



Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from Europe, America and south Asia, supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of "Quality Parts, Customers Priority, Honest Operation, and Considerate Service", our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip, ALPS, ROHM, Xilinx, Pulse, ON, Everlight and Freescale. Main products comprise IC, Modules, Potentiometer, IC Socket, Relay, Connector. Our parts cover such applications as commercial, industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!



## Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



<b>Title</b>	<b><i>Reference Design Report for a 225 W (286 W Peak) Power Factor Corrected LLC Power Supply Using HiperPLC (PLC810PG)</i></b>
<b>Specification</b>	90 VAC to 265 VAC Input 225 W (286 W Peak) Total Output Power 5 V <sub>SB</sub> at 0.5 W 5 V at 9.5 W 12 V at 48 W (60 W Peak) 24 V at 168 W (216 W Peak)
<b>Application</b>	LCD TV
<b>Author</b>	Applications Engineering Department
<b>Document Number</b>	RDR-189
<b>Date</b>	September 9, 2009
<b>Revision</b>	1.0.5

#### **Summary and Features**

- Integrated PFC and LLC controller
- Continuous mode PFC using small low-cost EE Sendust core and magnet wire
- Frequency and Phase locked PFC and LLC for ripple cancellation in bulk capacitor for reduced ripple current, reduced bulk capacitor and reduced EMI filter cost
- Tight LLC duty-cycle matching
- Tight LLC dead-time control
- Brownout detection circuit
- >92% full load PFC efficiency at 90 VAC using conventional ultrafast rectifier
- >93% full load LLC efficiency

#### PATENT INFORMATION

The products and applications illustrated herein (including transformer construction and circuits external to the products) may be covered by one or more U.S. and foreign patents, or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at [www.powerint.com](http://www.powerint.com). Power Integrations grants its customers a license under certain patent rights as set forth at <<http://www.powerint.com/ip.htm>>.

## Table of Contents

1	Introduction .....	4
2	Power Supply Specification .....	7
3	Schematic .....	8
4	Circuit Description .....	11
4.1	Input Filter / Boost Converter .....	11
4.1.1	EMI Filtering .....	11
4.1.2	Inrush limiting .....	11
4.1.3	Main PFC Stage .....	11
4.2	Main LLC Output .....	12
4.2.1	LLC Input Stage .....	12
4.2.2	LLC Outputs .....	12
4.2.3	Switched +5V Output .....	12
4.3	Controller .....	12
4.3.1	PFC Control .....	12
4.3.2	Bypassing/Ground Isolation .....	13
4.3.3	LLC Control .....	13
4.4	LLC Secondary Control Circuits .....	13
4.4.1	Voltage Feedback .....	13
4.5	5 V Standby/Primary Bias Supply/Remote Start .....	13
4.5.1	5 V Flyback Supply .....	14
4.5.2	Primary Bias regulator/Remote Start .....	14
4.5.3	Brownout Shutdown Circuit .....	14
5	PCB Layout .....	15
6	Bill of Materials .....	17
7	Magnetics .....	22
7.1	Main LLC 12/24 V Transformer (T2) Specification .....	22
7.1.1	Electrical Diagram .....	22
7.1.2	Electrical Specifications .....	22
7.2	5V Standby Supply Transformer (T1) Specification .....	23
7.2.1	Electrical Diagram .....	23
7.2.2	Electrical Specifications .....	23
7.2.3	Materials .....	23
7.2.4	Build Diagram .....	24
7.2.5	Construction .....	24
7.3	PFC Choke (L4) Specification .....	25
7.3.1	Electrical Diagram .....	25
7.3.2	Electrical Specification .....	25
7.3.3	Materials .....	26
7.3.4	Build Diagram .....	26
7.3.5	Winding Instructions .....	27
7.4	Ground Choke (L3) Specification .....	28
7.4.1	Schematic Diagram .....	28
7.4.2	Materials .....	28
7.4.3	Winding Instructions .....	28



Power Integrations

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

8	LLC Transformer Spreadsheet .....	29
9	RD-189 Performance Data .....	36
9.1	LLC Stage Efficiency .....	36
9.2	Total Efficiency .....	37
9.3	+5 V Standby Output – Input Power vs Output Power .....	38
9.4	Standby Load Raw Data .....	39
9.5	No-Load Input Power .....	40
9.6	THD and Power Factor .....	41
9.7	Output Regulation .....	43
10	Waveforms .....	44
10.1	Input Voltage and Current .....	44
10.2	LLC Primary Voltage and Current .....	45
10.3	PFC Switch Voltage and Current - Normal Operation .....	46
10.4	AC Input Current and PFC Output Voltage during Startup .....	46
10.5	LLC Startup .....	47
10.6	LLC Output Short Circuit .....	48
10.7	Output Voltage during Startup and Shutdown .....	49
10.7.1	Standby Supply .....	49
10.7.2	LLC (Main) Supply .....	50
10.8	Output Holdup Time .....	52
10.9	Output Ripple Measurements .....	53
10.9.1	Ripple Measurement Technique .....	53
10.9.2	Full Load Output Ripple Results .....	54
10.9.3	Output Load Step Response .....	55
11	Temperature Profiles .....	56
11.1	Thermal Results Summary .....	57
11.1.1	Testing Conditions .....	57
11.2	90 VAC, 47 Hz, 225 W <sub>OUT</sub> .....	58
11.3	108 VAC, 57 Hz, 225 W <sub>OUT</sub> .....	58
11.4	108 VAC, 57 Hz, 185 W <sub>OUT</sub> .....	59
11.5	Alternate PFC Choke Designs for Lower Operating Temperature .....	60
11.5.1	34 mm Toroidal Choke .....	60
11.5.2	PFC Choke Using EE41/33 Core .....	63
12	LLC Gain-Phase .....	66
13	Conducted EMI .....	68
14	Line Surge .....	69
15	Revision History .....	70

**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.



## 1 Introduction

This engineering report describes a 286 W reference design power supply for flat panel displays (LCD TVs) and also serves as a general purpose evaluation board for the PLC810PG.

The design is based on the PLC810PG controller IC which integrates both continuous current mode (CCM) boost PFC and resonant half-bridge (LLC) control functions together with a high-side driver for the upper MOSFET of the LLC stage and a low-side LLC driver.

RD189 demonstrates a design using the commonly employed single transformer and resonant inductor magnetic component (integrated magnetics) for the LLC stage (common in display applications). However, the PLC810 may as easily be used with separated transformer and resonating inductor. PI design materials support both approaches.

The board also includes a standby power supply using a TNY275PN from the TinySwitch-III IC family. This provides the 5 V output during both normal operation and standby.



