ShanghaiTech University

School of Information Science and Technology

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LABORATORY6

Strain Gauge Sensor

Guide

Objective

In this laboratory, you will build an analog circuit that will enable you to use a strain gauge to measure the deflection of a ruler. Then you will add a noninverting op-amp circuit to amplify the voltage output from your circuit and analog low-pass filter to remove voltage fluctuations caused by high-frequency noise. At last, you will see the output waveform by oscilloscope.

YOU NEED TO READ THIS LAB AHEAD OF TIME SO THAT YOU CAN COME PREPARED IN LAB. IF YOU DON'T YOU WILL NOT BE ABLE TO FINISH THE LAB IN 3 HOURS!

Theory

a. System Block Diagram

In this lab you will design a strain gauge system that you can interface to digital systems (like microcontrollers). Figure 1 shows the expected block diagram of your strain gauge system.

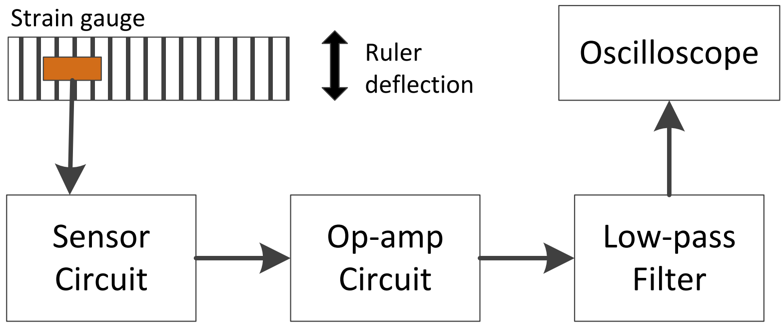

Figure 1. Strain Gauge Sensor System.

Let us examine the blocks in Figure 1 (excluding the oscilloscope).

b. Strain Gauge

A strain gauge operates on the principles that physical strain deforms the physical dimensions of a material. We know from physics that resistance is proportional to the length of the material, and inversely proportional to the width given by the following equation:

$$R = \rho l / A \text{ where } A = wh$$

Figure 2 shows a strain gauge with two electrical leads on the right side. The serpentine structure consists of a resistive material (e.g. a metal) mounted on top of an insulator. Increasing the length of the resistor (e.g. by adding additional serpentines) increases its value.
Question: what happens if we pull on the resistor to make it longer?
Well, its value increases.
In this laboratory we use this effect by gluing a strain gauge on one side of a flexible beam. When the beam is bent, one side gets longer while the other gets shorter. The glue transfers this effect to the strain gauge, which in turn changes its resistance value as a function of beam bending. Applications include airplane wings where strain gauges are used to determinate degree of wing deformation during flight from the change of resistance. Strain gauges are invaluable for evaluating not only airplane frames, but also automobiles, bridges, and buildings.

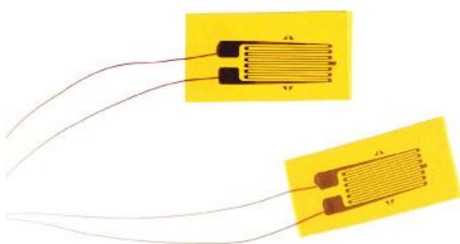

Figure 2. Resistive strain gauge with electrical leads on the left side.

c. Wheatstone bridge network

When we deform the strain gauge resistor, we either increase the length or decrease the area, thus increasing resistance, or we decrease the length and increase the area, decreasing resistance. Therefore, the strain gauge is a variable resistor represented as a resistor with an arrow as shown below:

Variable Resistor Circuit Symbol

When you deflect the strain gauge, the resistance of the strain gauge changes by a very small amount (around 0.5% to 1%). First, you need to convert the resistance measurement into a voltage output and then amplify this voltage.

