ELECENG 3EY4
ELECTRICAL SYSTEMS INTEGRATION PROJECT
COURSE OUTLINE

Please refer to course website for updated information.

COURSE DESCRIPTION

Calendar: An electrical engineering design and implementation project of reasonable complexity to be completed by small groups of students; oral presentations and written reports.

Course Summary: This course integrates knowledge from across multiple areas of the electrical engineering discipline including electric machines and drive systems, robotics, control systems, estimation, signal processing, and optimization. It introduces the students to the basic principles of electrified autonomous vehicles through their involvement in a system integration project. The students will develop and integrate software and hardware modules for the McMaster Autonomous Electrified Vehicle (AEV), which is built on a small-scale ($1/10^{th}$) RC vehicle platform. The goal is to develop sensing, planning, and control modules that allow the vehicle to operate in a range of scenarios from manual driving, through manual driving with driver-assist, to fully autonomous driving. The first few weeks of the course will focus on the electric propulsion system of the vehicle, exploring topics in modeling and control of electric motor drives. The second part of the course will concentrate on autonomous driving aspects of the vehicle. In this part, the student will explore strategies for manual driving with collision avoidance assistance, as well as fully autonomous driving. Moreover, the concept of localization and mapping in autonomous systems will be introduced. The students will be expected to gain practical skills in Linux OS, C/C++, Python, the Robot Operating System (ROS), and Matlab/Simulink. The knowledge integration objectives will be achieved by organizing the project around weekly/biweekly deliverables and milestones, while providing some flexibility as to how these goals will be achieved. The course will utilize some of the material and existing software stack from the F1TENTH project. Students can find many useful resources from the website of that project: https://f1tenth.org/.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): COMPENG 2DX4, ELECENG 3TP3 or ELECENG 3TP4 or IBEHS 3A03, ELECENG 2CI5, COMPENG 2DI4, COMPENG 2SH4, ELECENG 2CJ4.

Anti-Requisites: COMPENG 2DP4, COMPENG 3DY4.

SCHEDULE And MODE OF DELIVERY

The lectures will be delivered in-person format.

Lectures: Wednesday and Thursday 1:30pm – 2:20 pm
Tutorials: Wednesday 8:30am – 9:20am
Labs: Every week at 2:30pm - 5:30pm – L01, L06 Monday, L02, L07 Tuesday, L03, L08 Wednesday, L04, L09 Thursday, L05, L10 Friday (see course website for latest updates)

INSTRUCTORS

Dr. B. Bilgin
Email: bilginb@mcmaster.ca
Office: ITB-A218
Phone: 905-525-9140 ext. 27080
Office Hours: by appointment

Dr. S. Sirouspour
Email: sirous@mcmaster.ca
Office: ITB-A319
Phone: 905-525-9140 ext. 26238
Office Hours: by appointment

TEACHING ASSISTANTS

Names, contact information and office hours are provided on the course website.

COURSE WEBSITE/S

http://avenue.mcmaster.ca

COURSE OBJECTIVES

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

- Understand and use basic commands in the Linux operating system

- Understand the principles of the Robot Operating System (ROS) and use it to develop and implement a real-time control system on Nvidia Jetson Nano AI embedded computer
- Analyze the magnetic and electrical characteristics of electric motor drives
- Use reference frame transformations to develop a model of a permanent magnet synchronous motor
- Understand the basic principles of sensing, planning, and control in self-driving vehicles
- Use coordinate frames and rigid transformations for expressing configuration and movement of rigid bodies in two and three-dimensional space
- Develop driver-assist algorithm(s) for the autonomous electrified vehicle
- Understand the basic principles of simultaneous mapping and localization (SLAM) in autonomous systems
- Understand and develop autonomous driving algorithms using reactive methods
- Understand principals of Quadratic optimization

COURSE MATERIALS

Required Texts:
The instructors will provide lecture notes and materials which will be available on Avenue to Learn. The website of the F1TENTH project (https://f1tenth.org/) also contains ample resources relevant to the topics explored in this course.

Calculator:
Any type of calculator will be permitted in tests and examinations.

