

PR883: A 300-W, Universal Input, Isolated PFC Power Supply for LCD TV Applications

Power Management – Power Supply Controllers

1 INTRODUCTION

This guide documents a low-profile power supply that is suitable for powering LCD TVs or other flat screen applications. The power supply accepts a universal AC line-input voltage (85 VRMS to 265 VRMS), and produces an output voltage of 24-VDC for loads up to 12 A (288 W).

The requirements for a flat-panel display include a physical profile and the ability to operate from the ac-line input at close to unity power factor. Therefore a flat-panel display application demands that an internal power supply be thin so as to fit behind the screen inside the TV case, and comply with the power quality requirements defined in the IEC standard, 61000-3-2. In addition, the combination of a tight physical package and the desire to meet Energy Star® guidelines requires that the design also demonstrates very high efficiency. Described herein is a practical design that uses standard components. It achieves the requirements using a traditional two-stage power converter topology along with state-of-the-art power circuit control methods. The first stage is an interleaved, transition-mode, power factor correcting (PFC) boost pre-regulator. This is followed by an isolated LLC series-resonant DC-DC main converter.

The design takes advantage of three integrated circuit (IC) power controllers. The PFC pre-regulator stage is controlled by the UCC28061, a dual-phase, interleaved, transition-mode PFC controller. The resonant LLC converter uses the UCC25600; a low-cost 8-pin controller. The third IC is the UCC2813D-4. This is used to control a small 5-W flyback converter that provides a bias supply voltage. The bias supply is optional. It is provided for convenience so that the circuit can be demonstrated without the need for a bench supply.

2 SCOPE

A reference design is primarily intended to demonstrate the design of a functional circuit, the operation of which has been verified through a limited number of performance tests. This circuit incorporates essential safety features. These include an input line fuse, inrush current control, output over-current limit, and output over-voltage protection. An area not addressed by this design is electromagnetic compatibility (EMC). For most applications, EMI filter components would need to be added so that the design meets applicable environmental and system compatibility requirements. To comply with EMC standards, components such as input and output filters would be required to suppress electromagnetic interference (EMI). In addition components that suppress and/or protect the unit from high-voltage line surges and lightning would be required to meet power quality and safety standards.

3 ELECTRICAL PERFORMANCE

Table 1 Performance Specifications

Symbol	Parameter	Notes & Conditions	Min	Nom	Max	Units
INPUT CHARACTERISTICS						
V_i	Input Voltage		85		265	VRMS
f	Line Frequency		48		65	Hz
I_i	Input Current				4	ARMS
p.f.	Power Factor		0.95			
OUTPUT CHARACTERISTICS						
	PFC Stage:					
V_o (HVDC)	Output Voltage			390		VDC
	LLC Resonant Stage:					
V_i (HVDC)	Input Voltage		330		410	VDC
V_o	Output Voltage		22.8	24	25.2	V
I_o	Output Current		1 ¹		12	A
P_o	Output Power				288	W
I_{LIM}	Current Limit	$\Delta V_o = -4$ V		20		A
ΔV_{LOAD}	Load Regulation					% V_o
SYSTEM CHARACTERISTICS						
η	Full Load Efficiency	110 VAC, 80% load		87		%
t_{HOLD}	Hold-up Time	Nominal V_i , 80% load	40			ms
OV_{THLD}	Over-Voltage Threshold	OV shutdown and restart		30		V
	Overall thickness				20	mm
	Temp. Range	Nat'l Conv. airflow	0		50	°C
	Fuse Rating	Fast acting		5		A

Notes:

- Operates down to zero load with reduced regulation.

4 DESCRIPTION

Fig. 1 shows the circuit divided into three blocks. Each block represents one of the three converters that make up the complete power system. They include the boost PFC pre-regulator, the LLC series-resonant DC-DC converter, and the 5-W bias supply. The PFC boost pre-regulator operates off a universal ac-line input voltage and produces a regulated 390 VDC output. The output from this stage is fed to both the main LLC resonant and bias supply converters. The bias supply provides a regulated 15 VDC to power the control circuitry, and the LLC resonant converter produces an isolated output that is regulated at 24 VDC. For each of the three circuits, the theory of operation is described.

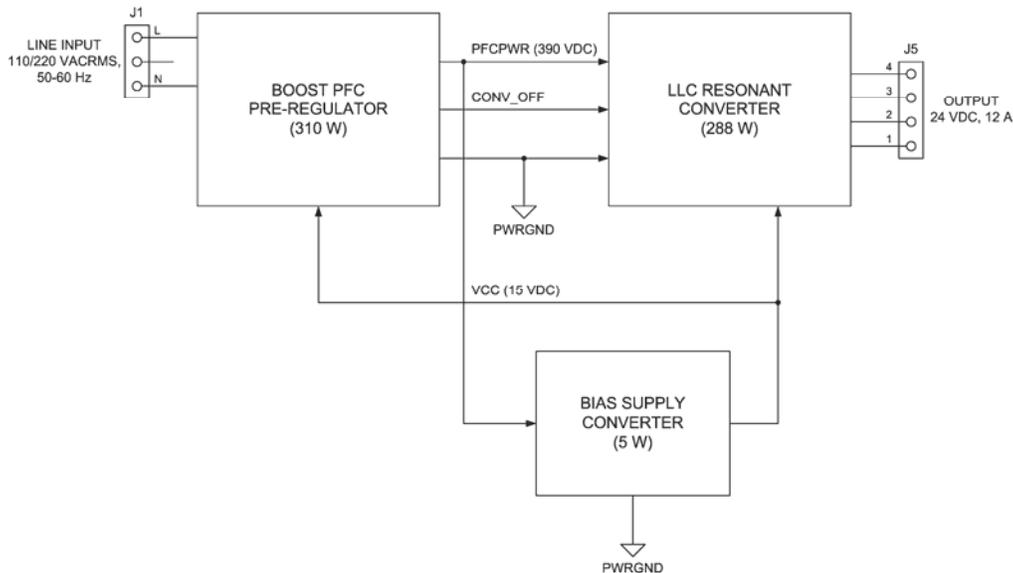


Fig. 1 LCD TV Power System Block Diagram

4.1 Boost PFC Pre-Regulator

The principle function of the boost PFC pre-regulator is to convert a wide-input voltage (universal) ac-line input source to a regulated DC voltage, while operating at near unity power factor. It achieves this by controlling the power MOSFET of a boost converter at a relatively constant ‘on’ time over each half period of the rectified ac input. Applying a constant ‘on’ time to each switch period causes the current in the boost inductor to rise proportionally to the applied input voltage. As the current in the inductor is equal to the input current, then the average switched current drawn from the input source is proportional to the source voltage. In this condition the input of the circuit appears as a pure resistance and the circuit operates at unity power factor. To maintain boost converter operation, the regulated output voltage is set at 390 VDC. This voltage must be higher than the peak of the maximum input ac rms voltage, which is 375 V. The output capacitance to the boost PFC converter is relatively large. This is because a large frequency component of the inductor ripple current is at just twice the minimum line frequency (94 Hz).

The circuit presented in this design is similar to that described in the UCC28060 evaluation module ([UCC28060EVM](#)). It includes a number of operating refinements to the basic boost PFC converter concept. The design uses two boost inductors and MOSFET switches. These are connected in parallel to form two phases that feed the common output capacitance. During normal operation the MOSFETS are operated 180° out of phase to each other, such that they are electrically interleaved. As a further enhancement the boost inductors are operated

in “transition mode.” With this technique the current in each inductor is required to completely decay to zero during the ‘off’ period of the transistor switch before the next ‘on’ period is initiated. Zero inductor current is detected by the control circuit using an auxiliary winding on each inductor. The voltage across the auxiliary winding collapses to zero when the inductor energy is exhausted. The combination of interleaved phases and transition-mode control results in improved efficiency and smaller component sizes when compared to a traditional single-phase solution. These and other control enhancements, such as phase management and input current shaping, are built in to the boost PFC control IC. This design uses the UCC28061 controller. The UCC28061 has improved audible noise performance over the UCC28060. In addition the phase management of the UCC28060 is determined purely by the total ‘on’ time demanded from the MOSFET switches. This results in lower switching losses when the circuit is operated from high AC line voltages (220 VAC). With high ac-line voltage the UCC28061 usually doesn’t see sufficient on-time demanded to engage phase ‘B’ of the circuit.

