

# ***UCC28019EVM 350-W PFC Converter***

## *User's Guide*

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The UCC28019 evaluation module (EVM) is a 350-W off-line Power Factor Correction (PFC) boost converter providing a 390-V regulated output at 0.9 A of load current. The PFC converter accommodates an input voltage range of 85 VAC to 265 VAC and uses average current mode control at a fixed frequency of 65 kHz. The UCC28019 incorporates a wide range of protection features to ensure safe system operation.

### **1 Description**

The UCC28019EVM highlights the many benefits of using the UCC28019 Continuous Current Mode PFC Controller ([TI Literature Number SLUS755](#)). The controller operates under average current mode control at a fixed frequency of 65 kHz. Simple external current and voltage loop compensation, along with advanced protection features, make this controller ideal for server and desktop power supplies, telecom rectifiers, and home electronics.

This user's guide provides the schematic, component list, assembly drawing for a single-sided printed circuit board application, and test set up necessary to evaluate the UCC28019 in a typical PFC application.

### **2 Applications**

The UCC28019 is suited for use in high-power off-line systems requiring high-efficiency and advanced fault protection features including:

- Server and desktop power supplies
- Telecom rectifiers
- Home electronics

### **3 Features**

The UCC28019EVM features include:

- 350-W, 390-V output
- Universal off-line input voltage range
- Average current mode PWM control
- Fixed 65-kHz oscillator frequency
- Cycle-by-cycle peak current limiting
- VCC under-voltage lockout
- Voltage regulation open-loop detection
- Output under-voltage protection
- Output over-voltage protection
- AC input brown-out protection
- Enhanced dynamic response
- Soft-start

## 4 UCC28019EVM Electrical Performance Specification

### CAUTION

High voltage levels are present on the evaluation module whenever it is energized. Proper precautions must be taken when working with the EVM. The large bulk capacitor across the output terminals must be completely discharged before the EVM can be handled. Serious injury can occur if proper safety precautions are not followed.

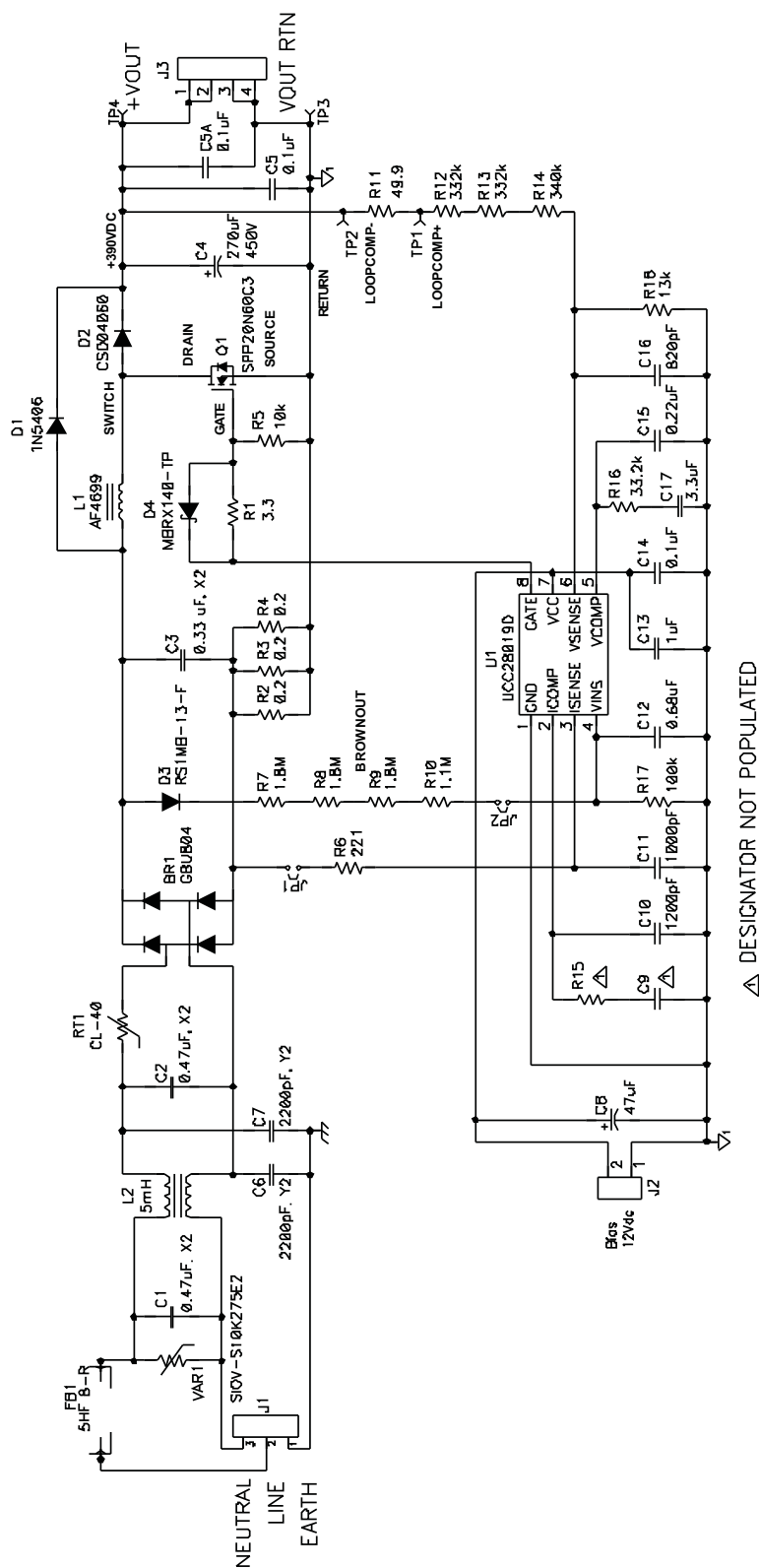
**Table 1. UCC28019EVM Performance Summary**

