MEASUREMENTS

A Typical 250W LCD TV AC-DC Power Supply application with TEA1611 ZVS Half-Bridge Resonant Controller

Rev.01 — March 21th, 2008

Document information

Info	Content
Keywords	SwingChip™, TEA1611, Half bridge, LLC Resonant, High efficiency, Zero voltage switching, Resonant frequency, Leakage inductance.
Abstract	The TEA1611 is a controller of Half Bridge LLC Resonant converter, this report describes a 250W Resonant Switching Mode Power Supply for a typical LCD TV reference design based upon the TEA1611, meanwhile PFC and Standby stage also together in reference design, the no load input power will around 350mW at high mains input, and efficiency higher than 87% for universal mains input with schottky rectifiers, and good cross regulation without any compensation circuit, so there are many advantages suitable for LCD-TV SMPS application, the detail test data will descript in this report.

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1. MEASUREMENTS

— Test Facilities

- Programmable AC Source: Chroma, Model 61503
- Power Analyzer: Chroma, Model 6630
- DC Electronic Load: Chroma, Model 63102
- Digital Phosphor Oscilloscope: Tektronix, Model TDS5104B
- 6 ½ Digit Multimeter: Agilent, Model 34401A

1.1 Standby Power Consumption

Measure the input power dissipation at no load condition, press the STBY button to switch off PFC & 24V & 12V, but remain 5V stand by.

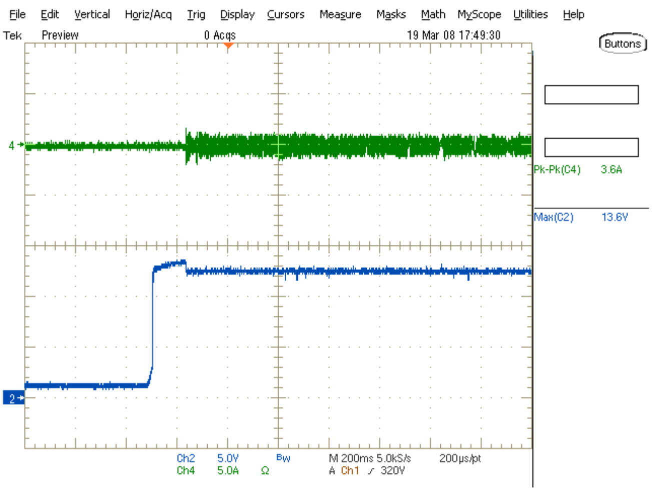
The measurement result

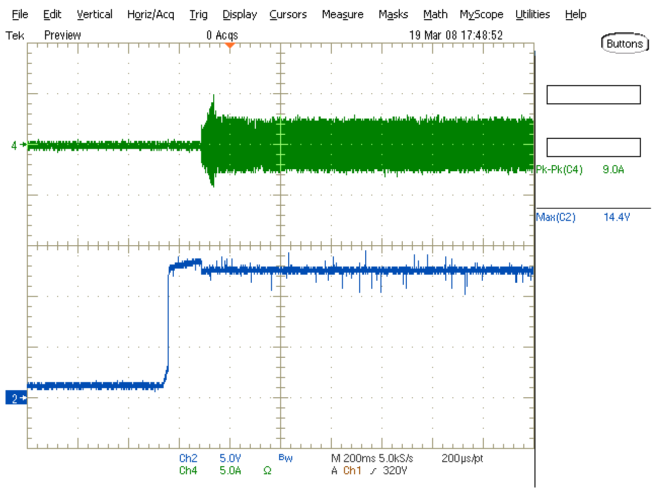
Vac input	Load	24V	12V	5V	Pin
90V/60Hz	0A	0	0	5.12V	0.15W
264V/50Hz	0A	0	0	5.12V	0.32W

1.2 Start-up behavior

1.2.1 Measure the VDD(pin13) of TEA1611 to make sure the waveform normally, the Vcc should be goes to Vcc_start point, then drop to lower Vcc_start but higher than Vcc_UVLO.

1.2.2 Measure the resonant current at start-up condition, as soon as the Vcc reach Vcc_start level the inrush current will be occur but minimize by soft-start during the start-up condition.
The waveforms as below:

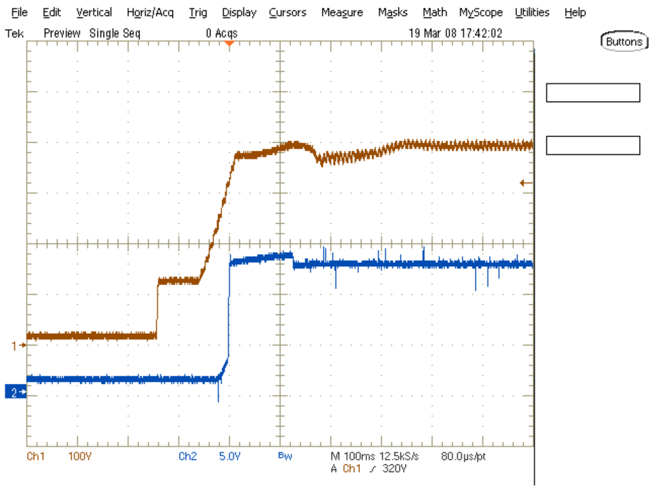




Ch2: VDD (pin13)
Ch4: Resonant Current (primary)

1.2.3 Measure the Vbus cross on bulk capacitor to ground, in order to secure start-up the resonant tank, VDD of TEA1611 must be start-up after Vbus reach to around 300V.

The waveform as below:

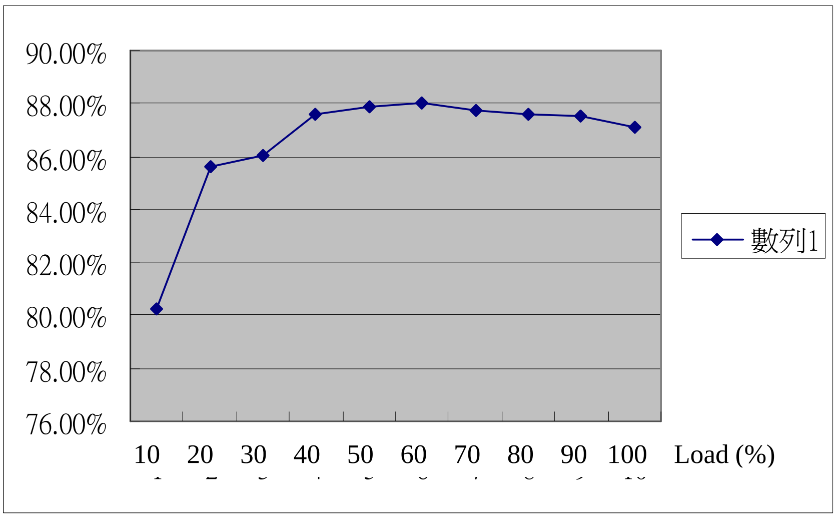


Ch1: Vbus (PFC)
Ch2: VDD (pin1)

1.3 Efficiency

Measure the input & output power by full load from low mains to high mains, calculate the efficiency after burn in 30 minutes at 25°C room without fan, the result as below:

VAC input	P_in	P_out	Efficiency
90V/60Hz	290.0W	252.6W	87.1%
115V/60Hz	283.8W	252.6W	89.0%
180V/50Hz	279.0W	252.6W	90.5%
230V/50Hz	276.9W	252.6W	91.2%
264V/50Hz	276.3W	252.6W	91.4%



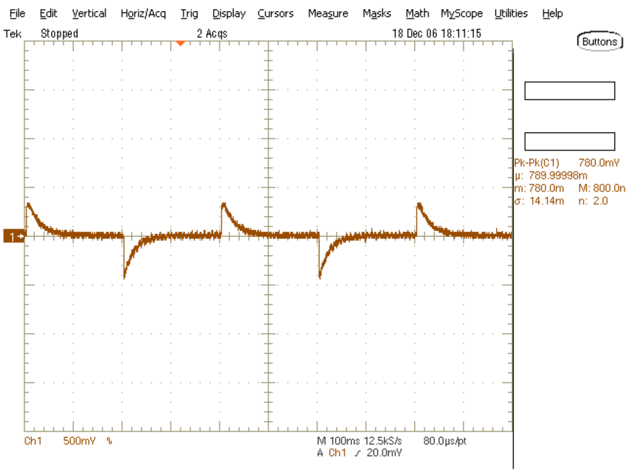
Efficiency Measurement 10%~100% load at 90Vac input.

