PR735, A 600-W Interleaved PFC Converter Using the UCC28060

Reference Design

Literature Number: SLUU299A
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PR735, A 600-W Interleaved Dual-Phase Transition Mode PFC Converter

1 INTRODUCTION

PR735 is an interleaved dual-phase transition-mode PFC converter providing a fixed 400-V output at up to 1.5 A from an 85 VRMS to 265 VRMS ac input supply. This reference design requires an additional bias voltage of 15 V at 100 mA to power the UCC28060 device. PR735 is designed to showcase the features of the UCC28060 by demonstrating the performance of the UCC28060 in a typical off-line high power application. The UCC28060 contains innovative features such as Natural Interleaving™ and can be used in a variety of applications such as those listed in Section 2.1 below.

2 DESCRIPTION

PR735 is compromised of two boards: the power board contains the magnetics, transistors, and other high power components, while the controller board consists of the UCC28060 integrated circuit in addition to various compensation and filter circuitry. The controller board connects to the power board via a header, J1. A status LED on the controller board is illuminated when the PFC output is in regulation. Please refer to the UCC28060 data sheet for more information on device operation.

WARNING

Due to high voltages present in the circuit, this design should only be handled by experienced power supply professionals.

2.1 Applications

- LCD, Plasma, and DLP TVs
- Computer Power Supplies
- Entry-Level Servers

2.2 Features

- 85 VRMS to 265 VRMS Input Range
- 400-V Fixed Output
- 1.5Adc Steady State Output Current
- Utilizes TI's Patented Natural Interleaving™ Technique
- Phase Mangement Increases Efficiency at Light Loads
- Brownout Protection

3 PR735 SPECIFICATIONS

3.1 Electrical Characteristics

Table 1. PR735 Electrical and Performance Specifications

PARAMETER	MIN	NOM	MAX	UNITS
Input voltage (ac line)	85		265	VRMS
Line frequency	47		63	Hz
Output voltage		400		V
Output current	0		1.5	A
Full load efficiency	92%			
Power factor at maximum load	0.99			-
Bias voltage for controller board	14		21	V
Current for controller board			100	mA
Output power	0		600	W

3.2 Thermal Requirements

This reference design operates up to 600 W without external cooling in an ambient temperature of 25°C. The user should ensure that all high power components (MOSFETs, rectifiers, etc.) are properly heat-sinked to avoid overheating. External cooling may be used to reduce the thermal stress experienced by the components at high output power levels.

4 SCHEMATIC

The schematics on the following pages illustrate the PR735 reference design. The power stage and controller circuitry are shown on separate pages for clarity.