|  | PARAMETER                            | TEST CONDITION  | MIN   | TYP   | MAX   | UNIT             |
|--|--------------------------------------|---|-------|-------|-------|------------------|
| Input Characteristics                    |                                      |   |       |       |       |                  |
| V <sub>IN</sub>                          | Input voltage                        |   | 85    |       | 265   | VAC              |
| f <sub>LINE</sub>                        | Input frequency                      |   | 47    |       | 63    | Hz               |
| I <sub>IN</sub> (No_Load)                | No load input current                | V <sub>IN</sub> = 265 VAC, f <sub>LINE</sub> = 50 Hz<br>I <sub>OUT</sub> = 0 A                            |       | 80    |       | mA               |
| I <sub>IN</sub> (MAX)                    | Maximum input current                | V <sub>IN</sub> = 85 VAC, f <sub>LINE</sub> = 50 Hz<br>I <sub>OUT</sub> = 0.9 A                           |       | 4.52  |       | A                |
| V <sub>IN</sub> (TURN_ON_THRESHOLD)      | Brown out voltage                    | I <sub>OUT</sub> = 0.9 A  |       | 82    |       | VAC              |
| V <sub>IN</sub> (TURN_OFF_THRESHOLD)     |                                      | I <sub>OUT</sub> = 0.9 A  |       | 66    |       |                  |
| Output Characteristics                   |                                      |   |       |       |       |                  |
| V <sub>OUT</sub>                         | Output voltage                       | 85 VAC ≤ V <sub>IN</sub> ≤ 265 VAC<br>47 Hz ≤ f <sub>LINE</sub> ≤ 63 Hz<br>0 A ≤ I <sub>OUT</sub> ≤ 0.9 A | 370.5 | 390   | 409.5 | VDC              |
|  | Line regulation                      | 85 VAC ≤ V <sub>IN</sub> ≤ 265 VAC<br>I <sub>OUT</sub> = 0.45 A   |       | 0.41% | 5%    |                  |
|  | Load regulation                      | V <sub>IN</sub> = 115 VAC, f <sub>LINE</sub> = 60 Hz<br>0 A ≤ I <sub>OUT</sub> ≤ 0.9 A                    |       | 0.05% | 5%    |                  |
|  |                                      | V <sub>IN</sub> = 230 VAC, f <sub>LINE</sub> = 50 Hz<br>0 A ≤ I <sub>OUT</sub> ≤ 0.9 A                    |       | 0.67% | 5%    |                  |
| V <sub>RIPPLE</sub> (SW)                 | High frequency output voltage ripple | V <sub>IN</sub> = 115 VAC, f <sub>LINE</sub> = 60 Hz<br>I <sub>OUT</sub> = 0.9 A                          |       | 1.68  | 3.9   | V <sub>P-P</sub> |
|  |                                      | V <sub>IN</sub> = 230 VAC, f <sub>LINE</sub> = 50 Hz<br>I <sub>OUT</sub> = 0.9 A                          |       | 1.12  | 3.9   |                  |
| V <sub>RIPPLE</sub> (f <sub>LINE</sub> ) | Line frequency output voltage ripple | V <sub>IN</sub> = 115 VAC, f <sub>LINE</sub> = 60 Hz<br>I <sub>OUT</sub> = 0.9 A                          |       | 10.8  | 19.5  |                  |
|  |                                      | V <sub>IN</sub> = 230 VAC, f <sub>LINE</sub> = 50 Hz<br>I <sub>OUT</sub> = 0.9 A                          |       | 12.4  | 19.5  |                  |
| I <sub>OUT</sub>                         | Output load current                  | 85 VAC ≤ V <sub>IN</sub> ≤ 265 VAC<br>47 Hz ≤ f <sub>LINE</sub> ≤ 63 Hz                                   |       |       | 0.9   | A                |
| P <sub>OUT</sub>                         | Output power                         |   |       |       | 350   | W                |
| V <sub>OUT</sub> (OVP)                   | Output over voltage protection       |   |       | 410   |       | V                |
| V <sub>OUT</sub> (UVD)                   | Output under voltage detection       |   |       | 370   |       |                  |

**Table 1. UCC28019EVM Performance Summary (continued)**

|                                     | PARAMETER                 | TEST CONDITION  | MIN  | TYP   | MAX  | UNIT               |
|-------------------------------------|---------------------------|---|------|-------|------|--------------------|
| <b>Control Loop Characteristics</b> |                           |   |      |       |      |                    |
| $f_{SW}$                            | Switching frequency       | $T_J = 25^{\circ}\text{C}$  | 61.7 | 65    | 68.3 | kHz                |
| $f_{(CO)}$                          | Control loop bandwidth    | $V_{IN} = 162\text{ VDC}$ ,<br>$I_{OUT} = 0.45\text{ A}$                            |      | 9.3   |      | Hz                 |
|                                     | Phase margin              | $V_{IN} = 162\text{ VDC}$ ,<br>$I_{OUT} = 0.45\text{ A}$                            |      | 70    |      | degrees            |
| PF                                  | Power factor              | $V_{IN} = 115\text{ VAC}$ , $I_{OUT} = 0.9\text{ A}$                                | 0.99 |       |      |                    |
| THD                                 | Total harmonic distortion | $V_{IN} = 115\text{ VAC}$ , $f_{LINE} = 60\text{ Hz}$ ,<br>$I_{OUT} = 0.9\text{ A}$ |      | 4.13% | 10%  |                    |
|                                     |                           | $V_{IN} = 230\text{ VAC}$ , $f_{LINE} = 50\text{ Hz}$ ,<br>$I_{OUT} = 0.9\text{ A}$ |      | 6.77% | 10%  |                    |
| $\eta_{PEAK}$                       | Peak efficiency           | $V_{IN} = 265\text{ VAC}$ , $f_{LINE} = 50\text{ Hz}$ ,<br>$I_{OUT} = 0.9\text{ A}$ |      | 97.3% |      |                    |
| $\eta_{FL}$                         | Full Load Efficiency      | $V_{IN} = 115\text{ VAC}$ , $f_{LINE} = 60\text{ Hz}$ ,<br>$I_{OUT} = 0.9\text{ A}$ |      | 94.4% |      |                    |
| $T_A$                               | Ambient Temperature       |   |      | 25    |      | $^{\circ}\text{C}$ |

## 5 Schematic



### Figure 1. UCC28019EVM Schematic

## 6 EVM Test Setup

Figure 2 shows the basic test set up recommended to evaluate the UCC28019EVM.

