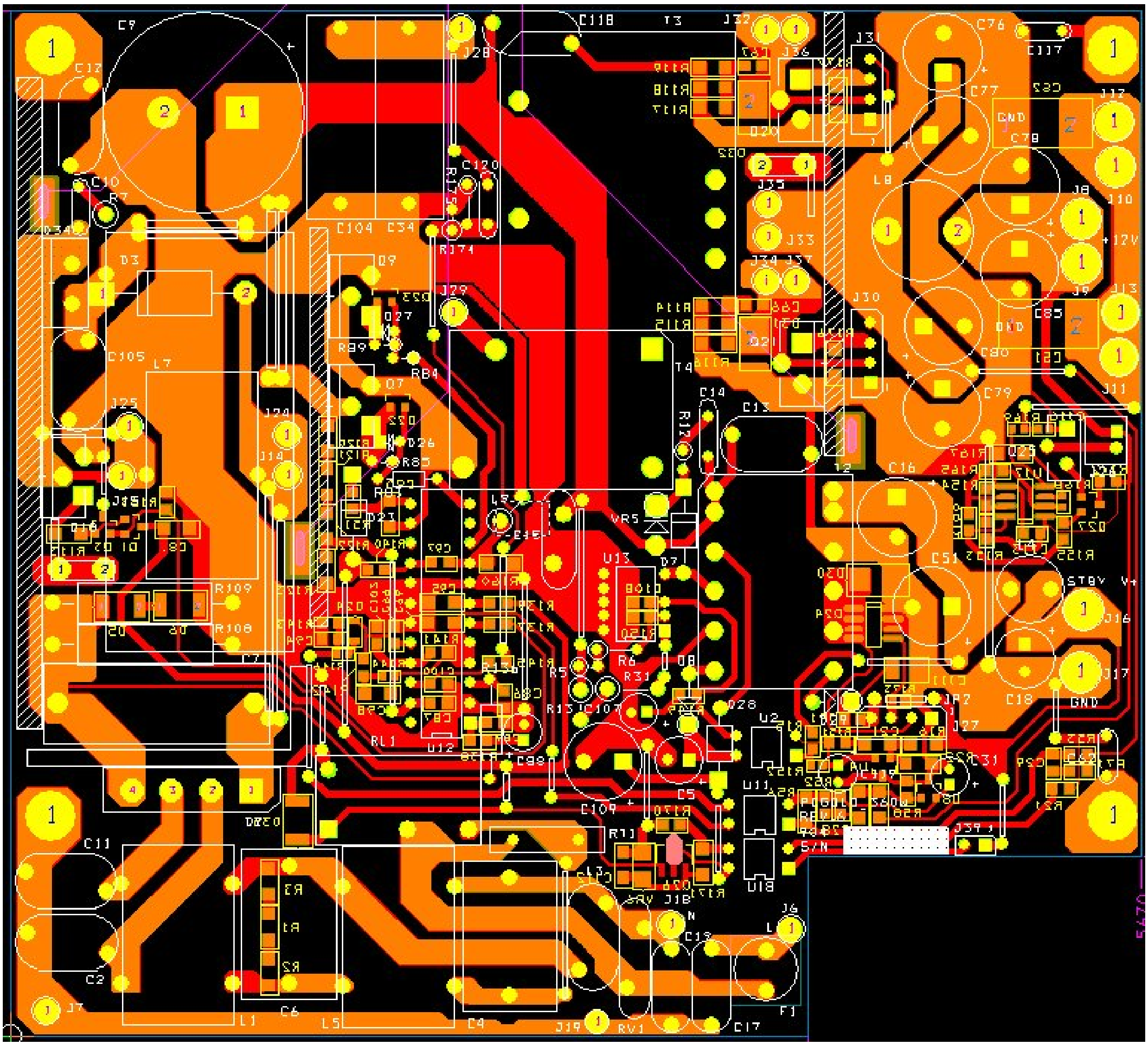

Figure 8 – Printed Circuit Layout.

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6 Bill Of Materials

Item	Qty	Ref Des.	Description	Manufacturer	Part Number
1	1	BEAD1	3.5 mm D x 3.25 L mm, 21 Ohms at 25 MHz, 1.6mm (.063) hole, Ferrite Bead	Fair-Rite	2643001501
2	2	C2 C11	2.2 nF, Ceramic, Y1	Vishay	440LD22-R
3	2	C4 C6	680 nF, 275 VAC, Film,MPX Series, X2	Carli	PX684K3ID6
4	1	C5	47 uF, 50 V, Electrolytic, Low ESR, 450 mOhm, (6.3 x 11.5)	Nippon Chemi-Con	ELXZ500ELL470MFB5D
5	1	C7	1 uF, 630 V, Polypropylene Film	Panasonic	ECW-F6105HL
6	4	C8 C90 C96 C112	1 uF, 25 V, Ceramic, X7R, 1206	Panasonic	ECJ-3YB1E105K
7	1	C9	390 uF, 400 V, Electrolytic, TS-UQ, (25 x 45)	Panasonic	EET-UQ2G391CA
8	1	C10	68 pF, 1 kV, Ceramic	Panasonic	ECC-D3A680JGE
9	1	C12	470 pF, 250 Vac, Thru Hole, Ceramic Y-Capacitor	Panasonic	ECK-ATS471MB
10	2	C13 C118	1 nF, Ceramic, Y1	Vishay	440LD10-R
11	1	C14	OBSOLETE Replaced by part 20-00739-00 1 nF, 1 kV, Disc Ceramic	Panasonic	ECK-D3A102KBP
12	1	C15	10 nF, 1 kV, Disc Ceramic	Vishay/Sprague	562R5HKMS10
13	8	C16 C51 C76 C77 C78 C79 C80 C85	1500 uF, 16 V, Electrolytic, Low ESR, 10 x 20)	Nichicon	UHZ1C152MPM
14	2	C17 C19	220 pF, Ceramic Y1	Vishay	440LT33-R
15	1	C18	1000 uF, 16 V, Electrolytic, Low ESR, 8 x 20)	Rubycon	16MCZ100M8X20
16	1	C21	100 nF, 25 V, Ceramic, X7R, 1206	Panasonic	ECJ-3VB1E104K
17	1	C28	2.2 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECJ-2VB1H222K
18	2	C29 C89	22 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECJ-2VB1H223K
19	1	C31	1 uF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	Nippon Chemi-Con	EKMG500ELL1R0ME11D
20	2	C34 C104	33 nF, 1600 V, Film	Vishay	2222 383 50333
21	1	C43	470 nF uF, 100 V, Ceramic, X7R, 1206	TDK	C3216X7R2A474K
22	2	C62 C117	100 nF, 50 V, Ceramic, X7R	Epcos	B37987F5104K000
23	2	C66 C67	3.3 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECJ-2VB1H332K
24	4	C86 C99 C100 C102	1 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECJ-2VB1H102K
25	2	C87 C94	10 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECJ-2VB1H103K
26	1	C88	10 uF, 50 V, Electrolytic, Gen Purpose, (5 x 11)	Panasonic	ECA-1HHG100
27	1	C95	10 uF, 25 V, Ceramic, X7R, 1206	Panasonic	ECJ-3YB1E106M
28	1	C97	1 uF, 25 V, Ceramic, X7R, 0805	Panasonic	ECJ-2FB1E105K
29	1	C98	2.2 uF, 50 V, Ceramic, Y5V, 1206	Murata	GRM31MF51H225ZA01L
30	1	C105	47 nF, 630 V, Film	Panasonic	ECQ-E6473KF
31	1	C107	47 uF, 25 V, Electrolytic, Very Low ESR, 300 mOhm, (5 x 11)	Nippon Chemi-Con	EKZE250ELL470ME11D
32	2	C108 C113	100 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECJ-2YB1H104K
33	1	C109	470 uF, 25 V, Electrolytic, Gen. Purpose, (10 x 12.5)	Nippon Chemi-Con	EKMG250ELL471MJC5S
34	1	C116	10 nF 50 V, Ceramic, X7R, 0603	Panasonic	ECJ-1VB1H103K
35	1	C119	10 uF, 16 V, Electrolytic, Gen. Purpose, (5 x 11)	Nippon Chemi-Con	KME16VB10RM5X11LL
36	1	C120	680 pF, 1 kV, Disc Ceramic	Panasonic	ECK-D3A681KBN
37	2	CS1 CS2	CURRENT SENSE .001 OHM	Vishay Dale	WSR21L000FEK

38	1	D2	600 V, 8 A, Bridge Rectifier, GBU Case	Vishay	GBU8J
39	1	D3	600 V, 3 A, Recitifier, DO-201AD	Vishay	1N5406
40	2	D5 D6	1000 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	Diodes Inc	DL4007-13-F
41	1	D7	800 V, 1 A, Fast Recovery Diode, 500 ns, DO-41	Diodes Inc.	FR106
42	1	D8	100 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	Vishay	UF4002-E3
43	1	D23	600 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	Vishay	UF4005-E3
44	1	D24	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	Diode Inc.	BAV19WS-7-F
45	2	D26 D27	75 V, 300 mA, Fast Switching, DO-35	Vishay	1N4148TR
46	1	D28	200 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	Vishay	UF4003-E3
47	1	D30	80 V,1 A, Schottky, SMD, DO-214AA	Diodes Inc	B180B-13
48	2	D31 D32	40 V, 10 A, Schottky, SMD, POWERD15	Diode Inc.	PDS1040L-13
49	1	D34	600 V, 8 A, Ultrafast Recovery, 12 ns, TO-220AC	ST Semiconductor	STTH8S06D
50	1	D35	100 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	Diodes Inc	DL4002
51	1	F1	10 A, 125V, Fast	Littelfuse	0224010.HXUP
52	2	HEATSINK BRACKET1 HEATSINK BRACKET3	Heatsink, Custome made from Clark	Clark Precision Sheetmetal	
53	16	J6 J7 J14 J15 J18 J19 J24 J25 J28 J29 J32 J33 J34 J35 J36 J37	PCB Terminal Hole, 18 AWG	N/A	N/A
54	8	J8 J9 J10 J11 J12 J13 J16 J17	CONN TERM CRIMP AWG16-18 PCB	Molex/Waldom Electronics Corp	02-09-2105
55	1	J26	2 Position (1 x 2) header, 2 mm pitch, Vertical	Hirose Electric Co	DF3A-2P-2DSA
56	1	J27	4 Position (1 x 4) header, 0.156 pitch, Vertical	Molex	26-48-1045
57	2	J30 J31	4 Position (1 x 4) header, 0.1 pitch, Vertical	Molex	22-28-4049
58	1	J39	2 Position (1 x 2) header, 0.1 pitch, Vertical	Molex	22-03-2021
59	1	JP2	Wire Jumper, Non insulated, 22 AWG, 0.3 in	Alpha	298
60	2	L1 L5	Common Mode Choke Toroidal	Customised	
61	1	L3			
62	1	L4	2.2 uH, 6.0 A	Coilcraft	RFB0807-2R2L
63	1	L7	715 uH, 5A, Kool Mu Core, Toroidal		
64	1	L8	1.2 uH, Choke, 2 Pins, Custom		
65	1	L9	3.5 mm x 10 mm, 400 Ohms at 10 MHz, 24 AWG hole, Ferrite Bead	Fair-Rite	2944666671
66	4	MTG_HOLE1 MTG_HOLE2 MTG_HOLE3 MTG_HOLE4	Mounting Hole No 4		
67	1	Q1	NPN,60V 1000MA, SOT-23	Zetex Inc	FMMT491TA
68	3	Q3 Q22 Q23	PNP, 60V 1000MA, SOT-23	Zetex Inc	FMMT591TA
69	3	Q7 Q9 Q18	600 V, 31 A, 99 mOhms, N-Channel, TO-220AB	Infineon Technologies	IPP60R099CP
70	2	Q20 Q21	40 V, 75 A, 2.3 mOhms, N-Channel, TO-220AB	International Rectifier	IRF2804PBF
71	1	Q24	80 V, 6A, 35 mOhm, N-Channel, SO-8	Vishay	SI4480DY-T1-E3
72	1	Q25	NPN, Power BJT, 35 V, 1 A, TO-126	Panasonic	2SC18460S

