**City University of Hong Kong**
**Course Syllabus**

**offered by Department of Electrical Engineering**
**with effect from Semester A in 2024/2025**

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## Part I Course Overview

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| **Course Title:** | Linear Systems Theory and Design |
| **Course Code**: | EE6620 |
| **Course Duration:** | One Semester (13 weeks) |
| **Credit Units**: | 3 |
| **Level**: | P6 |
| **Medium of Instruction:** | English |
| **Medium of Assessment:** | English |
| **Prerequisites**: *(Course Code and Title)* | Nil |
| **Precursors**: *(Course Code and Title)* | MA2170 Linear Algebra and Multi-variable Calculus, or<br>EE3210 Signals and Systems, or<br>EE3118 Linear Systems and Signal Analysis |
| **Equivalent Courses**: *(Course Code and Title)* | Nil |
| **Exclusive Courses**: *(Course Code and Title)* | EE5411 Linear Systems Theory and Design |

## Part II Course Details

### 1. Abstract

This course aims to introduce to students fundamental concepts, techniques, and tools in linear system analysis and design, required for a broad range of engineering disciplines including systems and control, signal processing, and communications.

### 2. Course Intended Learning Outcomes (CILOs)

*(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)*

| No. | CILOs | Weighting (if applicable) | Discovery-enriched curriculum related learning outcomes (please tick where appropriate) | | |
|---|---|---|---|---|---|
| | | | *A1* | *A2* | *A3* |
| 1. | Recognise and determine system characteristics. | | ✓ | ✓ | |
| 2. | Describe and apply state-space modelling. | | ✓ | ✓ | |
| 3. | Implement the solution/response of linear dynamical systems. | | ✓ | ✓ | |
| 4. | Describe and apply controllability and observability to linear systems. | | ✓ | ✓ | |
| 5. | Apply state feedback and state estimator to engineering design. | | ✓ | ✓ | ✓ |
| | | 100% | | | |

*A1:* *Attitude*
*Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.*

*A2:* *Ability*
*Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.*

A3: *Accomplishments*
*Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.*

## 3. Learning and Teaching Activities (LTAs)

*(LTAs designed to facilitate students' achievement of the CILOs.)*

| LTA | Brief Description | CILO No. | | | | | | Hours/week (if applicable) |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | |
| Lectures | Students will gain knowledge of fundamental concepts, essential criteria, and key techniques. | ✓ | ✓ | ✓ | ✓ | ✓ | | 2 hrs/wk |
| Tutorials | Students will participate in tutorials to strengthen understanding on key concepts and techniques by working on closely related problems. | ✓ | ✓ | ✓ | ✓ | ✓ | | 1 hr/wk |
| Written assignments | Students will develop skills and strengthen understanding by problem solving | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Case studies | Students will conduct mini-projects to be kept abreast of contemporary research and practical problems | | | | | ✓ | | |

## 4. Assessment Tasks/Activities (ATs)

*(ATs are designed to assess how well the students achieve the CILOs.)*

| Assessment Tasks/Activities | CILO No. | | | | | | Weighting | Remarks |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | | |
| Continuous Assessment: 50% | | | | | | | | |
| Tests (2) | ✓ | ✓ | ✓ | ✓ | ✓ | | 30% | |
| Assignments (6) | ✓ | ✓ | ✓ | ✓ | ✓ | | 20% | |
| Examination: 50% (duration: 2hrs , if applicable) | | | | | | | | |
| Examination | ✓ | ✓ | ✓ | ✓ | ✓ | | 50% | |
| | | | | | | | 100% | |

**Remark:**

To pass the course, students are required to achieve at least 30% in course work and 30% in the examination.

# may include homework, tutorial exercise, project/mini-project, presentation

## 5. Assessment Rubrics

*(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)*

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

| Assessment Task | Criterion | Excellent (A+, A, A-) | Good (B+, B, B-) | Fair (C+, C, C-) | Marginal (D) | Failure (F) |
|---|---|---|---|---|---|---|
| 1. Examination | Achievements in CILOs | High | Significant | Moderate | Basic | Not even reaching marginal level |
| 2. Coursework | Achievements in CILOs | High | Significant | Moderate | Basic | Not even reaching marginal level |

Applicable to students admitted from Semester A 2022/23 to Summer Term 2024

| Assessment Task | Criterion | Excellent (A+, A, A-) | Good (B+, B,) | Marginal (B-, C+, C) | Failure (F) |
|---|---|---|---|---|---|
| 1. Examination | Achievements in CILOs | High | Medium | Low | Not even reaching marginal level |
| 2. Coursework | Achievements in CILOs | High | Medium | Low | Not even reaching marginal level |

## 6. Constructive Alignment with Programme Outcomes

| PILO | How the course contribute to the specific PILO(s) |
|---|---|
| 1, 2 | The course will provide fundamental concepts and techniques required in the modeling, analysis, and design of modern engineering systems in broad fields such as control technology, communication systems, and signal processing algorithms. |
| 3, 4 | Student will be able to analyze and design state feedback and state observers, and consequently to analyze and design feedback systems using numerically efficient state-space methods. |
| 5 | The lectures will provide the necessary tools for students to access contemporary research developments. The case studies will expose students to new research frontiers. |
| 6,7 | The case studies and presentation will provide students with the opportunity to work as a team and to develop their communication skills. |

**Part III Other Information** (more details can be provided separately in the teaching plan)

## 1. Keyword Syllabus

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Mathematical Systems Descriptions

Review of basic concepts, causality, stability, linearity, time-invariance, input-output description, state-space description, LTI systems, linearization.

Basic Mathematical Background

Linear space, vector norms, linear equations, linear transformation, eigenvalues and eigenvectors, canonical forms, matrix function, positive definite matrices, matrix induced norms.

Linear Dynamical Equations

Solution space, fundamental matrix, transition matrix, adjoint systems, equivalent systems.

Controllability and Observability

Controllability Gramian, rank test, PBH test, output controllability, observability Gramian, observability test, PBH test, duality, canonical forms, canonical decomposition, minimal realizations.

State Feedback and Observer

State feedback, pole placement, performance index, full-state observer, reduced state observer, separation principle, tracking and regulation.

Stability Analysis

Input-output stability, system induced norms, internal stability, Lyapunov stability, Lyapunov equation.

## 2. Reading List

### 2.1 Compulsory Readings

*(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)*

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|---|---|
| 1. | C.T. Chen, Linear System theory and Design, 3rd Ed., Oxford Univ. Press, 1999 |

### 2.2 Additional Readings

*(Additional references for students to learn to expand their knowledge about the subject.)*

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| 1. | T. Kailath, Linear Systems, Prentice Hall, 1980 |
| 2. | P. Antsaklis and A.N. Michel, Linear Systems, Springer, 2006. |