# Lab 16 Report: Diff or SE signaling and ground noise.

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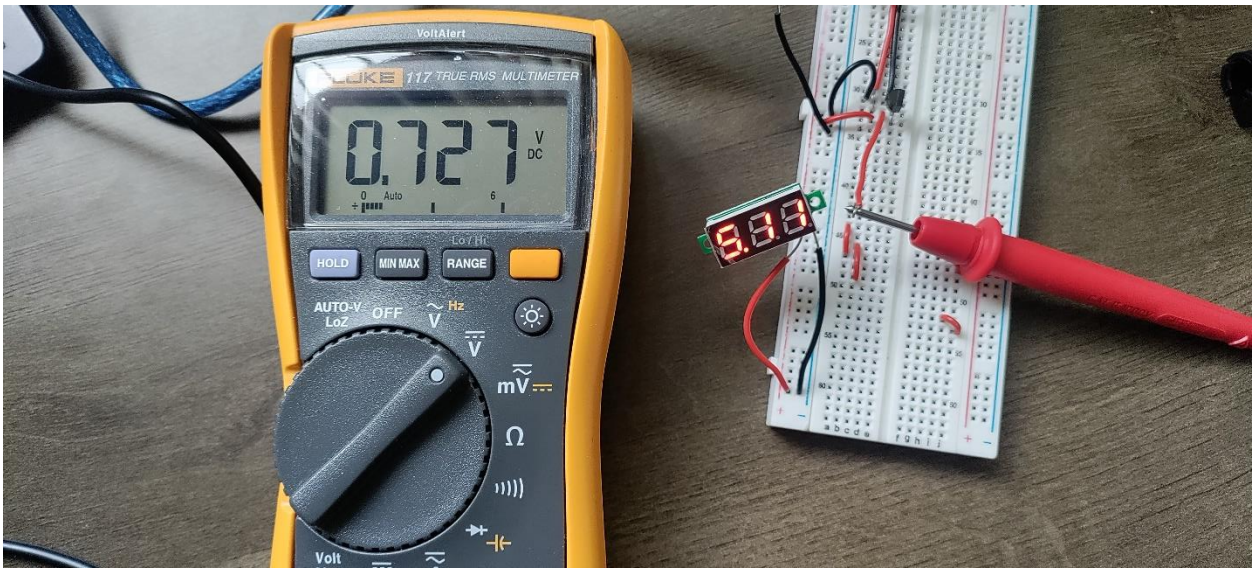
**Purpose:** To compare the quality of the analog signal measurements from a sensor using a single-ended and differential pair measurement and explore signals on the I2C bus.

**Experiment:**

For this experiment to find out the quality of the analog signal measurements we are using a TMP36 temperature sensor and to read the voltage in digital value, an ADS1115 a 16 bit ADC.

Initially when there is no ground connection between the TMP36 and ADS1115, the voltage read by the TMP36 is 727mV.