1.4 Transient Response

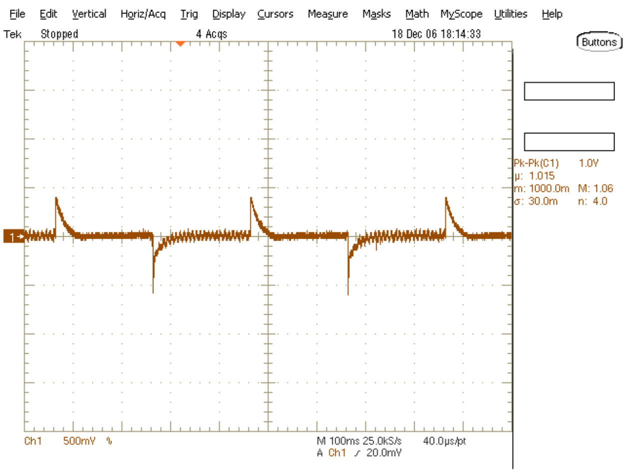
Measure the 12V & 24V output by dynamic loading, the transient voltage should be meet spec and without ringing or oscillation.

1.4.1 The measurement result (condition: 0 - 100% of full load, 200mS duty cycle, 1mA/uS rise/fall time)

Output Voltage	Over Shoot	Under Shoot	Ringing
12V	310mV	420mV	Free
24V	410mV	580mV	Free



12V (0 ~ 4A)



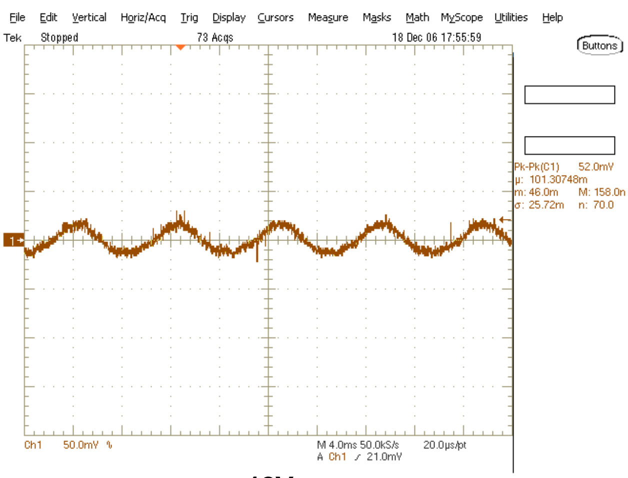
24V (0 ~ 8A)

1.5 Output Ripple & Noise

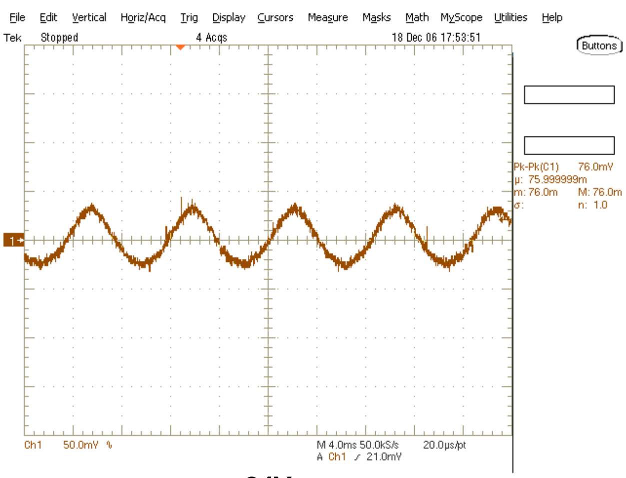
Ripple & Noise are measured by using 20MHz bandwidth limited oscilloscope with a 10uF paralleled with a high-frequency 0.1uF capacitor across each output by full load.

The measurement result

Vac input	Vout	Load	Ripple & Noise	Spec.	Result
90~264Vac / 50Hz	24V	8A	76mV	<100mV	Pass
	12V	4A	52mV	<100mV	Pass



12V



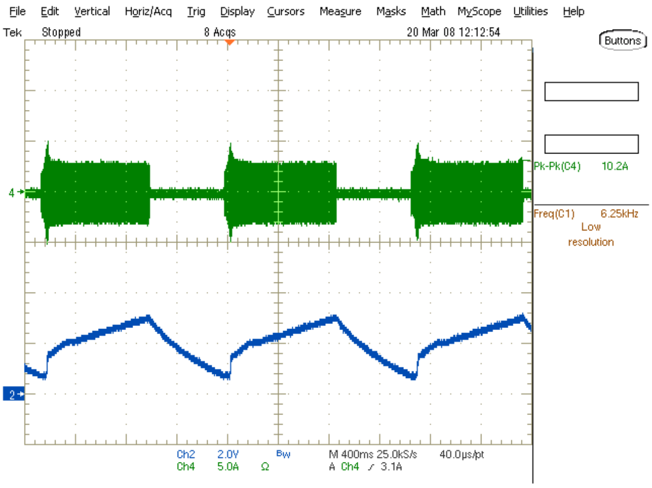
24V

1.6 Over Power Protection

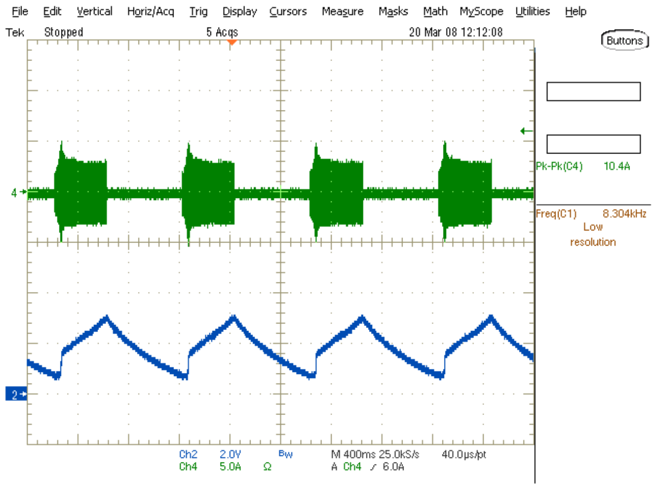
Measure the OPP trogger level by increase output loading gradually per universal AC input, as the result of higher load will put the CT charge time shorter of safe-restart mode, meanwhile, during the CT charge time, system allow to handle a peak load without trigger OPP untile a 3.0V present on CT pin level got reached.