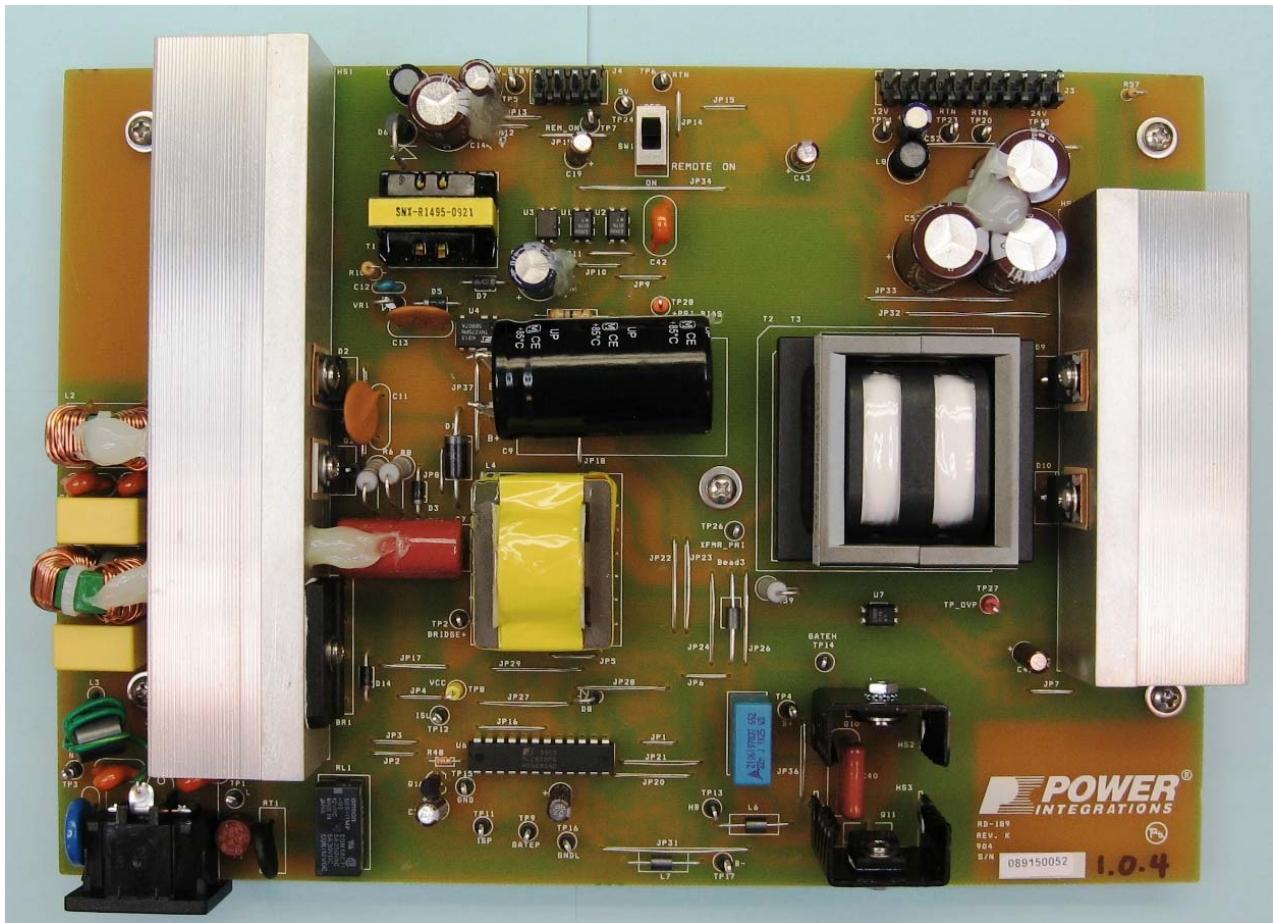
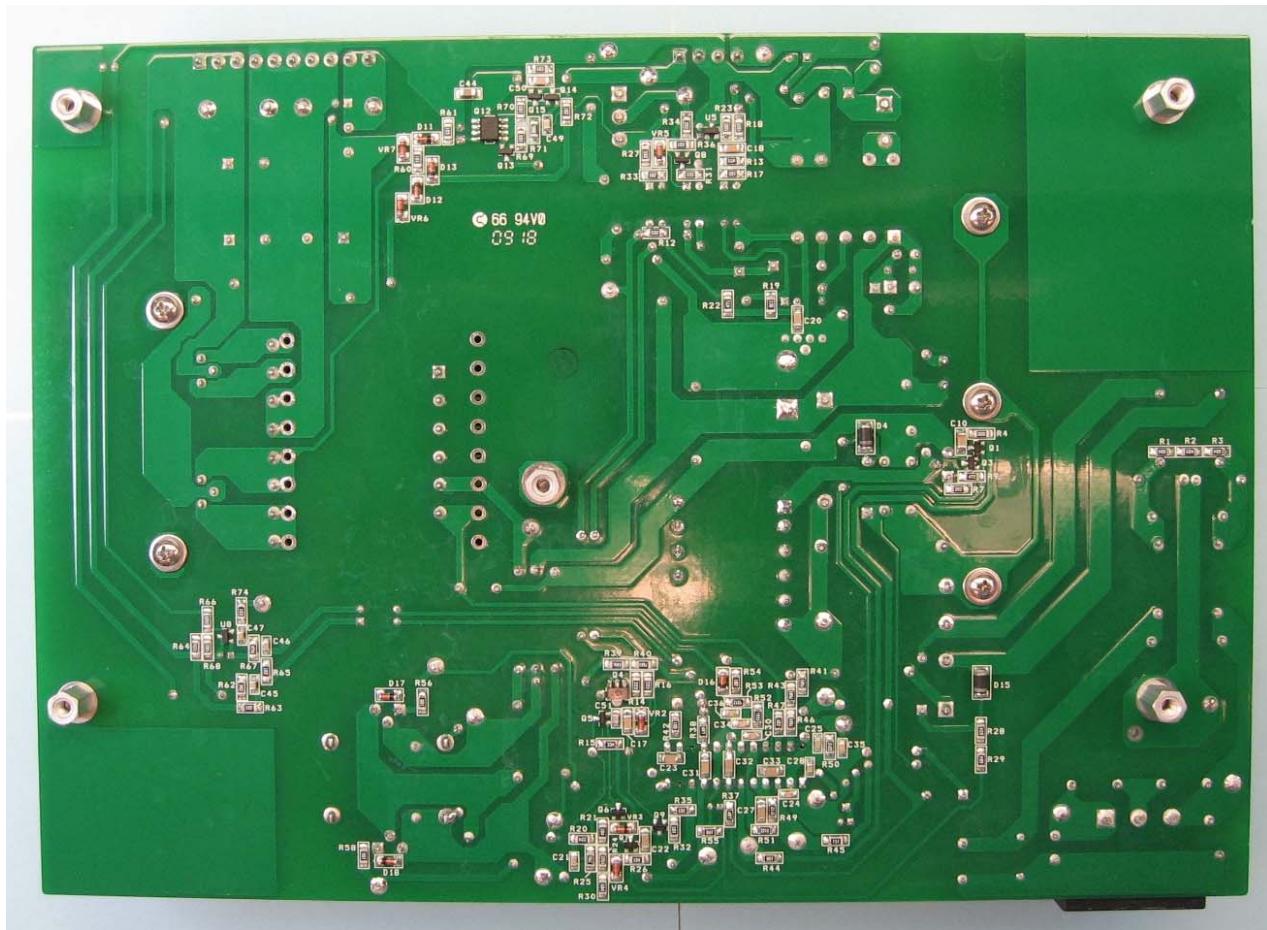


Figure 1 – RD189 Photograph, Top View.



**Figure 2 – RD-189 Photograph, Bottom View.**



**Power Integrations**

Tel: +1 408 414 9200 Fax: +1 408 414 9201  
[www.powerint.com](http://www.powerint.com)

