UCC28060EVM 300W Interleaved PFC Pre-Regulator

The UCC28060 is a dual-phase, transition-mode Power Factor Correction (PFC) pre-regulator. The UCC28060EVM is an evaluation module (EVM) with a 390V, 300W, dc output that operates from a universal input of 85V_{RMS} to 265V_{RMS} and provides power-factor correction.

Throughout this document, the acronym *EVM* and the phrases *evaluation board* and *evaluation module* are synonymous with the UCC28060EVM.

Contents

List of Figures

1 Description

The pre-regulator uses the UCC28060 PFC interleaved controller to shape the input current wave to provide power-factor correction. This device uses TI's *Natural Interleaving*™ technology to interleave boost phases.

This user's guide provides the schematic, bill of materials list, assembly drawing for a single-sided printed circuit board application, and test set-up information necessary to evaluate the UCC28060 in a typical PFC application.

2 Thermal Requirements

This evaluation module will operate up to 300W without external cooling in ambient tempatures of +25°C.

3 Electrical Characteristics

Table 1 summarizes the electrical specifications of the UCC28060EVM.

Table 1. UCC28060EVM Electrical Specifications

PARAMETER	CONDITIONS	UCC28060EVM			UNITS
		MIN	TYP	MAX	
RMS input voltage (ac line)		85		265	V_{RMS}
Output voltage, V_{OUT}			390		V
Line frequency		47		63	Hz
Power factor (PF) at maximum load		0.9			
Output power				300	W
Full load efficiency		0.92			%

4 Schematics

Figure 1 and Figure 2 show the schematics for this EVM. See the Bill of Materials for specific values.

To evaluate inductor ripple currents, Jumpers JP8 and JP9 can be removed and replaced with current loops.

