Electrical and Computer Engineering
ELECENG 4CL4
Control System Design
Fall 2026

McMaster University
ENGINEERING

Instructor Information

T. Kirubarajan (Kiruba)
Email:
kiruba@mcmaster.ca
Office Hours (ITB A314):
Mo/We 9:30AM – 11:00AM, Fr 9:00AM – 10AM / 11:30AM – 1:00PM
or by appointment (in person or on Teams)

TA Information (TBA)

Name:
Email:
Office Hour:

Teaching Assistants

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

Class Times

Lecture: MoWe 8:30AM - 9:20AM ABB 271

Fr 10:30AM - 11:20AM ABB 271

Tutorial: Tu 8:30AM - 9:20AM ABB 165

Course Dates: 09/08/2026 - 12/10/2026
Units: 4.00
Course Delivery Mode: In Person
Course Description: Design of linear control systems using classical and state-space techniques; performance limitation; sampled-data control; nonlinear systems; multi-input multi-output control systems

Pre-Requisite(s) and Anti-Requisite(s)

Prerequisite(s): ELECENG 3CL4, ELECENG 3TP4

Instructor-Specific Course Information

All aspects of course content will be posted on *Avenue to Learn*, including lecture and tutorial notes. Communications regarding course logistics will be made on MS Teams as necessary.

Meeting Details

Meetings will be held in person or on MS Teams as appropriate.

Important Links

- Mosaic
- Avenue to Learn
- Student Accessibility Services - Accommodations

- McMaster University Library
- eReserves
- Open Education Resources

Graduate Attributes

The Canadian Engineering Accreditation Board (CEAB) is a division of Engineers Canada and is responsible for accrediting undergraduate engineering programs across Canada. Accreditation by the CEAB ensures that the engineering programs meet a national standard of quality and cover essential educational requirements. Graduate Attributes are a set of qualities and skills that the CEAB expects engineering graduates to possess. These attributes are a benchmark for the learning outcomes of accredited engineering programs. This section lists the Graduate Attribute Indicators associated with the Learning Outcomes in this course.

Attributes	Indicators		Learning Outcome
	Number	Description	
Knowledge Base for Engineering	1.1	Competence in Mathematics	[1-8]

Attributes	Indicators		Learning Outcome
	Number	Description	
Problem Analysis	2.1	Identifies and states reasonable assumptions and suitable engineering fundamentals, before proposing a solution path to a problem	[1-8]
Problem Analysis	2.2	Proposes problem solutions supported by substantiated reasoning, recognizing the limitations of the solutions	[3-8]
Investigation	3.1	Selects appropriately from relevant knowledge base to plan appropriate data collection methods and analysis strategies	[4]
Investigation	3.2	Synthesizes the results of an investigation to reach valid conclusions	[7-8]

Course Learning Objectives

By the end of this course, students should be able to:
[1] Develop state-space models from differential equations describing behaviour of a continuous-time system
[2] Linearize nonlinear continuous-time dynamics around operating points/trajectories to obtain approximate linear state-space models
[3] Find solutions to linear-time-invariant (LTI) state-space dynamics using time-domain and Laplace-domain techniques
[4] Analyze fundamental properties of LTI state-space systems, i.e., stability, controllability, and observability
[5] Derive various equivalent canonical form representations of LTI state-space dynamics using similarity transformations
[6] Convert state-space and transfer matrix representations of LTI systems to each other
[7] Design state-feedback controllers for LTI state-space systems
[8] Design output-feedback controllers with state-space observers for LTI state-space systems

CEAB Graduate Attributes (GAs)

The CEAB Graduate Attributes (GAs) 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

Attributes		Indicators		Measurement Method(s)
		Number	Description	
Knowledge Base for Engineering		1.1	Competence in Mathematics	Questions in Midterm & Final Examinations
Problem Analysis		2.2	Proposes problem solutions supported by substantiated reasoning, recognizing the limitations of the solutions	Questions in Midterm & Final Examinations
Investigation		3.2	Capable of selecting appropriate models and methods and identifying assumptions and constraints	Questions in Midterm & Final Examinations
Design		4.2	Explores a breadth of potential solutions, considering their benefits and trade-offs as they relate to the project requirements.	Questions in the lab reports, Mid-term Exam or Final Exam
Use of Engineering Tools		5.2	Successfully uses engineering tools	Performance in Laboratory Experiments & Lab Reports

Assumed Knowledge

Background knowledge from an introductory course in linear controls using Laplace-domain techniques (e.g.

