Using the UCC28180EVM-573

User's Guide

Literature Number: SLUUAT3B
October 2013–Revised December 2013
1 Introduction
The UCC28180EVM-573 evaluation module (EVM) is a 360-W off-line power factor correction (PFC) boost converter providing a nominal output voltage of 390-V regulated output at 0.923 A of load current. The PFC converter accommodates an input voltage range of 85 V\textsubscript{AC} to 265 V\textsubscript{AC} and uses average current mode control at a fixed programmable switching frequency of 120 kHz. The UCC28180 incorporates a wide range of protection features to ensure safe system operation.

2 Description
The UCC28180EVM-573 highlights the many benefits of using the UCC28180 Continuous Current Mode Boost PFC Controller (TI Literature Number SLUSBQ5). The controller operates under average current mode control at a fixed programmable switching frequency of 120 kHz. Simple external current and voltage loop compensation, along with advanced protection features, make this controller ideal for server and desktop power supplies, industrial power supplies, and white goods.

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 UCC28180 in a typical PFC application.

2.1 Typical Applications
The UCC28180EVM-573 is suited for use in high-power off-line systems that require high-efficiency and advanced fault protection features, applications including, but not limited to:
- Server and Desktop Power Supplies
- Industrial Power Supplies (DIN Rail)
- White Goods
  - A/C Units
  - Refrigerators
  - etc.
2.2 Features

The UCC28180EVM-573 features include:

- AC Input Range 85 V<sub>AC</sub> to 265 V<sub>AC</sub>
- 360-W, 390-V Output
- Average Current Mode PWM Control
- No AC Line Sensing Needed
- Fixed 120-kHz Oscillator frequency, Programmable With a Single External Resistor
- Soft Over Current and Cycle-by-Cycle Peak Current Limiting
- VCC Under Voltage Lockout With Low Start-Up Current
- Voltage Regulation Open Loop Detection
- Output Over-Voltage Protection With Hysteresis Recovery
- Enhanced Dynamic Response
- Soft-Start

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.
### 3 Electrical Performance Specifications

