# ECEN 5053-003 Syllabus Fall 2018

|  |  |  |  |
| --- | --- | --- | --- |
| Instructor | Jay Mendelson | E-mail | Jay.Mendelson@Colorado.edu |
| Office | None (I teach online) |  |  |
| Office Hours | None fixed. Send email to me, and we can have Zoom meeting, if needed to discuss class issues |  |  |

## Overview: Embedding Sensors and Actuators

### Description:

This course will introduce students to the design of sensors and motors, and to methods that integrate them into embedded systems used in consumer and industrial products. Students will learn about sensor technologies and motors through lectures, recorded and online videos, online reading, and through laboratory experiments. Students will build systems that take sensor inputs, and sorts, filters and evaluate the resulting data. They will also learn how to use the sensor input to measure properties of motors. There will be quizzes given during lecture time, as well as a midterm and final to measure a student’s knowledge of the class material.

### Lectures:

Tuesday and Thursday, 6:00-7:15 PM, HUMN 1B90, also via Zoom Meeting run by Distance Learning Studio

### Synchronous Participation (for distance students)

- Meeting ID: 297-372-425

- Connection options:

- Join via web browser: <https://cuboulder.zoom.us/j/297372425>

- Join via Zoom app (using meeting ID)

- Join via iPhone one-tap: US: +16699006833,,297372425# or +16465588656,,297372425#

- Join via telephone: US: +1-669-900-6833 or +1-646-558-8656

(Note: for higher quality, dial a number based on your current location)

### Textbook:

Handbook of Modern Sensors by Jacob Fraden, Fifth Edition. Springer Science+Business Media, LLC ISBN 978-3-319-19302-1 for hardcover book. ISBN 978-3-319-19303-8 for ebook. Enrolled University of Colorado Boulder students may access the e-book free of charge from this web site: <http://ucblibraries.summon.serialssolutions.com/#!/search?ho=t&l=en&q=handbook%20of%20modern%20sensors>

### Other Reading Material or Videos:

There will be weekly online reading and online videos assigned in Canvas. You will need this information to do weekly homework and perform well on exams. You will be assigned all course material and expected to upload all course work to: <https://canvas.colorado.edu/courses/21120>

You will be able to see taped versions of the lectures created by the Distance Learning Studio. Go to this web site for information on how to do this:

<https://oit.colorado.edu/tutorial/distance-learning-studios-canvas-integration-mediasite>

### Homework:

There will be weekly, graded homework assigned in Canvas. Students may collaborate on homework, but each student is expected to do their own work and solve the problems independently. Rote copying from online solutions will not get you the full credit for the homework. All homework must be completed in electronic format (MS-Word, Google Docs, Excel, Google Sheets are the 4 formats accepted) All homework assignments must be loaded into Canvas on time. Late homework will not be accepted.

### Labs:

The class will have six graded, laboratory exercises throughout the semester. These will be performed in the ITLL, using the Cypress PSoC development kit along with the associated PSoC Creator” Software. All lab instructions, as well as excellent instruction for using the kit will be made available via pre-recorded videos. You will be given all components to use by our TA’s. We will have PSoC Creator running on our computers in ITLL lab stations for the 2018-2019 academic year. The lab projects will be done in groups of two, to be defined by the students themselves. You may ask the TA’s for assistance when performing the labs, but they are not there to give you explicit instructions for the work you need to do.

Students are expected to collaborate only with their lab partner. Each team of two will provide a lab report for their work, as defined in the lab assignments. All labs must be completed in electronic format (PSoC Creator files are the only format for code and schematic info. You may use either MS-Word or Google Docs for the lab report. All lab assignments must be loaded into Canvas on time. Late labs will not be accepted.

