ME461
Computer Control of Mechanical Systems
Fall 2023

Prerequisites: ME 360 Signal Processing or
SE320 Control Systems or
ECE 210 Analog Signal Processing or
AE461 Control Systems Lab or
ABE 425 Engineering Measurement Systems

Lecture Time: Lectures will be in person in **106B1 Engineering Hall** from 9am to 9:50am Monday and Wednesday. I will also be recording my laptop screen and audio. These recordings will be copied to a Box folder. You can request access to this Box folder if you miss a lecture. I highly recommend, and will be encouraging, you to attend all lectures in person. Being in person will allow you to get your questions answered and help direct my lecture to improve your understanding of the material. Lectures will be covering what we will be completing in lab. If you do not attend lectures, you will be very lost in the lab assignments.

Lab Times: Section 1: Thursday 9am – 11:50am.
Section 2: Thursday 2pm – 4:50pm.
Section 3: Friday 11am – 1:50pm.

Lab Location: **302 Transportation Building**, when needed I will be recording an additional "lab lecture" to go over specifics for that week's lab. I will post these lectures to the class Box folder and you are expected to watch this lab lecture before you come to your lab session. I will send out an email when there is a lab lecture for you to watch. The goal is to get you ready so that when you and your partner get to lab you can start right away on the assignment.

Instructor: Dan Block
Office: 3005 ECE Building
Telephone: 217-244-8573
E-mail: d-block@illinois.edu

Office Hours: Tuesday 2pm - 5pm in 302 TB
Wednesday 11am to 1pm in 302 TB
By Appointment, (Or just finding me)

Teaching Assistant: Cary Laird Butler (caryel2@illinois.edu)
Office Hours & Location: TBD in Room 302TB

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 the Integrated Development Environment, "Code Composer Studio." 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:

- Digital and analog inputs and outputs.
- Sensors, transducers, and actuators.
- Data conversion and serial transmission.
- Microcontroller programming and interfacing.
- Implementation of discrete time control algorithms.
- Response and control of electro-mechanical systems.
- DC circuits.

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 cannot) 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.

Lectures. The lecture content will follow the laboratory assignments. Failure to attend lectures will be a severe handicap as each of the lectures are preparing you for that week's lab assignment.

Labs. The lab exercises are the most critical component of this course. Attendance and participation are mandatory. 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 your 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.

Homework. I will be assigning and grading "teach yourself" homework you will perform outside of lab sessions. Each of these exercises will explain what items need to be completed and submitted by given due dates. These assignments will span multiple weeks and there will be graded "check off" due dates within those weeks to keep you on pace and no waiting until the night before the final due date to attempt to finish the work. The goal of these exercises is to make you even more comfortable developing code for C2000 processor and designing controllers for electro-mechanical systems. These will be individual homework, but just like the labs, you can ask questions of your fellow classmates and instructors as you work on these assignments.

LABVIEW Exercises. There will be four "Teach Yourself" LABVIEW assignments during the semester and Homework #2 has a LABVIEW assignment. We will be using LABVIEW to develop applications for our Windows 10 PCs to communicate data back and forth between the PC and the lab's robot card. Then by the time we get to designing controllers for the robot car in Labs 6 and 7, you will have an application that can send commands to steer the robot. I have found in previous semesters that some ME461 students prefer programming in the block diagram form of LABVIEW

compared to text based C programs. You will find that each programming methon has their advantages and disadvantages.

<u>Final Project.</u> **Friday December 15ᵗʰ 11am to 2pm. Put this in your calendar today! This is your final for the class and you MUST attend!** At the end of the semester, you and partners will choose a final project topic to complete that uses the TMS320F28379D processor as its controller. Details about this final project will be provided as the semester progresses. You will be working in groups of four for this end of the semester project.

