

ECE480 Design Team 5

Using effective signal conditioning for Resistive Temperature Detectors

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1. Introduction

Resistance Temperature Detectors (RTDs) is a particular type of temperature sensor that uses alterations of electrical resistance that correlate to the temperature coefficient of metal inside. As temperature increases around the sensor, the resistance increases linearly. These sensors are known to be very accurate over a wider range of temperatures and are manufactured in two basic forms, thin film devices or thin film devices. These advantages come at a cost, however. RTD's require additional circuitry not only to be able to function, but to remove the error attributed to the leads that connect to the sensor. These sensors are resistive devices that require an excitation current to create a voltage drop, and conditioning for lead wire resistance. The following information and figure portrays the linearity between resistance and temperature over a wide range of values based off of the ITS-90 standard values.

- A 100Ω RTD's resistance as a function of temperature:
 - $RTD(T) = 100\Omega * (1 + AT + BT^2 + CT^3 * (T - 100))$
 - Where
 - $A = 3.9083 * 10^{-3}$
 - $B = -5.775 * 10^{-7}$
 - $C = -4.183 * 10^{-12}$

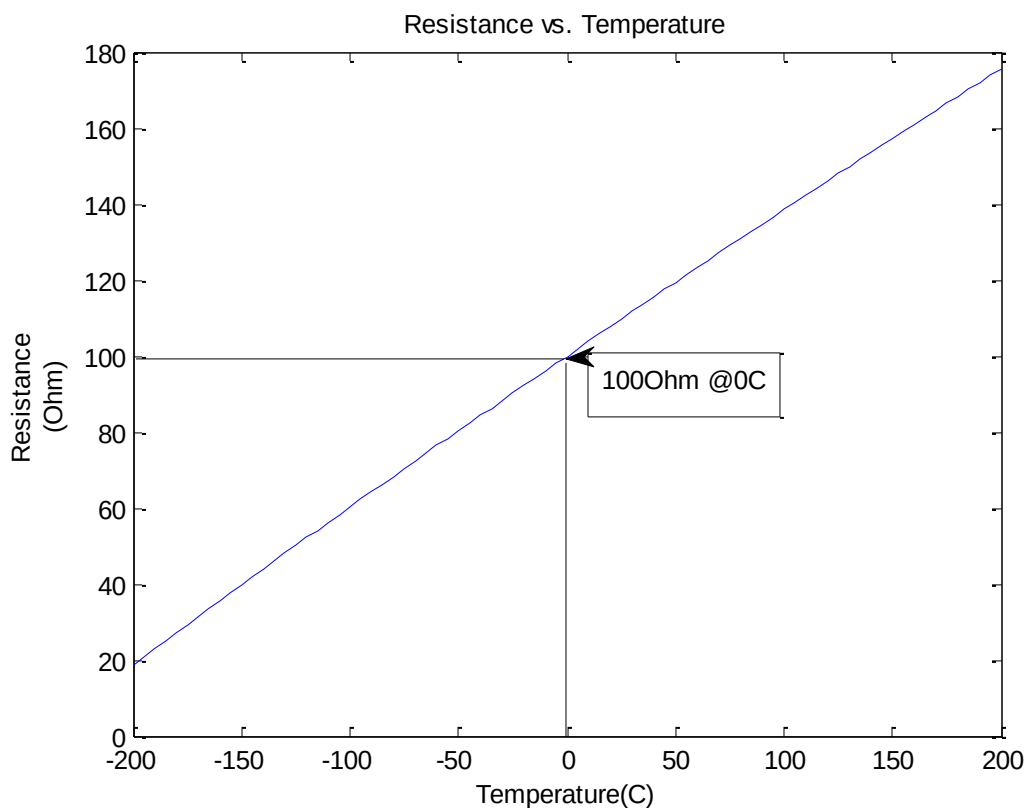


Figure 1: Matlab representation of a 100Ω RTD's resistance vs. temperature

2. Proper Excitation Current

As mentioned earlier, it is imperative to create an excitation current for any RTD sensor. Since RTD's relay the resistance measurements based off of a change in temperature, there need to be a current passing through to create a voltage drop. This voltage drop is the measurement that will be used to determine the temperature. However, if the excitation current is too high the power dissipated across the resistor will increase ($P_{dis} = I_{ex}^2 / R_{RTD}$), resulting in heat that will give false readings. Based off the equation $V_{out} = (R_{RTD}) * (I_{ex})$ and using a 100Ω sensor, one needs to find an acceptable excitation current that will produce a readable output voltage while not creating too much internal heating. One milliamp or less, for a 100Ω sensor, will keep the heat from causing critical error and still give enough output voltage to amplify. Figure 2, shows how error exponentially increases as the excitation current increases.