The measurement result (12V_4A, 24V_8A, 5V_2A, 250W max power)

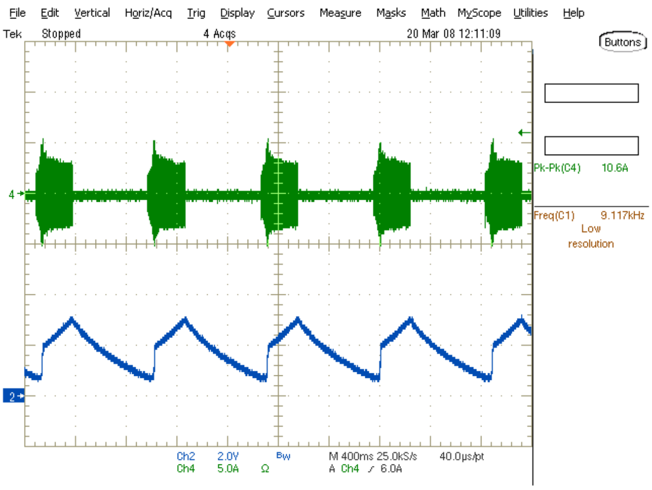
Vac input	OPP trigger level	Pout_max	Rating
90V/60Hz	305W	252.6W	120.7%
115V/60Hz	305W	252.6W	120.7%
230V/50Hz	305W	252.6W	120.7%
264V/50Hz	305W	252.6W	120.7%



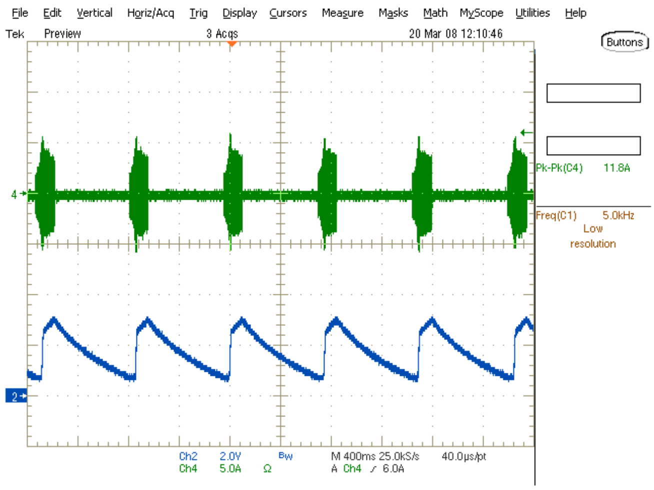
305W



320W



335W



350W

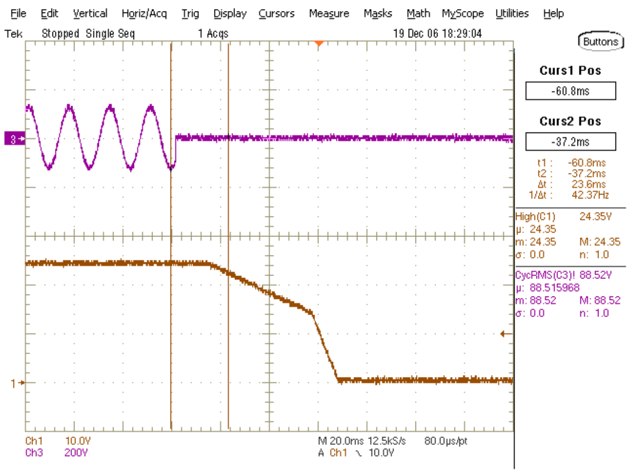
1.7 Hold-Up Time

1.7.1 Test Condition

Set output at full load, measure the time interval between AC input off (stop charge to bulk capacitor) and output voltage falling to lower limit of rate value (90%).

1.7.2 Test Result

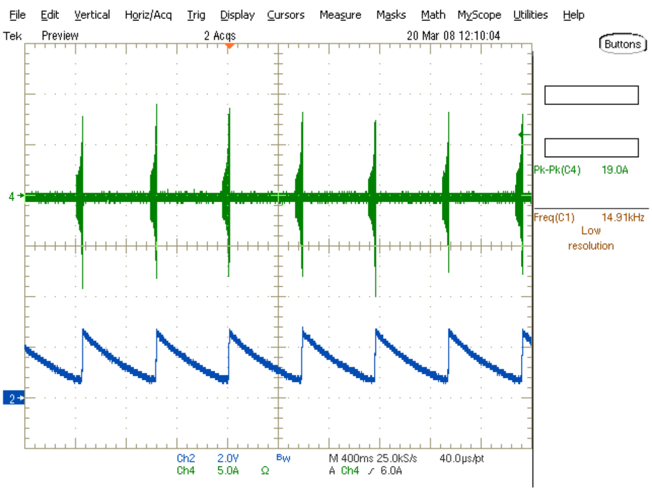
Vac input	Hold-up time	Spec.	Result
90V/60Hz	23.6mS	> 16mS	Pass
115V/60Hz	36.2mS		
230V/50Hz	127.6mS		
264V/50Hz	169.2mS		



1.8 Short Circuit Protection

1.8.1 Test Condition

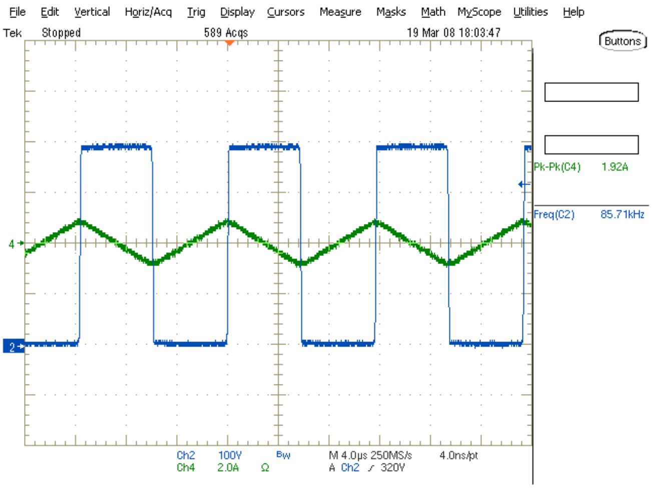
Short the output of the power supply during no load and full load, system will enter the safe-restart mode, here we got a 19.0A short circuit current.



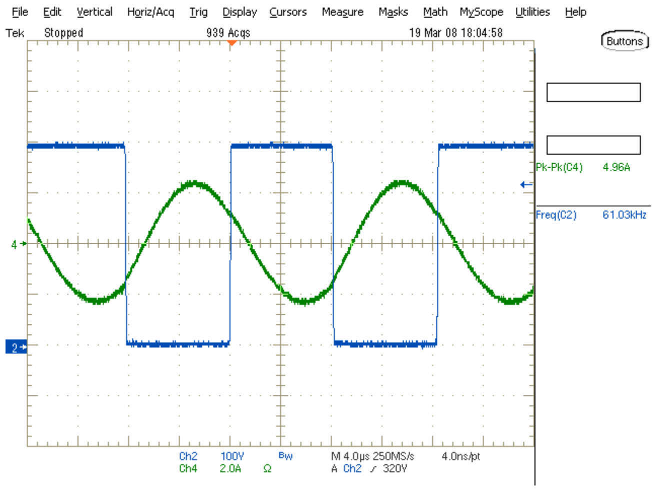
Ch2: CT (pin4)
Ch4: Resonant Current (primary)

1.9 Resonant Current Measurement

Measure the resonant current compare with gate driver and switching waveform, to make sure the MOSFETs under ZVS operation and resonant current works normally.



