SYLLABUS
ME EN 6240: ADVANCED MECHATRONICS

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Teaching Assistant:	TBD e-mail: TBD office: TBD
Lecture Time:	Mo/We 9:40 AM - 11:35 AM
Lecture Location:	WEB 1248
Office Hours:	*by appointment only*
Course Web Page:	Canvas: http://utah.instructure.com will be used to post all assignments and grades.
Prerequisites:	*Permission by the instructor.*
Textbook:	"Embedded Computing and Mechatronics with the PIC32 Microcontroller - 1st Edition" Kevin Lynch, Matthew Elwin, and Nicholas Marchuk; Elsevier Science, ISBN 9780124201651, 9780124202351. Get an electronic copy of the book at the following link: Embedded Computing and Mechatronics with the PIC32 Microcontroller
Notes:	**This syllabus is subject to change by the instructor. Student will be notified of any change. Revisions will be posted to Canvas.**

Course Purpose: ME EN 6240 will focus on providing you with the necessary skills to integrate sensors, actuators, and microcontrollers professionally. To this end, we will not rely on common software and hardware abstraction layers. About half of the course will be focused on programming a PIC32 microcontroller, specifically the PIC32MX795F512H. You will learn how to develop software for the PIC32 from scratch in C rather than using sample code. The second part of the course will be dedicated to the integration of sensors and actuators. In this part, the focus will be on hardware implementation, for example, we will be using low-level software commands rather than libraries to control the PIC's peripherals. The overarching goal of this course is to provide you with a foundation based on the lowest-level building blocks you will need for professional integration of microcontrollers with sensors and actuators.

Course Objectives: By the end of the course, you should be able to do the following things:

- Program modular, readable code in C
- Describe the architecture of a modern 32-bit microcontroller
- Use advanced references such as Microchip documentation to develop mechatronics projects based on microcontrollers
- Interface peripherals to microcontroller using series and parallel communication protocols
- Operate and control DC motors using microcontrollers

Video Lectures and Flipped Classroom

This is a flipped classroom, **you will be required to watch video lectures and do readings in advance of class**. We will use the time in class for Q&A and interactions with the instructor as you work on assignments. In class, I will briefly review the lecture comprehension quizzes and the material that was covered, get a little discussion going and take questions. Then, I will ask you to work on a practice exercise either individually or in small groups. If time remains, we may work on homework together. I will be available to help. On days when a homework assignment is turned in, I will leave time for any questions about it. On days before a quiz, I will spend as much time reviewing the material covered by the quiz as you would like. The purpose of the flipped classroom is to create a learner-centered environment; however, **you need to be proactive for this system to work**.

This course will take advantage of the material developed by Dr. Kevin Lynch and colleagues at Northwestern University. We will use the book Embedded Computing and Mechatronics with the PIC32 Microcontroller. Each book chapter has video lectures, which you can find on this channel: YouTube channel or at this page: NU32 Videos.

After the first day of class, we will have video lecture comprehension questions (L-comps) due before every class, assignments due before class as specified on the schedule, and quizzes as specified on the detailed schedule. ***An up-to-date detailed course schedule with videos, reading, assignments and quizzes can be found in this Google doc.***

Grading:

The final grade will be calculated using the following grading scheme: 30% homework assignments, 30% in-class quizzes, 20% L-comps, and 20% final project/exam. We will have short quizzes every Wednesday at the beginning of class covering material on the previous assignment. Bring a sheet of paper you can turn in with your quiz answers. Your lowest assignment score and L-comp score will be dropped. Each student will individually

complete all assignments, including a significant final project and demo that will take the place of the final exam.

Homework:

All homework assignment and quizzes (comprehension tests) will be submitted using the Canvas. Homework should be submitted by 1 PM on the day it is due. **Late homework will not be accepted under any circumstances. However, your lowest assignment will be dropped.**

Final project - DC motor control

In this final project, you will implement the electronics and software for a professional nested-loop brushed DC motor control system, where the outer-loop motion controller, running at hundreds of Hz, uses a motor reference trajectory and encoder feedback to generate a commanded torque (equivalently, motor current), and the inner-loop current controller, running at 5 kHz, controls the Pulse-Width Modulation (PWM) signal to an H-bridge to achieve the commanded motor current. Sensors for the project will include a motor current sensor and a motor encoder, and the software will use multiple interrupts and peripherals such as analog input, digital I/O, timers, output compare, and SPI and UART communication. Optional extensions save data to Flash memory and use the Parallel Master Port (PMP) to drive an LCD display. Students will create a MATLAB interface to the PIC32 MCU via communication over a USB cable. The interface will provide options that allow the user to set feedback gains, test the current-control loop in isolation, specify the coefficients of a motor trajectory, and plot the results of the controller's trajectory-tracking performance.

