UNIVERSITY OF BRITISH COLUMBIA
Department of Mechanical Engineering
MECH 423 – Mechatronic Product Design – Spring 2016

Course Syllabus

Objectives
MECH 423 – Mechatronic Product Design (formerly Biomechatronics) – 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-level design, product conceptualization, prototyping and development, and design for manufacturing.

Contact Information
Instructor:	Dr. Hongshen Ma (hongma@mech.ubc.ca);	Office hours: before lectures on Wed and Fri
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TA:	Jeff Chiu (jeffreycychiu@gmail.com);	Office hours: by appointment

We prefer to answer questions in person. When emailing, please add 'MECH423' to the subject line.
Class handout material will be available on Connect (connect.ubc.ca).

Schedule and Locations
Lectures: Wed & Fri 2-3 PM in CEME 1202
Labs: Mon 2-5 PM in KAIS 1120 (Mechatronics Teaching Lab)
Lab exams: Lab 1 exam 1/18 2-5 PM in EDC 102; Lab 2 exam 2/10 7-10 PM

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 (7-10). If you have a Mac, you will need to dual-boot or virtualize Windows. Parallels Desktop (~$40) and VirtualBox (free) are both good options for virtualizing.

2. Install Microsoft Visual Studio 2015
In Lab #1, we will develop user-interfaces using Visual C#. Search for Visual Studio 2015 and download the free "Community" version. Install, select the standard package for C#, register with your Microsoft account. After installing, start learning about Visual C# by taking the Getting Started with Visual C# and Visual Basic tutorial.

3. Digital Multimeter
A digital multimeter will be extremely useful for Lab #3 and the final project. We recommend students to buy their own since every engineer should have one and know how to use it. Any $20-30 digital multimeter (e.g. from Canadian Tire or Home Depot) will do. Look for ones with auto-shutoff and audible connectivity check features.

4. 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 version of Code Composer Studio (CCS) starting from this webpage: http://processors.wiki.ti.com/index.php/Download_CCS. Download the free "code size limited" version. You will have to register with TI.com and answer questions about how you will not use this product to help terrorist organizations, etc. After installing, upgrade the compiler for MSP430 microprocessors according to instructions. Also, download PuTTY, an open-source utility for communicating over serial ports. Download "putty.exe" for Intel x86 machines directly from http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html.

Lab Kit
Each student is provided with a kit required to complete the labs. The kit contains a custom-designed printed circuit board, a breadboard, MSP430 programming adaptor, ribbon cable, two USB cables, and a plastic container. Students are expected to return the kit and all its contents in working condition at the end of the semester. Any missing item from

the kit is subject to a replacement fee. A picture of the lab kit and replacement fee schedule is shown at the end of this document. Note: no wire strippers are included in this year's kit.

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 and Computing Expectations

This is an advanced-level project-based class. Therefore, a degree of subjectivity factors into many grading decisions. Certain 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 the ways that you can improve. However, students are not permitted to ask for grade increases during these discussions. Requests for grade adjustments must be submitted in writing and will be reviewed by the TAs and the professor.

Furthermore, this course requires extensive use of computers and other hardware components. It is the student's responsibility to ensure these systems are operational during tests and demos. Computer and/or hardware 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 documented medical emergencies. Missed deadlines or unexcused absences will result in a grade of 0.

Course Outline (tentative)

1. **Introduction**
    a. Traditional mechatronic systems versus mechatronic products
    b. Architecture of mechatronic systems
2. **Readout and User Interface 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. Serial communications
    g. Precise timing measurement and generation
    h. Polling vs. interrupt-driven vs. event-driven programming
4. **Actuators Interfaces**
    a. Source and load
    b. Power supply
    c. BJT output stages
    d. Pulse width modulation
    e. MOSFET as a switch
    f. Miller effect
    g. MOSFET drivers and H-bridges
5. **Sensors Interfaces**
    a. Switches
    b. Optical encoders

c. Signal impedance
d. Op amp circuits
e. Bootstrapping (anti-Miller effect)
f. Shielding and grounding
g. Peak detection and rectification

Suggested Reference Material

- Datasheet and User's guide (two documents!) for the MSP430F22xx microprocessors can be found at http://focus.ti.com/docs/prod/folders/print/msp430f2232.html.
- 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 primarily consist of 3 labs and 1 final project. Lab 1 and 2 are done individually, and are evaluated via lab exams. Lab 3 is done in groups of two and evaluated via a demo. The final project is generally worked on in teams of two. However, each student must identify individual contributions to the project *a priori* and are graded based on those contributions. The final project is evaluated based on the proposal, the final report, and in-lab demonstrations. Here are brief summaries of the labs and final project.

Lab 1 (15%): Students learn to develop digital readout and user-interface programs 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 self-organize into teams of two. The student teams learn to build and test a motor control printed circuit board (PCB). The PCB is a motor controller that may be useful for their final project. Student teams are evaluated on the quality of the PCB and completion of laboratory exercises in motor control.

Project proposal (5%): Students will work in teams of two to create a proposal to develop a mechatronic device. Students may propose to 1) develop a new device that is not commercially available, or 2) develop a product that is commercially 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 initially consult with the TAs and prof on a draft version of their proposal before submitting the final version. 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 Due	Wednesday Lecture	Friday Lecture
1/4 Lab kit distribution and lab 1 help session	1/6 Introduction	1/8 Readout 1
1/11 Lab 1 mini-projects 1-3 due	1/13 Readout 2	1/15 Readout 3
1/18 Lab 1 Exam in	1/20 Microprocessor 1	1/22 Microprocessor 2
1/25 Lab 2 exercises 1-5	1/27 Microprocessor 3	1/29 Microprocessor 4
2/1 Lab 2 exercises 6-9	2/3 Microprocessor 5	2/5 Microprocessor 6
2/8 Family day Lab 2 help session pending TA availability	2/10 Lab 3 info & materials Lab 2 exam 7-10 pm	2/12 Final project info
2/15 Reading break, no class	2/17	2/19
2/22 Lab 3 help session, Project proposal discussion	2/24 Actuator interfaces 1	2/26 Actuator interfaces 2
2/29 Lab 3 check-off begins, Project proposal due	3/2 Actuator interfaces 3	3/4 Actuator interfaces 4
3/7 Lab 3 check-off continued	3/9 Actuator interfaces 5	3/11 Actuator interfaces 6
3/14 Project help session	3/16 Sensor interfaces 1	3/18 Sensor interfaces 2
3/21 Project help session	3/23 Sensor interfaces 3	3/25 Good Friday, no class
3/28 Easter Monday	3/30 Sensor interfaces 4	4/1 Sensor interfaces 5
4/4 Project help session	4/6 Sensor interfaces 6 Evening: Final project demo	4/8 Final class

Lab Kit Contents and Replacement Fee

Kit Component	Replacement Fee
Gumstick PCB	$150
Breadboard	$20
MSP430 Programming Adaptor	$20
MSP430 Programming Cable	$20
USB cable ($10 each)	$20
Kit box	$20
Total	$250

Note: wire strippers are not included in this year's kit.