The PWMNTL pin (pin 9) of the UCC28061 provides an automatic on/off enable for a downstream converter. This is used to prevent the LLC series-resonant converter from starting up before the output voltage from the PFC pre-regulator has reached a minimum value. The output voltage is sensed through a resistor divider connected at the VSENS pin (pin 2). The on/off threshold and hysteresis are controlled by the gain and output impedance of the divider. The values selected for this design provide a nominal ‘on’ threshold of 330 VDC, and an ‘off’ threshold of 300 VDC for the resonant converter.

4.2 LLC Series-Resonant DC-DC Converter

The LLC series-resonant DC-DC converter is powered from the regulated output of the boost PFC pre-regulator. The circuit comprises of a ½-bridge power stage, which is connected to the series elements of an LLC resonant circuit. The resonant circuit is formed by the series combination of a low-value resonant inductance, the magnetizing inductance of the main transformer, and combined capacitance on the passive side of the bridge. The resonant frequency is set by resonant inductance ($17.5 \mu\text{H}^\ddagger$) and circuit capacitance ($0.045 \mu\text{F}$). These values set the resonant frequency of this circuit to between 175 kHz and 180 kHz.

When operated at the resonant frequency, the voltages across the resonant components of the circuit cancel, allowing the full peak-peak voltage from the power stage to be applied across the transformer primary. This is the unity gain operating condition. By then varying the stimulus frequency either below or above resonance, the gain of the circuit, and hence the output voltage, can be increased or decreased respectively. The switch frequency of the power stage is the control parameter that regulates the output of a resonant converter.

In this design the main transformer and resonant inductor are represented by separate components. Commercial designs often integrate the resonant inductor into the transformer as the leakage component. This is fairly easy to achieve when a traditional ferrite ‘E’ core is used for the main transformer. In order to meet the low-profile requirement of this design, planar magnetic components were selected. Integrating the resonant inductance into the main transformer is more difficult to achieve with a planar transformer. In particular, power dissipation is significantly increased. However the availability of new ferrite geometries may make it possible to achieve a low-profile design using a traditional E-core shape.

The magnetizing inductance of the main transformer affects the gain variation of the circuit versus the switching frequency. It also plays an important role in limiting the switching losses of the MOSFET drivers. Energy stored in the magnetizing inductance causes current to circulate during the short period when both MOSFET switches are ‘off’. The phase of this current has the effect of reducing the voltage across the next MOSFET to be turned on. This is referred to as zero-voltage switching (ZVS). It improves efficiency by significantly reducing the switching losses of the converter. It also reduces the magnitude of electrical noise generated by the circuit compared to a more rapid collapse of the MOSFET drain voltage with normal switching.

The ½-bridge power stage operates at 50% duty and varying frequency. The upper and lower MOSFETs of the bridge are controlled by the UCC25600 IC via an isolated gate drive. The converter output voltage is regulated by a TL431A shunt regulator located in the secondary. The error signal generated from the TL431A is passed back to the converter primary using an opto’ coupler. A decrease in the error voltage at the output of the opto’ coupler increases the current pulled from RC pin (pin 2) of the UCC25600. This increases the switching frequency of the converter, which reduces its gain and output voltage.

[‡] Includes the primary referred leakage inductance of the main transformer

The UCC25600 is a very simple and low-cost part to use. In addition to providing a variable drive frequency for ½-bridge power stage, it includes a soft-start feature, over-current shutdown protection, and adjustment of MOSFET switch dead time.

The circuit senses load current through the resonant capacitance using a parallel 0.001- μ F capacitor as an impedance divider. Current through this capacitor is half-wave rectified and then passed through a low-value sense resistor. The resulting signal is then filtered and fed to the OC pin (pin 3) of the UCC25600. Our testing suggests that this method of sensing current results in less variation of the sensed current with switching frequency.

The resonant current is susceptible to a high surge current during converter start-up. For this reason it is recommended that the sensitivity of the current sense is reduced during converter start up. In the reference circuit this is accomplished with a P-channel JFET and a divider resistor. The gate of the JFET is connected to the SS pin (pin 4) of the UCC25600, which is initially low during converter start up. The JFET places the divider resistor in circuit during the period that its gate voltage is low. When the soft start period is complete the JFET turns off to return current sensitivity to normal.

Other protection features, such as over-voltage shutdown, are easily implemented by momentarily pulling the SS pin (pin 4) of the UCC25600 to ground. Over-voltage protection has been added to the reference design using this method. At the converter output a 27-V Zener diode is used to sense an output over voltage. The diode is connected in series with an opto' coupler. When the output voltage is sufficiently high to break down the Zener diode, the output of the coupler pulls down the soft-start pin to the UCC25600.

A limitation of LLC series-resonant converters is that they operate over a limited input voltage range. This is because below a certain operating frequency the frequency-gain relationship of the converter is reversed. The operating frequency of the UCC25600 is controlled by the magnitude of current flowing from the RT pin (pin 2). A resistor to ground, R309, sets the minimum operating frequency to approximately 110 kHz.

To limit the surge current during start up the UCC25600 incorporates a soft-start feature. During the soft-start period the control frequency is pushed 100 kHz above the minimum frequency set by R309. For some designs the frequency may still not be high enough to limit the surge current in the series-resonant circuit. For this reason the components C323 and R324 are added so make the resistance, from the RT pin to ground, appear initially lower. This effect lasts for only the few milli-seconds it takes for C323 to charge.

An automatic on/off enable signal (CONV_OFF) prevents the resonant converter starting until there is sufficient voltage output from the upstream PFC pre-regulator. This signal is used to hold down the SS pin (pin 4) whenever the output voltage from the PFC stage is insufficient for the resonant converter to produce a regulated output. In this case a simple NPN bipolar transistor is used to ground the SS pin whenever the CONV_OFF control signal is high.

4.3 5-W Bias Converter

The 5-W bias supply is produced by a simple flyback converter. This regulator provides 15-VDC bias to power the control circuits on the primary side of the power supply. The circuit is based on the UCC2813D-4, a small current-mode controller. The converter is powered from the output of the PFC pre-regulator stage and must be able to start up prior to the PFC stage being operational. For this reason the circuit is designed to operate over a wide input voltage, 100 – 450 VDC. The low power level and current limit setting of this circuit eliminates the need for a snubber at the MOSFET drain. It also ensures that the flyback transformer is confined to operating in discontinuous current mode (DCM).

For applications that have higher bias power requirements, or require a significant amount of standby power in the secondary, a converter design based on the UCC28610 is recommended. The UCC28610 is a robust and efficient controller that is capable of meeting the high efficiency and low standby power limitations demanded by EnergyStar®.

4.4 PCB Jumper Settings

The PCB design includes two 0.1-in spaced pin headers, J3 and J6. Using standard shorting jumpers, these headers provide on/off and power-up options for the board for diagnostic purposes. The jumper settings are described as follows.

4.4.1 J3: BOOST PFC OFF

Placing a jumper at J3 prevents operation of the Boost PFC Pre-Regulator. With this setting the DC output voltage will only be as high as the peak AC voltage applied at the input connector, J1. This option allows the LLC Resonant Converter to be operated independent of the Boost PFC Pre-Regulator. Note that a relatively high AC-line voltage (265–280 V ACRMS) must be applied to the input in order for the LLC converter to properly regulate. The power supply will also operate at very poor power factor. The default setting is NQ jumper.