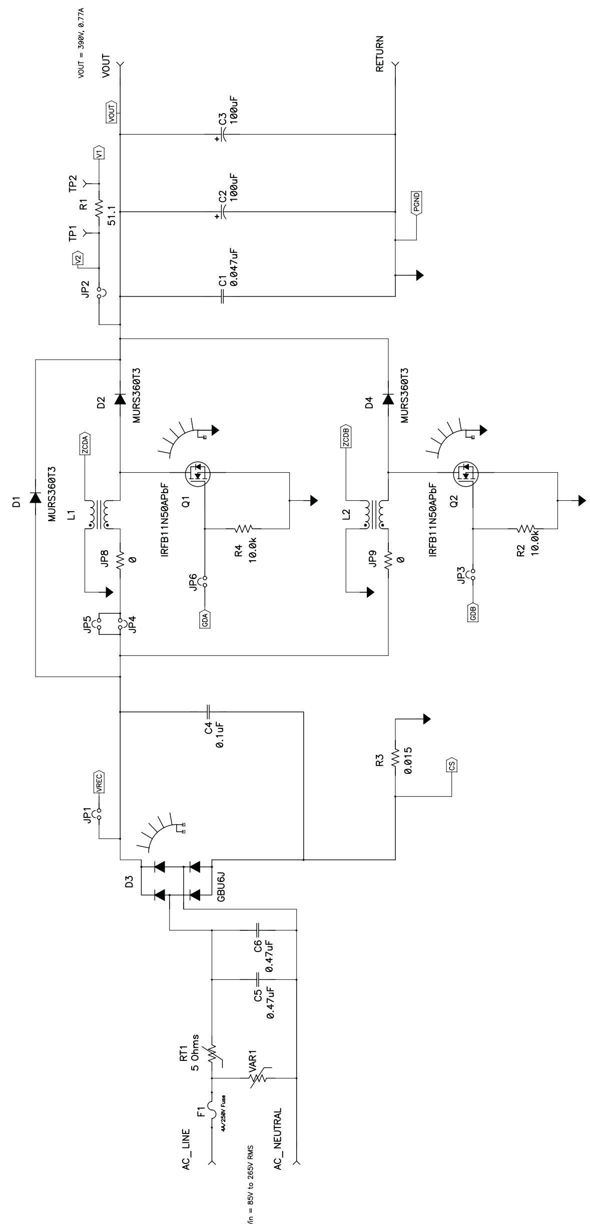

Figure 1. Interleaved PFC Power Stage

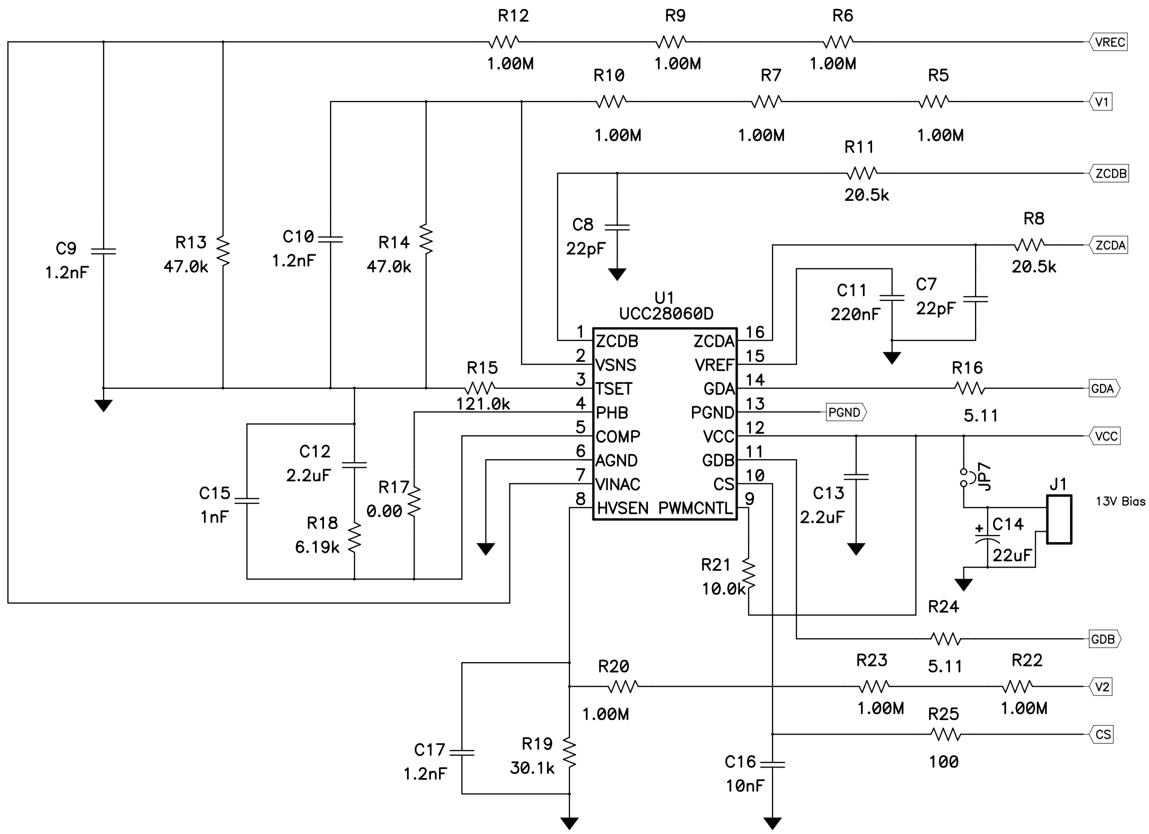

Figure 2. Controller Circuitry

5 Test Setup and Power-Up/Power-Down Instructions

> **WARNING**
>
> **There are high voltages present on the pre-regulator. It should only be handled by experienced power supply professionals. To evaluate this board as safely as possible, the following test configuration should be used:**
>
> - Connect an isolation transformer between the source and unit
> - Attach a voltmeter and a resistive or electronic load to the unit output **before** supplying power to the EVM.

A separate 13V bias supply is required to power the UCC28060 control circuitry. The unit will start up under no-load conditions. However, for safety, a load should be connected to the output of the device before it is powered up. The unit should also never be handled while power is applied to it or when the output voltage is above 50V dc. Refer to Figure 3 for a recommended test setup diagram.

> **CAUTION**
>
> There are very high voltages on the board. Components can and will reach temperatures greater than +100°C. Use caution when handling the EVM.

