Homework 7: Design Project

# Overall Goal

For the final homework assignment of this course, you will design a device that has a biomedical application. In the BIEN 435 Biomedical Senior Laboratory course, next year, you will perform an experiment designed to measure the elastic modulus of a chicken bone. The measurement centers around a force transducer that measures the resultant force when the bone is compressed with a known deflection. Some requirements for the transducer are.

1. It must be relatively thin, less than 1 cm.
2. It should measure forces up to 20 newtons.
3. The noise level should be less than 5% of full scale.
4. It should be inexpensive, less than $20 in total.
5. It should be durable such that an overload up to 100 newtons will not cause damage.
6. The calibration factor should be repeatable.
7. Total deflection of the transducer at 20 newtons should be no more than 1 mm.

Follow the following design process in this project. Remember, however, that engineering design is an iterative process, so you are allowed to step backwards as well as forwards. For example, you may run into a problem with model construction that requires you to revise the initial design, or in the process of testing the model, you may decide that a design criterion needs to be modified to account for a problem that was unanticipated.

1. **Define the Problem to be Solved and Specify the Design Criteria**: Look carefully at the seven design criteria listed above and decide whether (1) more criteria should be added or (2) any of the criteria need to be more quantitative. Consider the five types of factors that were described in Lecture 1, signal, environmental, social, safety, and economic. Make your design criteria as quantitative as possible.
2. **Consider Multiple Options and Choose an Initial Design**: You may choose any design that you consider to be viable. However, the following two concepts are suggested. (1) A resistive concept in which a semiconductive material is sandwiched between two conductive plates. A force on the plates decreases the separation between them, which reduces the resistance according to the resistor formula, . The semiconductive material can be silicon sealant doped with fine graphite (pulverized from a pencil lead). You will need to perform tests to determine the amount of doping needed to obtain a reasonable resistance. (2) A capacitive concept in which a dielectric is sandwiched between two conducting plates: A force imposed on the plates causes the separation between them to decrease, which increases the capacitance. This capacitor is placed in a Wheatstone bridge, driven by an AC voltage. The output voltage is rectified and low pass filtered to obtain a signal. One dielectric material is double-sided tape.
3. **Construct an LTSpice the Model of the needed circuitry**: The circuitry is the Wheatstone bridge and the accompanying circuitry to obtain a single-ended output proportional to force.
4. **Construct and characterize the sensor**: Whichever design you decide to implement, you must create a physical sensor and characterize output (resistance or capacitance) as a function of applied force.
5. **Incorporate the sensor in the circuitry**: Construct the Wheatstone bridge and use it to provide a voltage that corresponds to the resistance/capacitance value of the sensor element.

Present sketches of your design and results of LTSpice in a short report, following the lab report format used in this course. This format complies with the design process that was outlined above as follows:

**Introduction:** Define the problem to be solved and specify the design criteria. For the sake of brevity, you do not need to list all design criteria for sub-modules, but you should have at least five specific criteria that can be tested quantitatively.

**Methods:** Consider multiple options and choose an initial design. Describe your chosen design in some detail. Then describe the virtual experiments that you performed to test each design criterion. Introduce a figure of your overall sketch (Figure 1) at the beginning of the Methods section. The overall logic of your design should be clear from this figure and from its associated discussion.

**Results:** Describe the results of each test. Include appropriate plots. A plot of the primary signal as a function of time will be shown in the Results section along with simulation results from LTSpice and output from the microcontroller (if used). Provide enough results to either verify or contradict satisfaction of all the stated design criteria. Again, for the sake of brevity, show results for only the most important design criteria.

**Discussion:** Summarize which design criteria were met and which were not. Where criteria were not met, propose reasons that explain why. Describe modifications that should be made.

In your Discussion, describe first which design criteria were fulfilled (as verified by the LTSpice simulation). In addition, include at least five of the following factors, as related to the device: global, cultural, social, environmental, economic, and public welfare (e.g., health and safety). (An article about the distinction between cultural and social factors can be found at this URL <https://www.differencebetween.com/difference-between-social-and-vs-cultural-factors/>. For the sake of this assignment, social aspects correspond to those aspects of society that are common to nearly all who live within a society, such as our infrastructure and our educational and political systems, whereas cultural aspects are more internalized attitudes that may differ from one group to another.) Discuss how these factors may cause some (e.g., ethnic, cultural, socioeconomic, religious) groups of people to not accept the device or may be less favorable to some groups of people than to other groups.

**Conclusions:** State the extent to which the device is successful and the most important issue that needs to be addressed in the design.

Along with your report, upload your LTSpice .asc file.

Evaluation will be based on

1. Acquisition and presentation of the primary signal. (15%)
2. Use of LTSpice and/or other analysis. (15%)
3. Workability of your design. (20%)
4. Thorough testing of all stated design criteria. (20%)
5. Creativity (10%)
6. Report clarity (10%)
7. Discussion of global, cultural, social, environmental, economic, and public welfare (e.g., health and safety). (10%)