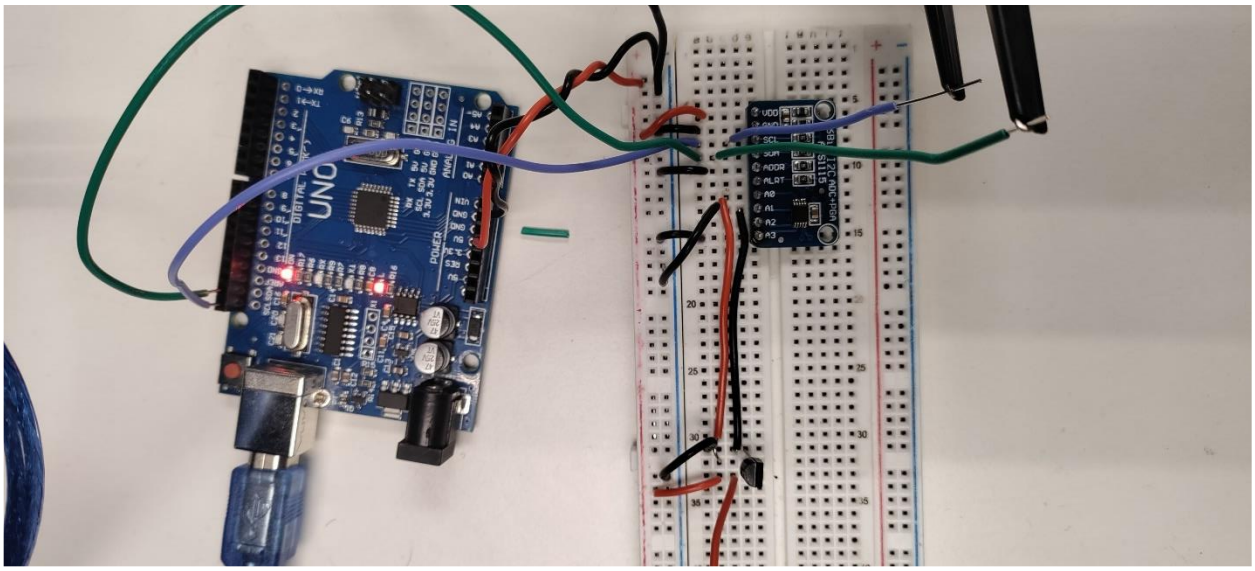

By using the formula given in the lab manual,

$T(^0C) = V(volts)*100(C/V) - 50(^0C) = 0.727*100 - 50 = 72.7-50 = 22.7^0C$

The room temperature was around 22.7 degree Celsius.

Setting up circuit for without noise measurements:

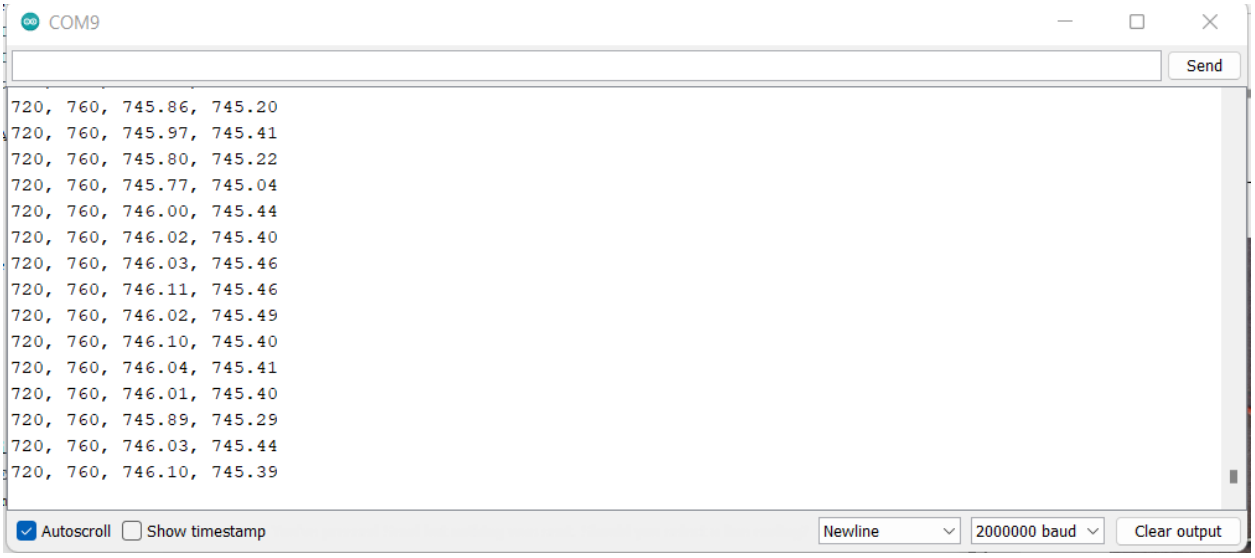
For the single ended and differential measurements, the following setup is connected.



The 5V supply is given from the Arduino. The VCC of the ADS1115 is connected to the 5V supply, Ground pin to the common ground of circuit. The SCL and SDA pins are connected to respective data lines on Arduino board. The ADDR pin is connected to ground. The AIN0 (Analog Input Channel 0) is connected to the TMP36 Vout pin. The AIN1 (Analog Input Channel 1) is connected to the ground pin of TMP36.

