

Western University  
Faculty of Engineering  
**Department of Electrical & Computer Engineering**  
ECE 9506/9056 – Linear Systems and Modern Control Theory  
**COURSE OUTLINE 2023-2024**

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### DESCRIPTION

After completing this course, the students will understand the behaviour of linear systems and be able to analyze and design linear control systems using state-space approach. Students will also understand proper approach to mathematical proofs.

### ENROLLMENT RESTRICTIONS

Enrollment in this course is restricted to graduate students as well as any student that has obtained special permission to enroll in this course from the course instructor as well as the Graduate Chair (or equivalent) from the student's home program.

### COURSE FORMAT

The course will be delivered by in person lectures. In case of in person learning being discontinued due to covid, theory will be delivered by weekly videos posted to owl and synchronous (via zoom) delivered examples during one of the regularly scheduled lecture periods

### TOPICS

Topic #	Description	Learning Activities	Tentative timeline
0	Mathematical background	<ul style="list-style-type: none"><li>• Lectures</li><li>• Additional reading material</li><li>• Assignment 1</li></ul>	Week 1-4
1	1. State-space analysis of dynamic systems.	<ul style="list-style-type: none"><li>• Lectures</li><li>• Additional reading material</li><li>• Assignment 2</li></ul>	Week 5
	2. Canonical forms and minimal realizations	<ul style="list-style-type: none"><li>• Lectures</li><li>• Additional reading material</li></ul> Midterm	Weeks 6
	3. Controllability and observability	<ul style="list-style-type: none"><li>• Lectures</li><li>• Assignment 3</li></ul>	Week 7

	4. MIMO equivalents of coprime, and finding coprime fraction representations, minimal realizations of MIMO systems	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Assignment 4</li> </ul>	Week 8-9
2	<ol style="list-style-type: none"> <li>1. Design of SISO and MIMO state-feedback controllers</li> <li>2. State estimation and observers.</li> </ol>	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Reading</li> <li>• Final Exam</li> </ul>	Week 10-11
	3. Quadratic optimal control.	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Reading</li> <li>• Final Exam</li> </ul>	Week 12
In addition	Time varying systems will be covered throughout the term		

### SPECIFIC LEARNING OUTCOMES 9056

Degree Level Expectation	Weight	Assessment Tools	Outcomes
<b>Depth and breadth of knowledge</b>	55%	<ul style="list-style-type: none"> <li>• Assignments</li> <li>• Midterm</li> <li>• Examinations</li> </ul>	<ul style="list-style-type: none"> <li>• Understanding of advanced concepts and theories</li> <li>• Awareness of important current problems in the field of study</li> <li>• Understanding of computational and/or empirical methodologies to solve related problems</li> </ul>
<b>Research &amp; scholarship</b>	3%	<ul style="list-style-type: none"> <li>• Midterm</li> <li>• Examinations</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to conduct critical evaluation of current advancements in the field of specialization</li> <li>• Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment</li> </ul>
<b>Application of knowledge</b>	35%	<ul style="list-style-type: none"> <li>• Assignments</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to apply knowledge in a rational way to analyze a particular problem</li> <li>• Ability to use coherent approach to design a particular engineering system using existing design tools</li> </ul>
<b>Professional capacity / autonomy</b>	5%	<ul style="list-style-type: none"> <li>• Assignments</li> </ul>	<ul style="list-style-type: none"> <li>• Awareness of academic integrity</li> <li>• Ability to implement established procedures and practices in the coursework</li> <li>• Defends own ideas and conclusions</li> <li>• Integrates reflection into his/her learning process</li> </ul>
<b>Communication skills</b>	2%	<ul style="list-style-type: none"> <li>• Assignments</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively</li> </ul>

Awareness of limits of knowledge	0%	•	•
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### SPECIFIC LEARNING OUTCOMES 9506

Degree Level Expectation	Weight	Assessment Tools	Outcomes
Depth and breadth of knowledge	25%	<ul style="list-style-type: none"> <li>• Assignments</li> <li>• Project</li> <li>• Examinations</li> </ul>	<ul style="list-style-type: none"> <li>• Understanding of advanced concepts and theories</li> <li>• Awareness of important current problems in the field of study</li> <li>• Understanding of computational and/or empirical methodologies to solve related problems</li> </ul>
Research & scholarship	15	<ul style="list-style-type: none"> <li>• Exam</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to conduct critical evaluation of current advancements in the field of specialization</li> <li>• Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment</li> </ul>
Application of knowledge	35%	<ul style="list-style-type: none"> <li>• Assignments</li> <li>• Project</li> <li>• Examinations</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to apply knowledge in a rational way to analyze a particular problem</li> <li>• Ability to use coherent approach to design a particular engineering system using existing design tools</li> </ul>
Professional capacity / autonomy	10%	<ul style="list-style-type: none"> <li>• Project</li> </ul>	<ul style="list-style-type: none"> <li>• Awareness of academic integrity</li> <li>• Ability to implement established procedures and practices in the coursework</li> <li>• Defends own ideas and conclusions</li> <li>• Integrates reflection into his/her learning process</li> </ul>
Communication skills	15%	<ul style="list-style-type: none"> <li>• Assignments</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively</li> </ul>
Awareness of limits of knowledge	0%	•	•

