University of Science and Technology of Hanoi
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# BACHELOR COURSE SYLLABUS

**Subject:** Signals and Systems
**Lecturer:** TRẦN Hoàng Tùng
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## I. Course Description:

| | | |
|---|---|---|
| **Credit points** | 3 ETCS | |
| **Level** | Bachelor | |
| **Time commitment** | Lecture | 20 hours |
| | Exercise | 10 hours |
| | Practice | 6 hours |
| | Lab-work | 0 hour |
| | Total | 36 hours |
| **Prerequisites** | Calculus | |
| **Subject description** | This course covers the fundamentals of signal and system analysis. It develops mathematical transform techniques and computational tools to analyze the behavior of analog and digital systems. The main focus is on representations of discrete-time and continuous-time signals, as well as discrete-time and continuous-time systems in time domain and frequency domain. | |
| **General Objectives** | When completing this course, it is expected that a student will have the ability to<br>- Recognize the terminology that is used in the Signal Processing field.<br>- Apply transform techniques and concepts in formulating and solving engineering problems.<br>- Think critically, ask questions, and apply problem-solving techniques. | |
| **Assessment/Evaluation** | Attendance | 20 % |
| | Class exercises | 10 % (Bonus) |
| | Assignments | 0 % |
| | Midterm exam | 30 % |
| | Final exam | 50 % |

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**Honor Code:**

**My answers to homework, quizzes, and exams will be my own work**

(Except for assignments that explicitly permit collaboration)

Students are encouraged to interact with others to discuss course material, form study groups for the exams, and provide each other with encouragement, and moral support. However, all individual assignments (i.e., homework and exams) are to be performed on their own.

## II. Course Philosophy / Teaching Methodology:

**1. Self-contained Lessons:** each lesson is made as independent as possible. Its benefits are twofold:
- If a student misses one lesson, he/she should be able to follow the current one.
- The most important definitions will be repeated from lesson to lesson, so students have multiple chances to absorb information.

**2. Exercises and Homework:** it is recommended that with each hour in class, students spend at least two hours at home.
- In-class exercises: most effective way to completely understand all lessons.
- Homework: enough to keep students busy for several hours.

**3. Lesson Objectives:** each lesson is followed by a set of objectives/expected outcomes. Student who is confident about his/her understanding should be able to answer them all.

**4. Examination**: Students are allowed to bring one A4 paper, they can write anything they want in that paper. No other documents are accepted! Two advs.:
- Some formulae are too complicated. If a student understands their meanings and knows how to apply them to a real problem, he is deserved to get a good exam score.
- Due to limited space of one A4 paper, students have to read and choose the most important ideas (in their understanding) to have a quality summary

**5. Attendance:** 5 last minutes of each class will be used to perform a mini-test with 7 random students (a random generation function within matlab will be run in front of students). I will have to make sure that any student will be called at least once, but there is no upper bound – a student can be named 10 times.

**6. Questions:** student has several options if he/she has questions:
- Raise hand in class.
- Come to ICT lab every Wednesday from 2PM to 5PM. This time frame is reserved for students.
- Re-watch the recorded video of the lesson.
- Send email to the professor or teaching assistants.

**7. Evolving:** this is an evolving course, any suggestions are welcome.

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- For example, if a student finds an interesting understanding from a certain lesson, and it is not included in "expected outcomes", please send an email to the professor.
- If an idea is chosen for the course for next semesters, student's name will appear in credit section.

## III. Syllabus:

Each lesson is equivalent to a 3-hour class. Within each class, about half of the time will be used for exercises.

| Lesson | Content | Objectives/Outcomes |
|---|---|---|
| 1 | 1.1. Signals:<br>- Examples of continuous-time and discrete-time signals<br>1.2. Operation/Transformations:<br>- Time shift<br>- Time reversal<br>- Time scaling<br>1.3. Signals:<br>- Periodic/aperiodic signals<br>- Even and odd signals<br>- Complex exponential and sinusoidal signals<br>1.4. System:<br>- Examples of real systems, and their mathematical representation<br>- Properties: memory, invertibility, causality, stability<br>- Time Invariance, Linearity<br>**- Exercises:** 1.23, 24, 27, 28 | - Determine whether systems are linear or nonlinear, causal or noncausal ...<br>- Determine whether signals are periodic or aperiodic, even or odd, shift-invariant, or shift varying.<br>- Special signals: exponential, sinusoidal, impulse, step function (need concrete questions!!)<br><br>**Homework**: 1.31, 32, 33, 34 |
| 2 + 3 | 2.1. Discrete-time LTI system: Convolution sum<br>- Unit Impulse and Unit Step Sequence (p.30)<br>- Representation of signals<br>- Unit impulse response & LTI systems<br>- Convolution sum: follow *k*, and follow *n*.<br>- **Exercises**: 2.1, 2.2, 2.3, 2.5<br><br>2.2. Continuous-time LTI system: Convolution Integral | - Understand why examined systems are linear and time-invariant. What will happen if these systems are not?<br>- Importance of unit impulse towards signals and systems. Is it related to impulse response?<br>- Visualize and compute convolution |