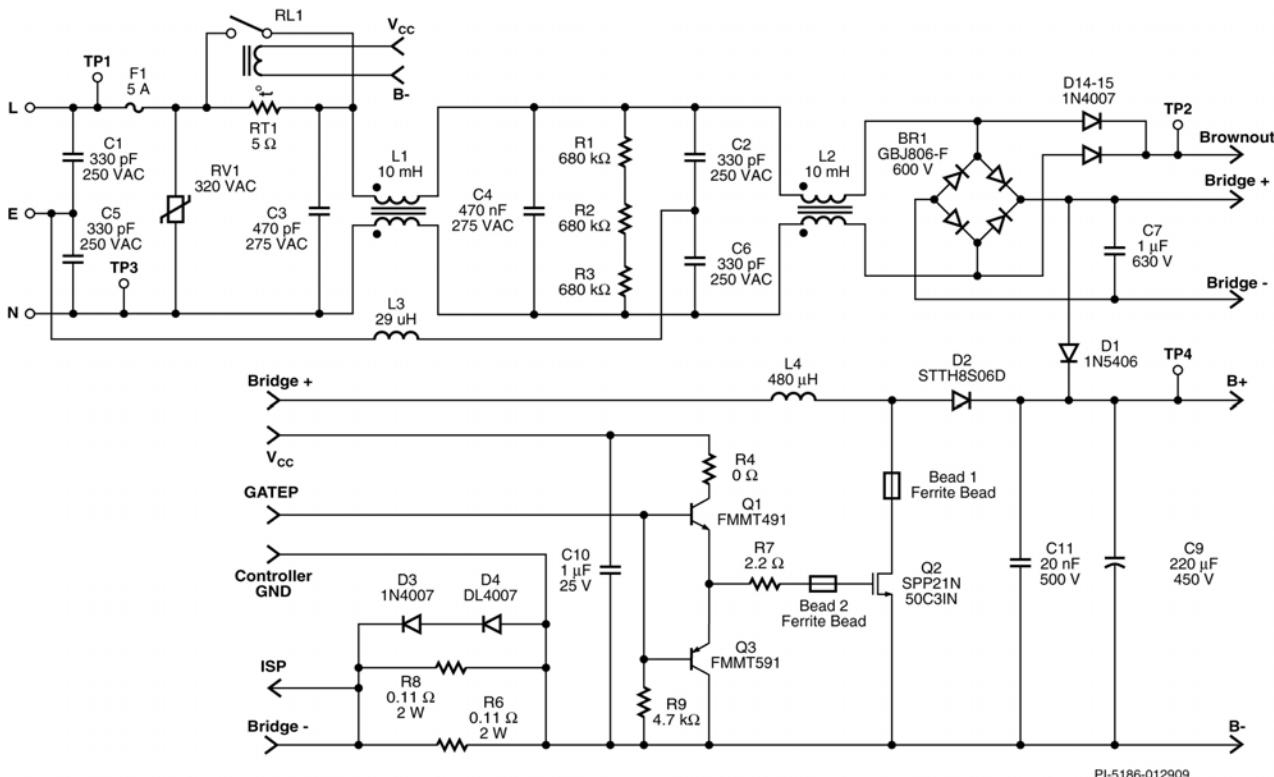
## 2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
<b>Input</b>						
Voltage	$V_{IN}$	90		265	VAC	3 Wire input.
Frequency	$f_{LINE}$	47	50/60	64	Hz	
Power Factor	$PF$	0.99				Full load, 100/115/230 VAC
No-load Input Power (230 VAC)				0.2	W	
No-load Input Power (100/115VAC)				0.08	W	
Available Standby Output Power	$P_{IN(1\ W)}$	0.6			W	For 1 W input power at 115/230 VAC
	$P_{IN(2\ W)}$	1.3			W	For 2 W input power at 115/230 VAC
<b>Standby Output</b>						
Standby Output Voltage	$V_{SB}$	4.75	5	5.25	V	$\pm 5\%$
Standby Output Ripple Voltage	$V_{RIPPLE(SB)}$			50	mV	20 MHz bandwidth
Standby Output Current	$I_{OUT(SB)}$	1			A	
<b>Main Converter Output</b>						
Logic Output Voltage	$V_{LG}$	4.75	5	5.25	V	$OVP_{MIN}: 115\%, OVP_{MAX}: 140\%$
Logic Output Ripple	$V_{RIPPLE(LG)}$			50	mV	20 MHz bandwidth
Logic Output Current	$I_{LG}$	0	2	2	A	
Audio Output Voltage	$V_{AU}$	11	12	13	V	$OVP_{MIN}: 115\%, OVP_{MAX}: 140\%$
Audio Output Ripple	$V_{RIPPLE(AU)}$			120	mV	20 MHz bandwidth
Audio Output Current	$I_{AU}$	0	4	5	A	
Backlight Output Voltage	$V_{BL}$	22	24	26	V	$OVP_{MIN}: 115\%, OVP_{MAX}: 140\%$
Backlight Output Ripple	$V_{RIPPLE(BL)}$			200	mV	20 MHz bandwidth
Backlight Output Current	$I_{BL}$	0	7	9	A	
<b>Total Output Power</b>						
Continuous Output Power	$P_{OUT}$			225	W	Standby + Main
Peak Output Power	$P_{OUT(PK)}$			286	W	Standby + Main (thermally limited)
<b>Efficiency</b>						
Standby at Full Load	$\eta_{SB}$	85			%	Measured at 115 VAC
Total system at Full Load	$\eta_{Main}$	85			%	Measured at 90 VAC
		87				Measured at 115 VAC / 230 VAC
<b>Environmental</b>						
Conducted EMI						Meets CISPR22B / EN55022B
Safety						Designed to meet IEC950 / UL1950 Class II
Surge						
Differential		2			kV	1.2/50 $\mu$ s surge, IEC 1000-4-5,
Common Mode		4			kV	Differential Mode: 2 $\Omega$
100 kHz Ring Wave		4			kV	Common Mode: 12 $\Omega$
						500 A short circuit current
Ambient Temperature	$T_{AMB}$	0		50	°C	See thermal section for conditions



