UNIVERSITY OF BRITISH COLUMBIA
Department of Mechanical Engineering
MECH 423 – Mechatronic Product Design – 2020W

Course Syllabus

Objectives
MECH 423 – Mechatronic Product Design – teaches the development of industrial and human-centric mechatronic products. Specific topics include data acquisition, user interfaces, embedded systems design, precision timing and control, and electronic interfaces for sensors and actuators. High-level concepts include system design, product conceptualization, prototyping and development, design for manufacturing, and self-directed knowledge acquisition.

Contact Information
Instructor:	Dr. Hongshen Ma (hongma@mech.ubc.ca);	
TA:	Samuel Berryman (samberry@mail.ubc.ca);	Office hours: See Canvas calendar
TA:	Alec Xu (alecxu@mail.ubc.ca);	Office hours: See Canvas calendar

Lecture Format
For fall 2020, MECH 423 will be delivered entirely online. We will use Canvas (https://canvas.ubc.ca/) to provide course materials, facilitate discussions, materials submission, and exams. Lectures will be delivered via Zoom app embedded in Canvas. The passcode for all Zoom sessions is '**423**'. Feel free to ask questions during lectures by typing them into the chat window. Lecture recording and notes and will be available online.

Schedule and Locations
Lectures: Wed & Fri 12-1 PM Vancouver time (Zoom 654 9966 1511, passcode: 423)
Labs: Mon 9-12 Vancouver time via Zoom
Lab exams: Lab 1 exam 9/28 via Zoom; Lab 2 exam 10/19 via Zoom;
Final project demo: Dec 4 6-9 pm via Zoom (to be confirmed)

Computer, Software, and Hardware Requirements
There are specialized hardware and software requirements for this class. Please prepare the following in advance:

1. Windows-based PC

Each student is required to have access to a Windows-based PC. We strongly encourage all students to use your own laptop running Windows. If you have a Mac, you will need to dual-boot or virtualize Windows. Parallels Desktop (~$50) and VirtualBox (free) are both good options for virtualizing.

2. Install Microsoft Visual Studio 2019

We will develop data acquisition and user-interface software using Visual C#. Students begin by searching for Visual Studio 2019 and download the installer for the free "Community" version. Run the installer and select only the ".NET Desktop Development" option. After installing, start learning about Visual Studio, programming in C#, and Windows Forms starting from the embedded links. Please also follow these two video tutorial series: C# 101 and .NET Core 101. The video tutorials are for console programs rather than Windows Forms, but the materials are still highly relevant for this course. Additional tutorials can be found on MSDN, Google, or YouTube.

3. Code Composer Studio (CCS) for MSP430 Microprocessors

For Lab #2 and beyond, we will use Code Composer Studio to program MSP430 microprocessors. Download and install the latest free version of Code Composer Studio (CCS) starting from this webpage: http://processors.wiki.ti.com/index.php/Download_CCS. After installing, update the compiler for MSP430 microprocessors according to instructions. It's also useful to download PuTTY, an open-source utility for communicating over serial ports. Download "putty.exe" for Intel x86 machines directly from here.

4. Digital Multimeter

A digital multimeter is a handy tool for mechatronics engineers. We are not providing one since it is not strictly required for this course. However, if you want to get one for yourself, any $30-50 digital multimeter (e.g. from Canadian Tire or Home Depot) will do. Look for the ones with auto-shutoff and audible connectivity check.

Lab Kit

Each student is provided with a lab kit required to complete the labs. The kit contains an MSP-EXP430FR5739 Experimenter board (we'll call it the EXP board), a breadboard, a ribbon cable, Analog Discovery 2 portable oscilloscope, and materials required to complete Lab 3. Students are expected to return the kit and all its contents in working condition at the end of the semester. Any missing items are subject to a replacement fee. A detailed bill of materials is provided in a separate document.

Grading Scheme

Lab 1 – 15%; Lab 2 – 25%; Lab 3 – 20%; Project proposal – 5%; Final project – 35%
Final grade is subject to scaling. Up to 10% discretionary grade may be awarded for exceptional creativity or effort.