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73	1	Q26	NPN, DARL 80V 500MA, SOT-89	Zetex Inc	BST52TA
74	1	Q27	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	On Semiconductor	MMBT3904LT1G
75	3	R1 R2 R3	270 k, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ274V
76	1	R7	470 R, 5%, 1 W, Metal Oxide	Yageo	RSF100JB-470R
77	1	R12	33 R, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-33R
78	2	R13 R31	2 M, 5%, 1/2 W, Carbon Film	Yageo	CFR-50JB-2M0
79	1	R15	680 R, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ681V
80	1	R16	38.3 k, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF3832V
81	5	R21 R71 R145 R165 R172	1 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ102V
82	1	R22	10.0 k, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF1002V
83	2	R51 R137	10 R, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ100V
84	1	R52	4.7 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ472V
85	1	R53	3.9 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ392V
86	1	R56	1 k, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ102V
87	1	R57	82.5 k, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF8252V
88	1	R58	21.5 k, 1%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6ENF2152V
89	4	R83 R84 R85 R89	10 R, 5%, 1/8 W, Carbon Film	Yageo	CFR-12JB-10R
90	3	R108 R109 R178	0.12 R, 5%, 2 W, Metal Oxide	Synton-Tech corporation	MO200J0R12B
91	2	R113 R160	1 R, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ1R0V
92	6	R114 R115 R116 R117 R118 R119	100 R, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF1000V
93	3	R120 R121 R122	1.20 M, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF1204V
94	1	R123	21.0 k, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF2102V
95	1	R136	150 R, 1%, 1/4 W, Metal Film	Yageo	MFR-25FBF-150R
96	2	R138 R151	2.2 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ222V
97	2	R139 R140	4.7 R, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ4R7V
98	1	R141	28 k, 1%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6ENF2802V
99	1	R142	26.1 k, 1%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6ENF2612V
100	1	R143	1.8 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ182V
101	1	R144	53.6 k, 1%, 1/16 W, Metal Film, 0603	Panasonic	ERJ-3EKF5362V
102	1	R146	22.1 k, 1%, 1/16 W, Metal Film, 0603	Panasonic	ERJ-3EKF2212V
103	1	R149	6.8 R, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ6R8V
104	1	R152	2 k, 5%, 1/10 W, Metal Film, 0603	Panasonic	ERJ-3GEYJ202V
105	1	R153	15 k, 1%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6ENF1502V
106	1	R154	1.43 k, 1%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6ENF1431V
107	2	R155 R163	10 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ103V
108	1	R166	1 M, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ105V
109	1	R167	1.0 k, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF1001V
110	1	R168	100 k, 1%, 1/16 W, Metal Film, 0603	Panasonic	ERJ-3EKF1003V
111	1	R169	1 k, 5%, 1/10 W, Metal Film, 0603	Panasonic	ERJ-3GEYJ102V
112	1	R170	22 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ223V
113	1	R171	22 k, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ223V
114	1	R173	10 k, 5%, 1/10 W, Metal Film, 0603	Panasonic	ERJ-3GEYJ103V
115	1	R174	10 R, 1%, 1/4 W, Metal Film	Yageo	MFR-25FBF-10R0

116	1	R175	200 R, 1%, 1/4 W, Metal Film	Yageo	MFR-25FBF-200R
117	4	R176 R177 R179 R180	10 k, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ103V
118	1	R181	12.4 k, 1%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6ENF1242V
119	1	RL1	SPST-NO, 5A 12VDC, PC MNT	OMRON	G6B-1114P-US-DC12
120	1	RT1	NTC Thermistor, 5 Ohms, 4.7 A	Thermometrics	CL150
121	1	RV1	320V, 84J, 15.5 mm, RADIAL	Epcos	S14K320
122	1	T2	Bobbin, EEL25.4, Vertical, 12 pins	Yih-Hwa Enterprises	YW-384-02B
123	1	T3	Bobbin, EER42, Vertical, 14 pins	TDK	BEER-42-1114CPFR
124	1	T4	Bobbin, EEL25, 14pins	TAIWAN SHULIN ENT CO. LTD.	
125	3	TERMINAL EYELET1 TERMINAL EYELET2 TERMINAL EYELET3	Terminal, Eyelet, Tin Plated Brass, Zierick PN 190	Zierick	190
126	2	U11 U2	Opto coupler, 35 V, CTR 300-600%, 4-DIP	Sharp	PC817X4
127	1	U17	DUAL Op Amp, Single Supply, SOIC-8	Texas Instruments	LM358D
128	1	U18	Opto coupler, 35 V, CTR 80-160%, 4-DIP	Liteon	LTV-817A
129	2	U4 U8	2.495 V Shunt Regulator IC, 2%, -40 to 85C, SOT23	National Semiconductor	LM431AIM
130	1	U12	Controller, PFC/LLC, 24-pin DIP	Power Integrations	PS-6110
131	1	U13	TOPSwitch-HX, TOP255MN, SDIP-10C	Power Integrations	TOP255MN
132	1	VR5	200 V, 5 W, 5%, TVS, DO204AC (DO-15)	OnSemi	P6KE200ARLG
133	1	VR6	15 V, 5%, 500 mW, DO-213AA (MELF)	Diodes Inc	ZMM5245B-7

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7 Transformer / Inductor Specification

7.1 LLC Transformer

7.1.1 Electrical Diagram

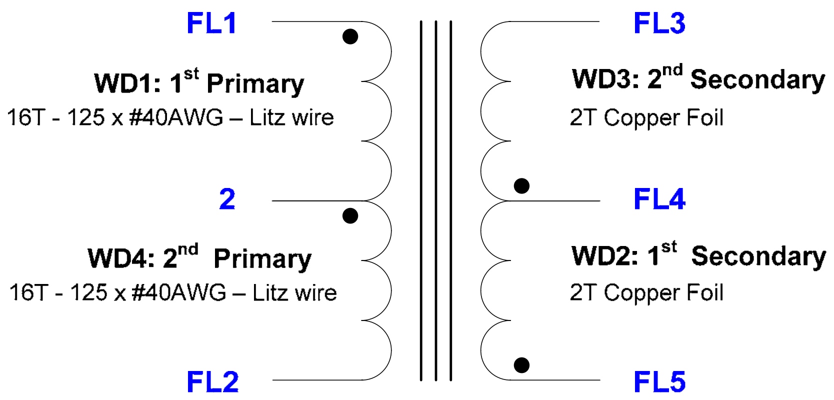


Figure 9 –LLC Transformer Electrical Diagram

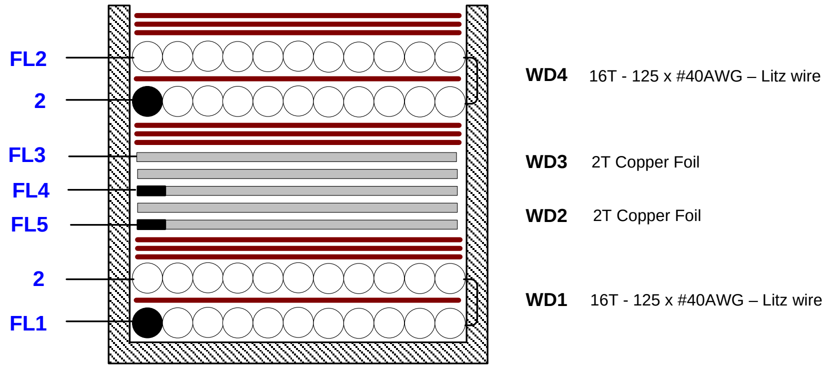
7.1.2 Electrical Specifications

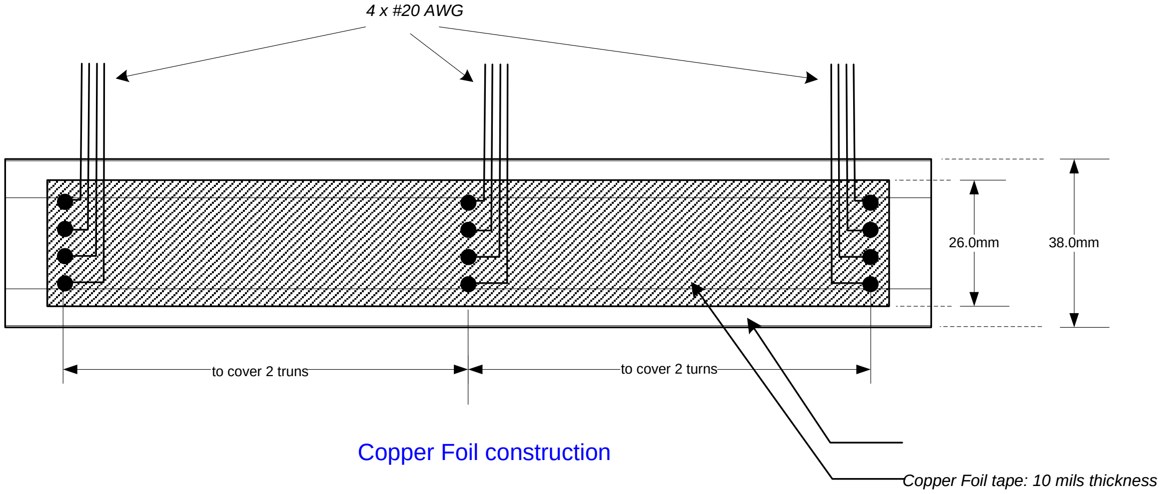
Electrical Strength	1 second, 60 Hz, from Pins FL1, FL2, 2 to Pins FL3-5	3000 VAC
Primary Inductance	Pins FL1-FL2, all other windings open, measured at 100 kHz, 0.4 VRMS	352 µH, -5/+5%
Resonant Frequency	Pins FL1-FL2, all other windings open	1000 kHz (Min.)
Primary Leakage Inductance	Pins FL1-FL2, with Pins FL3-5 shorted, measured at 100 kHz, 0.4 VRMS	6 µH (Max.)

7.1.3 Materials

Item	Description
[1]	Core: EER42, PC44RRR42-Z, TDK, gapped for ALG of 344nH/ T^2
[2]	Bobbin: EER42 Vertical, 14pins, (7/7).
[3]	Magnetic wire: 125x40AWG Litz wire
[4]	Magnetic wire: #20 AWG TIW
[5]	Copper Foil: 10 mil thick, 26 mm wide
[6]	Tape: 3M 1298 Polyester Film, 2.0 mils thick, 14 mm wide
[7]	Tape: 3M 1298 Polyester Film, 2.0 mils thick, 38 mm wide
[8]	Tape: 3M 1298 Polyester Film, 2.0 mils thick, 26.4 mm wide
[9]	Vanish

7.1.4 Transformer Build Diagram





Note: Copper Foil is wrapped with 3 layers of Polyester at edges with at least 6.0mm.

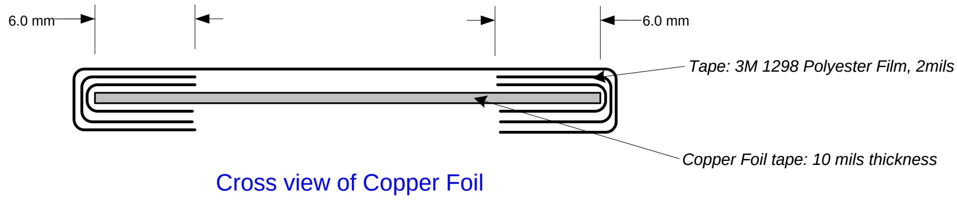


Figure 10 – Transformer Build Diagram.