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|---|---|---|
| | - Unit Impulse and Unit Step Function<br>- Representation of signals<br>- Unit impulse response & LTI systems<br>- Convolution Integral: approximate calculation, and integral<br>- **Exercises**: 1.7, 2.6, 2.7, 2.8, and 2.15 | sum/integral.<br><br>**Homework**: 2.21, 2.22 |
| 4 | 2.3. Properties of LTI system: commutative, distributive, associative, memory, invertibility, causality, and stability.<br>3.3. Frequency Response (system)<br>- Magnitude<br>- Phase<br>3.4. Response to complex exponentials<br>**- Exercises**: 2.3, 5, 6, 16, 17, 25 | - Know how to investigate properties of systems.<br><br>**Homework**:<br>- 2.24, 2.43 => associative<br>- 2.28, 2.29, 2.48 => causality and stability.<br>- 2.65, 2.66, 2.67 => recommend |
| 5 + 6 | 3.1. Fourier Series of Continuous-Time Periodic Signals:<br>- Some interesting facts about Fourier history.<br>- Fourier Representation<br>- Convergence<br>- Properties<br>**- Exercises**: 3.1, 5, 9, 11, 12<br><br>3.2. Fourier Series of Discrete-Time Periodic Signals:<br>- Fourier Representation<br>- Properties<br>- Fourier Series and LTI systems<br>**- Exercises**: 3.26, 30, 31, 37 | - Demonstrate an understanding of the Fourier series.<br>- Prove properties of Fourier Series.<br><br>**Homework**:<br>- Continuous-time signals: 3.22, 3.23, 3.43, 3.60<br>- Discrete-time signals: 3.28, 3.29, 3.48 |
| 7 + 8 | 3.3. Continuous-time Fourier Transform<br>- Development of Fourier Transform for aperiodic signals, examples 4.1, 2, 4, 5.<br>- Fourier Transform for periodic signals<br>- Properties<br>- Duality<br>**- Exercises**: 4.2, 3, 5, 9, 17, 21<br><br>3.4. Fourier Transform: signals & systems | - Understand the relationship between Fourier Series and Fourier Transform<br>- Convolution and multiplication in time and frequency domain.<br><br>**Homework** |

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|---|---|---|
| | - Convolution property<br>- Multiplication property<br>**- Exercises**: 4.25, 26, 27, 34, 38 | - Continuous-time: 4.1, 4.4, 4.11, 4.24, 4.37, 4.44<br>- Discrete-time: 5.21, 5.23, 5.26, 5.29, 5.41, 5.45 |
| 9 | 3.5. Discrete-time Fourier Transform<br>- Development of Fourier Transform for aperiodic signals, examples<br>- Fourier Transform for periodic signals<br>- Properties<br>- Duality<br>**- Exercises**: 5.2, 3, 5, 11, 15<br><br>3.6. Fourier Transform: signals & systems<br>- Convolution property<br>- Multiplication property<br>3.7 Duality (page 310, 396)<br>**- Exercises**: 5.21, 23, 27, 31 | |
| 10 | 4.1. Sampling Theorem<br>4.2. Reconstruction/Interpolation<br>- Linear<br>- Band-limited<br>- Zero/first/higher-order hold<br>4.3. Undersampling: Aliasing<br>**- Exercises**: 7.1, 2, 5, 11, 16 | - Choose the sampling rate for a digital system and understand the effects of aliasing.<br><br>**Homework**: 7.8, 7.11, 7.21, 7.23, 7.26, 7.43 |
| 11 | Reserved for unexpected situations! | |
| 12 | Octave Introduction | |

## IV. References:

[1] *Signals and Systems* [2nd Edition] by **Alan V. Oppenheim** and **Alan S. Willsky**
[2] *Linear Systems and Signals* [2nd Edition] by **B. P. Lathi**