UCC28061EVM 300-W Interleaved PFC Pre-Regulator

The UCC28061 is a dual-phase, transition-mode Power Factor Correction (PFC) pre-regulator. The UCC28061EVM is an evaluation module (EVM) with a 390-V, 300-W, dc output that operates from a universal input of 85 V_{RMS} to 265 V_{RMS} and provides power-factor correction.

Throughout this document, the acronym *EVM* and the phrases *evaluation board* and *evaluation module* are synonymous with the UCC28061EVM.

1 Description

The pre-regulator uses the UCC28061 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, List of Materials, assembly drawing for a single-sided printed circuit board application, and test set-up information necessary to evaluate the UCC28061 in a typical PFC application.

2 Thermal Requirements

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

3 Electrical Characteristics

Table 1 summarizes the electrical specifications of the UCC28061EVM.

Table 1. UCC28061EVM Electrical Specifications

PARAMETER	CONDITIONS	UCC28061EVM			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	AC line = 115 V		94%		
	AC line = 230 V		97%		

4 Schematics

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

To evaluate inductor ripple currents, resistors R25 and R26 can be removed and replaced with current loops.

Natural Interleaving is a trademark of Texas Instruments.

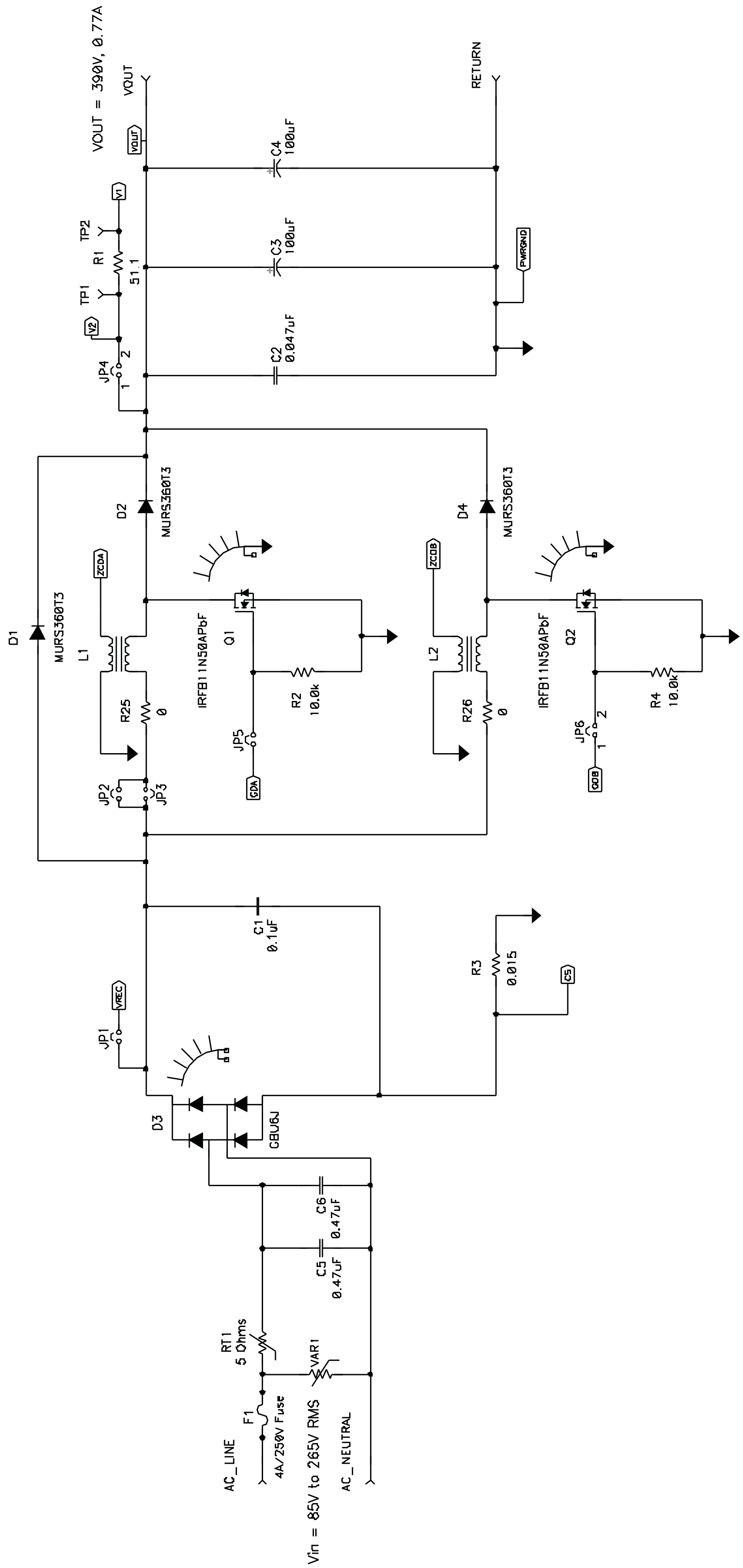

Figure 1. Interleaved PFC Power Stage

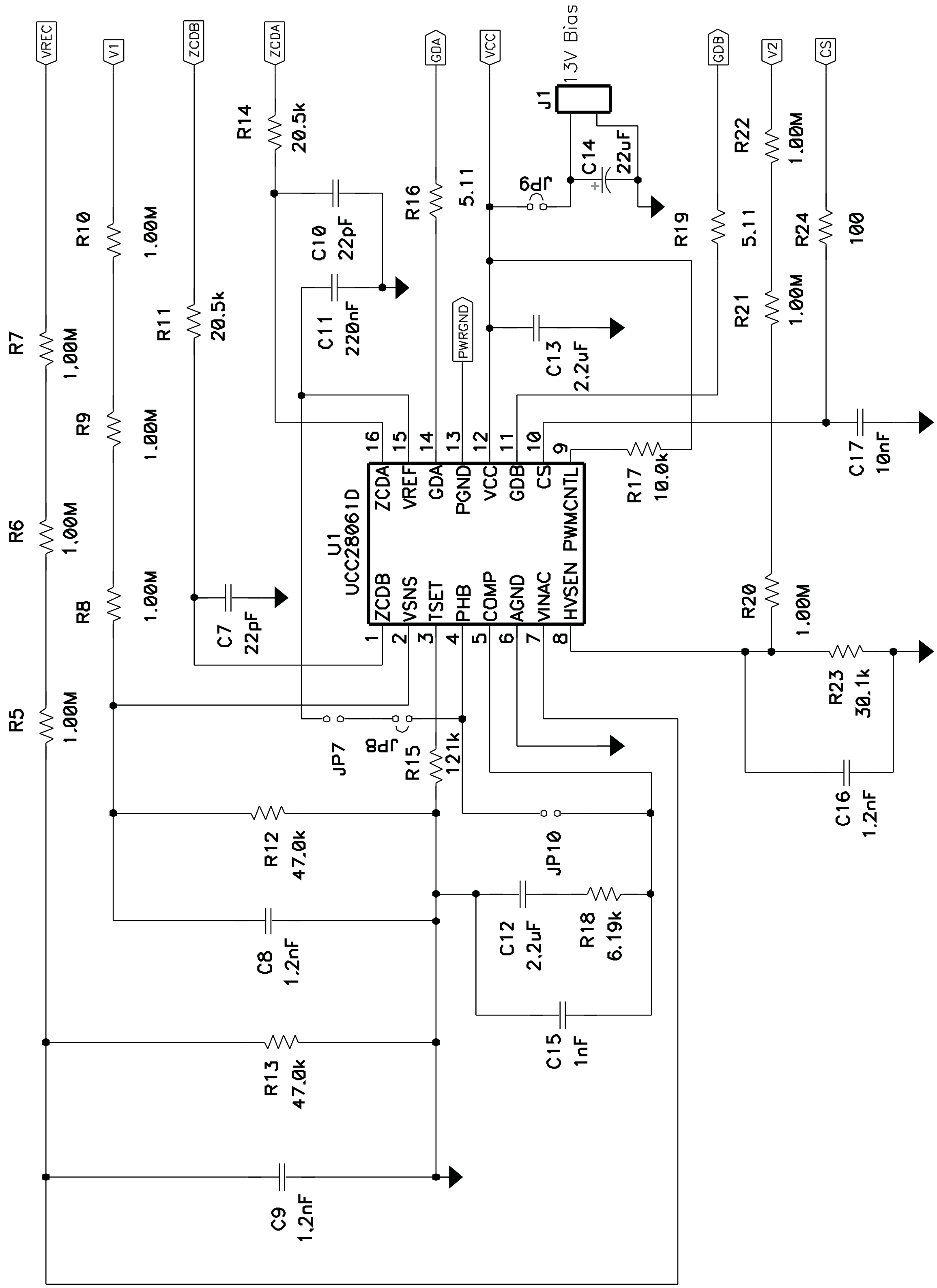

Figure 2. Controller Circuitry

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 13-V bias supply is required to power the UCC28061 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 50-V 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.