#### Table 1. UCC28180EVM-573 Performance Summary

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td>Input voltage</td>
<td>85</td>
<td>265</td>
<td></td>
<td>$V_{AC}$</td>
</tr>
<tr>
<td>$f_{LINE}$</td>
<td>Input frequency</td>
<td>47</td>
<td>63</td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td>$I_{IN(0\text{-load})}$</td>
<td>No load input current</td>
<td>$V_{IN} = V_{IN(max)}$, $f_{LINE} = 50$ Hz, $I_{OUT} = I_{OUT(max)}$</td>
<td>71</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{IN(max)}$</td>
<td>Peak input current</td>
<td>$V_{IN} = V_{IN(max)}$, $f_{LINE} = 60$ Hz, $I_{OUT} = I_{OUT(max)}$</td>
<td>6.8</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>Output Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td>Output voltage</td>
<td>$V_{IN(min)} \leq V_{IN} \leq V_{IN(max)}$, $f_{LINE(min)} \leq f_{LINE} \leq f_{LINE(max)}$, $I_{OUT(min)} \leq I_{OUT} \leq I_{OUT(max)}$</td>
<td>379</td>
<td>390</td>
<td>402</td>
</tr>
<tr>
<td>$I_{OUT}$</td>
<td>Output Load Current</td>
<td>$V_{IN} = 115$ VAC, $f_{LINE} = 60$ Hz, $I_{OUT(min)} \leq I_{OUT} \leq I_{OUT(max)}$</td>
<td>0</td>
<td>0.923</td>
<td></td>
</tr>
<tr>
<td>$P_{OUT}$</td>
<td>Output Power</td>
<td>$V_{IN(min)} \leq V_{IN} \leq V_{IN(max)}$, $f_{LINE(min)} \leq f_{LINE} \leq f_{LINE(max)}$</td>
<td>0</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>$V_{RIPPLE_{HF}}$</td>
<td>High frequency Output voltage ripple</td>
<td>$V_{IN} = 115$ VAC, $f_{LINE} = 60$ Hz, $I_{OUT} = I_{OUT(max)}$</td>
<td>3.9</td>
<td></td>
<td>$V_{p,p}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = 230$ VAC, $f_{LINE} = 50$ Hz, $I_{OUT} = I_{OUT(max)}$</td>
<td>3.9</td>
<td></td>
<td>$V_{p,p}$</td>
</tr>
<tr>
<td>$V_{RIPPLE_{LF}}$</td>
<td>Line frequency Output voltage ripple</td>
<td>$V_{IN} = 115$ VAC, $f_{LINE} = 60$ Hz, $I_{OUT} = I_{OUT(max)}$</td>
<td>19.5</td>
<td></td>
<td>$V_{p,p}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = 230$ VAC, $f_{LINE} = 50$ Hz, $I_{OUT} = I_{OUT(max)}$</td>
<td>19.5</td>
<td></td>
<td>$V_{p,p}$</td>
</tr>
<tr>
<td>$V_{OUT(OVP)}$</td>
<td>Output over voltage protection</td>
<td></td>
<td>425</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{OUT(UVP)}$</td>
<td>Output under voltage protection</td>
<td></td>
<td>370</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>PARAMETER</td>
<td>TEST CONDITION</td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
<td>UNIT</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td><strong>Control Loop Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f(_{SW})</td>
<td>Switching frequency</td>
<td>T(_J) = 25°C</td>
<td>114</td>
<td>120</td>
<td>126</td>
</tr>
<tr>
<td>f(_{CO})</td>
<td>Voltage Loop Bandwidth</td>
<td>V(_{IN}) = 162 VDC,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(_{OUT}) = 0.466 A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Voltage Loop Phase Margin</td>
<td>V(_{IN}) = 162 VDC,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(_{OUT}) = 0.466 A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF</td>
<td>Power Factor</td>
<td>V(_{IN}) = 115 VAC,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(<em>{OUT}) = I(</em>{OUT\text{(max)}})</td>
<td>0.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>THD</td>
<td>Total harmonic distortion</td>
<td>V(_{IN}) = 115 VAC,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(_{LINE}) = 60 Hz,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(<em>{OUT}) = I(</em>{OUT\text{(max)}})</td>
<td>4.1%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V(_{IN}) = 230 VAC,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(_{LINE}) = 50 Hz,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(<em>{OUT}) = I(</em>{OUT\text{(max)}})</td>
<td>4%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>η</td>
<td>Full load efficiency</td>
<td>V(_{IN}) = 115 VAC,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(_{LINE}) = 60 Hz,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I(<em>{OUT}) = I(</em>{OUT\text{(max)}})</td>
<td>94.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient temperature</td>
<td></td>
<td></td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. UCC28180EVM-573 Schematic
5 Test Setup

Figure 2 shows the basic test set up recommended in order to evaluate the UCC28180EVM-573

![Diagram of test setup]

Figure 2. UCC28180EVM-573 Recommended Test Set Up

WARNING

High voltages that may cause injury exist on this evaluation module (EVM). Please ensure all safety procedures are followed when working on this EVM. Never leave a powered EVM unattended.
5.1 Test Equipment

AC Voltage Source: The AC input source shall be capable of supplying between 85 V\(_{AC}\) and 265 V\(_{AC}\) 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. For accurate efficiency calculations, a power meter should be inserted between the neutral line of the AC source and the neutral terminal of the EVM. For highest accuracy, connect the voltage terminals of the power meter directly across the line and neutral terminals of the EVM.

12-V Bias Supply: The bias supply to the device shall be capable of supplying up to 12 V\(_{DC}\) at no less than 10 mA. Connect the bias supply to the – and + terminals of J2, UCC28180 12-V VCC bias, as shown in Figure 2.