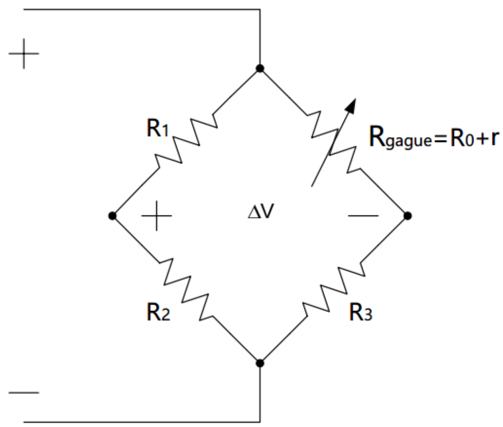

Figure 3. Wheatstone bridge network

To convert the change in resistance of the strain gauge into a voltage output, we use a Wheatstone bridge circuit shown in Figure 3. For simplicity, we will be using only one strain gauge and build a Wheatstone bridge network out of discrete resistors. The Wheatstone bridge is described in Figure 3.

d. Sensor Circuit

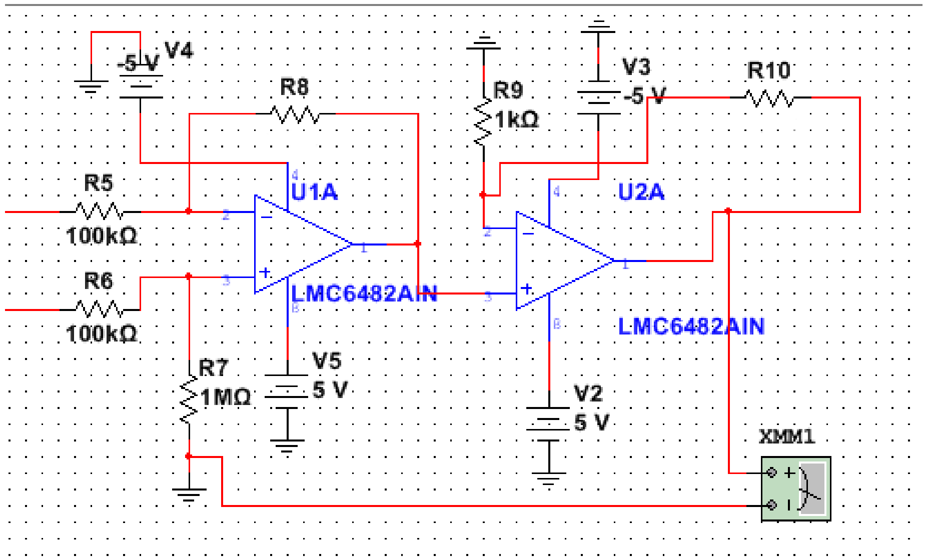

Figure 4. The sensor interface circuit.

A Multisim screen shot of your sensor circuit is shown in Figure 4. It contains two amplifiers: a difference amplifier followed by a non-inverting amplifier for additional gain. You will use your knowledge of amplifier learned from lab5 and derive the gain of this sensor circuit and verify your theoretical result (PRELAB). The connection diagram of the LMC6482 is as follows:

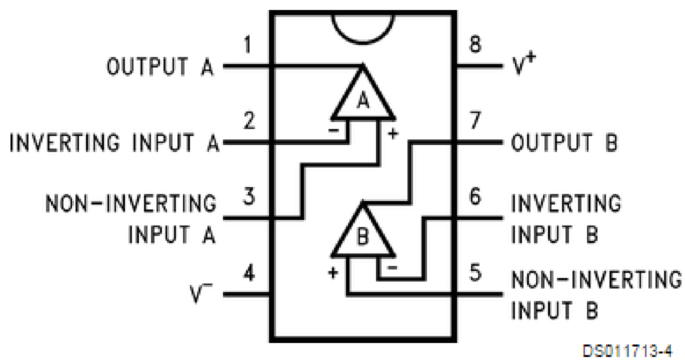

Figure 5. The connection diagram of the LMC6482

e. Low-pass Filter

The low-pass filter circuit is left to these guys who want to take a challenge. Of course, you will get extra 10 points if you finish this part well. In this part, you should find some relevant information on your own with the help of Internet. Then you will be able to draw the circuit and conclude its effect according to the result after observing the oscilloscope.(Four points for your circuit and the component you choose, and six points for the performance of your low-pass filter.)