4.1 Power Stage Circuitry

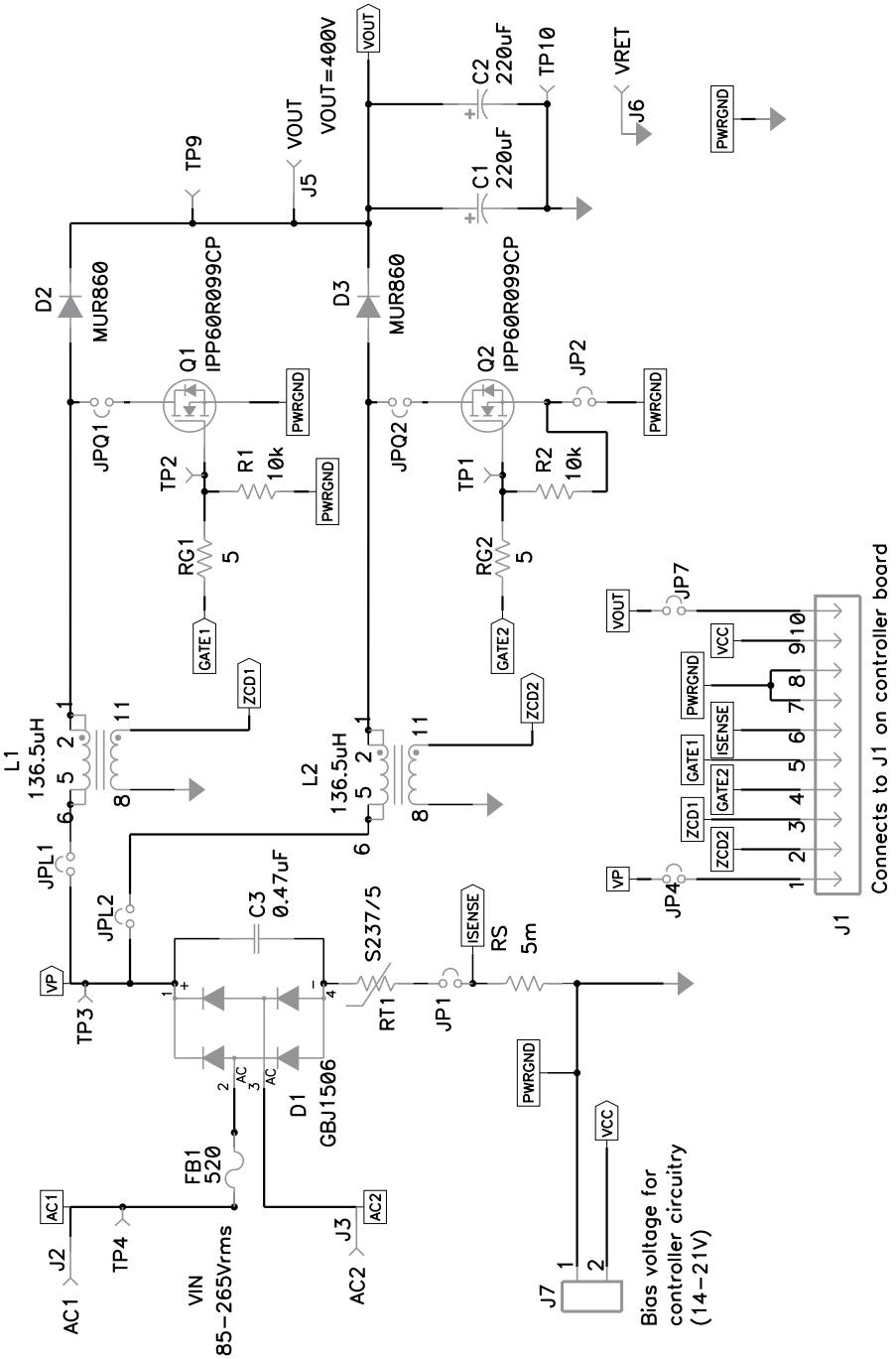

Figure 1. PR735 Power Stage

Note: For reference only, see Table 2, List of Materials, for specific values. Test points are for evaluation purposes only and are not required for converter operation.

4.2 Controller Circuitry

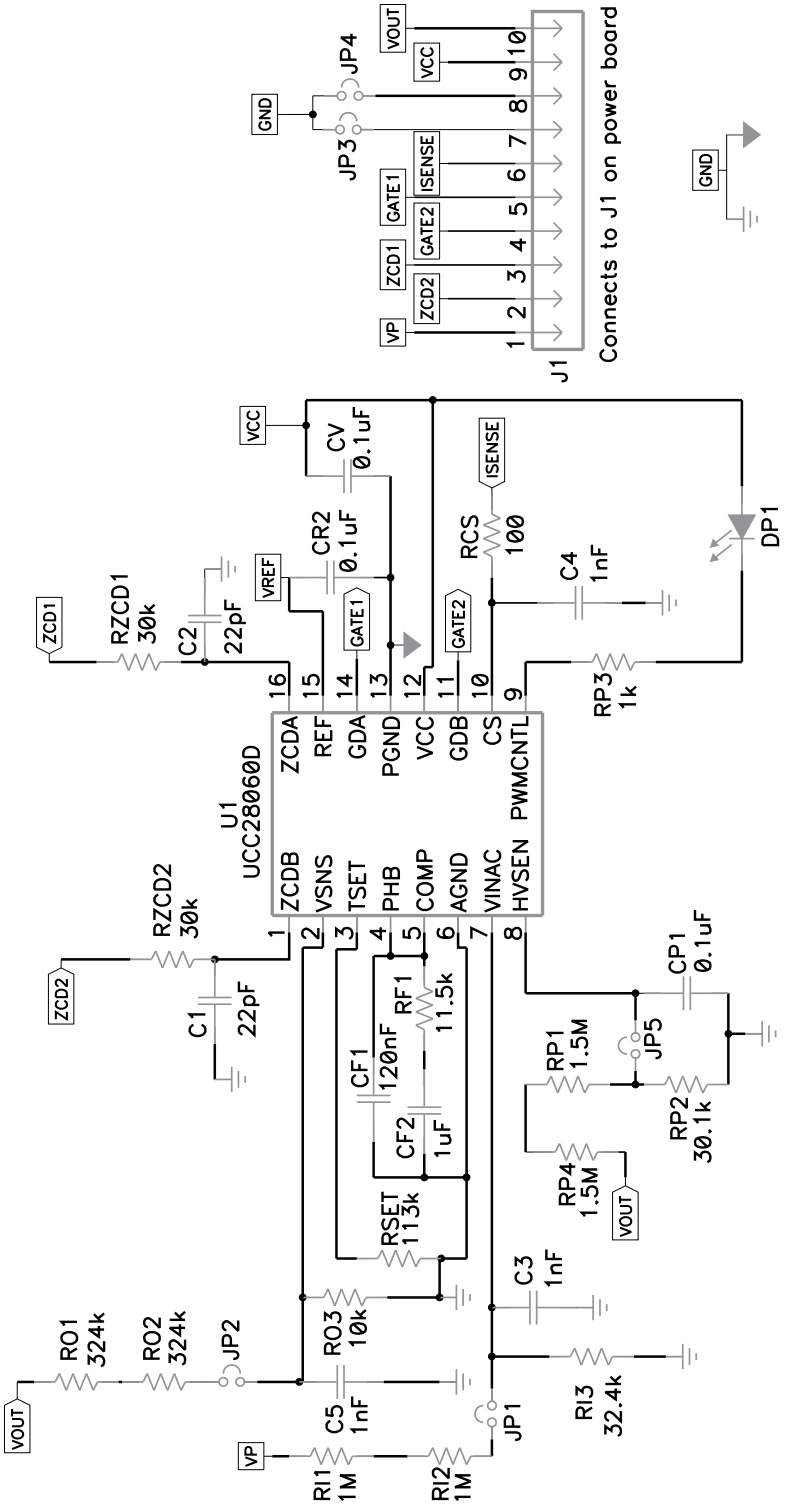

Figure 2. PR735 Controller Circuitry

Note: For reference only, see Table 3, List of Materials, for specific values.

