APPLIED PHYSICAL SCIENCES

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

APPL 240

Developing Your Sixth Sense: Designing Sensors and Electrical Circuits to Make Measurements

Spring 2024

Introduction	How can you measure temperature, pH, heart rate, movement, distance or anything else in the physical world? First, you need a sensor! These sensors typically measure that physical quantity and convert it into an electrical signal, which then gets processed with an electrical circuit. In most cases, you want to send the electrical signal to a computer or other development tool, such as an Arduino for processing, recording, and displaying the result to the user.
Method	In this class, we will learn how to analyze, design, and build systems for this entire process. We will use a variety of sensors that measure physical parameters such as force and acceleration, and environmental parameters such as temperature. We will model these sensors and understand how they work and interact with electrical circuits. We will learn the basics of circuit design and analysis so that we can amplify and "clean up" the signals with filters. Finally, we will learn how to acquire these signals to a computer through data acquisition hardware and Matlab software. The course will have an active learning format. Typically, we will start by learning new material, and then transition to problem solving or hands-on laboratory exercises to reinforce these new concepts. There will be a final project in which students design and develop a system that measures a parameter, and acquires and analyzes the resulting signal on the computer.
Results	By the end of the course, students should be able to do the following: ● Model and simulate the sensors that we cover in this course. ● Determine which sensor is appropriate for different applications. ● Design and analyze electrical circuits that are appropriate for amplifying and filtering signals from sensors. ● Use MultiSim software to simulate electric circuits. ● Interpret the information on data sheets and other materials about sensors and electronic components; use this information to ensure your designs are appropriate. ● Interface electrical circuits with computers through A/D acquisition board. ● Write Matlab programs to acquire, analyze, and display electrical signals on a computer.
Discussion	The technical material that you will learn will provide you with a valuable skillset. In addition, a goal of this class is to help you develop an entrepreneurial mindset so that you will understand the bigger picture. For example, when choosing a type of sensor and designing a circuit for a real-world application, what are the economic, environmental, and ethical issues that affect your decision? These considerations are

	important to make a positive impact on our society through engineering and technology.
Engineering Student Outcomes	By the end of this course, students will gain experience in the following engineering student outcomes: • Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. • Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. • Recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. • Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions. • Acquire and apply new knowledge as needed, using appropriate learning strategies. • Demonstrate constant curiosity about our changing world. • Integrate information from many sources to gain insight.

Class Essentials

Contact Information

Dr. Richard Goldberg	Teaching assistants
Office Location: 156 Caudill **Email:** r.goldberg@unc.edu Office phone: (919) 966-5768 Cell phone: (919) 260-9873 **Office Hours: Mondays 1-2pm, Tuesdays 12:30–1:30pm** **or by appointment**	N/A

Logistics

Class meeting times
Mon/Wed 2:30-4:25 pm

Class meeting location
213 Morehead labs

Required Texts & Software
zyBooks e-textbook ($64)
Matlab software (no cost)

Pre-requisites
- PHYS 115/117/119 Electricity and Magnetism

Course content

Course Topics	Types of sensors	Types of circuits
Part 1: Resistive sensors	Force sensitive resistor, thermistor, strain gauge	Resistor circuits Wheatstone bridge and amplifier circuits D/A and A/D conversion
Part 2: Optical sensors and indicators	Infrared LEDs and photodiodes/phototransistors	Non-linear circuits: diodes and LEDs
Part 3: Capacitive sensors	Microphones, accelerometers	RC circuits (resistors & capacitors) Digital sampling rates Filters
Part 4: Other indicators	motors and actuators	circuits needed to drive motors and actuators

Course Schedule

For week-by-week schedule, see link on Canvas

To help you succeed

Health

Your mental and physical health are very important to me! Let me know how I can support you and your health this semester. If you need accommodations from ARS, please let me know ASAP.