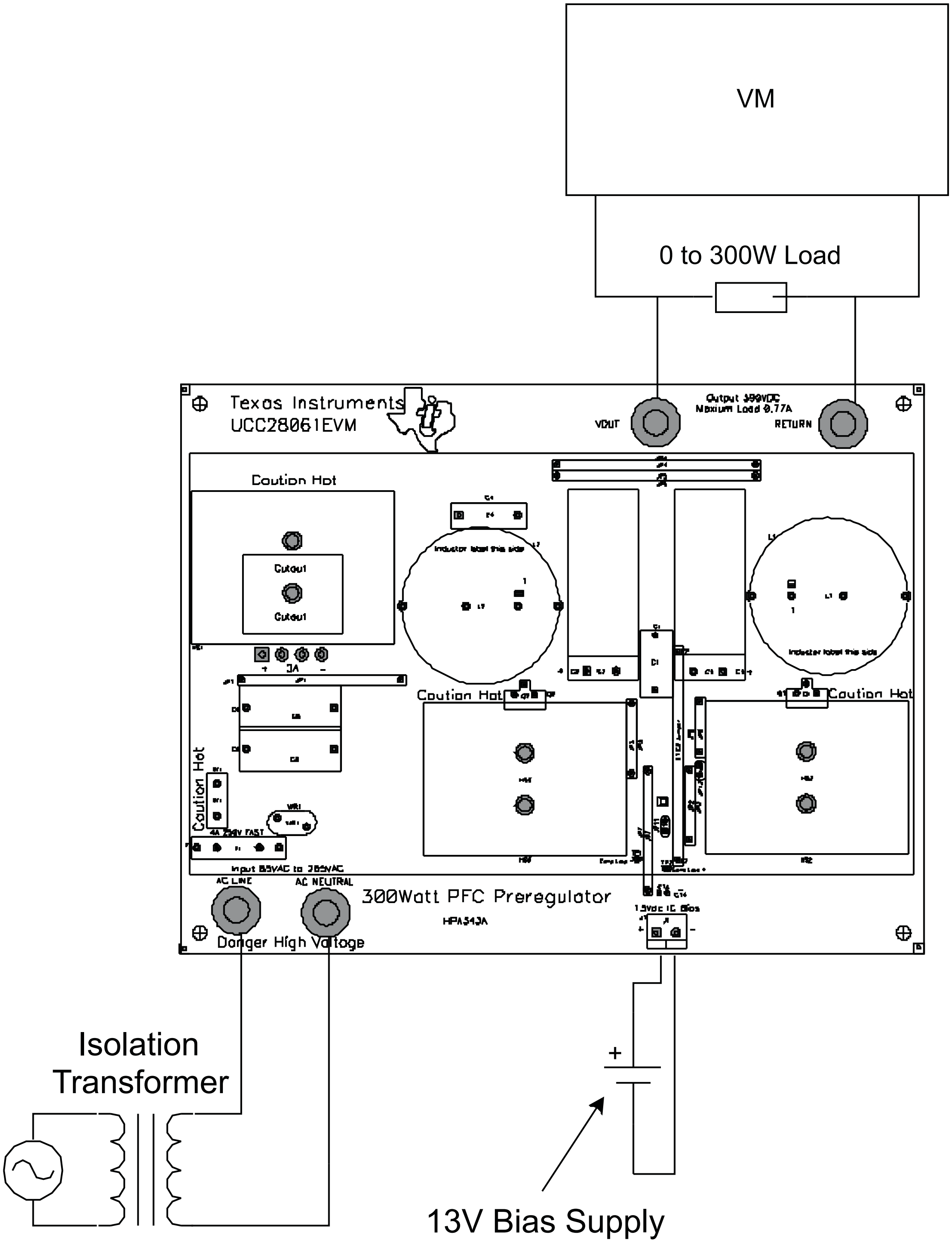

Figure 3. Test Setup

6 Typical Performance Data

Figure 4 through Figure 7 present characteristic performance data for the UCC28061EVM.

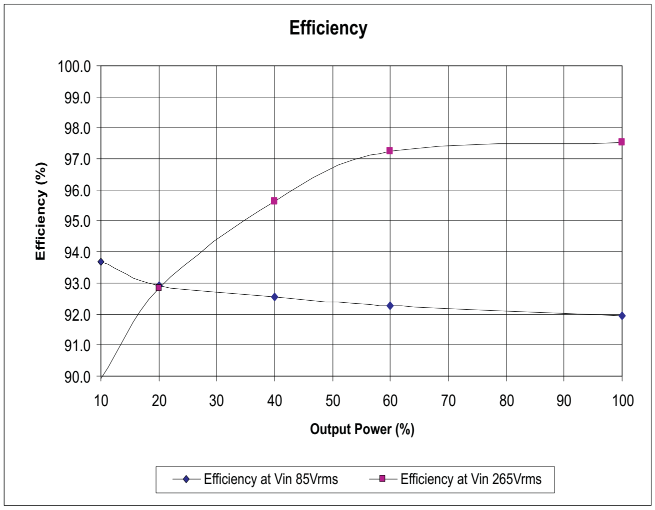

Figure 4. Efficiency at $85V_{RMS}$ and $265V_{RMS}$

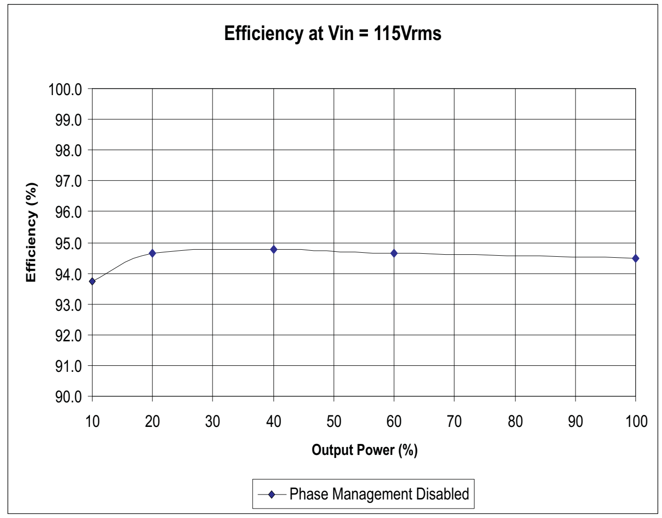

Figure 5. Efficiency at 115 V_{RMS}, Without Phase Management

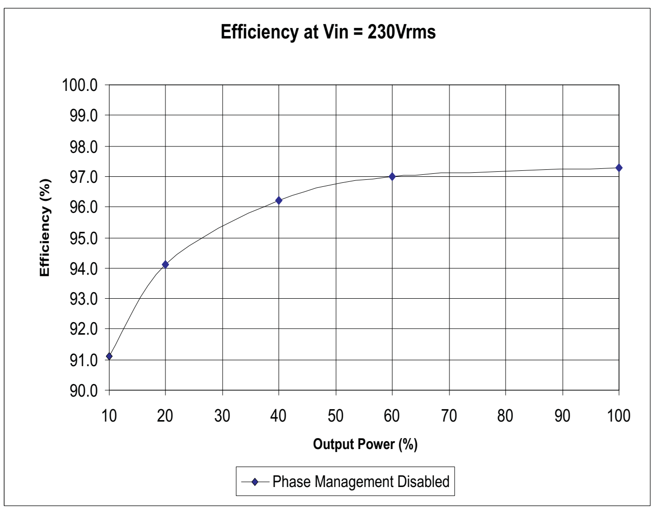

Figure 6. Efficiency at 230 V_{RMS}, Without Phase Management

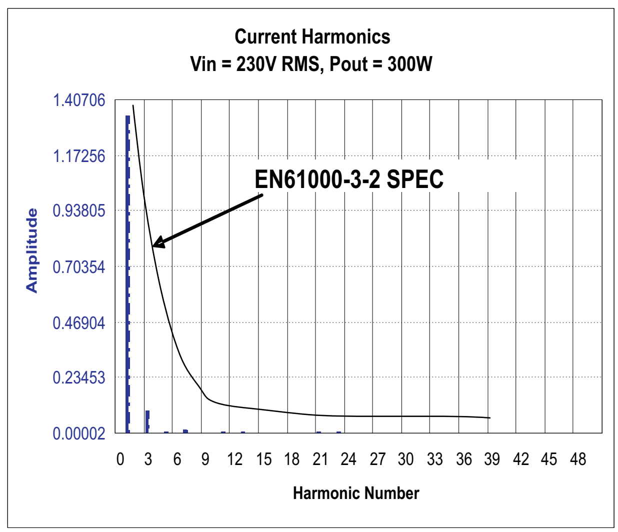

Figure 7. Current Harmonics

6.1 Output Ripple Voltage at Full Load

Figure 8 illustrates the output ripple voltage.