5 PR735 TYPICAL PERFORMANCE DATA

Figure 3 through Figure 15 present typical performance data for the PR735. 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.

5.1 Efficiency

The figure below illustrates the efficiency of PR735 over the full output power range under low line and high line conditions.

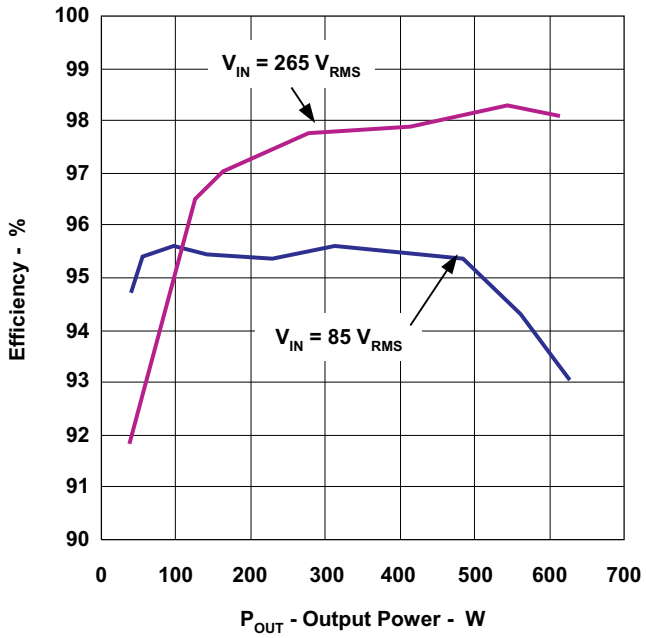

Figure 3. Efficiency at 85 VRMS and 265 VRMS

5.2 Current Harmonics at 230-VRMS Input

PR735 contains very low current harmonic content which easily meets the EN61000 standard. Most of the harmonic content is contained within the fundamental harmonic which results in low THD. The graph below illustrates the current harmonics of PR735 as well as the EN61000 standard for comparison.

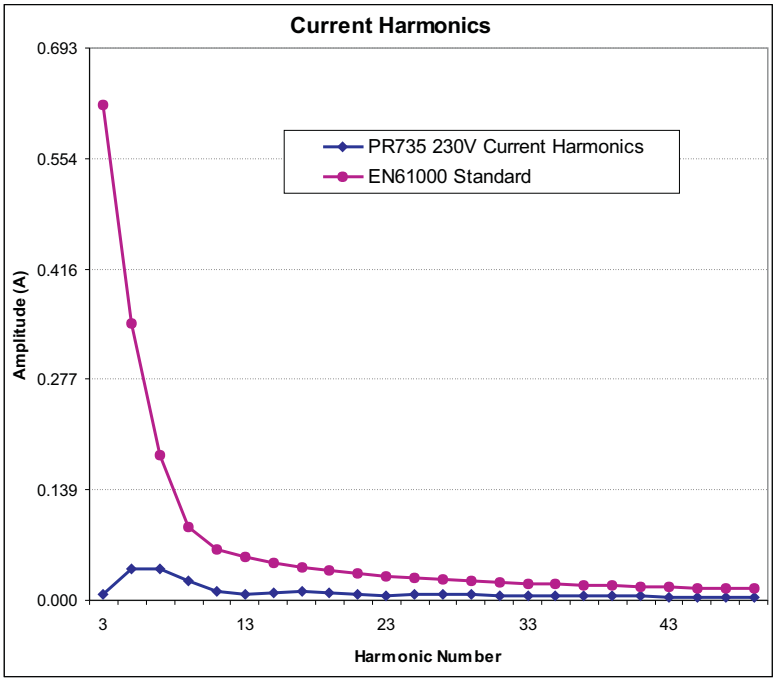

Figure 4. PR735 Current Harmonics with 230-VRMS Input

5.3 Output Voltage Ripple at Maximum Load

The output voltage ripple is seen to be approximately 10 V (peak-to-peak) in the figure below.

