MECHANICAL ENGINEERING 461
Computer Control of Mechanical Systems
Fall 2017

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

Lecture Time: MW 9:00-9:50 AM

Lecture Location: 135 MEB

Lab Times: Section 1: Thursday 9am – 12pm
Section 2: Thursday 2pm – 5pm
Section 3: Friday 11am – 2pm

Lab Location: 302 Transportation Building

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

Office Hours: W 11:00 AM – 1:00 PM (and by appointment)

Teaching Assistant: Tyler Matijevich (matjvch2@illinois.edu)

Office Hours & Location: In the lab (Room 302) Tuesday 5pm-6pm, Wednesday 5pm-6pm and by appointment.

Lab Final Hour to Check Off (*prefer to finish earlier though)* 302 Transportation Building
Section 1: Wednesday 5pm to 6pm.
Section 2: Thursday 5pm to 6pm.

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.
- *Effective LabView Programming* (National Technology and Science Press, 2013), by Thomas J. Bress.

- *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 MSP430 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 MSP430 microcontrollers and other embedded processors.
- 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.
- Be given a brief introduction to a higher end embedded ARM processor running embedded Linux. A serial communication between this ARM processor and the MSP430 microcontroller will be created allowing the investigation of what tasks should be run on the MSP430 processor and what tasks should be run on the ARM processor This introduction will give the interested student a jump start in working with higher end ARM processors after completing this class.
- Over the last decade National Instruments with their Real-Time extension to LabView and their real-time data acquisition systems have become a major player in Control System design and implementation. The last three labs of this course will give an introduction to using Real-time LabView to implement control of mechanical systems. Just as with the higher end ARM processor described above, a serial communication between the real-time hardware (Called the MyRIO) and a MSP430 chip will be used to allow parts of the real-time control to be run on the MSP430 chip.
- 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 architecture.
- Microcontroller programming and interfacing.
- Response and control of electro-mechanical systems.

- Introduction to sampled time control theory.
- Introduction using higher end processors for control of mechanical systems.

Course Website: Every effort will be made to use e-mail and the course Web site at http://coecsl.ece.uiuc.edu/me461/ as the principal means of information exchange for the class. Lab handouts, supplemental reading materials, assignments, etc will be made available. 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 lectures and 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.

Homework (Prelab) Assignments. Again, “learn by doing.” The homework/prelab assignments are intended to provide direction and focus before attempting a particular laboratory exercise. They are also intended to encourage individual effort, and will be graded on an individual basis. See the “Note on Collaborations” below. **Prelab assignments are due at the beginning of Wednesday’s lecture the week of that lab. Prelab assignments are considered late if not turned in the first 10 minutes of Wednesday’s lecture. Late assignments will not be graded and a grade of ‘0’ will be assigned.**

Labs. The lab exercises are the most critical component of this course. Attendance and participation are mandatory. The laboratory check-off procedures and requirements will be explained thoroughly in your lab section by your TA. No Laboratory check-offs will be made for

unexcused missed laboratory sessions. 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 by completing exercises in earlier labs. Consequently, failure to successfully complete and obtain a TA check-off on any exercise by the check-off deadline will result in a 20% penalty per calendar day until such time as the exercise is completed. Note that no credit will be earned if the exercise is completed more than 5 days past the deadline. Nonetheless, every exercise must be completed and checked-off by your TA. Failure to complete any lab exercise will result in no credit being earned for the entire lab.

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 developed during the semester. Or you may choose to build your own creation to impress and dazzle your teammates and course instructors. 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.

A Note on Collaborations. An often overlooked component of a course such as this one is its collaborative nature. Much of your lab and project work will be done in teams of two. Students are also encouraged to work together on homework (prelab) assignments. However, original solutions to the assignments and evidence of independent mastery of laboratory and project tasks will be required. For example, if the individual grading an assignment is able to identify students who have worked together based on their solutions, or other specific aspects of their approach to the solutions, then the solution will not be considered original. In such a case, the assignment will automatically receive a failing (i.e., 0%) grade. Detailed guidelines will be discussed in class.

Assessment

Mastery of the course material will be evaluated as follows:

1. Homework/Prelabs	25%
2. Labs	50%
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%

All concerns about grading of any particular course component must be brought to the attention of your Instructor within one week of the return of the work in question. No grades will be changed after one week.

Note: Every effort has been made to make this syllabus as complete and accurate as possible. It is meant to be used as a guide. Unforeseen or other circumstances may require changes or modifications to the lecture schedule, etc. As such, everything contained in this document is subject to change.

