

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

Reference Design



Literature Number: SLUU299A
November 2007–Revised April 2008

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 comprised 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

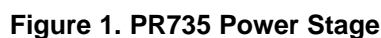
Table 1. PR735 Electrical and Performance Specifications

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.

4.1 Power Stage Circuitry



SLUU299A–November 2007–Revised April 2008
Submit Documentation Feedback

4.2 Controller Circuitry

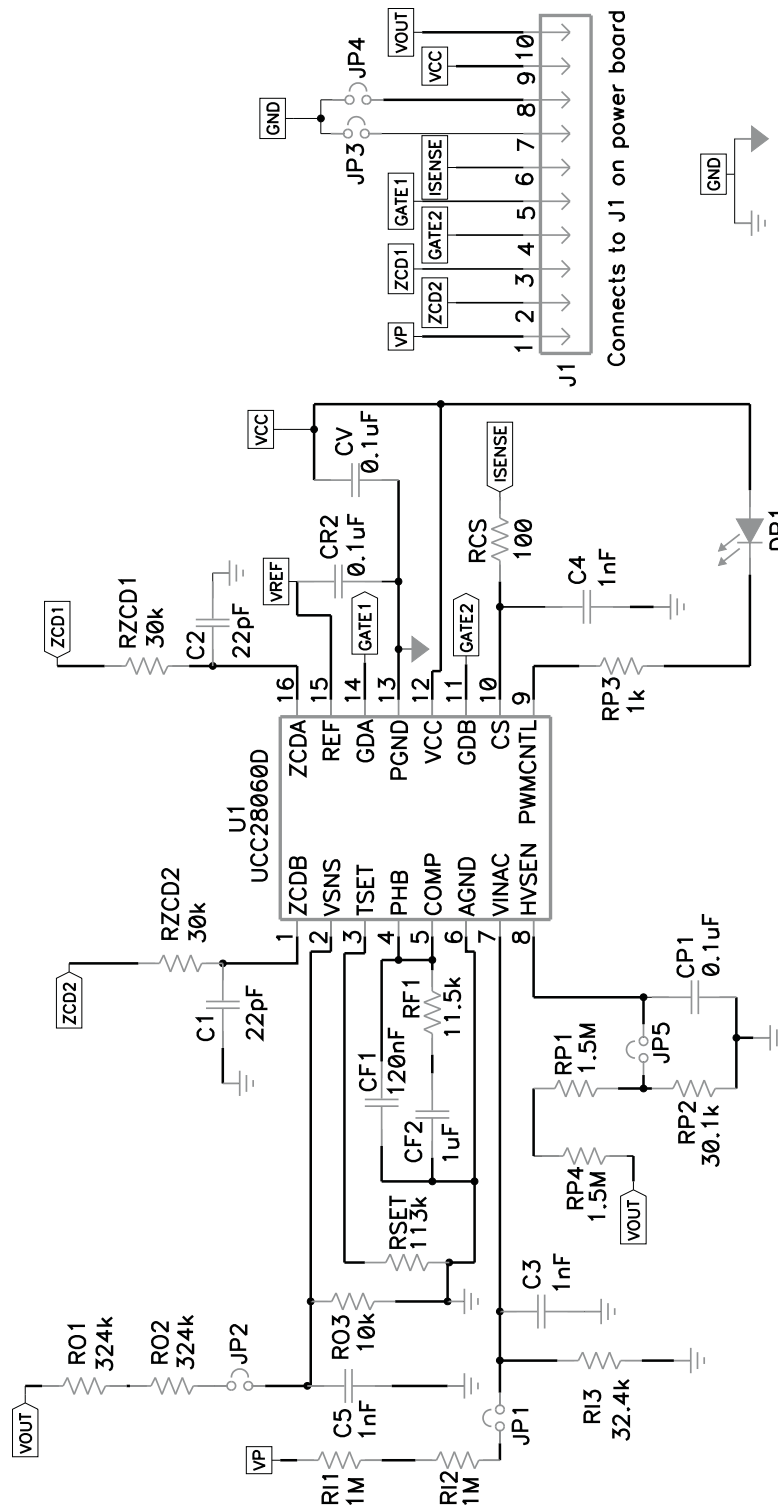


Figure 2. PR735 Controller Circuitry

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.