4.4.2 J6: LLC CONVERTER (OFF) / AUTO / RUN

The jumper setting at J6 provides three power-up options for the LLC Resonant Converter. A standard 2-pin jumper can be placed in either the “Auto” or “Run” position. The default jumper position is “Auto.” In this position the resonant converter powers up whenever the Boost PFC Pre-Regulator is operating.

When the jumper is in the “Run” position the resonant converter will operate whenever a valid V_{CC} supply voltage is available. This mode is useful for testing the resonant converter independently from the PFC pre-regulator. The removal of the jumper will then disable the resonant converter. The settings are summarized in Table 2.

Table 2: LLC Resonant Converter Jumper Settings

Jumper Position	LLC Converter Operating Mode
No Jumper	Disabled (no operation)
Auto (default) ^{1/}	Operates with PFC pre-regulator
Run ^{1/}	Operates without PFC pre-regulator

1. Use a standard 2-pin jumper in either position

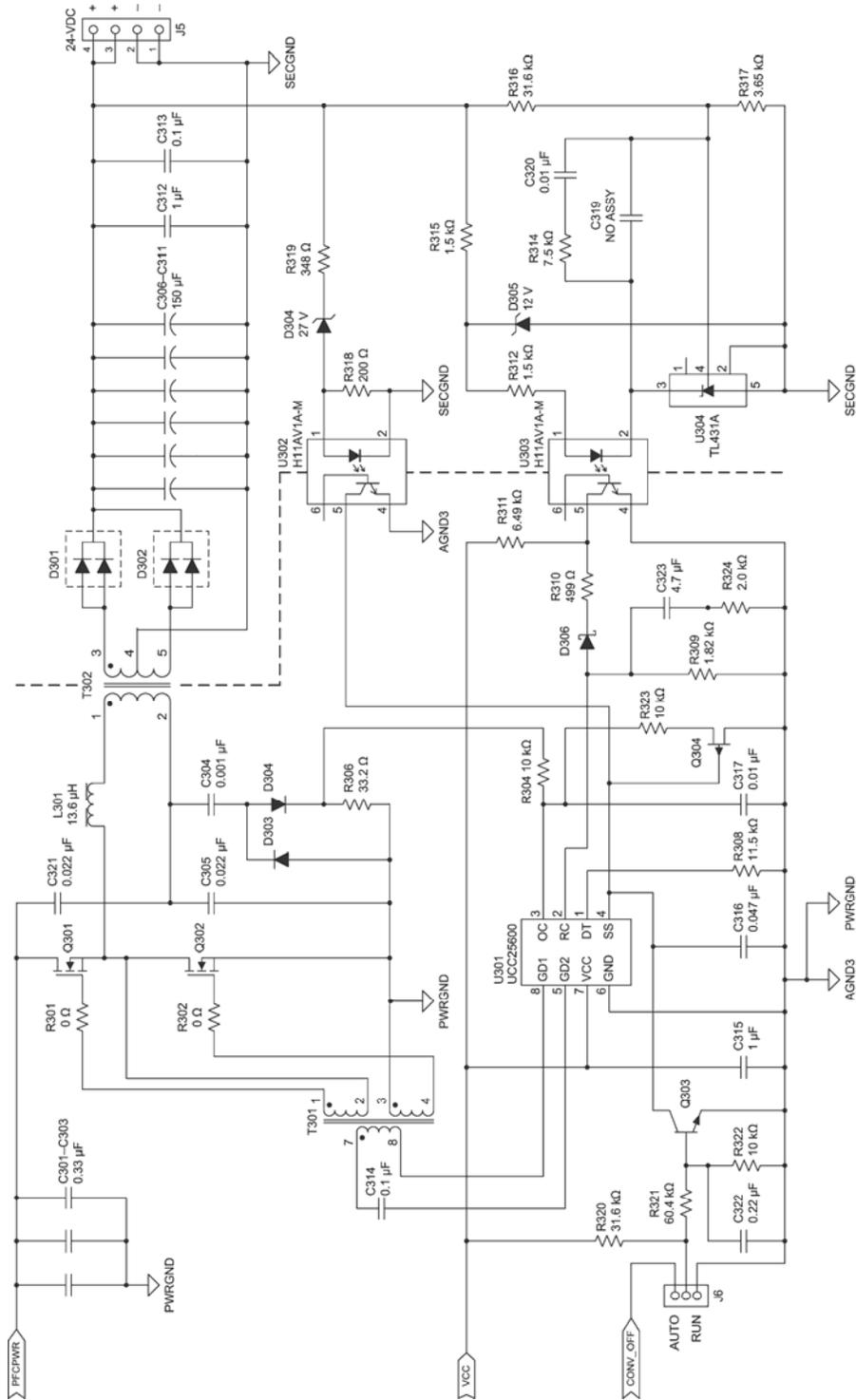


Fig. 3 Schematic, LLC Resonant Converter

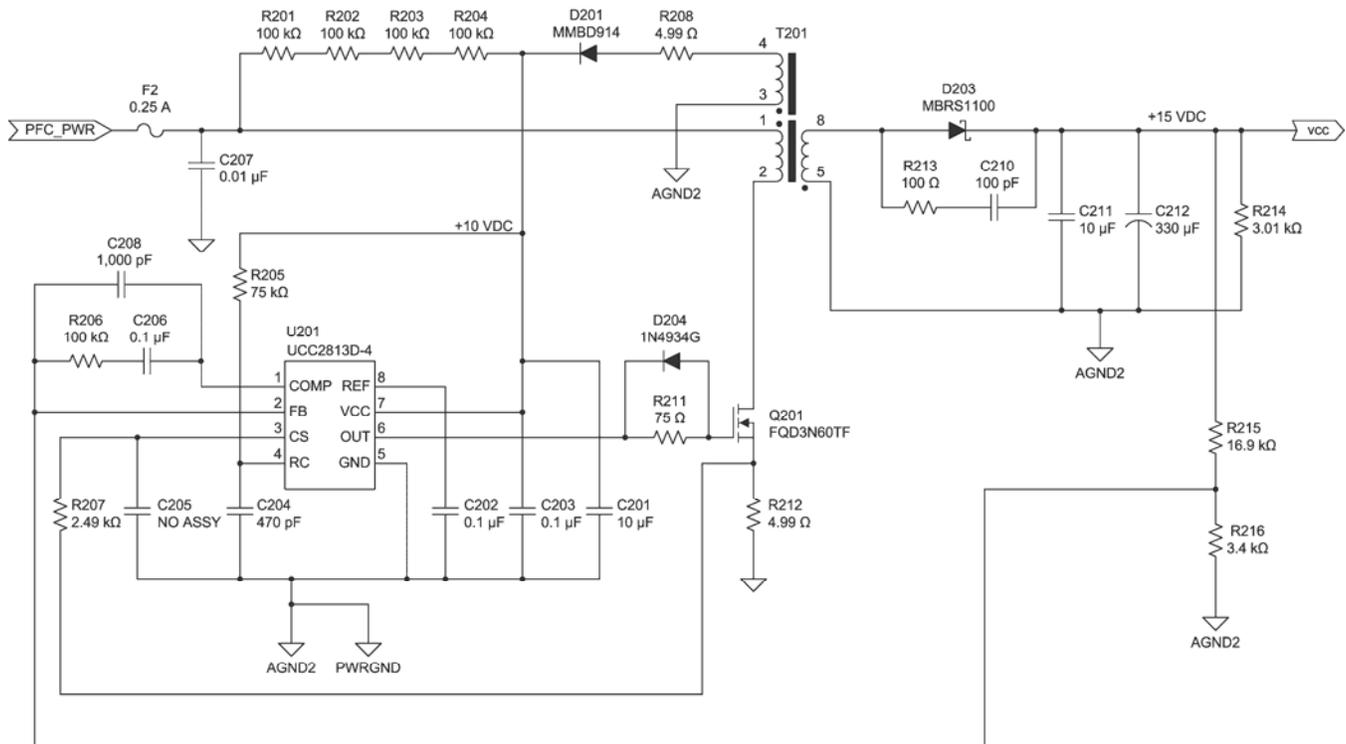


Fig. 4 Schematic, Bias Supply Converter

6 PCB DESIGN

6.1 General

Fig. 22 and Fig. 23 show the component placement and copper routing of the printed circuit board (PCB), that used to test and characterize this design. The PCB was designed using single-layer, 1-oz. copper foil. A combination of both through-hole (T/H) and surface mount devices (SMD) were used. T/H components are mounted on the top side of the PCB and SMD parts on the underside.