No Load



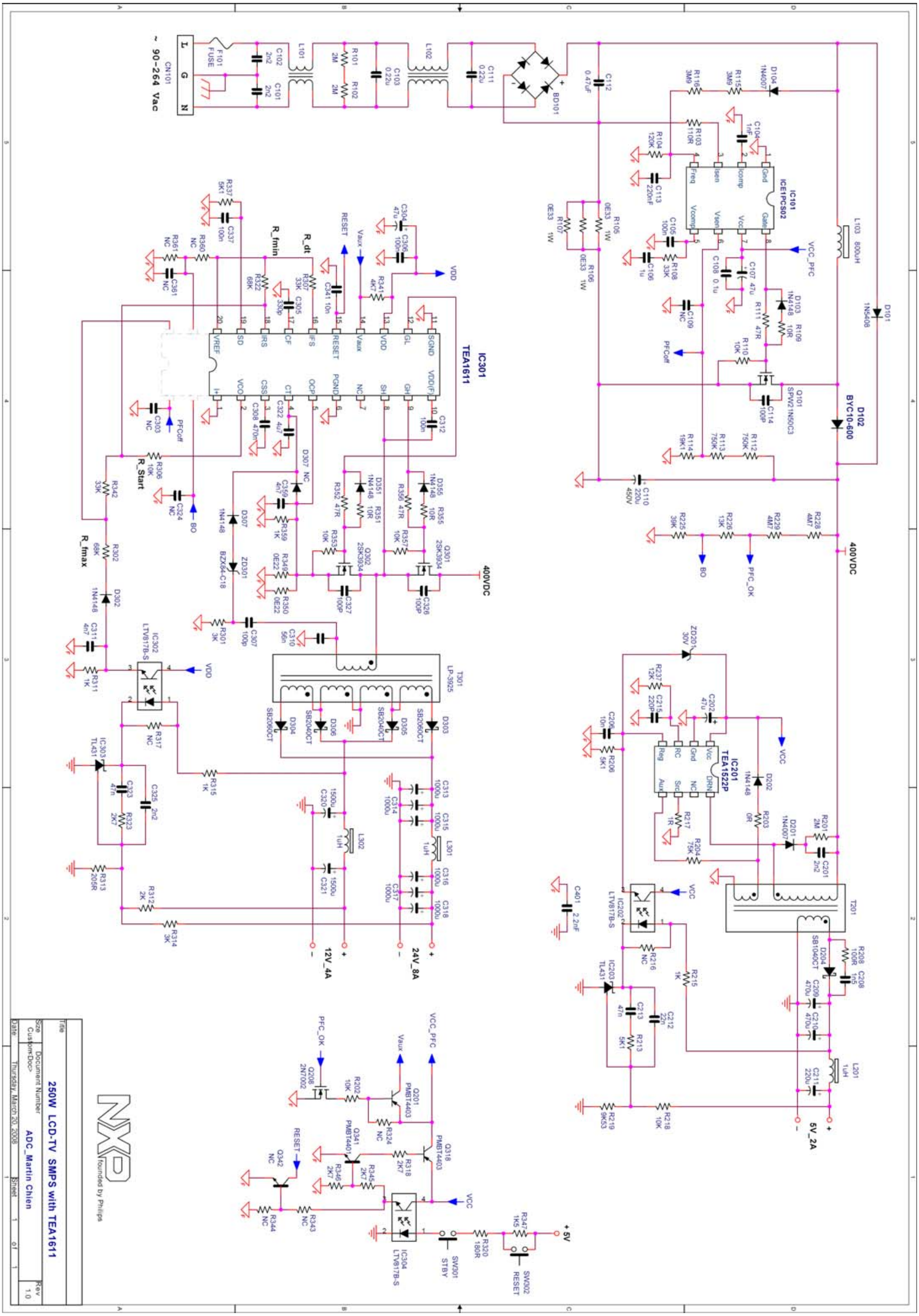
Full Load

2.0 Cross Regulation

Measure the Vout regulation by cross max load of 12V and 24V respectively.

Load Conditions	12V		24V		Spec	Result
	Measure	Regulation	Measure	Regulation		
12V_4A 24V_0A	11.6V	3.3%	24.8V	3.3%	< 5%	Pass
12V_0A 24V_8A	12.4V	3.3%	23.6V	1.7%	< 5%	Pass

APPENDIX 1. SCHEMATIC



APPENDIX 2. THE BILL OF MATERIAL

Resistors				
Item	Description	Value	Designation	Q'ty
1	Resistor, SMD 0805 Thin Film Chip	0 Ohm, 5%	R203	1
2	Resistor, SMD 0805 Thin Film Chip	10 Ohm, 5%	R109, R351, R355	3
3	Resistor, SMD 0805 Thin Film Chip	47 Ohm, 5%	R111, R352, R356	3
4	Resistor, SMD 0805 Thin Film Chip	56 Ohm, 5%	R344	1
5	Resistor, SMD 0805 Thin Film Chip	110 Ohm, 5%	R208, R103	2
6	Resistor, SMD 0805 Thin Film Chip	180 Ohm, 5%	R320	1
7	Resistor, SMD 0805 Thin Film Chip	205 Ohm, 1%	R313	1
8	Resistor, SMD 0805 Thin Film Chip	680 Ohm, 5%	R343	1
9	Resistor, SMD 0805 Thin Film Chip	1K Ohm, 5%	R215, R311, R359	3
10	Resistor, SMD 0805 Thin Film Chip	1.5K Ohm, 5%	R347	1
11	Resistor, SMD 0805 Thin Film Chip	2K Ohm, 5%	R312	1
12	Resistor, SMD 0805 Thin Film Chip	2.7K Ohm, 5%	R318, R323, R345, R346	4
13	Resistor, SMD 0805 Thin Film Chip	3K Ohm, 5%	R202, R301, R314	3
14	Resistor, SMD 0805 Thin Film Chip	4.7K Ohm, 5%	R341	1
15	Resistor, SMD 0805 Thin Film Chip	5.1K Ohm, 5%	R206, R213, R337	3
16	Resistor, SMD 0805 Thin Film Chip	9.53K Ohm, 1%	R219	1
17	Resistor, SMD 0805 Thin Film Chip	10K Ohm, 5%	R110, R218, R306, R353, R357	5
18	Resistor, SMD 0805 Thin Film Chip	13K Ohm, 5%	R226, R237	2
19	Resistor, SMD 0805 Thin Film Chip	19.1K Ohm, 1%	R114	1
20	Resistor, SMD 0805 Thin Film Chip	33K Ohm, 5%	R108, R307, R342	3
21	Resistor, SMD 0805 Thin Film Chip	39K Ohm, 5%	R225	1
22	Resistor, SMD 0805 Thin Film Chip	68K Ohm, 5%	R302, R322	2
23	Resistor, SMD 0805 Thin Film Chip	75K Ohm, 5%	R204	1
24	Resistor, SMD 0805 Thin Film Chip	120K Ohm, 5%	R104	1
25	Resistor, SMD 0805 Thin Film Chip	N.C.	R216, R317, R324, R360, R361	5
26	Resistor, SMD 0805 Thin Film Chip	3.9M Ohm, 5%	R115, R116	2
27	Resistor, SMD 1206 Thin Film Chip	750K Ohm, 5%	R112, R113	2
28	Resistor, SMD 1206 Thin Film Chip	2M Ohm, 5%	R101, R102	2
29	Resistor, SMD 1206 Thin Film Chip	4.7M Ohm, 5%	R228, R229	2
30	Resistor, Axial Lead, CF 1/4W, small size	1 Ohm, 5%	R217	1
31	Resistor, Axial Lead, CF 1/4W, small size	1K Ohm, 5%	R315	1
32	Resistor, Axial Lead, CF 1/4W, small size	510K Ohm, 5%	R201	1
33	Resistor, Axial Lead, MOF 1W, small size	0.18 Ohm, 5%	R349, R350	2
34	Resistor, Axial Lead, MOF 1W, small size	0.33 Ohm, 5%	R105, R106, R107	3

