Measuring an RTD Sensor with the TDC1000 and TDC7200 for Ultrasonic Sensing

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ABSTRACT

This application note describes the firmware procedure for measuring temperature via two RTD's using the TDC1000 and TDC7200. Temperature is monitored in heat meters and flow meters.

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1 Objective

The objective of this application note is to describe a firmware method for monitoring two RTD's for a heat meter application.

2 Background

Resistance Temperature Detectors (RTD), measure temperature by relating the resistance of the RTD element with temperature. Typically, an RTD consists of a length of fine coiled wire wrapped around a ceramic or glass core, placed inside a protective housing. The resistance of the element of the RTD is provided at various temperatures. The element acts as a temperature sensor because with the change of temperature, the material changes resistance in a predictable manner.

RTDs are characterized by a linear positive change in resistance with respect to temperature. They exhibit the most linear signal with respect to temperature of any electronic sensing device. Platinum is the most widely specified RTD element type due to its wide temperature range, accuracy, stability, as well as the degree of standardization among manufacturers. Nickel, copper, and nickel-iron alloys are also used.

RTDs are often characterized by their base resistance at 0°C. Typical base resistance values available for platinum thin-film RTDs include 100 Ω, 500 Ω and 1000 Ω. For other element types, typical base values include 120 Ω for nickel, and 1000 Ω and 2000 Ω for nickel-iron.

3 TDC1000 Embedded RTD Interface Circuit

TDC1000’s embedded interface block supports two external RTD sensors as shown in Figure 1.

The temperature sensor block supports PT1000 or PT500 sensors. The System requires a temperature-stable external reference resistor (R REF). If the RTD type is PT500, then RREF should be 500 Ω. In case a PT1000 sensor is used, the RREF should be 1000 Ω. The reference resistor needs to have a low temperature coefficient.

Figure 1. Temperature Sensor Interface

The temperature sensor block supports PT1000 or PT500 sensors. The System requires a temperature-stable external reference resistor (R REF). If the RTD type is PT500, then RREF should be 500 Ω. In case a PT1000 sensor is used, the RREF should be 1000 Ω. The reference resistor needs to have a low temperature coefficient.
4 Temperature Measurement with Multiple RTDs

The temperature sensor measurement can be performed without the need of an external ADC. The temperature sensor block operates by converting the resistance of a reference, RREF, and up to two RTDs into a series of START and STOP pulses. The interval between the pulses is proportional to the measured resistance, and therefore, the temperature. As shown in Figure 2, the TDC1000 performs three measurements per trigger event and generates the corresponding pulses on the START and STOP pins.

![Figure 2. Timing Sequence for Temperature Measurements](image)

5 RTD1 Temperature Measurement

In the temperature measurement mode only, short duration pulses can occur after the 2nd and 4th Stop pulses. These pulses can be detected by TDC7200 and result in invalid temperature measurement.

6 Software Solution

The solution to eliminate the effect of the short duration pulses is summarized as follows:

6.1 Solution for Measuring REF Resistor and RTD1

- Measure START to STOP1 for REF resistor value
- Measure START to STOP2, STOP3 (if it exists), and STOP4
- Discard START to STOP3 if too close in time to STOP2
- Subtract START to STOP2 from START to STOP4 for RTD1 value

![Figure 3. Timing Sequence for RTD1](image)
### Table 1. RTD1 TDC Clock Counts

<table>
<thead>
<tr>
<th>Time 1</th>
<th>CLKcount1</th>
<th>Time2</th>
<th>CLKcount2</th>
<th>Time3</th>
<th>CLKcount3</th>
<th>Time 4</th>
<th>CLKcount4</th>
<th>Time 5</th>
<th>CLKcount5</th>
<th>Time 6</th>
<th>CAL1</th>
<th>CAL2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example RTD1 calculation based on Data1</td>
<td>2320</td>
<td>1611</td>
<td>298</td>
<td>2768</td>
<td>807</td>
<td>2822</td>
<td>2210</td>
<td>4120</td>
<td>1581</td>
<td>5224</td>
<td>1127</td>
<td>2269</td>
</tr>
<tr>
<td>Example RTD1 calculation based on Data2</td>
<td>1544</td>
<td>1612</td>
<td>2342</td>
<td>2768</td>
<td>1543</td>
<td>4119</td>
<td>191</td>
<td>5224</td>
<td>1242</td>
<td>6485</td>
<td>1493</td>
<td>2268</td>
</tr>
</tbody>
</table>