### 3 Schematic

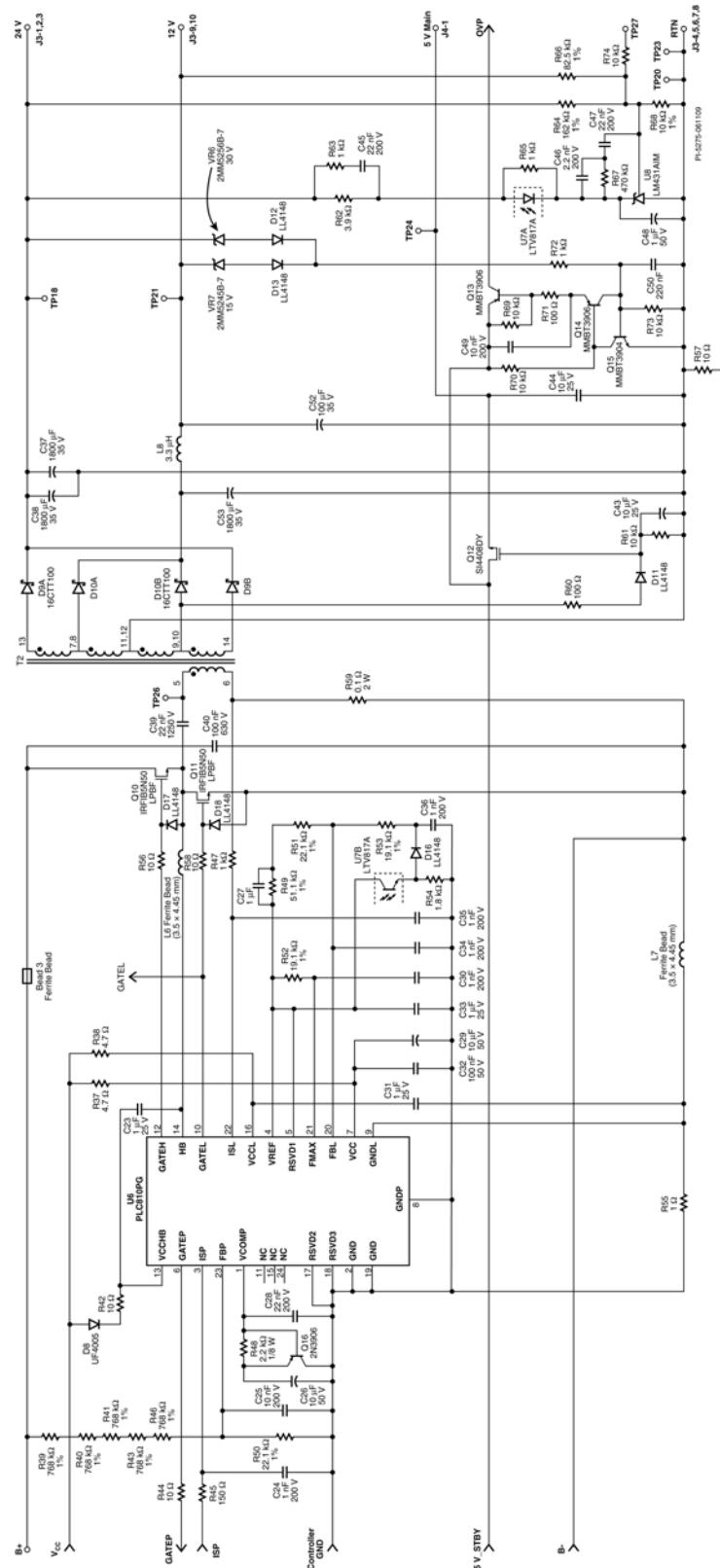


**Figure 3 – Schematic of PLC810PG LCD TV Power Supply Application Circuit, Input Circuit and PFC Power Stage.**



Power Integrations

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



**Figure 4 –Schematic of PLC810PG LCD TV Power Supply Application Circuit, PFC Circuit Control Inputs and LLC Stage.**



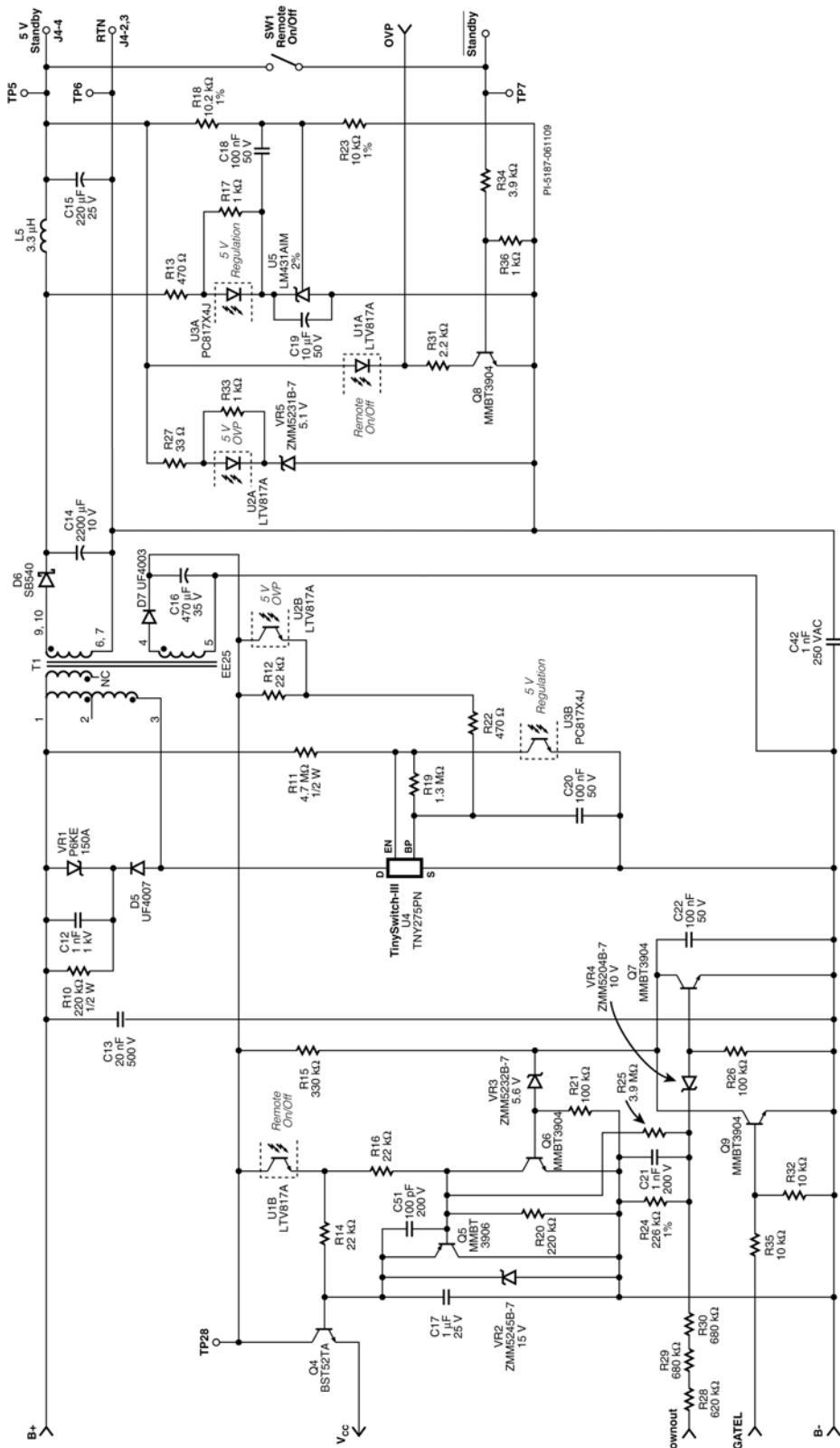


Figure 5 – Schematic of PLC810PG LCD TV Power Supply Application Circuit, Standby Supply.



Power Integrations

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

## 4 Circuit Description

The main converter uses the PLC810PG in a primary-side-control, PFC + LLC configuration.

### 4.1 Input Filter / Boost Converter

The schematic in Figure 3 shows the input EMI filter and main PFC stage.

#### 4.1.1 EMI Filtering

Capacitors C1 and C5 are connected directly across the pins of input receptacle J1 and are used to control common mode noise at frequencies greater than 30 MHz. A 5-turn ferrite bead inductor (L3) is used to connect the safety ground from J1 to chassis ground, providing damping at frequencies >30 MHz. Common mode inductors L1 and L2 control EMI at low frequencies and the mid-band (~10 MHz), respectively. Capacitors C2 and C6 control resonant peaks in the mid-band (~10 MHz) region.

PFC inductor L4 has a grounded shield band to prevent electrostatic and magnetic noise coupling to the EMI filter components. Capacitors C3 and C4 provide differential mode EMI filtering. To meet safety requirements resistors R1, R2 and R3 discharge these capacitors when AC is removed. The heat sink for PFC switch FET Q2 and PFC output diode D2 is tied to primary return at the cathode of D3 to eliminate the heat sink as a source of radiated noise.

#### 4.1.2 Inrush limiting

Thermistor RT1 provides inrush limiting. It is shorted by relay RL1 during normal operation, gated by the power supply remote-on signal, increasing efficiency by approximately 1 - 1.5%.

#### 4.1.3 Main PFC Stage

Components C9, C11, L4, Q2, and D2 form a continuous mode power factor correction circuit. Components Q1, Q3, R4, R9 and bead 2 buffer the PWM drive signal for Q2 from the PLC810 controller. Resistor R4 allows the turn-on speed and R7 the turn-off speed of Q2 to be adjusted to optimize the losses between D2 and Q2. In this design it was found that efficiency and EMI were both improved by reducing the value of R4 and R7 and adding ferrite beads to the gate and drain of Q2 (bead 2 and bead 1 respectively). In general, increasing MOSFET turn on drive current reduces MOSFET switching losses but increases the reverse recovery current through D2 and associated ringing. An ultra fast diode was selected for D2 as a lower cost alternative to a silicon carbide or other proprietary diode technology. These may provide higher efficiency by reducing reverse recovery charge, but significantly increase solution cost.

A 190 mΩ, 500 V power MOSFET was selected for Q2 to maximize the efficiency of the PFC stage.



Capacitor C10 provides local bypassing for the drive circuit. Current sensing for the PFC stage is provided by R6 and R8. The sense voltage is clamped to two diode drops by D3 and D4 protecting the current sense input of the controller IC during fault conditions. Diode D1 charges the PFC output capacitor (C11) when AC is first applied. This routes the inrush current around the PFC inductor L4 preventing it from saturating and causing stress in Q2 and D2 when the PFC stage begins to operate. Capacitor C11 is used to shrink the high frequency loop around components Q2, D2 and C9 to reduce EMI. The incoming AC is rectified by BR1 and filtered by C7. Capacitor C7 was selected as a low-loss polypropylene type due to its low loss and low impedance characteristics. This capacitor provides the high instantaneous current through L4 during Q2 on-time.

## 4.2 Main LLC Output

The Figure 4 schematic shows the LLC converter stage and the switched 5 V output, and the controller circuit.

### 4.2.1 LLC Input Stage

MOSFETs Q10 and Q11 are the switch MOSFETs for the LLC converter. They are driven directly by the controller IC via resistors R56 and R58. Capacitor C39 is the primary resonating capacitor, and should be a low-loss type rated for the RMS current at maximum load. Capacitor C40 is used for local bypassing, and is positioned adjacent to Q10 and Q11. Resistor R59 provides primary current sensing to the controller for overpower protection.

### 4.2.2 LLC Outputs

The secondaries of transformer T2 are rectified and filtered by D9-10, C37-38 and C53 to provide the +12 V and +24 V outputs. Inductor L8 and C52 provide additional filtering for the 12 V output, removing high frequency noise. Resistor R57 is connected between secondary return and chassis ground for high frequency EMI damping and to tie the secondary return to chassis ground. Capacitors C54 and C55 reduce the loop area for the 12 V and 24 V rectifier circuits.

### 4.2.3 Switched +5 V Output

MOSFET Q12 is used to switch the 5 V output of the standby supply to the +5 V logic output when the main converter is operating. The AC signal from one side of the 12 V output rectifier is used to turn on Q12 via R60, R61, D11, and C43. Capacitor C44 provides filtering of the 5 V logic output and is physically located near the output connection.

## 4.3 Controller

Figure 4 shows the circuitry around the main controller IC U6, which provides control functions for the input PFC and output LLC stages.

### 4.3.1 PFC Control

The PFC boost stage output voltage is fed back to the boost voltage sense pin (FBP of U13) via resistors R39-41, R43, R46, and R50. Capacitor C25 filters noise. Components

---



Power Integrations

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

C26, C28 and R48 provide frequency compensation for the PFC. Transistor Q16 turns on during large signal excursions, bypassing C26. This allows fast slewing of the PFC control loop in response to a large load step. The PFC current sense signal from resistors R6 and R8 is filtered by R45 and C24. The PFC drive signal from the GATEP pin is routed to the main switching FET via R44. This damps any ringing in the PFC drive signal caused by the trace length from U6 to PFC switch MOSFET Q2.

#### 4.3.2 Bypassing/Ground Isolation

Capacitors C29, C31, and C32 provide supply bypassing for the analog and digital supply rails for U6. Resistor R55 and ferrite bead L7 provide ground isolation between the PFC and LLC ground systems. Resistors R37 and R38 isolate the IC analog and digital supply rails. Ferrite bead L6 provides high frequency isolation between the LLC stage high side MOSFET drive return and the controller IC.

#### 4.3.3 LLC Control

Feedback from the LLC output sense/feedback circuit is provided by U7, which develops a feedback voltage across resistor R54. Capacitor C36 filters the feedback signal. Resistors R49, R51, and R53 set the lower frequency limit for the LLC converter stage. Capacitor C27 is used to provide output soft start. Resistor R52 sets the LLC upper frequency limit. Capacitor C30 is a noise filter. The LLC overload sense signal from resistor R59 is filtered by R47 and C35. Components C23, R42, and D8 provide bootstrapping for the LLC top side MOSFET drive.

### 4.4 LLC Secondary Control Circuits

Figure 4 shows the secondary control schematic for the LLC stage.