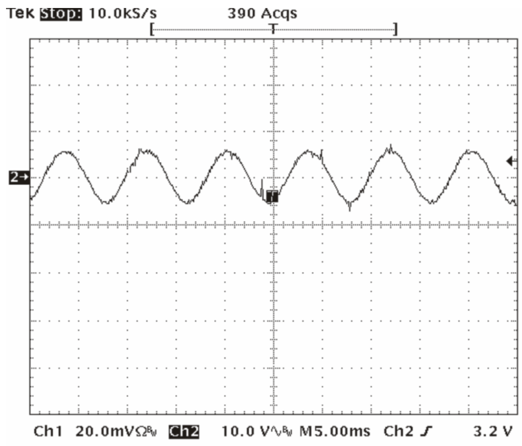

Figure 8. V_{OUT} Ripple, P_{OUT} = 300 W

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.

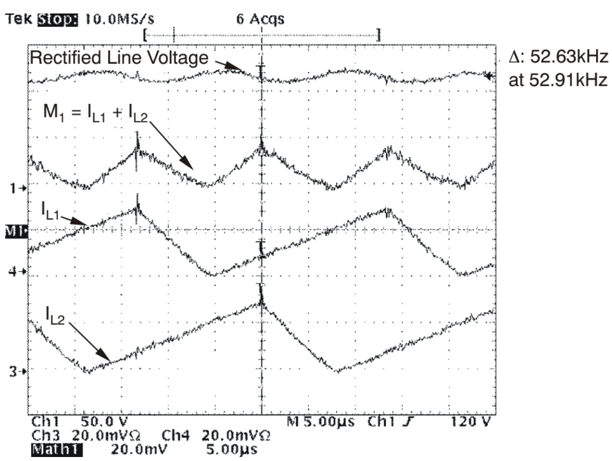

Figure 9. Inductor and Input Ripple Current at 85 V_{RMS} at Peak of Line Voltage

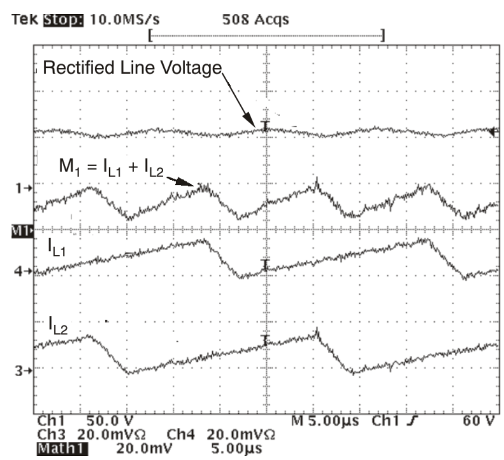

Figure 10. Inductor and Input Ripple Current at 85 V_{RMS} Input at Half the Line Voltage

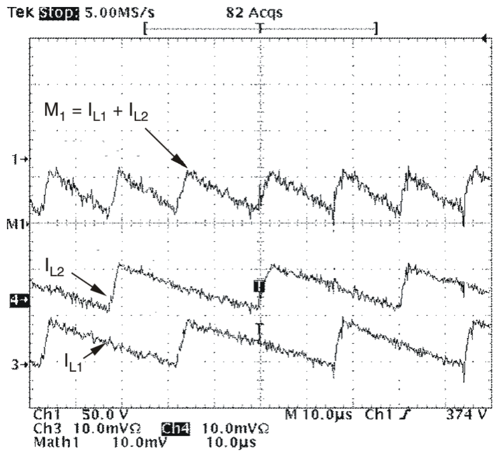

Figure 11. Inductor and Input Ripple Current at 265 V_{RMS} Input at Peak Line Voltage

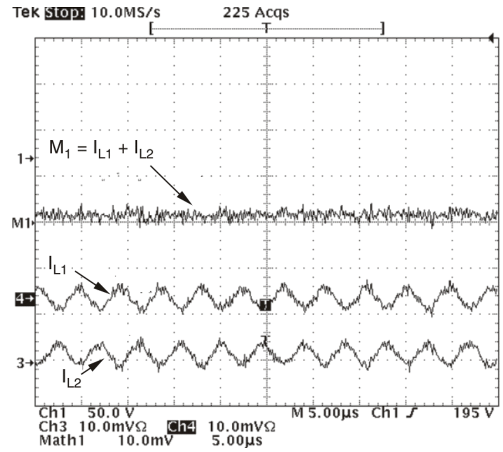

Figure 12. Inductor and Input Ripple Current at 265 V_{RMS} Input at Half Peak Line Voltage

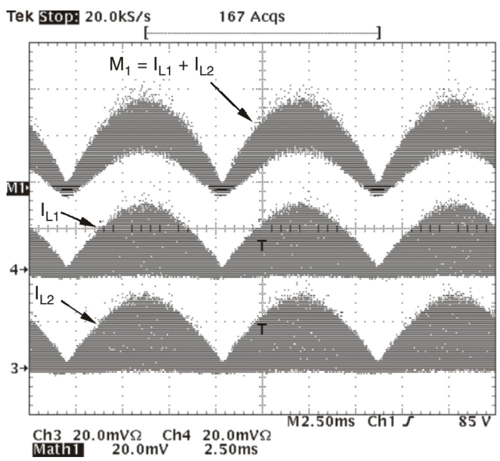

Figure 13. Inductor and Input Ripple Current at V_{IN} = 85 V_{RMS}, P_{OUT} = 300 W

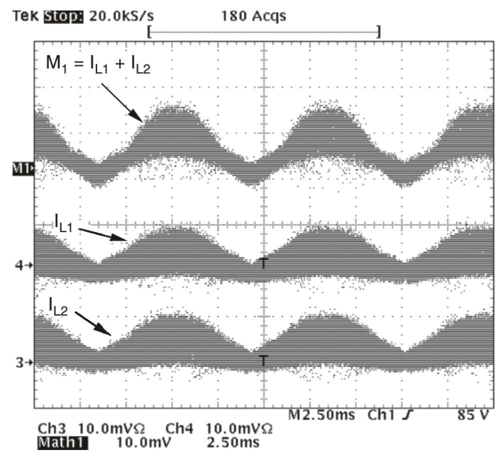

Figure 14. Inductor and Input Ripple Current at V_{IN} = 265 V_{RMS}, P_{OUT} = 300 W

6.3 Startup Characteristics

Figure 15 and Figure 16 illustrate the UCC28061EVM startup characteristics.