### TAs:

TA Contact Information: Monish Harish Nene <Monish.Nene@colorado.edu>

TA Contact Information: Anay Gondhalekar <Anay.gondhalekar@colorado.edu>

### Class web site:

<https://sites.google.com/a/colorado.edu/ecen5053-003/home>

## Content

This course is a blend of theoretical, practical, and commercial engineering education. Students will be taught the physics, chemistry, electrical engineering, and mechanical engineering principles that govern the operation of sensors and motors. They will reduce the principles to practice in lab experiments to create schematics, wire sensors and motors into working circuits, and write firmware within the PSoC operating system. They will learn how industrial companies design, calibrate, test, manufacture, and market these devices, and be trained to specify and purchase them for specific applications.

Topics will include:

* Physics and chemistry behind the sensor and block diagrams of sensor measurement systems
* Definition of the signal chain: excitation, amplification, filtering, offset, sample, convert, cache, and digital filter.
* Common types of amplifiers used for sensor signals
* Sources of noise and methods of reduction
* Practical details on supporting components for sensors and motors: resistor, capacitor, inductor, amplifier, ADC, DAC, GPIO, diode, transistor, switch, LCD,
* Physics, mechanical engineering, and electrical engineering governing operation of AC and DC motors
* Motor control systems, enclosures, and designs for both AC and DC motors
* Creation of schematics using the Cypress PSoC development kit and firmware using PSoC Creator software
* Measuring sensor and motor waveforms using a digital oscilloscope
* Method of specifying the right sensor or motor for an application based on customer needs
* Classes of AC motors include: 3-phase induction, wound rotor, synchronous motors, split phase, capacitor start, shaded pole, universal and gear
* Classes of DC motors include: brushed, brushless, shunt wound, series wound, compound wound, torque, permanent magnet, servo, and stepper
* Classes of thermal sensors include: thermocouple, RTD, thermistor
* Classes of rotary sensors include: encoder and resolver
* Classes of flow sensors include: variable area, differential, vortex, ultrasonic, turbine, thermal mass flow, and coriolis
* Classes of pressure sensors include: piezoresistive, capacitive, and vacuum
* Classes of force sensors include: strain gauge, load cell, resistive touch screen, capacitive touch screen
* Classes of motion sensors include: capacitive, magnetic, passive infrared, ultrasonic, and microwave
* Classes of accelerometers include: piezoelectric, piezoresistive, capacitive, and gyroscope
* Classes of humidity sensors include: resistive and capacitive
* Methods of sensor characterization include: linearization, temperature compensation, calibration, accuracy, and drift
* Methods of process control include: PID (proportional-integral-derivative), integration of sensors to plant-wide controllers, predictive machine maintenance, digital communication protocols (RS-485, DeviceNet, Profibus, etc.)
* Methods of sensor integration and manufacturing include: semiconductor processes (deposition, etch, etc.), MEMS, sensor housings, electrical interconnections, reliability testing

## Expected Outcomes

* Study a lab experiment or production process and understand how to specify the proper sensor for taking real-time process data and the proper motor for applying torque and speed to a physical process.
* Implement the sensor or motor into an embedded system in both hardware and software.
* Modify the existing hardware schematic to add the sensor and all support circuitry needed to implement the signal chain into the existing microprocessor-based system.
* Create hardware and firmware to process the sensor signal and feed data to a microprocessor for further evaluation.
* Study sensor signal noise and apply proper hardware and firmware techniques to reduce it to levels well below the measurement uncertainty of the system

## Requirements and Format

### Prerequisites:

* 4-year university degree in mechanical or electrical engineering
* Completed formal classes in DC and AC circuit design, microprocessor architecture, circuit analysis, and filtering.
* Experience prototyping and testing circuits in a lab environment using a digital oscilloscope.
* Has used simulation and circuit analysis tools such as LTspice, OrCAD Capture, OrCAD Pspice, Matlab or Simulink.

### Attendance and Participation:

Attendance at every class (in person for on campus students or via Zoom link for remote students) is expected. It is the student's responsibility to obtain materials from Canvas and to keep up with the course material. Attendance for on-campus students will be taken in class by our TA’s. ***Any on-campus student that misses more than 1/3 of the classes will be penalized one letter grade on their final grade.***

Expectations for Out-of-Class Study: Beyond the time required to attend each class meeting, students enrolled in this course should expect to spend an additional 10 to 15 hours per week of their own time in course-related activities, including reading required materials, completing assignments, performing labs, preparing for exams, etc.