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7.1.5 Winding Instructions

½ Primary Winding	Set flying lead FL1 temporily on pin1. Wind 8 turns of item [3] from left to right in one layer. Apply 1 layer of tape [8]. Wind 8 turns from right to left. Finish the winding at pin 2. Release FL1 and mark it.
Insulation	3 layer of tape [8] for insulation
Secondary Winding	Prepare item [5] with item [6], item [7] and item [4] for insulation and flying leads as illustrated in Figure 10. Start at pin 8 position, wind 4 turns of item [5] and finish at pin 14 position.
Insulation	3 Layers of tape [8] for insulation.
½ Primary Winding	Start on pin 2, Wind 8 turns of item [3] from left to right in one layer. Apply 1 layer of tape [8]. Wind 8 turns from right to left. Finish the winding as flying lead FL2.
Insulation	3 Layers of tape [8] for insulation.
Core Assembly	Assemble and secure core halves. Item [1]
Varnish	Varnish

7.2 LLC Inductor

7.2.1 Electrical Diagram

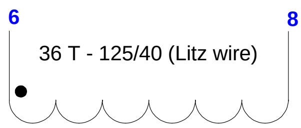

Figure 11 –LLC Inductor Electrical Diagram

7.2.2 Electrical Specifications

Primary Inductance	Pins 7- 8, measured at 100KHz	63 μH, -5/+5%

7.2.3 Materials

Item	Description
[1]	Bobbin: EEL25, Vertical, 14pins, (7/7).
[2]	Core: EEL25, NC-2H or Equivalent, gapped for ALG of 100 nH/ T^2
[3]	Magnetic wire: 125/40-Litz wire

7.2.4 Inductor Build Diagram

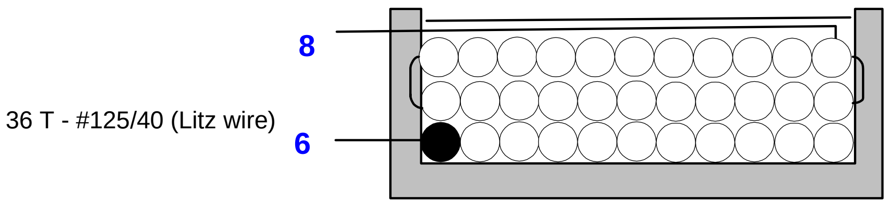

Figure 12 –LLC Inductor Build Diagram

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7.3 Standby Transformer

7.3.1 Electrical Diagram

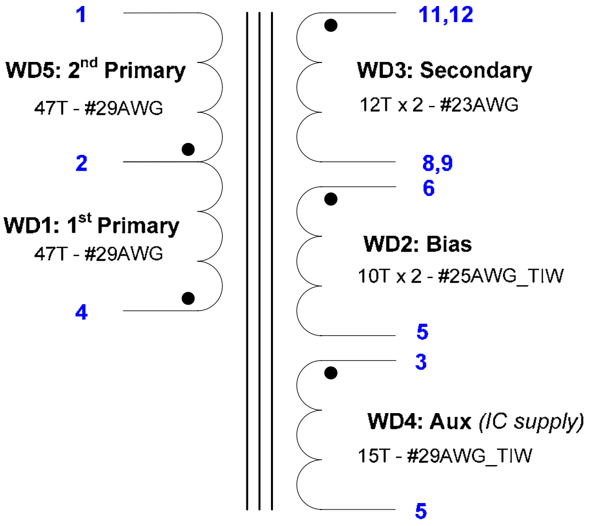

Figure 13 –Standby Transformer Electrical Diagram

7.3.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1-7 to Pins 8-14	3000 VAC
Primary Inductance	Pins 1-4, all other windings open, measured at 100 kHz, 0.4 VRMS	1333 μH, +/-5%
Resonant Frequency	Pins 1-4, all other windings open	1500 kHz (Min.)
Primary Leakage Inductance	Pins 1-4, with Pins X-Y shorted, measured at 100 kHz, 0.4 VRMS	18 μH (Max.)

7.3.3 Materials

Item	Description
[1]	Core: EEL25, NC-2H or Equivalent, Gaped for AL = 151 nH/T^2
[2]	Bobbin: EEL25, Vertical, 12 Pins
[3]	Magnet Wire: #29 AWG
[4]	Magnet Wire: #25 AWG TIW
[5]	Magnet Wire: #23 AWG
[6]	Magnet Wire: #29 AWG TIW
[7]	Tape: 3M 1298 Polyester Film, 2.0 mils thick 22.3 mm wide
[8]	Tape: Polyester web 3.00 mm wide
[9]	Teflon Tubing # 22
[10]	Varnish

7.3.4 Transformer Build Diagram

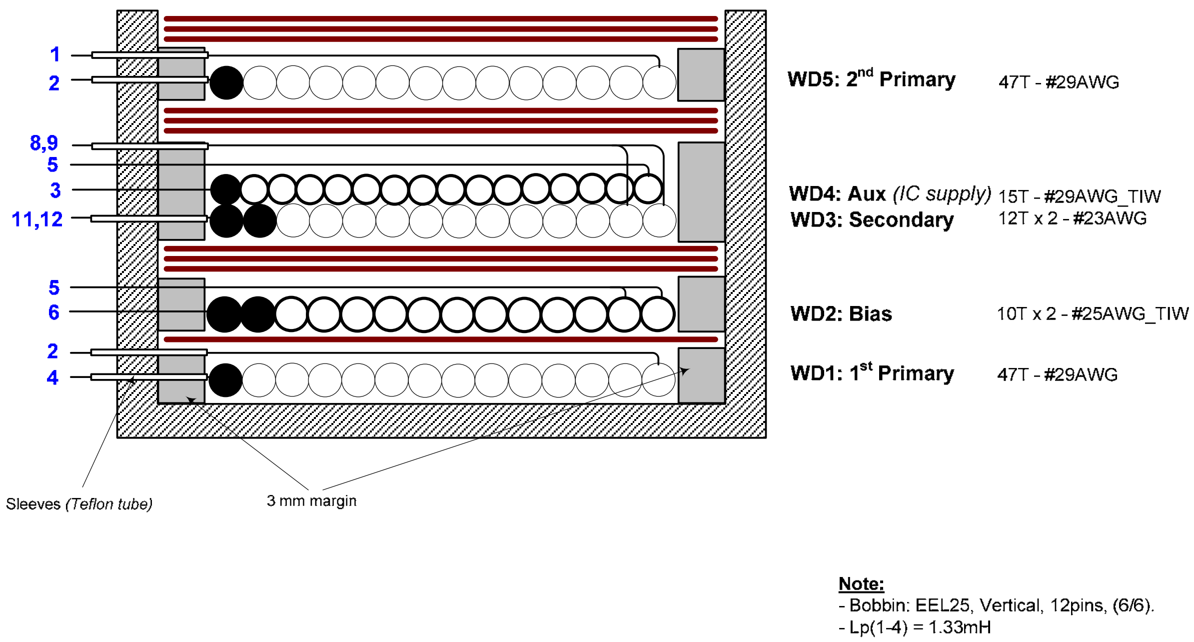

Figure 14 –Standby Transformer Build Diagram

7.3.5 Winding Instructions

Margin	Use item [8] on both side of the bobbin. Match height of half primary winding.
½ Primary Winding	Start on pin 4, using item [9], wind 47 turns of item [3] from left to right in one layer. Finish the winding at pin 2 using item [9]
Insulation	1 layer of tape [7] for insulation
Margin	Use item [8] on both side of the bobbin. Match height of bias winding.
Bias Winding	Start at pin 6, wind 10 bi-filar turns of item [4] from left to right in one layer evenly. Finish the winding at pin 5
Insulation	3 Layers of tape [7] for insulation.
Margin	Use item [8] on both side of the bobbin. Match the heights of secondary and auxiliary winding
Secondary Winding	Start on Pins 11 and 12, using item [9], wind 12 bi-filar turns of item [5] from left to right in one layer evenly. Set the wire temporarily at right side.
Auxiliary Winding	Start on Pins 3 wind 15 turns of item [6] from left to right in one layer evenly. Flip the wire to left side and finish at pin 5. Flip the wire for secondary winding and finish at pins 8 and 9
Insulation	3 Layers of tape [7] for insulation.
½ Primary Winding	Start on pin 2, using item [9], wind 47 turns of item [3] from left to right in one layer. Finish the winding at pin 1 using item [9]
Insulation	3 Layers of tape [7] for insulation.
Core Assembly	Assemble and secure core halves. Item [1]
Varnish	Varnish

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7.3.6 Spreadsheet

ACDC_TOPSwitchHX_100208; Rev.1.10; Copyright Power Integrations 2008	INPUT	INFO	OUTPUT	UNIT	TOP_HX_100208: TOPSwitch-HX Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					**Customer**
VACMIN	85			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	12.00			Volts	Output Voltage (main)
PO_AVG	16.00			Watts	Average Output Power
PO_PEAK			16.00	Watts	Peak Output Power
n	0.85			%/100	Efficiency Estimate
Z	0.50				Loss Allocation Factor
VB	15			Volts	Bias Voltage
tC	3.00			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	390.0		390	uFarads	Input Filter Capacitor
ENTER TOPSWITCH-HX VARIABLES					
TOPSwitch-HX	**TOP255MN**			Universal / Peak	115 Doubled/230V
Chosen Device		*TOP255MN*	Power Out	22 W / 52 W	30W
KI	0.50				External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN_EXT			0.791	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX_EXT			0.910	Amps	Use 1% resistor in setting external ILIMIT
Frequency (F)=132kHz, (H)=66kHz	**H**		H		Half frequency option is only available for P, G and M packages in addition to TOP259-TOP261YN devices. For full frequency operation choose E package or TOP254-TOP258YN devices.
fS			66000	Hertz	TOPSwitch-HX Switching Frequency: Choose between 132 kHz and 66 kHz
fSmin			59400	Hertz	TOPSwitch-HX Minimum Switching Frequency
fSmax			72600	Hertz	TOPSwitch-HX Maximum Switching Frequency
High Line Operating Mode			FF		Full Frequency, Jitter enabled
VOR	96.00			Volts	Reflected Output Voltage
VDS			10	Volts	TOPSwitch on-state Drain to Source Voltage
VD	0.30			Volts	Output Winding Diode Forward Voltage Drop
VDB	0.70			Volts	Bias Winding Diode Forward Voltage Drop
KP	1.00				Ripple to Peak Current Ratio (0.3 < KRP < 1.0 : 1.0< KDP<6.0)

PROTECTION FEATURES					
LINE SENSING					
VUV_STARTUP			95	Volts	Minimum DC Bus Voltage at which the power supply will start-up
VOV_SHUTDOWN			445	Volts	Typical DC Bus Voltage at which power supply will shut-down (Max)
RLS			4.0	M-ohms	Use two standard, 2 M-Ohm, 5% resistors in series for line sense functionality.
OUTPUT OVERVOLTAGE					
VZ			27	Volts	Zener Diode rated voltage for Output Overvoltage shutdown protection
RZ			5.1	k-ohms	Output OVP resistor. For latching shutdown use 20 ohm resistor instead
OVERLOAD POWER LIMITING					
Overload Current Ratio at VMAX			1.2		Enter the desired margin to current limit at VMAX. A value of 1.2 indicates that the current limit should be 20% higher than peak primary current at VMAX
Overload Current Ratio at VMIN			1.15		Margin to current limit at low line.
ILIMIT_EXT_VMIN			0.68	A	Peak primary Current at VMIN
ILIMIT_EXT_VMAX			0.71	A	Peak Primary Current at VMAX
RIL			12.32	k-ohms	Current limit/Power Limiting resistor.
RPL			N/A	M-ohms	Resistor not required. Use RIL resistor only
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	EEL25		EEL25		Core Type
Core		*EEL25*		*P/N:*	PC40EE25.4/32/6.4-Z
Bobbin		*EEL25_BOBBIN*		*P/N:*	*
AE			0.404	cm^2	Core Effective Cross Sectional Area
LE			7.34	cm	Core Effective Path Length
AL			1420	nH/T^2	Ungapped Core Effective Inductance
BW			22.3	mm	Bobbin Physical Winding Width
M	3.00			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00				Number of Primary Layers
NS	12		12		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			117	Volts	Minimum DC Input Voltage
VMAX	385		385	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.47		Maximum Duty Cycle

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					(calculated at PO_PEAK)
IAVG			0.16	Amps	Average Primary Current (calculated at average output power)
IP			0.68	Amps	Peak Primary Current (calculated at Peak output power)
IR			0.68	Amps	Primary Ripple Current (calculated at average output power)
IRMS			0.27	Amps	Primary RMS Current (calculated at average output power)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			1333	uHenries	Primary Inductance
LP Tolerance	5		5		Tolerance of Primary Inductance
NP			94		Primary Winding Number of Turns
NB			15		Bias Winding Number of Turns
ALG			152	nH/T^2	Gapped Core Effective Inductance
BM			2394	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			3365	Gauss	Peak Flux Density (BP<4200) at ILIMITMAX and LP_MAX. Note: Recommended values for adapters and external power supplies <=3600 Gauss
BAC			1197	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			2053		Relative Permeability of Ungapped Core
LG			0.30	mm	Gap Length (Lg > 0.1 mm)
BWE			32.6	mm	Effective Bobbin Width
OD			0.35	mm	Maximum Primary Wire Diameter including insulation
INS			0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.29	mm	Bare conductor diameter
AWG			29	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			128	Cmils	Bare conductor effective area in circular mils
CMA			475	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
Primary Current Density (J)			4.17	Amps/mm^2	Primary Winding Current density (3.8 < J < 9.75)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			5.30	Amps	Peak Secondary Current
ISRMS			2.22	Amps	Secondary RMS Current