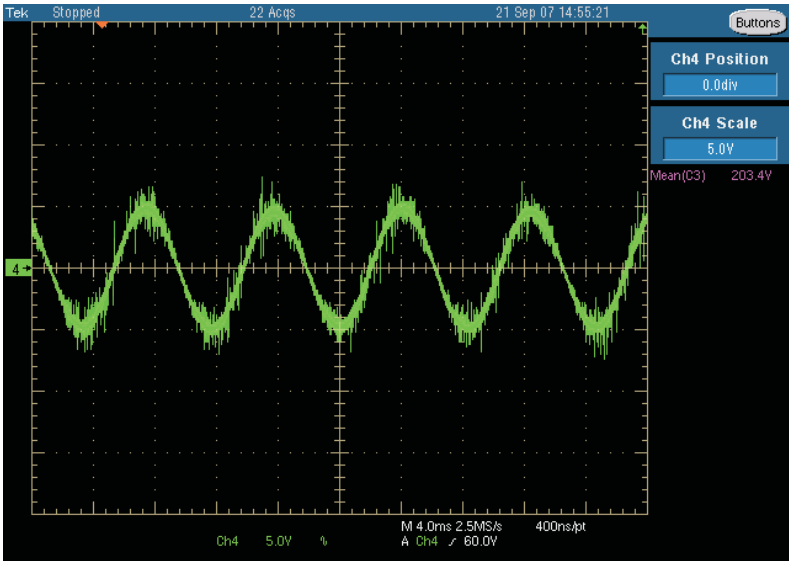

Figure 5. PR735 Output Voltage Ripple (5 V/DIV, ac coupled)

5.4 Input Ripple Current Cancellation

The following figures illustrate the input ripple cancellation of the PR735 converter at different input voltages during various portions of the line cycle. The M4 oscilloscope signal is the input current, consisting of both inductor currents added together.

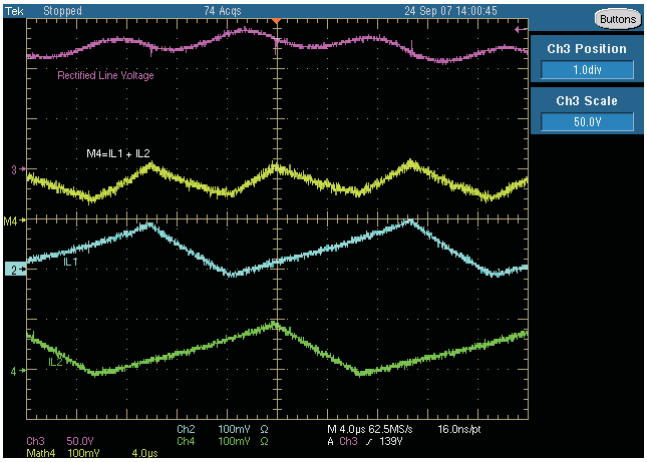

Figure 6. PR735 Inductor and Input Ripple Current at 85-VRMS Input at Peak Line Voltage

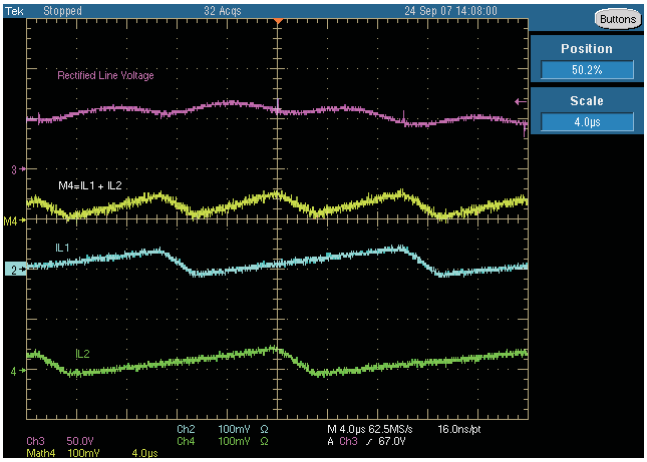

Figure 7. PR735 Inductor and Input Ripple Current at 85-VRMS Input at Half Peak Line Voltage

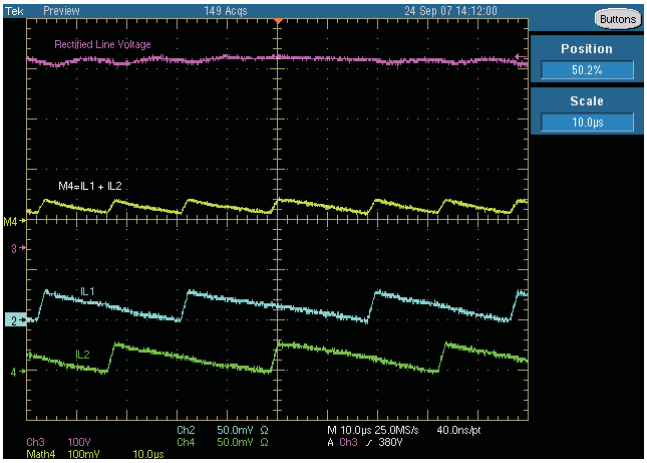

Figure 8. PR735 Inductor and Input Ripple Current at 265-VRMS Input at Peak Line Voltage

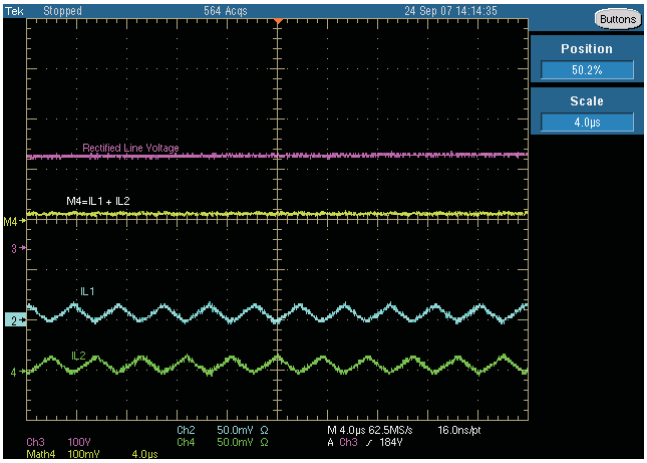

Figure 9. PR735 Inductor and Input Ripple Current at 265-VRMS Input at Half Peak Line Voltage