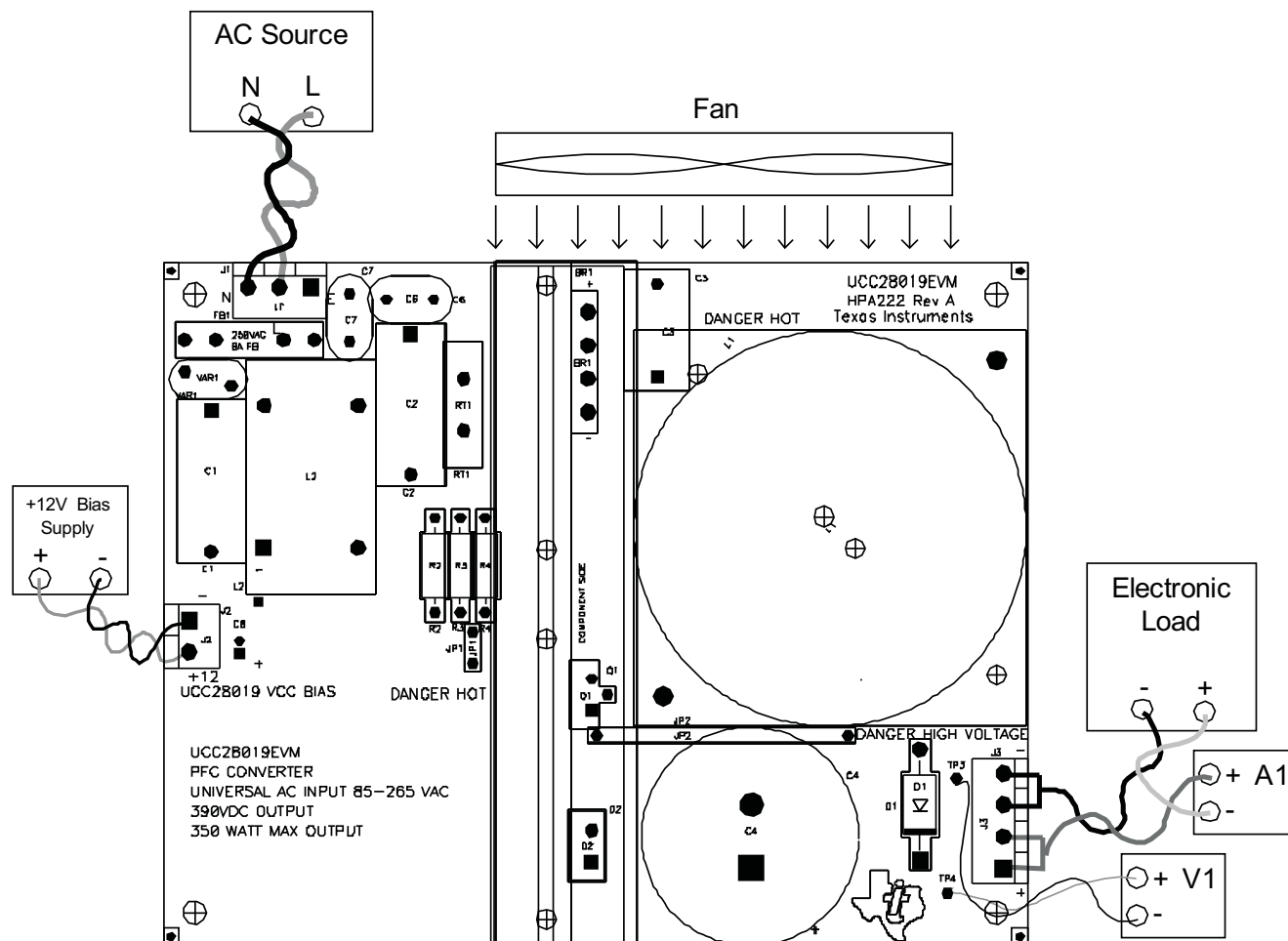


Figure 2. UCC28019EVM Test Set Up

## **6.1 AC Source**

The ac input source shall be capable of supplying between 85 VAC and 265 VAC at no less than 8 A peak. Connect the ac source to the L and N terminals of J1 on the EVM as shown in [Figure 2](#).

## **6.2 12-V Bias Supply**

The bias supply to the device shall be capable of supplying up to 12 VDC at no less than 10 mA. Connect the bias supply to the – and +12 terminals of J2, UCC28019 VCC BIAS, as shown in [Figure 2](#).

## **6.3 Electronic Load**

A programmable electronic load set to constant current mode and capable of sinking 0 A to 1 A at 390 VDC shall be used.

## **6.4 Digital Multimeters**

For highest accuracy, the output voltage of the UCC28019EVM shall be monitored by connecting a digital voltmeter, V1, directly across TP3 and TP4 with the positive terminal at TP4 and the negative terminal at TP3, as shown in [Figure 2](#). A dc current meter, A1, should be placed in series with the electronic load for accurate output current measurements.

## **6.5 Recommended Wire Gauge**

The connection between the ac source and the EVM input terminals can carry as much as 8 A peak during brownout testing. The recommended wire size is AWG #16 with the total length of wire less than 8 feet (4 feet input, 4 feet return). The connection between the EVM output terminals (J3) and the electronic load can carry as much as 1 A. The minimum recommended wire size is AWG #20, with the total length of wire less than 8 feet (4 feet output, 4 feet return).

## **6.6 Fan**

A fan, capable of 200 LFM to 400 LFM, should be used to maintain component temperatures within safe operating ranges at all times during operation of the UCC28091EVM. Position the fan so as to blow along the length of the heatsink as shown in [Figure 2](#).



## 7 Power-Up/Power-Down Procedure

The following test procedure is recommended primarily for power up and shutting down the evaluation module. Never leave a powered EVM unattended for any length of time. Also, the unit should never be handled while power is applied to it or the output voltage is greater than 50 VDC.

### **WARNING**

**There are very high voltages present on the EVM. Some components will reach temperatures above 50°C. Precautions must be taken when handling the board. Never operate the UCC28019EVM without the fan running. Always make certain the bulk capacitors have completely discharged prior to handling the EVM.**

1. Working at an ESD workstation, make sure that the ionizer is on before the EVM is removed from the protective packaging and power is applied. Electrostatic smock and safety glasses should also be worn. Because voltages in excess of 400 V may be present on the EVM, do not connect the ground strap from the smock to the bench.
2. Power-UP
  - a. Connect the equipment as shown in [Figure 2](#).
  - b. Turn on the fan.
  - c. Prior to turning on the ac source, limit the source current to 8 A and then turn on the ac source.
  - d. Turn on the 12-V bias supply and verify that the output is within regulation.
  - e. Increase the load from 0 A up to 0.9 A.
  - f. The DRAIN, SOURCE, GATE, SWITCH node, RETURN, and VOUT+ are labeled on the surface mount side of the board for user access.
3. Power-Down
  - a. Turn off ac source.
  - b. Turn off bias supply.
  - c. Discharge the output capacitor.
  - d. Turn off the load.

## 8 UCC28019EVM Performance Data and Characteristic Curves

The vertical lines on the following figures represent 20%, 50% and 100% load.

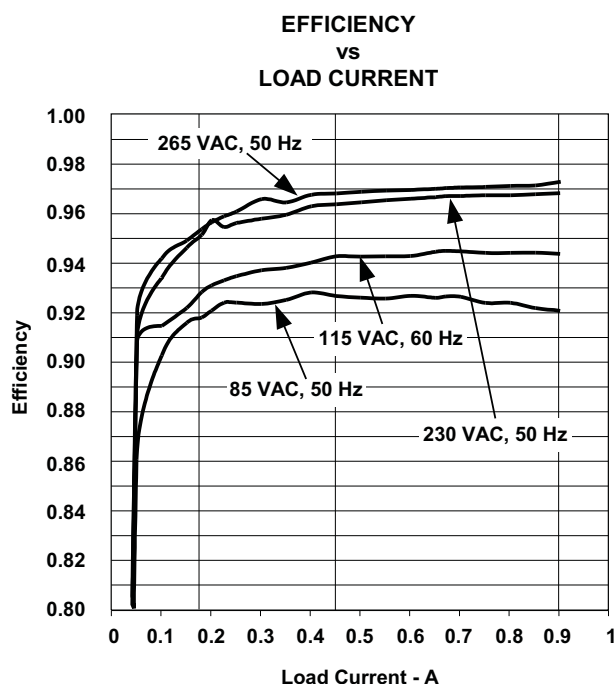


Figure 3. Efficiency as a Function of Line Voltage and Load Current

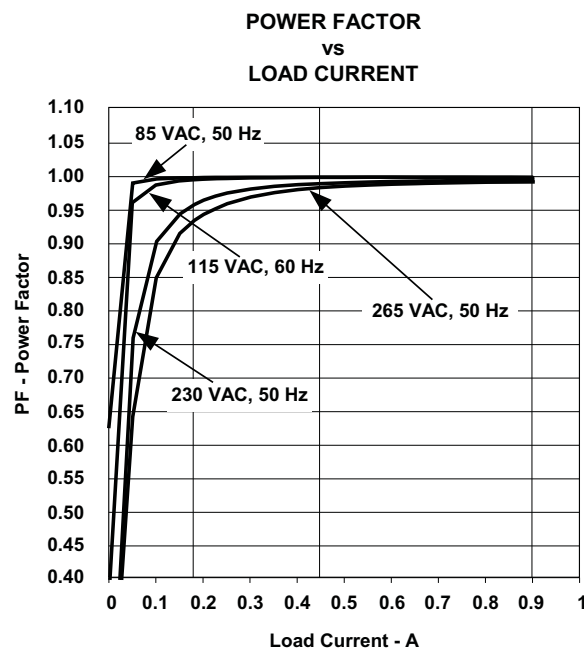


Figure 4. Power Factor as a Function of Line Voltage and Load Current

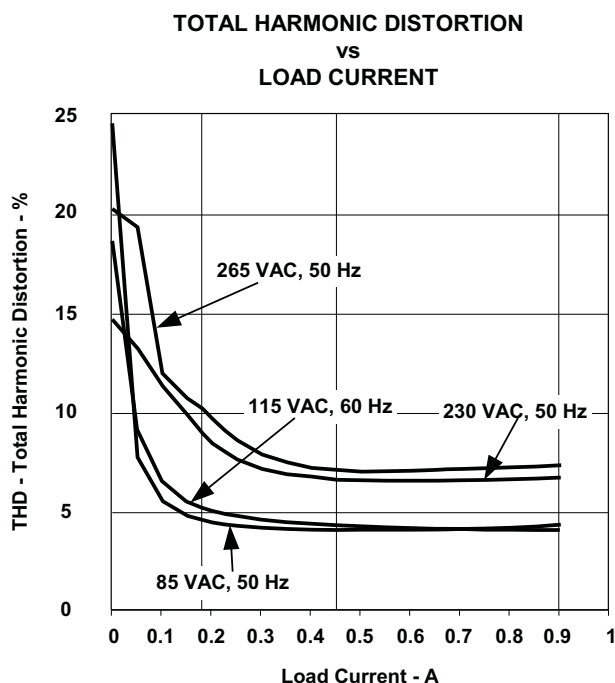


Figure 5. Total Harmonic Distortion as a Function of Line Voltage and Load Current