- $\Delta T =$ change in temperature (error)
- $\theta = 0.2 \frac{C}{mW}$, self-heating coefficient for CHS-GSS Humidity Sensor
- $P_{dis} = \left(\frac{I^2}{R}\right)$, power dissipated through resistor with varying excitation current
 - $\Delta T = P_{dis} * \theta$

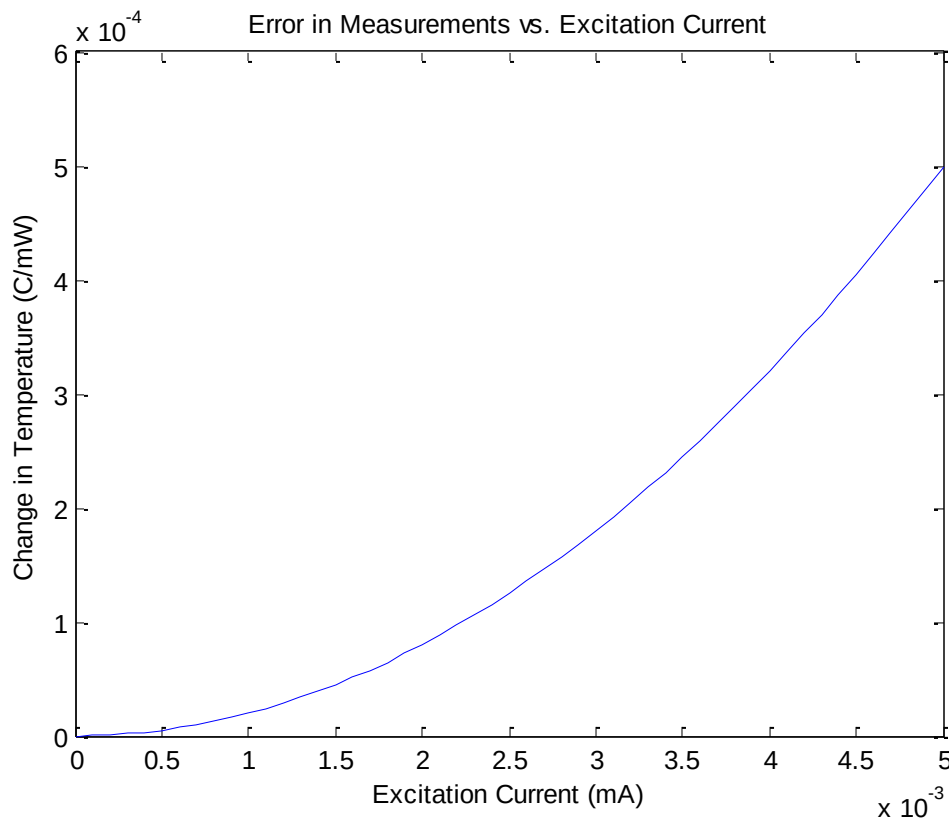


Figure 2: Showing how important it is to not have too high of an excitation current

3. Excitation Current Design

Choosing the correct design for creating an excitation current can become challenging. There are numerous ways to develop a current of less than a milliamp, but each present a different disadvantage, leaving it up to the engineer to decide which parameters are the most critical. While some are easier and cheaper to configure than others, the efficiency might be too low for customer specifications. Figure 3, represents an effective method for producing the excitation current, and giving the designer an easy option to adjust the current desired.

