# Instrumentation Amplifier on load cell sensor

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# Aim

* In this experiment,we wish to implement instrumentation amplifier on a load cell sensor.

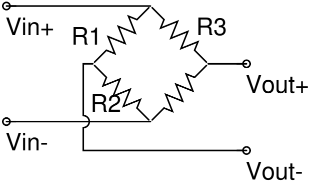
* In part 1,we will build instrumentation amplifier using TL084 IC.

* In part 2,we will be using instrumentation amplifier which is available on microcontroller board.

* In part 3,we will implement instrumentation amplifier using INA128 IC.

* This experiment mainly aims at observing the differences in characterisitcs and performances in above 3 parts.

A load cell is based on an electrical circuit called Wheatstone bridge.




This arrangement allows to measure very small changes in the resistance R, which occurs in the strain gauges placed in the arms of the bridge: R1, R2, R3 and R4.

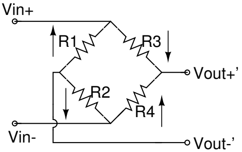
When the load cell has no load, the four gauges are at rest and have the same ohmic value, the nominal value of the strain gauge Rg:

$$R1 = R2 = R3 = R4 = Rg \tag{1}$$

Then, the output signal Vout, differential between Vout+ and Vout, is 0 Volt

# Theory and Design Procedure

When loading the load cell, the strain gauges changes its resistance value in a very small ratio ΔR:




R1=Rg+ΔR ; R2=Rg-ΔR ; R3=RgΔR ; R4=Rg+ΔR

Assuming Vin+=5V, Vin-=-5V, Rg=350 ohms, derive an expression for differential Vout as a function of ΔR. Comment on the nature of dependence of Vout on ΔR.

# Theory and Design Procedure

An instrumentation amplifier is a type of differential amplifier that has been outfitted with input buffer amplifiers.These input buffers eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment. Additional characteristics include very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, and very high input impedance. Instrumentation amplifiers are used to achieve high accuracy and stability.

# Theory and Design Procedure

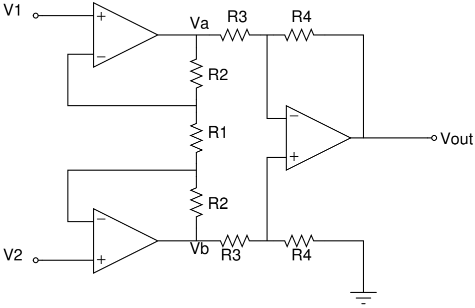



Figure: 1

# Theory and Design Procedure

Here, we define the input voltage signals small signal AC differential input $V_1$ and $V_2$, as the input of first stage opamps of the instrumentation amplifier. We assume input resistance of opamps to be infinite. Now applying KCL at inverting input of first stagee opamps. We get,

$$V_a = V_1(1 + R_2/R_1) + V_2(R_2/R_1) \tag{2}$$

And,

$$V_b = -V_1(R_2/R_1) + V_2(1 + R_2/R_1) \tag{3}$$

Using superposition principle of voltages at second stage opamp,

$$V_{out} = R_4/R_3(1 + 2R_2/R_1)(V_2 - V_1) \tag{4}$$

Rearranging this equation,the gain is

$$A_v = \frac{V_{out}}{V_1 - V_2} = \frac{R_4}{R_3}(1 + \frac{2R_2}{R_1}) \tag{5}$$

# Pre Lab Work

1. Read up on instrumentation amplifiers. Click here for reference
2. Read the additional document on weight scale machine uploaded on moodle.
3. Simulate instrumentation amplifier in SPICE and add it in your post lab report.
4. Derive the relation between differential Vout and $\Delta$R as mentioned in page 4 and comment on the dependence of Vout on $\Delta$R
5. Calculate the values of R1, R2, R3, R4 as mentioned in Point 2 of Page 9.

# Part 1

1 You will use Operational amplifier TL084. Refer to the data sheet of TL084

2 Refer to figure 1. Use Load Resistance of 10kohms. V+=12V, V-=-12V.Calculate the values of R1, R2, R3 and R4 properly to get a gain of about 300 (Keep in mind that any arbitrary value if resistance is not available in lab).Apply a single ended signal of 20mV p-p 1KHz sine wave as input and show the required amplification. Use decoupling capacitance if necessary.

3 Connect power adapter to the weighing machine. Connect unamplified differential output of load cell to the designed instrumentation amplifier. Refer to Fig 3.

4 Measure DMM voltage by varying weights. Calculate sensitivity in (mV/gm).

5 Adjust R1 value such that you get twice the previous gain. Plot voltage vs weight.

# Part 2

1. Connect the power adapter to the weighing machine. Now, connect the output of the weighing machine to DMM to measure voltage.
2. Adjust the potentiometer knob to achieve 0 V output at unloaded condition to correct offset.
3. For 100x gain (refer to Fig 2), note down DMM voltage by varying weights. Plot voltage vs weight. What is the sensitivity (in mV/gm) of the sensor
4. The weight machine has a load cell giving a differential output to an instrumentation amplifier made up of discrete op-amps (refer to the circuit diagram in the load cell manual). The gain of the instrumentation amplifier can be adjusted to take 5x, 10x, 20x, 50x, 100x by plugging the suitable jumper (JP1-JP5, refer to Fig. 2) . Can you identify how gain is being changed? What happens when 2 jumpers are connected

# Part 2

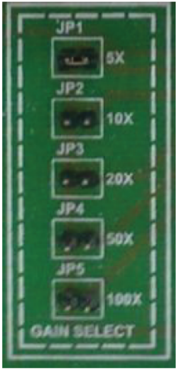



Figure: 2

# Part 3

1. Now you will use instrumentation amplifier INA128 for load cell signal amplification.Refer to the data sheet of INA128

2. Using $R_G = 220 ohms, R_L = 10 kohms, C_1 = 0.1 uF, V_+ = 13.6 V, V_- = -13.6 V$, wire up the instrumentation amplifier circuit. Refer to Fig. 4. Explain the purpose of capacitor $C_1$ connected in parallel with the power supply.

3. Connect unamplified differential output of load cell to the designed instrumentation amplifier. Refer to Fig 3.

4. Note down the DMM voltage by varying weights. Plot voltage vs weight. Calculate sensitivity in (mV/gm).

5. Adjust $R_G$ value such that you get twice the previous gain. Plot voltage vs weight.

# Part 3

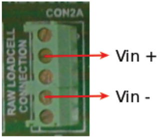



Figure: 3

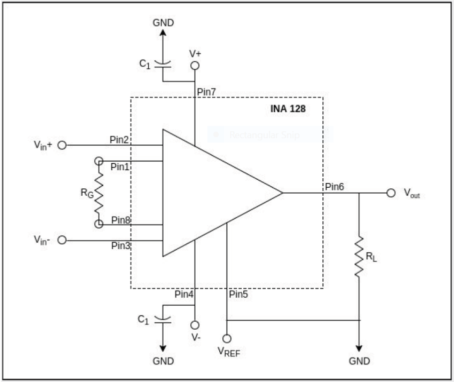



Figure: 4

# Additional Questions

1. Note down the differences in output/performance of various instrumentation amplifiers.
2. Mention the reasons of the difference in performance of instrumentation amplifiers.
3. The readings you have been taking by DMM in part 1, 2 and 3, observe the same with the help of oscilloscope. What do you observe? What is the reason for this type of observation?