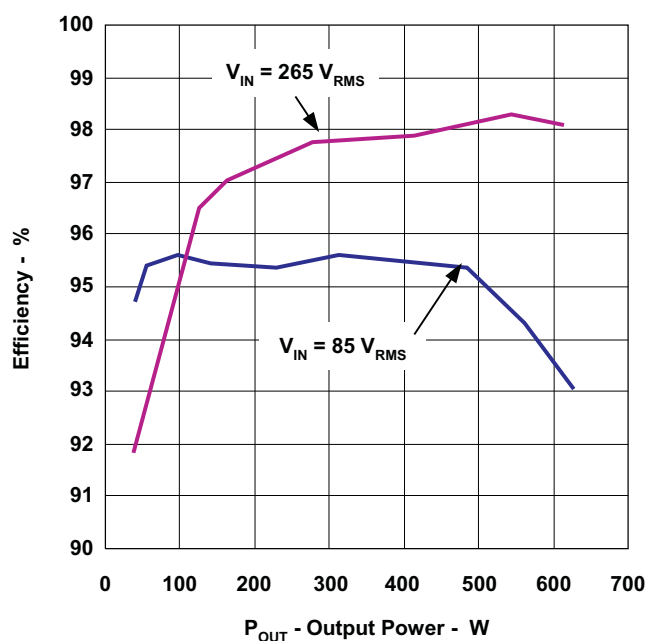


Figure 3. Efficiency at 85 VRMS and 265 VRMS

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.

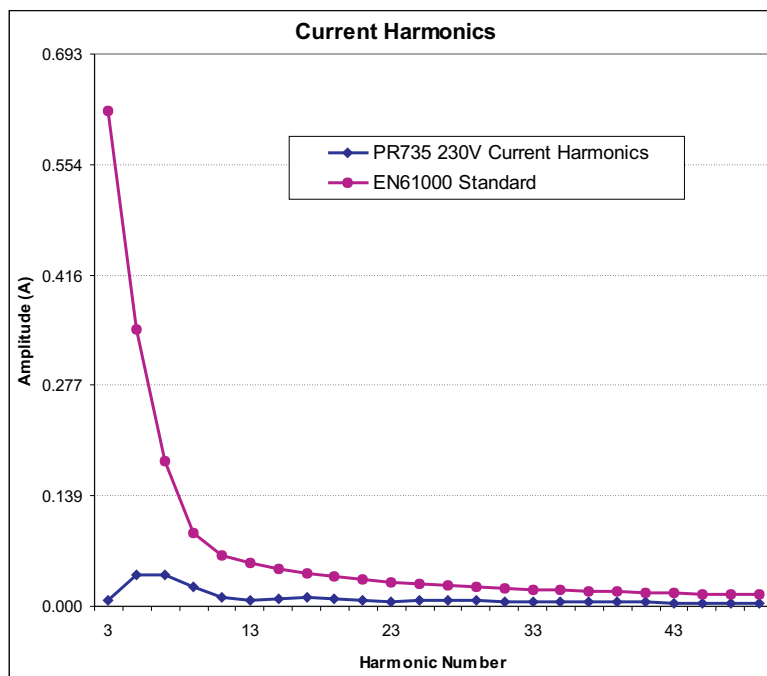


Figure 4. PR735 Current Harmonics with 230-VRMS Input

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.

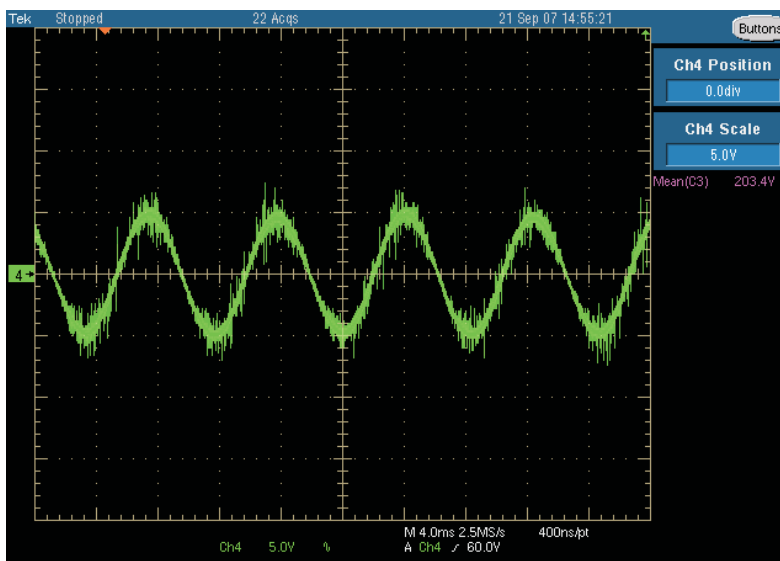


Figure 5. PR735 Output Voltage Ripple (5 V/DIV, ac coupled)

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.

