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 senor 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.

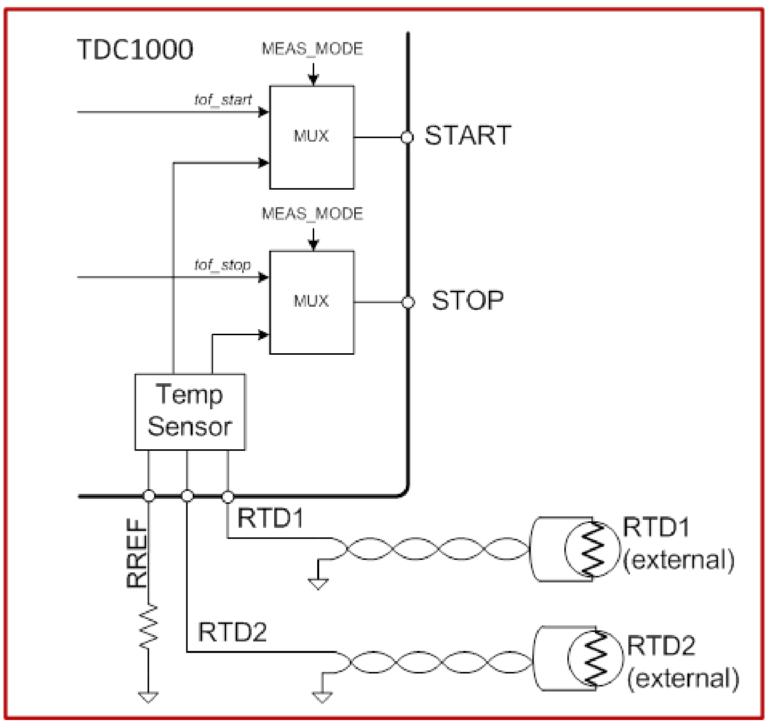

Figure 1. Temperature Sensor Interface

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.