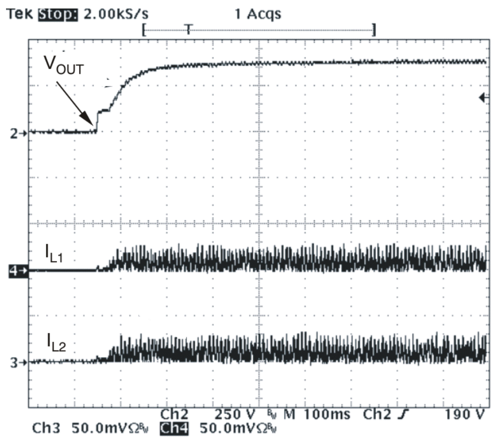

Figure 15. Start-Up at V_{IN} = 85 V_{RMS}, P_{OUT} = 300 W

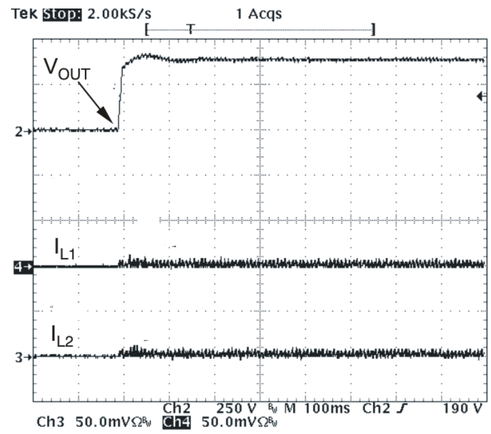

Figure 16. Start-Up at V_{IN} = 265 V_{RMS}, P_{OUT} = 0 W

6.4 Brownout Protection

The UCC28061 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 64 V_{RMS}. Once the UCC28061 control device has determined that the input is in a brownout condition, a 400-ms timer starts to allow the line to recover before shutting down the gate drivers. After 400 ms of brownout, both gate drivers turn off, as shown in Figure 17 and Figure 18.

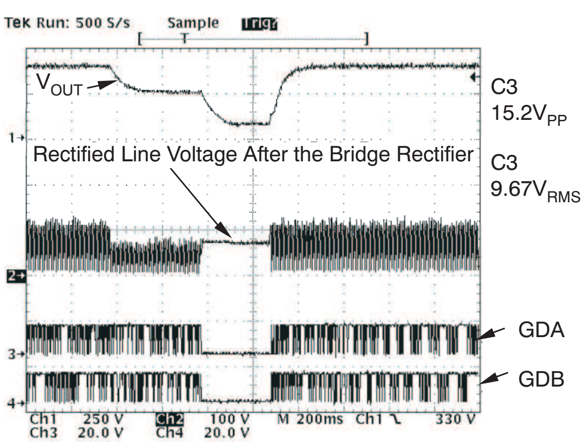

Figure 17. Brownout at 85 V_{RMS}

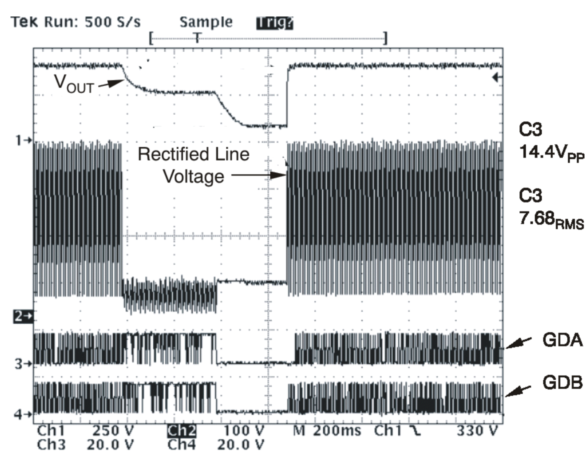

Figure 18. Brownout at 265 V_{RMS}

6.5 Line Transient

A line transient test was conducted with an ac source on the reference design. The line was varied from 230 V_{RMS} to 115 V_{RMS} to 230 V_{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.

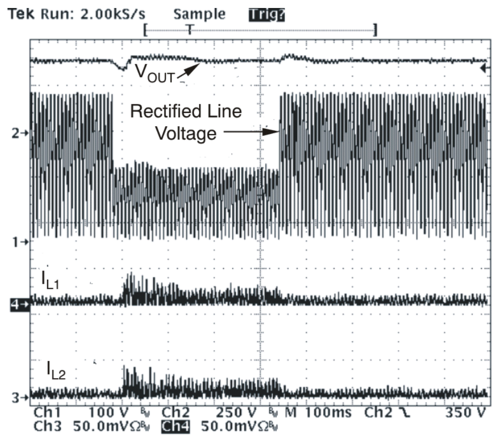

Figure 19. Line Transient, P_{OUT} = 300W

7 Reference Design Assembly Drawing

Figure 20 and Figure 22 show the top and bottom layers (respectively) of the UCC28061EVM.

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 UCC28061EVM PCBs.