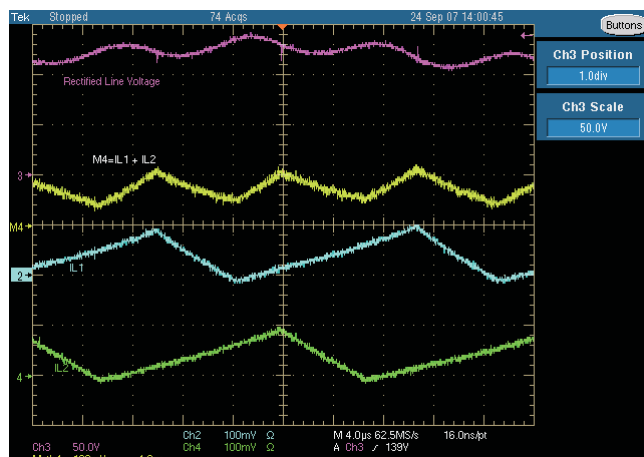


Figure 6. PR735 Inductor and Input Ripple Current at 85-VRMS Input at Peak Line Voltage

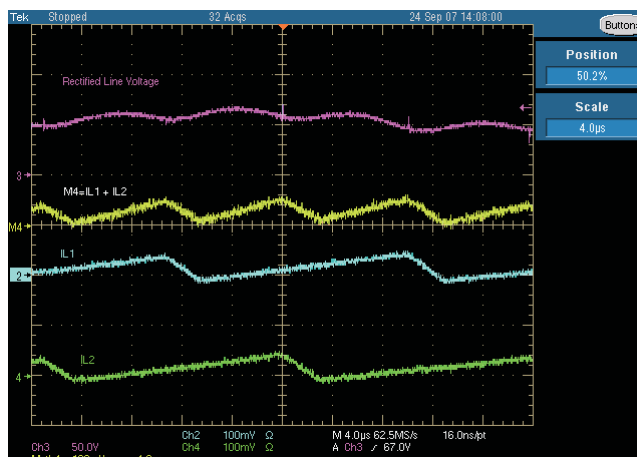


Figure 7. PR735 Inductor and Input Ripple Current at 85-VRMS Input at Half Peak Line Voltage

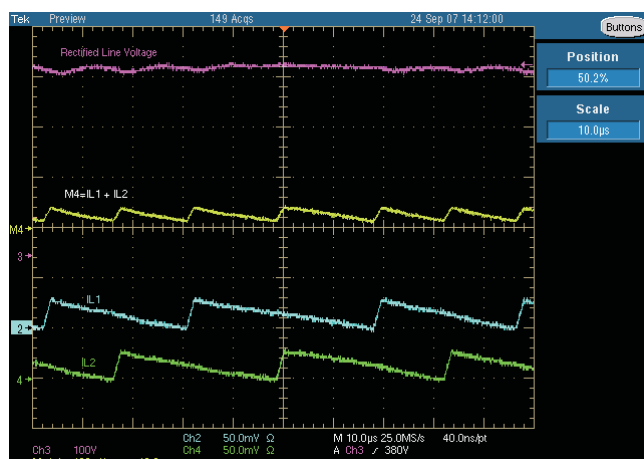


Figure 8. PR735 Inductor and Input Ripple Current at 265-VRMS Input at Peak Line Voltage