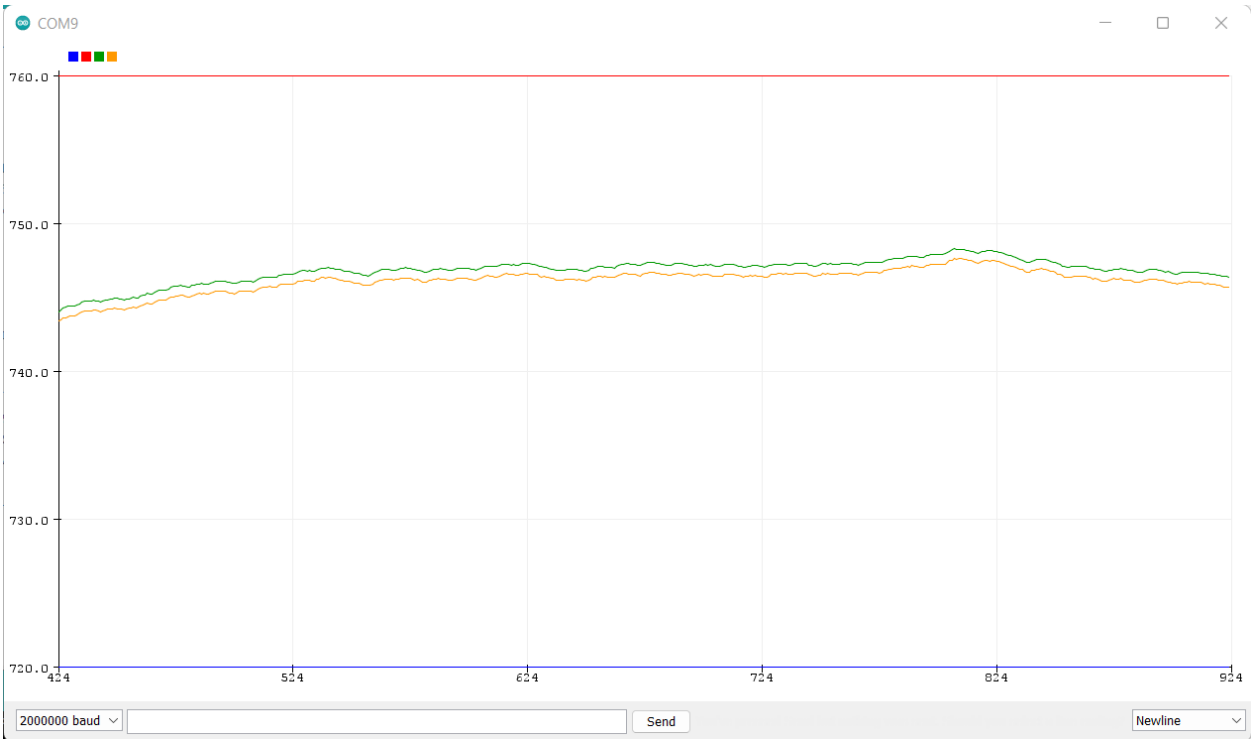
The code as per the lab manual, which sets the baud rate to 2000000, gain of 4x, with one bit resolution of 0.03125mV. The averaging is done to get some noise reduction. The function ads.readADC_Differential_0_1() is used to get the differential value of the analog signal between channels 0 and 1. The ads.readADC_SingleEnded(0) is used to get the analog signal value from that particular channel with 0.