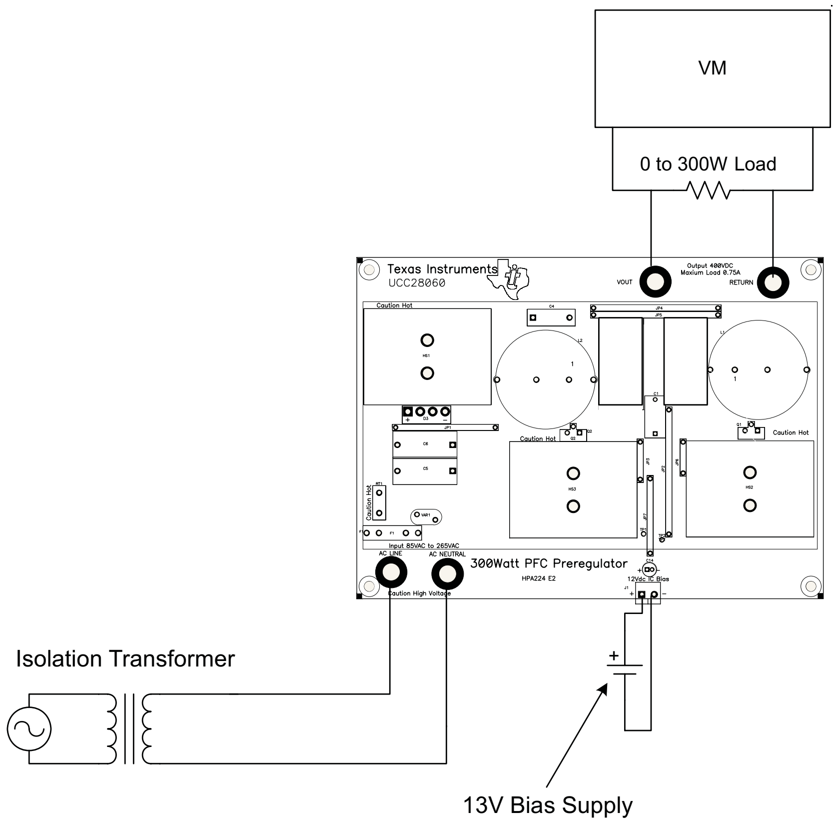

Figure 3. Test Setup

6 Typical Performance Data

Figure 4 through Figure 7 present characteristic performance data for the UCC28060EVM.

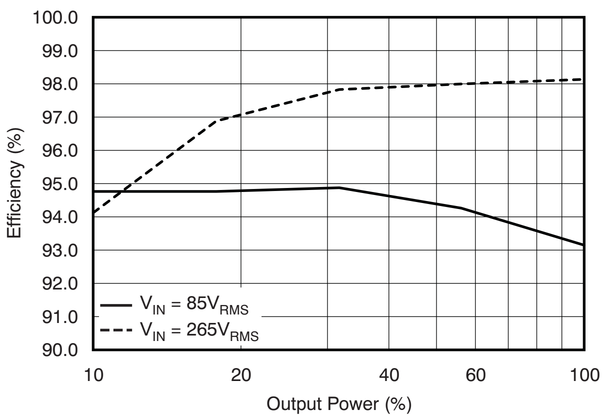

Figure 4. Efficiency at $85V_{RMS}$ and $265V_{RMS}$

The UCC28060 control IC has phase management capability to improve light load efficiency. To demonstrate the light load efficiency, the unit efficiency was measured with phase management enabled and disabled at $115V_{RMS}$ and $230V_{RMS}$ input voltages. Phase management improved the light load efficiency up to 3%. Refer to the UCC28060 data sheet for details on how to use the phase management function of this IC.

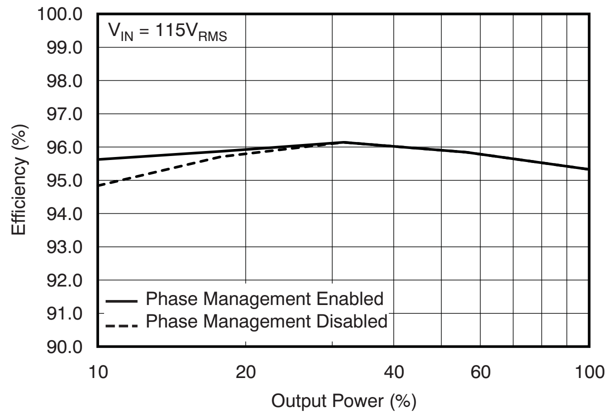

Figure 5. Efficiency at 115V_{RMS}, With and Without Phase Management

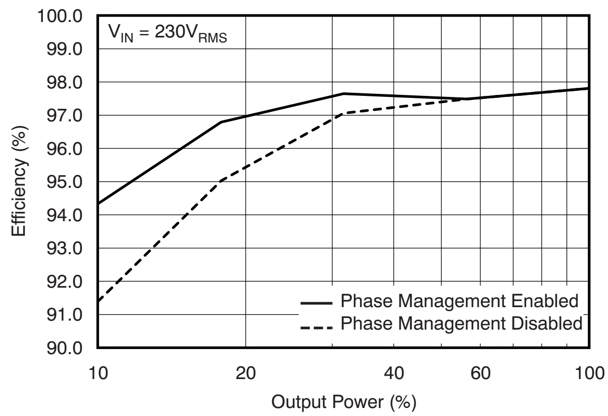

Figure 6. Efficiency at 230V_{RMS}, With and Without Phase Management

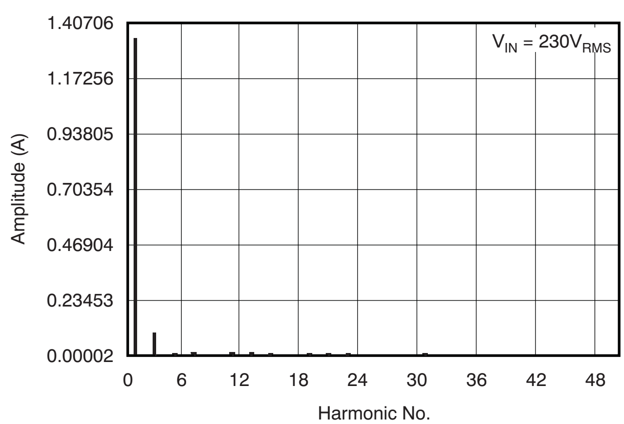

Figure 7. Current Harmonics

6.1 Output Ripple Voltage at Full Load

Figure 8 illustrates the output ripple voltage.

