ASEN 4067/5067 Microavionics for Aerospace

Syllabus, Fall 2021

Lecture:	AERO 114 (Classroom)	Mon and Wed	3:30 - 4:20 PM
Lab:	AERO 141 (PILOT Laboratory)	Thursday	3:00 - 4:50 PM

Instructor

Trudy Schwartz
Office: AERO 150B (Inside the Electronic Center AERO 150)
You can reach me at trudy.schwartz@colorado.edu or by phone at 303-735-2986
Office Hours: **Tuesdays 3 - 4 pm, and during lab hours**
Location: Attend in-person or over zoom

Teaching Fellow

Name: Emanuele “Emi” Costantino
Email: emco8172@colorado.edu
Office Hour: **Friday 1 - 2 pm, and during lab hours**

Internet Information

Class website on Canvas (https://canvas.colorado.edu/) will be used to post official announcements and submit some assignments. The majority of assignments will be submitted through Gradescope.

Communication: The primary forms of communication will be Canvas announcements and Slack discussions. The course email list provided through Canvas will be utilized if needed. Make sure you enable email notifications from Canvas and set up the Slack channel.

Prerequisites

CSCI 1320 (or GEEN 1300) – Basic programming in C and Matlab (or equivalent)
ASEN 3300 – Digital and analog electronics, sensors, and measurements done in a laboratory (or equivalent)
Some C programming experience is strongly recommended
Some Matlab or other programming experience is necessary to be successful in this programming course

Required Texts

Fundamentals of Microcontrollers and Applications in Embedded Systems (with the PIC18 Microcontroller Family) ***1st Edition*** by Ramesh S. Gaonkar, Thomson-DelMar, 2007. ISBN 1-4018-7914-4

References

PIC18F87K22 Data Sheet: http://ww1.microchip.com/downloads/en/DeviceDoc/39960d.pdf
PIC18F87K22 Errata Sheet: http://ww1.microchip.com/downloads/en/DeviceDoc/80507c.pdf
MPLAB XC8 PIC Assembler User’s Guide:
https://ww1.microchip.com/downloads/en/DeviceDoc/MPLAB%20XC8%20PIC%20Assembler%20User%27s%20Guide%2050002974A.pdf
Embedded Design with the PIC18F452 Microcontroller, John B. Peatman, Prentice-Hall.
Designing Embedded Systems with the PIC Microcontrollers: Principles and Applications, Tim Wilshurst.
The Art of Electronics, Horowitz and Hill, Cambridge University Press.

Learning Goals

Basic microcontroller architecture including various memory locations
Decimal, hexadecimal and binary conversions and mathematics
Assembly and C language microcontroller programming
Interfacing with sensors, servos, and Liquid Crystal Display (LCD)
Interfacing to the wide variety of onboard peripherals (Counter/Timers, ADC, DAC, USART, SPI, I2C)
Analog to Digital Conversion(ADC), and Digital to Analog Conversion (DAC) and Signal Conditioning
Various timing schemes and proper use of interrupt service routines and levels
Developing hardware/software systems for Aerospace applications
Embedded system debugging and troubleshooting of hardware and software

Course Calendar

Refer to the 2021 schedule document posted on Canvas (https://canvas.colorado.edu).

Required Hardware

This course was originally designed around the QwikFlash board that came as a kit students soldered themselves to supplement the Gaonkar book. The QwikFlash board had been used previously in this class for about 10 years, and contained the microcontroller referenced in the book – the PIC18F452 in particular. In 2014, we moved to a custom in-house PCB design with a two-part setup, a PIC Board and a Base Board, which utilized the newer and more capable PIC18F87K22 – but this solution was labor intensive to support our own PCB fabrication. The PIC18F87K22 is all around very capable in the PIC18 family as measured by program memory size, RAM size, number of peripherals and low power consumption. In 2017, to keep up with student demand, it was more cost effective to purchase a commercial-off-the-shelf (COTS) development board, the EasyPIC PRO V7 from MikroElektronika; which is readily available on Digikey or Mouser. The EasyPIC PRO V7 also consists of a main baseboard, and interchangeable PIC boards, where the default board is the PIC18F87K22 that we had already been using! For more information, refer to the hardware documents and datasheets provided on Canvas.

The intent of the modular baseboard/PIC board setup is to provide students a potential design to utilize for many different microcontroller needs. Students can start with the full EasyPIC PRO v7 as the microcontroller setup for initial development, then for other courses or projects design a custom-sized Base Board / Daughter Board later to satisfy particular design requirements to fit into an Aerospace application such as a cubesat, rover, airplane, etc. or to add additional microcontroller capabilities. Each small PIC board (in many varieties) is also available COTS for only ~$20. Not only does this give a head start on the hardware (every year there is at least one senior or grad project that never gets their hardware working), it also gives a head start on the software and provides familiarity with the PIC microcontroller family. If they choose, students can also leverage the EasyPIC PRO v7 to prototype a piece of their Senior, Grad or research project as their final project in this Microavionics class.