IO_PEAK			1.33	Amps	Secondary Peak Output Current
IO			1.33	Amps	Average Power Supply Output Current
IRIPPLE			1.78	Amps	Output Capacitor RMS Ripple Current
CMS			445	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			23	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.58	mm	Secondary Minimum Bare Conductor Diameter
ODS			1.36	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.39	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			578	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			61	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB			78	Volts	Bias Rectifier Maximum Peak Inverse Voltage
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1			12	Volts	Output Voltage
IO1_AVG			1.33	Amps	Average DC Output Current
PO1_AVG			16.00	Watts	Average Output Power
VD1			0.3	Volts	Output Diode Forward Voltage Drop
NS1			12.00		Output Winding Number of Turns
ISRMS1			2.225	Amps	Output Winding RMS Current
IRIPPLE1			1.78	Amps	Output Capacitor RMS Ripple Current
PIVS1			61	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS1			445	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			23	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.58	mm	Minimum Bare Conductor Diameter
ODS1			1.36	mm	Maximum Outside Diameter for Triple Insulated Wire

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7.4 PFC Inductor

7.4.1 Electrical Diagram

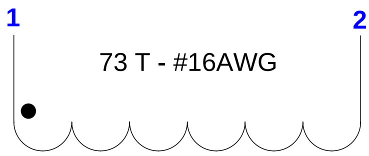

Figure 15 –PFC Choke Electrical Diagram

7.4.2 Electrical Specification

Primary Inductance	Pins 1- 2, measured at 100kHz	719 µH, -5/+5%
Core Effective Inductance		AL=135nH/N^2

7.4.3 Materials

Item	Description
[1]	Core: Toroidal Kool Mu Core by Magnetics. Part Number: 77439
[2]	Magnetic wire: 125/40-Litz wire

7.4.4 Inductor Build Diagram

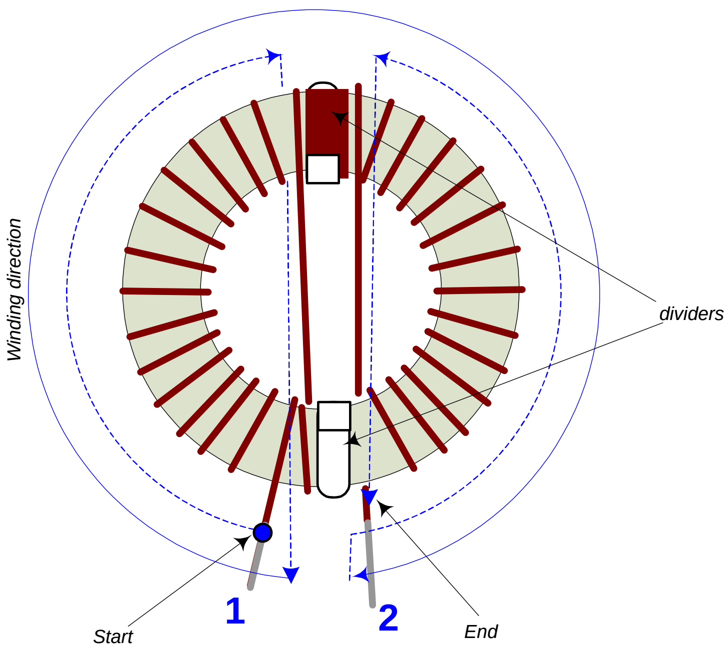

Figure 16 –PFC Choke Build Diagram

8 Performance Data

- All measurements performed at room temperature, 60 Hz input frequency.
- The unit was operated until the input power stabilized (>30 mins).
- All input power measurements were made sensing the input voltage directly at the AC inlet input terminals.
- All output voltage measurements were made at the board and did not include cable drop. This approach was taken as configuration of production units will vary (cable used vs blade connector, length of cable is used etc).

8.1 Overall Converter Efficiency

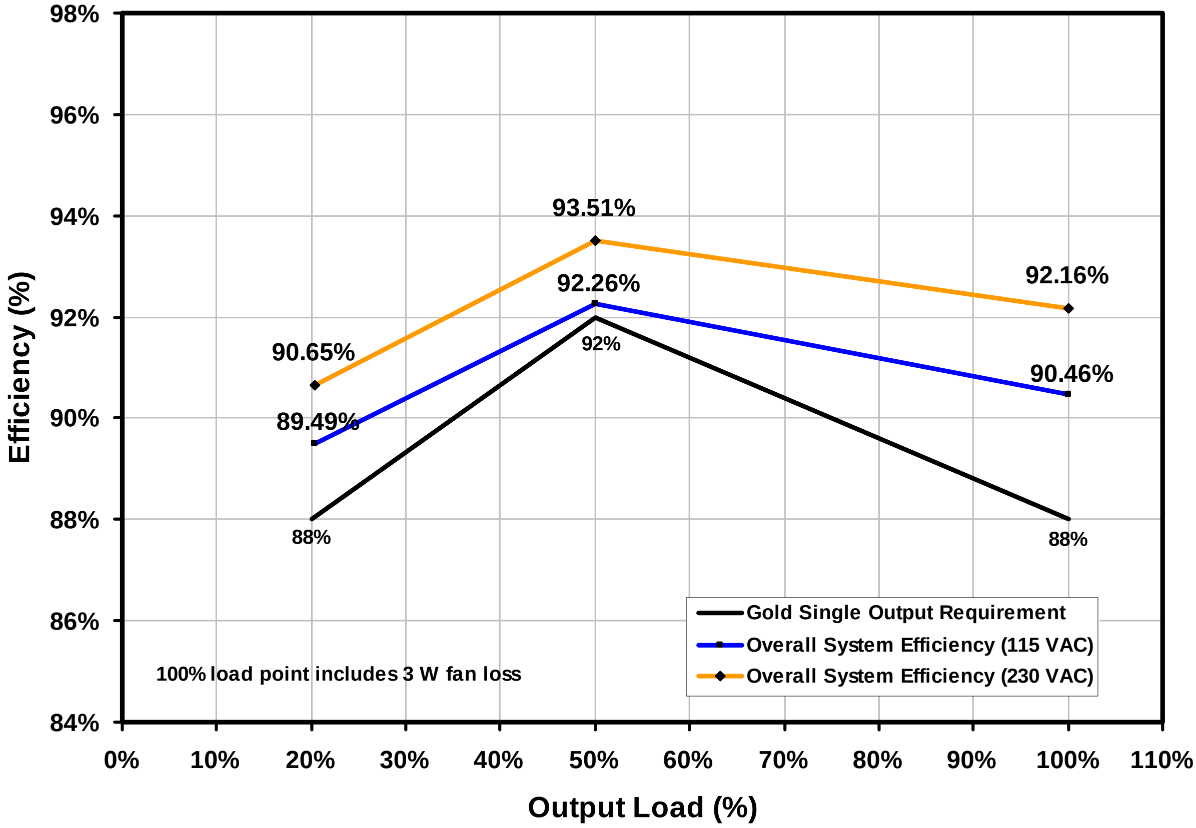

Figure 17- Efficiency vs Load at 115 VAC and 230 VAC, Room Temperature

Percent of Full Load	Efficiency (%)	
	115 VAC	230 VAC
20	89.49	90.65
50	92.26	93.51
100	90.46	92.16
80 PLUS GOLD Single Output requirement	***88% at 20% Load; 92% at 50% Load; 88% at 100% Load***	

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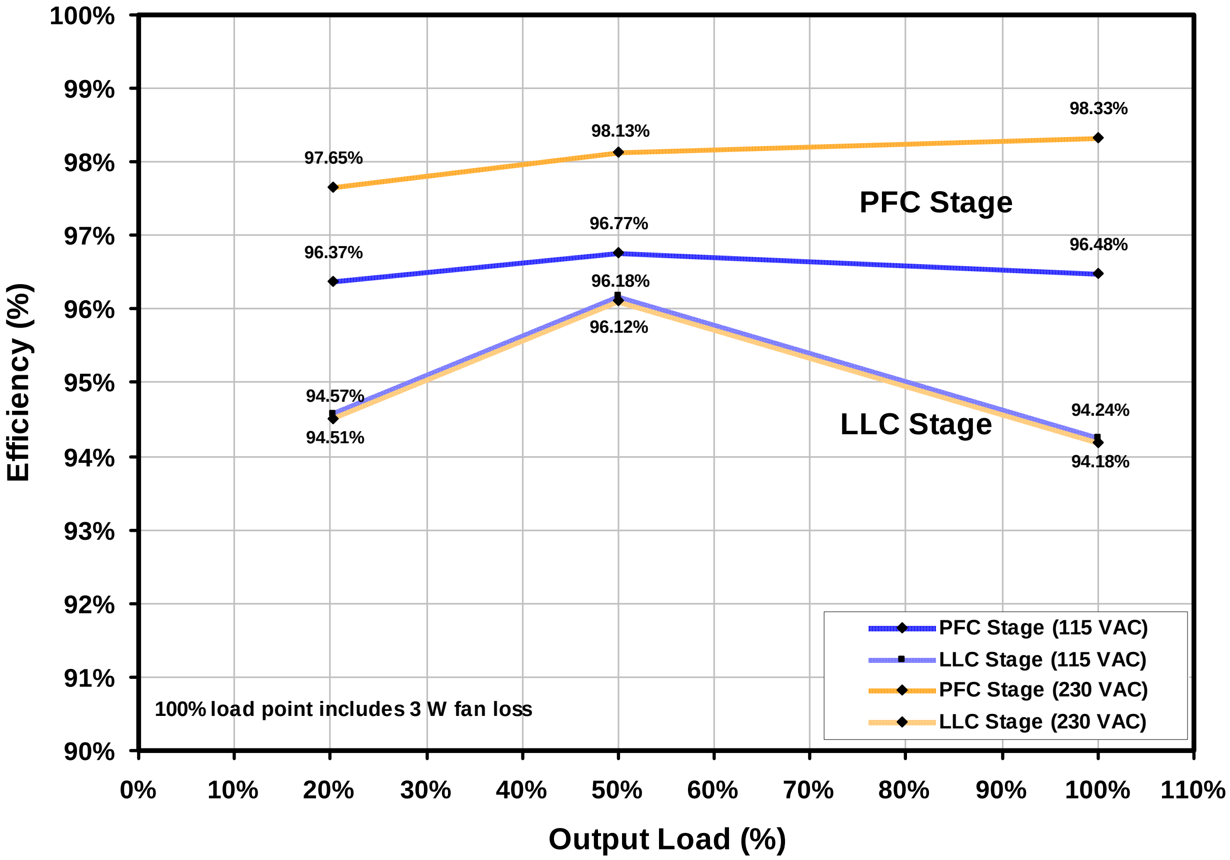
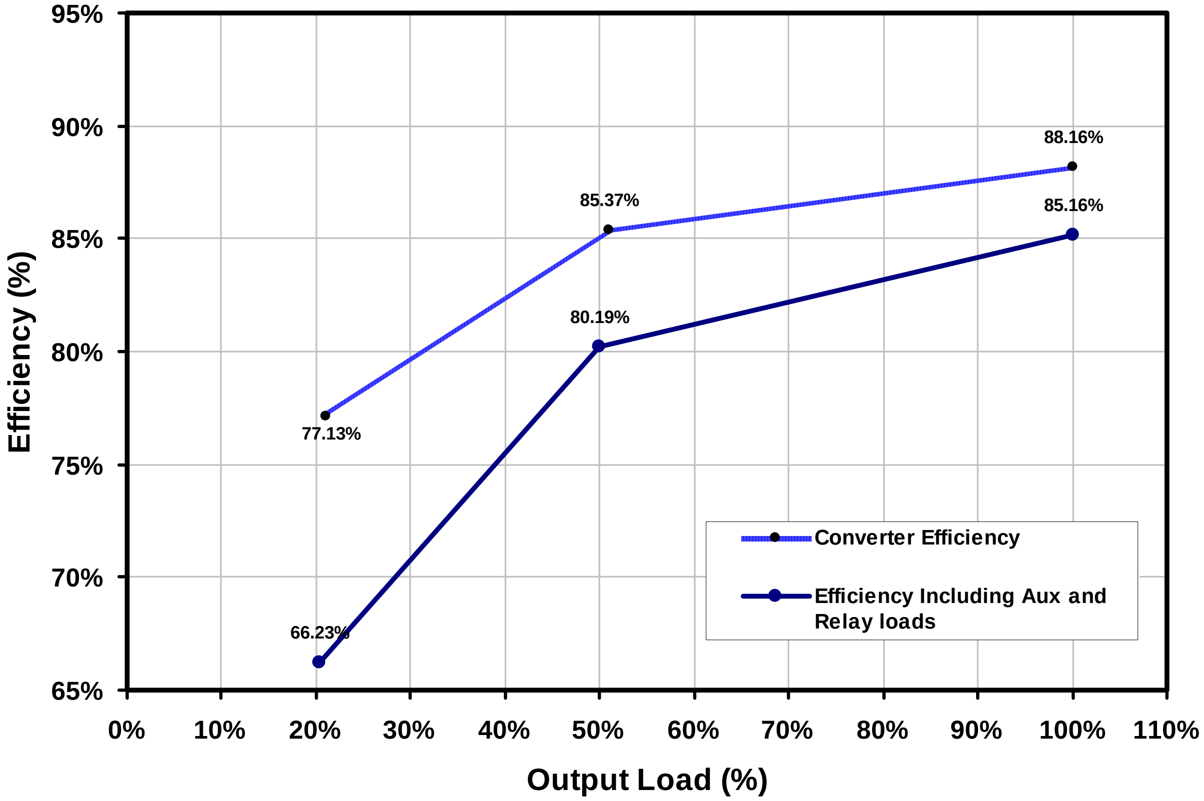
8.2 Efficiency of LLC and PFC Stages