ELEC ENG 3CL4) is essential. The course also requires a solid background in linear algebra; students are also strongly encouraged to review the background linear algebra material in the third chapter of the textbook.

Required Materials and Texts

Linear System Theory and Design
ISBN: 9780197545942
Authors: C.-T Chen
Publisher: OUP
Publication Date: 2013
Edition: 4th

Class Format

In Person

Graduate Grading Scale

Graduate Student Grading Scale (Except for MBA and Master of Finance)

Grade	Points	Equivalent Percentage	Pass/F
A+	12	90-100	P+
A	11	85-89	
A-	10	80-84	
B+	9	77-79	P
B	8	73-76	
B-	7	70-72	
F	0	69 and under	F

MBA and Master of Finance Grading Scale

Grade	Points	Equivalent Percentage	Pass/F
A+	12	90-100	P+
A	11	85-89	
A-	10	80-84	
B+	9	75-79	P
B	8	70-74	
B-	7	60-69	
F	0	59 and under	F

Course Overview

This is an advanced undergraduate course in analysis and design of modern control systems. The course focuses on continuous-time linear dynamical systems in the state-space domain. It exposes the students to fundamental concepts such as state-space representation of dynamics, solution of state-space dynamics, linearization of nonlinear dynamics, controllability and observability of state-space models, and stability of linear dynamical systems. The course also introduces methods for the design of linear feedback control systems via state and output feedback for regulation and tracking problems. The analysis and design topics cover examples from modern control engineering applications.

Course Schedule

A weekly breakdown of the course schedule

Week	Topic
1-2	**State-space Representation of Dynamical Systems**
1	Concept of State Space Dynamics
1	Examples of State-space Representations of Electrical and Mechanical Systems
1	Linear (Time-Invariant) State-space Representation
2	Linearization of Nonlinear Dynamical Systems
2	Composite Dynamic Systems
3-4	**Response of Linear Time-invariant Systems**
3	Solution of State-space Differential Equations: Homogenous and General cases
4	Impulse Response and Transfer Function
4	State Coordinate Transformation
5	Modal Canonical Representation of State-space Dynamics
5	**Stability of Linear Dynamical Systems**
5	Internal Stability
6	Input-Output Stability
6-8	**Controllability**
6	Concept and Fundamental Results
6	State Transformations and Controllability
7	Controllability Canonical Form
7-8	Controllability Tests
9	**Observability**
9	Concept and Fundamental Results
9	State Transformations and Observability
9	Observability Canonical Form
9	Observability Tests
9-10	**Minimal Realization of Linear Dynamical Systems**

9	Single-input/Single-output Systems
10	Multiple-input/Multiple-output Systems
10	Controllable & Observable Canonical Form Realizations
10-11	**Linear State Feedback Control**
10	State-feedback Control Law
11	Pole Placement
11	Stabilizability
12-13	**Linear Output Feedback Control**
12	Observers and Detectability
13	Observer-based Feedback Control and the Separation Principle
13	State and Output Feedback Control for MIMO Systems

Laboratory Overview: Modeling, Identification and Control of an Inverted Pendulum Mechanism

The course has a laboratory project to encourage problem-based learning and critical thinking. The project will expose the students to all aspects of modern control design process, from modeling and analysis, to design, implementation, and experimental verification of an advanced feedback control system. The project is organized into six phases with clear milestones that would guide the students towards the development of the final control system.

The objective of the lab project is to develop, implement, and experimentally verify a control system for balancing and positioning of a non-conventional inverted pendulum mechanism. This is a variation of the challenging classic inverted pendulum control problem.