TENTATIVE CALENDAR [SUBJECT TO CHANGE]

DATE	ACTIVITY	BACKGROUND READING	CURRENT LAB
Mon 08/28 Wed 08/30	Lecture: Overview; Introduction to the MSP430 architecture; Digital representations (binary, hex, etc); C review; Lab's C Program Structure.	MSP430 User's Guide (UG); Fx2xx datasheet (DS). Your favorite C review text. C&O Ch 2,3,6,7; A&H Ch 1, 6.1 & 6.2 and 7 (These books do not use a MSP430 microcontroller but the key concepts are the same for all microcontrollers)	
Thur 08/31	Laboratory Session Group #1		Lab #0: Soldering and Introduction to the Hardware and Software
Fri 09/01	Laboratory Session Group #2		
Mon 09/04	No Lecture: Labor Day	MSP430 UG; Fx2xx DS.	
Wed 09/06	Lecture: What is a Register? Digital I/O; GPIO interfacing; Interrupts & Timers	C&O Ch 8.3, 8.7; MSP430 UG; Fx2xx DS.	
Thur 09/07	Laboratory Session Group #1		Lab #0: Continued
Fri 09/08	Laboratory Session Group #2		
Mon 09/11	Lecture: Digital I/O; GPIO interfacing; Interrupts & Timers (con't)		
Wed 09/13	Lecture: Interrupts, Timers, PWM, RC Filter	C&O Ch 8.4, 8.7; Fx2xx DS & UG	
Wed 09/13 Thur 09/14	Laboratory #0 Check-Off Deadline (Group 1) Laboratory #0 Check-Off Deadline (Group 2)		
Thur 09/14	Laboratory Session Group #1		Lab #1: Digital I/O
Fri 09/15	Laboratory Session Group #2		
Mon 09/18	Lecture: Interrupts, Timers, PWM, RC Filter (con't)	C&O Ch 8.4, 8.7; Fx2xx DS & UG	
Wed 09/20	Lecture: Data Acquisition, sampling/conversion considerations, ADC, temperature sensors	C&O Ch 8.6, 19; A&H Ch 8; Fx2xx DS & UG; LM386 DS	
Wed 09/20 Thur 09/21	Laboratory #1 Check-Off Deadline (Group 1) Laboratory #1 Check-Off Deadline (Group 2)		

Thur 09/21	Laboratory Session Group #1		Lab #2: Timers and Pulse-Width Modulation
Fri 09/22	Laboratory Session Group #2		
Mon 09/25	Lecture: Data Acquisition, sampling/conversion considerations, ADC, temperature sensors (con't)	C&O 8.6, 19; A&H Ch 8; Fx2xx DS & UG; LM386 DS	
Wed 09/27	Lecture: DAC, Serial I/O Communications	C&O Ch 7.3, 19; A&H Ch 8; Fx2xx DS & UG; TLV5606 DS	
Wed 09/27 Thur 09/28	Laboratory #2 Check-Off Deadline (Group 1) Laboratory #2 Check-Off Deadline (Group 2)		
Thur 09/28	Laboratory Session Group #1		Lab #3: Analog-to-Digital Conversion
Fri 09/29	Laboratory Session Group #2		
Mon 10/2	Lecture: DAC, Serial I/O Communications (con't)	C&O Ch 7.3, 19; A&H Ch 8; Fx2xx DS & UG; TLV5606 DS	
Wed 10/4	Lecture: Electronics Review; Semiconductor Electronics, Op Amps, Signal Conditioning	C&O 9, 10, 11; A&H Ch 2, 3, 5;	
Wed 10/4 Thur 10/5	Laboratory #3 Check-Off Deadline (Group 1) Laboratory #3 Check-Off Deadline (Group 2)		
Thur 10/5	Laboratory Session Group #1		Lab #4: Digital-to-Analog Conversion and Sampling (Notice that Check-Off Deadline is in the Middle of Lab #5)
Fri 10/6	Laboratory Session Group #2		
Mon 10/9	Lecture: Electronics Review; Semiconductor Electronics, Op Amps, Signal Conditioning (con't)	C&O 9, 10, 11; A&H Ch 2, 3, 5;	
Wed 10/11	Lecture: PMDC Motors, H-Bridge	C&O Ch 22, 23.3 A&H Ch 10; Fx2xx DS & UG; LMD18200 DS	
Thur 10/12	Laboratory Session Group #1		Lab #5: PMDC Motor Interfacing, Characterization and Control of PMDC Motors
Fri 10/13	Laboratory Session Group #2		
Mon 10/16	Lecture: Embedded Linux Topics and the C.H.I.P. computer	www.nextthing.co	
Wed 10/18	Lecture: Embedded Linux Topics and the C.H.I.P.	www.nextthing.co	
Wed 10/18 Thur 10/19	Laboratory #4 Check-Off Deadline (Group 1) Laboratory #4 Check-Off Deadline (Group 2)		
Thur 10/19	Laboratory Session Group #1		Lab #5: Continued
Fri 10/20	Laboratory Session Group #2		