The layout detailed in Fig. 22 & Fig. 23 is missing one component. Fig. 3 Schematic, LLC Resonant Converter, shows two pairs of rectifiers connected to the T302 secondary; D301 and D306. The layout shows just one, D301. For improved efficiency and thermal management, two output rectifier pairs are recommended.

6.2 Grounding

The PCB design is limited to a single layer of copper foil. This requires careful attention to the layout of the copper traces. Differential high-frequency noise developed across discontinuities in the ground system can cause spurious operation of the control circuits. For this reason the design dedicates large areas of copper to the power ground node (PWRGND). Care should then be exercised to keep the ground contiguous and connected with wide paths of copper. The ground connections should take priority over the routing of all other signals. Where necessary, wire links or axial T/H components should be used to pass signals to other areas of the board. These techniques minimize the impedance to high-frequency ground currents to ensure low-noise operation.

Most of the control circuitry uses surface mount devices (SMDs), which are placed on the underside of the PCB. There are three control circuits, one for each of the power converters on the board. To provide noise immunity from the high-frequency currents generated by the power circuitry, the components associated with each control circuit are grouped together and referenced to one of three analog grounds. The control circuit for the PFC Boost converter uses AGND1, the Bias Supply Converter AGND2, and the LLC Resonant Converter AGND3. Each of

these analog grounds is represented on the PCB layout as a small copper area (or island) which is then connected to power ground (PWRGND) at just one location. This single-point grounding technique forces the high-frequency ground currents generated by the power circuitry to be directed around (as opposed to through) the quiet ground area occupied of the sensitive control circuits.

6.3 Creepage & Clearance

Both the component placement and spacing between the copper areas or the PCB were designed to comply with the creepage and clearance requirements defined in the UL 60950 safety standard. The board was designed to meet the requirements for functional isolation for the high-voltage nodes on the primary (ac-line) side of the power supply, and reinforced isolation between all primary and secondary circuits. To comply with the UL standard 4 mm of separation was used for the primary-side high-voltage traces, and 8 mm between all primary and secondary side traces. The default trace separation for low-voltage nodes, as used for control circuits, was 0.3 mm.

6.4 Thermal Considerations

The PCB assembly dissipates a significant amount of heat and requires some thermal management initiatives for it operate in a confined space over the defined ambient temperature range. Several components on the PCB either require a heat sink, or must be provided with a thermally conductive path to the metal surfaces of the enclosure. Table 3 provides a list of the components that may require conductive cooling, along with their approximate power dissipation.

Table 3 Parts with High Thermal Dissipation

Ref. Des.	Description	Dissipation ^{1/}
D101	Input bridge rectifier	5.7 W
T302	LLC converter transformer	5.3 W
L101, L102	PFC boost inductors	4.5 W
D301, D302	LLC output rectifiers	4.0 W
Q101, Q102	Boost PFC MOSFETs	2.0 W
Q301, Q302	LLC ½-Bridge MOSFETs	0.7 W

1. Estimated power dissipation at the maximum rated load

For the assembly that was tested, heat sinks were used for D101, Q101, Q102, Q301, Q302, D301, & D302. Standard (off-the-shelf) heat sinks were used wherever possible. The exception was the input bridge rectifier, D101. To spread the heat and maintain a low profile, a special heat sink was fabricated from 13 AWG (0.072 in. thick) aluminum sheet. The construction details are provided in Fig. 21: Heat Sink for Bridge Rectifier (D101).

7 PERFORMANCE CHARACTERISTICS

Fig. 5 through Fig. 20 present typical performance curves. Since actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and may differ from actual field measurements.

7.1 Typical Efficiency and Power Factor

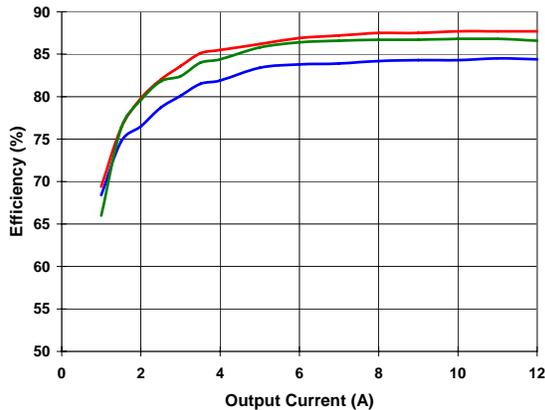


Fig. 5 Operating Efficiency; Low AC-Line Range¹

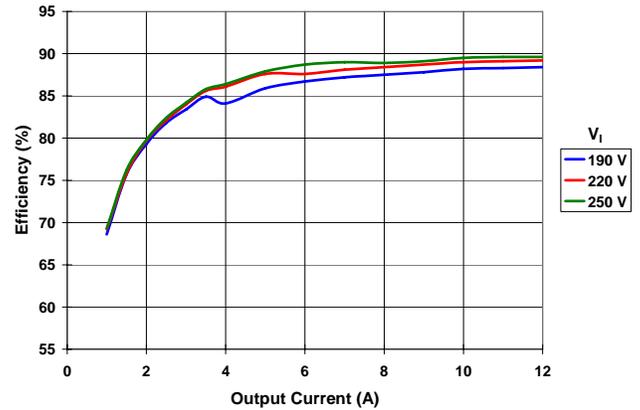


Fig. 6 Operating Efficiency; High AC-Line Range¹

7.2 Typical Power Dissipation

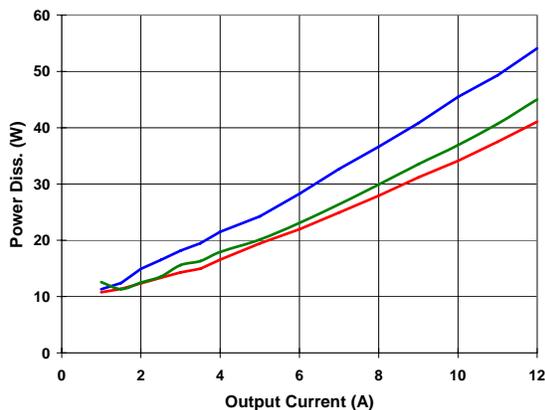


Fig. 7 Power Dissipation; Low AC-Line Range¹

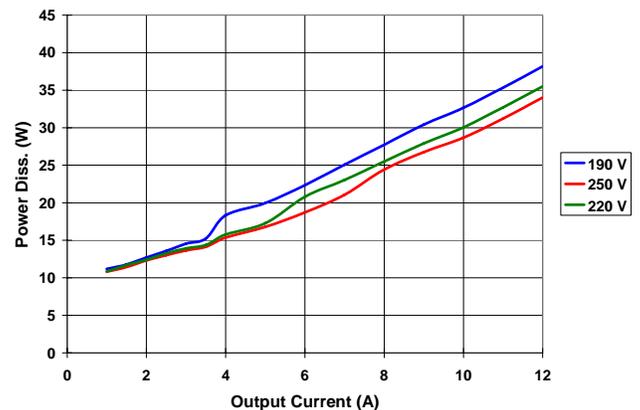


Fig. 8 Power Dissipation; High AC-Line Range¹

Notes:

1. The discontinuity in the performance curves at approximately 4 A of output current is caused by the phase management feature of the UCC28061 PFC control IC. The shift occurs when the IC transitions from single to dual-phase operation.

