RTD Measurement Details

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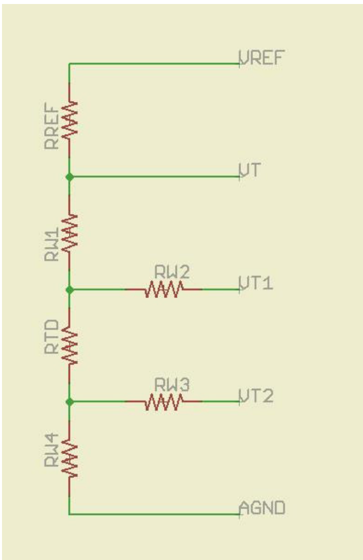
The full circuit for a four wire RTD is shown in the following figure. The specifics are:



1. VREF is an excitation voltage is provided to the circuit.
2. RREF is a reference resistor used in determining the amount of current passing through the RTD.
3. RW1, RW2, RW3, and RW4 are wiring resistances connecting the RTD to the measuring circuit.
4. RTD is the resistance used to measure the temperature.

In cases where a three wire RTD is used, RW3 and the corresponding voltage at VT2 are absent.

In passing a known current through the circuit, it can be seen that the only way to accurately measure the value of RTD is to measure the voltage between VT1 and VT2. As long as the amount of current passing through RW2 and RW3 is small enough that the voltage drop across them can be neglected, then the value of RTD can be determined from Ohms law. This leads to the first assumption:

Assumption 1: The current drawn by the measuring circuit must be small. This assumption is valid in that the input current of most ADC circuits is less than 3nA. If the excitation current through the RTD is 1mA, this is six orders of magnitude less and thus be safely ignored.

The, if the value of RREF is known, the values of (VT1 - VT2), the voltage across the RTD, and (VREF – VT), the voltage across the re reference resistor can be used to determine the value of RTD with the relationship:

$$RTD = RREF \times \frac{VT1 - VT2}{VREF - VT}$$

The problem with the four wire RTD is that if it is referenced to ground, the value of VT2 will be quite low. Many measuring circuits do not perform well when one input is close to ground. So you will see many circuits where a bias resistor is used to shift this reference. This is acceptable in cases where the circuit is excited by a constant current source in stead of a simple RREF. Another way is to remove the VT2 connection and move to three wire circuit. The logic behind this requires the second assumption.

Assumption 2: The wires connecting the RTD are all have the same characteristics. That is, they are made of the same material and same size – diameter and length. This means that all of RW1, RW2, RW3, and RW4 have the same resistance and temperature coefficients. (In the following discussion, this referenced as just RW.)

For a three wire RTD, the measurement circuit has access to three voltages referenced to AGND (VREF, VT, and VT1). In this case, the voltage across the RTD is not known directly. The voltage across RW is determined by (VT – VT1). Then, using assumption 2, the voltage across the RTD can be expressed as:

VT1 – (VT – VT1) or (2 * VT1 – VT).

Then the relationship for the RTD value becomes:

$$RTD = RREF \times \frac{2 \times VT1 - VT}{VREF - VT}$$

All of these values are known and thus we can determine the value of the resistance without the need for the fourth wire. It is easy to set up a simple spreadsheet to verify that this works for various values of resistances. It is important that assumption 2 be valid.

If we take this one step further and express the voltages as a fraction of VREF, then when read by an ADC, the other voltages become a number from 0 to the full scale reading. Then the resistance can be determined from the value of the reference resistor and a ratio of differences of the ADC readings. Note that the value for (VREF – VT) is merely the reading for VT subtracted from the full scale value.

For this to work for a single RTD, the important criteria are that the ADC have two single ended inputs with a true ground reference and that the ADC support an external reference that is the same source as is driving the RTD bridge. Extending this to measure three RTDs only requires six single ended inputs to the ADC.

In the case of a part like the ADS1243 where there are eight inputs and these can be configured in various differential forms, we can tie one input to ground. Selecting any other input and pairing it with this makes it operate like a single ended input.

There may be other parts with this level of resolution that would work. The only reason I can see for wanting to have more than one ADC is to handle various failure modes. In that case, I would recommend that each RTD have its own ADC, but then we must ask about the failure of the central microprocessor and this reason is no longer valid. For reasons of cost (parts, board space, and programming effort), I would recommend the use of a single ADC.