ENGG*3490 Introduction to Mechatronic Systems Design

01

Winter 2024
Section(s): 01

School of Engineering
Credit Weight: 0.75
Version 3.00 - January 24, 2024

---

1 Course Details

1.1 Calendar Description

This course covers the design of mechatronic systems, which are synergistic, combinations of components and controls drawn from mechanical engineering, electronics, and computer engineering. The course covers the following areas: (1) modeling of mechatronic systems (mechanical, electrical/electronic systems) and understanding their behaviour, (2) sensing and measurement including a variety of mechatronics sensors (fundamentals and applications), (3) actuators specific to mechatronics including motors and drivers (fundamentals and applications), (4) basic microcontroller programming as well as sensor/actuator integrations, and (5) control and its applications in mechatronics.

Pre-Requisites:	ENGG*2340, ENGG*2450
Co-Requisites:	ENGG*3410
Restrictions:	Non-BENG students may take a maximum of 4.00 ENGG credits.

1.2 Course Description

This course covers an introduction to mechatronics systems. Mechatronics, in general, is involved with mechanical, electrical, and computer systems. Recently, mechatronics has found various applications in many fields, especially in the automation and manufacturing industries. In this course, you will learn about mechatronics systems: how are they designed and controlled. As well, some control techniques for mechatronic systems will be introduced, and finally, mobile robotic systems and their recent advances will be reviewed. By the end of the term, you should have a good understanding of the design, modeling, and control of mechatronic systems. This course contains theory and practical applications of those systems. More importantly, the course has hands-on labs that provide you with the great skill

sets required to succeed in your career. This course covers the following topics:

1. Introduction to mechatronic systems: Basics
2. Modeling of mechatronics system: Closed-loop control system
3. Modeling of mechatronics system: Mechanical systems.
4. Signal processing: Op-Amps
5. Modeling of mechatronics system: Electrical systems.
6. Sensors and instrumentation: MEMS sensors.
7. System response
8. Electromechanical and Smart Actuators
9. PID Control system.

1.3 Timetable

Lectures

T/TH: 11:30 am–12:50 pm, MCKN, Room 116

Laboratory:

M: 11:30 am-1:20 pm, THRN Room 2307

F: 11:30 am-1:20 pm, THRN Room 2307

* The TA will conduct all the labs. Once the grouping is done, and you receive your equipment, you will perform the labs at home. The TA will provide all the necessary instructions and arrange with the students for grouping and equipment pick up the first week of classes. This information will be posted on the Courselink. For all the lab related materials, equipment, reports, etc. please contact the TA.

Note: Labs start the week of January 15

1.4 Final Exam

Final Exam: No final exam.

---

2 Instructional Support

2.1 Instructional Support Team

Instructor: Mohammad Al Janaideh Ph.D., P.Eng
Email: maljanai@uoguelph.ca

Telephone:	519-824-4120
Office:	THRN 1505
Office Hours:	T: 10:00-11:00 am
	TH: 2:00-3:00 pm

Lab Technician:	Kevin Dong , P.Eng.
Email:	kdong@uoguelph.ca
Telephone:	519-824-4120 x53729
Office:	RICH 2506
Office Hours:	By Appointment

2.2 Teaching Assistants

Teaching Assistant (GTA):	Michael Pumphrey
Email:	mpumphre@uoguelph.ca
Office Hours:	TBA on CourseLInk or By Appointment

---

3 Learning Resources

3.1 Required Resources

Course Website (Website)

News, homeworks, announcements, and grades will be regularly posted to the ENGG*3490 Courselink site. Students are responsible for checking the site very regularly.

Required Resources (Other)

Students are expected to attend all the lectures. Students are responsible for whatever material is taught in the class. Note that the textbook may not have all the material taught in the class.

There is no single textbook that can cover all the material taught in a Mechatronics course in general, simply because Mechatronics is multidisciplinary. The following book is a great source:

“Mechatronics: A Multidisciplinary Approach”, W. Bolton, 6th edition, Prentice Hall, 2015.

3.2 Recommended Resources

Recommended Resources (Textbook)

"Introduction to Mechatronics - Measurement Systems," David Alciatore, 2018.
"Modeling and Analysis of Dynamic Systems," Charles M. Close, Dean K. Frederick, 2001.
"The Design of High-Performance Mechatronics," 3rd edition R. Schmidt, G. Schitter, A. Rankers, J. Van Eijk, IOP, 2020.

“Applied Mechatronics”, A. Smaili, F Mrad, Oxford University Press, 2008.

