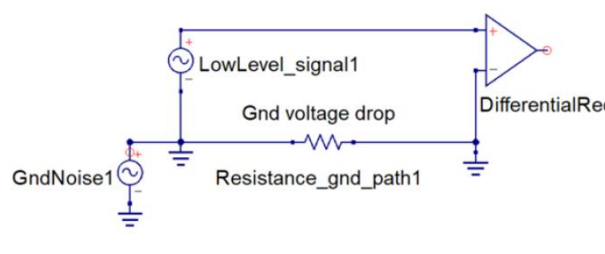
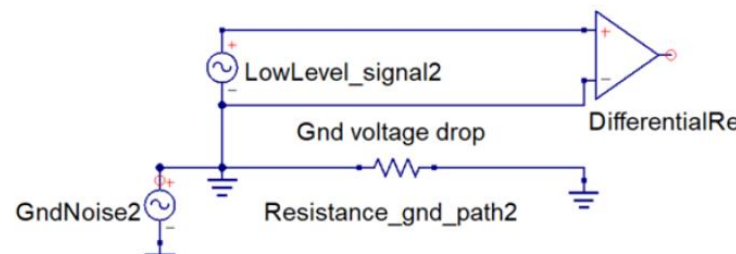


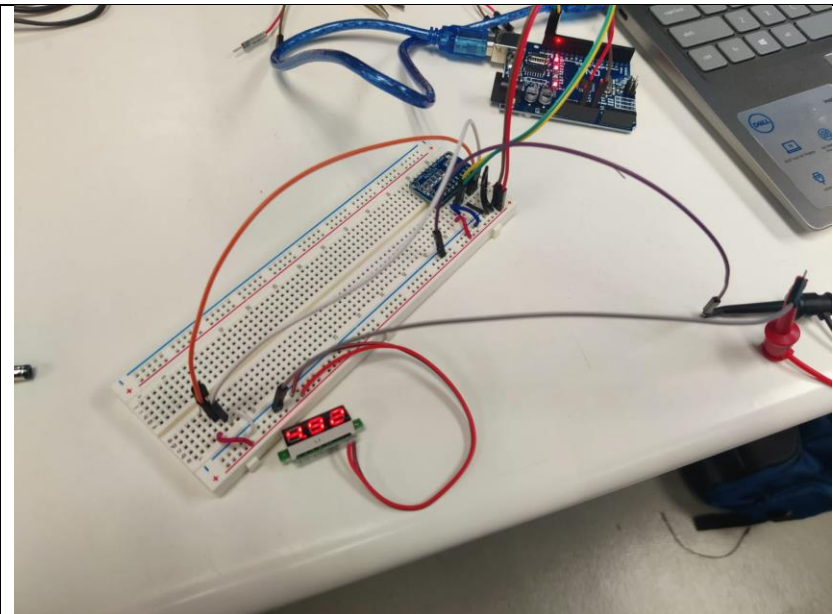
## Lab 18: Differential vs Single-ended signaling and ground noise

-Rishab Shah

Goal: An I2C-based ADC is used to obtain the digital temperature value of the analog voltage fed into the AIN pin of the ADC read from a TMP36 temperature sensor. The measurement of the signals happens w.r.t ground. The ground can be either local to the measurement taking device (ADC's ground in this case) or it could be from the ground of the sensor.

<p><b>Single-ended Voltage Measurement</b></p> 	<p><b>Differential Voltage Measurement</b></p> 
<p>In this setup, the measurement happens with analog input taken from TMP36 and the ground reference of ADC's ground</p>	<p>In this setup, the measurement happens with analog input taken from TMP36 and the ground reference of TMP36's ground pin.</p>

SBB Image:

	<p>In the circuit, purple and grey jumpers are used to introduce noise of 1HZ and 1Vpp nature. This is a periodic noise.</p>
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1. With **no current** in the ground connection between the TMP36 and ADS1115, what was the temperature read by the TMP36?

Solution:

Following temperature should have been read for the corresponding analog voltage fed into ADC.

Temperature = Analog (Voltage Temp) temp – Analog voltage(ambient)/ Output scale factor + 25  
= (763.25 (estimated from graph)-750)/10 + 25 = **26.32** degree C -> Datasheet

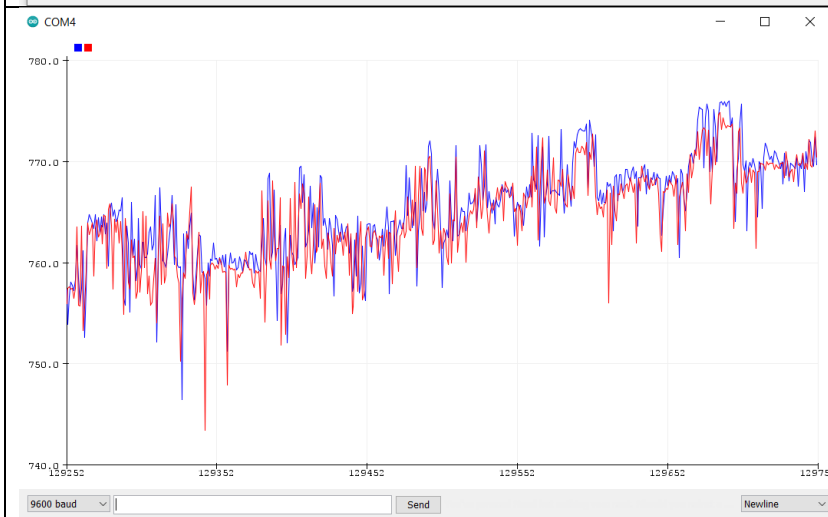
2. With **no current** in the ground return path, what was the voltage difference between the differential measurement and the single-ended measurement of the TMP36?