Capacitors				
Item	Description	Value	Designation	Q'ty
35	MLCC, SMD 0805, X7R	220PF, 50V	C215	1
36	MLCC, SMD 0805, X7R	330PF, 50V	C305	1
37	MLCC, SMD 0805, X7R	1nF, 50V	C104	1
38	MLCC, SMD 0805, X7R	2.2nF, 50V	C325	1
39	MLCC, SMD 0805, X7R	4.7nF, 50V	C311, C359	2
40	MLCC, SMD 0805, X7R	10nF, 50V	C341, C206	2
41	MLCC, SMD 0805, X7R	22nF, 50V	C212	1
42	MLCC, SMD 0805, X7R	47nF, 50V	C109, C213, C323, C203	4
43	MLCC, SMD 0805, X7R	100nF, 50V	C105, C108, C306, C312, C337	5
44	MLCC, SMD 0805, X7R	220nF, 50V	C113	1
45	MLCC, SMD 0805, X7R	1μF, 50V	C106	1
46	MLCC, SMD 0805, X7R	2.2μF, 50V	C308	1
47	MLCC, SMD 0805, X7R	4.7μF, 50V	C322	1
48	MLCC, SMD 0805, X7R	N.C.	C303, C324, C361	3
49	MPX, X-Cap	0.22μF, 275Vac	C103, C111	2
50	MPP Cap. Radial Lead	1μF, 450V	C112	1
51	MPP Cap. Radial Lead, high current	56nF, 800V	C310	1
52	Ceramic, Y2-Cap, Disc 9φ, , KX/Murata	2200pF, 250Vac	C101, C102	2
53	Ceramic, Y1-Cap, Disc 9φ, , KX/Murata	3300pF, 250Vac	C401	1
54	Ceramic Cap, Disc, 5φ	2200pF, 1KV	C201	1
55	Ceramic Cap, Disc, 5φ	100pF, 1KV	C307, C114	2
56	E/C, Radial Lead, 105°C, 35x25mm, TY/LTEC	220μF, 450V	C110	1
57	E/C, Radial Lead, 105°C, 6.3x11mm, LZP/LTEC	47μF, 50V	C107, C304, C202	3
58	E/C, Radial Lead, 105°C, 5x12mm, LZP/LTEC	470μF, 16V	C209, C210, C211	3
59	E/C, Radial Lead, 105°C, 12x25mm, LZP/LTEC	1000μF, 35V	C313, C314, C315, C316, C317, C318	6
60	E/C, Radial Lead, 105°C, 10x25mm, LZP/LTEC	1500μF, 16V	C319, C320	2

Diodes & Transistors				
Item	Description	Value	Designation	Q'ty
61	Bridge Diode, Flat/Mini, GBU806, Lite-On	8A, 600V	BD101	1
62	Hyper Fast Diode, BYC10-600, NXP	10A, 600V	D102	1
63	Switching Diode, SMD SOD-80, LL4148, NXP	0.2A, 75V	D103, D301, D302, D307, D351, D355	6
63-1	Switching Diode, DIP, 1N4148, NXP	0.2A, 75V	D202	1
64	General Purpose Diode, 1N4007	1A, 1KV	D104, D201	2
65	General Purpose Diode, 1N5408	3A, 1KV	D101	1
66	Zener Diode, SMD BZX84-C15, NXP	15V	ZD301	1
67	Zener Diode, SMD BZX84-C30, NXP	30V	ZD201	1
68	Schottky Diode, TO220AB, SBL1040CT, Lite-On	10A, 40V	D204	1
69	Schottky Diode, TO220AB, SBL2060CT, Lite-On	20A, 60V	D303, D304	2
70	Schottky Diode, TO220AB, SBL2040CT, Lite-On	20A, 40V	D305, D306	2
71	N-MOSFET, TO3P, SPW21N50C3, Infineon	21A, 500V	Q101	1
72	N-MOSFET, TO220AB, 2SK3934, Fairchild	15A, 500V	Q310, Q302	2
73	NPN Switching Transistor, PMBT4401, SOT23, SMD		Q341, Q342	2
74	PNP Switching Transistor, PMBT4403, SOT23, SMD		Q201, Q318	2
75	N-MOSFET, 2N7002, SOT23, SMD		Q208	1

Chokes & Transformers, Others				
Item	Description	Value	Designation	Q'ty
76	Transformer, EF20 (TDK PC40)	2.1mH	T201	1
77	Transformer, LP3925, Lk=110uH	660uH	T301	1
78	PFC Choke, QP3325	500uH	L103	1
79	Power Choke, R4 x 15, 1.2D*6.5T, / Sendpower	0.9uH	L201, L301, L302	3
80	EMI Choke, Ring core, 18mm, / Sendpower	2.0mH	L101	1
81	EMI Choke, FOTC2508000900A, / YuJing	9.0mH	L102	1
82	Fuse, / PTU	6.3A, 250V	F101	1
83	Connector, 3pin, pitch 8mm		CN101	1
84	Connector, 4pin, pitch 2.5mm		CN201, CN301, CN302	3
85	Heat Sink, 40mm x 33mm x 28mm		for BD101	1
86	Heat Sink, 95mm x 82mm x 28mm		for Q101, D102	1
87	Heat Sink, 52mm x 28mm		for Q301, Q302	1
88	Heat Sink, 75mm x 28mm		for D303, D304, D305, D306	1
89	PCB, 199mm x 135mm		APBADC020 ver.B	1
90	Switch, small signal, 6 pin		S1, S2	2
91	Jumper, 0.6mm, pitch 7.5mm.		JP2, JP3, JP24	3
92	Jumper, 0.6mm, pitch 10mm.		JP4, JP6, JP17, JP21	4
93	Jumper, 0.6mm, pitch 12.5mm.		JP11, JP12, JP15,	3
94	Jumper, 0.6mm, pitch 15mm.		JP16, JP20, JP25	3
95	Jumper, 0.6mm, pitch 17.5mm.		JP9	1
96	Jumper, 0.6mm, pitch 20mm.		JP8, JP22, JP23,	3
96	Jumper, 0.6mm, pitch 32.5mm.		JP1, JP5	2
97	Jumper, 1.0mm, pitch 20mm.		JP18, JP19	2
98	Jumper, 1.0mm, pitch 22.5mm.		JP7, JP14	2
99	Jumper, 1.0mm, pitch 23.5mm.		JP13	1
100				

APPENDIX 3. LAYOUT CONSIDERATION

See next page for the implementation.

General guidelines:

- Minimise area of loops that carry high dI/dt current transients (transformer in- and output loops)
- Minimise area of traces and components with high dV/dt voltage excitation; reduce trace lengths and component size
- Keep functional circuit blocks close together
- Keep transformer, resonance capacitor C310, TEA1611 and input capacitor C110 as close as possible to each other such that the main current loop area is as small as possible

Layout flow:

1. Start layout with high current (large signal) primary circuit:
   - Minimise high current AC-loop area (transformer, TEA1611, input capacitor C110)
   - Minimise bridge traces (TEA1611 pin8 SH, source Q301 and drain Q302) surface area