#### 4.4.1 Voltage Feedback

The LLC converter 12 V and 24 V outputs are sensed, weighted, and summed by resistors R64, R66, and R68. VR6, VR7 and D12, D13 sense any overvoltage condition in the 12 V or 24 V outputs. An overvoltage signal from either output is used to trigger a bipolar latch (Q14, Q15, R70, R73), which turns on transistor Q13. This transistor is used to deactivate the remote-on circuit (Figure 5), which turns off the primary bias, and hence the main controller IC.

### 4.5 5 V Standby/Primary Bias Supply/Remote Start

The schematic in Figure 5 shows the 5 V flyback standby and bias supply implemented using a TNY275PN. It provides +5 V for standby power and is switched to provide the 5 V output when the main converter is running. It also provides a primary referenced output used to supply the power for the PLC810PG controller IC. The schematic also shows the primary bias regulator, remote start, and brown-in/brown-out protection circuits.



#### 4.5.1 5 V Flyback Supply

A TNY275PN (U4) is used in a single-ended Flyback supply to provide +5 V output and primary bias. Components VR1, R10, C12, and D5 clamp the primary leakage spike. This Zener-type clamp was selected over a RCD type for low standby power consumption. Resistor R11 sets the standby supply turn-on threshold to approximately 80 VAC. Components VR5, U2, R27, and R33 are used for overvoltage shutdown protection during an open loop fault condition. Components U3, R13, R17, R18, R23, C18 and C19 are the secondary output sensing and feedback components.

Capacitor C13 is used for local primary bypassing for the flyback converter. Resistor R12 provides sufficient bias to U4 to turn off its internal HV bias supply, reducing low load and no-load power consumption. Capacitor C42 reduces common mode EMI.

#### 4.5.2 Primary Bias regulator/Remote Start

Components Q4, Q5, Q8, VR2, U1, C17, C51 R14, R16, R20, and SW1 constitute the bias regulator and remote on-off functions. Darlington transistor Q4, R14, and VR2 form a simple emitter-follower voltage regulator that is switched via optocoupler U1. Capacitor C17 limits the rate of rise of the bias voltage to avoid triggering the current limit of the standby supply. Components Q5, C51, and R20 quickly discharge C17 when optocoupler U1 is turned off.

Optocoupler U1 is turned on and off by Q8, SW1, R34, and R36. The supply can also be turned on by shorting test points TP5 and TP7.

#### 4.5.3 Brownout Shutdown Circuit

A brownout shutdown circuit is provided. This circuit operates by sensing the AC input voltage and the presence of a switching signal from the LLC controller. When the power supply is operating, the absence of both of these signals, indicating insufficient AC input voltage and insufficient B+ voltage at the input to the LLC converter stage will cause the supply to shut down by switching off the primary bias regulator.

Components R24, R26, R28-30, C21, VR4, and Q7 are used to sense The AC input voltage. The voltage threshold of this circuit is set below the turn-on threshold of the standby/primary bias converter. Sufficient AC voltage triggers Q7, discharging capacitor C22, which is charged via R15. Resistor R25 provides some hysteresis to prevent chattering around the AC threshold voltage. Components R32, R35, and Q9 sense the switching drive from the lower output FET of the LLC converter. Transistor Q9 discharges capacitor C22 when the switching signal is present.

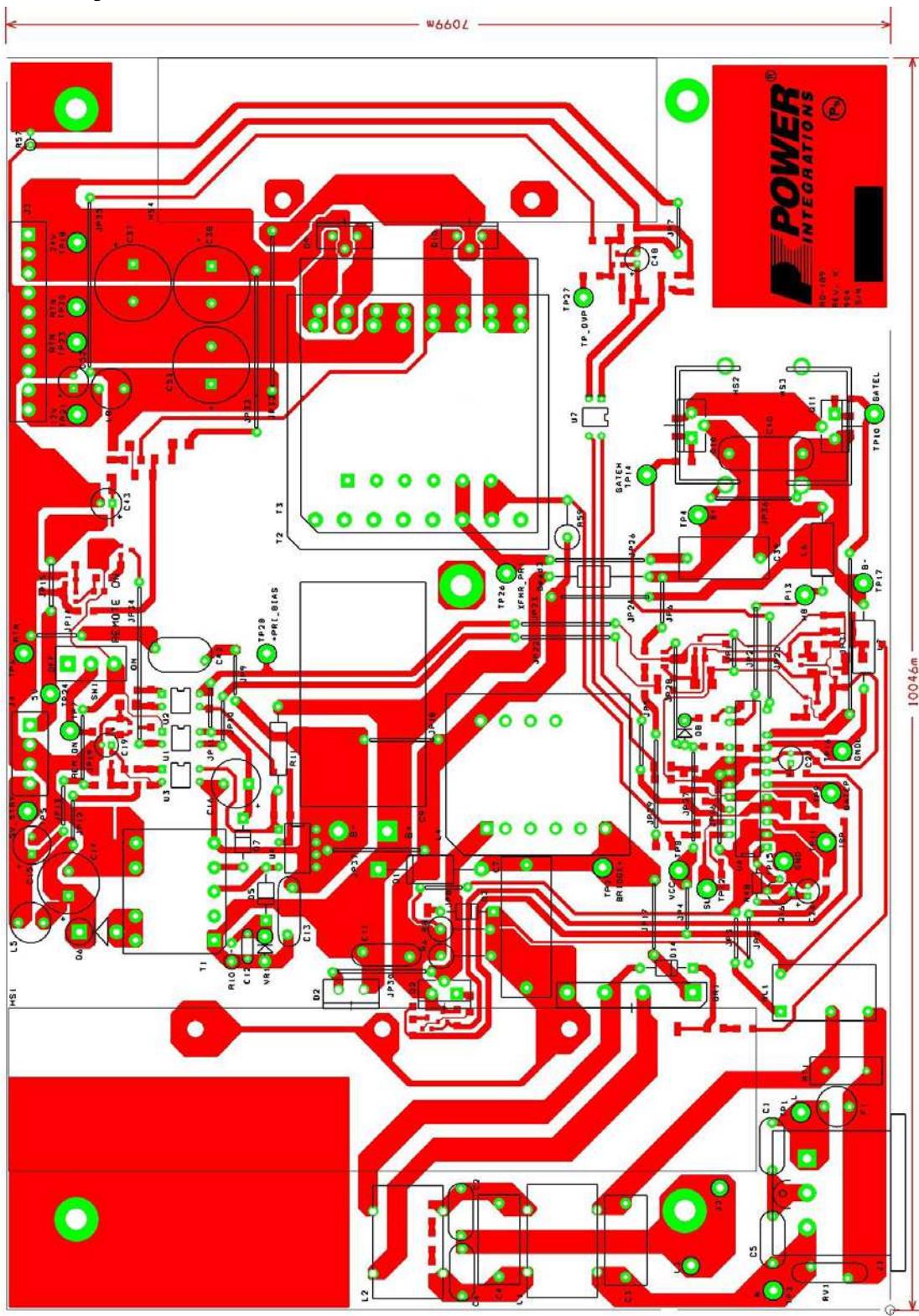
When the input voltage is sufficiently low, Q7 and Q9 turn off, allowing C22 to charge. Components Q6, R21, and VR3 sense the voltage at C22. When C22 has charged sufficiently, Q6 turns on, turning off the primary bias supply via Q4 and Q5, shutting down the PFC and LLC stages.