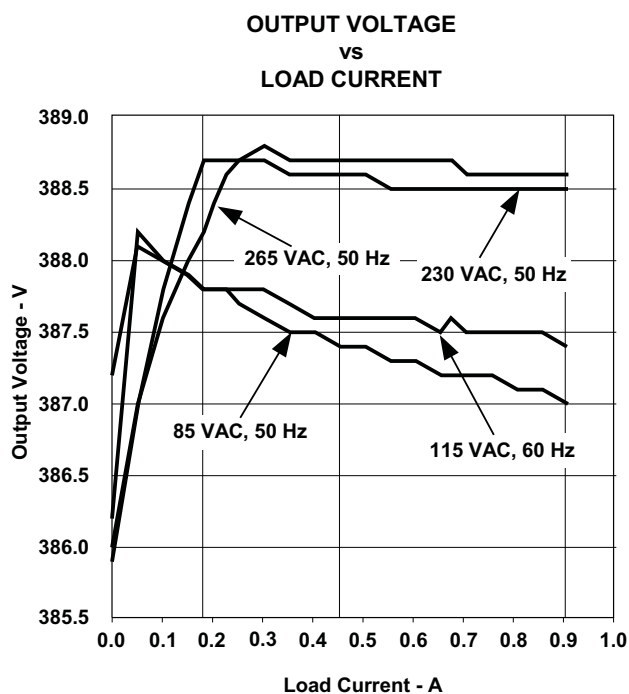


Figure 6. Output Voltage as a Function of Line Voltage and Load Current

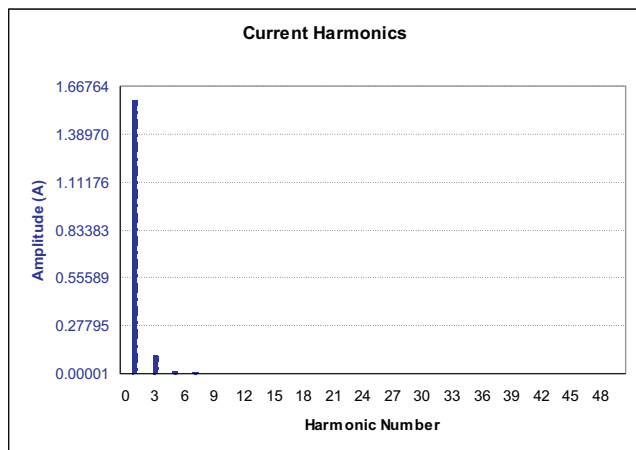


Figure 7. Current Harmonics, 230 VAC, 50 Hz input, Full Load

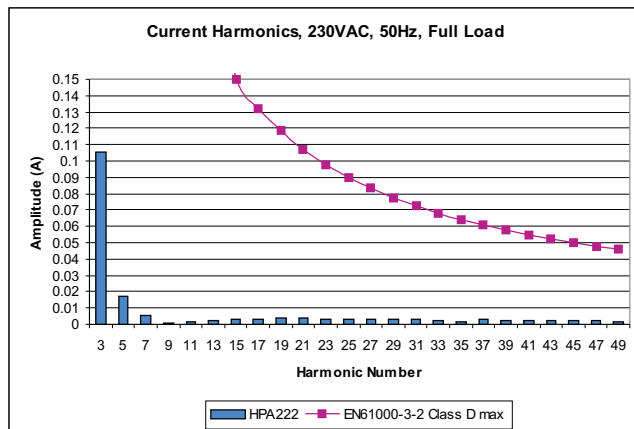


Figure 8. Current Harmonics, 230 VAC, 50 Hz Input, Full Load, Re-Scaled Without the Fundamental

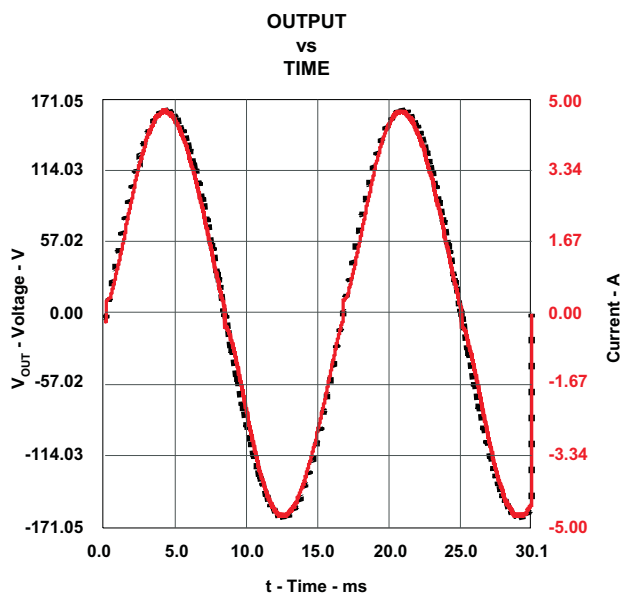


Figure 9. Input Voltage and Current Waveforms, 115 VAC, 60 Hz, Full Load

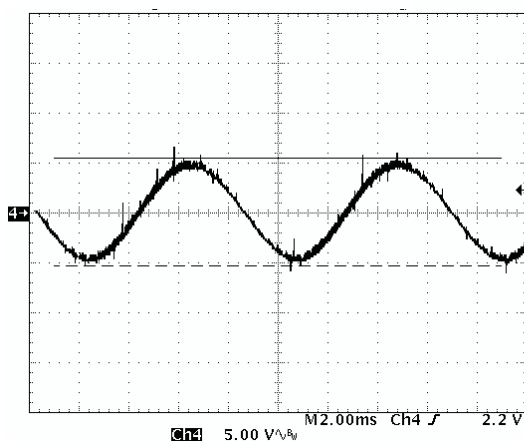
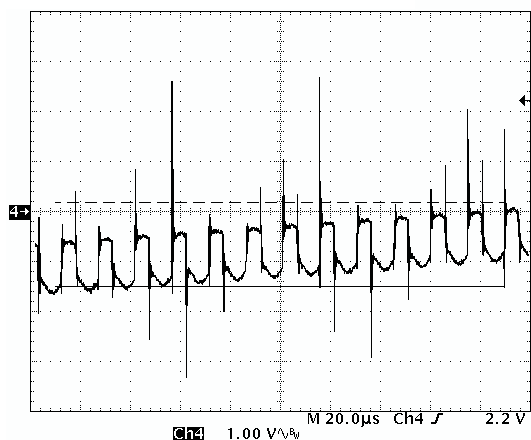
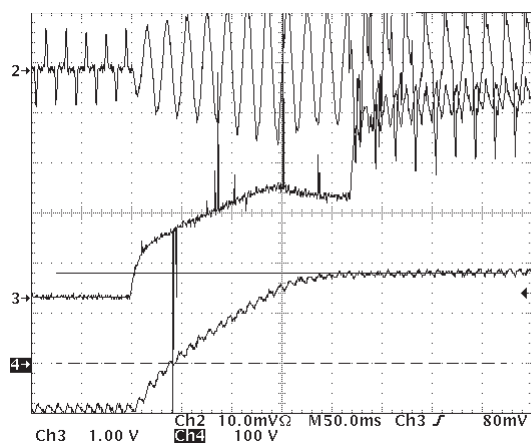