Reference

[1] UC Berkeley, course EECS 100, Summer 2008.

[2] UC Berkeley, course EECS 100, Summer 2010.

[3] UC Berkeley, course EECS 100, Spring 2011.

[4] University of California, course ME 104, Fall 2003, Laboratory 3

Lab6 Prelab

Name ______________________ TA ________________________

Teammate ______________________ Score ________________________

Prelab Assignment

1. Complete the prelab tasks over the next few pages (40 points).

2. Familiarize yourself with the rest of this document before arriving in lab!

3. Simulate and build your sensor circuit in Multisim.

TASK 1

Watch Figure 3, Derive an expression for ΔV. What value should you set for R_1, R_2 and R_3 to simplify measuring the resistance of strain gauge? Why?

Expression for ΔV: __________________________ **__/7pt**

R_1: _________ R_2: _________ R_3: _________ **__/3pt**

Show your work and explanation here:

TASK 2

Derive the gains of the two op-amp circuit in Figure 4. Use your knowledge of amplifier learned from lab5 and fill Table 1.

Op-amp	Gain expression
U1A (Difference amplifier)	G1:
U2A (Noninverting amplifier)	G2:

Show your work here: **__/10pt**

TASK 3

In practice the output is still not exactly zero, even if strain gauge is not pulled or pushed. Give two reasons why.

Reason: **__/5pt**

TASK 4

Build your sensor circuit in Multisim or PSpice and finish the table below. At the same time, you should take a screen shot of your whole circuit, which should be glued in the box below.

__/10pt

R_{gauge}	ΔV	V_{out}
		4V
		2V
		0V
		-1V
		-3V

Your MultiSim or PSpice screen shot: **__/10pt**

Lab6 Report

Name ____________________ TA ____________________

Teammate ____________________ Score ____________________

TASK 1

Measure the resistance of the strain gauge when you bend the ruler up or down. One can fix one side of the ruler and bend it on the other side. At the same time, another teammate should use another ruler to measure how much the ruler is bent and record corresponding resistance. **Be careful and don't bend the ruler too much**. Finish the measurements of strain gauge according to table below:

__/10pt

Bending-up(cm)	Resistance(Ω)	Bending-down(cm)	Resistance(Ω)
0		0	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	

TASK 2

Based on your measurements above, pick a value for R_1, R_2 and R_3 in your Wheatstone bridge from Figure 3. Then you should refer to Figure 3 and build the Wheatstone bridge circuit. Add a potentiometer in the circuit to make the $\Delta V = 0$. If the DC power output is 5V, what value is the maximum ΔV(bend the ruler at 6cm)?

__/10pt

The value for potentiometer when $\Delta V = 0$: _______________

The maximum ΔV(6cm): ______________

TASK 3

Build the circuit shown in Figure 4. <u>You may need to determine the values of two resistors in the op-amp circuits depending on your strain gauge.</u> The design criterion is that your output voltage should swing from -4 V to 4 V as you push and pull the strain gauge. Record the simulated and actual output voltage and the resistance value of the strain gauge when you push and pull the strain gauge, and fill the table below and **check off by your TA before you disassembly circuit**.

Check off:_______________ **__/10pt** for the circuit

The value of R8:__________ The value of R10:__________ **__/4pt**

The gain of U1A (Difference amplifier):__________________ **__/3pt**

The gain of U2A (Noninverting amplifier):________________ **__/3pt**

__/10pt

ΔV	Calculated Output Voltage	Actual Output voltage
		-4V
		-2V
		0V
		1V
		3V

TASK 4

After this lab, what do you think of the function of strain gauge sensor? Can you get an idea about the application of strain gauge? Describe your idea briefly. **__/5pt**

Challenge Part:

What value for your components? What's the difference between before and after adding low-pass filter circuit? Why it happens? __/10pt

Check off by your TA: ______________