Course Expectations and policies

Attendance:

- Much of the work of this course takes place during class time
- Attendance may be a factor when I compute your final course grade
- If you cannot make it to class (and you have a good excuse!), please let me know, especially if we have a lab or quiz that day
- During class time, do not use your phone or computer for something unrelated to class

Assignments and late policy

- There are lots of assignments in this class
- Deadlines come quickly and are listed clearly on Canvas
- You are responsible for keeping track of deadlines – note both the date and time of each deadline
- Deduction 5% for each day late (except for homework). After 1 week, assignment submissions are closed and you get a zero
- Exceptions will be made for severe illness or emergency, but you must let me know ASAP

Homework and quizzes

- Each two week period will start with 1 week of new material; the second week will have a HW and quiz on the material from the previous week
- HW answers will be revealed during or right after class on Monday
- Therefore, I cannot grant extensions on HW
- Once the quiz is over, you still may need to use that material in a future assignment
- There will be a comprehensive final exam
- I will drop lowest HW grade and lowest quiz grade

AI Policy

Generative AI can be useful. But the use of AI could be counter-productive in helping you to develop strong engineering and communication skills.

With that in mind, here are the AI guidelines:

- Writing Matlab programs: AI is permitted but you must cite its use
- Circuit analysis and design: AI is not going to be helpful! However, Multisim may be helpful to check your answers and you are permitted to use this.
- Writing reports: In principle, you may submit material that contains some AI-generated content, or is based on or derived from it, if this use is properly documented. This may include drafting an outline, preparing individual sections, combining elements, removing redundant parts, and compiling and annotating references. Therefore, AI can be the starting point but not the end point, and you should not be copying significant amounts of text word-for-word and submitting it as your own, without making changes first. In addition, your documentation must make the process transparent – the submission itself must meet the relevant standards of attribution and validation.
- Any violation of this policy may result in a zero on the assignment and/or submission to the honor court

Academic Honesty

There will be clear communication if assignments are individual or group. For individual assignments, while I encourage collaboration, it is a violation of the honor code if a student duplicates work or obtains solutions from another student and submits it on their own. Please reference the honor code: http://honor.unc.edu.

Assignments & Evaluation

Your Course Grade

Assignments	Weight	Details
Participation activities, class attendance	10%	These are done after reading the book or watching video lecture but before coming to class
Homework (7 HW, drop lowest grade)	15%	These will focus on circuit analysis and design problems
Bi-weekly quizzes (7	30%	These will be open-book, open-note

quizzes, 20 min each, drop lowest grade)		
Final Exam	10%	Open-book, open note
Labs and lab report (5)	20%	Labs will take place during class time. Students will submit lab reports.
Final project due at MakerFest	15%	A design project to develop a sensor system.

Grade Interpretation & Honor Code

Your final course grade will be determined from a standard scale:

A	93+
A-	90.0 - 92.9
B+	87.0 - 89.9
B	83.0 - 86.9
B-	80.0 - 82.9
C+	77 - 79.9
C	73 - 76.9
C-	70 - 72.9
D+	67 - 69.9
D	60 - 66.9
F	<60

Major Course Due Dates

Final Project	Due at Makerfest

Class recording policies

The University may record meetings of this class for educational purposes. These recordings will be shared only with students enrolled in the course for purposes of academic instruction only. Your instructor will communicate to you how you may access any available recordings.

Unauthorized student recording of classes on personal devices or on any other format is prohibited.

Students requesting the use of assistive technology as an accommodation should contact Accessibility Resources & Service. Other students must obtain express permission from the department to record the class, and the University will only grant such permission in extraordinary circumstances in which the student otherwise lacks access to a recording made by the University or instructor. Students shall not copy, reproduce, or distribute any recordings of their classes, and students shall delete any recordings at the conclusion of the course.

Any violation of these prohibitions or restriction on the making, use, copying, or distribution of recording of classes shall constitute an honor code violation.

This class will follow all UNC policies, as outlined here: https://curricula.unc.edu/wp-content/uploads/sites/1311/2024/01/Spring-2024-Abbreviated-Syllabus-Policy-Insert_Final.pdf

I reserve the right to make changes to the syllabus, including project due dates and test dates (excluding the officially scheduled final examination), when unforeseen circumstances occur. These changes will be announced as early as possible so that students can adjust their schedules.