Laboratory #2: Sensors, Data Acquisition Systems, and Signal Conditioning

We pledge our honor that this lab represents our own work in accordance with university regulations.

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1.1 Measuring Position Using an FSR

Materials

- A computer that runs Microsoft Windows
- Programs available at:
  http://www.CS.Princeton.EDU/courses/cs436/Lab2/Lab2Code/
- A Long FSR
- A Battery Powered Circuit Board with 4 pin connector
- A National Instruments input block
- Two 9 volt Batteries

Procedure

1. Connect the four pin connector of the long FSR to the circuit making sure to match the black dots.
2. Connect the output wires of the circuit to the National Instruments input block by connecting the black wire (ground) to pin 67 and the red wire (signal) to pin 68 (at Princeton this is done internally, and these are already brought out to binding posts on the outside of the box).
3. Connect the two 9V batteries to bias the circuit.
4. Load the program called scope.prj in LabWindows CVI and run it.

Results & Conclusions

1. What happens as you press on the FSR in various locations?
   The higher we press on the FSR, the higher the voltage. The Lower we press on the FSR, the lower the voltage

2. Is the output a function of how hard you press?
   The harder we pressed, the less noise we got. The weaker we pressed the more noise we got.

3. What is the voltage range of the sensor?
   The voltage goes from 0 volts to 9 volts
4. **How fast can you tap the sensor and see the effects?**
   We set the sampling rate at 44100 Hz. We could tap the sensor approximately 2 times per second and see our results. Once we went to 3 times a second the output signal was unreadable.

5. **What is the effect of changing the sampling rate?**
   When we lowered the sampling rate, the output response got much slower with less precision. When the sampling rate was raised, the output response got much faster and more precise.

6. **What kind of signal conditioning circuit is this (Figure 1.1)?**
   Non-Inverting Amplifier

7. **What are the pros and cons of using this circuit?**
   The advantage of this the Non-Inverting Amplifier is that there is no conversion necessary to obtain a voltage. The disadvantage of this signal conditioning circuit is that we are especially sensitive to the direct output of the sensor so that if physical properties of that sensor change, or a different sensor is used, we will have to recalibrate the system.

### 1.2 Measuring Force Using an FSR

**Materials**

- A computer that runs Microsoft Windows
- Matlab
- A Square FSR
- A Battery Powered Circuit Board with 4 pin connector
- A National Instruments input block
- Two 9 volt Batteries

**Procedure**

1. Remove the long FSR and connect the four pin connector of the square FSR to the circuit making sure to match the black dots. Answer questions 1 through 4 below.
2. Stop running scope.prj.
3. Launch MATLAB
4. Load the program called daqstart.prj in LabWindows CVI and run it.
Set the number of samples to 1000
Set the sampling rate to 500
While slowly increasing the pressure on the sensor, start the data collection. Try to linearly increase pressure across the data collection window, but DO NOT look at the trace while doing it! Have one lab partner say "go" while another pushes the FSR.
Click on the Matlab button. This sends the acquired samples to MATLAB.
In Matlab, execute the plot(cvi_data) command to see the acquired data. Answer Questions 5 and 6 below.
Go back to CVI and acquire 1000 more samples with the sensor at rest on the table.
As before, plot the result in MATLAB.
Repeat steps 11 and 12 while simply holding the sensor in your hand, but applying no pressure.
Remove all of the batteries from the signal conditioning circuit

Results & Conclusions

1. Is the output a function of how hard you press?  
   The harder you press, the higher the voltage. The weaker you press the lower the voltage.

2. What is the voltage range of the sensor?  
   The voltage ranges from 0 volts to 9 volts.

3. How fast can you tap the sensor and see the effects?  
   We set the sampling rate at 44100 Hz. We could tap the sensor approximately 8 times per second and see our results.

4. What is the effect of changing the sampling rate?  
   When we lowered the sampling rate, the output response got much slower with less precision. When the sampling rate was raised, the output response got much faster and more precise.

5. What is the relationship between pressure on the sensor and the voltage output of the circuit?  
   The relationship of pressure to voltage is not linear. However, the greater the pressure the greater the voltage output.

6. Write a function in MATLAB to linearize the relationship between pressure on the sensor and the plotted result.
since we are assuming that force increased linearly across the window, if we plot voltage vs force on a log scale, we obtain a linear relationship.

Formula \[ \text{Voltage} = b \log \text{ (pressure) } \], where \( b \) is a constant

7. What do you see? How does this relate to the quantization of the analog to digital converter?
As noise is a function of pressure, the pressure exerted by the computers in the room and other sources showed up in our graph in digital format. Our graph shows that there is a sharp peak at 90. It does not show the real analog curve from start to finish.

8. Now, what do you see? Why is this different?
There are many more peaks on this graph. This is probably the sound of our heartbeat.