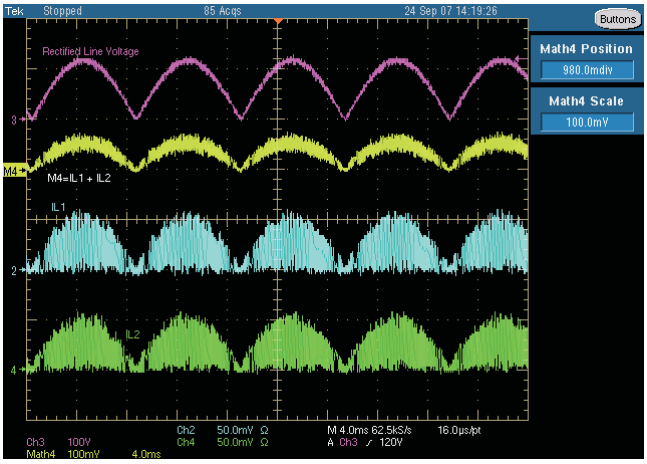

Figure 10. PR735 Inductor and Input Ripple Current at 85-VRMS Input, P_{OUT} = 300 W

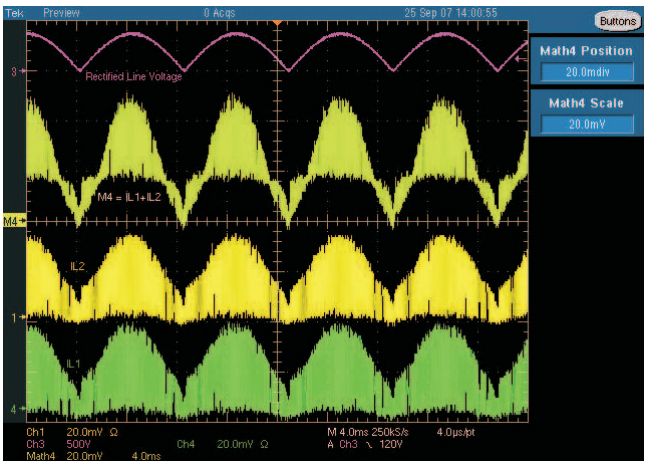

Figure 11. PR735 Inductor and Input Ripple Current at 265-VRMS Input, P_{OUT} = 600 W

5.5 Startup Characteristics

The figures below show the startup characteristics of PR735 under different input voltage and output power conditions.

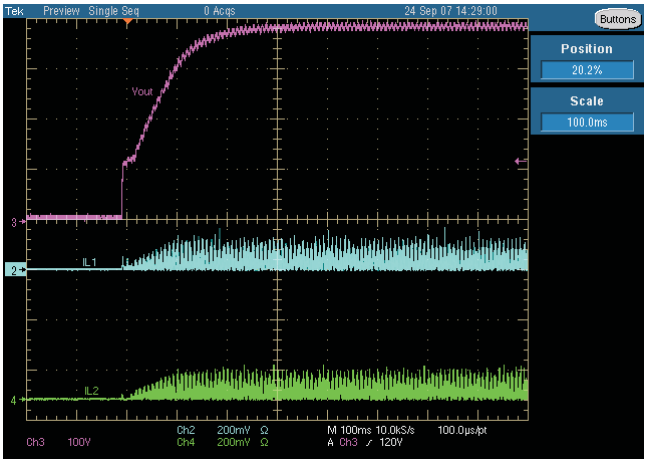

Figure 12. PR735 Start-Up at V_{IN} = 85 VRMS, P_{OUT} = 600 W

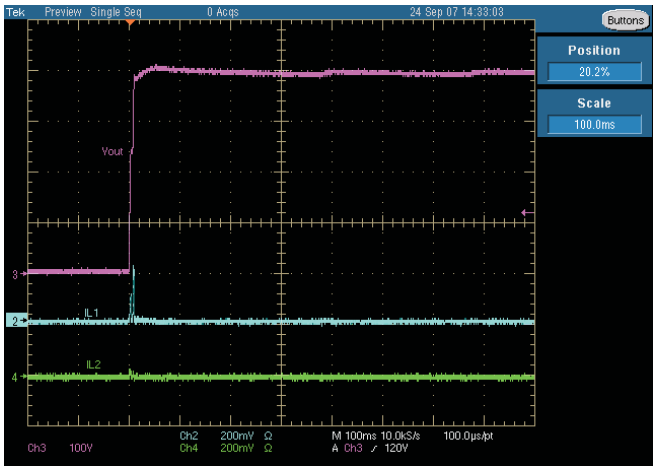

Figure 13. PR735 Start-Up at V_{IN} = 265 VRMS, P_{OUT} = 0 W

5.6 Brownout Protection

The figures below demonstrate the brownout protection feature of the UCC28060. If the VIN ac voltage drops below the brownout threshold voltage, the converter will stop switching after the brownout filter time (typically 440 ms).