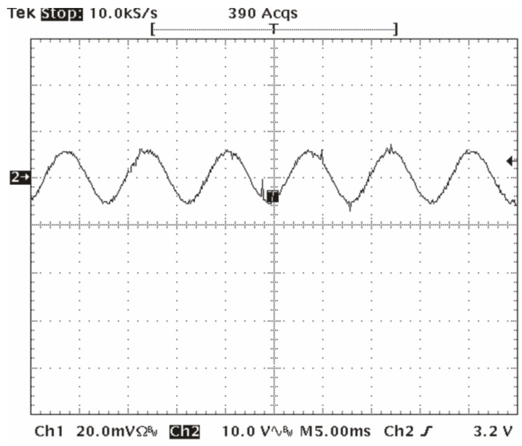

Figure 8. V_{OUT} Ripple, P_{OUT} = 300W

6.2 Input Ripple Current Cancellation

Figure 9 through Figure 14 show the input current ($M_1 = I_{L1} + I_{L2}$), Inductor Ripple Current (I_{L1}, I_{L2}) versus rectified line voltage. From these graphs, it can be observed that interleaving reduces the magnitude of input ripple current caused by the inductor ripple current.

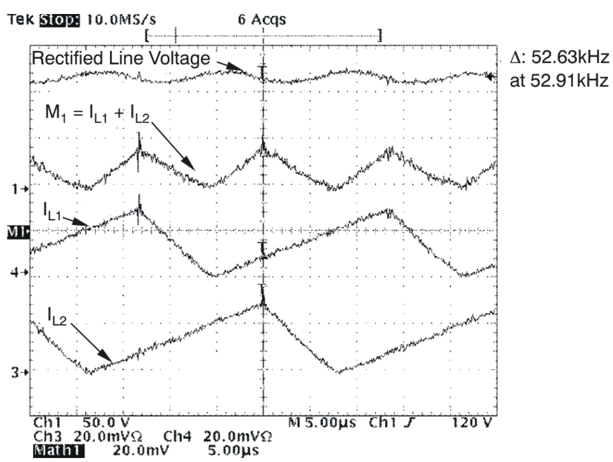

Figure 9. Inductor and Input Ripple Current at 85V_{RMS} at Peak of Line Voltage

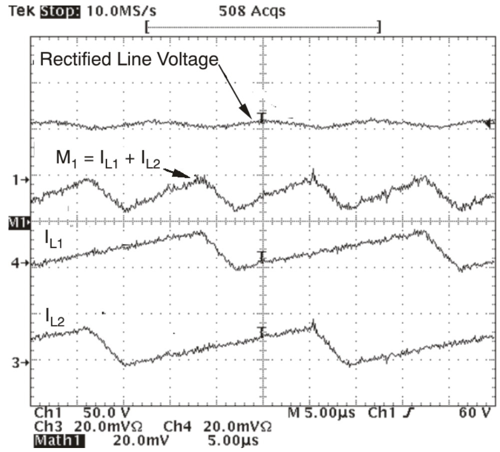

Figure 10. Inductor and Input Ripple Current at 85V_{RMS} Input at Half the Line Voltage

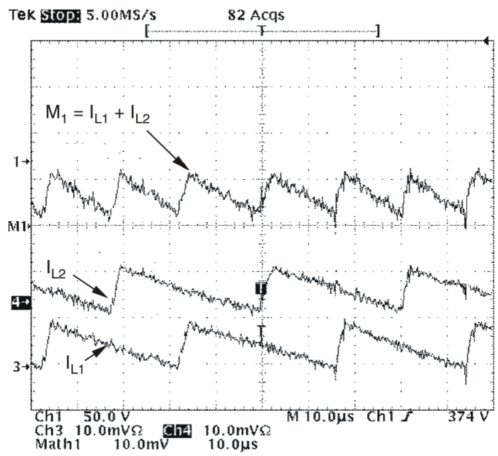

Figure 11. Inductor and Input Ripple Current at 265V_{RMS} Input at Peak Line Voltage

