# PreLab 1 – Load Cell Measurement System
# (8 problems for 30 pts)

## INTRODUCTION

In this lab, you will develop a fully functioning load cell measurement system. A system block diagram is shown in Fig. 1. Here's how it works:

1) The load cell converts the mechanical load (grams) into a very tiny voltage signal.
2) The instrumentation amplifier increases the signal amplitude.
3) The amplifier output is recorded by the Arduino and sent to a computer.
4) The computer displays the measured load (grams).

The load cell will be provided during the lab session. The instrumentation amplifier is the AD620 chip. In the lab session, you will program an Arduino to record the amplifier output, and send the data to a computer for display.

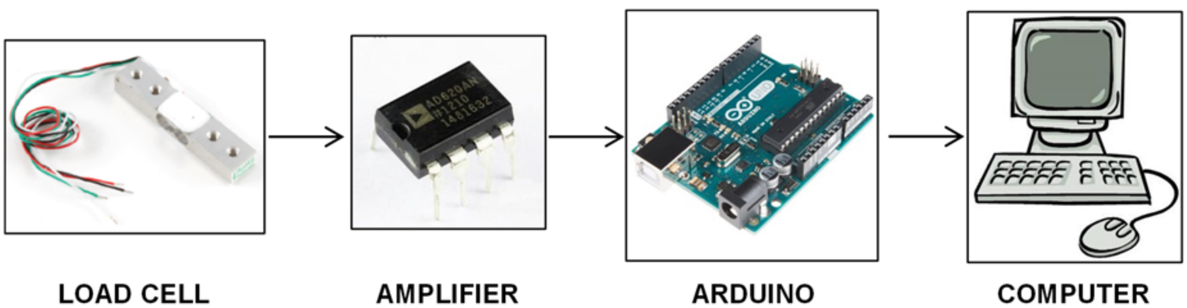


**Fig. 1: Overall load cell measurement system. The load cell and Arduino will be provided during the lab session.**

## SYSTEM DESIGN

How do we go about designing our system? This depends on the constraints of the problem and any requirements. Let the constraints be the following:

1) The load cell has the following specifications:
    a. Rated output: $RO = 0.8$ mV/V
    b. Rated load: $L_{RATED} = 780$ g
    c. Excitation voltage: $V_S = 5V$
2) Maximum desired load to be measured is 780 g.
3) The AD620 output has a reference voltage $V_{REF} = +2.5V$ (this will be explained later).
4) The Arduino's ADC has 10 bits and operates from 0-to-5V.

For this lab, there are no specific requirements regarding sensitivity, so we do not need to be concerned with noise voltages (e.g. from the amplifier) or vertical resolution. Therefore, the only thing we need to figure out is the **proper amplifier gain**. This is usually based on the maximum expected signal. When the load is 780 g, the amplifier output better not exceed 5 V!

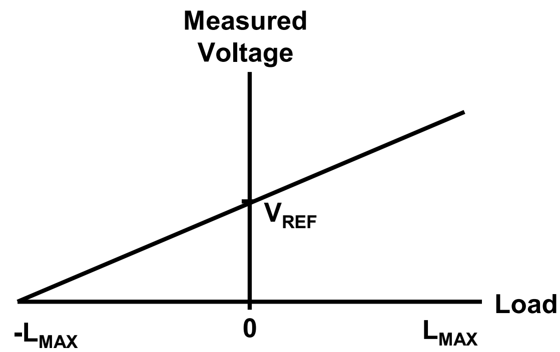


**Fig. 2: Illustration of the reference voltage $V_{REF}$ for the amplifier output $V_{MEAS}$.**

As shown in Fig. 2, the instrumentation amplifier output has a non-zero value for zero load. We'll call this the "reference voltage" $V_{REF}$. This is actually not a bad thing. Remember that the Arduino's ADC measures voltages from 0 to 5 V. If a system has $V_{REF} = 0$, then we cannot measure negative loads (e.g. pulling rather than pushing on the load cell) because negative voltages are not accurately recorded by the Arduino! Instead, the Arduino will simply round any negative voltages to zero, which is obviously an incorrect recording.

- PROBLEM 1: In class, we derived the expression $V_{MEAS} = A_d \Delta V = A_d \cdot RO \cdot V_S \cdot L/L_{RATED}$, where L is the measured load. Derive a new expression for $V_{MEAS}$ that includes the reference voltage $V_{REF}$.

  NOTE: Our in-class expression for $V_{MEAS}$ implicitly assumed that $V_{REF} = 0$. In this lab, $V_{REF}$ will be somewhere between 2 to 3V (depends on the system).

- PROBLEM 2: Compute the maximum expected voltage change $\Delta V_{MAX}$ from the load cell. Show all work.

  Hint: You should get 4 mV.

- PROBLEM 3: Assuming $V_{REF} = 2.5$V, compute the maximum allowable gain of the instrumentation amplifier. Show all work.

  Hint #1: Remember that $V_{MEAS}$ must not exceed 5V!

  Hint #2: You should get $A_d = 625$.

- PROBLEM 4: Suppose you are limited to amplifier gain values of 10, 20, 50, 100, 200, 500, 1000, 2000, or 5000 (choose one). Which is the best choice?

  Hint: **Make sure you do not exceed the maximum allowable gain!** Otherwise, you run the risk of saturating your system when measuring the maximum load.

The AD620 can be configured to almost any gain you want! ☺ The key is the resistor $R_G$ between pins 1 and 8. According to the AD620 data sheet, the gain is related to $R_G$ by:

$$A_d = 1 + \frac{49400}{R_G} \qquad \text{Eq. (1)}$$

For example, a gain resistor $R_G$ = 499 ohm produces an amplifier gain of 100.

- PROBLEM 5: Determine the 5% resistor value that gives you a gain value that is as close as possible, but does not exceed, your answer to Problem 4. See the course website for a chart of 5% resistor values. Also compute your **actual gain** (i.e. plug in your chosen value of $R_G$ into Eq. 1). Show all work.

  Hint: You should get $R_G$ = 100 ohm.

- PROBLEM 6: Your measured voltage is not the final output from your measurement system. You want the load in grams! Based on your answer to Problem 1, derive an expression for the load in terms $V_{MEAS}$, $V_{REF}$, and other circuit parameters. Show all work.

Sensitivity refers to the minimum change in load $\Delta L_{MIN}$ that produces a detectable voltage change $\Delta V_{MEAS,MIN}$. What is considered "detectable" is the LARGER value of two factors: (1) noise in the data acquisition system and (2) vertical resolution of the ADC.

- PROBLEM 7: Suppose your data acquisition system has a noise floor $V_{N,RMS}$ = 1 mV. Is your data acquisition limited by noise or vertical resolution?

- PROBLEM 8: Compute the sensitivity of your system.

  Hint: Your $\Delta L_{MIN}$ should be just under 2g.

(End of PreLab1)