Assessment

Mastery of the course material will be evaluated as follows:

1. Labs	35%
2. Homework	30%
3. Final Project	30%
4. LABVIEW Exercises	5%

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

Grade Percent

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

Lecture Dates	Topics	Current Lab
Monday, August 21, 2023	Mechatronics covers many topics. What are we going to focus on. Go through the syllabus.	- Lab #1 - Homework #1 "Soldering and C Review"
Wednesday, August 23, 2023	Look at the LaunchXL-F28379D board and the green expansion board to see how pins are connected.	- LABVIEW #1
Monday, August 28, 2023	Digital Outputs. Turn on and off an LED. How many IO pins do we have to work with?	- Lab #1 - Homework #1 "Soldering and C Review"
Wednesday, August 30, 2023	Talk about pin multiplexer. Go through starter code.	- LABVIEW #1
	Digital Inputs. Pull-up resister. Passive push button. What is a peripheral register?	- Lab #2 - Homework #1 "Soldering and C Review" - Homework #2 "EagleCAD and ESP32" - LABVIEW #1
Wednesday, September 6, 2023	What is an interrupt in a CPU? Timer interrupt function. Printf C function. %d, %ld, %c, %s, %x, %lx %.3f 16bit integer, 32bit integer, 2s compliment number Hexidecimal representation, bitwise operators, &,|,~,^,<<,>>	
Monday, September 11, 2023	UART Serial Port for displaying text in Serial Terminal	- Lab #3 - Homework #1 "Soldering and C Review" - Homework #2 "EagleCAD and ESP32" - LABVIEW #1
Wednesday, September 13, 2023	Peripheral registers and Texas Instruments Bitfield structures. PWM signals used to command actuators. EPWM peripheral.	
Monday, September 18, 2023	The RC Servo and its PWM command signal. The H-bridge circuit for driving motors both in the positive and negative direction.	- Lab #3 - Homework #2 "EagleCAD and ESP32" - LABVIEW #2
Wednesday, September 20, 2023		
Monday, September 25, 2023	Analog Signals. Resolution of an Analog Signal. The analog to digital converter (ADC).	- Lab #4 - Homework #2 "EagleCAD and ESP32" - LABVIEW #2
Wednesday, September 27, 2023	Successive Approximation Register (SAR) ADC. Speed of conversion. F28379D ADC peripheral registers More on interrupt functions.	
Monday, October 2, 2023	Designing and implementing Discrete Filters.	- Lab #4 - Homework #2 "EagleCAD and ESP32" - LABVIEW #3
Wednesday, October 4, 2023	Timing code using a Logic Analyzer.	
Monday, October 9, 2023	Review three serial ports UART, SPI, I2C. SPI details. SPI 4 clock modes.	- Lab #5 - Homework #2 "EagleCAD and ESP32" - Homework #3 "I2C" - LABVIEW #3
Wednesday, October 11, 2023	SPI peripheral data sheets. F28379D SPI peripheral registers	
Monday, October 16, 2023	Review the DAN28027 SPI interface datasheet. Connecting multiple slave devices to one SPI serial port.	- Lab #5 - Homework #3 "I2C" - LABVIEW #4
Wednesday, October 18, 2023	Understand the F28379D SPI's Receive and Transmit FIFO	
Monday, October 23, 2023	Review the MPU-9250 (IMU) datasheet and registers. MPU-9250 16bit SPI interface.	- Lab #5 - Homework #3 "I2C" - LABVIEW #4
Wednesday, October 25, 2023		
Monday, October 30, 2023	Quadrature Encoder Sensors Calculating Motor Speed. Implementing PI speed control algorithm.	- Lab #6 - Homework #3 "I2C" - Homework #4
Wednesday, November 1, 2023		

Monday, November 6, 2023	Correcting for integral windup. Implementing a coupled PI control law to allow for steering of a two wheel plus caster robot car.	- Lab #6 - Homework #4
Wednesday, November 8, 2023		
Monday, November 13, 2023	Implement a Full State Feedback control law to balance our two wheel balancing robot or Segbot.	- Lab #7 - Homework #4 - Final Project
Wednesday, November 15, 2023		
Week of November 20, Fall Break		
Monday, November 27, 2023	Implement a steering PID control law to allow for steering of the Segbot.	- Lab #7 - Homework #4 -Final Project
Wednesday, November 29, 2023		
Monday, December 4, 2023	Kalman filtering. Using the Kalman filter to fuse the tilt, and tilt rate measurements of the MPU-9250 to produce a responsive tilt measurement.	- Final Project
Wednesday, December 6, 2023		
Friday, December 15, 2023 11am to 2:00pm		**- Final Project Demonstration Time**

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 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.