Figure 10. Line Frequency Output Voltage Ripple, 115 VAC, 60 Hz Input, Full Load

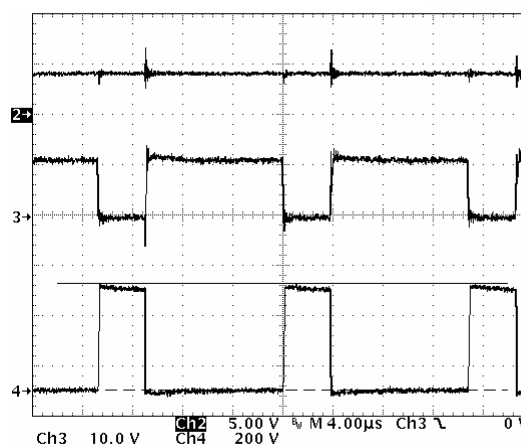


**Figure 11. Switching Frequency Output Voltage Ripple, 115 VAC, 60 Hz Input, Full Load**

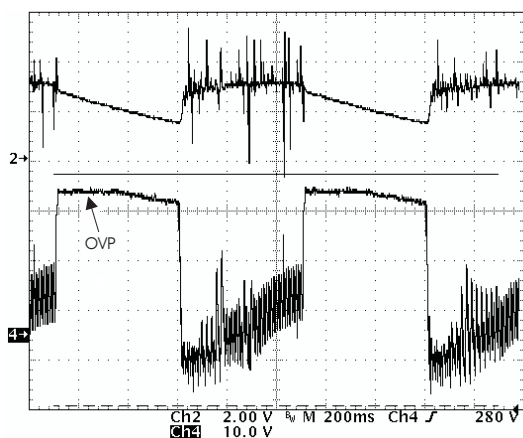
The following figure shows the start-up waveform of the UCC28019EVM as the 12-V bias supply is turned on. Note the constant  $30\ \mu\text{A}$  of source current from VCOMP into the compensation capacitor which allows a linear voltage rise enabling a controlled increase of the input current until the output voltage reaches 95% of its regulated output voltage (370.5 VDC).



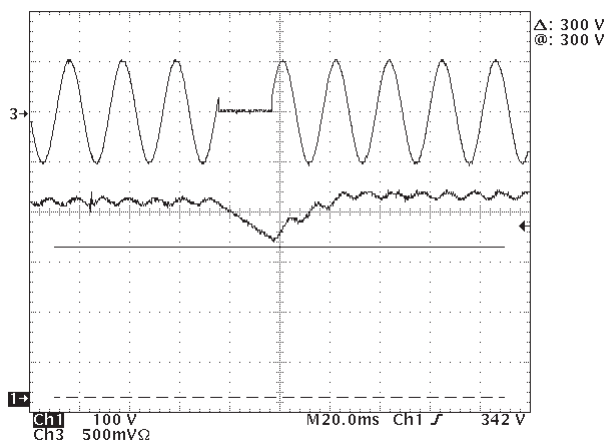
**Figure 12. Start-Up Waveform (115 VAC, 60 Hz, 0.45 A load. Ch1 =  $I_{IN}$  @ 5 A/div, Ch.2 = VCOMP @ 2 V/div, Ch. 3 = VSENSE @ 5 V/div, Ch. 4 = VOUT @ 100 V/div offset by 155 VDC)**



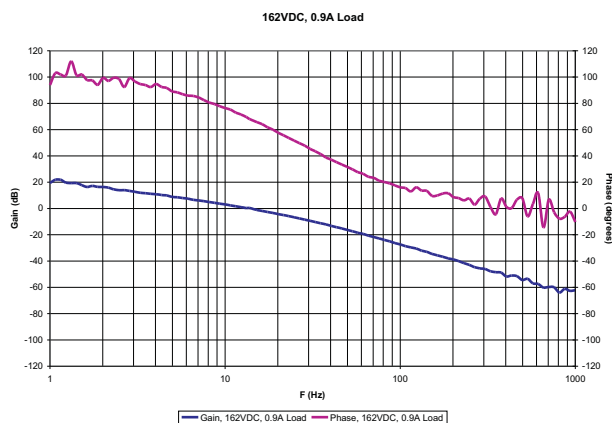
**Figure 13. Switching Waveform (115 VAC, 60 Hz, full load. Ch. 2 = VCOMP @ 5 V/div, Ch. 3 = GATE @ 10 V/div, Ch. 4 = DRAIN @ 200 V/div.)**



**Figure 14. Load Transient (Load step: 0% to 100%. Ch. 2 = VCOMP @ 2 V/div., Ch. 4 = V<sub>OUT</sub> @ 10 V/div. offset by 375 VDC. Note the plateau on V<sub>OUT</sub> (Ch. 4) resulting from OVP triggering at 404.4 V.)**



**Figure 15. Line Drop Out, V<sub>IN</sub> = 85 VAC, 50 Hz, Full Load (Ch. 3 = V<sub>IN</sub> @ 500 mV X 200 V/div; measured with a differential probe, Ch. 1 = V<sub>OUT</sub> @ 100 V/div. Drop out was one line cycle.)**



