**EN 580.471** **Fall 2008**
**Principles of Design of Biomedical Instrumentation**

# Lab 5: Application of Sensors

This is a semi-open ended lab where you will become familiar with various types of sensors used in biomedical applications. You will be working with the following sensors:

- Phototransistor Reflective Object Sensor (QRB1114)
- Thin film piezo-resistive force sensor (FlexiForce)
- Pressure sensor (HoneyWell)

**General Instructions:**

i. The datasheets for the components are on WebCT. Refer to them before working on the pre-lab. The other sensors on the list will be available for you to experiment with if time permits.
ii. The pre-lab for this lab is worth more than usual pre-labs as you will be using sensors for the rest of the course.
iii. Read the entire lab handout before working on the pre-lab.
iv. Since your answers to this pre-lab will determine to a great extent what you build in the actual lab, the graded pre-labs will be available for pick-up in Clark 318 after 12pm on the Monday following the lab session.

**<u>Pre-lab</u>** **[30 points]**

For **each** of the above sensors do the following: (**Please do this one sensor at a time**)

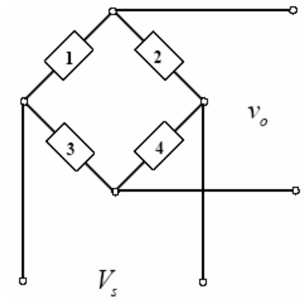
i. Describe how the sensor works **[2 x 3 = 6]**
ii. Describe how you would calibrate the sensor (in bullet points) **[2 x 3 = 6]**
iii. Draw a schematic of a circuit that implements the sensor and provides usable output that can be viewed on the scope and its interfacing with a PIC chip to do something creative based on the sensor output. Read the post-lab to figure out what kind of things we are expecting you to implement. The lab has sound buzzers, LED's of different sizes/colors available for use.
If you want to use some other parts email the TA's to check if it is available in the lab. **[5 x 3 = 15]**
iv. Give a creative biomedical application of the sensor **[1 x 3 = 3]**

**Note:** You are responsible for choosing an appropriate circuit based on the nature of the sensor and your desired application. You may use anything in the lab that you have had experience with, i.e. analog circuitry, amplifiers, filters or any other circuits you like. Points will be deducted if you miss significant circuit components/connections that are required for your sensor to work.

**Study Question (to be handed in with the pre-lab)** **[15 points]**

On the datasheet for the pressure sensor a Wheatstone bridge is used.

i. For the following bridge compute the output voltage $V_o$ in terms of $V_s$ and the resistors $R_1$, $R_2$, $R_3$ and $R_4$. No credit will be given just for the result. Please show the entire derivation. When is the null condition satisfied? **[5 + 1 = 6]**




ii. Draw a complete circuit schematic that employs a Wheatstone bridge in a typical biomedical circuit that measures a small physiological signal. If powered with a 5V signal the sensor gives an output in the range 0-150mV in response to varying pressure. Assume that the code in the PIC chip used to interface with this circuit requires a voltage input in the range 0-4V with 4V corresponding to the highest possible value the sensor can read. Please show all relevant calculations needed for the schematic. **[6]**

iii. Describe how the bridge works. **[2]**

iv. Give a biomedical application where this bridge could be used. **[1]**

**Lab Procedure**

From the above sensors, a distance sensor must be implemented. In addition, pick one of the two other sensors (FlexiForce or Honeywell) to implement. Be sure to get one of the TA's to check you off after each stage.

**Stage 1:** Build a circuit implementing the 2 sensors as indicated in your pre-lab.
Make sure to include appropriate filtering and amplification wherever necessary.

**NOTE:** The PIC is a very delicate piece of equipment! It cannot handle voltages above 5 volts or below 0 volts (which your op amps produce!). In order to protect the PIC, a resistor must be placed between your sensor curcuit (for example, op amp output) and the PIC. This way, if the voltages go past the PIC's tolerance, no excess current will be drawn from or into the PIC. A good resistance is around 10k for op amp outputs. Furthermore, you should design your sensor circuits so that the valid output does not go past the PIC's tolerances.

**Stage 2:** Characterize the operation of the sensor. The goal is to understand how the sensor works and how to implement it. Please make sure to characterize and calibrate the sensor! Look at performance criteria that you can quantify or at least qualify, in particular, think of the following:
i. Draw a transfer function based on your data. Is it linear or non-linear?
ii. How sensitive is the device? Can you obtain a quantifiable measure?
iii. How much gain is required to make reasonable measurements?

**Stage 3:** Based on your distance sensor output, pick a reasonable measure (for example, 3cm from the distance sensor) and use this to produce some binary output on your PIC (turn on a buzzer, turn on a light)

**Stage 4:** Use your other sensor's output to produce a variable output on the PIC (increase the frequency of the buzzer, or increase the intensity of the LED). How could you implement variable frequency, or intensity on from the PIC?

**Stage 5:** Once you have implemented these, combine them to produce some output on the PIC (for example, only when a threshold distance AND theshold pressure is detected and maintained, the PIC turns on an LED). The goal is for you to think about how to combine signals from various sensors on the PIC, and how to process these signals for useful output. Feel free to be creative, you won't be penalized if you can't get it working in the limited amount of lab time. Keep in mind that these sensors, along with others, will be available for use during your projects.

And finally, please save you circuit(s) for next week's lab.

Wireless fun coming up!

**<u>Lab Write-Up</u>** **[40 points]**

i. Plot the **calibration curves** of the 2 sensors you used in the lab [Attach neatly formatted data tables]. Comment on the transfer function and wherever possible come up with an equation or value for sensitivity. **[15]**
ii. Draw neat labeled schematics of the circuits you built in lab. If you choose to draw them by hand make sure your work is legible. Label different components, sensors and include the actual values of resistors and capacitors used. **[15]**
iii. Explain what final circuit does. **[3]**
iv. How did you test the operation of your circuit? Please write this in point format as opposed to paragraphs. **[3]**
v. Include briefly commented and indented PIC code that you used in lab. **[4]**

**Survey Questions [Extra Credit]**

i. Explain any problems you faced and how you solved them. (Was buffering required? Was input resistance a problem? Was the device unreliable? etc) **[1.5]**
ii. How could this lab be improved for the future? Any particular assistance you needed from the TA's? Any cool sensors you would like the instrumentation lab to invest in? **[1.5]**

**NOTE:** Bonus points will be awarded at the TA's discretion for creative and ingenious ideas that were implemented in lab or schematically attached with the pre or post labs. This is a great opportunity to make up for lost points during the semester.