Policy on Grading

MECH 423 is an advanced-level project-based class. Therefore, a degree of subjectivity factors into many grading decisions. Some evaluations of student work are done based on committee review by the TAs, professor, and class alumni. We are happy to discuss the rationale for your grades and ways that you can improve. However, students are not permitted to ask for grade adjustments during these meetings. <u>Requests for grade adjustments must be submitted in writing and will be reviewed by the TAs and the professor.</u>

Expectations on Computer Maintenance

This course requires extensive use of computers and other hardware components. <u>It is the student's responsibility to ensure your computers and software are operational during lab demos and exams.</u> Computer and software problems cannot be used as a reason to retake lab exams or for grade adjustments.

Policy on Deadlines and Excused Absences

All deadlines are non-negotiable. Excused absences for mandatory lab sessions (lab exams and project evaluations) are only granted in exceptional circumstances, such as for <u>documented</u> medical emergencies. Missed deadlines or unexcused absences will result in a grade of 0.

Course Outline (subjective to change)

1. **Introduction**
    a. Architecture of mechatronic systems
    b. Traditional mechatronic systems versus mechatronic products
2. **Data Acquisition and User Interface Software Design**
    a. Libraries and objects in Visual C#
    b. Forms and controls
    c. Event-driven programming
    d. Serial communications
    e. Circular buffers (Queues)
    f. State machines
3. **Embedded Systems Design**
    a. Microprocessors versus computers
    b. C programming syntax for microprocessors
    c. Digital I/O
    d. Clock configuration
    e. Interrupts
    f. Analog-to-digital conversion
    g. Serial communications
    h. Precise timing generation and measurement
    i. Programming structure (Polling vs. interrupt-driven vs. event-driven)
    j. Packet communications

4. **Actuators and Circuits**
    a. Source and load
    b. Pulse width modulation
    c. Brushed DC motors
    d. Stepper motors
    e. Quadrature encoders
    f. Negative feedback
    g. PID control
    h. MOSFETs and H-bridges
    i. MOSFET drivers
    j. Power supply
    k. Diodes and transistors
    l. Op amp and impedance transforms
    m. Sensor interfaces
5. **Computer Vision for Mechatronic Applications**
    a. Software libraries and packages
    b. Camera interfaces
    c. Basic image processing

Suggested Reference Material

- Datasheet and User's guide (two documents!) for the MSP430FR573x family of microprocessors can be found at http://www.ti.com/product/MSP430FR5739.
- MSP430 Microcontroller Basics, Davies, J.H., 2008. Available electronically through the UBC library.
- Practical Electronics for Inventors, Scherz, P., 2000. Available electronically through the UBC library.
- Op Amps for Everyone, Mancini, R., and Carter, R. Eds, 3rd Ed., 2009.
- The Art of Electronics, Horowitz, P., and Hill, W., 2nd Ed., 1989. (TK7815.H67 1989).
- Capacitive Sensors: Design and Applications, Baxter, L., 1997. Available online.
- Sensors and Signal Conditioning, Pallas-Areny, R. and Webster, J.G., 2nd Ed., 2001 (TK7872.T6 P25 2001)
- You are encouraged to find additional resources from web or the library.

Labs and Final Project

The exercises for this class consist of 3 labs and 1 final project, all of which are completed individually. The final project is evaluated based on the proposal, final report, and in-lab demonstrations. Here are brief summaries of the labs and final project.

Lab 1 (15%): Students learn to develop data acquisition and user-interface software using Visual C#. Students complete exercises on their own. Students are evaluated in a lab exam where they will complete a set of programming exercises and then demo their program to the TAs.

Lab 2 (25%): Students learn to program the MSP430 microprocessor and completes practice exercises on their own. Students are evaluated in a lab exam where they will complete a set of exercises and then demo their work to the TAs.

Lab 3 (20%): Students learn to build and program a motor controller. The motor controller may be useful for their final project. Students are evaluated based on completion of laboratory exercises and quality of their lab report.