### Table 2. RTD1 Conversion Results

<table>
<thead>
<tr>
<th>calCount</th>
<th>normLSB</th>
<th>Start-Stop1 (ns)</th>
<th>Start-Stop2 (ns)</th>
<th>Start-Stop3 (ns)</th>
<th>Start-Stop4 (ns)</th>
<th>Start-Stop5 (ns)</th>
<th>stop2 to stop3 (ns)</th>
<th>stop2 to stop4 (ns)</th>
<th>RTD1 (°C)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2270</td>
<td>0.055066079</td>
<td>201486.3436</td>
<td>346083.315</td>
<td>352756.0573</td>
<td>515040.6938</td>
<td>653065.6938</td>
<td>6672.742291</td>
<td>168957.3789</td>
<td>50.05718539</td>
<td>Note: If (stop2 to stop3 (ns) &lt; 20000), use (stop2 to stop4 (ns)). Else: use (stop2 to stop3 (ns)) in RTD1 calculation.</td>
</tr>
<tr>
<td>2269.666667</td>
<td>0.055074167</td>
<td>201456.0508</td>
<td>346000.0551</td>
<td>514949.5153</td>
<td>653016.6324</td>
<td>2.808782494</td>
<td>168949.4603</td>
<td>307016.5773</td>
<td>50.02509938</td>
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6.2 **RTD2 Temperature Measurement**

This procedure deviates from the steps to measure RTD1 because the TDC7200 can only measure START to STOP for the first 5 STOP pulses (including short duration pulses).

6.2.1 **Solution for Measuring REF Resistor and RTD2**

- Use the blanking feature of the TDC7200 to skip measuring the first three STOP pulses. Use information from first START to STOP2 to set the appropriate amount of blanking. A STOP mask period of 400 us (program stop mask register to 0x0C80 for 8 MHz clock) is used in the EVM GUI software.
- Next measure START to STOP1, STOP2, STOP3 (if exists) and Stop 4
- Discard START to STOP3 if too close in time to STOP2
- Subtract START to STOP2 from START to STOP4 for RTD value

![Figure 4. Timing Sequence for RTD2](image-url)
### Table 3. RTD2 TDC Clock Counts

<table>
<thead>
<tr>
<th>Time</th>
<th>CLKcount1</th>
<th>Time2</th>
<th>CLKcount2</th>
<th>Time3</th>
<th>CLKcount3</th>
<th>Time4</th>
<th>CLKcount4</th>
<th>Time5</th>
<th>CLKcount5</th>
<th>Time6</th>
<th>CAL1</th>
<th>CAL2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Example RTD2 calculation based on one shot TOF Measurement Result</td>
<td>606</td>
<td>4120</td>
<td>1980</td>
<td>5224</td>
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<td>1585</td>
<td>6485</td>
<td>819</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 4. RTD2 Conversion Results

<table>
<thead>
<tr>
<th>calCount</th>
<th>normLSB</th>
<th>Start-Stop1 (ns)</th>
<th>Start-Stop2 (ns)</th>
<th>Start_stop3 (ns)</th>
<th>Start_Stop4 (ns)</th>
<th>stop2 to stop3 (ns)</th>
<th>stop2 to stop4 (ns)</th>
<th>RTD1 (°C)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2269.77778</td>
<td>0.0550071471</td>
<td>514924.3318</td>
<td>653021.3127</td>
<td>659696.085</td>
<td>810613.2698</td>
<td>0</td>
<td>6674.772371</td>
<td>157591.9571</td>
<td>72.36831479 Note: If (stop2 to stop3 (ns) &lt; 20000), use (stop2 to stop4 (ns)); Else: use (stop2 to stop3 (ns)) in RTD2 calculation.</td>
</tr>
</tbody>
</table>

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