- V_{DC} = any voltage level with in the 2 chosen Op Amp's limits.
- The 4 resistors (R) need to be equal to each other and:
 - $R = 10,000 * V_{DC}$
- $R_{REF} = 1,000 * V_{DC}$
 - Following these stipulations
 - $I_{ex} = \frac{V_{dc}}{R_{ref}}$

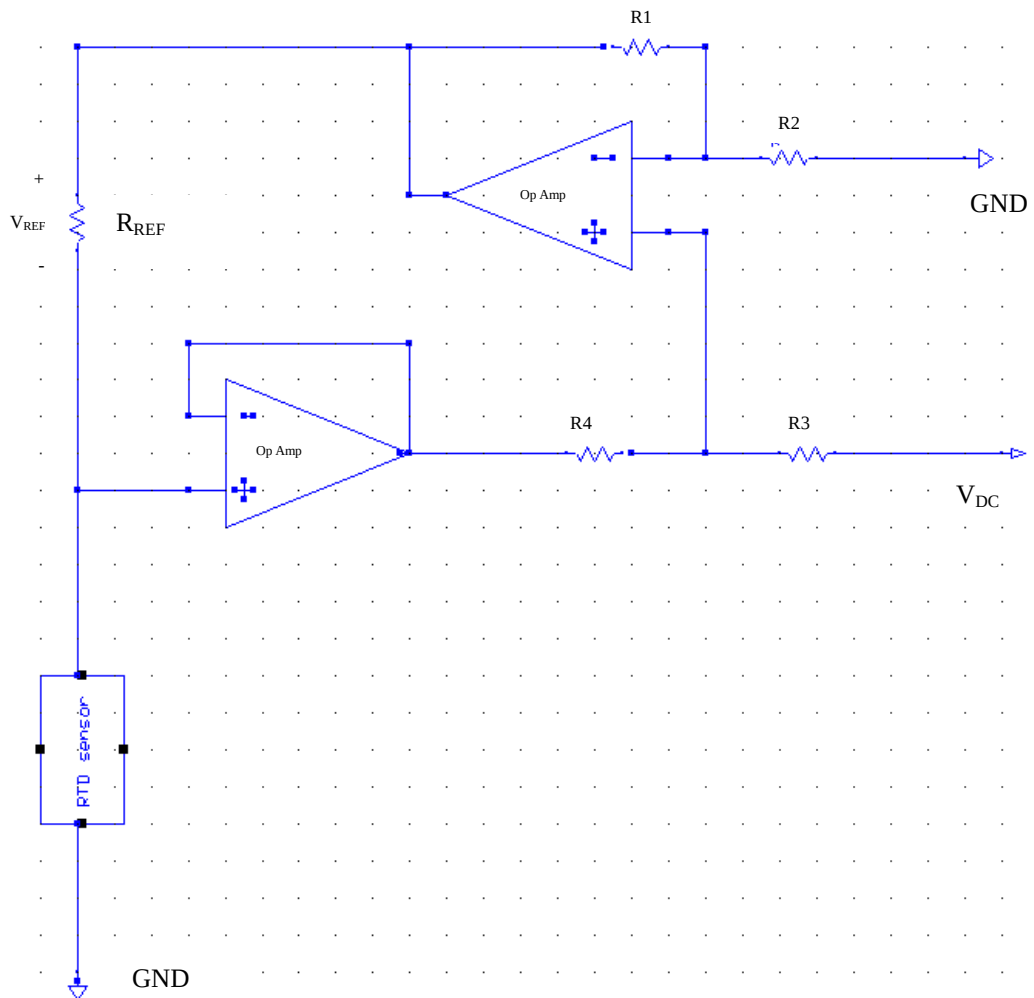


Figure 3: Schematic of creating an excitation current for the RTD sensor.

4. Signal Conditioning

The RTD, from the excitation current, can readily relay the resistance levels that are correlated to temperature, leaving the next step of accurately amplifying the levels. Amplification is necessity due to the fact that the change in resistance from temperature gives millivolt changes. Therefore, the signal coming from the sensor must be amplified so the microprocessor can distinguish the different voltage levels. As mentioned earlier, leads can have a result in significant error for these resistive sensors based on the length. A very simple method of adding a wire on each of the two pins (4-wire method) will effectively bypass the high impedance of the leads. Feeding these two wires into an operational amplifier, with filtering, will produce an accurate reading for further experimentation. Figure 4, shows a RTD sensor with complete signal conditioning. The capacitor and resistor values for the filtering section, is dependent on a multitude of parameters such as; type of amplifier used, ADC resolution and voltage ranges.