7.3 Typical Output AC Ripple Voltage

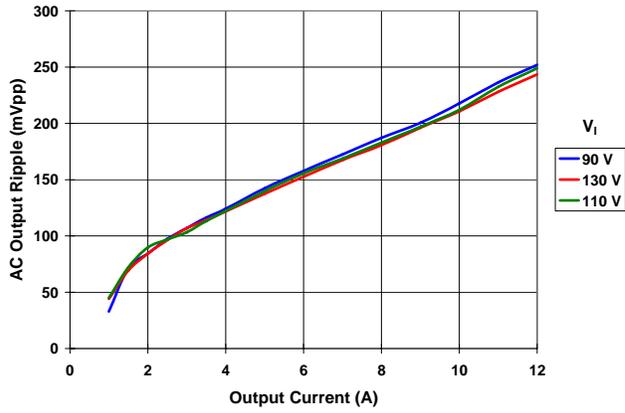


Fig. 9 Output AC-Ripple; Low AC-Line Range

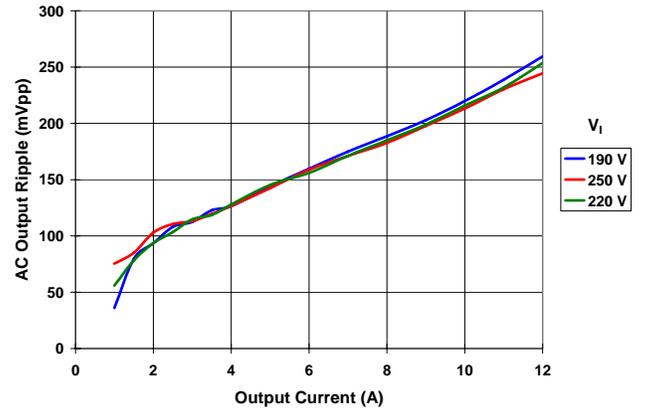
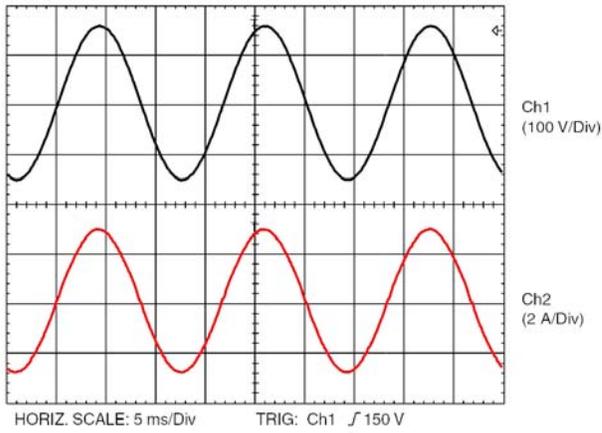


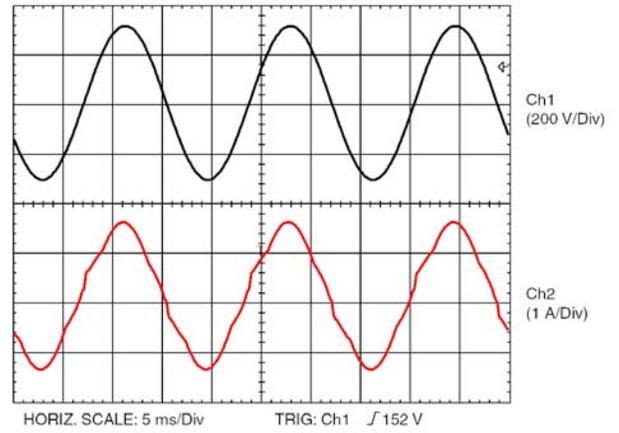
Fig. 10 Output AC-Ripple; High AC-Line Range

8 CIRCUIT WAVEFORMS

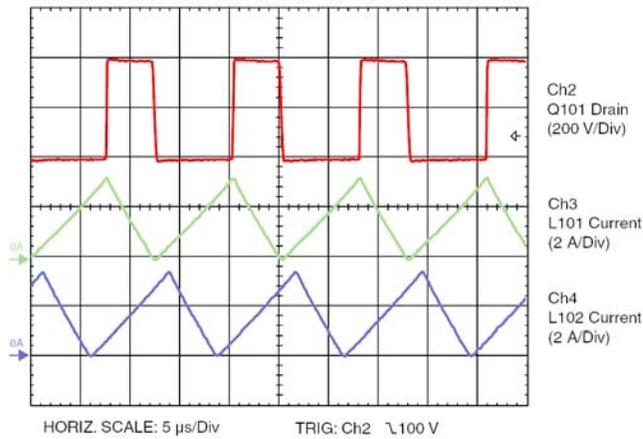
8.1 Boost PFC Pre-Regulator



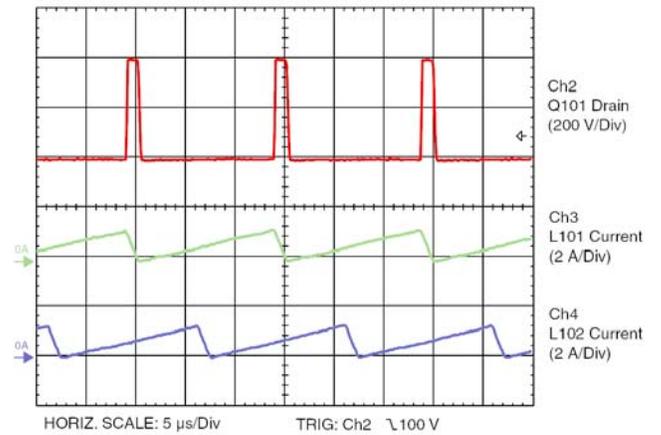
**Fig. 11 V & I Input AC Waveforms;
110 V AC-Line & 8-A Load**



**Fig. 12 V & I Input AC Waveforms;
220 V AC-Line & 8-A Load**



**Fig. 13 PFC Inductor Waveforms; 8-A Load &
with AC-Line at 160 V (110-V pk)**



**Fig. 14 PFC Inductor Waveforms; 8-A Load &
with AC-Line at 40 V (Crossover)**

8.2 LLC Resonant Converter

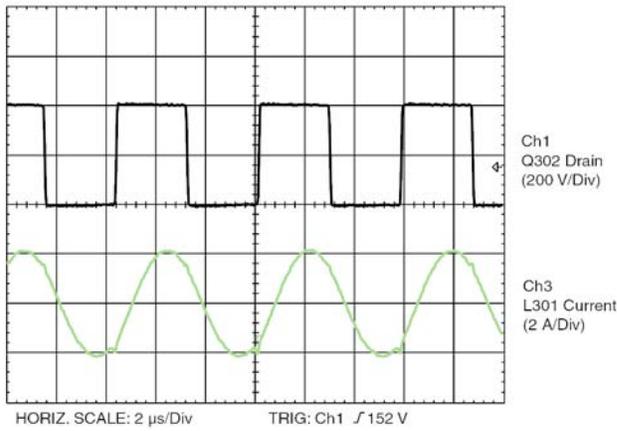


Fig. 15 Switch Node & Inductor Current;
8-A Load & 390 VDC Link (174 kHz)