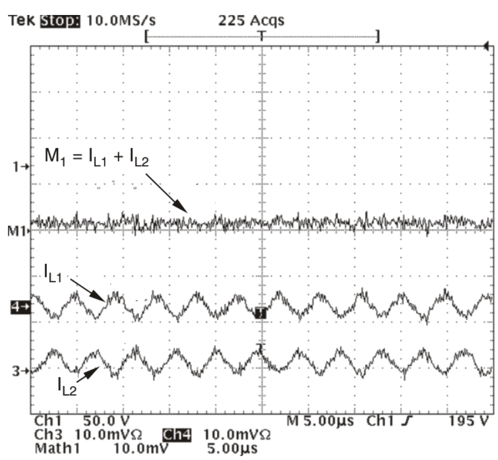

Figure 12. Inductor and Input Ripple Current at 265V_{RMS} Input at Half Peak Line Voltage

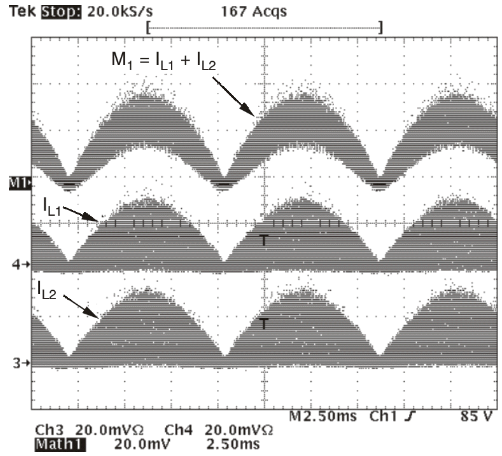

Figure 13. Inductor and Input Ripple Current at V_{IN} = 85V_{RMS}, P_{OUT} = 300W

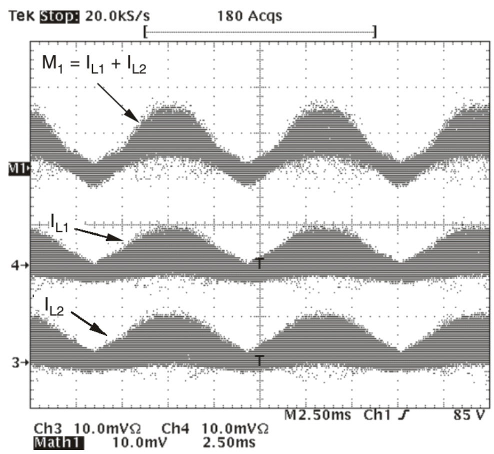

Figure 14. Inductor and Input Ripple Current at V_{IN} = 265V_{RMS}, P_{OUT} = 350W

6.3 Startup Characteristics

Figure 15 and Figure 16 illustrate the UCC28060EVM startup characteristics.

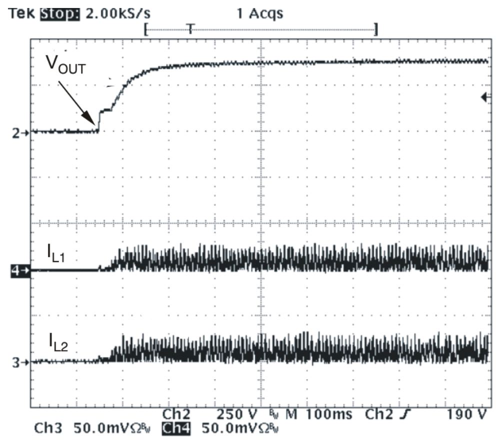

Figure 15. Start-Up at V_{IN} = 85V_{RMS}, P_{OUT} = 350W

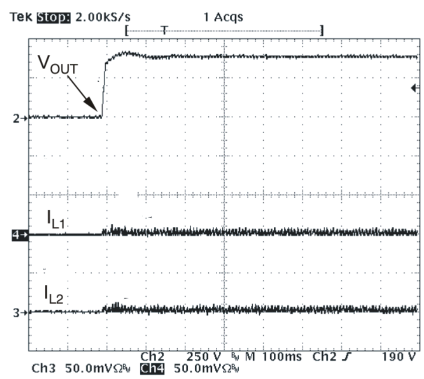

Figure 16. Start-Up at V_{IN} = 265V_{RMS}, P_{OUT} = 0W

6.4 Brownout Protection

The UCC28060 has a brownout protection that shuts down both gate drives (GDA and GDB) when the VINAC pin detects that the RMS input voltage is too low. This EVM was designed to go into a brownout state when the line drops below 64V_{RMS}. Once the UCC28060 control IC has determined that the input is in a brownout condition, a 400ms timer starts to allow the line to recover before shutting down the gate drivers. After 400ms of brownout, both gate drivers turn off, as shown in Figure 17 and Figure 18.