COURSE OVERVIEW

Week	Topic
1	Introduction to electrification and engineering system integration
2	Overview of electric motor drives
3	Operating principles of synchronous motors
4	Reference frame transformation and torque control in synchronous motors
5	Field-oriented control of synchronous motors
6	Introduction to hardware and software architecture of the McMaster AEV
6	Rigid body and coordinate frames
6	Ackermann vehicle driving model
7	Vehicle wheel odometry and its calibration
7	Manual driving with collision avoidance assistance using force fields
8	Principles of simultaneous localization and mapping (SLAM) in autonomous systems
9	Review of feedback control of first-order second-order systems

9	Reactive self-driving using reactive wall-following method
10-11	Quadratic optimization and finding virtual barriers
11	Self-driving using virtual barriers
12	Principles of stereo vision

At certain points in the course, it may make good sense to modify the schedule. The instructor may modify elements of the course and will notify students accordingly (in class, on the course website).

LABORATORY OVERVIEW:

The system integration project is organized into several laboratory modules described in the table below.

Week	Topic
2	**Linux Commands for the Control of McMaster AEV** The students will practice the essential commands that they will need to program and control the McMaster AEV.
3	**Setting up Jetson Nano and ROS in McMaster AEV** In this lab, the students will set up Jetson Nano and install Robot Operating System to Jetson Nano. These are essential steps to control the McMaster AEV.
4	**udev Rules and Testing McMaster AEV Components** The udev rules are a set of files that specify an outside device that may be connected to the peripheral of Jetson Nano. In this lab, the students will establish the udev rules that allow the Jetson Nano to detect devices and gain permissions to communicate with them.
5	**Programming of the Electronic Speed Controller in McMaster AEV** In this lab, the students will operate the motor drive system of the McMaster AEV. The motor drive converts the electrical input power from the battery to mechanical output power to rotate the wheels.
6	**Controlling Electronic Speed Controller from Jetson Nano** In this lab, the students will start controlling the Electronic Speed Controller in the McMaster AEV through Jetson Nano and analyze the operation of the motor drive at different operating conditions.
7	**Remote Control of McMaster AEV and Calibration of Vehicle Odometry** The students will become familiar with the vehicle control software architecture and its integration with various on-board sensors and the vehicle propulsion system. They will drive the vehicle manually and calibrate the vehicle odometry parameters. They will also learn about the f110 simulator platform.
8	**Localization and Mapping with McMaster AEV** This week's project activities will concentrate on the localization of the vehicle and mapping of its surrounding environment. The student will use a combination of the on-board LiDAR scan data, VESC-based wheel odometry, and IMU measurements for this purpose. They will employ the ROS implementation of the hector SLAM algorithm to construct a map of the vehicle environment and localize the vehicle in that environment at the same time.
9-10	**Driver-Assist Collison Avoidance and Autonomous Driving Using Reactive Wall-Following** The students will develop an algorithm for manual driving assist using the LiDAR scan data. They will then develop and implement an algorithm for self-driving by following wall(s) in the surrounding environment. They will use the LiDAR scan data to detect the walls on both sides of

	the vehicle. They will then implement a feedback-linearizing + PD controller to regulate the vehicle distance(s) from the wall(s).
11	**Autonomous Driving Using Virtual Barriers** The students will develop and implement an optimization-based algorithm for constructing virtual barriers on both sides of the vehicle that would separate it from obstacles in the environment. The vehicle is then controlled by regulating the vehicle distances to the virtual barriers.
12	**Improving Autonomous Driving using RGB-D Camera Data (Bonus Activity)** The students will have the option of improving the vehicle self-driving capability by integrating data from an RGB-D camera in addition to the LiDAR data. This is a bonus activity.