Output Load: A programmable electronic load set to constant current mode and capable of sinking 0 to 1 A at 390 V\(_{DC}\) shall be used. Connect the load to J3, as shown in Figure 2.

Power Meter: For highest accuracy, power analyzer shall be used to measure the input power, THD, and power factor. An example of such an analyzer is the Voltech PM100 Single Phase Power Analyzer.

Multimeters: For highest accuracy, the output voltage of the UCC28180EVM-573 shall be monitored by connecting a digital voltmeter, V1, directly across TP11 and TP12 with the positive terminal at TP11 and the negative terminal at TP12. A DC current meter, A1, should be placed in series with the electronic load for accurate output current measurements.

Oscilloscope: A digital or analog oscilloscope with 500-MHz scope probes is recommended.

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 UCC28180EVM-573. Position the fan so as to blow along the length of the heatsink as shown in Figure 2.

Recommended Wire Gauge: 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).

5.2 List of Test Points

<table>
<thead>
<tr>
<th>TEST POINT</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>PGND</td>
<td>Power ground</td>
</tr>
<tr>
<td>TP2</td>
<td>ICOMP</td>
<td>UCC28180 pin 2</td>
</tr>
<tr>
<td>TP3</td>
<td>ISENSE</td>
<td>UCC28180 pin 3</td>
</tr>
<tr>
<td>TP4</td>
<td>VCC</td>
<td>UCC28180 pin 7</td>
</tr>
<tr>
<td>TP5</td>
<td>GATE</td>
<td>UCC28180 pin 8</td>
</tr>
<tr>
<td>TP6</td>
<td>VSENSE</td>
<td>UCC28180 pin 6</td>
</tr>
<tr>
<td>TP7</td>
<td>SW</td>
<td>Switch node, MOSFET drain</td>
</tr>
<tr>
<td>TP8</td>
<td>VCOMP</td>
<td>UCC28180 pin 5</td>
</tr>
<tr>
<td>TP9</td>
<td>+ LOOP</td>
<td>Loop injection point, EVM output</td>
</tr>
<tr>
<td>TP10</td>
<td>- LOOP</td>
<td>Loop injection point</td>
</tr>
<tr>
<td>TP11</td>
<td>+VOUT</td>
<td>Positive output terminal of the EVM to the load</td>
</tr>
<tr>
<td>TP12</td>
<td>-VOUT</td>
<td>Return connection of the EVM output to the load</td>
</tr>
</tbody>
</table>
5.3 **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 V_{DC}.

**WARNING**

There are very high voltages present on the EVM. Some components reach temperatures above 50°C. Precautions must be taken when handling the board. Never operate the UCC28180EVM-573 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. If testing with a load, set the electronic load to constant resistance mode.

2. Power-Up
   (a) Connect the equipment as shown in Figure 2.
   (b) Turn on the fan.
   (c) Set the AC source voltage between 85 V_{AC} and 265 V_{AC}.
   (d) Turn on the 12-V bias supply and verify that the output of the module is within regulation.
   (e) Increase the load from 0 A up to 0.923 A.

5.4 **Line/Load Regulation and Efficiency Measurement Procedure**

1. For load regulation, use the test set up shown in Figure 2.
   (a) Set the AC source to a constant voltage between 85 V_{AC} and 265 V_{AC}.
   (b) Vary the load so that the output current varies from 0 A up to 0.923 A, as measured on DMM A1.
   (c) Observe that the output voltage on DMM V1 remains within 5% of the full load regulation value.

2. For line regulation, use the test set up shown in Figure 2.
   (a) Set the load to sink the full-load current, 0.923 A.
   (b) Vary the AC source from 85 V_{AC} to 265 V_{AC}.
   (c) Observe that the output voltage on DMM V1 stays within 5% of the output voltage regulation value.