“Programmable Logic Controllers”, Frank D. Petruzella, 3/E, McGrawHill, 2005.
“Mechatronics”, Dan S. Necsulescu, Prentice Hall, 2002.

“Principles of Robot Motion”, H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki and S. Thrun, MIT Press, Boston, 2005.

"Electric Machinary Fundamental”, by S. J. Chapman, McGraw-Hill, 5th edition, 2011.

“Principles and Applications of Electrical Engineering”, G. Rizzoni, McGraw-Hill, 5th edition, 2007. “Electric Machinary Fundamental”, by S. J. Chapman, McGraw-Hill, 5th edition, 2011.

“Programmable Logic Controller”, J. R. Hackworth, F. D. Hackworth, Jr., 4th edition, Prentice Hall, 2004.

3.3 Additional Resources

Additional Resources (Other)

Lecture Information: Students should attend the online classes and make their own notes. The lecture notes will be posted on the Courselink after each class.

Lab Information: The handouts for all the lab sessions will be posted in the lab section in the Courselink. All types of resources and links to web pages can be found in this section.

Homework: Homeworks with solutions will be posted on the Courselink.

Miscellaneous Information: Other information related to Mechatronics are also posted on the web page.

---

4 Learning Outcomes

4.1 Course Learning Outcomes

By the end of this course, you should be able to:

1. Learn how to work with sensors; learn how to acquire data; learn how to calibrate sensors.
2. Learn how to work with actuators and micro-controllers; learn to connect sensors and actuators to micro-controllers; learn to program micro-controllers.
3. Learn how to integrate mechatronics components
4. Learn how to design, solve problems, and perform data analysis for mechatronics systems.
5. Learn reporting and engineering communication.

4.2 Engineers Canada - Graduate Attributes (2018)

Successfully completing this course will contribute to the following:

#	Outcome	Learning Outcome
1	Knowledge Base	1
1.2	Recall, describe and apply fundamental principles and concepts in natural science	1
2	Problem Analysis	1, 2, 3, 4
2.2	Identify, organize and justify appropriate information, including assumptions	3
2.3	Construct a conceptual framework and select an appropriate solution approach	3
2.4	Execute an engineering solution	4
2.5	Critique and appraise solution approach and results	1, 2
3	Investigation	1
3.2	Design and apply an experimental plan/investigative approach (for example, to characterize, test or troubleshoot a system)	1
3.3	Analyze and interpret experimental data	1
4	Design	1, 3, 4
4.1	Describe design process used to develop design solution	1, 3, 4
4.2	Construct design-specific problem statements including the definition of criteria and constraints	1, 4
4.3	Create a variety of engineering design solutions	1, 4
4.4	Evaluate alternative design solutions based on problem definition	1, 4
4.5	Develop and refine an engineering design solution, through techniques such as iteration, simulation and/or prototyping	1, 4
7	Communication Skills	5
7.1	Identify key message(s) and intended audience in verbal or written communication as both sender and receiver	5

5 Teaching and Learning Activities

5.1 Lecture

Topics: Background and Review

Topics: Modeling of mechatronics system: Mechanical systems.

References: Class lectures

Topics: Signal processing: Op-Amps

References: Class lectures

Topics: Modeling of mechatronics system: Electrical systems.

References: Class lectures

Topics: Sensors and instrumentation: MEMS sensors.

References: Class lectures

Topics: System response

References: Class lectures

Topics: Electromechanical and Smart Actuators

References: Class lectures

Topics: PID Control system.

References: Class lectures

Topics: Control concepts
References: Class lectures

Topics: Mobile robots

References: Class lectures

5.2 Other Important Dates

Monday, January 8: Classes commence

ENGG4480 first lecture is on Tuesday, Jan 9. In-person.

Lectures: Tuesday -Thursday: 11:30 - 12:50 PM.

Monday, February 19, Winter Break -- No Classes Scheduled This Week.

Friday, February 29: Project plan presentation and progress (in the classroom)

Friday, March 29: Holiday -- No Classes Scheduled. Classes rescheduled to Monday, April 8.

Friday, April 4: last lecture.

Friday, April 4: project presentation in the lab.

Friday, April 12: final project report (via course link)

---

6 Assessments

6.1 Marking Schemes & Distributions

Name	Scheme A (%)
Labs	5
Exam 01	20
Exam 02	20
Project	55
Total	100

6.2 Assessment Details

Labs (5%)
Learning Outcome: 1, 2, 3, 4, 5

- **Lab 01:** Arduino Intro / Sensor Calibration
- **Lab 02:** Speed Control of Motor

Exam 01 (20%)
Date: Tue, Feb 13, 11:30 AM - 12:30 PM, Classroom
Learning Outcome: 4

Exam 02 (20%)
Date: Thu, Mar 28, 11:30 AM - 12:30 PM, Classroom
Learning Outcome: 4

Project (55%)
Learning Outcome: 1, 2, 3, 4, 5
Project: Mobile robot design.