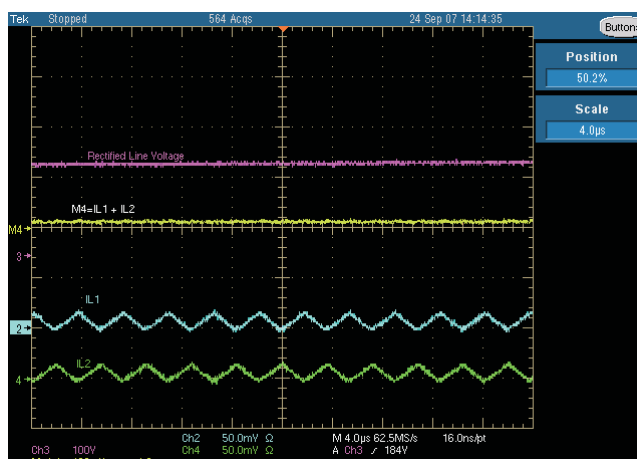


Figure 9. PR735 Inductor and Input Ripple Current at 265-VRMS Input at Half Peak Line Voltage

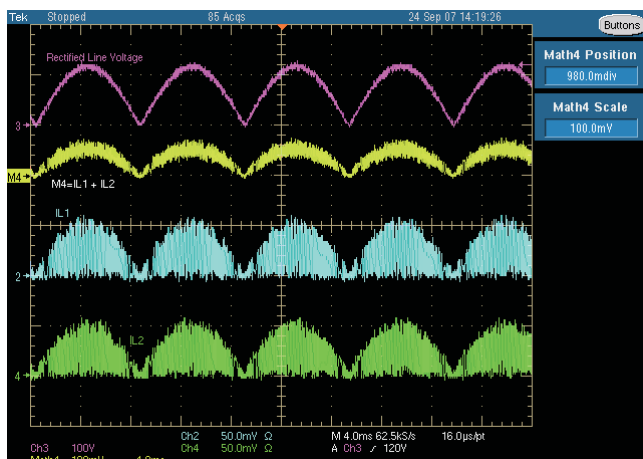


Figure 10. PR735 Inductor and Input Ripple Current at 85-VRMS Input, $P_{OUT} = 300\text{ W}$

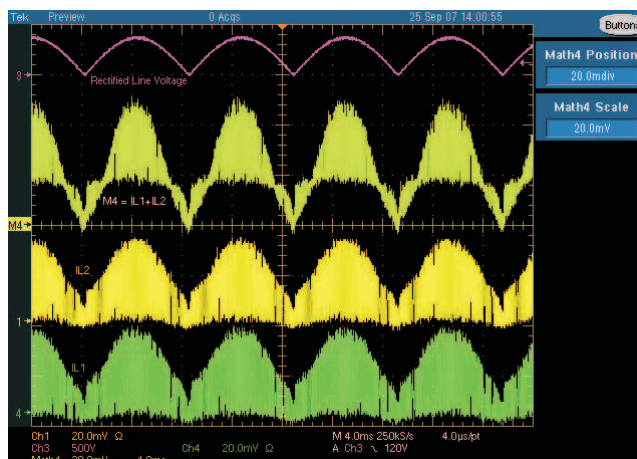


Figure 11. PR735 Inductor and Input Ripple Current at 265-VRMS Input, $P_{OUT} = 600\text{ W}$