2. Continue with the output AC loops:
   - Minimise AC loop areas (start with high current output)

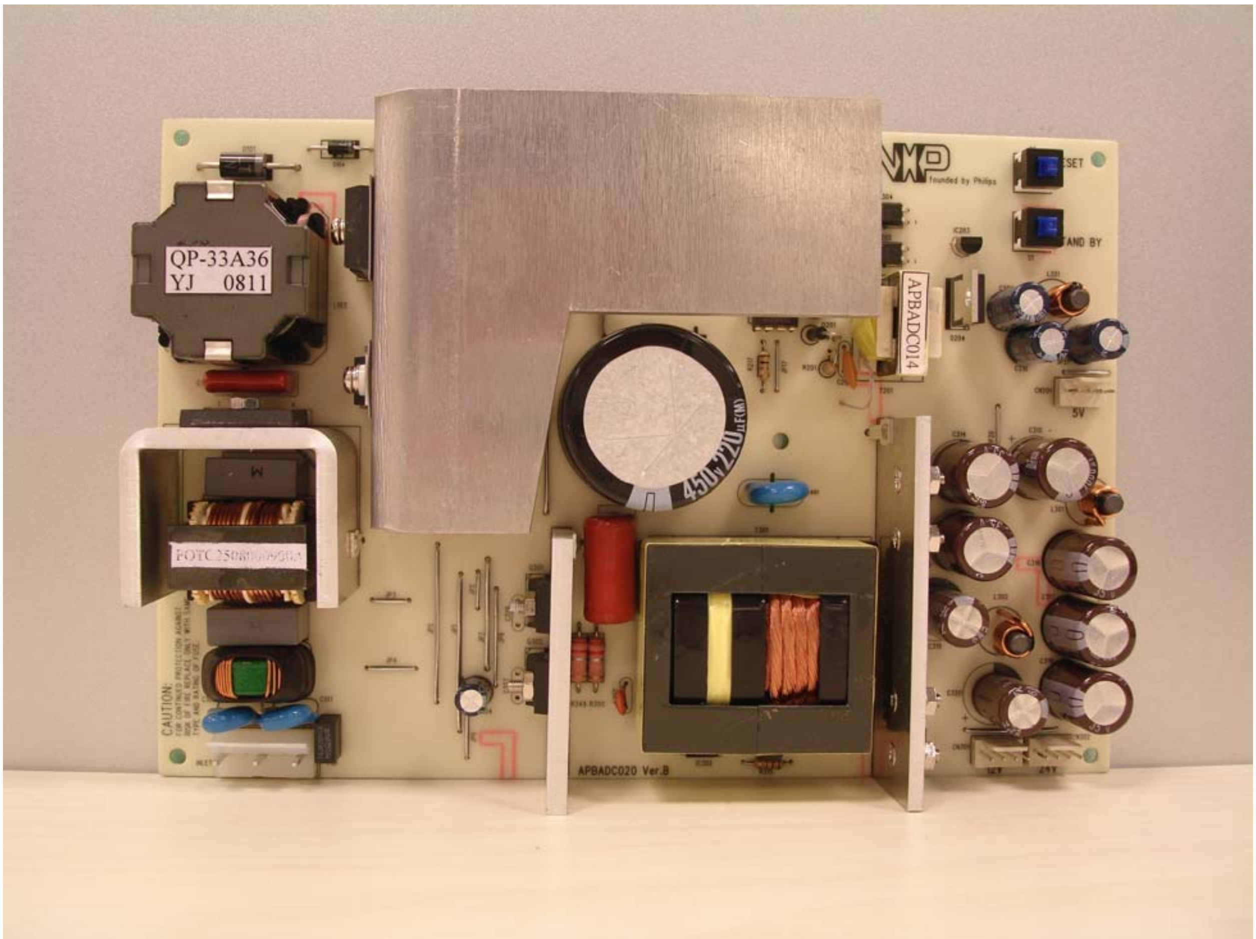
3. Continue with the controller section:
   - Compact set-up
   - Keep Signal Ground (SGND) and Power Ground (PGND) separated on PCB, but short connection of pin6 to pin11.

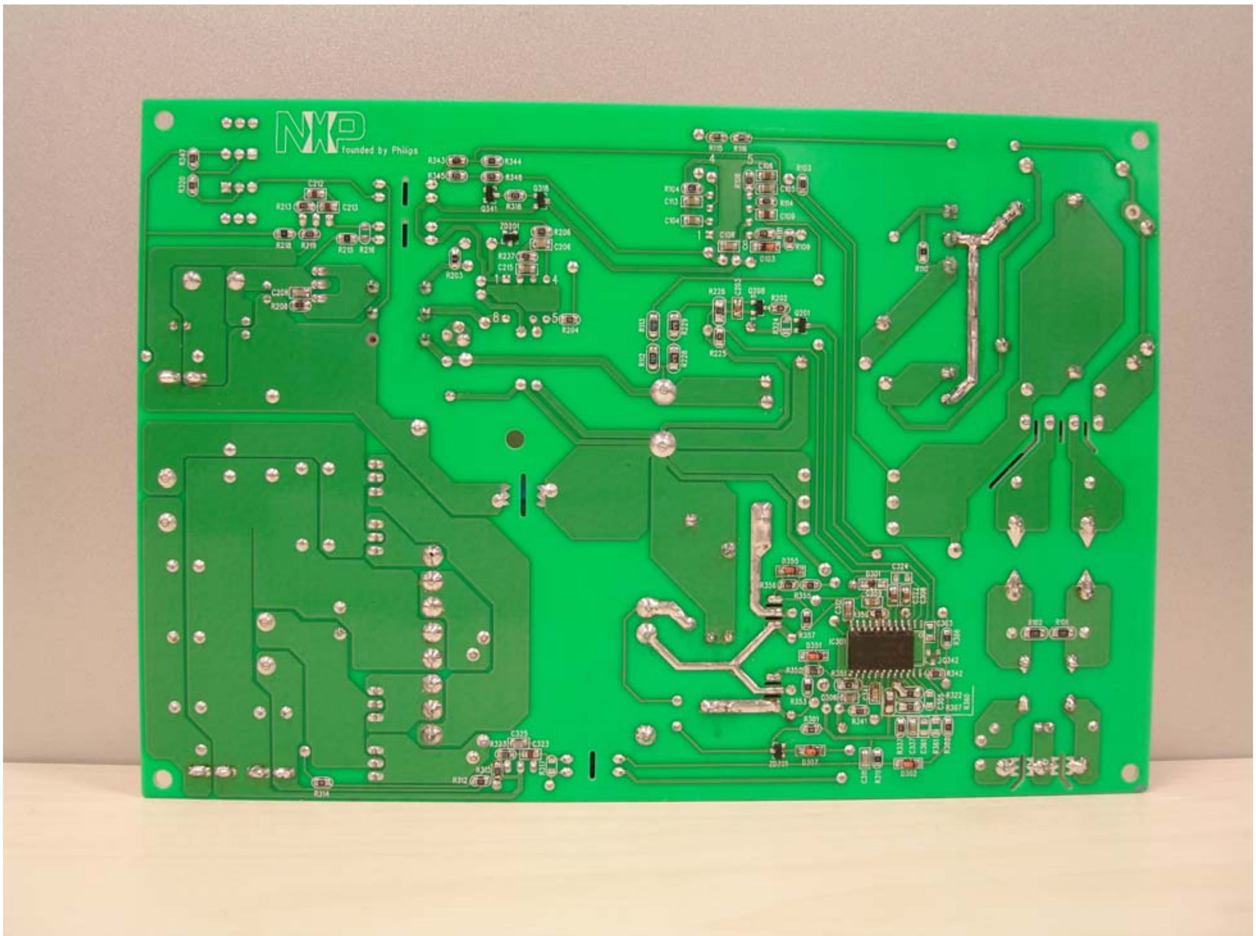
4. Continue with regulator section:
   - Compact set-up