6.3 Important Note

While you are encouraged to discuss with other classmates about the labs, there is zero tolerance for plagiarism or copying. Cases of academic misconduct will be reported.

6.4 Project

- **Project Description and Plan: presentation in the classroom and a brief report (up to five pages), (Feb 27 and Feb 29)**

The description of the project with all the necessary details will be posted on Courselink. This course project requires you to design and build a Mechatronics system based on your selection. The proposed system should include mechanical design, fabrication, actuators, sensors, and microcontroller (Control design). The objective of the proposed system should be identified and get approval before starting work on the project.

- **Project Rules**

1. Each group consists of 4~5 people (max. 5).
2. There is no late policy for the final demo. The late demonstration is **not** acceptable. Each group needs to demonstrate their project (whatever they have done by the deadline).

- **Project Milestones**

The project includes:

1. **Project Description and Objective:** This requires each group to present the project's

idea and objectives and the block diagram of the system's main components.
2. **Project structure and mechanical design:** This requires each group to show the proposed mechanical structure of the mechanical structure, show the CAD, and process the fabrication using a 3D printer.
3. **Components selection:** Each group must (i) determine the motor specifications (maximum torque, maximum speed, and power) to be suitable for the mechanical design. (ii) determine necessary sensors and the types of measured signals. (iii) the microcontroller should be selected.
4. **Modelling and Control Design:** In this stage, the mathematical model of the proposed system should be obtained and used to design a PID controller to achieve the desired tracking performance. Simulate the system using MATLAB/SIMULINK.
5. **Implementation and Experimental test:** This milestone includes the implementation of the proposed controller using a microcontroller and experimental test.

- **Project Submission**

In addition to the individual milestone reports, each group needs to submit the following.

1. **Experimental Demonstration in the Lab (April 5)**: Each group needs to run and test the mobile robot.
2. **Final Report (April 12):** The final report should include the following chapters

- Section 1: Introduction (Background, system applications, project description).
- Section 2: Mechanical Design and Fabrication.
- Section 3: Components Selection.
- Section 4: Modeling and Controller Design.
- Section 5: Experimental Test Results.
- Section 6: Conclusion.

Report deliverables will be marked based on the requirements detailed in the Report Deliverables Section. All reports are to be submitted on time. The design will be scored such that the best design in each category will receive the highest mark for that respective category.

Table 2: Important dates

Item	**Date**	**Mark**	**Excellent (90-100%)**	**Good (80-89%)**	**Satisfactory (70-79%)**	**Needs Improvement (0-69%)**
Project	Feb 27	15%	Comprehensive	Well-	Adequate	Lacks

Milestones and Progress: (a) presentation (in the classroom) (b) a brief report (up to 5 pages) Slides and report to be submitted via Courselink	(Lab 01-Monday) and Feb 29 (Lab 02-Friday)		and well-organized report. Clearly presents objectives, methodology, and results.	structured with minor room for improvement. Presents objectives, methodology, and results.	structure but lacking in detail and clarity. Some important components may be missing.	organization, detail, or key components. Fails to demonstrate an understanding of the task.
Project test (in the lab) THRN 2307	April 5 (11:30-1:20 pm)	65%	Outstanding performance in the competition. Demonstrates exceptional problem-solving and innovation.	Strong performance with room for improvement. Applies solid problem-solving and innovation skills.	Adequate performance but with notable shortcomings. Demonstrates basic problem-solving and innovation skills.	Poor performance in the competition. Lacks problem-solving skills and innovation
Final Report (via Course link)	April 12	20%	Exceptional depth, structure, and clarity. Thoroughly covers all aspects of the project.	Well-structured, but minor improvements needed. Adequately covers project components.	Adequate structure but lacks detail and clarity. Some critical components are missing.	Poorly structured, unclear, and lacking detail. Fails to cover critical aspects of the project.

7 Course Statements

7.1 Relationships with other Courses & Labs

Previous Courses:

ENGG*2340: Systems, first-order, 2nd order systems, signals
ENGG*3450: Fundamentals of DC and AC circuits, KVL, KCL

Courses:

ENGG*3410: Control systems, feedback, etc.