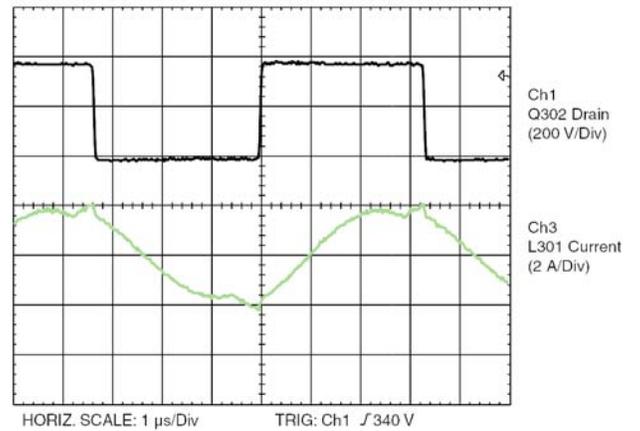


Fig. 16 Switch Node & Inductor Current;
8-A Load & 340 VDC Link (150 kHz)

8.3 Response to AC-Line Input Drop-outs

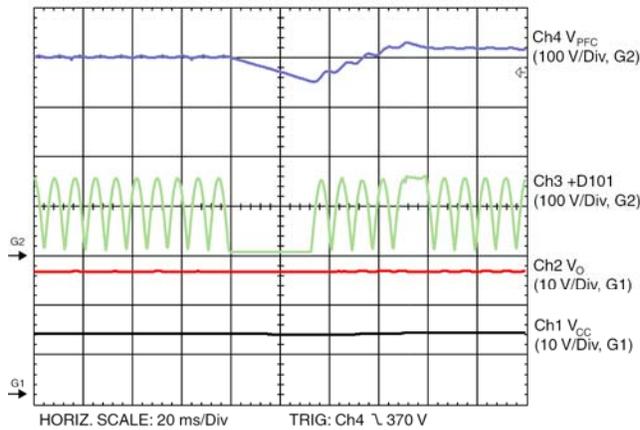


Fig. 17 Line Dropout: 2 Cycles;
8-A Load & 110 V 60 Hz AC-Line

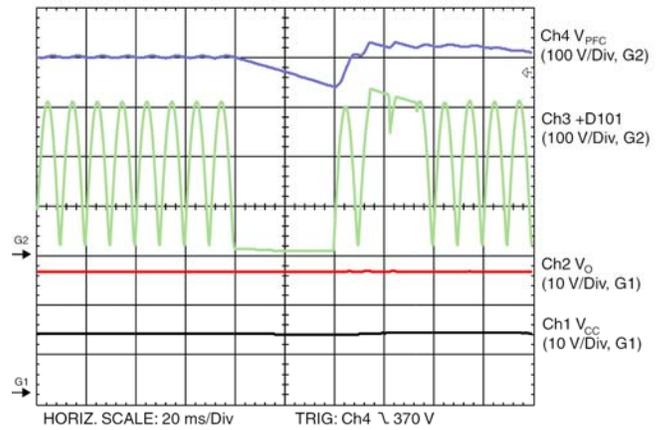


Fig. 18 Line Dropout: 2 Cycles;
8-A Load & 220 V 50 Hz AC-Line

8.4 Start Up & Shut Down

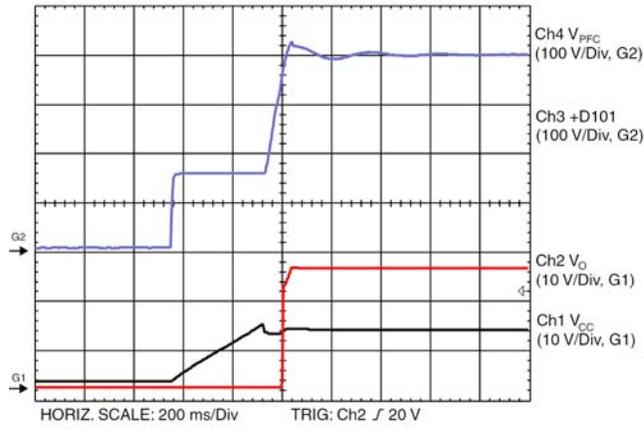


Fig. 19 Start-up Sequence; 110 V AC-Line Input

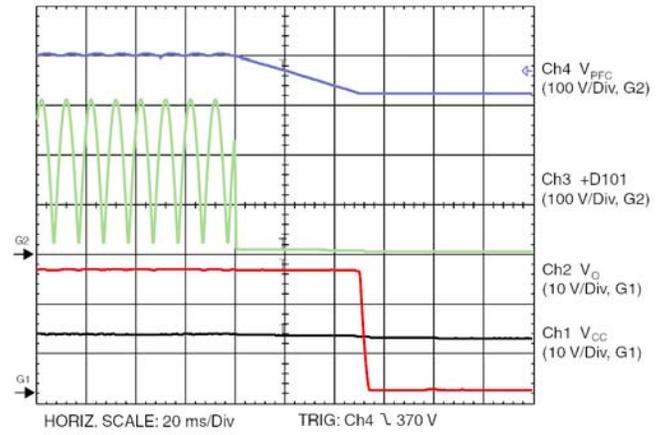


Fig. 20 Shut-Down Sequence; 220 V AC-Line Input

9 ASSEMBLY DRAWINGS AND LAYOUT

9.1 Special Part Drawings

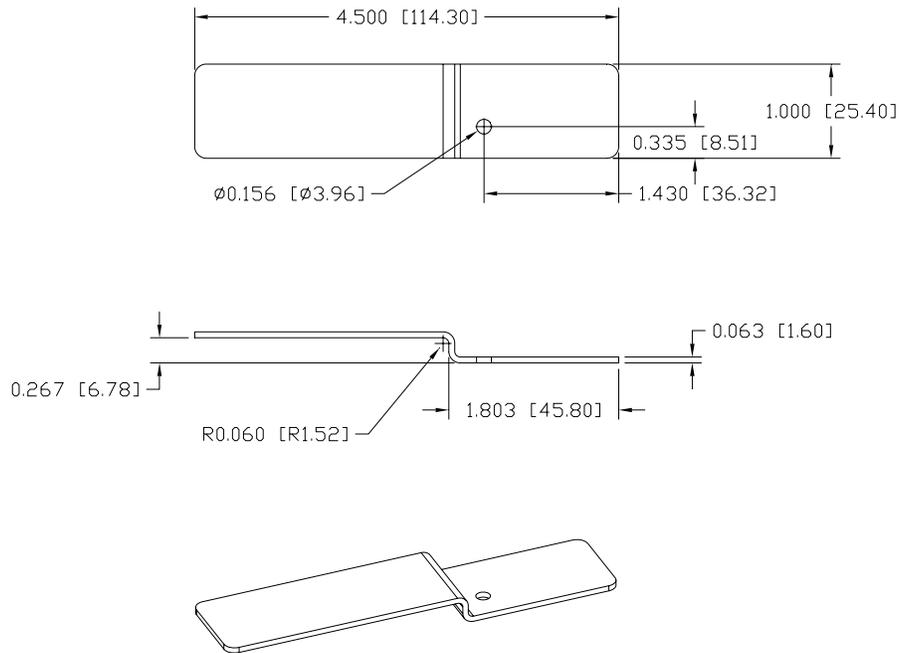
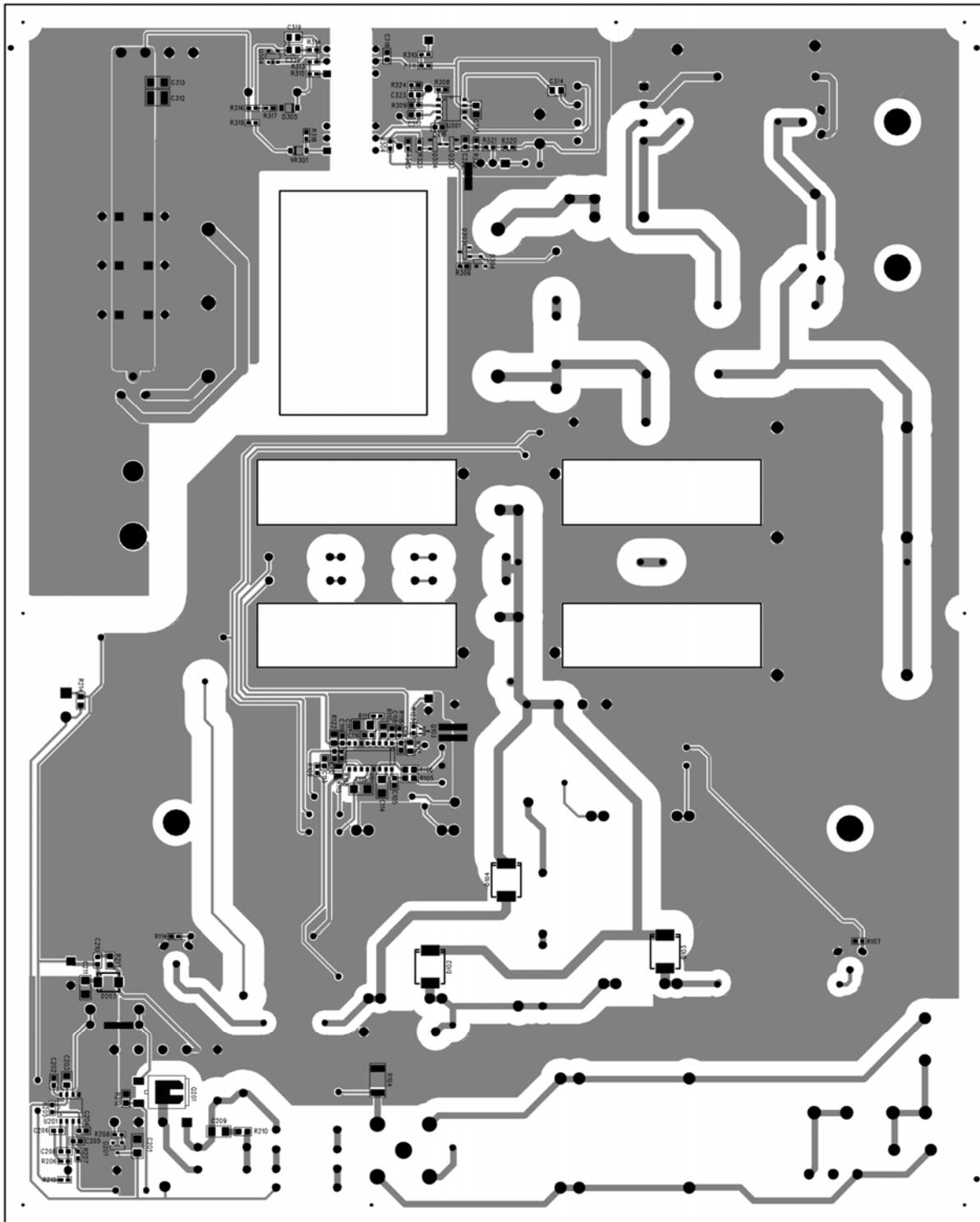


Fig. 21: Heat Sink for Bridge Rectifier (D101)



9.3 LIST OF MATERIALS

Table 4 lists the components as configured according to the schematic shown in Fig. 2 through Fig. 4.

Table 4 Bill of Materials

Qty.	Ref. Des.	Value	Description	Part Number	Manufacturer
3	C101-C103	0.33 μ F	CAPACITOR, PET FILM, X1, 250 VAC, 20%	ECQ-U3A334MG	Panasonic
1	C104	0.1 μ F	CAPACITOR, PET FILM, X2, 250 VAC, 20%	ECQ-U2A104BC1	Panasonic
2	C105, C106	22 pF	CAPACITOR, MLC, 0603, 50 V, 5%	Generic	Multi-sourced
1	C107	0.047 μ F	CAPACITOR, PET FILM, 630 V, 10%	ECQ-E6473KZ	Panasonic
4	C108-C111	100 μ F	CAPACITOR, ELECTROLYTIC, 450 V, 10%	EKXG451ELL101MM40S	Nippon Chemi-Con
2	C112, C118	1200 pF	CAPACITOR, MLC, 0603, 50 V, 10%	Generic	Multi-sourced
2	C113, C317	0.01 μ F	CAPACITOR, MLC, 0603, 50 V, 10%	Generic	Multi-sourced
1	C114	0.33 μ F	CAPACITOR, MLC, 1206, 25 V, 20%	Generic	Multi-sourced
2	C115, C117	2.2 μ F	CAPACITOR, MLC, 1206, 25 V, 20%	Generic	Multi-sourced
2	C116, C208	1000 pF	CAPACITOR, MLC, 0603, 100 V, 5%	Generic	Multi-sourced