### Assessments:

There will be four scheduled quizzes held in class, roughly every 3-4 weeks over material since the last quiz or exam. There will be 1 mid-term exam and 1 final exam. These assessments are to be done using individual effort alone. Distance students should make arrangements to come to class on the days of quizzes or exams. All quizzes and exams will be announced at least 1 week in advance.

## Evaluation and Grading Procedures

The course grade will be based on homework assignments, labs quizzes, 1 midterm exam, and 1 final exam. The grade proportions are as follows:

* Homework 20%
* Labs 20%
* Quizzes 10%
* Mid-term exam 25%
* Final exam 25%

Grading will be based on total points accumulated from each of these areas. Scoring for ***individua***l ***questions*** on all assessments will be assigned only 3 categories: full credit for full understanding, half credit for partial understanding, and zero credit for limited or no understanding of the subject matter.

Assignment of grades will be based on a class curve. To be assured of an A grade, a student must show mastery of the material and need to acquire more than 90% of the points possible. A student earning less than 50% of the points possible will be given a failing grade. In between these marks, grades will be assigned on a curve.

**Make-up Exam Policy**: No make-up exams are given, except for medical hardships or conflicts with religious holidays where advanced arrangements are made with the instructor; or in case of non-selective medical emergencies with physician’s note or documentation. Otherwise, failure to take the exam at the scheduled time will result in a zero grade in the exam.

## ECE Program Policies

### General Attendance:

Going forward, the following will be in effect for ESE program courses, as reported by ESE course instructors:

* Students enrolled but not engaging in an ESE course for the first week will be moved to the end of any existing waitlist.
* Students enrolled but not engaging in an ESE course for the first two weeks will be administratively dropped from the course.

*Per the* [*Registrar, administrative drops can occur for two reasons*](https://www.colorado.edu/registrar/students/registration/enroll/drop-class)*:*

* *nonattendance or*
* *missing required course prerequisites or corequisites.*

### *Academic Integrity:*

*Any suspected violations of the Honor Code will be submitted to our Honor Code Office.* ***Students found responsible for any violation by our faculty* and the Honor Code Office will earn an automatic F in the course.**  We take these issues seriously and have a responsibility to all students who uphold the Honor Code, and to the highest industry standards for which we are preparing students.  If you have any questions whatsoever regarding what collaboration is permissible in the course, consult your instructor directly before proceeding.  By default, you are expected to turn in your own original work and cite any and all portions you did not create.  All aspects of the Honor Code apply.

### *Lab Policy:*

All students must read and sign the laboratory policy, available by clicking on the following link:

<http://bit.ly/ECEELabs>

They will not be allowed to use the laboratory to perform the labs otherwise.

## University Policies

# Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](http://www.colorado.edu/disabilityservices/students). Contact Disability Services at 303-492-8671 or [dsinfo@colorado.edu](mailto:dsinfo@colorado.edu) for further assistance. If you have a temporary medical condition or injury, see [Temporary Medical Conditions](http://www.colorado.edu/disabilityservices/students/temporary-medical-conditions) under the Students tab on the Disability Services website.

# Classroom Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on [classroom behavior](http://www.colorado.edu/policies/student-classroom-and-course-related-behavior) and the [Student Code of Conduct](http://www.colorado.edu/osccr/).

# Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code ([honor@colorado.edu](mailto:honor@colorado.edu)); 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the [Honor Code Office website](https://www.colorado.edu/osccr/honor-code).

# Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, [anonymous reporting](https://cuboulder.qualtrics.com/jfe/form/SV_0PnqVK4kkIJIZnf), and the campus resources can be found on the [OIEC website](http://www.colorado.edu/institutionalequity/).

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

# Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance.

No make-up quizzes or exams are given for religious holidays, except where advanced arrangements are made with the instructor; Otherwise, failure to take the quiz or exam at the scheduled time will result in a zero grade in the exam.

See the [campus policy regarding religious observances](http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams) for full details.