DEPARTMENT OF MECHANICAL AND AUTOMATION ENGINEERING 香 港 中 文 大 學
THE CHINESE UNIVERSITY OF HONG KONG 機械與自動化工程學系

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# MAEG4050 Modern Control Systems Analysis and Design (2nd Term 2022-23)

## Course Syllabus

**Instructor** Dr. LI Yiyang
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Tel.: 3943 8476
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**Tutors**

| Tutors | ...@link.cuhk.edu.hk |
|---|---|
| CHENG Haoshu | 1155154225 |
| JIN Liuchao | 1155184008 |
| PENG Cheng | 1155186652 |
| ZHAO Zuoquan | 1155170426 |

**Lectures** Tuesday 2:30pm – 4:15pm ERB 404
Thursday 10:30am – 11:15am MMW 703

**Tutorial** TBA

**Office hours** Monday 4:30pm–5:30pm@ERB315B, or by appointment

**Textbook** Feedback Control of Dynamic Systems, 6ed, Gene F. Franklin, Prentice Hall, 2010.

**References** See on the last slide of lecture notes (if any)

**Homepage** https://blackboard.cuhk.edu.hk/ultra/stream

**Course Objectives**

- Understanding the linear time-invariant system
- Familiarization of the mathematical process and techniques from modeling to analysis to design
- Application of relevant knowledge to design a control system with given performance specifications

**Learning outcomes**

Upon completion of the course, students should have achieved the following outcomes:

1. be able to derive a state-space model for a given physical system;
2. be able to perform stability analysis and computer simulation of time responses of the model;
3. be able to perform various feedback controller design methods such as pole placement, observer design, feedforward design, internal model design, LQR method for fulfilling different design specifications;
4. be able to analyze and design a discrete-time control system in both frequency domain and time domain.

**Support to Programme Outcomes**

The following table lists the support of the Course Learning Outcomes 1 to 4 to the MAEG Programme Outcomes:

| Course Learning Outcomes | Programme Outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 |
| 1 | x | | | | x | | | | | | | x |
| 2 | x | | | | x | | | | | | | x |
| 3 | x | | | | x | | | | | | | x |
| 4 | x | | | | x | | | | | | | x |

- **Programme Outcome M1:** Acquired basic science and engineering knowledge, including physics, mathematics, mechanics, thermodynamics, heat transfer, power electronics, material science, chemistry, biology, and environmental science.
- **Programme Outcome M5:** An ability to identify, formulate, and solve engineering problems.
- **Programme Outcome M12:** Acquired the ability to use the computer/IT tools relevant to the discipline along with an understanding of their processes and limitations.

**Selected Programme Outcome to Assess: M1** and **M12.**

**Contents**

- State space representation
- Realizability; Stability; Controllability; Observability
- Linear control design methods (Pole placement; Observer; Asymptotic tracking and disturbance rejection; Internal model design; Feedforward design)
- Digital control (Discrete-time system and difference equation; Z-transform; State space representation of DT systems; Stability of discrete time systems; Controllability and observability analysis; Controller design)
- Case studies

**Grading**

Your overall score for the course will be computed based on the weighting scheme below:

| | |
|---|---|
| Homework | 25% |
| Midterm Test | 30% |
| Final Exam | 45% |
| Bonus (Class activities, if any) | < 5% |

**Assessment Criteria**

**Homework** You will be given FIVE problem sets during the semester. The due day for the problem set will be specified. It will carry a 30% penalty if handed in late. No credit will be given to a problem set that is late for more than three days.

**Midterm Test** If for any reason you are unable to attend midterm test, you must seek approval of absence from the course teacher directly before the test. Your request should be supported by valid documents, such as medical certificate issued by a registered medical practitioner. Absence from the test without prior approval of absence would result in ZERO score. (See Undergraduate Student Handbook Regulations and Rules: Absence from examinations).

**Final Exam** For students who are absent from the final exam with approval from RES, a make-up exam (and only one) will be arranged and scheduled as soon as possible. It is the responsibility for those who request for a make-up exam to ensure their availability.

Please note that the course teacher has the final discretion on all arrangements of the make-up exam.

**Grading Disputes**

Please check the grades of homework assignments, midterm test and final exam as

soon as they are released. Any discrepancy should be reported to TAs **within one week from the date of releasing your score**. Late complaints will NOT be accommodated.

**Academic Honesty**

Attention is drawn to University policy and regulations on honesty in academic work, and to the disciplinary guidelines and procedures applicable to breaches of such policy and regulations. Details may be found at http://www.cuhk.edu.hk/policy/academichonesty/.

**Teaching and Learning Expectations from Students/Faculty Members**

The classroom is a special environment in which students and instructor come together to promote learning and communication. Any successful learning experience requires mutual respect on the part of the student and the instructor. Neither instructor nor student should be subject to others' behavior that is rude, disruptive, intimidating, or demeaning.

You are expected to be punctual for both lectures and tutorials. You are welcome to bring your laptop or other devices to lectures for learning purposes. Respect the others in class and do not disturb others with side conversation, Internet surfing, emails-checking or instant-messaging during class time.

Details can be found from the "Student/Faculty Expectations on Teaching and Learning, Faculty of Engineering, CUHK" posted on the course website.

## **Course Schedule** (Tentative, subject to revision)

| Date | Week | Chapter | Topics |
|---|---|---|---|
| 10/01 | 1 | 1, 2 | Course outline; Introduction; Mathematical modeling; State space representation of continuous systems: From the higher order ODEs |
| 12/01 | | | |
| 17/01 | 2 | 2 | State space representation of continuous systems: From the higher order ODEs (ditto); From transfer function |
| 19/01 | | | |
| | 3 | | Chinese Lunar New Year (No class) |
| 31/01 | 4 | 2 | Solution to state equation; Discussion and exercise |
| 02/02 | | | |
| 07/02 | 5 | 3 | BIBO Stability; Stability concept for state equation; Lyapunov stability |
| 09/02 | | | |
| 14/02 | 6 | 4 | Controllability analysis |
| 16/02 | | | |
| 21/02 | 7 | 4,5 | Observability analysis; State space design: basic concepts |
| 23/02 | | | |
| 28/02 | 8 | 5 | State space design: eigenvalue placement problem Asymptotic tracking feed-forward design; Estimator design |
| 02/03 | | | |
| | 9 | | Reading week |
| 14/03 | 10 | | Midterm Exam |
| 16/03 | | 5 | Compensator design: combined control law and estimator |
| 21/03 | 11 | 6 | Digital control: Introduction; Discrete-time systems and difference equations, Z-transform |
| 23/03 | | | |
| 28/03 | 12 | 6 | Digital control: State Space Representation of DT systems; Stability of discrete systems; Controllability/Observability Analysis |
| 30/03 | | | |

| | | | |
|---|---|---|---|
| 04/04<br>06/04 | 13 | 6 | Digital control: Emulation and discrete design; Tustin's method |
| 11/04<br>13/04 | 14 | 6 | Digital control: Matched pole-zero (MPZ) method; State space design |
| 18/04<br>20/04 | 15 | 7 | Case studies; Revision |