5.5 **Output Voltage Ripple**

1. Expose the ground barrel of the scope probe and place the tip of the probe on TP11, +VOUT, and rest the exposed ground barrel of the probe on TP12, -VOUT, for output voltage ripple measurements.

5.6 **Equipment Shutdown**

1. To quickly discharge the output capacitors, make sure there is a load greater than 0 A on the EVM.
2. Turn off the AC source.
3. Turn off the Bias source.
6 Performance Data and Typical Characteristic Curves

Figure 3 through Figure 21 present typical performance curves for UCC28180EVM-573.

6.1 Efficiency

Figure 3. UCC28180EVM-573 Efficiency
(as a function of line voltage and load current)

6.2 Power Factor

Figure 4. UCC28180EVM-573 Power Factor
(as a function of line voltage and load current)
6.3 Total Harmonic Distortion

Figure 5 shows the measured total harmonic distortion (THD). This design allows the converter to enter into discontinuous current mode (DCM) at the higher line voltages which impacts THD. The converter still meets the design goal of less than 10% THD at full load over the entire input line range despite using a relatively small inductor that allows 40% inductor ripple current.

![Figure 5. UCC28180EVM-573 Total harmonic Distortion (as a function of line voltage and load current)](image)

Figure 6 demonstrates improved THD by doubling inductance (20% ripple).

![Figure 6. Total Harmonic Distortion with 2x Inductance](image)
Using swinging inductors which exhibit higher inductance value at lower magnetization (lowest current) can also help to achieve low THD. Figure 7 shows the total harmonic distortion resulting from using a current of 6.4 A (switching frequency = 18 kHz). The total harmonic distortion measures less than 5% from 50% load to full load under these conditions.

Figure 7. Total harmonic distortion (as a function of line voltage and load current) with L = 3.4 mH and fSW = 18 kHz

Figure 8 shows the total harmonic distortion resulting from a swinging choke that measured 530 µH at a current of 6.4 A (switching frequency = 66 kHz). The total harmonic distortion measures less than 5% from 50% load to full load under these conditions.

Figure 8. Total harmonic distortion (as a function of line voltage and load current) with L = 0.4 mH and fSW = 66 kHz
6.4 Current Harmonics

Figure 9. UCC28180EVM-573 Current Harmonics, (230-V<sub>AC</sub>, 50-Hz input, full load, without the fundamental)

Figure 10. UCC28180EVM-573 Current Harmonics, (115-V<sub>AC</sub>, 60-Hz input, full load, without the fundamental)
6.5 Input Current

Figure 11. UCC28180EVM-573 Input Current and Input Voltage at the Output of the Bridge Rectifier, (115-V_{AC}, 60 Hz, full load. (CH 1 = rectified input voltage on BR1, 100 V/div., CH 3 = I_{IN} 2 A/div.))

Figure 12. UCC28180EVM-573 Input Current and Input Voltage at the Output of the Bridge Rectifier, (230 V_{AC}, 50 Hz, full load. (CH 1 = rectified input voltage on BR1, 100 V/div., CH 3 = I_{IN} 1 A/div.))
6.6 Output Voltage Ripple

Figure 13. UCC28180EVM-573 Line Frequency Output Voltage Ripple
(115 V\textsubscript{AC}, 60 Hz input, full load)

Figure 14. UCC28180EVM-573 Line Frequency Output Voltage Ripple
(230 V\textsubscript{AC}, 50 Hz input, full load)
Figure 15. UCC28180EVM-573 Switching Frequency Output Voltage Ripple (115 V<sub>AC</sub>, 60 Hz input, full load)

Figure 16. UCC28180EVM-573 Switching Frequency Output Voltage Ripple (230 V<sub>AC</sub>, 50 Hz input, full load)
6.7 Start Up

Figure 17. UCC28180EVM-573 Start-Up Waveform
(115-V_{AC}, 60-Hz input, full load, CH 1 = V_{SENSE} at 2 V/div, CH 2 = V_{OUT} at 100 V/div., offset by 150 V, CH 3 = I_{IN} at 5 A/div., CH 4 = V_{COMP} at 2 V/div.)