1	C119	3300 pF	CAPACITOR, MLC, 0603, 50 V, 10%	Generic	Multi-sourced
2	C201, C211	10 μ F	CAPACITOR, MLC, 1206, 25 V, 10%	Generic	Multi-sourced
2	C202, C206	0.1 μ F	CAPACITOR, MLC, 0603, 16 V, 10%	Generic	Multi-sourced
2	C203, C314	0.1 μ F	CAPACITOR, MLC, 0805, 25 V, 20%	Generic	Multi-sourced
1	C204	470 pF	CAPACITOR, MLC, 0603, 50 V, 5%	Generic	Multi-sourced
1	C207	0.01 μ F	CAPACITOR, FILM, 630 V, 10%	ECQ-E6103KZ	Panasonic
1	C210	100 pF	CAPACITOR, MLC, 0603, 100 V, 10%	06031A101KAT2A	AVX
1	C212	330 μ F	CAPACITOR, ELECTROLYTIC, 25 V, 20%	EEU-FC1E331	Panasonic
3	C301-C303	0.33 μ F	CAPACITOR, FILM, 630 V, 10%	MF630V.33K	Xicon
1	C304	0.001 μ F	CAPACITOR, PP FILM, 1 KV, 10%	MKP10 1000/1600/10	WIMA
2	C305, C321	0.022 μ F	CAPACITOR, PP FILM, 1 KV, 10%	MKP10-.022/1KV/10	WIMA
6	C306-C311	150 μ F	CAPACITOR, ELECTROLYTIC, 35 V, 10%	EEUFM1V151	Panasonic
1	C312	1 μ F	CAPACITOR, MLC, 1210, 50 V, 20%	Generic	Multi-sourced
1	C313	0.1 μ F	CAPACITOR, MLC, 1206, 50 V, 20%	Generic	Multi-sourced
1	C315	1 μ F	CAPACITOR, MLC, 0805, 25 V, 10%	Generic	Multi-sourced
1	C316	0.047 μ F	CAPACITOR, MLC, 0603, 25 V, 10%	Generic	Multi-sourced
1	C320	0.01 μ F	CAPACITOR, MLC, 0805, 50 V, 10%	Generic	Multi-sourced
1	C322	0.22 μ F	CAPACITOR, MLC, 0603, 10 V, 10%	Generic	Multi-sourced
1	C323	4.7 μ F	CAPACITOR, MLC, 0603, 6.3 V, 5%	Generic	Multi-sourced
1	D101		BRIDGE RECTIFIER	GBPC606-E4/51	Vishay
3	D102-D104		RECTIFIER, POWER, ULTRA-FAST	MURS360T3G	ON Semiconductor
3	D201, D303, D304		DIODE, SIGNAL	MMBD914LT1G	ON Semiconductor
1	D203		DIODE, SCHOTTKY	MBRS1100T3G	ON-Semiconductor
1	D204		DIODE, FAST RECOVERY, T/H	1N4934G	ON-Semiconductor
2	D301, D302		DIODE, DUAL, SCHOTTKY, 100-V, 10-A	STPS20H100CT	ST Microelectronics
1	D304	27 V	DIODE, ZENER, 0.5-W, 27 V	MMSZ5254B	Diodes, Inc.