Expectations:

This flipped classroom has been designed to promote your engagement and tailor the learning to your needs. For this system to work you need to stay fully engaged during the class period; even if your computer is open no other distractions should lessen your contribution to the class. Learning from classmates, and helping classmates, is encouraged, up to the stage of conceptualizing solutions. You are not allowed to fully complete a solution in a team unless specified by the instructor. Plagiarism will not be tolerated, including copying another student's work, allowing another student to copy your work, copying code or solutions internet without attribution.

Reading, Assignment, and Class Schedule

Wk.	*Date*	*Topic*	*Before class*	*In class*
1	01/10 M	Introduction		Talk about goals and expectations Familiarize with SpatialChat, room dividers, and screen sharing Install GCC and start covering the first videos
	Preliminaries			
	01/12 W	Crash Course in C	*Reading:* pp 515-527 *Videos:* 1-7 of Appendix A **Assignment A1 due** (Exercise 1 of Appendix A)	Video Q&A Work on assignment A2 Demo: Exercise 15
2	01/17 M	Martin Luther King Jr. Day		
	01/19 W	Crash Course in C	*Reading:* pp 528-539 *Videos:* 8-11 of Appendix A	Video Q&A Work on assignment A2 Demo: Exercise 15 and 42
3	01/24 M	Crash Course in C	*Reading:* pp 540-567 *Videos:* 12-17 of Appendix A **Assignment A2 due** (Exercises 2-4, 6-8, 10-13, 14-15, 16-19, 21-22 of Appendix A)	Video Q&A Work on assignment A3 Demo: Exercise 35
	01/26 W	Crash Course in C	*Reading:* pp 567-573 **Assignment A3 due** (Exercises 27-28, 30-32, 34-35 of Appendix A)	**Quiz on Appendix A** Demo Makefile
	The PIC32 microcontroller			
4	01/31 M	Fundamentals 1 – Getting started	*Reading:* Chapter 1 pp 3-14 *Videos:* Chapter 1, video 1 ONLY **Assignment 1 due**	Video Q&A Demo: Compiling the bootloader Your first PIC32 program
	02/02 W	Fundamentals 2 – Hardware	*Reading:* Chapter 2 (pp.17-32) *Videos:* 1-4 of Chapter 2	Video Q&A Work on Assignment 2
5	02/07 M	Fundamentals 3 - Software	*Reading:* Chapter 3 (pp.35-49) *Videos:* 1-2 from Chapter 3 **Assignment 2 due**	**Quiz on Chapter 2** Video Q&A Work on Assignment 3

	02/09 W	Fundamentals 3 - Software	*Reading:* Chapter 3 (pp. 50-56) *Videos:* 3-4 from Chapter 3	Video Q&A Work on Assignment 3
6	02/14 M	Fundamentals 4 – Libraries	*Reading:* Chapter 4 (pp. 59-67) *Videos:* 1 from Chapter 4 **Assignment 3 due**	**Quiz on Chapter 3** Video Q&A Work on Assignment 4
	02/16 W	Fundamentals 5 – Time and space optimization	*Reading:* Chapter 5 (69-84) *Videos:* 1-2 from Chapter 5 **Assignment 4 due**	**Quiz on Chapter 4** Video Q&A Work on Assignment 5
7	02/21	Presidents Day		
	02/23 W	Fundamentals 6 – Interrupts	*Reading:* Chapter 6 (91-108) *Videos:* 1-5 from Chapter 6 **Assignment 5 due**	(Teaching Assistant) **Quiz on Chapter 5** Video Q&A Work on Assignment 6
8	02/28 M	Peripherals 1 – DIO, Counter/Timers	*Reading:* Chapter 7-8 *Videos:* ALL from Ch 7-8 **Assignment 6 due**	**Quiz on Chapter 6** Video Q&A Work on Assignment 7-8-9-10
	03/02 W	Peripherals 2 – Output Compare - Analog Input	*Reading:* Chapter 9-10 *Videos:* Chapter 9-10	(Teaching Assistant) Video Q&A Work on Assignment 7-8-9-10