Week	Topic
1	**Phase 0. Modeling and Simulation of State-space Control Systems in MATLAB/SIMULINK Environment:** Become familiar some of the tools available in MATLAB/Simulink environment for modelling and simulation of state-space dynamical systems.
2	**Phase 1. Analytical Modeling and Simulation:** Develop a full nonlinear model of the inverted pendulum mechanism in the state-space domain. Linearize the model around desired equilibrium points. Implement the model in Matlab/Simulink environment and simulate the system response.
3	**Phase 2. System Identification and Verification:** Estimate the unknown model parameters by carrying out system identification experiments on the laboratory setup. Evaluate the quality of the parameter estimates.
4	**Phase 3. System Analysis & Linear State-Feedback Control:** Examine stability, controllability and observability of the open-loop linearized model. Synthesize a state-feedback controller to achieve the control objectives. Analyze and simulate the closed-loop system response in Matlab/Simulink environment in order to verify the design.
5	**Phase 4. Linear State Estimation and Feedback Control:** Develop and implement estimators to estimate the joint velocities. Combine the estimator and state-feedback controller. Evaluate system response in simulations and in experiments with the actual inverted pendulum.
6	**Phase 5 (Optional): Hybrid Energy and State-feedback Control** Develop and implement a hybrid control strategy where the pendulum is initially swung up by injecting energy into the system and then use the linear state-feedback controller as the system nears its equilibrium state.

LABORATORY OPERATION

The lab project should be carried in groups of two students. The students must form these groups at the beginning of the term for the entire duration of the course. Each group will submit an electronic report for each of the phases. Detailed lab instructions for each phase of the project and the format of the reports will be provided throughout the term.

Course Evaluation

Component	Weight
Assignments /Laboratory Projects (3)	35 %
Mid-term Exam (1)	25 %
Final Exam	40 %
Total	100 %

Course Evaluation Details

Grading and Evaluation Policies

- There are three (3) assignments/laboratory projects, one (1) mid-term exam, and one (1) final exam to be evaluated in this course.
- All grades are final unless error(s) in marking is proven.
- No make-up/deferred mid-term exam
- MSAF transfers the weight of a missed mid-term exam to that of the final exam.

Undergraduate Grading Scale

The McMaster 12 Point Grading Scale

Grade	Equivalent Grade Point	Equivalent Percentages
A+	12	90-100
A	11	85-89
A-	10	80-84
B+	9	77-79
B	8	73-76
B-	7	70-72
C+	6	67-69
C	5	63-66
C-	4	60-62
D+	3	57-59
D	2	53-56
D-	1	50-52
F	0	0-49

Absences, Missed Work, Illness

University policy on MSAF will be applied; in case of missed assignments due extra time will be granted for completion.

APPROVED ADVISORY STATEMENTS

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.

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

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. Avenue to Learn, 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, 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.

Online Proctoring

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.

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 Accommodation of Students with Disabilities

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.

Requests for Relief for Missed Academic Term Work

In the event of an absence for medical or other reasons, students should review and follow the Policy on Requests for Relief for Missed Academic Term Work.

Academic Accommodation for Religious, Indigenous, or Spiritual Observances (RISO)

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.

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.

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, Avenue to Learn and/or McMaster email.

Course Modification

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).

Generative AI: Use Prohibited

Students are not permitted to use generative AI in this course. In alignment with McMaster academic integrity policy, it "shall be an offence knowingly to … submit academic work for assessment that was purchased or acquired from another source". This includes work created by generative AI tools. Also state in the policy is the following, "Contract Cheating is the act of "outsourcing of student work to third parties" (Lancaster & Clarke, 2016, p. 639) with or without payment." Using

Generative AI tools is a form of contract cheating. Charges of academic dishonesty will be brought forward to the Office of Academic Integrity.

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 protocols 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

Main Lobby of ITB, 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.

Who to Contact	
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.

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 non-flammable 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

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	spencers@mcmaster.ca
ECE Chair	Shahram Shirani- ITB A111	shirani@mcmaster.ca

ECE Administrator	Shelby Gaudrault- ITB A111/ B	gaudraus@mcmaster.ca
ECE Course Instructor	Please contact your specific course instructor directly	