EECS 100/43 Lab 7 – Project Sensor: Strain Gauge

1. Objective

In this lab, you will build an op-amp amplifier circuit for a strain gauge. You will then interface this circuit to a PIC board (labs 8 and 9).

2. Equipment

- a. Breadboard
- b. Wire cutters
- c. Wires
- d. Oscilloscope
- e. Function Generator
- f. Power supply
- g. LMC6482 op-amp
- h. Strain gauge bridge on your lab bench
- i. Various connectors for the power supply, function generator and oscilloscope
- j. Resistors (you will pick their values depending on your strain gauge)

3. Theory

a. System Block Diagram

In this lab you will design a strain gauge system that you can interface to your PIC microcontroller (the last two labs of the summer). Figure 1 shows the expected block diagram of your strain gauge system.



Figure 1. Strain Gauge block diagram

YOU NEED TO READ THIS LAB AHEAD OF TIME SO THAT YOU CAN COME PREPARED IN LAB. MY SUGGESTION IS TO GET TOGETHER WITH YOUR LAB PARTNER(S) WELL BEFORE LAB STARTS AND MAKE SURE YOU UNDERSTAND THE SYSTEM. IF YOU DON'T YOU WILL NOT BE ABLE TO FINISH THE LAB IN 3 HOURS!

ALSO NOTE: THIS LAB IS WORTH 7% OF YOUR TOTAL CLASS POINTS, IT IS THE CRUX OF THE PROJECT (DIGITAL PART IS 3%).

Let us examine the blocks in figure 1 (excluding the scope).

b. Strain Gauge

A nice description of strain gauges is in Chapter 5 of your book. Thus, READ:

- 1. p. 155 in your book (Practical Perspective).
- 2. pp. 165 166 in your book (Section 5.6: The Difference Amplifier Circuit)

We will not be using the 4-pair strain gauge model in your book. Rather (for simplicity) we will be using only one strain gauge and build a Wheatstone bridge network out of discrete resistors. Figure 2 shows the first circuit you will build in lab, this is the "Strain Gauge" block in figure 1.



Figure 2. The circuit inside the Strain Gauge block. The actual strain gauge is modeled by a variable resistor R_{Strain} .

The Wheatstone bridge is also described in your book. Hence, **READ pp. 71 – 72** (Section 3.6: Measuring Resistance – The Wheatstone Bridge) in your book. You will understand that the Wheatstone Bridge in figure 2 is "balanced"¹. Therefore, in figure 2, $V_a = V_b$.

When you deflect the strain gauge, R_{Strain} changes by a very small amount (around 0.5% to 1%). This deflection causes a very small change in V_{ab} . Thus you need to amplify V_{ab} , this is the purpose of your Sensor Interface block in figure 1.

c. Sensor Circuit

Figure 3 below shows a MultiSim screen shot of your sensor circuit. It contains two amplifiers²: a difference amplifier followed by a non-inverting amplifier for additional gain.

¹ A more general condition for a balanced Wheatstone Bridge is in your book. Here we chose all the resistors to be equal, this is a special case of the general condition.

² Note that I have logged into iserver1.eecs.berkeley.edu for the LMC6482 model in MultiSim. Please log into iserver1 (or iserver2 or iserver3) and use the LMC6482 model. Also notice that a real LMC6482 has two op-amps in every IC. So, one IC is enough for this lab.



Figure 3. The sensor interface circuit

Figure 4 shows a screen shot of the completed system in MultiSim. **NOTICE THAT THE POWER SUPPLIES IN THIS LAB ARE 0 and 5 V.** So you should not use the 25 V supply on the bench for this lab. I also assumed a theoretical "rest" resistance of the strain gauge to be 119.4 ohms. The actual resistance in lab will vary depending on your strain gauge. But, AGAIN, PLEASE MAKE SURE YOU UNDERSTAND THIS LAB REALLY WELL BEFORE THE ACTUAL LAB SESSION OR YOU WILL NOT BE ABLE TO FINISH THIS IN LAB IN 3 HOURS! You should now answer the question(s) in your prelab.



Figure 4. The completed Strain Gauge interface. Rstrain is the resistance of the strain gauge. For the simulation above, I have assumed the strain gauge is at rest.

NAME:_____/SECTION____ 4. PRELAB

a. TASK 1 Derive the gains of the two op-amp circuit in figure 3. Fill table 1.

Op-amp	Gain Expression (in terms of output voltages and input voltages)
U1A (Difference amplifier)	G1:
U1B (Noninverting Amplifier)	G2:

Table 1. Theoretical Gain Calculations

Show your work here:

The total gain is: $G = V7/(Vb-Va) = G1 \times G2 =$ _____

b. TASK 2 Log into the remote server and design the circuit in figure 4 using MultiSim. Record the values of (Vb-Va) and the output voltage (V7) of the non-inverting amplifier from figure 4 in table 2 below (use a simulated Multimeter to measure the voltages). You are simulating push and pull on the strain gauge by changing the value of Rstrain.

Rstrain (Ω)	Vb-Va (V) (from Multsim)	V7 (V) (from Multsim)	Simulated Gain [V7/(Vb-Va)]	Theoretical Gain: G [From TASK 1]
120.1				
119.4				
118.7				

Table 2. Simulated vs. Theoretical Gain

Do you have a nice dynamic range for V7 (i.e. does V7 go from approx. 5 V down to approx. 1.5 V)?

PRELAB COMPLETE: _____ (TA CHECKOFF)

5. REPORT NAME(S):_____/SECTION____

<u>a. TASK 1</u> Make sure that there is a strain gauge apparatus on your workbench. Out of the 4 strain gauges on the apparatus, pick one. Measure the resistance of the strain gauge at rest, at the maximum pull and maximum push. I recommend that one partner hold the strain gauge on the bench while the other pushes or pulls³. Record your resistance measurements in table 3.

Position	Rstrain (Ω)
Maximum Pull	
Rest	
Maximum Push	

Table 3. Rstrain values that indicate the position

<u>b. TASK 2</u> Based on your measurements, pick a value for R6, R7 and R8 (R6 = R7 = R8) in your Wheatstone bridge from figure 4. Get this value checked off by the TA.

R for Wheatstone bridge: _____

<u>c. TASK 3</u> Build the circuit shown in figure 4. You may have to change the values of the resistors in the op-amp circuits depending on your strain gauge. The design criterion is that your output voltage at node 7 (V7) in figure 4 should swing from approx. 1.0 V to 5.0 V as you push and pull the strain gauge.

TURN IN ONE REPORT PER GROUP AT THE END OF YOUR LAB SESSION. THERE IS NO TAKE HOME REPORT.

6. REVISION HISTORY

Date/Author	Revision Comments
Summer 2007/Bharathwaj Muthuswamy	Typed up source documentation, organized lab report, typed up solutions.

³ DO NOT APPLY "SUPERHUMAN STRENGTH" ON THE STRAIN GAUGE! If the strain gauge breaks, the person who broke it PAYS for buying a new strain gauge!