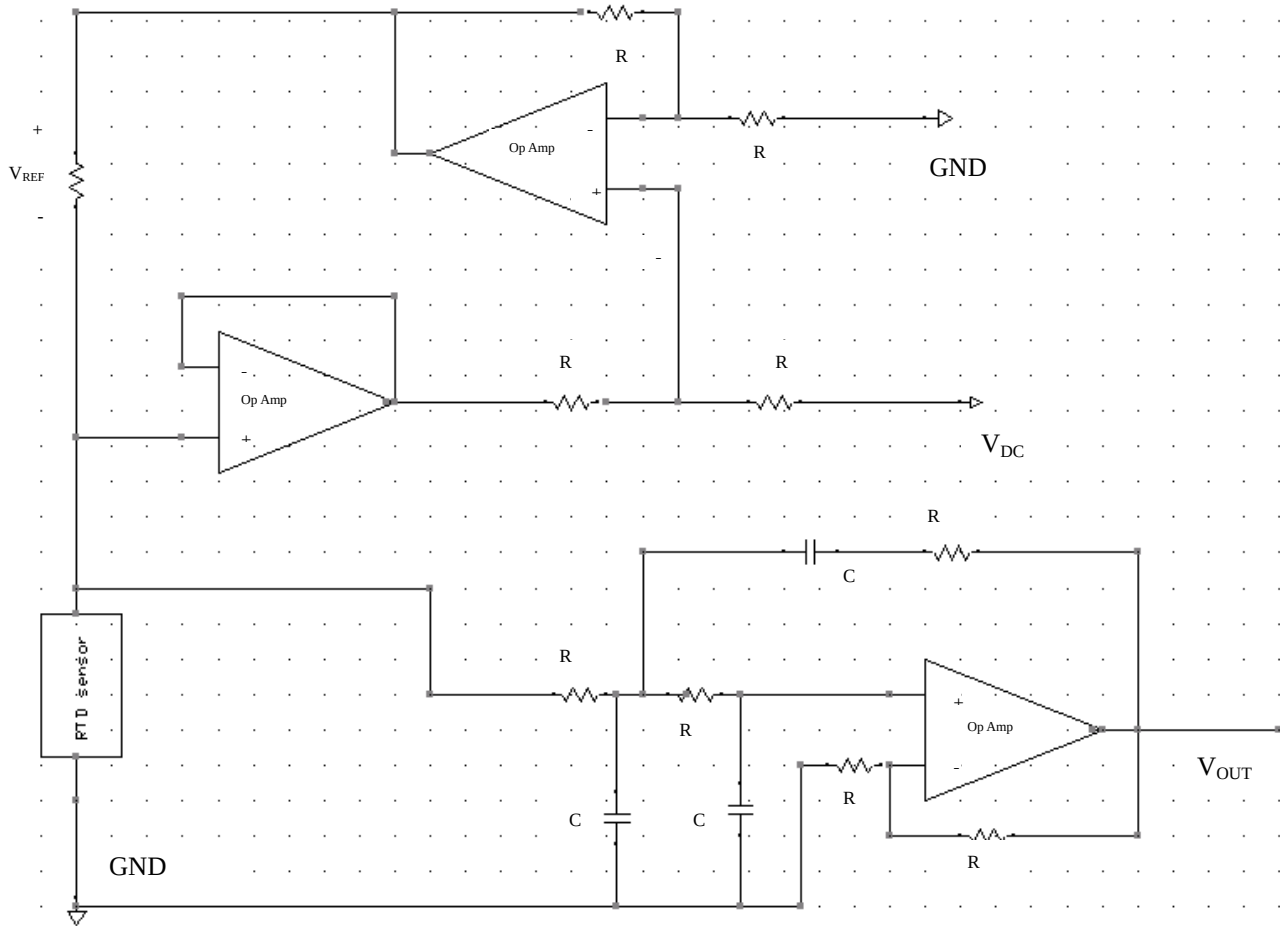


Figure 4: Signal conditioning for RTD sensor

5. Conclusion:

Resistance Temperature Detectors are a very popular method of sensing temperature in numerous configurations, offering output linearity over a very wide range of temperatures. Due to the physical composition of the sensor; proper conditioning is needed to produce accurate measurements. An excitation current is needed for functionality of the sensor that can be executed by following a structured schematic and equations. Being a resistive circuit, the length of lead wires can drastically alter the precision of the sensor. To combat this problem a 4-wire method and filter can be utilized to give accurate measurements.