8.3 Efficiency of Standby Converter



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8.4 No-load Input Power

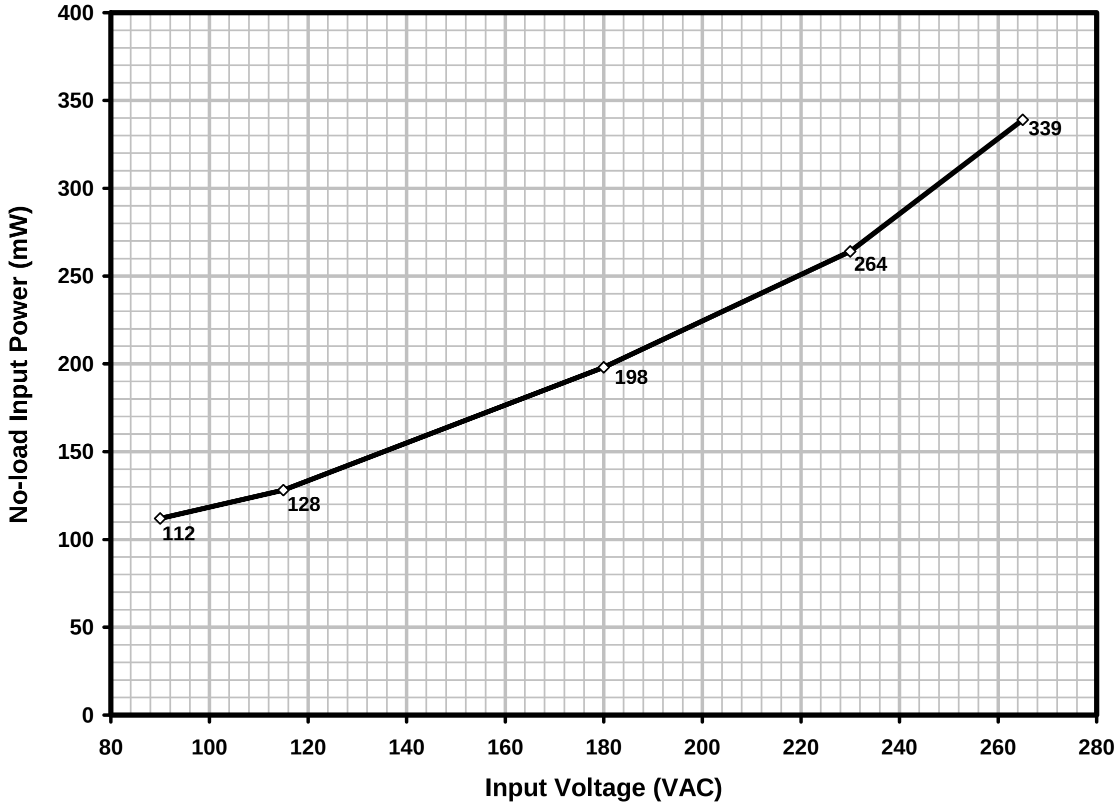

Figure 18- Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

8.5 Available Standby Output Power

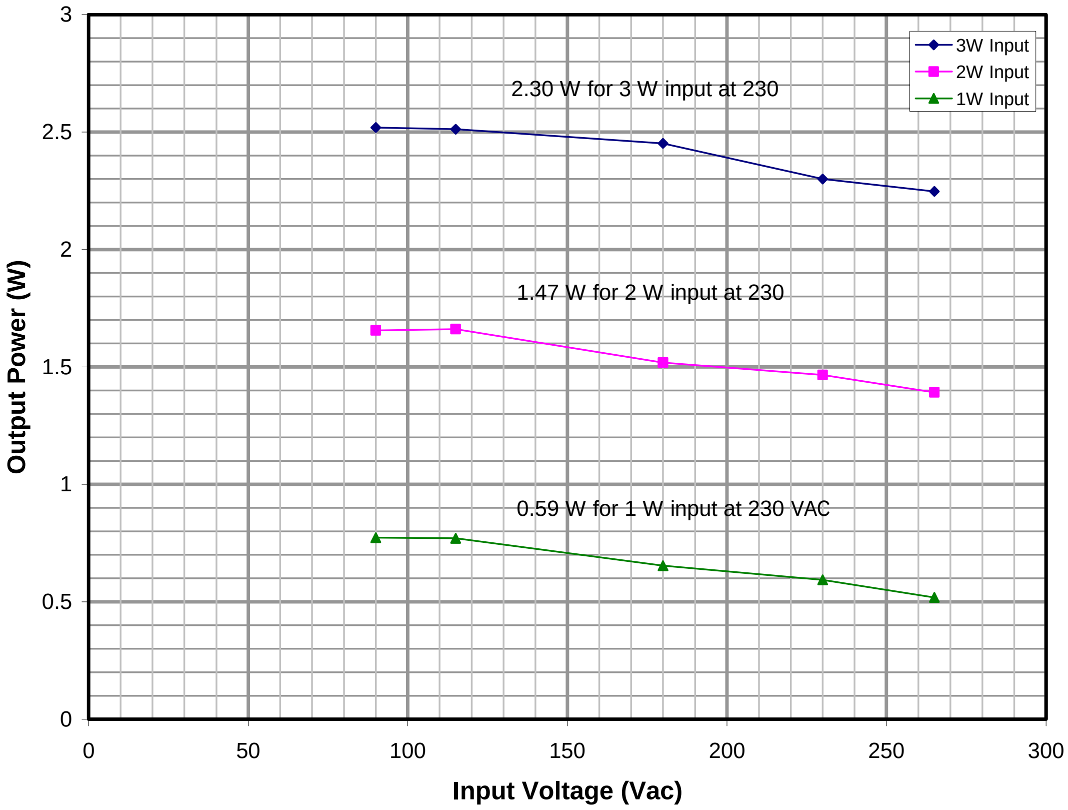

Figure 19- Output Power vs. Input Line Voltage at 1W, 2W and 3W Input Power, Room Temperature, 60 Hz.

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8.6 Regulation

8.6.1 Load

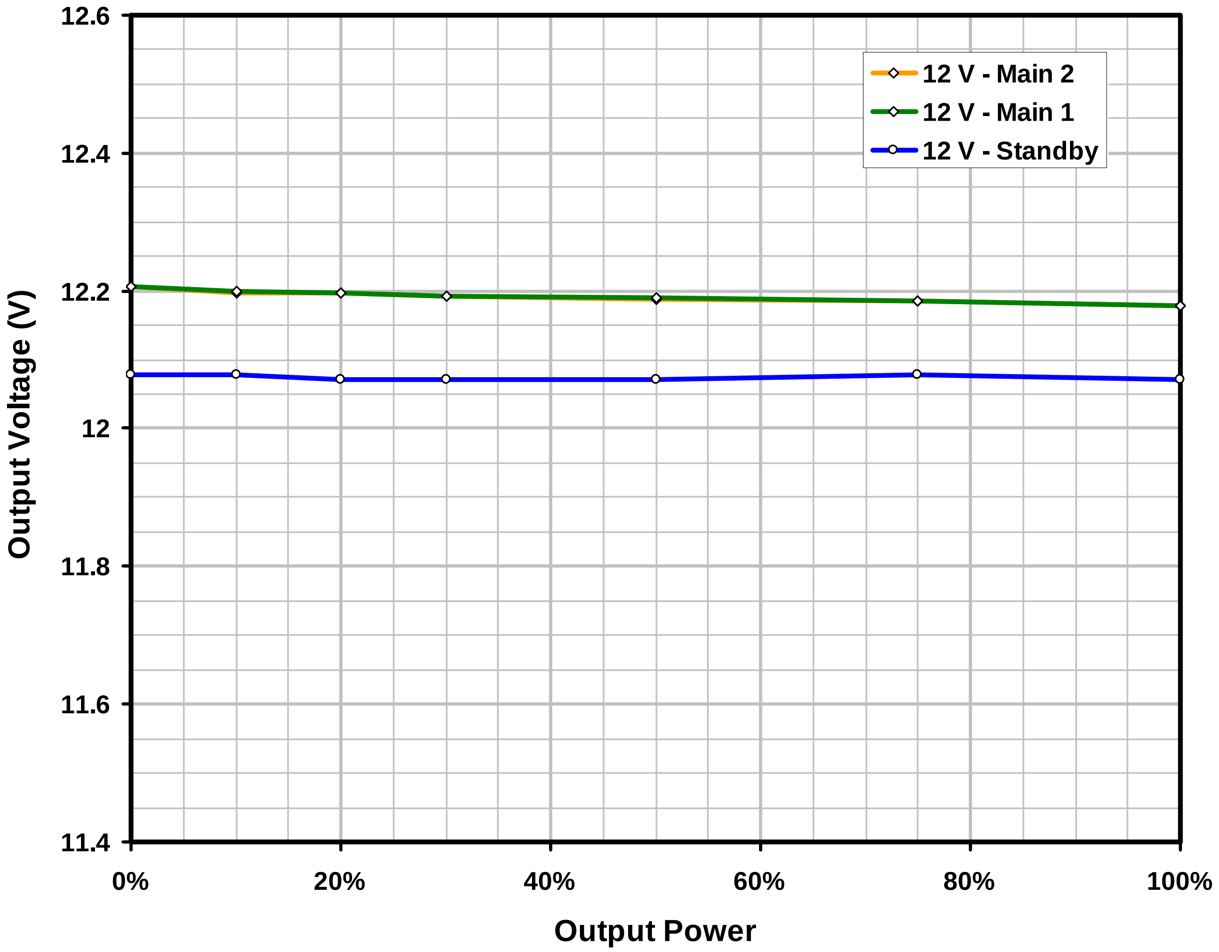

Figure 20 –Load Regulation, Room Temperature.

8.6.2 Line

Line regulation data is not applicable here as the PFC output which feeds the LLC stage is already regulated.