5.5 Startup Characteristics

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

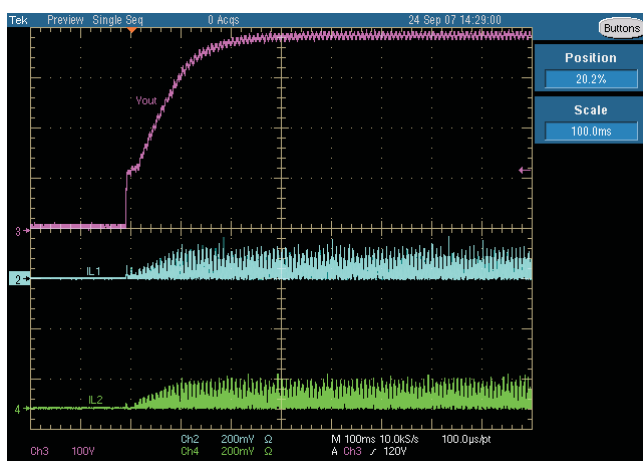


Figure 12. PR735 Start-Up at $V_{IN} = 85\text{ VRMS}$, $P_{OUT} = 600\text{ W}$

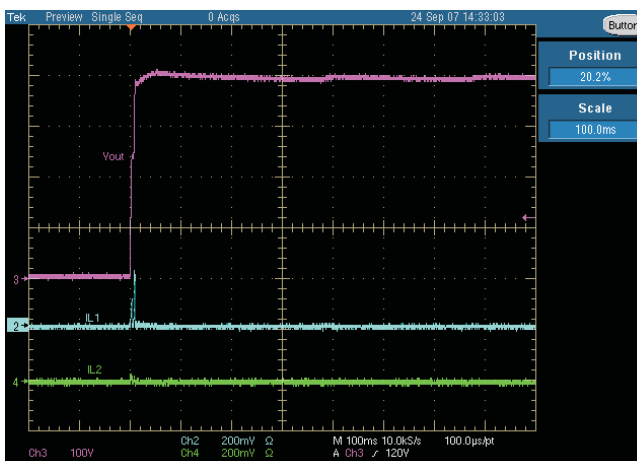


Figure 13. PR735 Start-Up at $V_{IN} = 265\text{ VRMS}$, $P_{OUT} = 0\text{ W}$

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).

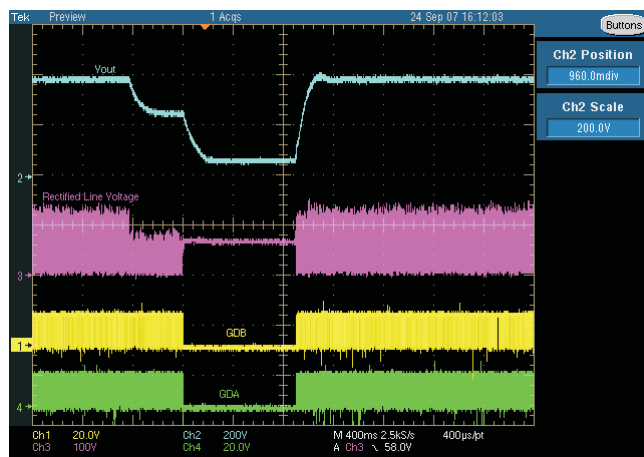


Figure 14. PR735 Brownout at 85 VRMS

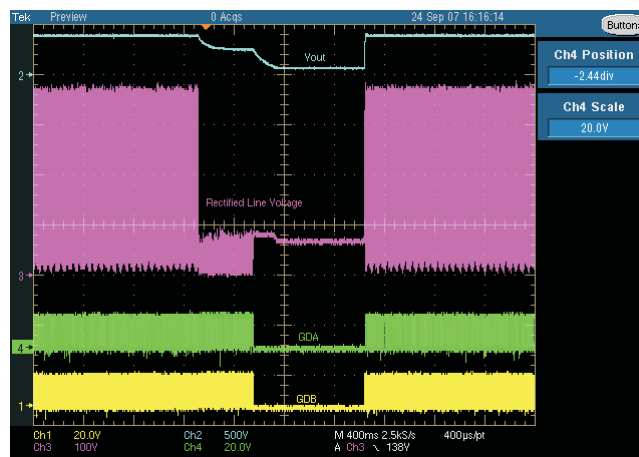


Figure 15. PR735 Brownout at 265 VRMS

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.

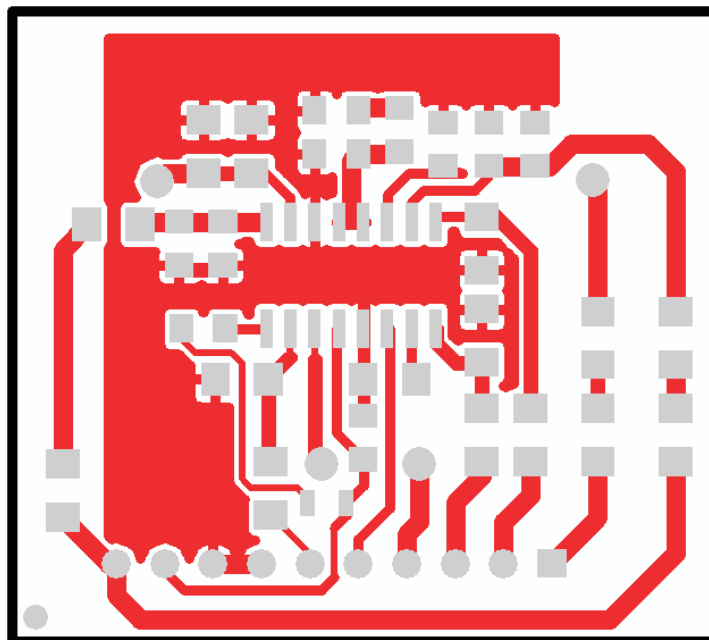


Figure 16. PR735 Controller Board Layout (viewed from top)