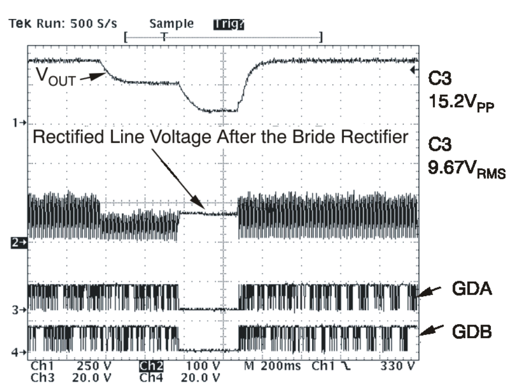

Figure 17. Brownout at 85V_{RMS}

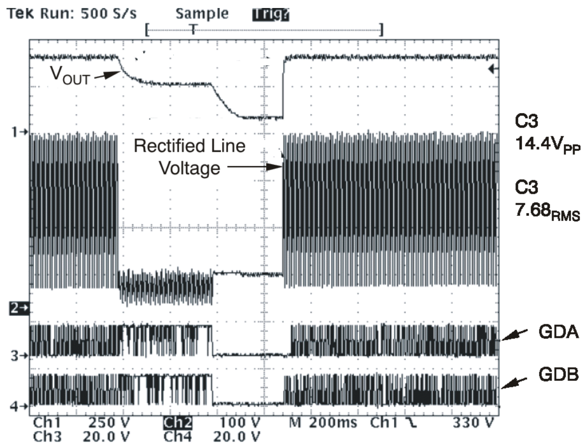

Figure 18. Brownout at 265V_{RMS}

6.5 Line Transient

A line transient test was conducted with an ac source on the reference design. The line was varied from 230V_{RMS} to 115V_{RMS} to 230V_{RMS} and the transient response was evaluated in each case. From the oscilloscope image in Figure 19, it can be observed that the output recovered from line transients within 300ms at full load.

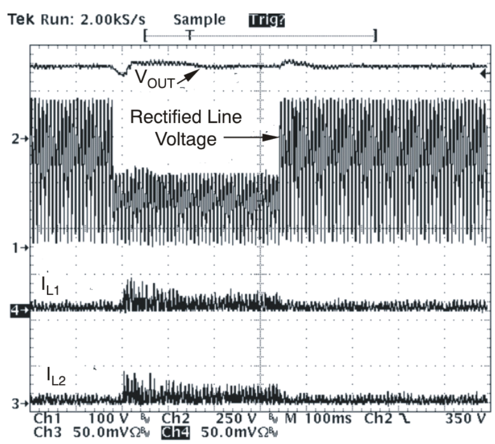

Figure 19. Line Transient, P_{OUT} = 300W

7 Reference Design Assembly Drawing

Figure 20 and Figure 21 show the top and bottom layers (respectively) of the UCC28060EVM.

Note: Board layouts are not to scale. These figures are intended to show how the board is laid out; they are not intended to be used for manufacturing UCC28060EVM PCBs.