9 Thermal Performance

Item	Temperature (°C)		
	90 VAC, 47 Hz, 50% Load, Cooling Fan Not Running	265 VAC, 64 Hz, 50% Load, Cooling Fan Not Running	90 VAC, 47 Hz, 100% Load, Cooling Fan Running
Ambient	25	25	25
Common Mode (L5)	51.2	35.4	37.9
Common Mode (L1)	50.4	33.7	34.5
Bridge (D2)	92.9	51.1	71.6
PFC Choke (L7)	58.8	48.2	29.2
PFC MOSFET (Q18)	61.1	48.3	35.3
PFC Diode (D34)	69.6	49.7	35.8
LLC MOSFET (Q7)	63.3	61.1	38.6
LLC MOSFET (Q9)	57.7	57.7	39.1
LLC Inductor (T4)	62.5	66.9	48.1
LLC Transformer (T3)	61.4	61.7	36.7
Sync. Rect. FET (Q20)	58.7	57.5	44
Sync. Rect. FET (Q21)	58.4	57.1	44.1
S. R. Diode (D32)	56.6	55.8	45.7
S. R. Diode (D31)	55.7	57.2	45.3
TOPSwitch (U13)	47.9	45.4	31.9
Standby Xfmr(T2)	44.1	42.8	32.8
Standby S.R. FET (Q24)	42.8	42.9	35.7
Standby S.R. Diode (D30)	42.8	43.3	35.2

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10 Waveforms

10.1 Input AC Voltage and Current

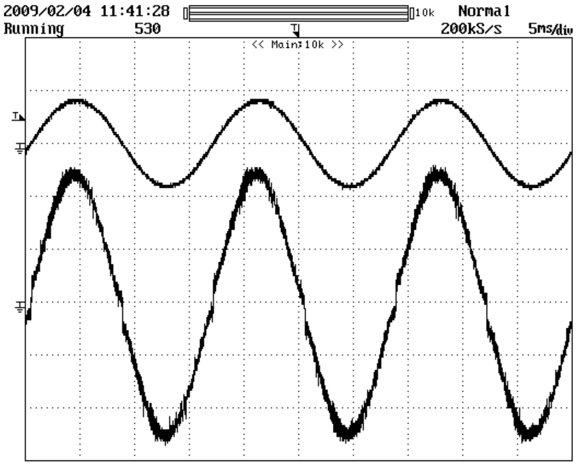

Figure 21 - 115 VAC, 50% Load.
Upper: Input Voltage, 200 V / div
Lower: Input Current, 2 A, 5 ms / div

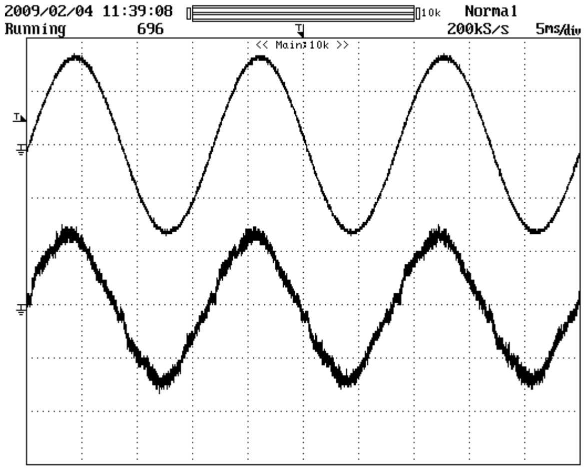

Figure 22 - 230 VAC, 50% Load
Upper: Input Voltage, 200 V / div
Lower: Input Current, 2 A, 5 ms / div

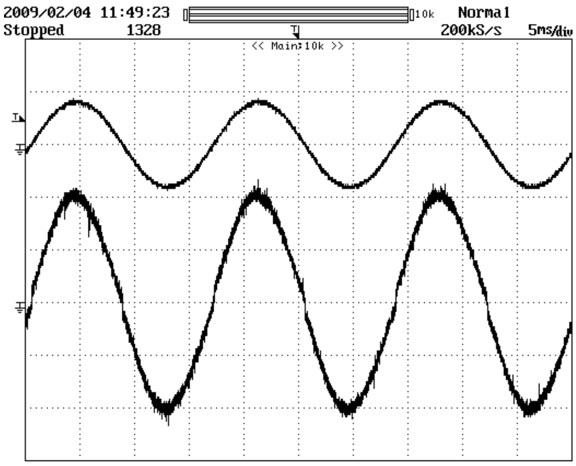

Figure 23 - 115 VAC, Full Load.
Upper: Input Voltage, 200 V / div
Lower: Input Current, 5 A, 5 ms / div

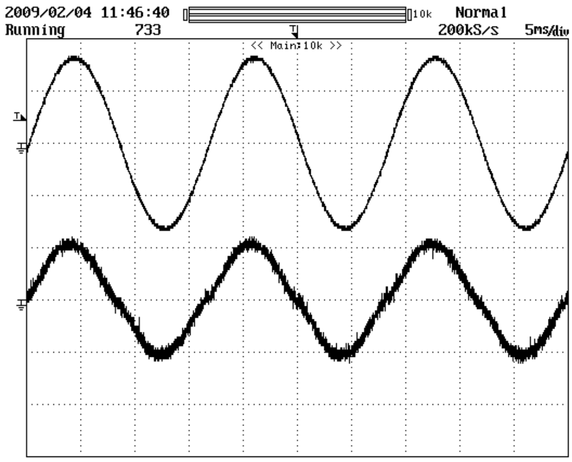

Figure 24 - 230 VAC, Full Load
Upper: Input Voltage, 200 V / div
Lower: Input Current, 5 A, 5 ms / div

10.2 PFC MOSFET Drain Voltage and Current, Normal Operation

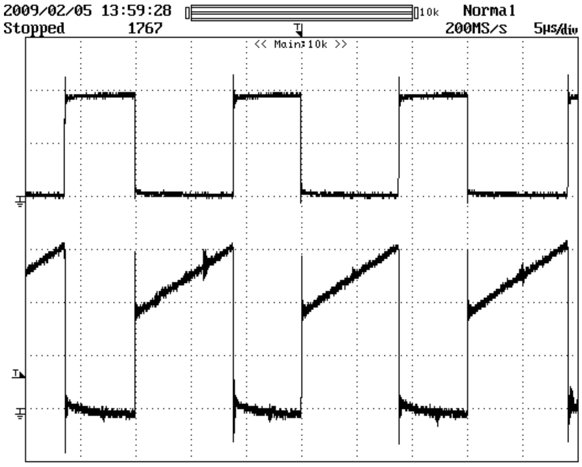

Figure 25 - 115 VAC, Full Load.
Upper: PFC FET Drain Voltage, 200 V / div;
Lower: PFC FET Drain Current, 2 A, 5 µs / div

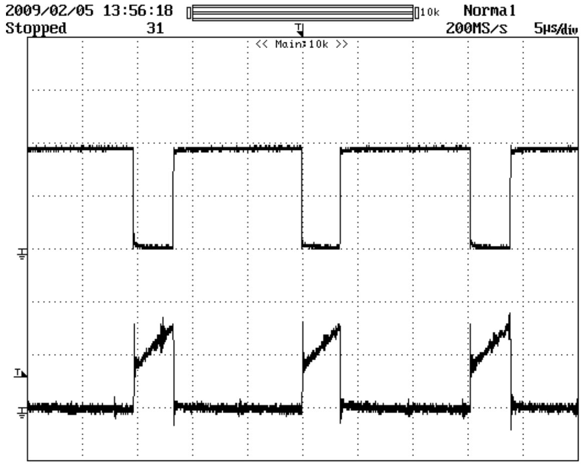

Figure 26 - 230 VAC, Full Load
Upper: PFC FET Drain Voltage, 200 V / div;
Lower: PFC FET Drain Current, 2 A, 5 µs / div

10.3 LLC Resonant Voltage and Current, Normal Operation

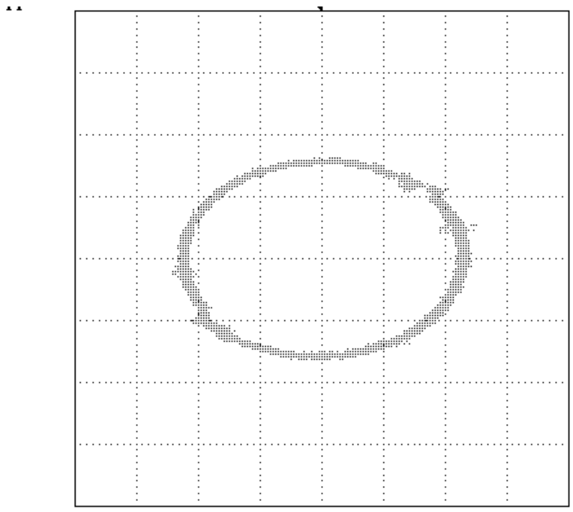

Figure 27 – 50% Load.
X: Resonant current, 1 A / div
Y: Resonant capacitor voltage 50 V/div

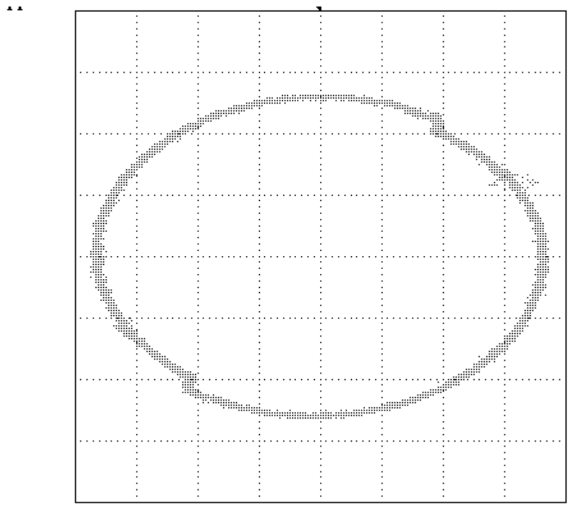

Figure 28 - Full Load
X: Resonant current, 1 A / div
Y: Resonant capacitor voltage 50 V/div

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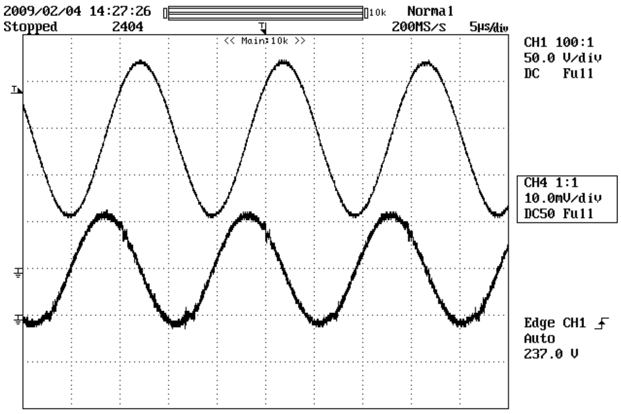

Figure 29 – 50% Load.
Upper: Resonant capacitor voltage, 50V / div;
Lower: Resonant current 2 A, 5µs/div

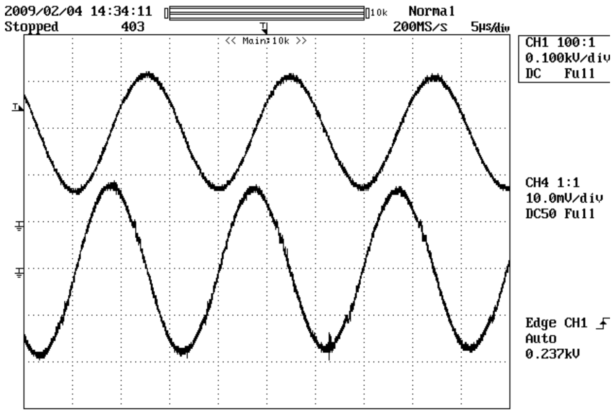

Figure 30 - Full Load.
Upper: Resonant capacitor voltage, 100V /div;
Lower: Resonant current 2 A, 5µs/div

10.4 LLC MOSFETS Drain Voltage and Current, Normal Operation

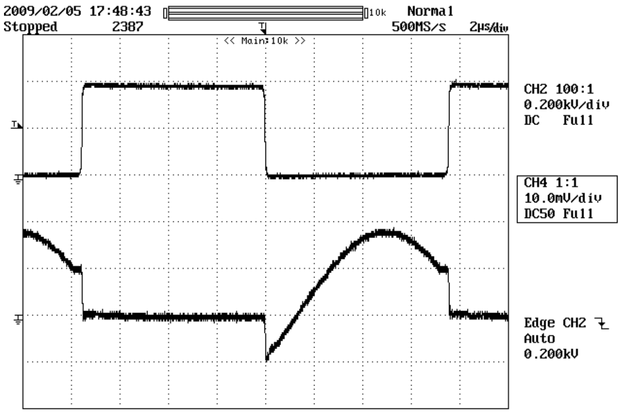

Figure 31 – Full Load.
Upper: High side FET Drain Voltage, 200 V / div;
Lower: Current, 2 A/div, 2 µs /div