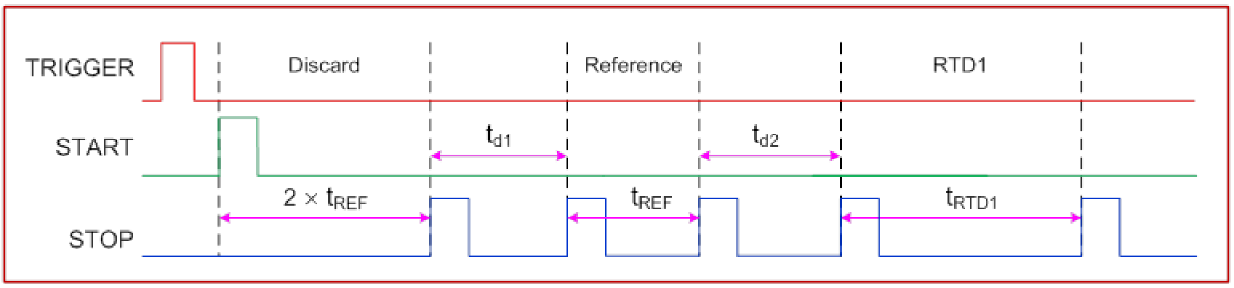

Figure 2. Timing Sequence for Temperature Measurements

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

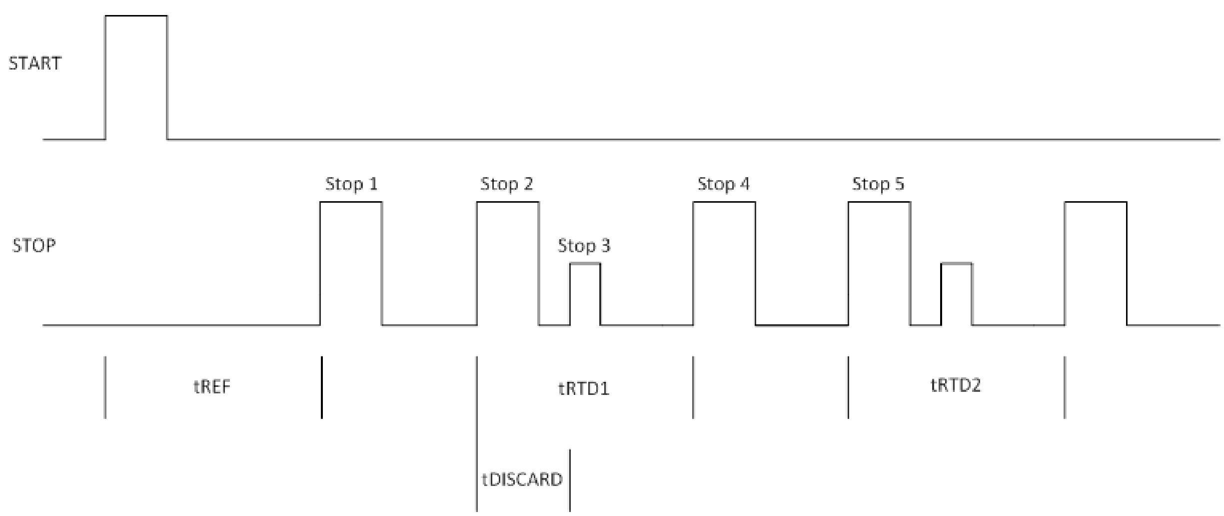

Figure 3. Timing Sequence for RTD1

Table 1. RTD1 TDC Clock Counts

	Time 1	CLKcount1	Time2	CLCKcount2	Time3	CLKcount3	Time 4	CLKcount4	Time 5	CLKCount5	Time6	CAL1	CAL2
Example RTD1 calculation based on Data1	2320	1611	298	2768	807	2822	2210	4120	1581	5224	1127	2269	22699
Example RTD1 calculation based on Data2	1544	1612	2342	2768	1543	4119	191	5224	1242	6485	1493	2268	22695

Table 2. RTD1 Conversion Results

calCount	normLSB	Start-Stop1(ns)	Start-Stop2 (ns)	Start-Stop3 (ns)	Start-Stop4 (ns)	Start-Stop5 (ns)	stop2 to stop3 (ns)	stop2 to stop4 (ns)	RTD1 (°C)	Remarks
2270	0.055066079	201486.3436	346083.315	352756.0573	515040.6938	653065.6938	6672.742291	168957.3789	50.05718539	Note: If (stop2 to stop3 (ns) < 20000), use (stop2 to stop4 (ns)). Else: use (stop2 to stop3 (ns)) in RTD1 calculation.
2269.666667	0.055074167	201456.0508	346000.0551	514949.5153	653016.6324	2.808782494	168949.4603	307016.5773	50.02509938	

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

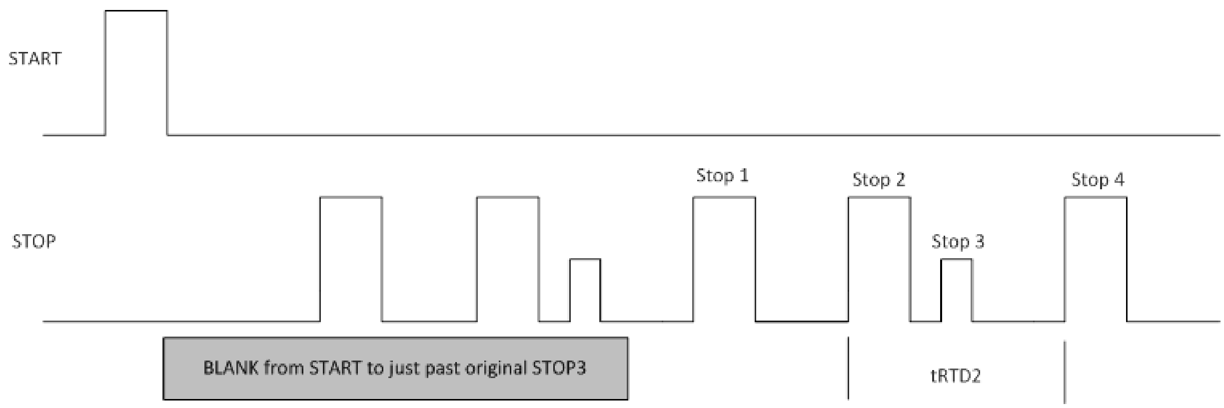

Figure 4. Timing Sequence for RTD2

Table 3. RTD2 TDC Clock Counts

	Time 1	CLKcount1	Time2	CLKcount2	Time3	CLKcount3	Time4	CLKcount4	Time5	CLKcount5	Time6	CAL1	CAL2
Example RTD2 calculation based on one shot TOF Measurement Result	606	4120	1980	5224	219	5278	1585	6485	819	0	0	2268	22696

Table 4. RTD2 Conversion Results

calCount	normLSB	Start-Stop1 (ns)	Start-Stop2 (ns)	Start_stop3 (ns)	Start_Stop4 (ns)	Start-Stop5 (ns)	stop2 to stop3 (ns)	stop2 to stop4 (ns)	RTD1 (°C)	REMARKS
2269.777778	0.0550071471	514924.3318	653021.3127	659696.085	810613.2698	0	6674.772371	157591.9571	72.36831479	Note: If (stop2 to stop3 (ns) < 20000), use (stop2 to stop4 (ns)). Else: use (stop2 to stop3 (ns)) in RTD2 calculation.