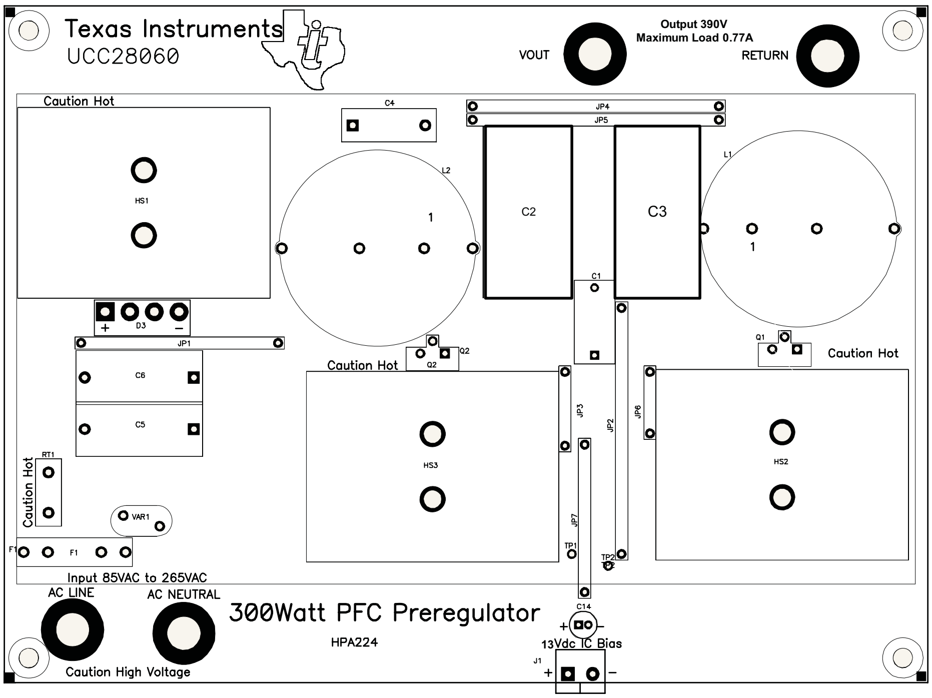

Figure 20. Top Layer Assembly

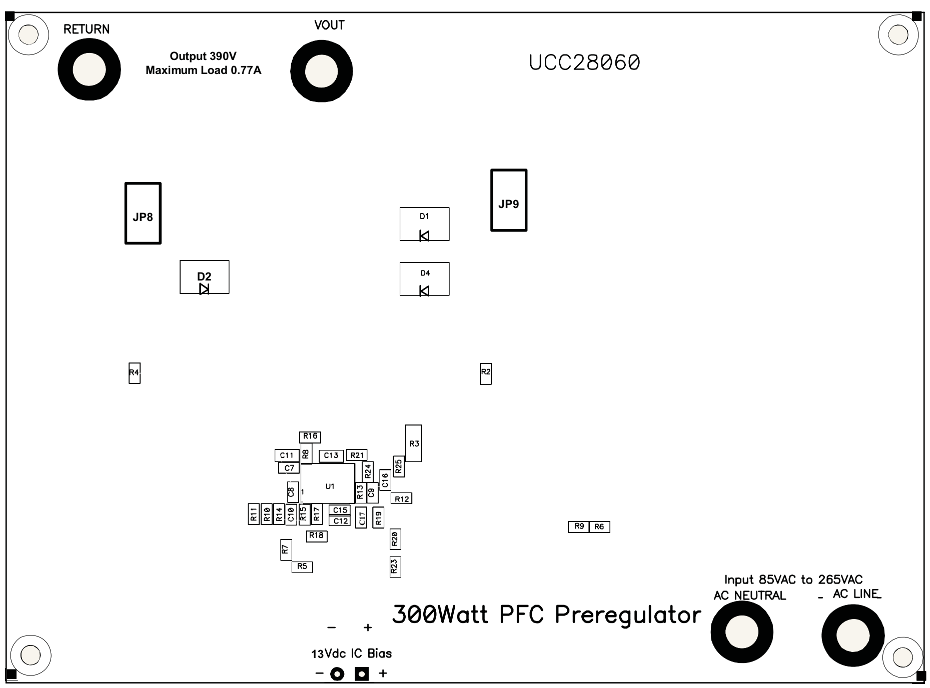

Figure 21. Bottom Layer Assembly

8 Bill of Materials

Table 2 lists the EVM components as configured according to the schematics (see Section 4).