5. GND of input capacitor C110 with a short track via safety capacitor C401 to output capacitor C313 and C319.

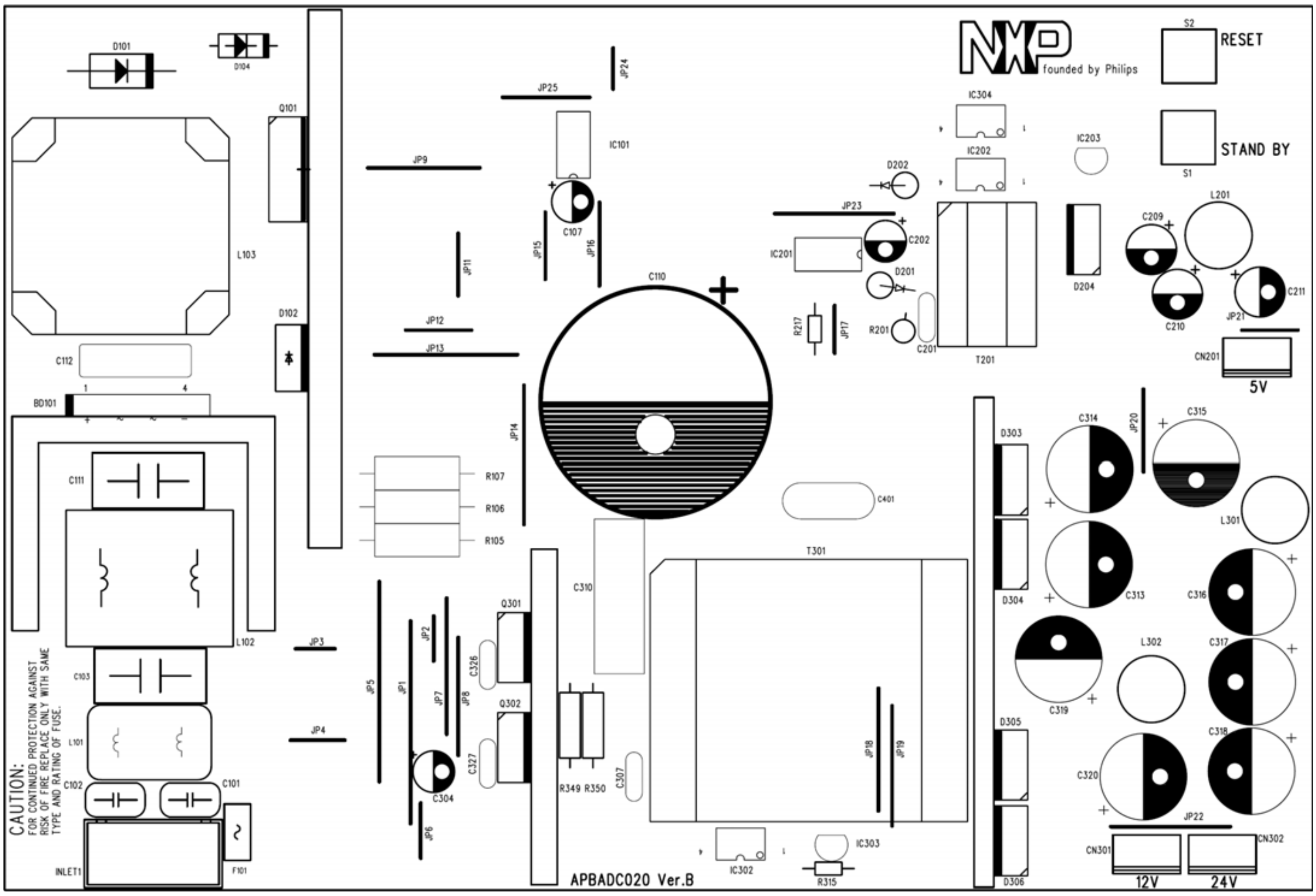
6. Avoid HF interference between mains filter section (C103, L102, C111) and connector P1 coming from circuits that carry high dI/dt's (magnetic interference).

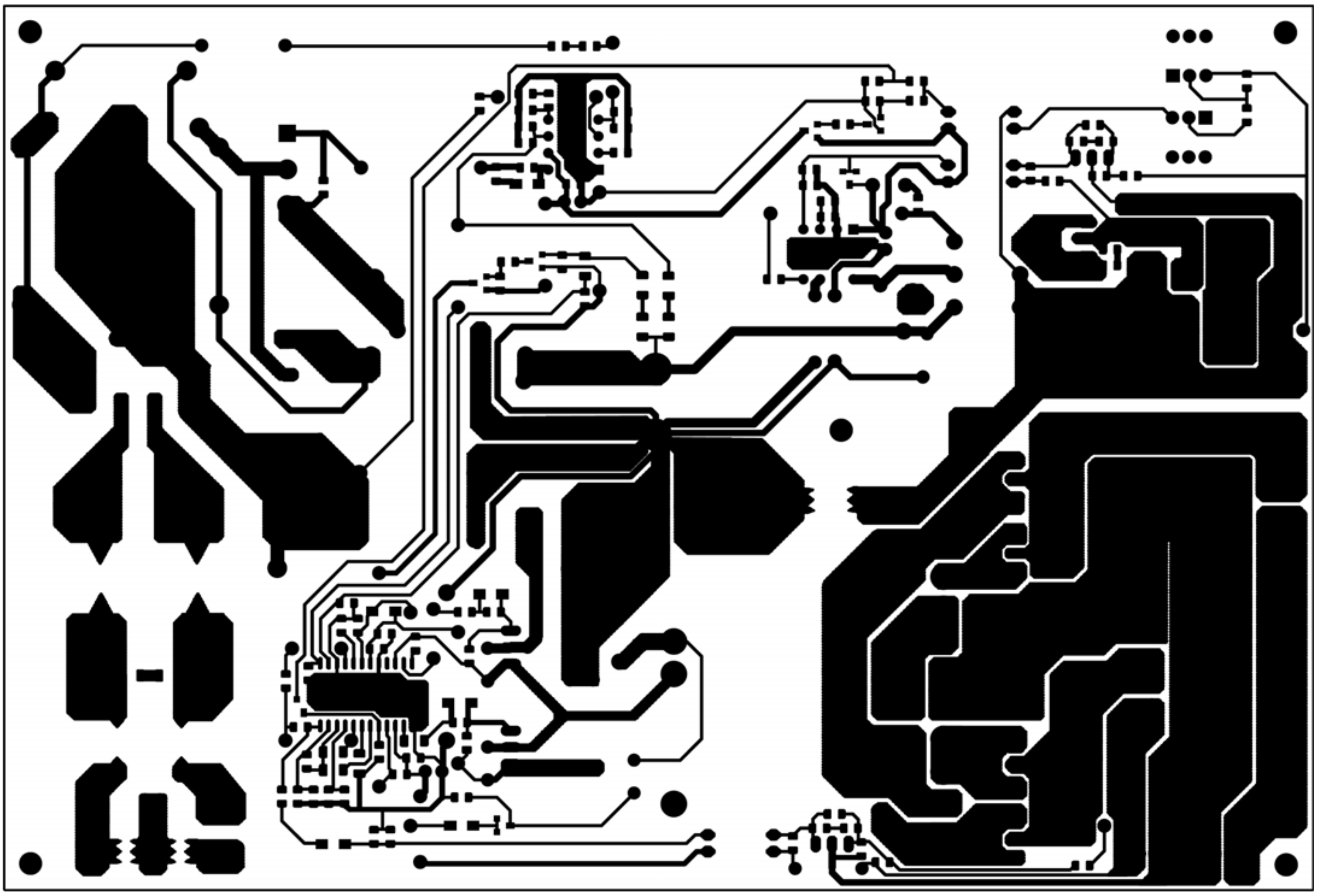
APPENDIX 4. EVALUATION BOARD OUTLINE





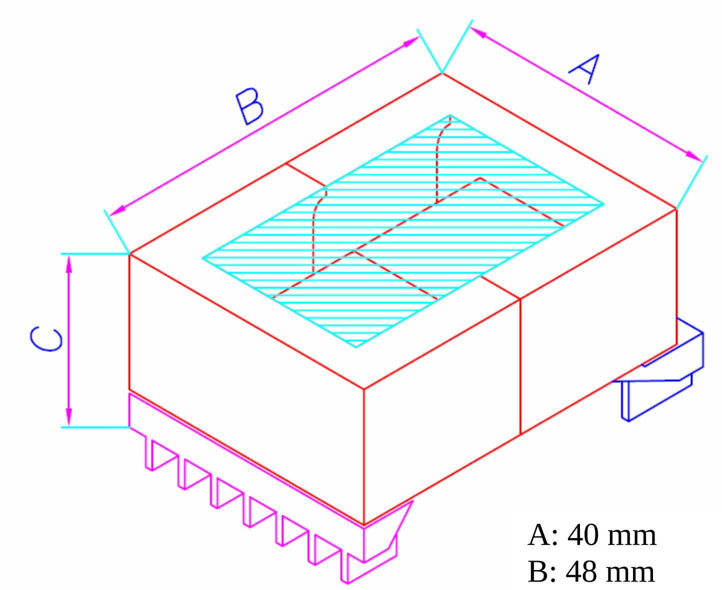
APPENDIX 5. COMPONENTS PLACEMENT OUTLINE