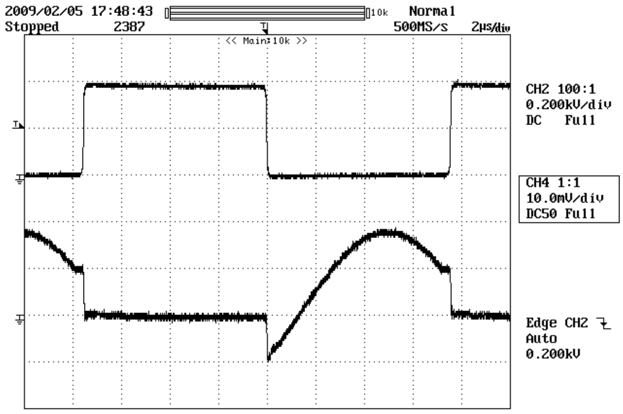

Figure 32 - Full Load
Upper: Low side FET Drain Voltage, 200 V / div;
Lower: Current, 2 A/div, 2 µs /div

10.5 LLC Synchronous Rectifier MOSFET Drain Voltage and Gate Signal, Normal Operation

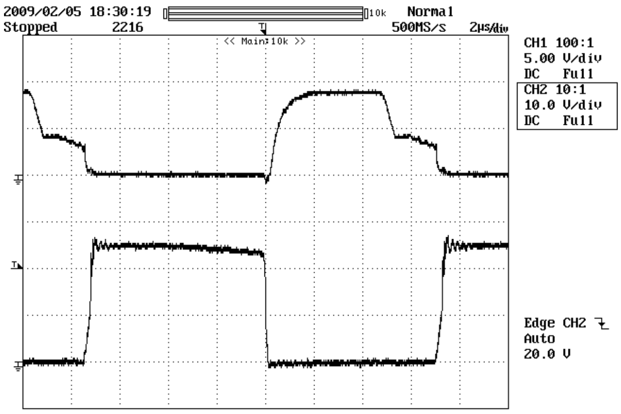

Figure 33 – 50% Load.
Upper: LLC Sync. Rect. FET Gate Signal 5 V / div; Lower: Drain Voltage, 10V, 2µs /div

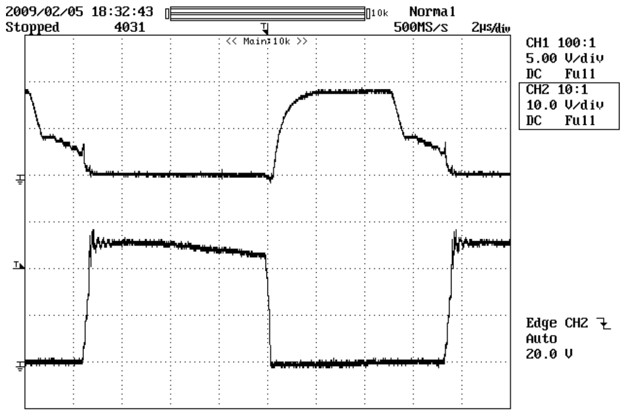

Figure 34 - Full Load
Upper: LLC Sync. Rect. FET Gate Signal 5 V / div; Lower: Drain Voltage, 10V, 2µs /div

10.6 TOPSwitch based Standby Converter Waveforms

10.6.1 Drain Voltage and Current and Synchronous Rectifier Drive Signals

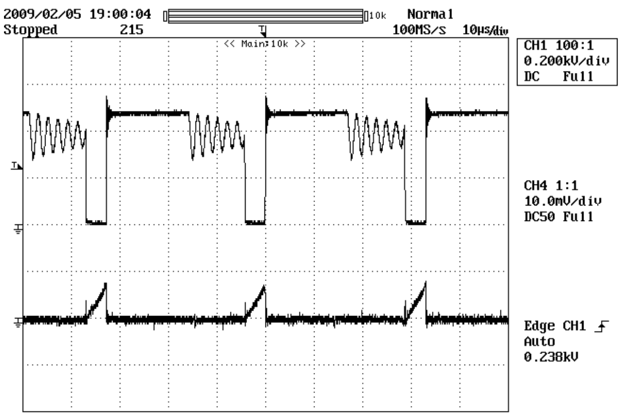

Figure 35 – Full Load.
Upper: TopSwitch Drain Voltage 200 V / div; Lower: Drain Current, 1A, 10µs /div

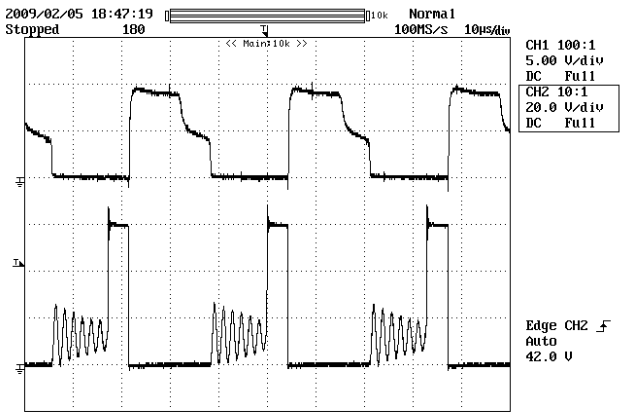

Figure 36 - Full Load
Upper: Standby Sync. Rect. FET Gate Signal 5 V / div; Lower: Drain Voltage, 10V, 10µs /div

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10.7 Start-up Profile

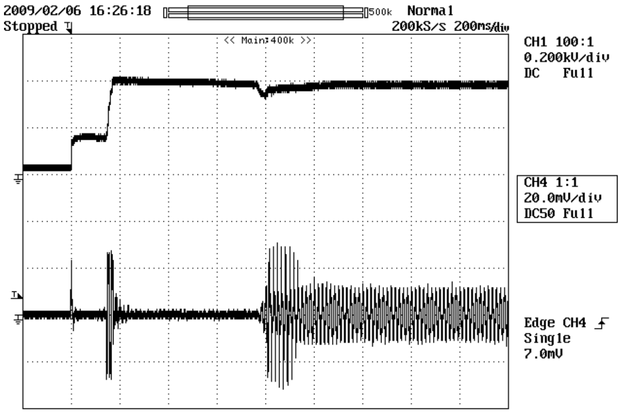

Figure 37 – Upper: PFC Voltage Start-up Profile, 115 VAC, 200 V/div;
Lower: AC Input Current, 10 A, 200 ms / div.

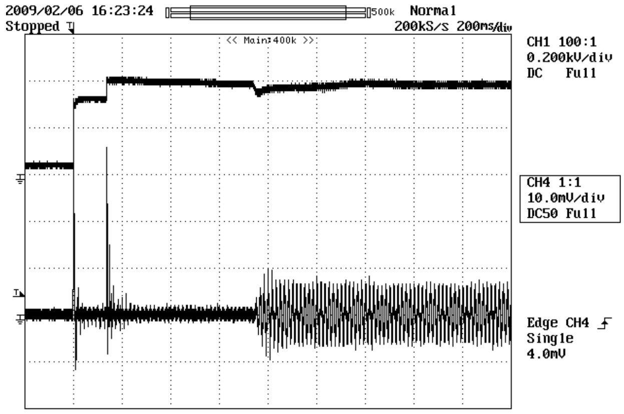

Figure 38 - Upper: PFC Voltage Start-up Profile, 230 VAC, 200 V/div;
Lower: AC Input Current, 5 A, 200 ms / div.

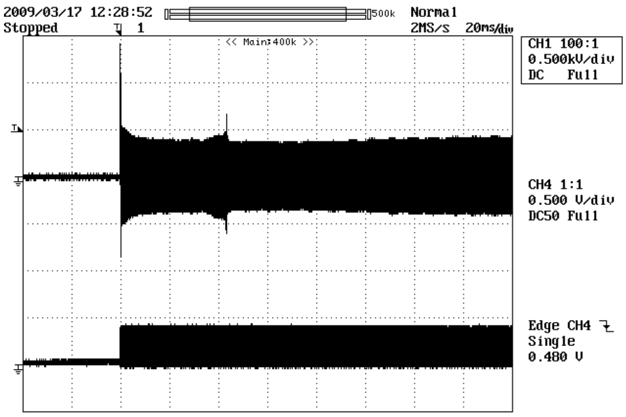

Figure 39 – Upper: LLC Primary Current Start-up Profile, 5 A/div;
Lower: LLC Low Side MOSFET Voltage, 500 V, 20 ms / div.

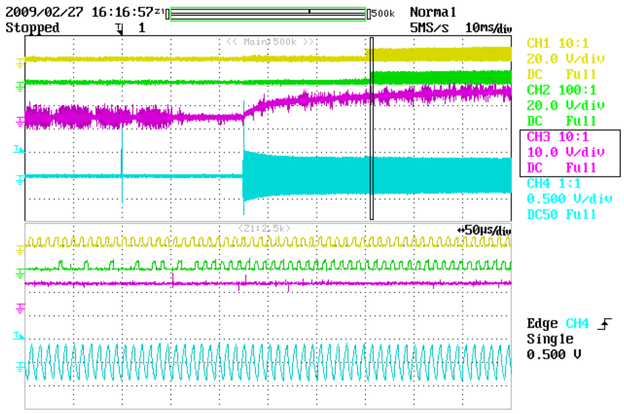

Figure 40 – Upper: LLC Secondary Synchronous Rectifier High Side MOSFET Gate Start-up Profile, 20 V/div;
Middle 2nd : Synchronous Rectifier High Side MOSFET Gate Signal, 20 V / div;
Middle 3rd : Main Output Voltage, 10 V / div;
Bottom: LLC Primary Current, 5 A/div, 10ms/div

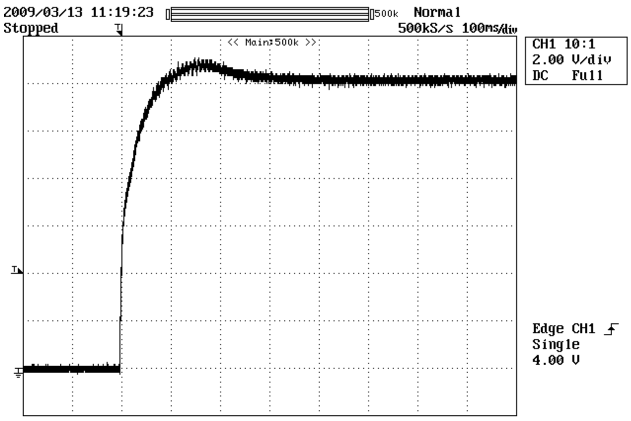

Figure 41 – 12V Main Start-up Profile,
2 V, 100 ms /div;

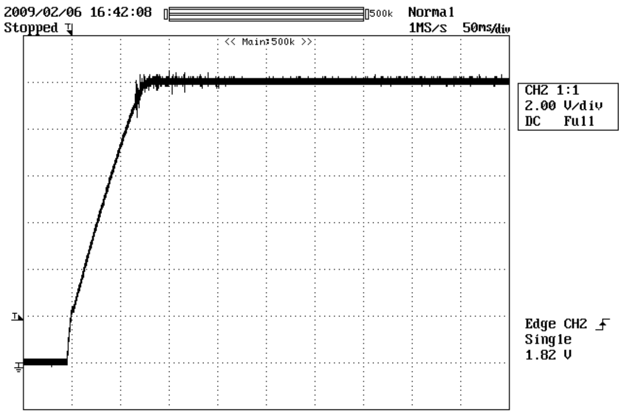

Figure 42 - 12V Standby Start-up Profile,
2 V, 200ms/div;.