LABORATORY OPERATION

- Some of the course laboratory modules build on content from F1TENTH project (https://f1tenth.org/). Students are encouraged to visit their website for some useful resources.
- Each student is required to pass the lab safety quiz prior to attempting any of the laboratories. The video and quiz will be on Avenue to Learn.
- The integration project will be carried out in groups of no less than **3** and no more than **4** students based on availability of AEVs.
- Each group will be assigned a dedicated AEV kit, which they keep throughout the term.
- Each group must designate a contact person to pick up the AEV kit at the beginning of the term and return it in “working condition” at the end of term. The location and times of pick-ups/drop-offs will be announced on avenue to learn.
- Failure to return the AEV kit at the end of the term could result in a grade “0” for the project component or all group members.
- The group members must strictly follow safety instructions on the operation of the vehicle and all of its components. These instructions will be available on avenue to learn. Failure to follow the instructions can potentially lead to equipment damage and even injury.
- The group members will be responsible for replacing any damaged components due to improper operation of the AEV kit.
- The group members are expected to share the AEV kit as they see fit. It is recognized that member’s individual access to the equipment may vary depending to their circumstances. However, all group members must “equally” contribute to the project development. Group members will be required to explicitly state their contributions in the laboratory module reports. The instructors and TAs may ask questions to evaluate the stated contribution.
- Some project integration work is expected to be carried out outside regular laboratory and tutorial hours. This is strictly limited to modeling, coding, and testing in the simulation environment. The course instructors and TAs will use the tutorial and laboratory hours to guide students as to how to achieve interim module objectives and to resolve any issues arising during project development. *However, no work that involves the actual operation of motor drive system and battery unit may be carried out outside*

the regular laboratory hours without TAs and/or instructors' supervision. This type of work is strictly limited to laboratory and tutorial hours in the "in-person" setting under supervision.

- Each group must submit an electronic report for each laboratory module through Avenue to Learn. Detailed instructions and objectives for the laboratory modules, reporting requirements, and information about deadlines and late submission penalties will be announced on Avenue.

ASSESSMENT

Component	Weight
Test 1	15%
Project	70%
Test 2	15%
Total	100%

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. It is your responsibility to understand what constitutes academic dishonesty. Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at https://secretariat.mcmaster.ca/university-policies-proceduresguidelines/
The following illustrates only three forms of academic dishonesty:
• plagiarism, e.g., the submission of work that is not one's own or for which other credit has been obtained.
• improper collaboration in group work.
• copying or using unauthorized aids in tests and examinations.

AUTHENTICITY / PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online

learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.
Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, including lectures by University instructors.
The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the Code of Student Rights & Responsibilities (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and

personal growth of all McMaster community members, whether in person or online. It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATIONS

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's Academic Accommodation of Students with Disabilities policy.

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office normally within 10 working days of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC WORK

McMaster Student Absence Form (MSAF): In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

ACCREDITATION LEARNING OUTCOMES

Note: The *Learning Outcomes* defined in this section are measured throughout the course and form part of the Department's continuous improvement process. They are a key component of the accreditation process for the program and will not be taken into consideration in determining a student's actual grade in the course. For more information on accreditation, please ask your instructor or visit: http://www.engineerscanada.ca .

Outcomes	Indicators	Measurement Methods(s)
Actively contributes to the planning and execution of a team project.	6.1	Lab assignments and reports
Manages interpersonal relationships, taking leadership responsibilities as needed.	6.2	Lab assignments and reports
Demonstrates comprehension of technical and non-technical instructions and questions.	7.1	Lab assignments and reports
Composes an effective written document for the intended audience.	7.2	Lab reports
Composes and delivers an effective oral presentation for the intended audience.	7.3	Lab and exam questions
Describes the duty of a Professional Engineer to the public, client, employer, and the profession.	8.1	Exam questions
Evaluates the social impact of engineering activities, including health, safety, legal, cultural, and other relevant factors, and identifies uncertainties in decisions.	9.2	Lab assignments and reports
Plans and effectively manages a project's time, recourses, and scope, following business practices as appropriate.	11.2	Lab assignments and reports
Reflects on one's educational needs and opportunities for growth.	12.1	Lab and exam questions
Seeks and acquires appropriate external information as required, including showing awareness of sources of information and ability to critically evaluate them.	12.2	Lab and exam questions

Electrical and Computer Engineering Lab Safety

Information for Laboratory Safety and Important Contacts

This document provides important information for the healthy and safe operation of ECE instructional laboratories. This document is required reading for all laboratory supervisors, instructors, researchers, staff, and students working in or managing instructional laboratories in ECE. It is expected that revisions and updates to this document will be done continually. A McMaster University lab manual is also available to read in every laboratory and online https://hr.mcmaster.ca/app/uploads/2019/07/2019-McMaster-Lab-Manual.pdf

General Health and Safety Principles

Good laboratory practice requires that every laboratory worker and supervisor observe the following whether conducting lab work at school or at home:

1. Food and beverages are not permitted in the instructional laboratories.
2. A Laboratory Information Sheet on each lab door identifying potential hazards and emergency contact names should be known.
3. Laboratory equipment should only be used for its designed purpose.
4. Proper and safe use of lab equipment should be known before using it.
5. The course TA leading the lab should be informed of any unsafe condition.
6. The location and correct use of all available safety equipment should be known.
7. Potential hazards and appropriate safety precautions should be determined, and sufficiency of existing safety equipment should be confirmed before beginning new operations.
8. Proper waste disposal procedures should be followed.
9. Personal ergonomics should be practiced when conducting lab work. https://bit.ly/3fOE71E
10. Current University health and safety issues, and protocol should be known.

https://hr.mcmaster.ca/resources/covid19/workplace-health-and-safety-guidance-during-covid-19/

Location of Safety Equipment

Fire Extinguisher
On walls in halls outside of labs

First Aid Kit
ITB A111, or dial “88” after 4:30 p.m.

Telephone
On the wall of every lab near the door

Fire Alarm Pulls
Near all building exit doors on all floors

Who to Contact

Emergency Medical / Security: On McMaster University campus, call Security at extension **88** or **905-522-4135** from a cell phone.
Non-Emergency Accident or Incident: Immediately inform the TA on duty or Course Instructor.
University Security (Enquiries / Non-Emergency): Dial 24281 on a McMaster phone or dial 905-525-9140 ext. 24281 from a cell phone.
See TA or Instructor: For problems with heat, ventilation, fire extinguishers, or immediate repairs
Environmental & Occupational Health Support Services (EOHSS): For health and safety questions dial 24352 on a McMaster phone or dial 905-525-9140 ext. 24352 from a cell phone.
ECE Specific Instructional Laboratory Concerns: For non-emergency questions specific to the ECE laboratories, please contact 24103.

In Case of a Fire (On Campus Dial 88)

When calling to report a fire, give name, exact location, and building.

1. Immediately vacate the building via the nearest Exit Route. Do not use elevators!
2. Everyone is responsible for knowing the location of the nearest fire extinguisher, the fire alarm, and the nearest fire escape.
3. The safety of all people in the vicinity of a fire is of foremost importance. But do not endanger yourself!
4. In the event of a fire in your work area shout "*Fire!*" and pull the nearest fire alarm.
5. Do not attempt to extinguish a fire unless you are confident it can be done in a prompt and safe manner utilizing a hand-held fire extinguisher. Use the appropriate fire extinguisher for the specific type of fire. Most labs are equipped with Class A, B, and C extinguishers. Do not attempt to extinguish Class D fires which involve combustible metals such as magnesium, titanium, sodium, potassium, zirconium, lithium, and any other finely divided metals which are oxidizable. Use a fire sand bucket for Class D fires.
6. Do not attempt to fight a major fire on your own.
7. If possible, make sure the room is evacuated; close but do not lock the door and safely exit the building.

Clothing on Fire

Do not use a fire extinguisher on people

1. Douse with water from safety shower immediately or
2. Roll on floor and scream for help or
3. Wrap with fire blanket to smother flame (a coat or other nonflammable fiber may be used if blanket is unavailable). Do not wrap a standing person; rather, lay the victim down to extinguish the fire. The blanket should be removed once the fire is out to disperse the heat.

Equipment Failure or Hazard

Failure of equipment may be indicative of a safety hazard - You must report all incidents.
Should you observe excessive heat, excessive noise, damage, and/or abnormal behaviour of the lab equipment:

1. Immediately discontinue use of the equipment.
2. In power labs, press wall-mounted emergency shut-off button.
3. Inform your TA of the problem.
4. Wait for further instructions from your TA.
5. TA must file an incident report.

Protocol For Safe Laboratory Practice

Leave equipment in a safe state for the next person - if you're not sure, ask!
In general, leave equipment in a safe state when you finish with it. When in doubt, consult the course TA.

Defined Roles

TA	The first point of contact for lab supervision	
ECE Lab Supervisor	Steve Spencer- ITB 147	steve@mail.ece.mcmaster.ca
ECE Chair	Tim Davidson- ITB A111	davidson@mcmaster.ca
ECE Administrator	Kerri Hastings- ITB A111	hastings@mcmaster.ca
ECE Course Instructor	Please contact your specific course instructor directly	

eng.mcmaster.ca/ece