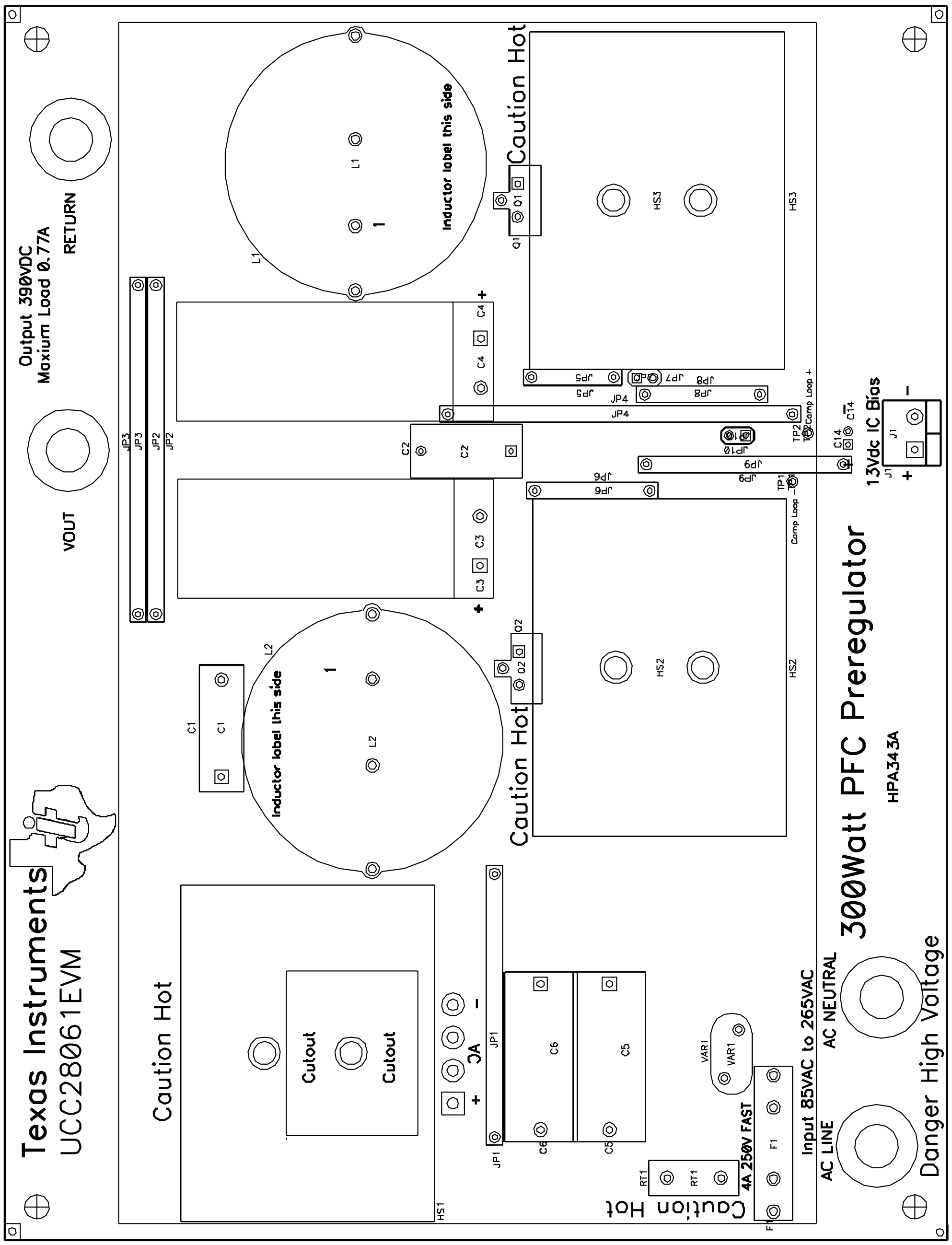

Figure 20. Top Layer Assembly

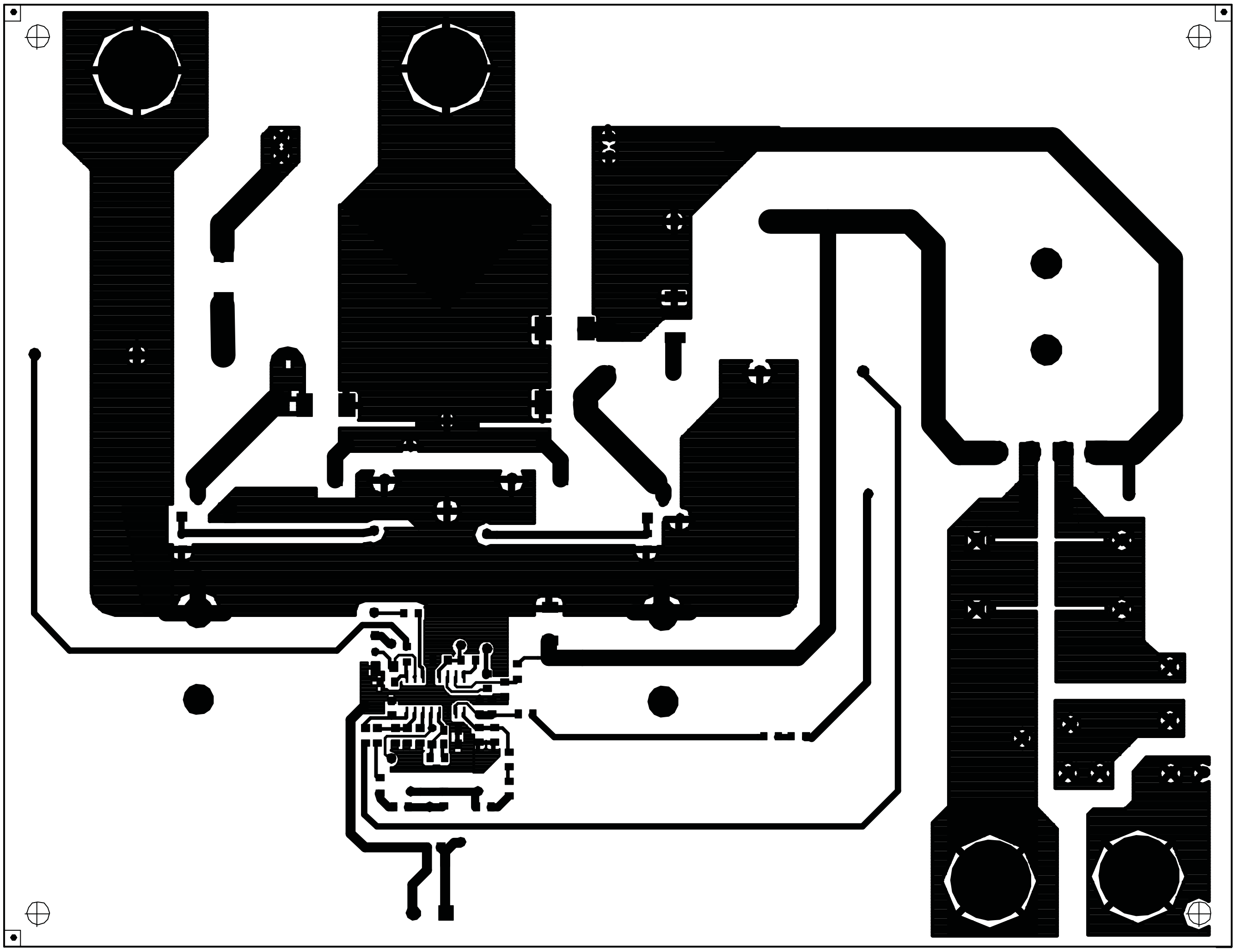

Figure 21. Bottom Layer Copper

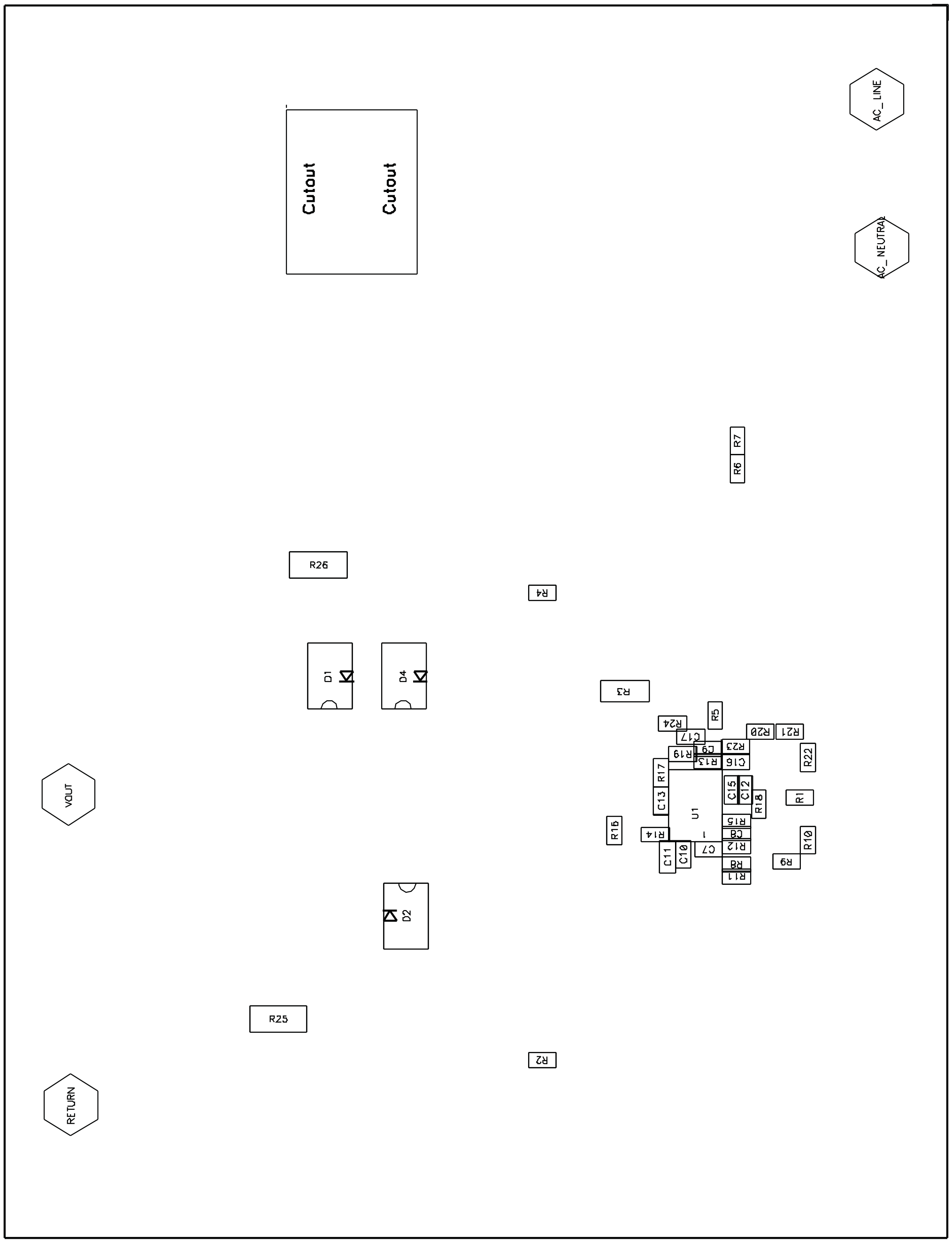

Figure 22. Bottom Layer Assembly

8 List of Materials

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

Table 2. List of Materials

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
4	AC_LINE, AC_NEUTRAL, RETURN, VOUT	Connector, banana jack, uninsulated, 3267, 0.500 dia. inch	3267	Pomona
1	C1	Capacitor, film, 275VAC, 20%, 0.1 µF, 0.689 x 0.236 inch	ECQU2A104BC1	Panasonic
1	C11	Capacitor, ceramic, 16 V, X7R, 10%, 220 nF, 1206	Std	Std
2	C12, C13	Capacitor, ceramic, 16 V, X7R, 10%, 2.2 µF, 0805	Std	Std
1	C14	Capacitor, aluminum, 35 V, 20%, 22 µF, 0.200 * 0.435 inch	ECA-1VM220	Panasonic
1	C15	Capacitor, ceramic, 25 V, X7R, 10%, 1 nF, 0805	Std	Std
1	C17	Capacitor, ceramic, 25 V, X7R, 10%, 10 nF, 0805	Std	Std
1	C2	Capacitor, polyester, 630 V, 10%, 0.047 µF, 0.256 x 0.650 inch	ECQ-E6473KZ	Panasonic
2	C3, C4	Capacitor, aluminum, 450 VDC, 20% , 100 µF, 18 x 40 mm	EKXG451ELL101 MM40S	Nippon Chemi-con
2	C5, C6	Capacitor, film, 275 VAC, 20%, 0.47 µF, 0.236 X 0.591	ECQ-U2A474MG	Panasonic
2	C7, C10	Capacitor, ceramic, 25 V, X7R, 10%, 22 pF, 0805	Std	Std
3	C8, C9, C16	Capacitor, ceramic, 25 V, X7R, 10%, 1.2 nF, 0805	Std	Std
3	D1, D2, D4	Diode, 3000 mA, 600 V, SMC	MURS360T3	On Semi
1	D3	Diode, bridge, 6 A, 600 V, BU6	GBU6J	Vishay
2	F1	Fuse clip, 5x20 mm	0100056H	Wickmann