Figure 18. UCC28180EVM-573 Start-Up Waveform
(230-V_{AC}, 50-Hz input, full load, CH 1 = V_{SENSE} at 2 V/div, CH 2 = V_{OUT} at 50 V/div., offset by 300 V, CH 3 = I_{IN} at 5 A/div., CH 4 = V_{COMP} at 2 V/div.)
6.8 Load Transient

Figure 19. Load Transient
(115 -V\textsubscript{AC}, 60-Hz, load step: 0% to 100%. Ch 2 = V\textsubscript{OUT} at 20 V/div., offset by 386 V, Ch.4 = V\textsubscript{COMP} at 2 V/div)
6.9 **Bode Plot**

The gain, phase bode plots were measured with an AP Instruments Inc. Model 200 analog network analyzer. The loop result was obtained by inserting a 1.77-V AC signal across TP9 and TP10. A DC input equal to the peak of the RMS input was used.

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**Figure 20.** UCC28180EVM-573 Voltage Loop Response Gain and Phase, (311-V\text{DC}, full load, f_{CO} = 10.7-Hz, phase margin = 68 degrees)

**Figure 21.** UCC28180EVM-573 Voltage Loop Response Gain and Phase, (162-V\text{DC}, full load, f_{CO} = 8.6-Hz, phase margin = 63 degrees)
7 **EVM Assembly Drawing and PCB Layout**

The following figures (Figure 22 through Figure 25) show the design of the UCC28180EVM-573 printed circuit board.

**Figure 22.** UCC28180EVM-573 Top Layer Assembly Drawing (top view)

**Figure 23.** UCC28180EVM-573 Bottom Layer Assembly Drawing (bottom view)
Figure 24. UCC28180EVM-573 Top Copper (top view)

Figure 25. UCC28180EVM-573 Bottom Copper (bottom view)
List of Materials

The EVM components list according to the schematic shown in Figure 1.