Qty.	Ref. Des.	Value	Description	Part Number	Manufacturer
1	D305	12 V	DIODE, ZENER, 0.5-W, 12 V	MMSZ5242BT1	ON Semiconductor
1	D306		DIODE, SCHOTTKY, T/H	1N5711	STMicroelectronics
1	F1		FUSE CLIPS, 5X20MM, CARTRIDGE	3517	Keystone
1	F2	0.25 A	FUSE, AXIAL-LEADED, FAST-ACTING	0263.250	Littelfuse
1	J1		HEADER, PLUGGABLE, HORIZ, 3-WAY	39522-1003	Molex
1	J3		CONNECTOR, HEADER, 0.025 SQ., 2-WAY	68001-202HLF	FCI BergStik
1	J5		HEADER PLUGGABLE, HORIZ, 4-WAY	39522-1004	Molex
1	J6		CONNECTOR, HEADER, 0.025 SQ., 3-WAY	68001-203HLF	FCI BergStik
2	L101, L102	330 μ H	INDUCTOR, BOOST, 5.5 A	I080-330 μ H/5.5A	Payton America
1	L301	13.6 μ H	INDUCTOR, RESONANT, 175 KHZ	I40-13.6 μ H/3.5A	Payton America
2	Q101, Q102		MOSFET, POWER, N-CHANNEL	IRFB11N50APbF	Vishay
1	Q103		TRANSISTOR, BIPOLAR, PNP	BC857BTT1G	ON-Semiconductor
1	Q201		MOSFET, DPAK	FQD3N60TF	Fairchild
2	Q301, Q302		MOSFET, TO-220	2SK3934	Toshiba
1	Q303		TRANSISTOR, NPN	MMBT3904LT1G	ON-Semiconductor
1	Q304		TRANSISTOR, JFET, P-CHANNEL	MMBFJ176	Fairchild
6	R101-R103, R115-R117	1M0	RESISTOR, T/H, 0.25 W, 1%	271-1.0M/AP-RC	Xicon
1	R104	0R015	RESISTOR, SMD, 2010, 1%	WSL2010R0120FEB	Vishay-Dale
2	R105, R112	20k5	RESISTOR, SMD, 0805, 1%	Generic	Multi-sourced
4	R106, R113, R208, R212	4R99	RESISTOR, SMD, 0805, 1%	SR732ATT4R99F	KOA
4	R107, R114, R322, R323	10k0	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
2	R108, R118	47k0	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R109	100R	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R110	121k	RESISTOR, SMD, 0805, 1%	Generic	Multi-sourced
1	R111	6k34	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R119	178k	RESISTOR, T/H, 0.25 W, 1%	271-178K/AP-RC	Xicon
2	R120-R121	536k	RESISTOR, T/H, 0.25 W, 1%	271-536K/AP-RC	Xicon
1	R122	10k2	RESISTOR, SMD, 0805, 1%	Generic	Multi-sourced
2	R123, R206	100k	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
4	R201-R204	100k	RESISTOR, T/H, 0.25 W, 1%	271-100K/AP-RC	Xicon
1	R205	75k0	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R207	2k49	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R211	75R0	RESISTOR, T/H, 0.25 W, 1%	271-75/AP-RC	Xicon
1	R213	100R	RESISTOR, SMD, 0805, 1%	Generic	Multi-sourced
1	R214	3k01	RESISTOR, SMD, 0805, 1%	Generic	Multi-sourced
1	R215	16k9	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R216	3k4	RESISTOR, T/H, 0.25 W, 1%	271-3.4K/AP-RC	Xicon
2	R301-R302	0R0	RESISTOR, ZERO LINK, T/H, 0.25 W	291-0/AP-RC	Xicon
1	R304	10k	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced

Qty.	Ref. Des.	Value	Description	Part Number	Manufacturer
1	R306	33R2	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R308	11k5	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R309	1k82	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R310	499R	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R311	6k49	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R312	1k5	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R314	7k5	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R315	1k5	RESISTOR, T/H, 0.25 W, 1%	271-1.5K/AP-RC	Xicon
1	R316	31k6	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R317	3k65	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R318	200R	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R319	348R	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R320	31k6	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R321	60k4	RESISTOR, SMD, 0603, 1%	Generic	Multi-sourced
1	R324	2k	RESISTOR, SMD, 0603, 1%	Generic	Multi-Sourced
1	RT1	5 Ohms	THERMISTOR, NTC	CL-40	GE Sensing
1	T201		TRANSFORMER, FLYBACK	HA3950-AL	Coilcraft
1	T301		TRANSFORMER, GATE DRIVE, 1:1:1	HA3858-AL	Coilcraft
1	T302		TRANSFORMER, 350VA, 175 KHZ	T250AC-16-4C	Payton America
1	U101		INTEGRATED CIRCUIT	UCC28061D	Texas Instruments
1	U201		INTEGRATED CIRCUIT	UCC2813D-4	Texas Instruments
1	U301		INTEGRATED CIRCUIT	UCC25600D	Texas Instruments
2	U302, U303		OPTO-COUPLER	H11AV1A-M	Fairchild
1	U304		INTEGRATED CIRCUIT	TL431AIDBV	Texas Instruments
1	VR1		VARISTOR	SIOV-S10K275E2	EPCOS
2	Q101, Q102		HEATSINK, EXTRUDED, LOW-PROFILE	7-345-1PP-BA	IERC
2	D301, D302		HEATSINK, EXTRUDED, LOW-PROFILE	7-345-2PP	IERC
1	J1		CONNECTOR PLUG, 3-WAY	39520-0003	Molex
1	J5		CONNECTOR PLUG, 4-WAY	39520-0004	Molex
2	Q301, Q302		HEATSINK, LOW-PROFILE, TO-220	274-1AB	Wakefield
4	Q101, Q102, D301, D302		INSULATOR PAD, TO-220	SP900S-58	Berquist
1	F1	5 A	FUSE, 5X20MM, GLASS, FAST-ACTING	0217005P	Littelfuse
8	Q101, Q102, D301, D302		NUT, STAINLESS STEEL, #4-40		Generic
2	D301, D302		LOCK WASHER, INTERNAL TOOTH, #4		Generic
4	Q101, Q102, D301, D302		PLAIN WASHER, #4		Generic
8	Q101, Q102, D301, D302		SCREW, PANHEAD, PHILLIPS, #4-40 × 3/8		Generic
4	Q101, Q102, D301, D302		INSULATOR, MOLDED, NYLON		Richco Plastic Co.

10 References

The following is a list of data sheets, evaluation guides, and papers that were used to design of the 300-W LCD TV power supply.

- [1] UCC28061 Data Sheet, Texas Instruments Ref. [SLUS837](#)
- [2] UCC28061EVM 300-W Interleaved PFC Pre-Regulator User's Guide, Texas Instruments Ref. [SLUU316](#)
- [3] UCC25600 Data Sheet; Texas Instruments Ref. [SLUS846](#)
- [4] Bing Lu, Wenduo Liu, Yan Liang, Fred C. Lee, and Jacobus D. van Wyk, "Optimal Design Methodology for LLC Resonant Converter," IEEE APEC 2006.

11 Additional Information

The PCB layout for this reference design was created using PADS 2005 CAD software by Mentor Graphics. PADS 'Logic' was used for schematic capture, and PADS 'Layout' was used to design the PCB. The Gerber file, silk screen, solder mask, and drill drawing files produced by PADS, including the program files that created them, are available to designers. Enquiries should be made to the regional Texas Instruments Product Information Center (PIC), or the local TI sales representative. Use the prototype reference design number, PR883, for this request.

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