**Figure 16. Bode Plot (162 VDC input, full load. Crossover frequency = 13 Hz, phase margin = 68°.)**

## 9 Board Layout Diagrams

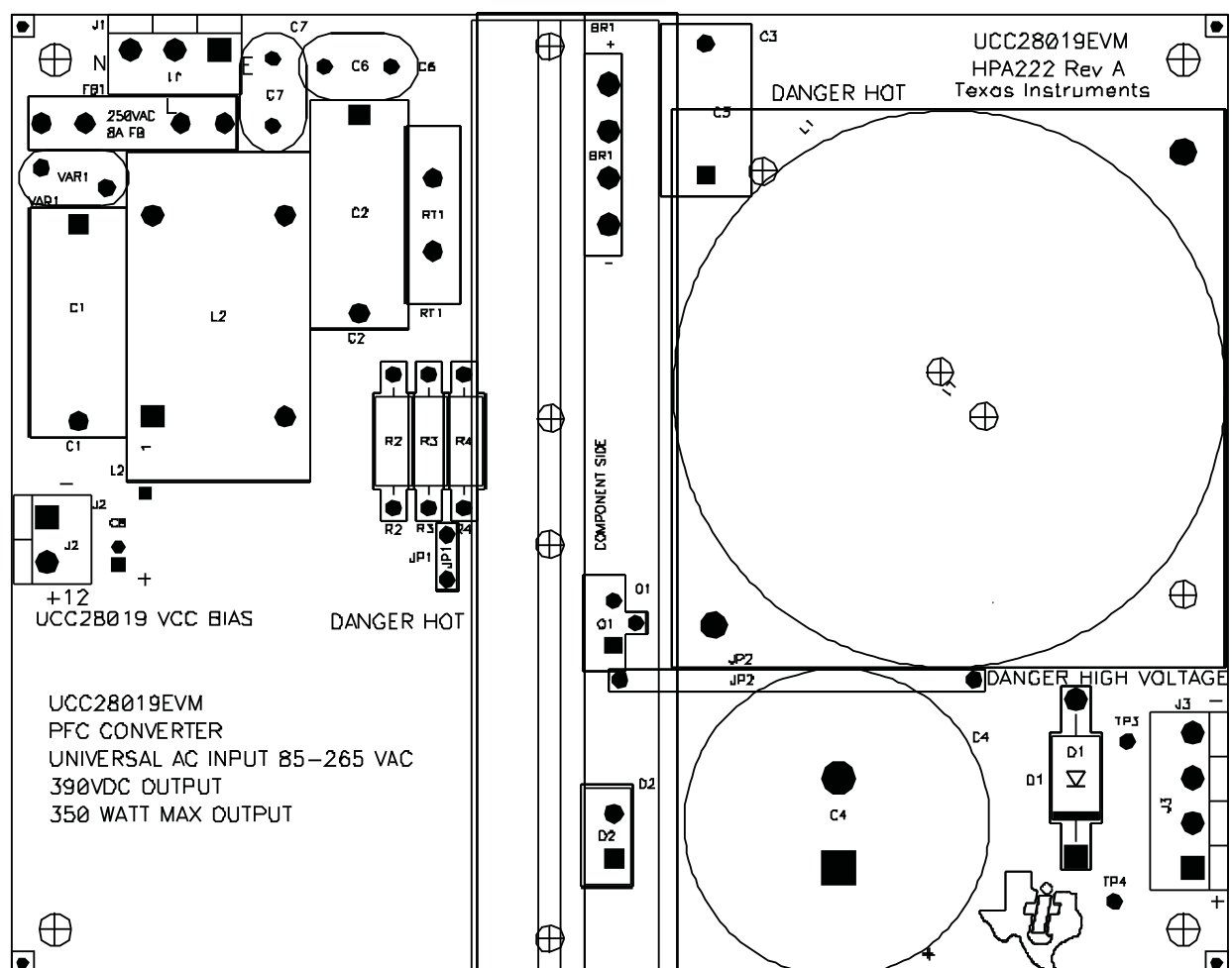


