MECHANICAL ENGINEERING 461
Computer Control of Mechanical Systems
Fall 2020

Prerequisites:
ME 360 Signal Processing or
ABE 425 Engineering Measurement Systems or
SE 320 Control Systems or
ECE 486 Control Systems

Lecture Time:
I will be recording both my Monday and Wednesday morning lectures. I will post these lectures to a Box folder.

Lab Times:
Section 1: Thursday 9am – 1pm, split into two 2 hour sections
Section 2: Thursday 2pm – 6pm, split into two 2 hour sections
Section 3: Friday 11am – 3pm, split into two 2 hours sections

Lab Location:
302 Transportation Building, I will be recording a lab lecture each week to go over specifics in the lab. I will post these lectures to a Box folder.

Instructor:
Dan Block
Office: 3005 ECE Building
Telephone: 244-8573
E-mail: d-block@illinois.edu

Office Hours:
Posted at Box each week (and by appointment)

Teaching Assistant:
Chuanzheng Li (cli67@illinois.edu)

Office Hours & Location:
In the lab (Room 302) Monday 7pm-9pm

References:
There is no required textbook for the course. However, the following references serve very well as supplemental background and review materials. There are several copies of each of these titles in the lab that are available for your use. Please leave these books in the lab so everyone in the class can have access to them.

- *Introduction to Mechatronic Design* (Prentice Hall, 2011), by J. Edward Carryer, R. Matthew Ohline, Thomas W. Kenny.
- *Introduction to Mechatronics and Measurement Systems* (3rd edition, McGraw-Hill, 2007), by David G. Alciatore & Michael B.Histand.
- *Teach Yourself C* (3rd edition, McGraw-Hill Osborne Media, 1997), by Herbert Schildt.
- Various manufacturer data sheets, catalogs, websites, etc.
- *Feedback Control of Dynamic Systems* (3rd edition, Prentice Hall, 1994), by Gene Franklin, J.D. Powell, and A. Emami-Naeini.

Objectives:
This is an intensive, hands-on multidisciplinary course that provides an opportunity to develop and integrate electronic and mechanical systems with the TI C2000 family of microprocessors. All control algorithms and other microprocessor code is written using the C

programming language within an Integrated Development Environment. During this course students will:

- Develop an understanding of the fundamentals of mechatronic systems.
- Develop an understanding of the design and construction of microprocessor controlled electro-mechanical sensing and actuating systems.
- Develop an understanding of the operation and application of Texas Instruments C2000 DSP/microcontrollers.
- Develop a working knowledge of basic analog, digital, and power electronics used in mechatronic systems.
- Develop an understanding of the principle of operation and application of signal conditioning techniques.
- Develop an understanding of the principle of operation and application of sensors, transducers, and actuators to mechanical systems.
- Develop an understanding of the application of open-loop and closed-loop control algorithms to mechanical systems, and an appreciation for the need of sampled time control theory in computer controlled systems.

Topics:

- DC circuits.
- Analog and digital electronics.
- Sensors, transducers, and actuators.
- Data conversion and transmission.
- Microcontroller programming and interfacing.
- Response and control of electro-mechanical systems.
- Introduction to sampled time control theory.

Course Website: http://coecsl.ece.uiuc.edu/me461/ has lab handouts, supplemental reading materials, assignments, etc. It is the responsibility of the student to stay current with this material. Your Instructor will not be pleased to answer questions that can be easily answered by reading the posted course material.

Course Components

The most common images that come to mind when discussing computers are ones of large mainframes, desktop PCs, and portable laptops. However, the vast majority of computers are actually found embedded in everyday devices such as automobiles, cell phones, MP3 players and toasters. These embedded systems are often built around microprocessors that differ from conventional PCs and workstations in many ways. For example, embedded microprocessors usually will not (or can not) be programmed or maintained by the end-users, and often present significantly different design constraints such as limited memory, low cost and low power. At the same time, many embedded microprocessors must also interact with and control their physical environment using a variety of electromechanical sensors and actuators.

This class provides an opportunity to investigate the characteristics of microprocessor-controlled electromechanical systems through active participation in laboratory exercises. Lectures will focus on providing background, theory, and review of the key topics that will be explored in the laboratory. Laboratory exercises will provide direct hands-on experience with both the hardware

(e.g., microprocessor, sensors, actuators, electronic components) and software (e.g., development environment, debugging, control algorithms) commonly used in embedded system design.

Exams. This is a course guided by the philosophy of "learn by doing." No exams/quizzes are planned. This could change depending on class attendance in lecture.

Lectures. The lecture content will attempt to follow the laboratory assignments in an obvious manner. Failure to attend a lecture will be a severe handicap. Before attending each lecture, students are expected to complete the reading assignment(s), review the lecture notes, and be prepared to ask questions and participate in discussions of the course material. Participation also includes class attendance.