Solution:



There is not much difference between SE and DE measurements when there is no noise i.e. **no current** in the ground connection between the TMP36 and ADS1115.

Blue – DE measurement  
Red – SE measurement



The graph with temperature rising when no noise is added and both the SE and DE measurements are in sync.

Blue – DE measurement  
Red – SE measurement

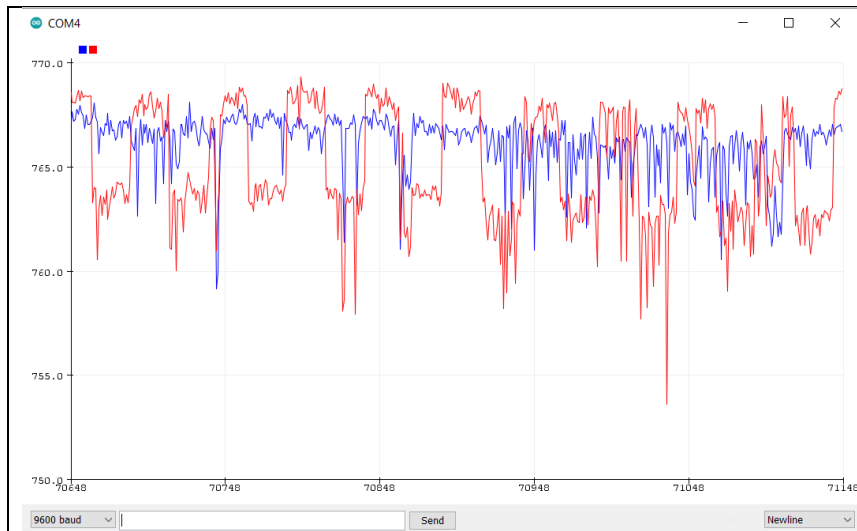
3. What was the current from the function generator in your ground return between the TMP36 and ADS1115 in your set up?

Solution:

The resistance of function generator is 50 Ohm. Voltage introduced is 1Vpp. Hence, Current is  $(1/50) \rightarrow 20\text{mA}$ .

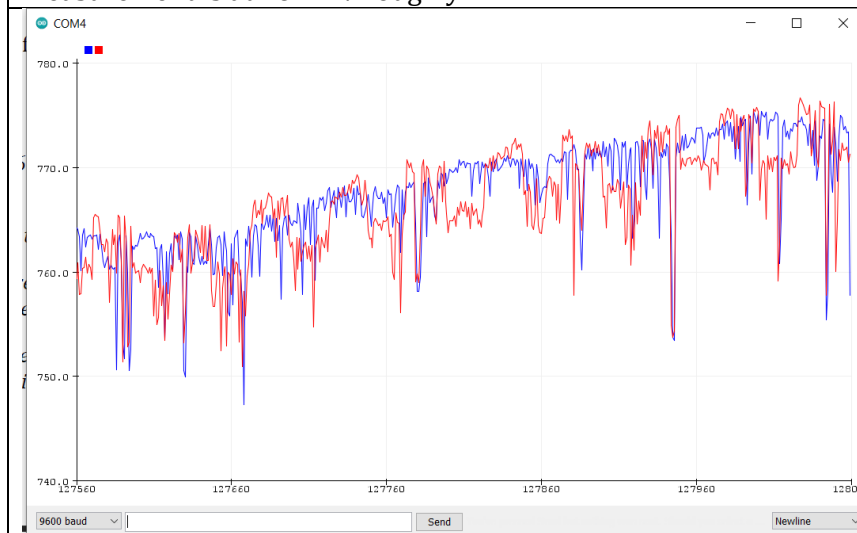
4. What is the voltage difference you measured between the single-ended and differential measurements when there was this current flowing through the ground path?

Solution:



The noise introduced is periodic in nature and it can be seen from the graph. The differential signal has withstood the noise whereas the SE did not.  
Blue – DE measurement  
Red – SE measurement

(Image 1) The voltage difference is about 5mV. The DE measurement is at about 766 mV whereas the SE measurement is at 761 mV roughly.



The noise introduced is periodic in nature and it can be seen from the graph. The differential signal has withstood the noise whereas the SE did not.  
Blue – DE measurement  
Red – SE measurement

The voltage increases gradually with rise in temperature due to finger.

5. How would you recommend routing the differential pair from the sensor to the ADS1115 for the lowest noise pick up?

From the analysis,

1. It becomes clear that ground to be chosen should be w.r.t to the sensor under test. In real-world, if a noise is added, it will be added to both the signal and return paths which are placed or will travel towards the controller. Noise introduced at that end will be eliminated using the differential method of measurement as the noise will be cancelled. This will give error-free measurements as no noise is introduced.
2. The signal (analog voltage) and ground pins will be twisted with each other and fed into ADC analog channel. This would also be the reference ground voltage provided.
3. The distance between the sensor and ADC would be kept as small as possible.
4. In case of PCB, common ground plane would be utilized with proximity of sensors.