**Signal Conditioning Entrepreneurially Minded Learning (EML) Design Project**

ECCS 2311

**Project Overview:**

Students should organize into groups of *two to three students* (from at least two different departments, if possible) to design and build a ***signal conditioning circuit*** that is applied to the underlying robotics problem described below. Each group represents a fictitious startup company bidding for seed funding from a group of venture capitalists (played by the Electric Circuits instructor) in order to bring your signal conditioning circuit to market. Each company must pitch a proposal in an effort to convince the venture capitalists that the design is a suitable, scalable, and cost-effective *solution to the problem* that is in some way unique and more advantageous than competing signal conditioning solutions for this problem.

**Problem Description:**

A linear taper potentiometer is used as a position sensor in the control process of an electric DC servomotor for a joint of a robotic arm. The sensor output signal indicates the instantaneous position of the rotor allowing closed loop position control of the motor (joint of the robot arm) between 0$°$ and 270$°$. Based on the position of the rotor [0˚, 270$°$], the sensor output can be seen as a voltage signal in the range [5V, 12V] as shown in Figure 1.

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| Figure 1 (a). Rotor diagram | Figure 1 (b). Rotor position signal |

Figure 1. Data specifications of a motor control potentiometer position sensor.

In order to digitize the control loop, an Analog to Digital Converter (ADC) is used and the digital version of the sensor signal is then fed to a digital processor. According to the data sheet, the ADC has an input range of [1.0V, 4.0V] and sinks no more than 10mA at its input (this means the ADC requires no more than 10mA to operate correctly).

**Minimal Design Requirements:**

The signal conditioning system should map the position sensor voltage signal to another voltage signal applied to the input of the ADC *without any loss of information*. The signal conditioning system is integrated in the system as shown in Figure 2. A successful circuit must deliver a [1, 4] volt DC signal when the input is a [5, 12] volt DC signal, and be capable of sourcing up to 10mA to the ADC. An affine mapping of the sensor signal to the ADC input signal is desired (i.e., a straight line).



Figure 2. The overall digital sensing system.

**Design Hints:**

Op amp circuits may perform the desired mapping of the signal conditioning circuit described above and can source 10mA of current. It is a good design practice to leave some room for run-time user adjustments. This can be achieved by using one or more adjustable components. For example, a potentiometer instead of a resistor or a variable capacitor instead of a fixed value capacitor enables the performance of the circuit to be tuned in order to improve accuracy.