### ASSESSMENTS

Assessment Type	Material Covered	Tentative Due Date	Weight
Homework Assignments (four)	Topic 0, 1, 3		30%
Midterm	Topic 1		30%
Examination	All but primarily Topic 2		40%

### Activities in which collaboration is permitted:

- Assignments, but handed in work must be students own

**Activities in which students must work alone (collaboration is not permitted):**

- Midterm and final

**EVALUATION: 9506**

- The final course grade will be based on the results of four assignments, a 24 hour take home midterm and 48 hour take home final. For those who would like to have the course appear on their transcripts as AUDIT have to complete all assignments, though they will not be marked. The assignment component will include a teaching component.

**EVALUATION: 9056**

- The final course grade will be based on the results of four assignments, a 24 hour take home midterm and an open book 3 hour final.

**REQUIRED TEXTBOOK**

Chi-Tsong Chen, “Linear system theory and Design, 4ed”, Oxford University Press, 2013

**OPTIONAL COURSE READINGS**

W. J. Rugh, “Linear System Theory”, Second Edition, Prentice Hall, 1996

**CHEATING, PLAGIARISM/ACADEMIC OFFENCES**

Academic integrity is an essential component of learning activities. Students must have a clear understanding of the course activities in which they are expected to work alone (and what working alone implies) and the activities in which they can collaborate or seek help; see information above and ask instructor for clarification if needed. Any unauthorized forms of help-seeking or collaboration will be considered an academic offense. University policy states that cheating is an academic offence. If you are caught cheating, there will be no second warning. Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence. Academic offences are taken seriously and attended by academic penalties which may include expulsion from the program. Students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence at the following website: [https://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/scholastic\\_discipline\\_grad.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_grad.pdf)

All required papers may be subject to submission for textual similarity review to the commercial plagiarism-detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

## **CONDUCT**

Students are expected to follow proper etiquette to maintain an appropriate and respectful academic environment. Any student who, in the opinion of the instructor, is not appropriately participating in course activities and/or is not following the rules and responsibilities associated with the course activities, will be reported to the Associate Dean (Graduate) (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Associate Dean (Graduate), the student could be debarred from completing the assessment activities in the course as appropriate.

## **HEALTH/WELLNESS SERVICES**

As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several health and wellness related services to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. Information regarding health- and wellness-related services available to students may be found at <http://www.health.uwo.ca/>.

Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Faculty of Engineering has a Student Wellness Counsellor. To schedule an appointment with the counsellor, contact Kristen Edwards ([khunt29@uwo.ca](mailto:khunt29@uwo.ca)) via confidential email and you will be contacted by our intake office within 48 hours to schedule an appointment.

Students who are in emotional/mental distress should refer to Mental Health@Western: <http://www.uwo.ca/uwocom/mentalhealth/> for a complete list of options about how to obtain help.

## **SICKNESS**

Students should immediately consult with the Instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

Students who are not able to meet certain academic responsibilities due to medical, compassionate or other legitimate reason(s), could request for academic consideration. The Graduate Academic Accommodation Policy and Procedure details are available at:

<https://www.eng.uwo.ca/graduate/current-students/academic-support-and-accommodations/index.html>

## **ACCESSIBLE EDUCATION WESTERN (AEW)**

Western is committed to achieving barrier-free accessibility for all its members, including graduate students. As part of this commitment, Western provides a variety of services devoted to promoting, advocating, and accommodating persons with disabilities in their respective graduate program. Graduate students with disabilities (for example, chronic illnesses, mental health conditions,

mobility impairments) are strongly encouraged to register with Accessible Education Western (AEW): [http://academicsupport.uwo.ca/accessible\\_education/index.html](http://academicsupport.uwo.ca/accessible_education/index.html)

AEW is a confidential service designed to support graduate and undergraduate students through their academic program. With the appropriate documentation, the student will work with both AEW and their graduate programs (normally their Graduate Chair and/or Course instructor) to ensure that appropriate academic accommodations to program requirements are arranged. These accommodations include individual counselling, alternative formatted literature, accessible campus transportation, learning strategy instruction, writing exams and assistive technology instruction.