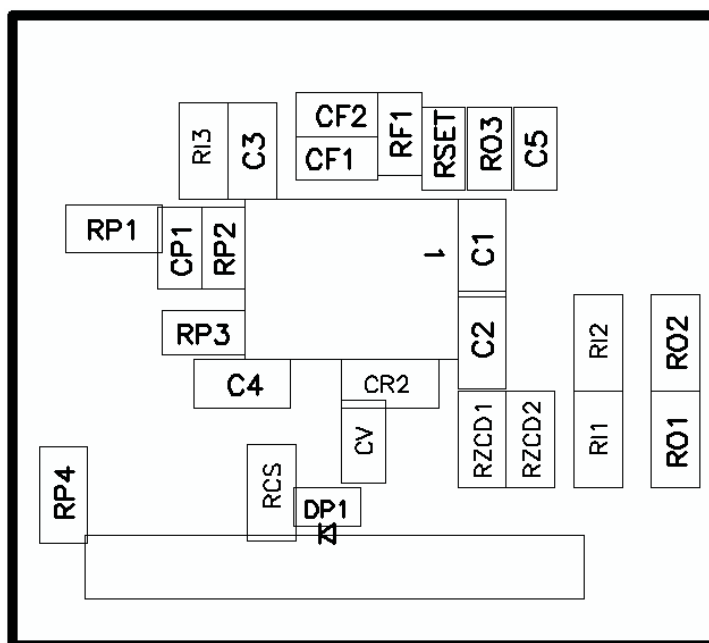


Figure 17. PR735 Controller Board Parts Placement (viewed from top)

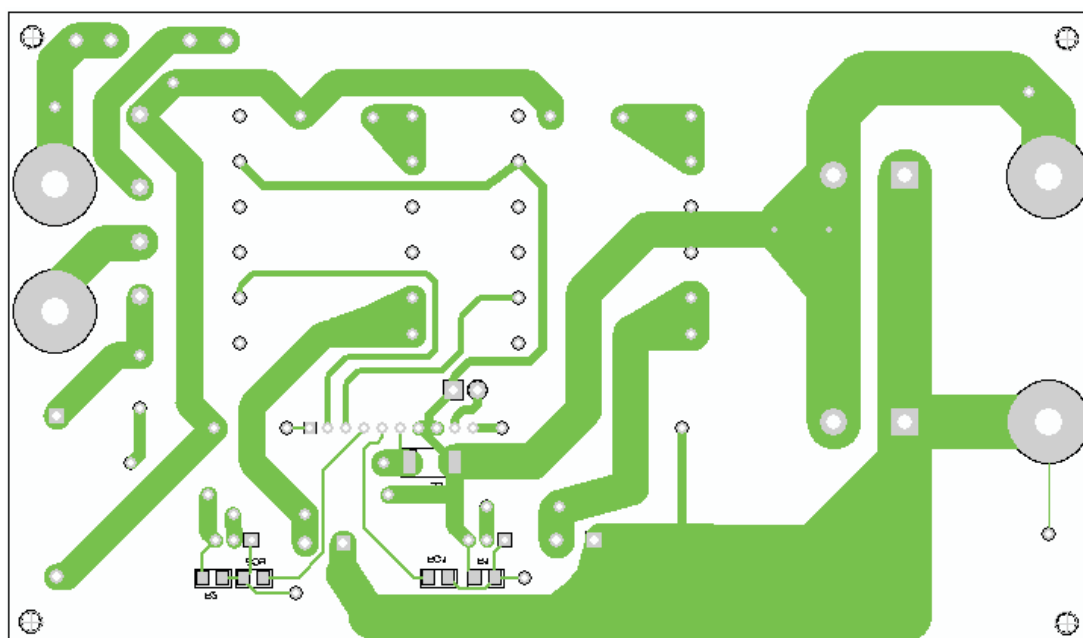


Figure 18. PR735 Power Stage Bottom Layer Layout (viewed from top)