We have decided to invest *significantly* in this set of EasyPIC PRO v7 development boards in the hopes that they will last for many years to come and therefore they are the property of the department that will be on ***loan*** to you. We will also provide a protective padded static bag, static strap, laptop case and all the accessories. This also means ***you are responsible*** for treating all the hardware appropriately and will be held responsible for fixing or replacing the hardware. ALWAYS place the hardware in the provided padded anti-static bag and laptop case when not in use, and do not expose to excessive heat (i.e. do not leave in your car!). We will also provide the PicKit-3 In-Circuit Debugger for use as a programmer and debugger for the microcontroller as well as a kit of accessories and testing components to complete the labs. In addition, this semester each student will check out the expensive Analog Discovery 2 - a USB powered oscilloscope and function generator.

Overview

The world of aerospace engineering is growing quickly and becomes more interdisciplinary every year. The major aerospace products such as aircraft and satellites are becoming more complex and intelligent in part due to the explosion of information technology. This increase in capabilities requires more detailed information about the system state, provided by sensors and processed in real-time, to make a decision based on a future action. The collection and/or processing of this data is often made by a distributed network of inexpensive processors called microcontrollers.

This course has been developed to provide engineers with a basic understanding about the fundamental architecture of a microcontroller and how it operates and interfaces with various inputs (sensors, communication, etc) and outputs (actuators, displays, communication, etc.). The course focuses on sensors and strict timing requirements that are especially important in aerospace engineering, but also applicable to other disciplines of engineering. The goal of this course is to learn how to properly interface inputs to a microcontroller, collect/store/convert that input, make decisions and take action in real-time.

To gain a full appreciation about how microcontrollers really work on the inside you will develop your own software code using MPLAB X to program the development board hardware. This board uses the Microchip PIC18F87K22 microcontroller and will be the foundation of the course. In this course you will "**learn by doing**" through lab assignments and a semester final project using the PIC18F87K22. This will include mostly programming in assembly language first to appreciate hardware specifics and then progress to C programming for more advanced programming and the final project.

Class Format

This class is a demanding and fulfilling senior/grad level Aerospace Engineering Sciences elective designed to provide students a solid background and some experience working with microcontrollers with specific Aerospace applications in mind. The course meets three times each week for a total of 3.5 hours.

This includes two 50-minute lecture periods and one 1-hour 50-minute lab period. Lectures are generally much more productive for students if you are ready to ask questions. **This lecture format expects students to come prepared!** Being prepared means doing the required reading ***before*** lecture and attempting all of the labs prior to the lab periods. All of the labs will take much more than the allotted lab period, and as a result you should attempt the labs on your own ***before*** the lab session. The lab periods should be used to receive assistance from the instructor/TF and to help troubleshoot and debug. In addition to the lab assignments, your grade for this course will also include quizzes, exams, and a final project at the end of the semester. The relative weighting for each is provided below. The idea is to have a dynamic and interactive lecture where we can focus on the material that is giving students the most problems and not spend a lot of time on concepts that can be self-taught from the book, online resources, and working through the labs.

This class is cross-listed as both a 4000 and 5000 level course. If you are taking this course for graduate credit (5000 level) then you will be expected to answer additional/more difficult exam questions, complete more in-depth tasks on your lab assignments, and develop a graduate caliber final project. The 4000 and 5000 level students will be graded separately to ensure fairness in the evaluation of performance.

Logistics

1. Lecture slides will be posted at least 24 hrs in advance. – it is expected that you read those lecture slides before attending lectures.

2. The course teaching team reserves the right to make changes to the weekly course schedule based on occurring events that require different dispositions. Sufficient advance notice will be given through announcements in class and posting on the web. Changes to this syllabus and schedule may be announced at any time during class periods. We will post the current syllabus and schedule on the Canvas course website.

3. Slack will be the main form for communication amongst the class. Please post your questions to the appropriate channel for each assignment. Students are encouraged to use this platform to answer questions of others as a form of collaboration and peer learning. The teaching team will respond to questions usually within 24 hours during business hours, i.e. Monday through Friday, 8:00 am – 5:00 pm. Questions sent over email will be redirected to use the appropriate Slack channel. Questions that are 24 hours or less of the lab due date or exam date may not receive a response in time from the teaching team. Please utilize the exam reviews given in the lecture prior to exams and office hours effectively.

4. In-person lab attendance is expected for as long as the campus remains open. If necessary, the course can transfer to remote mode as long as you have a personal computer or laptop installed with the necessary free software downloads. (Which is highly recommended regardless so you can work on the labs from home in addition to on campus.)