**Project Deliverables, Grading, and Due Dates:**

1. **Team Charter** **(5%)**
* List the set of rules and expectations for your team you believe will help to avoid the common pitfalls discussed in the Overcoming Pitfalls of Team Projects worksheet. Some examples of rules may be proper preparation and attendance at group meetings, exercises to quiz each other on the demonstration, honest communication when conflicts arise, etc. Each team member must sign the sheet thereby indicating acceptance to comply with the rules and expectations.
* Note: This set of rules and expectations is for your use and benefit. The instructor will make a copy and return it to you to use as a reminder of how to avoid the common pitfalls.
* **Due:** Tuesday, October 3, 2017 by the end of lab
1. **Design Alternatives Document** **(10%)**
* Producing alternative design solutions is a beneficial step in the engineering design process. For this project, your alternative designs will be considered competing solutions to the problem. Each solution must be *viable* (i.e., meet the constraints set forth in the problem statement) and *unique* (one cannot be a trivial modification of the other!), and should be compared using identified *evaluation metrics* (cost, power requirements, adjustability, etc.). In order to effectively compare the design solutions, each solution should be *analyzed mathematically* (e.g., nodal analysis) to show the desired input-output mapping and should be *simulated* in PSPICE (with a detailed description of the simulation setup). This document may be handwritten or drawn, but include the PSPICE circuit models and simulation results. For the cost criterion, identify one circuit component supplier (such as Digi-key, Mouser, Jameco Electronics, etc.) and find all parts necessary to build your designs. Use bulk pricing (e.g., consider constructing 10,000 circuits). Be sure to list the *bill of materials* (BoM) and *supplier part numbers* so the cost analysis may be double checked.
* **Due:** Friday, October 27, 2017 at the beginning of class
1. **Written Product Proposal (65%)**
* Feedback on the design alternatives will be provided by the instructor within a week in order to improve the design presentation, simulations, and mathematical approach. The written product proposal should include the following:
	+ **Introduction section** that motivates the underlying problem, briefly describes the approach to the solution, and provides an outline for the remainder of the proposal.
	+ **Problem Description section** that describes the problem and system architecture and identifies the design constraints and evaluation metrics. The input and output signals to each component of the system should be identified and described.
	+ **Alternative Solution and Analysis section** that should describe each design alternative first at the conceptual level. The circuit diagram of each solution should be provided (drawn neatly using PowerPoint, Word, or other drawing software). Nodal analysis should be applied to each solution to show that each solution provides the correct input-output mapping of the voltage that meets the need. Real component values should be selected, so the designs may be implemented
	+ **Simulations section** that provides the PSPICE circuit models of each alternative solution. The simulation setup should be described in detail with the type of analysis performed and all necessary details. The simulation results should be provided and analyzed to validate that each design alternative is viable (i.e., meets constraints). Be sure that all plots and figures are embedded within the proposal (not as attachments) and colors are inverted on the PSPICE plots (do NOT have a black background!).
	+ **Cost Analysis section** that first identifies at least two suppliers for the circuit components necessary to construct the circuit and secondly identifies at least one distributor who would potentially sell the signal conditioning circuit. Provide a Bill of Materials (BoM) that outlines all necessary components for each alternative solution and the associated cost for each component for each solution and for each supplier (include supplier part numbers). Assume you plan to construct 10,000 units of the signal conditioning circuit to take advantage of bulk pricing. Compare the cost per unit of each alternative design solution and indicate which supplier is a better choice.
	+ **Value Proposition section** that uses the NABC approach to advocate for the superior design alternative. The approach should be emphasized, as well as the benefits per costs, compared to the inferior design alternative. However, it is also necessary to clearly restate the underlying need (from the robotics example) and identify based on the evaluation metrics why the preferred design is selected (use results from simulation or measurements from implementation where appropriate to provide evidence for your assertions). This is the section in which you make the case for this decision.
	+ **Testing and Implementation section** that outlines all measurements and unit testing that is performed on the superior design solution. At a minimum, all component values should be measured (e.g., resistance values), op amps should be tested (e.g., using a simple buffer amplifier), and currents, voltages, and powers should be measured in order to validate component selection (e.g., ¼ watt resistors better dissipate less than ¼ watt!). By power conservation remember that power supplied equals power absorbed, so if you measure the power supplied by each source, you can easily state the power required by your circuit. Hint: Use a few values of input voltage to try to find approximately the maximum power required in this power measurement. The ADC may be crudely modeled using a 500Ω resistor in your testing (will sink 10mA with 5V across it). Report the results of the tests and measurements, and organize the measurements and tests into a set of methods and procedures. Ideally, the test procedures and methods should read like a set of laboratory procedures.
	+ **Conclusion section** that briefly summarizes the problem and superior solution at a high-level. Summarize the critical aspects of the approach and benefits that make it (the superior solution) better than the alternative. Describe the lessons learned from the design and implementation process of the project.
* **Due:** Friday, December 1, 2017 at the beginning of class
1. **Working Prototype and Demonstration Pitch (20%)**
* The superior design should be constructed on a breadboard and tested. Brad Hummel, our electronics technician, can aid you in component selection and troubleshooting, or you may ask your instructor during office hours. There is a lab period dedicated to constructing the prototype of the design before Thanksgiving break, but be sure to use that time wisely (have all components selected, and have your procedure in place and ready to go before lab so you can use that lab to complete as much of testing as possible). The demonstration will be a 5-minute pitch of your superior design, with a concise review of the design alternative, the constraints of the designs, and evaluation metrics used. Describe your NABC value proposition for your superior design. Thus, at the minimum, the group must briefly describe the underlying problem (i.e., the need), describe the functionality of the two circuits (approach), describe the means to validate the design (simulations, measurements, test procedures, etc.), and finally indicate which evaluation metrics led to the choice of your superior design and why those metrics are reasonable (benefits per costs…note that cost here may mean power or other evaluation metric). Be sure to demonstrate that the prototype works (i.e., it achieves the design requirements).
* **Demonstration:** Lab period, last week of classes (December 5, 2017).