Table 3. UCC28180EVM-573 List of Materials

<table>
<thead>
<tr>
<th>QTY</th>
<th>REFDES</th>
<th>DESCRIPTION</th>
<th>MFR</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BR1</td>
<td>Diode, Switching-Bridge, 420 V, 8 A, TH</td>
<td>Micro Commercial Components</td>
<td>GBU8J-BP</td>
</tr>
<tr>
<td>2</td>
<td>C1, C5</td>
<td>Capacitor, film, 0.47 µF, 275 V, ±20%, radial, 25 x 8.5 x 18.5 mm</td>
<td>Panasonic</td>
<td>ECQ-U2A474ML</td>
</tr>
<tr>
<td>2</td>
<td>C2, C4</td>
<td>Capacitor, ceramic, 2200 pF, 250 V, ±20%, E, radial disc D10.5 x 7 mm</td>
<td>TDK</td>
<td>CS11-E2GA222MYNS</td>
</tr>
<tr>
<td>1</td>
<td>C3</td>
<td>Capacitor, aluminum, 47 µF, 35 V, ±20%, radial, 5 x 1mm</td>
<td>Panasonic</td>
<td>ECA-1VM470</td>
</tr>
<tr>
<td>0</td>
<td>C6</td>
<td>Capacitor, ceramic, 0.1 µF, 50 V, ±10%, X7R, 0603</td>
<td>AVX</td>
<td>0603SC104KAT2A</td>
</tr>
<tr>
<td>1</td>
<td>C7</td>
<td>Capacitor, ceramic, 2700 pF, 50 V, ±10%, X7R, 0603</td>
<td>MuRata</td>
<td>GRM188R71H272KA01D</td>
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<tr>
<td>1</td>
<td>C8</td>
<td>Capacitor, ceramic, 1000 pF, 100 V, ±10%, X7R, 0603</td>
<td>AVX</td>
<td>06031C102KAT2A</td>
</tr>
<tr>
<td>0</td>
<td>C9</td>
<td>Capacitor, ceramic, 0.68 µF, 10 V, ±10%, X5R, 0603</td>
<td>Kemet</td>
<td>C0603C684K8PAC</td>
</tr>
<tr>
<td>1</td>
<td>C10</td>
<td>Capacitor, FILM, 0.33 µF, 275 V, ±20%, radial, 17.5 x 17.5 x 9.5 mm</td>
<td>Panasonic</td>
<td>ECQ-U2A334ML</td>
</tr>
<tr>
<td>1</td>
<td>C11</td>
<td>Capacitor, ceramic, 1 µF, 50 V, ±10%, X7R, 1210</td>
<td>MuRata</td>
<td>GRM32RR71H105KA01L</td>
</tr>
<tr>
<td>1</td>
<td>C12</td>
<td>Capacitor, ceramic, 0.1 µF, 50 V, ±10%, X7R, 1206</td>
<td>AVX</td>
<td>1206SC104KAT2A</td>
</tr>
<tr>
<td>1</td>
<td>C13</td>
<td>Capacitor, ceramic, 4.7 µF, 10 V, ±10%, X7R, 0805</td>
<td>MuRata</td>
<td>GRM21BR71A475KA73L</td>
</tr>
<tr>
<td>1</td>
<td>C14</td>
<td>Capacitor, ceramic, 0.47 µF, 16 V, ±10%, X7R, 0603</td>
<td>Kemet</td>
<td>C0603C474K4RACTU</td>
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<tr>
<td>1</td>
<td>C15</td>
<td>Capacitor, ceramic, 820 pF, 50 V, ±10%, X7R, 0603</td>
<td>Kemet</td>
<td>C0603C821K5RACTU</td>
</tr>
<tr>
<td>1</td>
<td>C16</td>
<td>Capacitor, aluminum, 270 µF, 450 V, ±20%, 0.737 Ω, radial, 30 x 30 mm</td>
<td>Panasonic</td>
<td>EETUQ2W271DA</td>
</tr>
<tr>
<td>2</td>
<td>C17, C18</td>
<td>Capacitor, ceramic, 0.1 µF, 630 V, ±10%, X7R, 1812</td>
<td>MuRata</td>
<td>GRM43DR72J104KW01L</td>
</tr>
<tr>
<td>1</td>
<td>D1</td>
<td>Diode, Schottky, 40 V, 1 A, SOD-123FL</td>
<td>ON Semiconductor</td>
<td>MBR140SFT1G</td>
</tr>
<tr>
<td>1</td>
<td>D2</td>
<td>Diode, Switching, 600 V, 3 A, DO-201AD</td>
<td>Vishay-Semiconductor</td>
<td>1N5406</td>
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<td>1</td>
<td>D3</td>
<td>Diode, Schottky, 600 V, 4 A, TO-220-F2</td>
<td>Cree</td>
<td>C3D04060A</td>
</tr>
<tr>
<td>1</td>
<td>F1</td>
<td>Fuse, 8 A, 250 V, 20 x 5.2 mm</td>
<td>Littelfuse</td>
<td>0216008.MXESPP</td>
</tr>
<tr>
<td>3</td>
<td>H9, H10, H11</td>
<td>Max clip</td>
<td>Aavid Thermalloy</td>
<td>MAX01NG</td>
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<tr>
<td>1</td>
<td>HS1</td>
<td>Heatsink vertical max clip, black, 4.25 inches</td>
<td>Aavid</td>
<td>782653B04250G</td>
</tr>
<tr>
<td>1</td>
<td>J1</td>
<td>Terminal block, 5.08 mm, vertical 3 pos</td>
<td>On-Shore Technology</td>
<td>ED120/3DS</td>
</tr>
<tr>
<td>1</td>
<td>J2</td>
<td>Terminal block, 5.08 mm, vertical, 2 pos</td>
<td>On-Shore Technology</td>
<td>ED120/2DS</td>
</tr>
<tr>
<td>1</td>
<td>J3</td>
<td>Terminal block, 5.08 mm, vertical, 4 pos, TH</td>
<td>On-Shore Technology</td>
<td>ED120/4DS</td>
</tr>
<tr>
<td>1</td>
<td>JP1</td>
<td>Jumper wire, 200 mil spacing, red</td>
<td>3M</td>
<td>923345-02-C</td>
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<tr>
<td>1</td>
<td>L1</td>
<td>Coupled inductor, 5 mH, 0.022 A, 0.022 Ω, 1450 x 1500 x 800 mil</td>
<td>Bourns</td>
<td>8113-RC</td>
</tr>
<tr>
<td>1</td>
<td>L2</td>
<td>Inductor, toroid, ferrite, 327 µH, 0.065 Ω, 1380 x 1310 x 880 mil</td>
<td>Nova Magnetics</td>
<td>7840-09-0014</td>
</tr>
<tr>
<td>1</td>
<td>Q1</td>
<td>MOSFET, N-channel, 650 V, 20.7 A, TO-220AB</td>
<td>Infineon Technologies</td>
<td>SPP20N60C3</td>
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### Table 3. UCC28180EVM-573 List of Materials (continued)