Project proposal (5%): Students create a proposal to develop a mechatronic device. Students may propose to 1) develop a new device that is not currently available, or 2) develop a device that is currently available using principles and tools taught in the class. In the latter case, a polished final product is expected. The proposal should consist of rationale and goals for the product, existing examples of the proposed mechatronic product, functional requirements (FRs) that will be met, and the work plan for meeting each FR. Each student must identify parts of the project that he/she will be individually responsible for. Students will consult with the prof and TAs about their idea before finalizing a proposal. Proposals are graded based on the originality of their proposal, creativity of their approach, appropriateness of their functional requirements, feasibility of their plan, and clarity of their writing. Proposals must be approved by the TAs and prof.

Final project (35%): Students work to develop the product described in their proposal. Hardware and software developed by the student team should be functional, robust, user-friendly, and have an appearance of a finished product. Students are encouraged and expected to explore all available resources for components and fabrication. Students may need to purchase some hardware components by themselves. Some modest components may be purchased using departmental funds. Deliverables include functional hardware, detailed project report, graphical abstract, and video. Students will demonstrate their project to TAs and the prof in lab. The project report should provide a clear and comprehensive documentation of the project in such a way to allow a senior undergraduate student to duplicate this project. Both working and non-working components should be documented. The report should include graphics such as schematic drawings, block diagrams, circuit diagrams, mechanical design drawings, photos of components, screen shots from computer programs, and videos of the functioning device. All design files should be packaged as appendixes to the report and submitted electronically. The report should also document components of the project that each student worked on.

Lecture and Lab Schedule (Subject to Change)

Monday Lab Activity / Deliverables	Wednesday Lecture	Friday Lecture
9/07 Labour Day	9/09 Introduction	9/11 Readout 1
9/14 Lab 1 exercises 1-3 due	9/16 Readout 2 Lab 1 exercises 4-5 due	9/18 Readout 3
9/21 Lab 1 exercises 6-7 due	9/23 Microprocessor 1	9/25 Microprocessor 2
9/28 **Lab 1 Exam**	9/30 Microprocessor 3 Lab 2 exercises 1-3 due	10/02 Microprocessor 4
10/05 Lab 2 exercises 4-7 due	10/07 Microprocessor 5	10/09 Microprocessor 6
10/12 Thanksgiving: No lab	10/14 Final project info Lab 2 exercises 8-10 due	10/16 Lab 3 info
10/19 **Lab 2 Exam**	10/21 Motor control 1	10/23 Motor control 2
10/26 Lab 3 exercise 1 Project proposal discussions	10/28 Motor control 3	10/30 Motor control 4
11/02 Lab 3 exercises 2-3 Project proposal due	11/04 Motor control 5	11/06 Motor control 6
11/9 Lab 3 exercises 4-5	11/11 Remembrance Day	11/13 Circuits 1
11/16 Project help session, Lab 3 report due	11/18 Circuits 2	11/20 Circuits 3
11/23 Project help session	11/25 Circuits 4	11/27 Circuits 5
11/30 Project help session	12/02 Readout 6	12/04 Final project demo
12/07 No more classes		

Statement on Academic Freedom

During this pandemic, the shift to online learning has greatly altered teaching and studying at UBC, including changes to health and safety considerations. Keep in mind that some UBC courses might cover topics that are censored or considered illegal by non-Canadian governments. This may include, but is not limited to, human rights, representative government, defamation, obscenity, gender or sexuality, and historical or current geopolitical controversies. If you are a student living abroad, you will be subject to the laws of your local jurisdiction, and your local authorities might limit your access to course material or take punitive action against you. UBC is strongly committed to academic freedom, but has no control over foreign authorities (please visit http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,33,86,0 for an articulation of the values of the University conveyed in the Senate Statement on Academic Freedom). Thus, we recognize that students will have legitimate reason to exercise caution in studying certain subjects. If you have concerns regarding your personal situation, consider postponing taking a course with manifest risks, until you are back on campus or reach out to your academic advisor to find substitute courses. For further information and support, please visit:http://academic.ubc.ca/support-resources/freedom-expression