3	HS1, HS2, HS3	Heatsink, universal-mount TO-220, 7-345-2PP, 1.500 x 2.000 inch	7-345-2PP	IERC-CTS
1	J1	Terminal block, 2 pin, 15 A, 5.1 mm, ED1609-ND, 0.40 x 0.35 inch	ED1609	OST
3	JP1, JP2, JP3	Jumper, 2.000 inch length, PVC insulation, AWG 22, 0.035 inch dia.	923345-20-C	3M
1	JP4	Jumper, 2.100 inch length, PVC insulation, AWG 22, 0.035 inch dia.	923345-21-C	3M
1	JP5	Jumper, 0.500 inch length, PVC insulation, AWG 22, 0.035 inch dia	923345-05-C	3M
2	JP6, JP8	Jumper, 0.700 inch length, PVC insulation, AWG 22	923345-07-C	Belden
1	JP7	Jumper, 0.100 inch length, non-insulated, AWG 22	923345-01-C	Belden
1	JP10	Header, 2-pin, 100-mil spacing, (36-pin strip), PTC36SAAN, 0.100 inch x 2	PTC36SAAN	Sullins
1	JP9	Jumper, 1.2 inch length, PVC insulation, AWG 22, 0.035 inch dia.	923345-20-C	3M
2	L1, L2**	Inductor, boost PFC with aux. 330 uH @ 5.3 A PK, 1.555 Dia. inch	CTX16-17769R	Cooper
2	Q1, Q2	MOSFET, N-channel, 500 V, 11 A, 520 mΩ, TO-220V	IRFB11N50APbF	IR
1	R1	Resistor, chip, 1/10 W, 1%, 51.1 Ω, 0805	Std	Std
2	R11, R14	Resistor, chip, 1/10 W, 1%, 20.5 kΩ, 0805	Std	Std

Table 2. List of Materials (continued)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
2	R12, R13	Resistor, chip, 1/10 W, 1%, 47.0 kΩ, 0805	Std	Std
1	R15	Resistor, chip, 1/10 W, 1%, 121 kΩ, 0805	Std	Std
2	R16, R19	Resistor, chip, 1/10 W, 1%, 5.11 Ω, 0805	Std	Std
1	R18	Resistor, chip, 1/10 W, 1%, 6.19 kΩ, 0805	Std	Std
3	R2, R4, R17	Resistor, chip, 1/10 W, 1%, 10.0 kΩ, 0805	Std	Std