<table>
<thead>
<tr>
<th>QTY</th>
<th>REFDES</th>
<th>DESCRIPTION</th>
<th>MFR</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>R1</td>
<td>Resistor, 100 Ω, ±1%, 0.1 W, 0603</td>
<td>Vishay-Dale</td>
<td>CRCW0603100RFKEA</td>
</tr>
<tr>
<td>1</td>
<td>R2</td>
<td>Resistor, 221 Ω, 1%, 0.1 W, 0603</td>
<td>Vishay-Dale</td>
<td>CRCW0603221RFKEA</td>
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<tr>
<td>1</td>
<td>R3</td>
<td>Resistor, 17.8 kΩ, ±1%, 0.1 W, 0603</td>
<td>Vishay-Dale</td>
<td>CRCW060317K8FKEA</td>
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<td>1</td>
<td>R4</td>
<td>Resistor, 0.032 Ω, ±1%, 2 W, 2512</td>
<td>Vishay-Dale</td>
<td>WSL2512R0320FEA18</td>
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<tr>
<td>1</td>
<td>R5</td>
<td>Resistor, 3.3 Ω, 0.5%, 0.1 W, 1210</td>
<td>Panasonic</td>
<td>ERJ-P14J3R3U</td>
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<tr>
<td>1</td>
<td>R6</td>
<td>Resistor, 22.6 kΩ, ±1%, 0.1 W, 0603</td>
<td>Vishay-Dale</td>
<td>CRCW060322K6FKEA</td>
</tr>
<tr>
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<td>R7</td>
<td>Resistor, 10.0 kΩ, ±1%, 0.1 W, 0603</td>
<td>Vishay-Dale</td>
<td>CRCW060310K0FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R8</td>
<td>Resistor, 49.9 Ω, ±1%, 0.25 W, 1206</td>
<td>Vishay-Dale</td>
<td>CRCW120649R9FKEA</td>
</tr>
<tr>
<td>2</td>
<td>R9, R10</td>
<td>Resistor, 332 kΩ, ±1%, 0.125 W, 0805</td>
<td>Vishay-Dale</td>
<td>CRCW0805332KFKEA</td>
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<tr>
<td>1</td>
<td>R11</td>
<td>Resistor, 340 kΩ, ±1%, 0.125 W, 0805</td>
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<td>CRCW0805340KFKEA</td>
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<td>R12</td>
<td>Resistor, 0 Ω, ±5%, 0.25 W, 1206</td>
<td>Vishay-Dale</td>
<td>CRCW12060000Z0EA</td>
</tr>
<tr>
<td>1</td>
<td>R13</td>
<td>Resistor, 13.0 kΩ, ±1%, 0.1 W, 0603</td>
<td>Vishay-Dale</td>
<td>CRCW060313K3FKEA</td>
</tr>
<tr>
<td>1</td>
<td>RT1</td>
<td>Thermistor NTC, 5 Ω, ±25%, Disc, 220 x 770 mil</td>
<td>GE Sensing</td>
<td>CL-40</td>
</tr>
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<td>SIL1, SIL2</td>
<td>Silicon thermal pad</td>
<td>Bergquist Company</td>
<td>Q3-0.005-00-58</td>
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<td>Silicon thermal pad</td>
<td>Bergquist Company</td>
<td>SP900S-0.009-00-114</td>
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<td>TP1, TP12</td>
<td>Test point, multipurpose, black, TH</td>
<td>Keystone</td>
<td>5011</td>
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<tr>
<td>8</td>
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<td>Test point, multipurpose, white, TH</td>
<td>Keystone</td>
<td>5012</td>
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<tr>
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<td>TP4, TP11</td>
<td>Test point, multipurpose, red, TH</td>
<td>Keystone</td>
<td>5010</td>
</tr>
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<td>1</td>
<td>U1</td>
<td>8-Pin Continuous Conduction Mode (CCM) PFC Controller, SOIC-8</td>
<td>Texas Instruments</td>
<td>UCC28180D</td>
</tr>
<tr>
<td>1</td>
<td>VAR1</td>
<td>Varistor, 275 V_{RMS}, 10 mm, radial, 10 mm</td>
<td>EPCOS Inc</td>
<td>S10K275E2</td>
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</table>