Follow-on Courses:

ENGG*4480: Advanced Mechatronics
ENGG*4030: Manufacturing System Design
ENGG*4480: Advanced Mechatronic Systems Design

8 School of Engineering Statements

8.1 Instructor's Role and Responsibility to Students

The instructor’s role is to develop and deliver course material in ways that facilitate learning for a variety of students. Selected lecture notes will be made available to students on Courselink but these are not intended to be stand-alone course notes. Some written lecture notes will be presented only in class. During lectures, the instructor will expand and explain the content of notes and provide example problems that supplement posted notes. Scheduled classes will be the principal venue to provide information and feedback for tests and labs.

8.2 Students' Learning Responsibilities

Students are expected to take advantage of the learning opportunities provided during lectures and lab sessions. Students, especially those having difficulty with the course content, should also make use of other resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This will allow the instructor to recommend extra resources in a timely manner and/or provide consideration if appropriate.

8.3 Lab Safety

Safety is critically important to the School and is the responsibility of all members of the School: faculty, staff and students. As a student in a lab course you are responsible for taking all reasonable safety precautions and following the lab safety rules specific to the lab you are working in. In addition, you are responsible for reporting all safety issues to the laboratory supervisor, GTA or faculty responsible.

9 University Statements

9.1 Email Communication

As per university regulations, all students are required to check their e-mail account regularly: e-mail is the official route of communication between the University and its students.

9.2 When You Cannot Meet a Course Requirement

When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons please advise the course instructor (or designated person, such as a teaching assistant) in writing, with your name, id#, and e-mail contact. The grounds for Academic Consideration are detailed in the Undergraduate and Graduate Calendars.

Undergraduate Calendar - Academic Consideration and Appeals
https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml

Graduate Calendar - Grounds for Academic Consideration
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml

Associate Diploma Calendar - Academic Consideration, Appeals and Petitions
https://www.uoguelph.ca/registrar/calendars/diploma/current/index.shtml

9.3 Drop Date

Students will have until the last day of classes to drop courses without academic penalty. The deadline to drop two-semester courses will be the last day of classes in the second semester. This applies to all students (undergraduate, graduate and diploma) except for Doctor of Veterinary Medicine and Associate Diploma in Veterinary Technology (conventional and alternative delivery) students. The regulations and procedures for course registration are available in their respective Academic Calendars.

Undergraduate Calendar - Dropping Courses
https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-drop.shtml

Graduate Calendar - Registration Changes
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/genreg-reg-regchg.shtml

Associate Diploma Calendar - Dropping Courses

https://www.uoguelph.ca/registrar/calendars/diploma/current/c08/c08-drop.shtml

9.4 Copies of Out-of-class Assignments

Keep paper and/or other reliable back-up copies of all out-of-class assignments: you may be asked to resubmit work at any time.

9.5 Accessibility

The University promotes the full participation of students who experience disabilities in their academic programs. To that end, the provision of academic accommodation is a shared responsibility between the University and the student.

When accommodations are needed, the student is required to first register with Student Accessibility Services (SAS). Documentation to substantiate the existence of a disability is required; however, interim accommodations may be possible while that process is underway.

Accommodations are available for both permanent and temporary disabilities. It should be noted that common illnesses such as a cold or the flu do not constitute a disability.

Use of the SAS Exam Centre requires students to make a booking at least 14 days in advance, and no later than November 1 (fall), March 1 (winter) or July 1 (summer). Similarly, new or changed accommodations for online quizzes, tests and exams must be approved at least a week ahead of time.

For Guelph students, information can be found on the SAS website
https://www.uoguelph.ca/sas

For Ridgetown students, information can be found on the Ridgetown SAS website
https://www.ridgetownc.com/services/accessibilityservices.cfm

9.6 Academic Integrity

The University of Guelph is committed to upholding the highest standards of academic integrity, and it is the responsibility of all members of the University community-faculty, staff, and students-to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University's policy on academic misconduct regardless of their location of study; faculty, staff, and students have the responsibility of supporting an environment that encourages academic integrity. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member or faculty advisor.

Undergraduate Calendar - Academic Misconduct

https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml

Graduate Calendar - Academic Misconduct
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml

9.7 Recording of Materials

Presentations that are made in relation to course work - including lectures - cannot be recorded or copied without the permission of the presenter, whether the instructor, a student, or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

9.8 Resources

The Academic Calendars are the source of information about the University of Guelph's procedures, policies, and regulations that apply to undergraduate, graduate, and diploma programs.

Academic Calendars
https://www.uoguelph.ca/academics/calendars

9.9 Illness

Medical notes will not normally be required for singular instances of academic consideration, although students may be required to provide supporting documentation for multiple missed assessments or when involving a large part of a course (e.g.. final exam or major assignment).