**Temperature Sensing Entrepreneurially Minded Learning (EML) Design Project**

ECCS 2311

**Project Overview:**

Students should organize into groups of *three to five students* (from at least two different programs, if possible) to design and build a ***temperature sensing circuit*** that is applied to a problem you will identify (see below for more details). 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 temperature sensing circuit to market (treat this documents similar to a Request for Proposals (RfP)). Each company must pitch a proposal in an effort to convince the venture capitalists their 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 Framing and Needs Finding:**

Assume the temperature sensing circuit will interface with a microcontroller that accepts a voltage in the range of 0 to 5[V] and will be used in a control law implemented on the microcontroller. For this, the customer needs the voltage-temperature characteristic of your temperature sensor circuit. The only specified guidelines are to make sure the output voltage is 0[V] at a temperature of 25˚C, and 5[V] at a temperature of 50˚C.

The problem is only loosely defined intentionally. In order to convince the venture capitalists that your idea is worth investing in, you must envision a compelling or important need that is addressed by the temperature sensing circuit. This “need” will be integrated later into your value proposition for your solution. The key features to consider are the temperature range (25˚C - 50˚C) and the fact that there would be an embedded processor available to address the need (although you will NOT implement anything with a microcontroller; this is just for framing the need/application). You will want to identify any other constraints and evaluation metrics that are relevant to your identified application and need.

**Design Requirements:**

The temperature sensing circuit should use a *thermistor*, which is a variable resistor whose resistance value varies significantly with temperature. The thermistor available for you to use in your design is made by GE and is a Negative Temperature Coefficient (NTC) thermistor, which means that the resistance decreases with increasing temperature. The specific model you are to use is the RL1005-5744-103-D1 (the data sheet is provided separately). The temperature dependence of an NTC thermistor is given by the equation:

$β=\frac{ln⁡(^{R}/\_{R\_{0}})}{^{1}/\_{T}-^{1}/\_{T\_{0}}}$,

where *T*0 is the reference temperature in Kelvin [K], *R*0is the resistance of the thermistor at the reference temperature in ohms [Ω], *T* is the temperature under consideration (in Kelvin), *R* is the resistance of the thermistor at temperature *T*, and *β* is a constant called the B-constant (measured in Kelvin), which is used for a given temperature range to approximate the temperature-resistance dependence. For the RL1005-5744-103-D1model, *T*0 = 298.15[K] (equal to 25˚C), *R*0= 10[kΩ], and *β* = 4073[K] for the range of 25˚ to 85˚C (which includes the operating range for the temperature sensor). The error tolerance for this model is ±10% (in resistance at a given temperature). The time constant is $τ=10$ seconds. The power dissipation constant (δ in the data sheet) at 25˚C is 2.5mW/˚C. This parameter specifies the power dissipation per degree Celsius. Keep this and other power considerations in mind for your design (especially, how will the circuit be powered along with battery life). Be careful operating the NTC thermistor above the mA range, in which case self-heating can be a problem, and significantly complicates the analysis.

**Design and Implementation Hints:**

Op amp circuits may be integrated with the thermistor described above to provide the 0V to 5V signal needed. 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 enables the performance of the circuit to be tuned in order to improve accuracy.

When selecting components for the bill of materials, try to be consistent with the mounting styles. For example, if one component is surface mount, it is better for all components to be surface mount from a manufacturing standpoint. Also, do not select a panel mount potentiometer for use in a circuit where the potentiometer should just be used to tune it to a specific value of resistance without further user adjustment. The size of a panel mount potentiometer is larger than desired for this application as well. Finally, ensure the power rating of components is verified in your analysis or simulations. Try to find the least expensive components given the constraints and design criteria.

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

1. **Design Alternatives and Problem Framing Document** **(40%)**
* *Problem Framing*: The problem statement for the need should be described in a few paragraphs. Identify the constraints and evaluation metrics used (okay to be a bulleted list). This will be submitted with all team member’s names on the document and separate from the individually submitted design alternatives, described below.
* *Design Alternatives*: 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 underlying need you have identified. 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). *Each student will submit their own design alternative and this part of the assignment will be graded on an individual basis*. 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:** Tuesday, October 30, 2018 in lab
1. **Written Product Proposal (60%)**
* Feedback on the problem framing and design alternatives will be provided by the instructor in order to improve the problem framing, design presentation, simulations, and mathematical approach. The written proposal should use ***present tense*** throughout the report (except in reflecting) and include the following:
	+ **Introduction section** that motivates the identified need, briefly describes the solution approach with major results, 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. Be consistent in part selection across designs and suppliers so there is a like for like comparison.
	+ **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 alternatives. However, the underlying need is critically important and should be a major focus of the value proposition. Be sure to 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. Use structured text (i.e., bullets).
	+ **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. 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. Outline in a table the tasks done by the group in the project and provide a percent breakdown of contribution in each task by each member.
* **Due:** Tuesday, November 27, 2018 in the lab