Figure 17. Top layer Component Placement

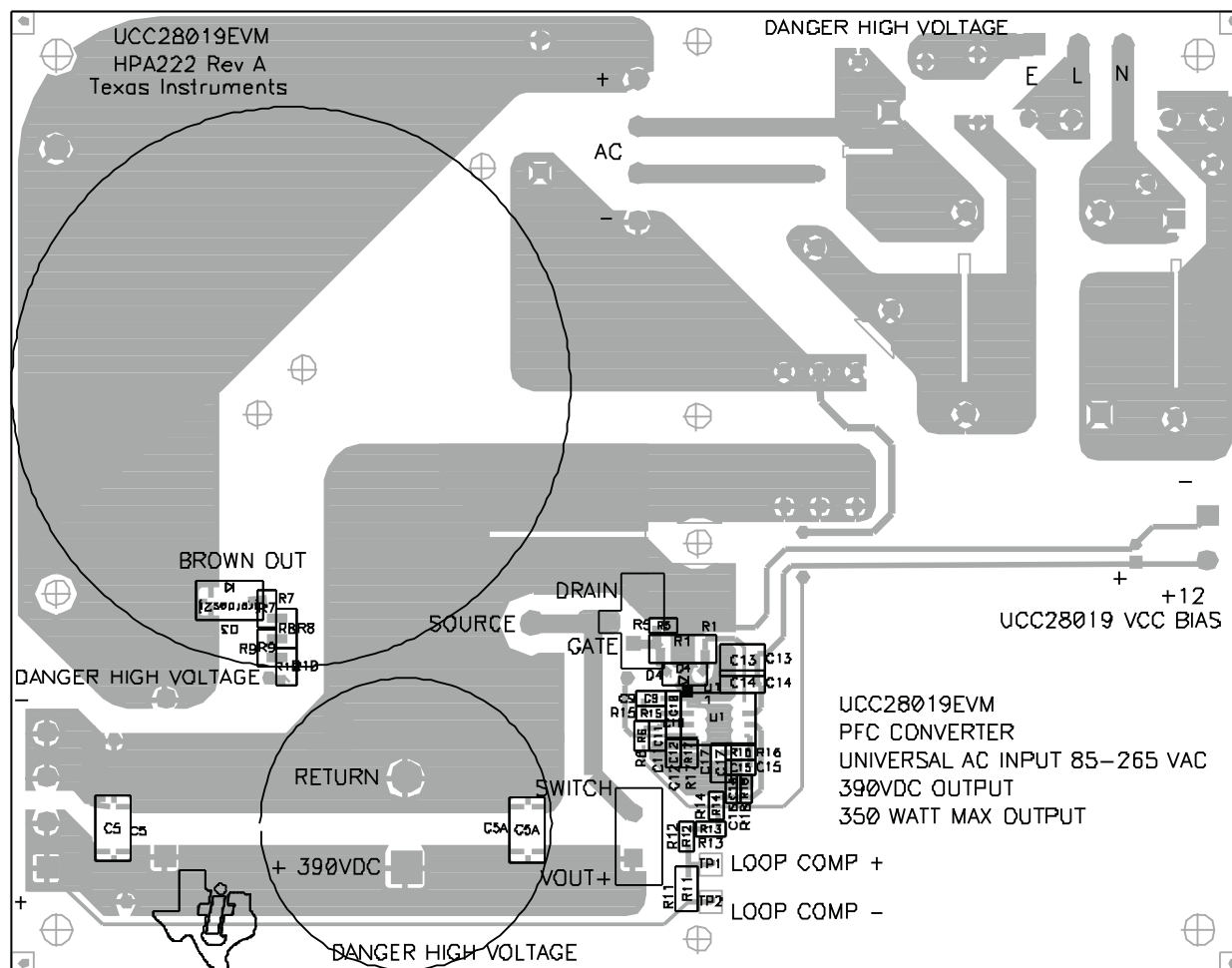
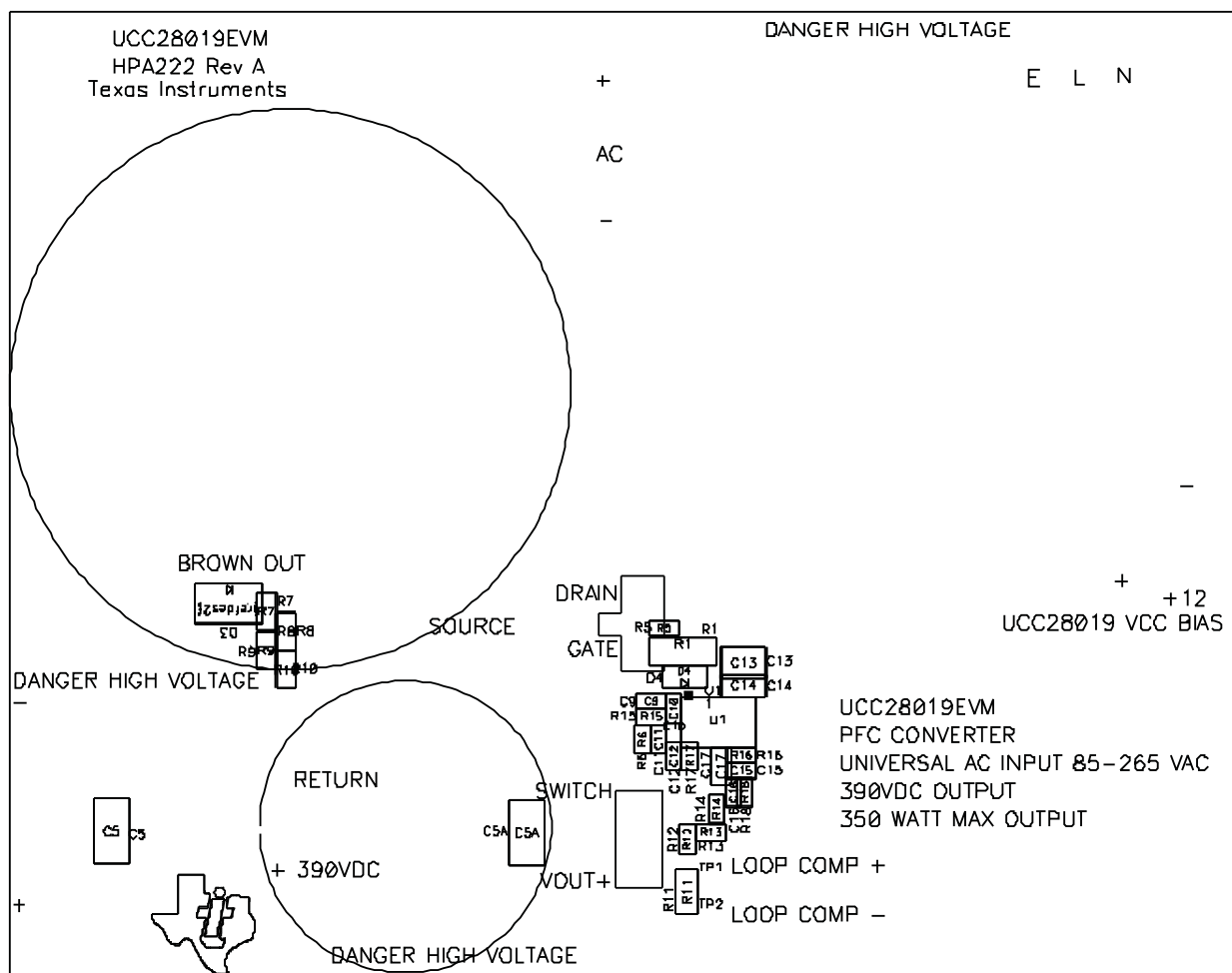
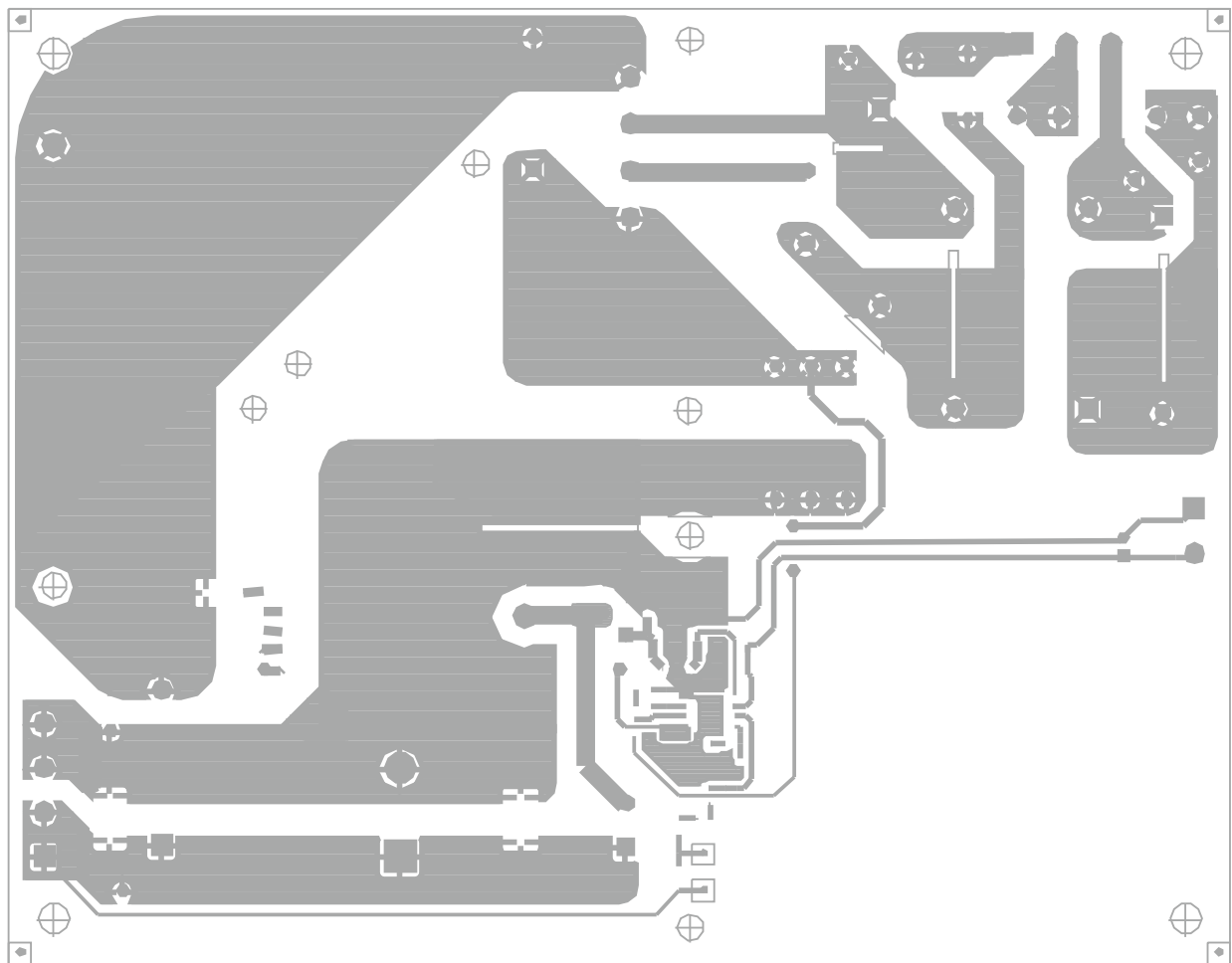