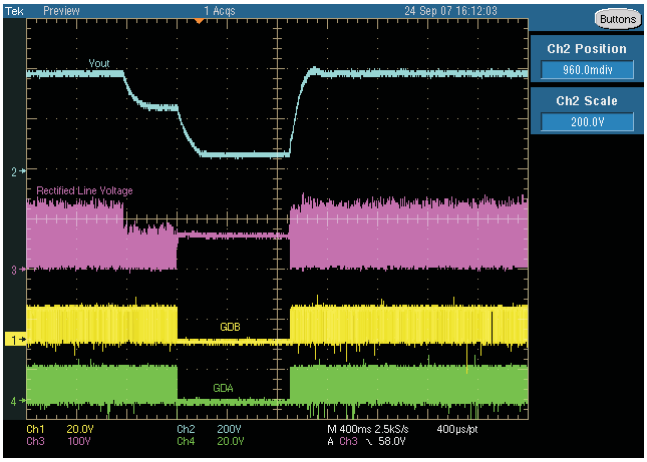

Figure 14. PR735 Brownout at 85 VRMS

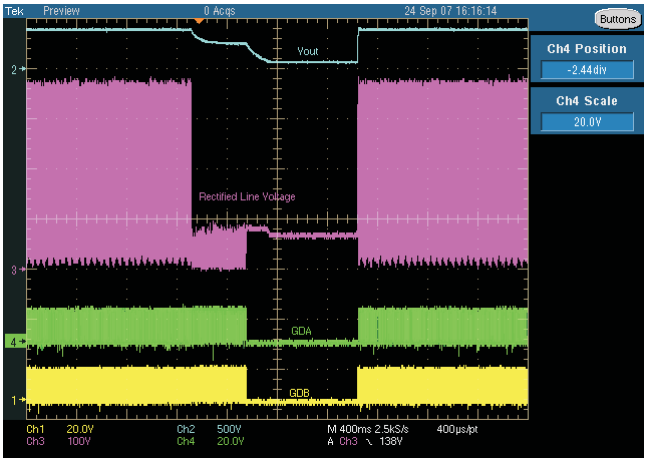

Figure 15. PR735 Brownout at 265 VRMS

6 EVM ASSEMBLY DRAWINGS AND LAYOUT

The following figures show the design of the PR735 printed circuit boards. The controller board is made up of a one-layer PCB with all of the components mounted on the top side. The power board consists of a one-layer PCB with trace routing on the bottom of the board and components placed on the top side of the board.

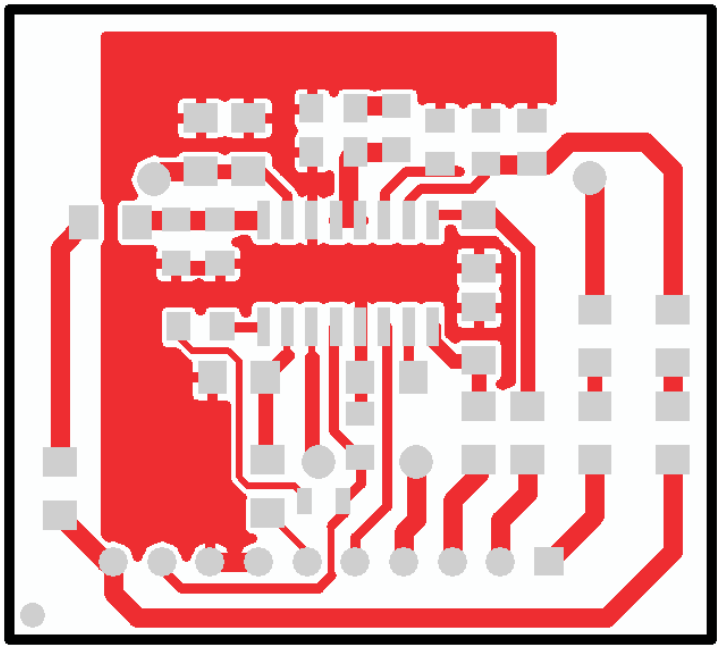

Figure 16. PR735 Controller Board Layout (viewed from top)

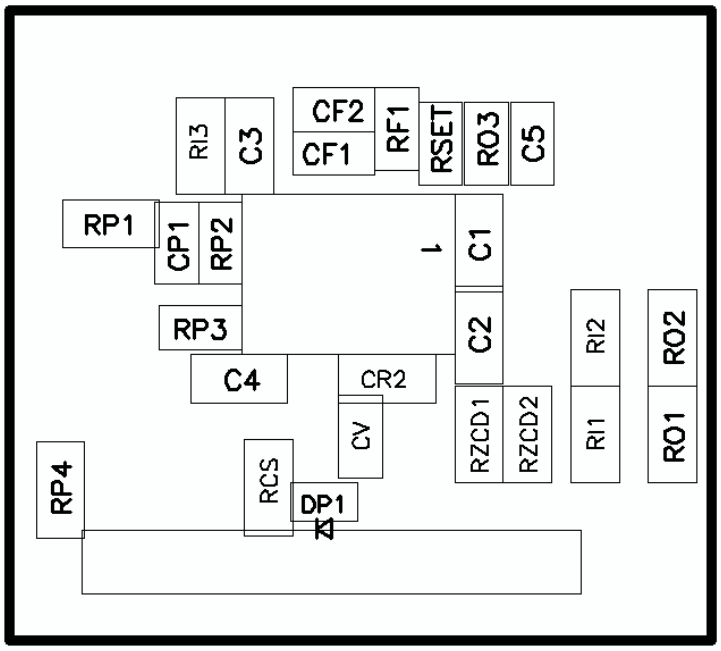

Figure 17. PR735 Controller Board Parts Placement (viewed from top)