9. Could choosing another signal conditioning circuit eliminate this?  
   Yes, use a Single Pole Low Pass Filter.

10. Could we do some signal averaging to eliminate this?  
    Yes! We did this to eliminate noise on the accelerometer. (look below)

2. Piezo

Materials

- A computer that runs Microsoft Windows
- Matlab
- Piezo
- A Battery Powered Circuit Board with 4 pin connector
- A National Instruments input block
- Two 9 volt Batteries
Procedure
1. Remove the square FSR and connect the four pin connector of the Piezo-transducer to the circuit making sure to match the black dots.
2. Run scope.prj. Answer questions 1 through 5 below.
3. Stop running scope.prj.
4. Launch MATLAB
5. Load the program called daqstart.prj in LabWindows CVI and run it.
6. Set the number of samples to 1000
7. Set the sampling rate to 500
8. While banging the Piezo 3 or 4 times, collect data.
9. Click on the Matlab button. This sends the acquired samples to MATLAB.
10. In Matlab, execute the plot(cvi_data) command to see the acquired data.
11. Try to measure the time-constant of the output.
12. Go back to CVI and acquire 1000 more sampled with the sensor at rest.
13. As before, plot the result in MATLAB.
14. Remove all batteries from the signal conditioning circuit
15. Disconnect the Piezo circuit.

Results & Conclusions

1. Is the output a function of how hard you press?
   The output is not a function of how hard you press.

2. Is the output useful to measure constant forces/pressure?
   There is no output when force/pressure is constant. Thus it would not be useful.

3. What is the voltage range of the sensor?
   The voltage ranges from 0 volts to 9 volts.

4. How fast can you tap the sensor and see the effects?
   We can tap the sensor no more then 8 times a second.

5. What is the effect of changing the sampling rate?
   When we lowered the sampling rate, the output response got much slower with less precision. When the sampling rate was raised, the output response got much faster and more precise.

The piezo is more noisy at rest than the FSR. Thus it can benefit from a low pass filter to reduce the noise.
3. Accelerometer

Materials

- A computer that runs Microsoft Windows
- Matlab
- An Accelerometer
- A National Instruments input block
- 9 volt Batteries

Procedure

1. Connect the output wires of the accelerometer circuit to the National Instruments input block by connecting the black wire (ground) to pin 67 and the red wire (signal) to pin 68.
2. Connect the two 9V batteries to bias the circuit.
3. Point the tab of the accelerometer directly toward the floor.
4. Acquire 1000 points of data at 500Hz sampling rate as you did previously with the FSR.
5. In Matlab: take the mean of the data and store it into maxavg:
   \[
   \text{maxavg} = \text{mean(cvi\_data)}
   \]
6. Point the tab of the accelerometer directly toward the ceiling.
7. Acquire 1000 points of data at 500Hz sampling rate as you did previously.
8. In Matlab: take the mean of the data and store it into minavg:
   \[
   \text{minavg} = \text{mean(cvi\_data)}
   \]
9. Point the tab of the accelerometer level with the floor.
10. Acquire 1000 points of data at 500Hz sampling rate as you did previously.
11. In Matlab: take the mean of the data and store it into zeroavg:
   \[
   \text{zeroavg} = \text{mean(cvi\_data)}
   \]
12. Quit Matlab
13. Write a formula to convert the acquisition levels to acceleration in g's.
14. Load scope.prj in CVI
15. Modify scope.c beginning on line 80 to convert the sensor output to acceleration in g's and save the file in your directory.
16. Run the new scope program.
17. Disconnect all batteries before leaving the lab!

Results & Conclusions

1. What was your formula to convert the acquisition levels to acceleration in g's?

   \[
   (\text{Voltage} - \text{flatAverage})/(0.039) = \text{acceleration in g's}
   \]
2. List the lines you modified or added in scope.c to convert the sensor output to acceleration in g's.

   formula to correct to g's

   scaled_data[i] = (scaled_data[i]-1.416) * 24.7;

   we also tried to eliminate some of the noise by running a 32-point running average

   double sum =0;
   double last[32];
   int j;

   for ( j=0 ; j < 32 ; j++ ) last[j] = 0;

   /** Change this to convert the measured voltage to the actual acceleration in g's **/
   for (i = 0; i<acquired; i++) {
      last[0] = scaled_data[i];
      sum =0;
      for ( j = 0; j < 32 ; j++ ) {
         sum += last[j]/32;
      }
      scaled_data[i] = (sum-1.416) * 24.7;
      for ( j = 31; j > 0 ; j-- ) {
         last[j] = last[j-1];
      }
   }

3. Does the output do what it is supposed to?

   Yes! When we tilted downward we got –1 Voltage (with noise). When we tilted upward we got +1 Voltage (with noise).
reading of new probe at zero-g ( sensor flat on table )

reading at –g ( tab facing up )

reading at 1 g ( tab facing down )

4. **Could you use this output to track head tilt?**
Yes! We could convert voltage into degrees to track head tilt.

5. **Describe some ways to eliminate the noise.**
Calculate the running average, or use a low pass filter.

4. **Questions about the equipment**

1. **The FSRs and Piezo film plug into a small battery powered circuit board.**
   **What is the purpose of that board?**
   To achieve signal conditioning circuitry.

2. **The large square FSR has a resistor attached to it. Why is this necessary?**
The resistor on the large square FSR acts as a reference voltage. The long FSR has two resistive films interweaved so it does not need the extra resistor.