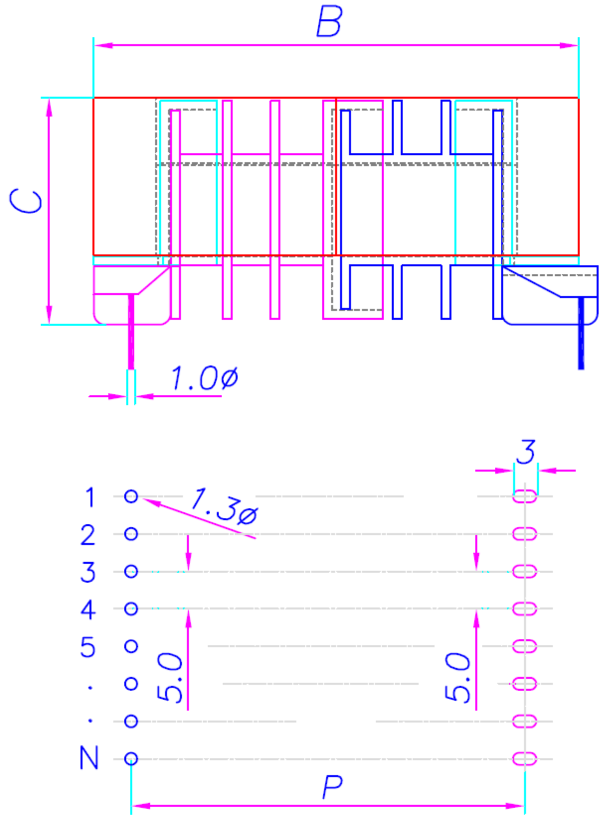




APPENDIX 6. RESONANT TRANSFORMER DATA

1. LP-3925 OUTLINE:

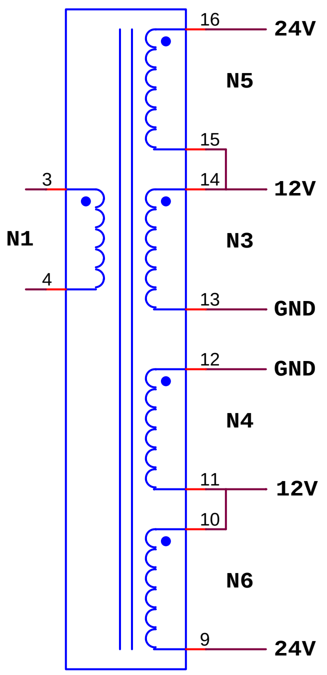




A: 40 mm
B: 48 mm
C: 25 mm
N: 8 pin
P: 41 mm
Ae: 170 mm^2

2. Winding Order:

LP-3925



N1 = 34Ts (0.2mm x 15s)

N3 = 2Ts (0.2mm x 80s)

N4 = 2Ts (0.2mm x 80s)

N5 = 2Ts (0.2mm x 60s)

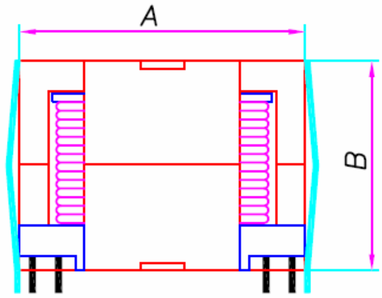
N6 = 2Ts (0.2mm x 60s)

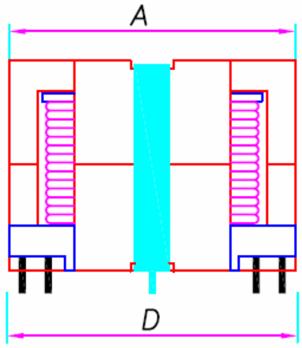
L_N1 = 660uH (All Secondary Open)

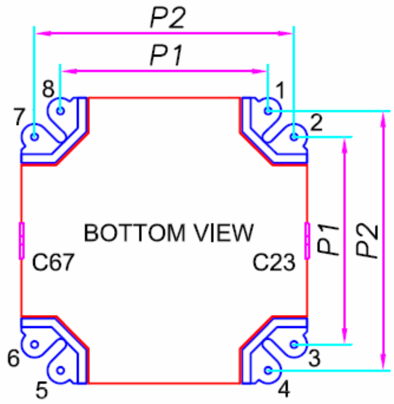
Lk_N1 = 110uH (All Secondary Short)

APPENDIX 7. PFC TRANSFORMER DATA

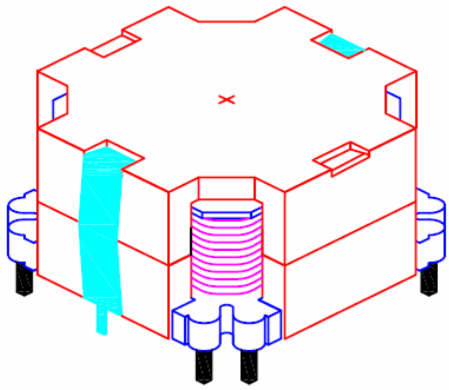
1. QP-3325 OUTLINE:





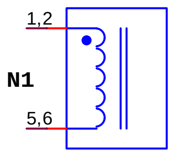


Ae: 200 mm^2



2. Winding Order:

QP-3325

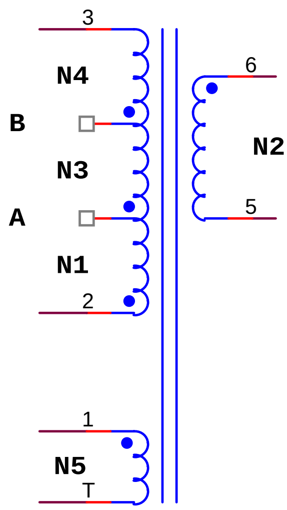


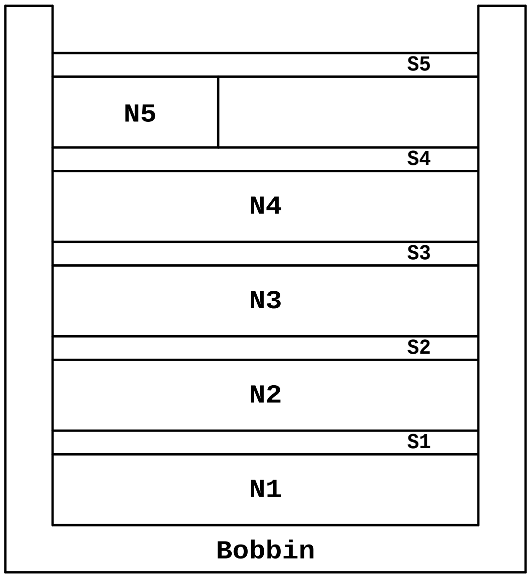
L_N1 = 800uH

N1 = 60.5Ts (0.1mm x 50s)

APPENDIX 8. STANDBY TRANSFORMER DATA

1. Transformer Schematic





2. Winding Specification

Layer	Winding		Wire	Turns	Winding Method	Tape Insulation		
	Start	Finish				N0.	Turns	Width
N1	2	A	0.25φ x 1	40	Center	S1	2	13mm
N2	6	5	0.35φ x 4 (3L)	5	Center	S2	2	13mm
N3	A	B	0.25φ x 1	40	Center	S3	1	13mm
N4	B	3	0.25φ x 1	40	Center	S4	2	13mm
N5	1	T	0.3φ x 1	18	Side	S5	3	13mm

3. Electrical Characteristics

Item	Pin	Specification	Condition
Inductance	2 - 3	2.1mH ± 5%	80KHz, 1V
Leakage Inductance	2 - 3	< 100uH	2'nd all short.

4. Core & Bobbin

Core: EF-20 (TDK PC40 or Equiv.)
Bobbin: EF-20 (6Pin, Vertical Type, Chang Chun Plastics Co., Ltd.)
Ae: 32.1mm^2.

APPENDIX 6. REFERENCE

- **Product Data Sheet**
  TEA1611T **Rev. 01.4 _ Aug 2007**
- **Application Note**
  TEA1611 draft application note **Rev. 00.01_Dec 2007**
- **Application Note**
  90W Resonant SMPS with TEA1610 Swing Chip **AN990011**