Table 2. Bill of Materials

Qty	RefDes	Value	Description	Size	Part Number	MFR
4	AC_LINE, AC_NEUTRAL, VOUT, RETURN	3267	Connector, Banana Jack, Uninsulated	0.500 dia. inch	3267	Pomona
1	C1	0.047µF	Capacitor, Polyester, 630V, 10%	0.256in × 0.650in	ECQ-E6473KZ	Panasonic
1	C11	220nF	Capacitor, Ceramic, 16V, X7R, 10%	1206	Std	Std
2	C12, C13	2.2µF	Capacitor, Ceramic, 16V, X7R, 10%	0805	Std	Std
1	C14	22µF	Capacitor, Aluminum, 35V, ±20%	0.200in × 0.435in	ECA-1VM220	Panasonic
1	C15	1nF	Capacitor, Ceramic, 25V, X7R, 10%	0805	Std	Std
1	C16	10nF	Capacitor, Ceramic, 25V, X7R, 10%	0805	Std	Std
2	C2, C3	100µF	Capacitor, Aluminum, 450VDC, ±20%	18mm × 40 mm	EKXG451ELL101 MM40S	Nippon Chemi-con
1	C4	0.1µF	Capacitor, Film, 275VAC, ±20%	0.689in × 0.236in	ECQU2A104BC1	Panasonic
2	C5, C6	0.47µF	Capacitor, Film, 275VAC, ±20%	0.236 × 0.591	ECQ-U2A474MG	Panasonic
2	C7, C8	22pF	Capacitor, Ceramic, 25V, X7R, 10%	0805	Std	Std
3	C9, C10, C17	1.2nF	Capacitor, Ceramic, 25V, X7R, 10%	0805	Std	Std
3	D1, D2, D4	MURS360T3	Diode, 3000mA, 600V	SMC	MURS360T3	On Semi
1	D3	GBU6J	Diode, Bridge, 6A, 600V	BU6	GBU6J	Vishay
2	F1	0100056H	Fuse Clip, 5mm x 20mm	0.205in × 0.220in x2	0100056H	Wickmann
1	F1	BK/GDA-4A	4A, Fast Acting Fuse	5mm × 20mm	BK/S501-4-R	Cooper/ Bussman
3	HS1, HS2, HS3	7-345-2PP	Heatsink, Universal-mount TO-220	1.500in × 2.000in	7-345-2PP	IERC-CTS
1	J1	ED1609-ND	Terminal Block, 2-pin, 15-A, 5.1mm	0.40in × 0.35in	ED1609	OST
1	JP1	923345-20-C	Jumper, 1.600 inch length, PVC Insulation, AWG 22	0.035in dia.	Cut to Dimension	3M
3	JP2, JP4, JP5	923345-20-C	Jumper, 2.000 inch length, PVC Insulation, AWG 22	0.035in dia.	923345-20-C	3M
1	JP3	923345-06-C	Jumper, 0.600 inch length, PVC Insulation, AWG 22	0.035in dia.	923345-06-C	3M
1	JP6	923345-05-C	Jumper, 0.500 inch length, PVC Insulation, AWG 22	0.035in dia.	923345-05-C	3M
1	JP7	923345-20-C	Jumper, 1.200 inch length, PVC Insulation, AWG 22	0.035in dia.	Cut to Dimension	3M
2	JP8, JP9	0	Resistor, Chip, 1W, 5%	2512	Std	Std
1	PCB		HPA224 Printed Circuit Board			
2	L1, L2	CTX16-17769R	Inductor, Boost PFC With Aux. 330µH at 5.3 A PK	1.555in dia.	CTX16-17769R	Cooper
2	Q1, Q2	IRFB11N50APbF	MOSFET, N-ch, 500V, 11A, 520mΩ	TO-220V	IRFB11N50APbF	IR
1	R1	51.1	Resistor, Chip, 1/10W, 1%	0805	Std	Std
2	R13, R14	47.0k	Resistor, Chip, 1/10W, 1%	0805	Std	Std
1	R15	121.0k	Resistor, Chip, 1/10W, 1%	0805	Std	Std
2	R16, R24	5.11	Resistor, Chip, 1/10W, 1%	0805	Std	Std
1	R17	0.00	Resistor, Chip, 1/10W, 1%	0805	Std	Std
1	R18	6.19k	Resistor, Chip, 1/10W, 1%	0805	Std	Std
1	R19	30.1k	Resistor, Chip, 1/10W, 1%	0805	Std	Std
3	R2, R4, R21	10.0k	Resistor, Chip, 1/10W, 1%	0805	Std	Std
1	R25	100	Resistor, Chip, 1/10W, 1%	0805	Std	Std
1	R3	0.015	Resistor, Chip, 1/2W, 1%	2010	WSL2010R0150F EA	Vishay
9	R5–R9, R10, R12, R20, R22, R23	1.00M	Resistor, Chip, 1/10W, 1%	0805	Std	Std

Table 2. Bill of Materials (continued)

Qty	RefDes	Value	Description	Size	Part Number	MFR
2	R8, R11	20.5k	Resistor, Chip, 1/10W, 1%	0805	Std	Std
1	RT1	5Ω	Thermistor, NTC, 5Ω, 6A	0.180in × 0.550in	CL-40	Thermo-metrics
2	TP1, TP2	K24A/M	Pin, Thru Hole, Tin Plate, for 0.062 PCBs	0.039in	K24A/M	Vector
1	U1	UCC28060D	IC, Interleave PFC Controller	SO16	UCC28060D	TI
1	VAR1	SIOV-S10K275E2	VARISTOR 275V RMS	0.472in × 0.213in	S10K275E2	Epcos
6	X1 at HS1 and D3, HS2 and Q1, HS3 and Q2		Nut #4-40 (steel)		Std	Std
6	X1 at HS1 and D3, HS2 and Q1, HS3 and Q2		Pan Head Screw #4-40X3/8 (steel)		Std	Std
1	X1 D3 and HS1		Thermal Grease		Std	Std
6	X1 at HS1 and D3, HS2 and Q1, HS3 and Q2		Split Lock Washer #4(steel)		Std	Std
6	X1 at HS1 and D3, HS2 and Q1, HS3 and Q2		Nylon Shoulder Washer #4		3049	Keystone Electronics
2	X1 at HS2 and Q1, HS3 and Q2		Thermal Pad Silicon TO220		3223-07FR-51	BERQUIST

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of $85V_{RMS}$ to $265V_{RMS}$ and the output voltage range of 375V to 450V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than +100°C. The EVM is designed to operate properly with certain components above +100°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265