5. ***Students are expected to work independently on all assignments!!*** All work submitted ***must be your own***, you may only discuss higher-level concepts and approaches with your classmates. **You may not share or tell someone else exactly how to complete the assignment.** We will check your assignments for similarities and penalize you accordingly. The ***only*** way to learn in this class is to do the programming yourself. Copying online resources for code examples is strictly not allowed for lab assignments and only allowed in small portions of the final project if properly cited and with prior instructor approval.

6. **INDIVIDUAL** Lab reports are due by 11:59 PM on the specified due date. These labs must be submitted electronically. **Late labs will be assessed a 5% penalty for up to 1 hour late, and then a 15% penalty for that day and each additional day late and will not be accepted after 4 days.**

7. These are **INDIVIDUAL** lab assignments that make up a significant portion of your final grade. While having code that meets the assigned requirements is important, this is not the only criterion by which the labs are graded. As part of this course you are expected to learn good coding practices, such as reasonable variable names, good documentation practice, good modular coding implementation and coding style and efficiency. The labs will be graded on whether your solution meets the assigned requirements, code is well documented/commented and has good programming techniques i.e. using efficient loops and functions where appropriate.

8. If you are ill and will not be able to complete an assignment or attend an exam, you must contact the instructor via email as soon as possible to make specific arrangements. Late lab policy is covered above. Make ups for exams are extremely difficult to accommodate. There will be no unexcused exam makeups provided. If you miss an exam, the course instructor will evaluate each case on an individual basis based on the context and information available to decide if a makeup exam will be provided. Students are encouraged to provide as much documentation as possible to enable an informed decision. If necessary, the instructor may choose to use your existing grades to cover your missed grade(s).

9. There will be 2 in-lecture Exams and one Final Presentation/Demo for the course. **Exams may be cumulative**. Copying, collaborating, or discussing material during an exam constitutes **cheating and will result in an F for the exam** and will be reported to the University Honor Code.

   Mandatory - All students must be available these days/times, please *plan your schedule* accordingly:

   - **Exam #1** — **Monday Oct 11, 2021 (during lecture)**
   - **Exam #2** — **Monday Nov 15, 2021 (during lecture)**
   - **Final Presentation Slides and Video** — **Monday Dec 13, 2021 @ 12:00 PM (NOON)**
   - **Final Project EXPO (Final Exam Time)** — **Monday Dec 13, 2021 1:30 PM- 4:00 PM**
   - **Final Peer Reviews** — **Monday Dec 13, 2021 @ 4:00 PM**

10. Review quizzes will be given to test yourself on the course content and if you are retaining the necessary information from the readings, lectures and labs.The lowest quiz score will be dropped.

Course Grading

60%	**6 Lab Assignments (10% each)**
20%	**2 Exams (10% each)**
5%	**Quizzes**
15%	**Final Project**
100%	**Final Grade**

Grading Meetings

You will *sign up for a 15 time slot* to meet with the Teaching Fellow (TF) after each lab submission to demonstrate your code is working on the hardware and your knowledge and understanding of the code *you have* written as part of the grade for each lab assignment.

Grading Disputes

If you feel that a lab, exam, or project has been graded incorrectly you must submit your regrade request via Gradescope (if available) or in writing via email to the instructor and TF. All requests must be filed within 1 week after the grading is completed. Your request must clearly state your reasoning. In this case, the *entire* assignment will be re-graded during the reassessment process and the new grade may increase or decrease.

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. 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. For more information, see the policies on classroom behavior and the Student Conduct & Conflict Resolution policies.

Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

As of Aug. 13, 2021, CU Boulder has returned to requiring masks in classrooms and laboratories regardless of vaccination status. This requirement is a temporary precaution during the delta surge to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is

essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, please email the instructor that you will miss class and/or lab due to illness for each date missed. You are not required by FERPA to say you have or suspect that you may have COVID-19.

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. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

This course requires the use of MPLAB X, Realterm and Waveforms software as well as the EasyPIC PRO v7 hardware which has not yet been reviewed fully for accessibility. This course also uses Slack for class discussions, which may not be fully accessible to users using assistive technology. If you use assistive technology to access the course material, please contact your faculty member immediately to discuss.
If you use assistive technology to access the course material, please contact the Instructor and Disability Services at 303-492-8671 *or by e-mail at* dsinfo@colorado.edu *as soon as possible to discuss other effective means for providing equal alternate access.*

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

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); 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 website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or 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 OIEC, university policies, reporting options, and the campus resources can be found on the OIEC website.

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

Religious Observance

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. In this class, you need to email the instructor Trudy.Schwartz@colorado.edu with as much advance notice as possible if you have any conflicts due to religious observance.
See the campus policy regarding religious observances for full details.