### Revision History

**Changes from Original (October 2013) to A Revision**

- Changed 39-V regulated output to 390-V regulated output. ................................................................. 2
- Added Figure 7. ................................................................................................................................. 12
- Added Figure 8. ................................................................................................................................. 12
- Changed CH2 to Ch3. ......................................................................................................................... 14
- Changed Ch2 to CH3. .......................................................................................................................... 14
- Changed R13 resistor value from 13.3 kΩ to 13.0 kΩ. ......................................................................... 23

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from A Revision (November 2013) to B Revision**

- Changed Performance data and typical characteristic curve images. ..................................................... 10

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.
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User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user’s sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
FCC Interference Statement for Class B EVM devices
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

• Reorient or relocate the receiving antenna.
• Increase the separation between the equipment and receiver.
• Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
• Consult the dealer or an experienced radio/TV technician for help.

For EVMs annotated as IC – INDUSTRY CANADA Compliant
This Class A or B digital apparatus complies with Canadian ICES-003.
Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

Concerning EVMs including radio transmitters
This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas
Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.
Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l’autorité de l’utilisateur pour actionner l’équipement.

Concernant les EVMs avec appareils radio
Le présent appareil est conforme aux CNR d’Industrie Canada applicables aux appareils radio exempts de licence. L’exploitation est autorisée aux deux conditions suivantes : (1) l’appareil ne doit pas produire de brouillage, et (2) l’utilisateur de l’appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d’en compromettre le fonctionnement.

Concernant les EVMs avec antennes détaillables
Conformément à la réglementation d’Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d’un type et d’un gain maximal (ou inférieur) approuvé pour l’émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l’intention des autres utilisateurs, il faut choisir le type d’antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l’intensité nécessaire à l’établissement d’une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d’antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l’impédance requise pour chaque type d’antenne. Les types d’antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l’exploitation de l’émetteur.
【Important Notice for Users of EVMs for RF Products in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.

2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.

3. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.

4. You will take care of proper disposal and recycling of the EVM’s electronic components and packing materials.

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