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10.8 Overload and Short Circuit Test

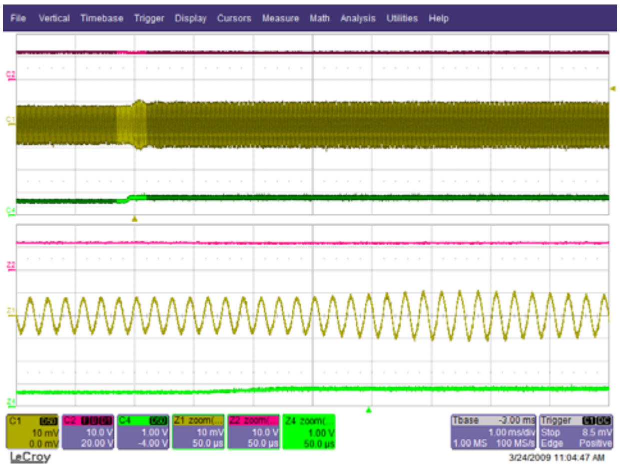

Figure 43 – 125% Overload Test
Upper: Main Output Voltage, 10 V /div;
Middle: LLC Primary Current, 5 A/div;
Lower: Main Load Current, 50 A/div, 1 ms/div

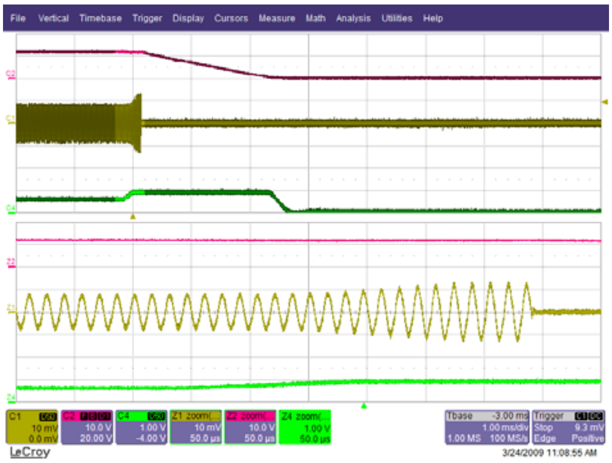

Figure 44 - 150% Overload Test
Upper: Main Output Voltage, 10 V /div;
Middle: LLC Primary Current, 5 A/div;
Lower: Main Load Current, 50 A/div, 1 ms/div

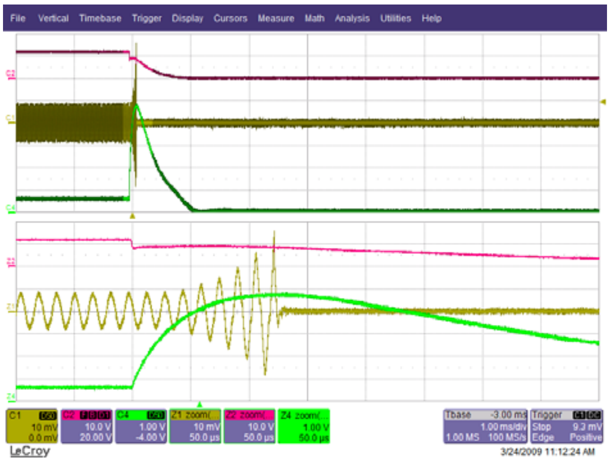

Figure 45 – Short Circuit Test
Upper: Main Output Voltage, 10 V /div;
Middle: LLC Primary Current, 5 A/div;
Lower: Main Load Current, 50 A/div, 1 ms/div

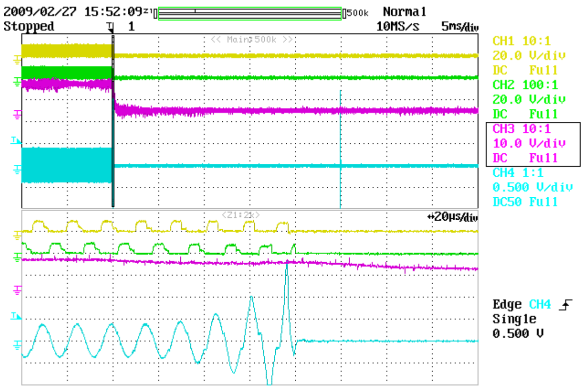

Figure 46 - Short Circuit Test
Upper: High Side Sync. Rect. Gate Signal, 20 V /div;
Middle 2nd: High Side Sync. Rect. Gate Signal, 20 V /div;
Middle 3rd: Main Output Voltage, 10 V/div;
Lower: LLC Primary Current, 5 A/div, 5 ms/div

10.9 Load Transient Response (75% to 100% Load Step)

In the figures shown below, signal averaging was used to better enable viewing the load transient response. The oscilloscope was triggered using the load current step as a trigger source. Since the output switching and line frequency occur essentially at random with respect to the load transient, contributions to the output ripple from these sources will average out, leaving the contribution only from the load step response.

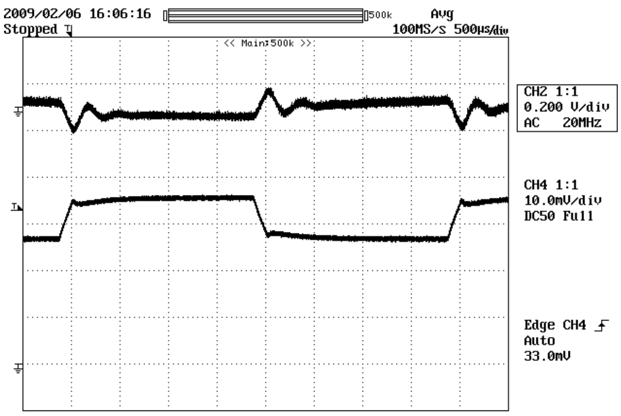

Figure 47 – 12 V Main Transient Response, 75-100-75% Load Step. Upper: Output Voltage, 200 mV/div; Lower: Load Current, 8 A, 500 µs / div.

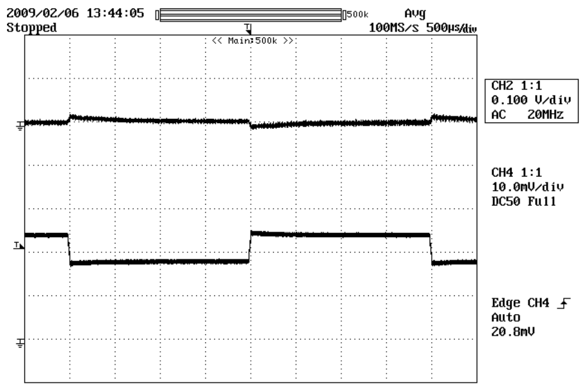

Figure 48 – 12 V Standby Transient Response, 230 VAC, 75-100-75% Load Step Upper: Output Voltage, 100 mV/div; Lower: Load Current 0.5 A, 500 µs / div.

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10.10 Output Ripple Measurements

10.10.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pickup. Details of the probe modification are provided in the Figures below.

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF/50 V ceramic type and one (1) 1.0 μF/50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

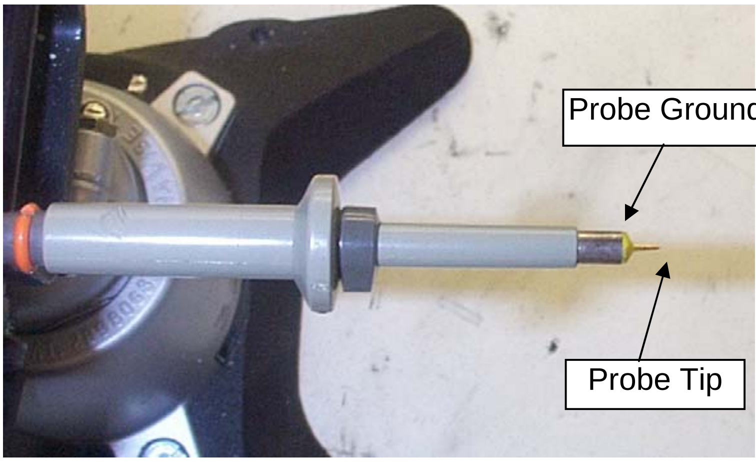

Figure 49 - Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

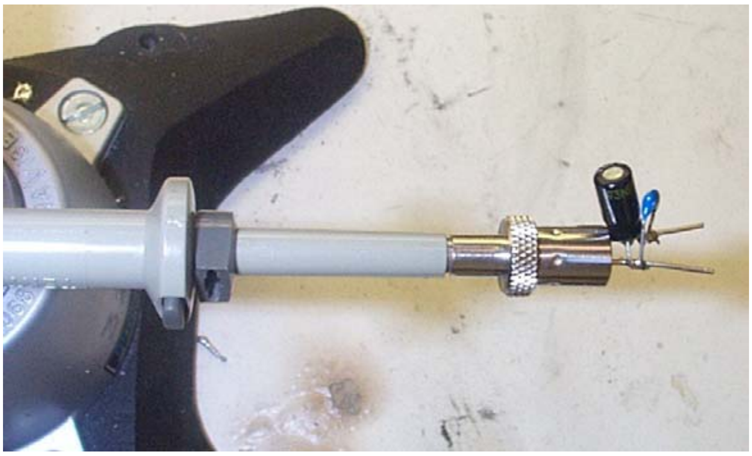

Figure 50 - Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

10.10.2 Measurement Results

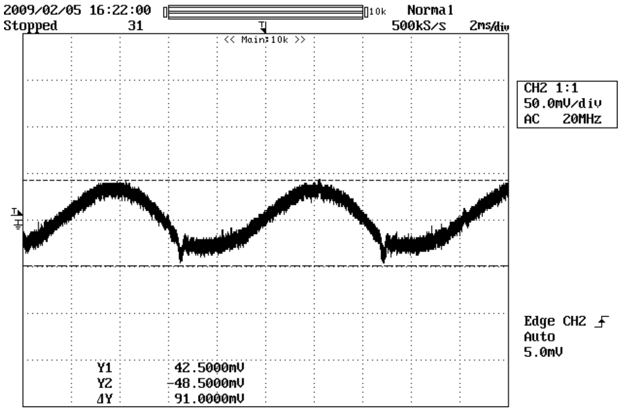

Figure 51 – 12V Main Ripple, 115 VAC, Full Load. 2 ms, 50 mV / div

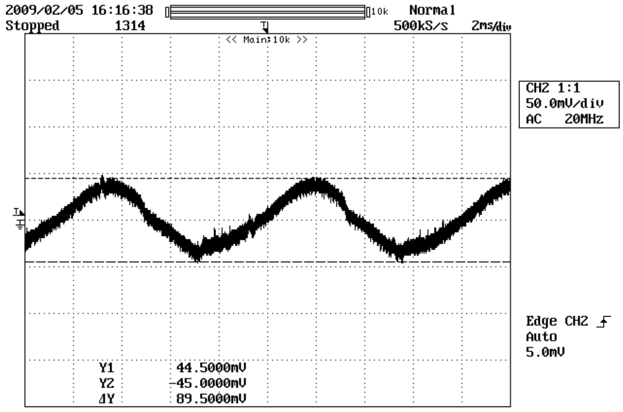

Figure 52 – 12V Main V Ripple, 230 VAC, Full Load. 2 ms, 50 mV / div

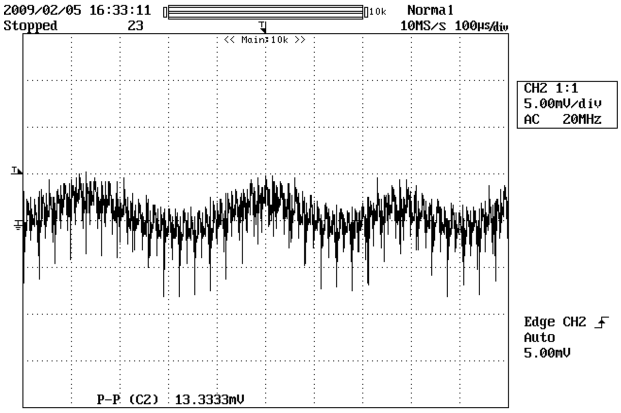

Figure 53 – 12V Standby Ripple, 115 VAC, Full Load. 100 µs, 5 mV /div

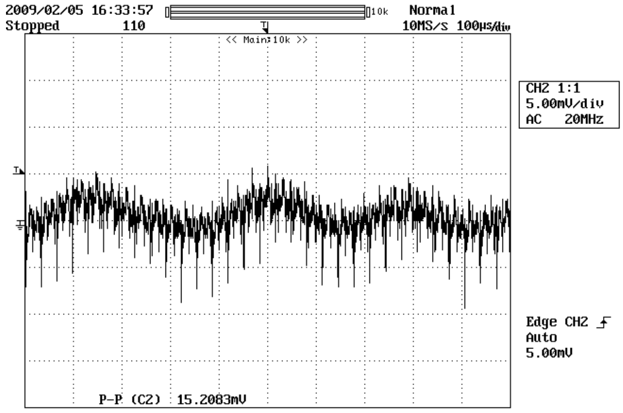

Figure 54 – 12V Standby Ripple, 230 VAC, Full Load. 100µs, 5 mV /div

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11 Control Loop Measurements

Measurement still to be taken

12 Line Surge

Testing still to be performed

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13 Conducted EMI

Measurement still to be taken.

14 Revision History

Date	Author	Revision	Description & changes	Reviewed
08-Feb-09	JY	0.3	First Draft	PV
25-Mar-09	JY	1.0	Updated Schematics, BOM, standby transformer, startup, overload and short circuit waveform	ME_PV_AS_KM

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