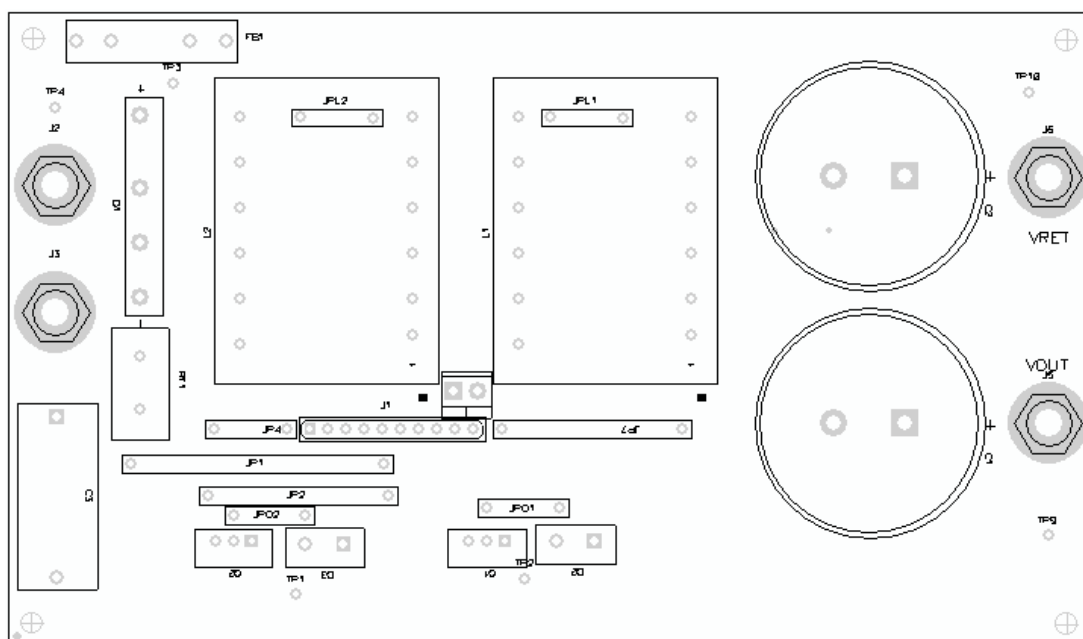


Figure 19. PR735 Power Stage Parts Placement (viewed from top)

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 μ F, 450 V elect KMQ snap	United Chemi-con	EKMQ451VSN221MR30S
C3	1	Capacitor, Film, 0.047 μ F, 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 k Ω , 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 μ F, 10%, 50 V, X7R 1206	AVX	12065C124KAT2A
CF2	1	Capacitor, ceramic, 1 μ F, 50 V, Y5V 1206	AVX	12065G105ZAT2A
CP1, CR2, CV2	3	Capacitor, ceramic, 0.1 μ F, 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 k Ω , 1/4 W, 1% 1206 SMD	Panasonic	ERJ-8ENF1152V
RI1, RI2	2	Resistor, 1.00 M Ω , 1/4 W, 1% 1206	Panasonic	ERJ-8ENF1004V
RI3	1	Resistor, 32.4 k Ω , 1/4 W, 1% 1206	Yageo	RC1206FR-0732K4L
RO1, RO2	2	Resistor, 324 k Ω , 1/4 W, 1% 1206	Yageo	RC1206FR-07324KL
RO3, RP1, RP2	3	Resistor, 10.0 k Ω , 1/4 W, 1% 1206	Panasonic	ERJ-8ENF1002V
RP3	1	Resistor, Chip, 1/8 W, 1%	Panasonic	ERJ-8ENF1001V
RP4	1	Resistor, 10.0 k Ω , 1/4 W, 1% 1206	Panasonic	ERJ-8ENF1002V
RSET3	1	Resistor, 113 k Ω , 1/4 W, 1% 1206	Yageo	9C12063A1133FKHFT
RZCD1, RZCD2	2	Resistor, 30.0 k Ω , 1/4 W, 1% 1206	Yageo	RC1206FR-0730KL
U1	1	IC, Interleave PFC Controller	TI	UCC28060D

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
RF/IF and ZigBee® Solutions	www.ti.com/lprf

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital Control	www.ti.com/digitalcontrol
Medical	www.ti.com/medical
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2008, Texas Instruments Incorporated