Power Integrations

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

## 5 PCB Layout



**Figure 6 – Printed Circuit Layout, Top Side.**



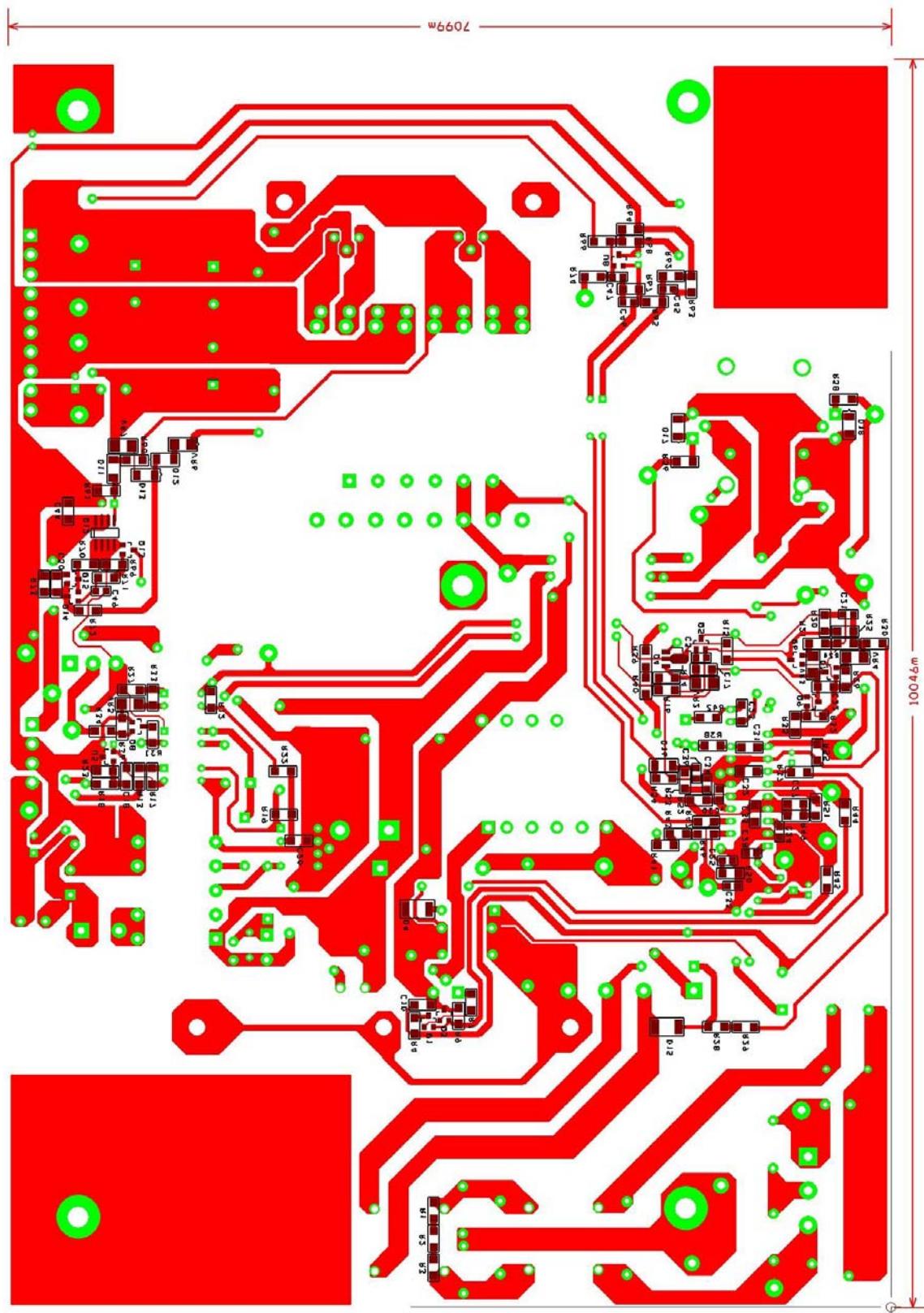


Figure 7 – Printed Circuit Layout, Bottom Side.



Power Integrations

Tel: +1 408 414 9200 Fax: +1 408 414 9201  
[www.powerint.com](http://www.powerint.com)

## 6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	2	BEAD1 BEAD2	3.5 mm D x 3.25 L mm, 21 Ω at 25 MHz, 1.6mm (.063) hole, Ferrite Bead	2643001501	Fair-Rite
2	3	BEAD3 L6 L7	3.5 mm x 4.45 mm, 68 Ω at 100 MHz, 22 AWG hole, Ferrite Bead	2743001112	Fair-Rite
3	1	BR1	600 V, 8 A, Bridge Rectifier, GBJ Package	GBJ806-F	Diodes, Inc.
4	4	C1 C2 C5 C6	330 pF, Ceramic Y1	440LT33-R	Vishay
5	2	C3 C4	470 nF, 275 VAC, Film, X2	PX474K31D5	Carli
6	1	C7	1 μF, 630 V, Polypropylene Film	ECW-F6105HL	Panasonic
7	1	C9	220 μF, 450 V, Electrolytic, (25 x 45)	ECO-S2WP221CX	Panasonic
8	6	C10 C17 C23 C27 C31 C33	1 μF, 25 V, Ceramic, X7R, 1206	ECJ-3YB1E105K	Panasonic
9	2	C11 C13	20 nF, 500 V, Disc Ceramic	D203Z59Z5UL63L0R	Vishay/BC
10	1	C12	1 nF, 1 kV, Disc Ceramic	DEBE33A102ZC1B	Murata
11	1	C14	2200 μF, 10 V, Electrolytic, Very Low ESR, 21 mΩ, (12.5 x 20)	EKZE100ELL222MK20S	Nippon Chemi-Con
12	1	C15	220 μF, 25 V, Electrolytic, Gen. Purpose, (8 x 11.5)	EKMG250ELL221MHB5D	Nippon Chemi-Con
13	1	C16	470 μF, 35 V, Electrolytic, Low ESR, 52 mΩ, (10 x 20)	ELXZ350ELL471MJ20S	Nippon Chemi-Con
14	4	C18 C20 C22 C32	100 nF, 50 V, Ceramic, X7R, 1206	ECJ-3VB1H104K	Panasonic
15	4	C19 C26 C29 C43	10 μF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG500ELL100ME11D	Nippon Chemi-Con
16	6	C21 C24 C30 C34 C35 C36	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
17	2	C25 C49	10 nF, 200 V, Ceramic, X7R, 0805	08052C103KAT2A	AVX
18	3	C28 C45 C47	22 nF, 200 V, Ceramic, X7R, 0805	08052C223KAT2A	AVX
19	3	C37 C38 C53	1800 μF, 35 V, Electrolytic, Very Low ESR, 16 mΩ, (16 x 25)	EKZE350ELL182ML25S	Nippon Chemi-Con
20	1	C39	22 nF, 1250 V, Film	B32652A7223J	Epcos
21	1	C40	100 nF, 630 V, Film	ECQ-E6104KF	Panasonic
22	1	C42	1 nF, Ceramic, Y1	440LD10-R	Vishay
23	1	C44	10 μF, 25 V, Ceramic, X5R, 1206	ECJ-3YB1E106M	Panasonic
24	1	C46	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
25	1	C48	1 μF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG500ELL1R0ME11D	Nippon Chemi-Con
26	1	C50	220 nF, 25 V, Ceramic, X7R, 1206	ECJ-3VB1E224K	Panasonic
27	1	C51	100 pF, 200 V, Ceramic, COG, 0805	08052A101JAT2A	AVX
28	1	C52	100 μF, 35 V, Electrolytic, Low ESR, 180 mΩ, (6.3 x 15)	ELXZ350ELL101MF15D	Nippon Chemi-Con
29	1	D1	600 V, 3 A, Rectifier, DO-201AD	1N5406	Vishay
30	1	D2	600 V, 8 A, Ultrafast Recovery, 12 ns, TO-220AC	STTH8S06D	ST Semiconductor
31	2	D3 D14	1000 V, 1 A, Rectifier, DO-41	1N4007-E3/54	Vishay



32	2	D4 D15	1000 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	DL4007-13-F	Diodes Inc
33	1	D5	1000 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	UF4007-E3	Vishay
34	1	D6	40 V, 5 A, Schottky, DO-201AD	SB540	Vishay
35	1	D7	200 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	UF4003-E3	Vishay
36	1	D8	600 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	UF4005-E3	Vishay
37	2	D9 D10	100 V, 16 A, Dual Schottky, TO-220AB	16CTT100	Vishay
38	6	D11 D12 D13 D16 D17 D18	75 V, 0.15 A, Fast Switching, 4 ns, MELF	LL4148-13	Diode Inc.
39	1	F1	5 A, 250 V, Slow, TR5	3721500041	Wickman
40	1	GREASE1	Thermal Grease, Silicone, 5 oz Tube	CT40-5	ITW Chemtronics
41	2	HS PAD1 HS PAD2	HEATSINK PAD, TO-220, Sil-Pad K10	K10-54	Bergquist
42	2	HS PAD3 HS PAD4	HEATSINK PAD, TO-220, Sil-Pad K10	K10-58	Bergquist
43	1	HS1	HEATSINK, Alum, EXT, 3 hole, 3 mtg holes, 6.00" L x 1.150" W x 1.300" H	62230U06000G,MOD	Aavid
44	2	HS2 HS3	HEATSINK, TWISTED FIN, 13.4°C/Watt, TO-220	593002B03400G	AavidThermalloy
45	1	HS4	HEATSINK, Alum, EXT, 2 hole, 2 mtg holes, 4.00" L x 1.150" W x 1.300" H	62230U04000G,MOD	Aavid
46	1	J1	AC Input Receptacle and Accessory Plug, PCB Mount	161-R301SN13	Kobiconn
47	1	J3	10 Position (1 x 10) header, 0.156 pitch, Vertical	26-48-1105	Molex
48	1	J4	4 Position (1 x 4) header, 0.156 pitch, Vertical	26-48-1045	Molex
49	15	JP1 JP2 JP3 JP4 JP5 JP6 JP7 JP8 JP9 JP10 JP11 JP12 JP13 JP14 JP15	Wire Jumper, Non insulated, 22 AWG, 0.4 in	298	Alpha
50	5	JP16 JP17 JP18 JP19 JP36	Wire Jumper, Non insulated, 22 AWG, 0.6 in	298	Alpha
51	4	JP20 JP21 JP_C9+ JP_C9-	Wire Jumper, Non insulated, 22 AWG, 0.7 in	298	Alpha
52	9	JP22 JP23 JP24 JP26 JP27 JP28 JP29 JP30 JP37	Wire Jumper, Non insulated, 22 AWG, 0.8 in	298	Alpha
53	4	JP31 JP32 JP33 JP34	Wire Jumper, Non insulated, 22 AWG, 1.3 in	298	Alpha
54	1	JP35	Wire Jumper, Non insulated, 22 AWG, 1.4 in	298	Alpha
55	2	L1 L2	Common Mode Choke Toroidal, 10 mH	T22148-902S	Fontaine Tech CO. LTD
56	1	L3	29 µH, Ground Choke, Flying Lead		
57	1	L4	PFC Choke, EE35/28, horizontal, 480 uH	SNX-R1493	Santronics