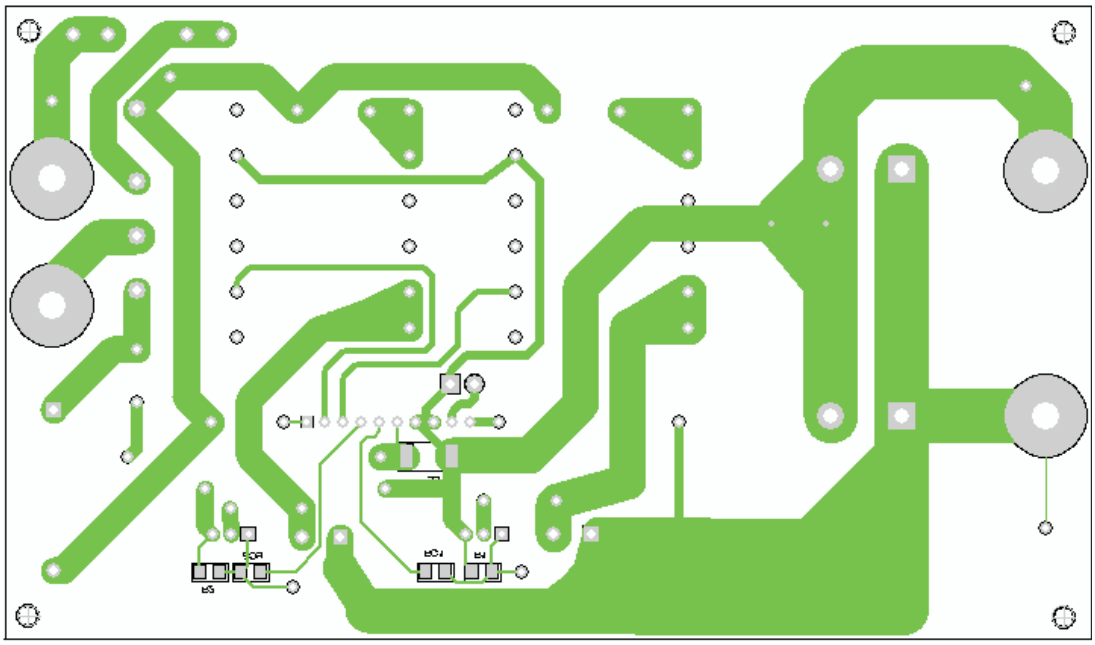

Figure 18. PR735 Power Stage Bottom Layer Layout (viewed from top)

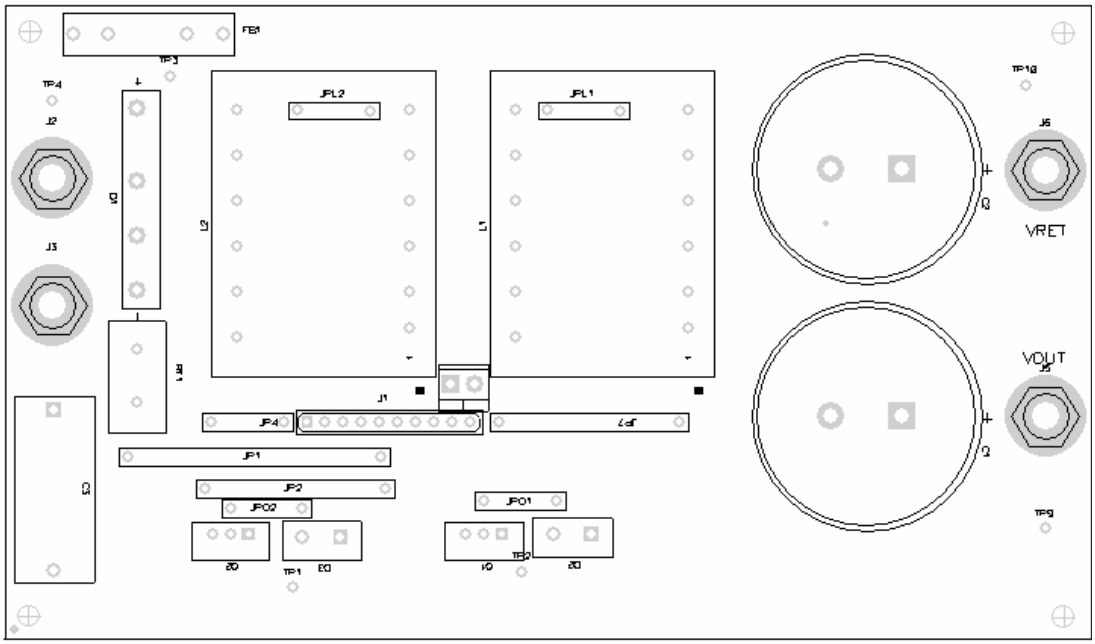

Figure 19. PR735 Power Stage Parts Placement (viewed from top)

7 POWER STAGE AND CONTROLLER STAGE LIST OF MATERIALS

7.1 Power Stage List of Materials

Table 2 lists the EVM components as configured according to the schematic shown in Figure 1.