The following is the output obtained on serial monitor,



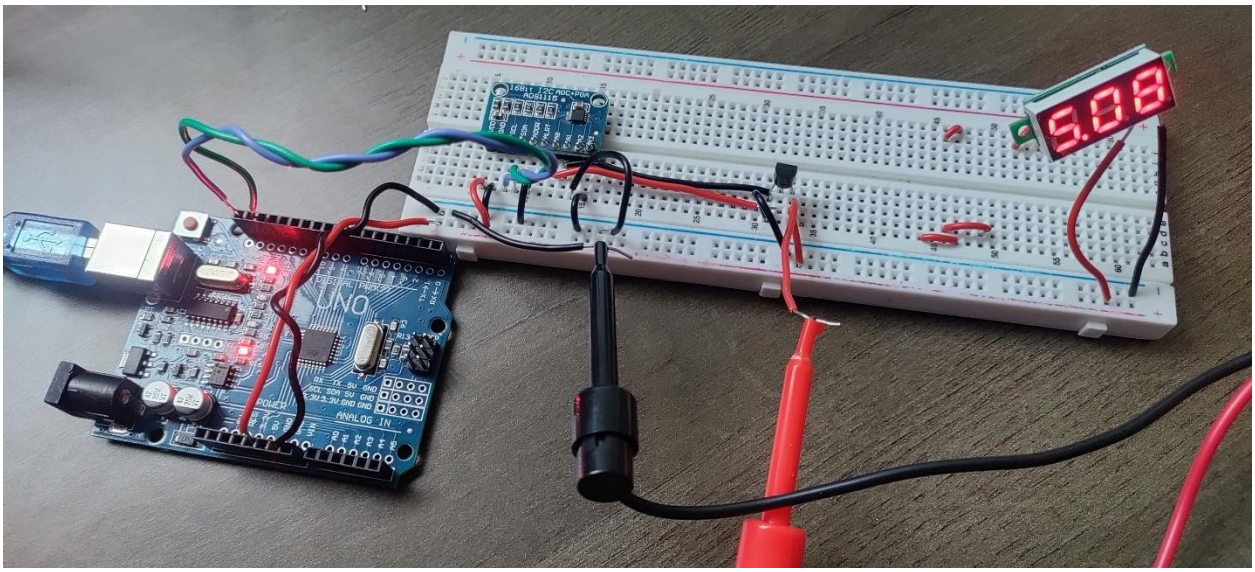
The differential value is around 746mV on an average and single ended value is around 745mV. There is a difference of about 1mV.

The following is the serial plotter of differential (green curve) and single ended (orange curve) configuration.



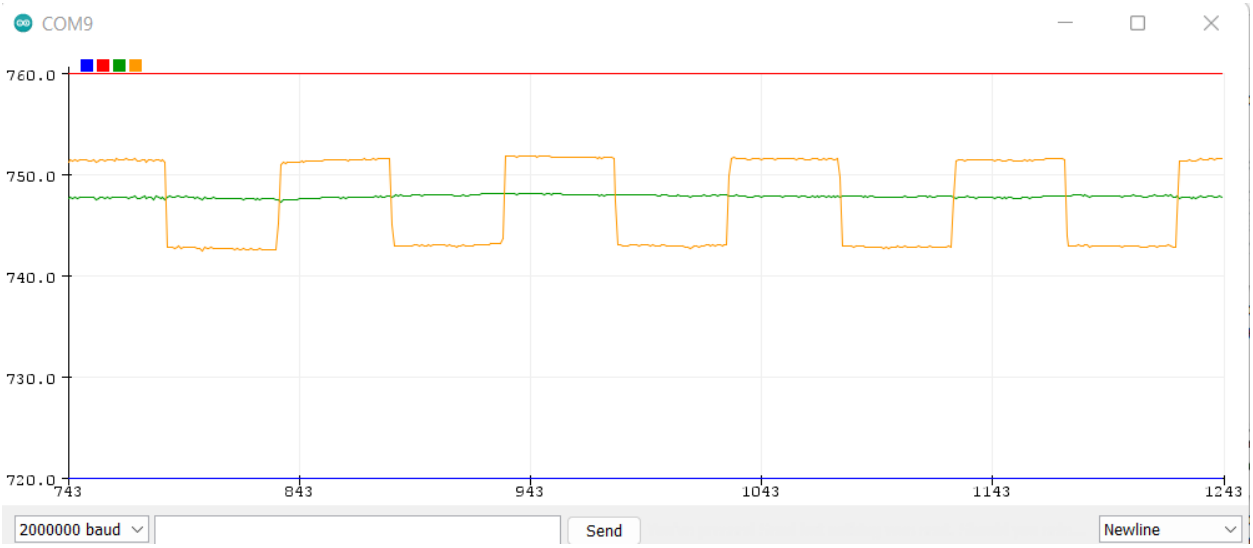

**Adding Noise to the Return Path:**

A noise is introduced in the ground plane of the setup. This is given through a function generator.