Figure 18. Bottom Layer



### Figure 19. Bottom Layer Component Placement





**Figure 20. Bottom Layer Routing**

## 10 List of Materials

**Table 2. List of Materials<sup>(1)(2)(3)(4)</sup>**

| RefDes  | COUNT | Description  | MFR                   | Part Number             |
|---------|-------|--|-----------------------|-------------------------|
| BR1     | 1     | Diode, bridge rectifier, 8 A, 400 V, 0.880 x 0.140 inch                      | Diode Inc.            | GBU804                  |
| C1, C2  | 2     | Capacitor, film, 0.47 $\mu$ F, X2, 275 VAC, $\pm$ 20%, 0.236 x 0.591 inch    | Panasonic             | ECQ-U2A474ML            |
| C3      | 1     | Capacitor, film, 0.33 $\mu$ F, X2, 275 VAC, $\pm$ 20%, 0.690 x 0.374 inch    | Panasonic             | ECQ-U2A334ML            |
| C4      | 1     | Capacitor, aluminum, 270 $\mu$ F, 450 VDC, $\pm$ 20%, 30 x 30 mm             | Panasonic             | EETUQ2W271DA            |
| C5, C5A | 2     | Capacitor, ceramic, 0.1 $\mu$ F, 630 V, X7R, $\pm$ 10%, 1812                 | muRata                | GRM43DR72J104KW01L      |
| C6, C7  | 2     | Capacitor, ceramic disc, 2200 pF, Y2, 250 VAC, $\pm$ 20%, 0.276 x 0.413 inch | TDK Corporation       | CS11-E2GA222MYNS        |
| C8      | 1     | Capacitor, aluminum, 47 $\mu$ F, 35 V, $\pm$ 20%, 0.200 x 0.435 inch         | Panasonic             | ECA-1VM470              |
| C9      | 0     | Capacitor, ceramic, not populated, 50 V, X7R, $\pm$ 10%, 0603                | muRata                | not populated           |
| C10     | 1     | Capacitor, ceramic, 1200 pF, 50 V, X7R, $\pm$ 10%, 0603                      | Panasonic             | ECJ-1VB1H122K           |
| C11     | 1     | Capacitor, ceramic, 1000 pF, 100 V, X7R, $\pm$ 10%, 0603                     | Panasonic             | ECJ-1VB2A1001K          |
| C12     | 1     | Capacitor, ceramic, 0.68 $\mu$ F, 10 V, X7R, $\pm$ 10%, 0603                 | muRata                | GRM188R61A684KA61D      |
| C13     | 1     | Capacitor, ceramic, 1 $\mu$ F, 50 V, X7R, $\pm$ 10%, 1210                    | Panasonic             | ECJ-4YB1H105K           |
| C14     | 1     | Capacitor, ceramic, 0.1 $\mu$ F, 50 V, X7R, $\pm$ 10%, 1206                  | muRata                | ECJ-3VB1H104K           |
| C15     | 1     | Capacitor, ceramic, 0.22 $\mu$ F, 16V, X7R, $\pm$ 10%, 0603                  | muRata                | GRM188R71C224KA01D      |
| C16     | 1     | Capacitor, ceramic, 820 pF, 50 V, X7R, $\pm$ 10%, 0603                       | Kemet                 | C0603C821K5RACTU        |
| C17     | 1     | Capacitor, ceramic, 3.3 $\mu$ F, 10 V, X5R, $\pm$ 10%, 0805                  | muRata                | GRM219R61A335KE19D      |
| D1      | 1     | Diode, standard recovery, 3 A, 600 V, DO-201AD                               | Micro Commercial Co.  | 1N5406-TP               |
| D2      | 1     | Diode, silicon carbide Schottky diode, 4 A, 600 V, TO220AC                   | Cree                  | CSD04060A               |
| D3      | 1     | Diode, fast recovery, 1 A, 1000 V, SMB                                       | Diode Inc.            | RS1MB-13-F              |
| D4      | 1     | Diode, Schottky, 1 A, 40 V, SOD-123  | Micro Commercial Co.  | MBRX140-TP              |
| FB1     | 1     | Fuse clip, PC mount, 10 A, 5 x 20 mm   | Littelfuse, Inc.      | 01000056H               |
| F1      | 1     | Fuse, fast acting, ceramic, 8 A, 5 x 20 mm                                   | Bel Fuse Inc.         | 5HF8-R                  |
| HS1     | 1     | Heatsink, 78265 3 B 4250, vertical-mount, 4.25 inches                        | Aavid Thermalloy      | 44125                   |
| J1      | 1     | Terminal block, 3 pin, 15 A, 5.1 mm  | OST                   | ED1610                  |
| J2      | 1     | Terminal block, 2 pin, 15 A, 5.1 mm  | OST                   | ED1609                  |
| J3      | 1     | Terminal block, 4 pin, 15 A, 5.1 mm  | OST                   | ED2227                  |
| JP1     | 1     | Jumper, 0.200 inch length, PVC insulation, AWG 22                            | 3M                    | 923345-02-C             |
| JP2     | 1     | Jumper, 1.7 inch length, PVC insulation, AWG 22                              | STD                   | STD                     |
| L1      | 1     | Inductor, PFC boost, 1.25 mH, 7 A, 2.500 Dia.                                | Vitec                 | AF4699-111306           |
| L2      | 1     | Inductor, common mode choke, 5 mH, 8.9 A, 22 m $\Omega$                      | J.W.Miller            | 8113-RC                 |
| Q1      | 1     | MOSFET, N-channel, 650 V, 20.7 A, 190 m $\Omega$ , TO-220V                   | Infineon Technologies | SPP20N60C3-Q67040-S4398 |

- (1) These assemblies are ESD sensitive, ESD precautions shall be observed.  
 (2) These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.  
 (3) These assemblies must comply with workmanship standards IPC-A-610 Class 2.  
 (4) Ref designators marked with an asterisk (\*\*\*) cannot be substituted. All other components can be substituted with equivalent MFG's components.

**Table 2. List of Materials (continued)**

|            |   |  |                   |                         |
|------------|---|--|-------------------|-------------------------|
| R1         | 1 | Resistor, chip, 3.3 $\Omega$ , 1/2 W, $\pm 5\%$ , 2010                       | Panasonic         | ERJ-12ZYJ3R3U           |
| R2, R3, R4 | 3 | Resistor, metal oxide, 0.2 $\Omega$ , 1 W, $\pm 5\%$                         | RCD Components    | RMF1R20JBW              |
| R5         | 1 | Resistor, chip, 10 k $\Omega$ , 1/16 W, $\pm 1\%$ , 0603                     | Panasonic         | ERJ-3EKF1002V           |
| R6         | 1 | Resistor, chip, 221 $\Omega$ , 1/16 W, $\pm 1\%$ , 0603                      | Panasonic         | ERJ-3EKF2210V           |
| R7, R8, R9 | 3 | Resistor, chip, 1.8 M $\Omega$ , 1/10 W, $\pm 1\%$ , 0805                    | Panasonic         | ERJ-6ENF1804V           |
| R10        | 1 | Resistor, chip, 1.1 M $\Omega$ , 1/10 W, $\pm 1\%$ , 0805                    | Panasonic         | ERJ-6ENF1104V           |
| R11        | 1 | Resistor, chip, 49.9 $\Omega$ , 0.25 W, $\pm 1\%$ , 2010                     | Panasonic         | ERJ-8ENF49R9V           |
| R12, R13   | 2 | Resistor, chip, 332 k $\Omega$ , 1/10 W, $\pm 1\%$ , 0603                    | Panasonic         | ERJ-3EKF3323V           |
| R14        | 1 | Resistor, chip, 340 k $\Omega$ , 1/10 W, $\pm 1\%$ , 0603                    | Panasonic         | ERJ-3EKF3403V           |
| R15        | 0 | Resistor, chip, not populated, 1/10 W, $\pm 1\%$ , 0603                      | STD               | not populated           |
| R16        | 1 | Resistor, chip, 33.2 k $\Omega$ , 1/10 W, $\pm 1\%$ , 0603                   | Vishay/Dale       | CRCW060333K2FKEA        |
| R17        | 1 | Resistor, chip, 100 k $\Omega$ , 1/10 W, $\pm 1\%$ , 0603                    | Panasonic         | ERJ-3EKF1003V           |
| R18        | 1 | Resistor, chip, 13 k $\Omega$ , 1/10 W, $\pm 1\%$ , 0603                     | Panasonic         | ERJ-3EKF1302V           |
| RT1        | 1 | Thermistor, NTC, 5 $\Omega$ , 6 A, 0.220 X 0.770 inch                        | GE                | CL-40                   |
| U1**       | 1 | Device, Continuous Current Mode PFC Controller, SO8                          | Texas Instruments | UCC28019D               |
| VAR1       | 1 | Varistor, 430 V, clamping max. 710 V, 25 A, 0.472 x 0.213 inch               | GE                | S10K275E2               |
| clip       | 3 | Heatsink clips, MAX01G, standard force, T0-220 clips                         | Aavid Thermalloy  | 406098                  |
| Sil Pad    | 2 | Thermal Pad Silicon TO220 (Electrically Insulating Material) .009" SP400     | Bergquist         | 7403-09FR-58: BER107-ND |
| Sil Pad    | 1 | Thermal Pad Silicon Rectifier (Electrically Insulating Material) .009" SP400 | Bergquist         | Q3-46: BER144-ND        |

## 11 7. References

1. [UCC28019 8-Pin Continuous Conduction Mode \(CCM\) PFC Controller data sheet, TI Literature number SLUS755](#)

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## **EVM WARNINGS AND RESTRICTIONS**

It is important to operate this EVM within the input voltage range of 85 VAC to 265 VAC.

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 50°C. The EVM is designed to operate properly with certain components above 50°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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