Spring Break (03/06-03/13)

	Mechatronics			
9	03/14 M	Review of electrical circuits	*Reading:* Appendix B (pp 587-609) **Assignment on 7-8-9-10 due**	**Quiz on Chapter 7-8-9-10** **Work on Assignment B**
	03/16 W	Review of brushed motors	*Reading:* pp 399-421 *Videos: 1*-9 of Ch 25	Video Q&A Work on Assignment 25-26 **Work on Assignment B**
10	03/21 M	Gearing and Motor Sizing	*Reading:* pp 427-437 *Videos:*1-3 of Ch 26 **Assignment B due**	Video Q&A Work on Assignment 25-26
	03/23 W	DC motor control	*Reading:* pp 439-455 *Videos:*1-4 of Ch 27	Work on Assignment 27 Video Q&A

11	03/28 M	DC motor control Project (1)	**Assignment 25-26 due** *Reading:* Ch 28 Videos: Ch 28	**Quiz on Chapter 25-26** Video Q&A Project review
	03/30 W	DC motor control Project (2) and Feedback Control	**Assignment 27 due** *Reading:* Ch 23 Videos: 1-5 Ch 23	**Quiz on Chapter 27** Summary of Ch.23 Video Q&A Work on Assignment 23
12	04/04 M	Digital Signal Processing	**Assignment 28 due** **Assignment 23 due** Reading: Ch 22	Summary of Ch.22 Work on Assignment 22
	04/06 M	DC motor control Project (3) and UART	*Reading:* Ch 11 *Submit Project Update 1*	(Teaching Assistant) Discussion on 11, 12 Work on Project
13	04/11 W	DC motor control Project (4) and SPI	**Assignment 22 due** *Reading:* Ch 12	(Teaching Assistant) Discussion on 11, 12 Work on Project
	04/13 M	DC motor control Project (5) and I2C, CAN bus	*Reading:* Ch 13, 19 *Submit Project Update 2*	(Teaching Assistant) Discussion on 13, 19 Work on Project
14	04/18 W	*Work on Project*	*Work on Project*	*Work on Project*
	04/20 M	*Work on Project*	*Work on Project* *Submit Project Update 3*	*Work on Project*
15	04/25	*Work on Project*	*Work on Project*	*Work on Project*
	04/27	Reading Day		
16	05/03 M 8-10 AM	**FINAL PROJECT DUE**	**Submit your code**	**Demonstration of the motor control project**

Assignments

Assignment A1: Exercises 1, of Appendix A

Assignment A2: Exercises 2-4, 6-8, 10-13, 14-15, 16-19, 21-22 of Appendix A

Assignment A3: Exercises 27-28, 30-32, 34-35 of Appendix A

Assignment B: See Assignment B.pdf on Canvas

Assignment 1: Download, install all software as indicated through the end of chapter 1.3.

Assignment 2: Exercises 3-16 from Chapter 2 (pp. 33-34)

Assignment 3: Exercises 1-9 from Chapter 3 (pp. 56-57)

Assignment 4: Exercise 1,2 from Chapter 4 (pp. 67-68)

Assignment 5: Exercise 3, 4, 6, 10 from Chapter 5 (pp. 85-87)

Assignment 6: Exercise 1, 4, 5, 8, 13, 19 from Chapter 6 (pp. 108-111)

Assignment 7-8-9-10: Exercise 1,2 from Chapter 7, Exercise 1, 2 from Chapter 8, Programming Exercise, Exercise 1 from Chapter 9, Exercise 2, 3 from Chapter 10

Assignment 22: Exercise 2,3 from Chapter 22 (pp. 373)

Assignment 23: See Canvas (modified form Exercise 1 from Chapter 23 (pp. 273))

Assignment 25-26: Exercises 1, 2, 3, 7, 8 from Chapter 25 (pp. 421-425). Exercise 1, 4 from Chapter 26;

Assignment 27: Exercise 3,4,5,7, Chapter 27.

Assignment 28: See Canvas