Power Integrations

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

58	2	L5 L8	3.3 uH, 5.5 A	RL622-3R3K-RC	JW Miller
59	2	NUT1 NUT2	Nut, Hex, Kep 4-40, S ZN Cr3 plateing RoHS	4CKNTZR	Olander
60	1	Q1	NPN,60V 1000MA, SOT-23	FMMT491TA	Zetex Inc
61	1	Q2	560 V, 21 A, 190 mOhm. N-Channel, TO-220	SPP21N50C3IN	Infineon
62	1	Q3	PNP, 60V 1000MA, SOT-23	FMMT591TA	Zetex Inc
63	1	Q4	NPN, DARL 80V 500MA, SOT-89	BST52TA	Zetex Inc
64	3	Q5 Q13 Q14	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3906LT1G	On Semiconductor
65	5	Q6 Q7 Q8 Q9 Q15	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semiconductor
66	2	Q10 Q11	500 V, 4.7 A, 670 mOhm. N-Channel, TO-220FP	IRFIB5N50LPBF	IR/Vishay
67	1	Q12	20 V, 14 A, 4.5 mOhm, N-Channel, SO-8	SI4408DY-T1-E3	Vishay
68	1	Q16	PNP, Small Signal BJT, 40 V, 0.2 A, TO-92	2N3906G	On Semiconductor
69	5	R1 R2 R3 R29 R30	680 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ684V	Panasonic
70	1	R4	0 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEY0R00V	Panasonic
71	2	R6 R8	0.11 Ω, 5%, 2 W, Metal Oxide	MO200J0R11B	Synton-Tech corporation
72	1	R7	2.2 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ2R2V	Panasonic
73	1	R9	4.7 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ472V	Panasonic
74	1	R10	220 kΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-220K	Yageo
75	1	R11	4.7 MΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-4M7	Yageo
76	3	R12 R14 R16	22 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ223V	Panasonic
77	2	R13 R22	470 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ471V	Panasonic
78	1	R15	330 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ334V	Panasonic
79	7	R17 R33 R36 R47 R63 R65 R72	1 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ102V	Panasonic
80	1	R18	10.2 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF1022V	Panasonic
81	1	R19	1.3 MΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ135V	Panasonic
82	1	R20	220 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ224V	Panasonic
83	2	R21 R26	100 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ104V	Panasonic
84	2	R23 R68	10.0 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF1002V	Panasonic
85	1	R24	226 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF2263V	Panasonic
86	1	R25	3.9 MΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ395V	Panasonic
87	1	R27	33 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ330V	Panasonic
88	1	R28	620 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ624V	Panasonic
89	1	R31	2.2 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ222V	Panasonic
90	7	R32 R35 R61 R69 R70 R73 R74	10 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ103V	Panasonic
91	2	R34 R62	3.9 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ392V	Panasonic
92	2	R37 R38	4.7 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ4R7V	Panasonic
93	5	R39 R40	768 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF7683V	Panasonic



		R41 R43 R46			
94	4	R42 R44 R56 R58	10 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ100V	Panasonic
95	1	R45	150 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ151V	Panasonic
96	1	R48	2.2 kΩ, 5%, 1/8 W, Carbon Film	CFR-12JB-2K2	Yageo
97	1	R49	51.1 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF5112V	Panasonic
98	2	R50 R51	22.1 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF2212V	Panasonic
99	2	R52 R53	19.1 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF1912V	Panasonic
100	1	R54	1.8 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ182V	Panasonic
101	1	R55	1 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ1R0V	Panasonic
102	1	R57	10 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-10R	Yageo
103	1	R59	0.1 Ω, 5%, 2 W, Metal Oxide	MO200J0R1B	Synton-Tech Corporation
104	1	R60	100 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ101V	Panasonic
105	1	R64	162 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF1623V	Panasonic
106	1	R66	82.5 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF8252V	Panasonic
107	1	R67	470 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ474V	Panasonic
108	1	R71	100 Ω, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF1000V	Panasonic
109	1	RL1	SPST-NO, 5A 12VDC, PC MNT	G6B-1114P-US-DC12	OMRON
110	1	RT1	NTC Thermistor, 5 Ohms, 4.7 A	CL150	Thermometrics
111	1	RV1	320V, 84J, 15.5 mm, RADIAL	S14K320	Epcos
112	5	SCREW1 SCREW2 SCREW3 SCREW4 SCREW21	SCREW MACHINE PHIL 6-32X5/16 SS	PMSSS 632 0031 PH	Building Fasteners
113	12	SCREW5 SCREW6 SCREW7 SCREW8 SCREW9 SCREW10 SCREW11 SCREW12 SCREW13 SCREW14 SCREW15 SCREW16	SCREW MACHINE PHIL 4-40X5/16 SS	PMSSS 440 0031 PH	Building Fasteners
114	5	STD OFF1 STD OFF2 STD OFF3 STD OFF4 STD OFF5	Standoff Hex, 6-32, .375L, Alum	2209	Keystone Elect
115	1	SW1	SLIDE MINI SPDT PC MNT AU	1101M2S3CBE2	ITT Ind/C&Kdiv
116	1	T1	Transformer, 5V Stby/Bias, EE25, Vertical, 9 pins	SNX-R1495	Santronics
117	1	T2	Transformer, LLC, 12/24V, EX4841, Horizontal, 14 pins	SRX48EM-P241200H8701	TDK
118	22	TP1 TP2 TP3 TP4 TP5 TP6 TP7 TP9 TP10 TP11 TP12 TP13 TP14 TP15	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone



Power Integrations

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

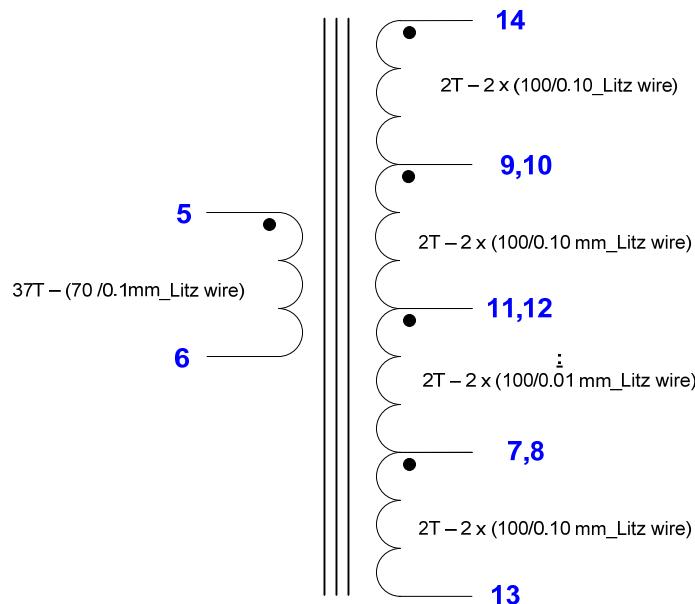
		TP16 TP17 TP18 TP20 TP21 TP23 TP24 TP26			
119	1	TP8	Test Point, YEL,THRU-HOLE MOUNT	5014	Keystone
120	1	TP27	Test Point, RED,THRU-HOLE MOUNT	5010	Keystone
121	1	TP28	Test Point, ORG,THRU-HOLE MOUNT	5013	Keystone
122	3	U1 U2 U7	Optocoupler, 35 V, CTR 80-160%, 4-DIP	LTV-817A	Liteon
123	1	U3	Optocoupler, 80 V, CTR 300-600%, 4-DIP	PC817X4J000F	Sharp
124	1	U4	TinySwitch-III, TNY275PN, DIP-8C	TNY275PN	Power Integrations
125	2	U5 U8	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semiconductor
126	1	U6	Controller, PFC/LLC, 24-pin DIP	PLC810PG	Power Integrations
127	1	VR1	150 V, 5 W, 5%, TVS, DO204AC (DO-15)	P6KE150A	LittleFuse
128	2	VR2 VR7	15 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5245B-7	Diodes Inc
129	1	VR3	5.6 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5232B-7	Diodes Inc
130	1	VR4	10 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5240B-7	Diodes Inc
131	1	VR5	5.1 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5231B-7	Diodes Inc
132	1	VR6	30 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5256B-7	Diodes Inc
133	5	WASHER1 WASHER2 WASHER3 WASHER4 WASHER18	Washer Flat #6, SS	FWSS 006	Building Fasteners
134	12	WASHER5 WASHER6 WASHER7 WASHER8 WASHER9 WASHER10 WASHER11 WASHER12 WASHER13 WASHER14 WASHER15 WASHER16	WASHER FLAT #4 SS	FWSS 004	Building Fasteners
135	2	WASHER17 WASHER18	Washer Nylon Shoulder #4	3053	Keystone
136	2	WASHER19 WASHER20	Washer Nylon Shoulder #4	3049	Keystone
137	1		Printed Circuit board, RD189, Rev. K		