Table 2. UCC28060, (PR735), Power Stage List of Materials

REF DES	NUMBER	DESCRIPTION	MANUFACTURER	PART NUMBER
C1, C2	2	Capacitor, 220 µF, 450 V elect KMQ snap	United Chemi-con	EKMQ451VSN221MR30S
C3	1	Capacitor, Film, 0.047 µF, 275 VAC	Panasonic	ECQ-U2A474ML
D1	1	Rectifier bridge, GPP, 600 V, 15 A	Diodes	GBJ1506-F
D2, D3	2	Diode ultra fast, 8 A, 600 V	On Semi	MUR860
FB1	1	Fuse clip, 5x20 mm	Wickmann	520
J1	1	Straight socket, 10P, 1 row	3M	929850-01-10-10
J2, J3, J5, J6	4	Connector, binding post, insulated	Johnson	111-0703-001
J7	1	Terminal block, 2 pin, 6 A, 3.5 mm	OST	ED555/2DS
JP1, JP2, JP4, JP7, JPL1, JPL2, JPQ , JPQ2	8	Jumper, thru hole, 0.035	STD	STD
L1, L2	2	Inductor, E Core	Ferroxcube	E41/17/12
Q1		MOSFET, N-channel, 600 V, 31 A	Infineon	IPP60R099CS
Q2		MOSFET, N-channel, 600 V, 31 A	Infineon	IPP60R099CS
R1, R2	2	Resistor, 10.0 kΩ, 1/4 W 1%, 1206	Std	Std
RG1, RG2	2	Resistor, 5.10 Ω, 1/4 W 1%, 1206	Std	Std
RS2	1	Resistor, 0.005 Ω, 1 W 1%, 2512	Panasonic	ERJ-M1WSF5M0U
RT1	1	Current limiter inrsh, 4.7 Ω, 20%	Epcos	B57238S479M
TP, TP2, TP3, TP4, TP9, TP10	6	Pin, thru hole, for 0.062 PCB's	Vector	K24A/M

7.2 Controller Stage List of Materials

Table 3 lists the EVM components as configured according to the schematic shown in Figure 2.

Table 3. UCC28060, (PR735), Controller Stage List of Materials

REF DES	NUMBER	DESCRIPTION	MANUFACTURER	PART NUMBER
C1, C2	2	Capacitor, ceramic, 50 V, 22 pF	AVX	12065A220JAT2A
C3, C4, C5	3	Capacitor, ceramic, 50 V, 1 nF	AVX	12065C103KAT2A
CF1	1	Capacitor, ceramic, 0.12 µF, 10%, 50 V, X7R 1206	AVX	12065C124KAT2A
CF2	1	Capacitor, ceramic, 1 µF, 50 V, Y5V 1206	AVX	12065G105ZAT2A
CP1, CR2, CV2	3	Capacitor, ceramic, 0.1 µF, 100 V, X7R 1206	Kemet	C1206C104K1RACTU
DP1	1	LED 470 NM super blue	Lumex	SML-LX0805USBC-TR
J1	1	Straight socket, 10P, 1 row	3M	929850-01-10-10
JP1, JP2, JP3, JP4, JP5	5	Jumper, thru hole, 0.035	STD	STD
RCS3	1	Resistor, 100 Ω 1/4W 1% 1206	Yageo	RC1206FR-07100RL
RF1	1	Resistor, 11.5 kΩ, 1/4 W, 1% 1206 SMD	Panasonic	ERJ-8ENF1152V
RI1, RI2	2	Resistor, 1.00 MΩ, 1/4 W, 1% 1206	Panasonic	ERJ-8ENF1004V
RI3	1	Resistor, 32.4 kΩ, 1/4 W, 1% 1206	Yageo	RC1206FR-0732K4L
RO1, RO2	2	Resistor, 324 kΩ, 1/4 W, 1% 1206	Yageo	RC1206FR-07324KL
RO3, RP1, RP2	3	Resistor, 10.0 kΩ, 1/4 W, 1% 1206	Panasonic	ERJ-8ENF1002V
RP3	1	Resistor, Chip, 1/8 W, 1%	Panasonic	ERJ-8ENF1001V
RP4	1	Resistor, 10.0 kΩ, 1/4 W, 1% 1206	Panasonic	ERJ-8ENF1002V
RSET3	1	Resistor, 113 kΩ, 1/4 W, 1% 1206	Yageo	9C12063A1133FKHFT
RZCD1, RZCD2	2	Resistor, 30.0 kΩ, 1/4 W, 1% 1206	Yageo	RC1206FR-0730KL
U1	1	IC, Interleave PFC Controller	TI	UCC28060D

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