Mon 10/23	Lecture: Embedded Linux Topics and the C.H.I.P.	www.nextthing.co	
Wed 10/25	Lecture: Encoders, Position & Velocity Sensors, Quadrature counters	C&O Ch 13.5 A&H Ch 9; LS7266 DS;	
Wed 10/25 Thur 10/26	Laboratory #5 Check-Off Deadline (Group 1) Laboratory #5 Check-Off Deadline (Group 2)		
Thur 10/26	Laboratory Session Group #1		Lab #6: Embedded Linux, ARM Processors, Building Linux C Applications and Serial Communication
Fri 10/27	Laboratory Session Group #2		
Mon 10/30	Lecture: System Response;	A&H Ch 4;	
Wed 11/1	Lecture: Continuous Control Review	Franklin & Powell	
Thur 11/2	Laboratory Session Group #1		Lab #6: Continued
Fri 11/3	Laboratory Session Group #2		
Mon 11/6	Lecture: Review Given Optical Encoder C Functions; Continuous Control Review (con't)	Franklin & Powell	
Wed 11/8	Lecture: System ID; Sampled Time Control Considerations; Discrete Equivalents	Franklin & Powell	
Wed 11/8 Thur 11/9	Laboratory #6 Check-Off Deadline (Group 1) Laboratory #6 Check-Off Deadline (Group 2)		
Thur 11/9	Laboratory Session Group #1		Lab #7: Open Loop Motor Control and Friction Compensation
Fri 11/10	Laboratory Session Group #2		
Mon 11/13	Lecture: System ID; Sampled Time Control Considerations; Discrete Equivalents (con't)	Franklin & Powell	
Wed 11/15	Lecture: Discrete Filters (FIR and IIR)		
Wed 11/15 Thur 11/16	Laboratory #7 Check-Off Deadline (Group 1) Laboratory #7 Check-Off Deadline (Group 2)		
Thur 11/16	Laboratory Session Group #1		Lab #8: System Identification and Model-Based Control Design
Fri 11/17	Laboratory Session Group #2		
Mon 11/20 – Fri 11/24	Thanksgiving Break		
Mon 11/27	Lecture: High Level Processor Peripherals		

Wed 11/29	Lecture: Designing an embedded controller circuit board. What different components are needed?		
Wed 11/29 Thur 11/30	Laboratory #8 Check-Off Deadline (Group 1) Laboratory #8 Check-Off Deadline (Group 2)		
Thur 11/30	Laboratory Session Group #1		Lab #9: Wall Following and RC Driving
Fri 12/1	Laboratory Session Group #2		
Mon 12/4	Lecture: Designing an embedded controller circuit board. What different components are needed?		
Wed 12/6	Lecture: Designing an embedded controller circuit board. What different components are needed?		
Wed 12/6 Thur 12/7	Laboratory #9 Check-Off Deadline (Group 1) Laboratory #9 Check-Off Deadline (Group 2)		
Thur 12/7	Laboratory Session Group #1		Lab #10: Final Project
Fri 12/8	Laboratory Session Group #2		
Mon 12/11	(No) Lecture: Project Work Day		
Wed 12/13	(No) Lecture: Project Work Day		
Fri 12/15	Final Project Demonstration (7PM–10PM)		

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.

Student Responsibilities

Students are responsible for all information covered in class and in lab. No extensions or make-ups for homework, labs, or the project will be given without prior permission or (in case of unforeseen absence) appropriate documentation. Class attendance is required. If you are going to miss a class you must speak to your Instructor prior to that class. If there is an emergency, you must talk to your Instructor upon your return. If you would like to discuss any grade, you must do so within one week of when the work was returned to you.

Laptops, Cell Phones, Pagers, etc.

Laptops may be used to take notes but not for activities that are unrelated to class (e.g., checking email, browsing, playing games ...). As a courtesy to the rest of the class, students are asked to keep cell phones, pagers, and other electronic devices silenced and put away at all times.

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.