## 7 Magnetics

### 7.1 Main LLC 12/24 V Transformer (T2) Specification

#### 7.1.1 Electrical Diagram



**Figure 8 – Transformer Electrical Diagram.**

#### 7.1.2 Electrical Specifications

<b>Electrical Strength</b>	60 second, 60 Hz, from pins 1-6 to pins 7-14	3000 VAC
<b>Primary Inductance</b>	Pins 5-6, all other windings open, measured at 100 kHz, 0.4 VRMS	350 $\mu$ H $\pm$ 10%
<b>Resonant Frequency</b>	Pins 5-6, all other windings open	1000 kHz (Min.)
<b>Primary Leakage Inductance</b>	Pins 5-6, with pins 7-14 shorted, measured at 100 kHz, 0.4 VRMS	100 $\mu$ H $\pm$ 10%

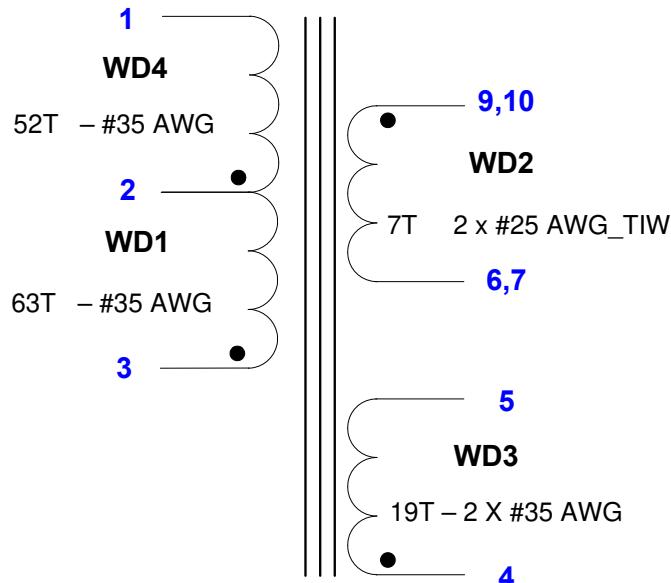


Power Integrations

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

## 7.2 5V Standby Supply Transformer (T1) Specification)

### 7.2.1 Electrical Diagram



**Figure 9 – Standby Transformer Schematic.**

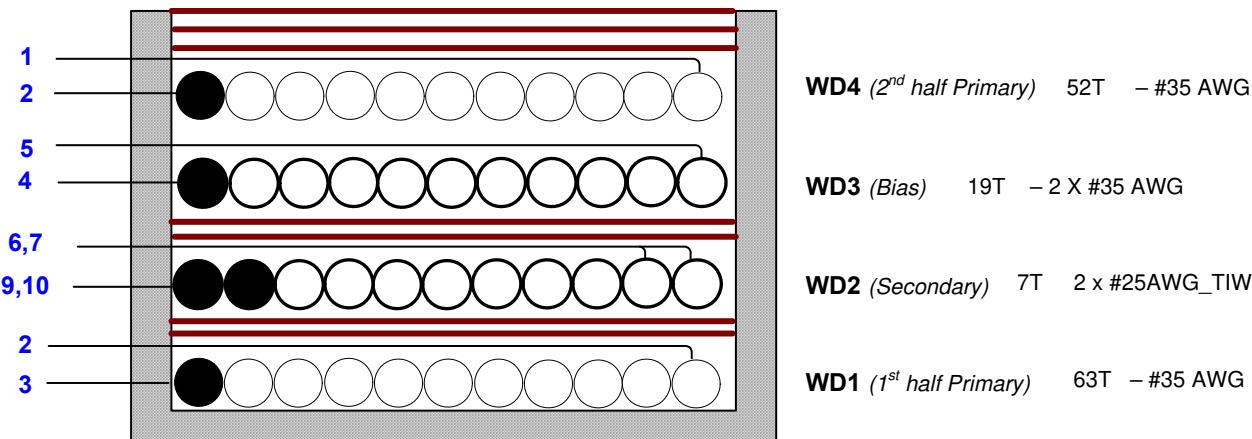
### 7.2.2 Electrical Specifications

<b>Electrical Strength</b>	1 second, 60Hz, from pins 1-5 to pins 6-10	3000 VAC
<b>Primary Inductance</b>	Pins 1-3, all other winding open, measured at 100 kHz, 0.4 VRMS	4.41 mH, $\pm 10\%$
<b>Resonant Frequency</b>	Pins 1-3, all other winding open	800 kHz (min)
<b>Primary Leakage Inductance</b>	Pins 1-3, with pins 6-10 shorted, measured at 100 kHz, 0.4 VRMS	45 $\mu$ H (max)

### 7.2.3 Materials

Item	Description
[1]	Core Pair: EE25, Nippon Ceramic NC-2H or equivalent, gapped for $A_L$ of 333 nH/T <sup>2</sup> .
[2]	Bobbin: EE25, Phenolic, Vertical, 10 pins, (5/5), Yih Hwa YW360-02B or equivalent.
[3]	Magnet Wire: #35 AWG, solderable double coated.
[4]	Triple Insulated Wire: #25 AWG, Furukawa Tex-E or equivalent.
[5]	Tape: Polyester Film 3M 1350F-1 or equivalent, 10.6 mm wide.
[6]	Transformer Varnish, Dolph, BC-359-MS or equivalent.

## 7.2.4 Build Diagram



**Figure 10 – Standby Transformer Build Diagram.**

## 7.2.5 Construction

<b>Winding/Bobbin preparation</b>	Orient bobbin (item [2]) on winding machine such that the pin side of bobbin is on the left side. Remove pin 8.
<b>WD1 (1<sup>st</sup> half Primary)</b>	Starting at pin 3, wind 63 turns of wire item [3] in one layer from left to right. After the last turn, place ½" piece of tape item [7] on winding to insulate the crossover, and bring the wire back to the left side to terminate at pin 2.
<b>Insulation</b>	Apply two layers of tape (item [5]).
<b>WD2 (Secondary)</b>	Starting at pins 9 and 10, wind 7 bifilar turns of triple insulated wire (item [4]) in one layer, from left to right, finishing at pins 6&7.
<b>Insulation</b>	Apply two layers of tape (item [5]).
<b>WD3 (Bias)</b>	Starting at pin 4, wind 19 bifilar turns of wire (item [3]) in one layer from left to right, spreading turns evenly across the bobbin, finishing at pin 5.
<b>Insulation</b>	Apply one layer of tape (item [5]).
<b>WD4 (2<sup>nd</sup> half Primary)</b>	Starting at pin 2, wind 52 turns of wire (item [3]) from left to right in one layer, spreading the turns evenly across the bobbin. After the last turn, use ½" of tape (item [5]) to insulate finish lead crossover, and finish at pin 1.
<b>Insulation</b>	Apply 3 layers of tape (item [5]) as finish wrap.
<b>Finish</b>	Gap core halves (item [1]) for inductance of 4.41 mH ±10%. Assemble and secure core halves. Dip varnish using (item [6]).



### 7.3 PFC Choke (L4) Specification

#### 7.3.1 Electrical Diagram

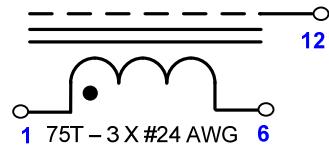


Figure 11 – PFC Choke Schematic.

#### 7.3.2 Electrical Specification

Inductance:  $480 \mu\text{H} \pm 15\%$

*Note – Do not measure inductance without copper strap (shield) in place!*