Labs. The lab exercises are the most critical component of this course. Attendance and participation are mandatory (unless you are quarantined due to COVID-19). If you must miss a laboratory session, you must obtain an excused absence beforehand, from your instructor, and discuss alternative arrangements for making up the missed work. Many exercises in later labs depend upon on code and skills developed completing exercises in earlier labs. The laboratory "check-off" procedures and requirements will be explained in each of you lab assignments. A large portion of each lab grade is simply completing the work assigned. In addition you will submit your final commented code for the lab and we will grade the code and comments kind of like a lab report for the assignment. You should explain what you learned in the lab assignment in your code's comments. Short one-liner comments, that do not quite explain what the code is accomplishing, will be given lower scores. Get in the habit of writing comments where you changed code and then before submitting your code go back to those lines and create more descriptive explanations.

Take Home Exercises. I will be assigning and grading exercises you will perform outside of lab. For these assignments, you will submit the commented code you developed for the assignment along with a video showing the exercise working on your kit. Any line of code that you modify for the exercise needs to have explaining comments and these comments, along with the correct code, we be what you are graded on for these assignment. The goal of these exercises is to make you even more comfortable developing code for the TMS320F28379D processor and designing controllers for mechanical systems.

Final Project. A final project will provide an opportunity to extend and enhance your skills by adding sensors/actuators to the wall following/WiFi controlled robot/Segbot developed during the semester. Details will be provided as the semester progresses.

Graduate Students. Graduate students can register for and receive either 3 or 4 credit hours for completing ME 461. Those students registered for 4 credit hours will be required to submit a research paper on a Mechatronic topic that is approved by the instructor. The paper will be worth 25% of the course grade. Details will be discussed in class.

Assessment

Mastery of the course material will be evaluated as follows:

1. Labs	50%
2. Take Home Exercises	25%
3. Final Project	25%

The final course letter grade will be based on the end of the semester overall course percentage as indicated below:

Grade	**Percent**
A+	98% and up
A	92.0%-97.99%
A-	90%-91.99%
B+	88%-89.99%
B	82.0%-87.99%
B-	80%-81.99%
C+	78%-79.99%
C	72.0%-77.99%
C-	70%-71.99%
D+	68%-69.99%
D	62.0%-67.99%
D-	60%-61.99%

CURRENT PLAN OF TOPICS TO BE COVERED THIS SEMESTER

WEEK OF	TOPICS
Aug 24	Building the Segbot Kit. Goal is to get the kit built in the first 3 or 4 weeks of the semester. What is a microcontroller? What is a Digital I/O Pin?
Aug 31	Continue building the Segbot Kit. Using Code Composer Studio to develop C code for the TMS320F28379D processor. Git repository tool.
Sept 7	Hopefully finish building and debugging Segbot Kit. What is a timer? What is an interrupt and more specifically, what is a timer interrupt? How to use a Digital I/O pin to read the state of a momentary push button.
Sept 14	What is a peripheral register? Explain Bit Fields in C code, and why are they useful in register programming. PWM and timers to drive a piezo buzzer to create tones. The UART (Universal Asynchronous Receive Transmit) serial port. Print messages to serial terminal like Tera Term.
Sept 21	PWM to drive the Motor. Quadrature encoder to sense the angle of the motor.
Sept 28	The ADC (Analog to Digital Converter) to read voltage signal. Sample voltage signal from a microphone.
Oct 5	The DAC (Digital to Analog Converter) to output an analog voltage signal. Aliasing and Filtering of analog voltage signals.
Oct 12	The SPI and I2C serial port. Use SPI to communicate with MPU9250 IMU sensor.
Oct 19	Use the I2C serial port to communicate with the BQ32000.
Oct 26	System Identification DC motor system/robot. Friction compensation. The PID controller.
Nov 2	Steering the two-wheeled robot car.
Nov 9	Control of the two-wheeled Segbot. Pole Placement.
Nov 16	Kalman filter/Sensor fusion for two-wheeled Segbot vehicle
Nov 23	Thanksgiving Break
Nov 30	Time for working on your take-home final project.

OTHER IMPORTANT INFORMATION

Academic Honesty

This course has a zero tolerance policy on cheating. It is expected that all students will conform to University of Illinois Rules on Academic Integrity. Academic integrity is the pursuit of scholarly activity in an open, honest and responsible manner. Any infraction of academic integrity as defined by the Student Code will be met with severe consequences that may include a grade of F for the entire course and a recommendation of suspension or dismissal from the University. Cheating on a quiz includes (but is not limited to) using written aids, copying another person's answers, talking or trading signals. Cheating on a written assignment includes (but is not limited to) copying or paraphrasing from a classmate, course readings, or any other published or unpublished materials including information from web pages, on-line resources, and other sources. Please note that you are not permitted to turn in the same written work for this class and for another past or current class. If you have any questions about what constitutes cheating or plagiarism, consult your Instructor ahead of time.

Accommodation of Students with Special Needs

Students who require any accommodation in this course should contact the professor early in the semester to make the necessary arrangements. To receive accommodation services, students must be registered with the Division of Disability Resources and Educational Services (DRES).

Resources for Students

If you are having academic difficulties in this course, please see me early in the semester. If my set office hours conflict with your schedule, I am always willing to make an appointment for another time; see me before or after class to set up a time or send me a message via e-mail.

Changes to the Syllabus

All of the information in this syllabus is subject to change, with advance notice from the instructor.