The output load across the function generator being 50Ohm, the input voltage can be at the range of 10Vp-p to 20Vp-p. The resistance when calculated on the ground line is around 0.04 ohms. With a current of 400mA, the voltage or the noise generated is 200*0.04 = 8mV. This value is considerable and should be visible on the serial plotter as per the change in voltage or noise added from function generator.

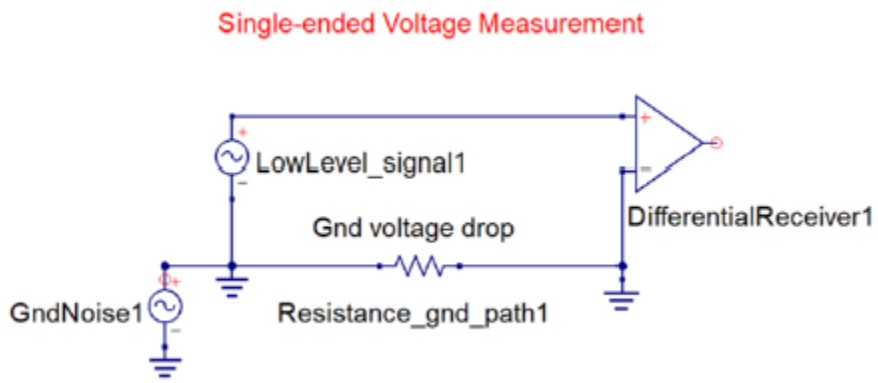
To get a 200mA current, the voltage is 10Vp-p (200mA*50Ohm). With a frequency of 0.1Hz, the following curve is observed on the serial plotter for differential (green curve) and single ended (orange curve).




The voltage observed with noise added on a single ended measurement fluctuates between 743mV to 752mV. This 8-9mV difference is caused due to the 8mV noise added to the return path. This fluctuates with a frequency of 0.1Hz. Since a square waveform is updated in the function generator a square wave noise is obtained. If a sinusoidal waveform is updated on function generator a sinusoidal noise would be visible on the serial plotter.

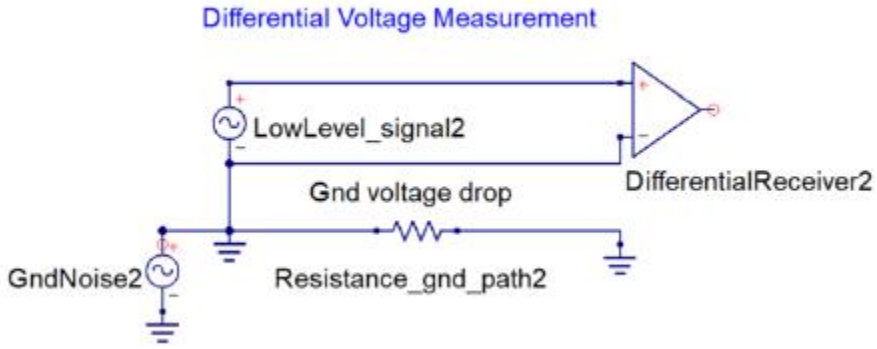
**Observations:**

When observing the above serial plotter, the differential measurement did not get effected due to additional noise whereas single ended measurements were effected. This method in which single ended measurements are taken are calculating the analog value of a particular channel with respect to the common ground.




When a noise is added to ground plane or return path and the measurement is taken with respect to zero on a single ended, the value of noise added to the calibration. This gives a value with noise and is not immune to noises in the circuit.

While measuring using a differential measurement, the method is calculating the analog difference between channels connected to the ADC.




According to the measurement setup above, the difference between the channels is considered which gives no connection with return path or the path where noise is added. This gives a more accurate value always and differential measurement is immune to the noise in the circuit on the return path or ground plane.

**Conclusion:**

Hence, it is observed that differential measurement of analog signals is preferred over single ended measurement. For routing in the circuits, a differential pair from sensor to the ADS1115 is recommended for the lowest noise pick up since it is immune to noise in the return path or ground plane.