1	R23	Resistor, chip, 1/10 W, 1%, 30.1 kΩ, 0805	Std	Std
1	R24	Resistor, chip, 1/10 W, 1%, 100 Ω, 0805	Std	Std
2	R25, R26	Resistor, chip, 1 W, 5%, 0 Ω, 2512	Std	Std
1	R3	Resistor, chip, 1/2 W, 1%, 0.015 Ω, 2010	WSL2010R0150F EA	Vishay
9	R5, R6, R7, R8, R9, R10, R20, R21, R22	Resistor, chip, 1/10 W, 1%, 1.00 MΩ, 0805	Std	Std
1	RT1	Thermistor, NTC, 5 Ω, 6 A, 5 Ω, 0.180 X 0.550 inch	CL-40	Thermometrics
2	TP1, TP2	Pin, thru hole, tin plate, for 0.062 PCB's, K24A/M, 0.039 inch	K24A/M	Vector
1	U1	Interleave PFC Controller, SO16	UCC28061D	TI
1	VAR1	Varistor 275 V RMS, 0.472 x 0.213 inch	S10K275E2	Epcos
1	PCB	HPA343 printed circuit board	HPA343	
1	X1 @ F1	4 A, fast acting fuse, BK/GDA-4A, 5mmX20mm	BK/S501-4-R	Cooper/Bussman
6	"X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2"	Nut #4-40 (steel)	Std	Std
6	"X1 @ 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 @ HS1 and D3, HS2 and Q1, HS3 and Q2"	Split lock washer #4(steel)	Std	Std
6	"X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2"	Nylon shoulder washer #4	3049	Keystone Electronics
2	"X1 @ HS2 and Q1, HS3 and Q2"	Thermal pad silicon TO220	3223-07FR-51	BERQUIST
4	1903C	Standoff hex .500/6-32THR nylon	1903C	Keystone Electronics
4	4824	Nut	4824	Keystone Electronics
AR	Note 9	RTV, adhesive sealant	RTV 167	GE

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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.

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