ELEG 305 Signals and Systems

Credits: 3, Semester: Spring, Year: 2021

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Tues./Thurs. 2–2:45 p.m

Course Description

Description

Introduction to signals and systems, with an emphasis on time and frequency characterization of linear, time-invariant systems. Covers discrete and continuous time systems, sampling, and Fourier, Laplace, and Z transforms. Topics include:

- Operations on and properties of signals
- Basic characteristics of systems
- Impulse response
- Convolution
- Difference and differential equations
- Laplace transform
- Fourier series and transform
- Frequency response of systems
- Modulation
- Sampling
- Discrete-time Fourier transform
- Z transforms

The course relies heavily on mathematical techniques but emphasizes the engineering aspects of the design and analysis of physical—electrical, acoustic, and mechanical—and digital systems and signals. Key skills include graphing signals and system transfer functions in different domains, drawing and interpreting block diagrams and analytic expressions of systems, and implementing numerical representations of signals and systems using MATLAB.

Learning outcomes can be succinctly stated as the mathematical and numerical analysis and visualization of signals and systems, for both discrete and continuous time, in frequency and transform domains, and the role and design of sampling.

"Signals and Systems" is a required course for computer and electrical engineering majors. The content assumes a previous introduction to programming and familiarity of electrical circuits with resistors, capacitors, and inductors introduced in the study of electrical circuits seen in "Fundamentals of Physics II" or "Analog Circuits I". Equivalent experience with mechanical systems and biological processes should suffice.

"Signals and Systems" is a prerequisite for "Digital Signal Processing", "Digital Control", "Digital Imaging and Photography", "Communication Systems Engineering", and "Radar Systems". These courses cover the engineering principles and techniques for communication, sensing and processing, and control of dynamical systems. There is a related vertically integrated project "Acoustics & Signal Processing".

The concepts introduced in "Signals and Systems" are fundamental to machine learning, computer vision, speech recognition, autonomous robotics, and artificial intelligence, emerging topics such as quantum communication and computing, and computer and network design including physical security.

The course content is applicable to various contexts of sensors and systems, including biomedical equipment; climate and environmental monitoring; remote sensing of weather, oceans, agriculture, transportation, infrastructure, and urban activity; acoustic, audio, and sound engineering for music and fine arts. Additionally, the concepts are useful for understanding human and animal senses, perception, and communication.

Grasping the mathematical concepts and intuition in "Signals and Systems" may be challenging, but the benefit is that once learned these concepts can be applied throughout computing, engineering, and science fields.

Prerequisites

MATH 242 Analytic Geometry and Calculus B: functions and their inverses (especially logarithm/exponential), derivatives and integrals of univariate functions on the real line, conversion between rectangular and polar coordinates, sequences and series, convergent series, elementary differential equations

Student Engagement and Effort

- Students are encouraged to take their own hand-written notes during lectures to maintain attention.
- Students are expected to spend sufficient class time to read the textbook, review the notes, and perform homework exercises for submission.
- Group work will be permitted for certain assignments (this will require coordination outside of class time) and not permitted in other situations (take-home exams).
- MATLAB will be used as a numerical programming language for signal processing and analysis. There will be additional assignments that require computer programming and plotting, and digital submission of legible code, scripts, and results in reports.
- Plan to spend on average 9+ hours per week for competency.

Learning Outcomes

ABET Outcomes:
(1) An ability to identify, **formulate**, and **solve** complex engineering problems by applying principles of **engineering**, **science**, and **mathematics**.
(1.5) Apply knowledge of science and math towards problems in **signal processing** and **communications**
(8) An ability to use the techniques, skills, and modern engineering tools necessary for engineering **practice**.
(8.1) An ability to **write computer codes** to solve an engineering problem.

Learning Outcomes:
1. Analyze, relate, and visualize signals—Recognize properties of signals and convert between their mathematical, graphical, and numerical representations.
2. Characterize and represent systems—Analyze systems (and their effect on idealized inputs) whether they are expressed analytically through formula, code, or depicted as block diagrams, and convert between equivalent representations.
3. Compute system responses—Describe the effect of various transformations in different domains (time, frequency, etc.) on signals, especially computing the output of linear time-invariant systems.
4. Determine sampling and analog-to-digital conversion parameters—Choose an appropriate sampling rate and filtering in order to uniquely preserve the information of bandlimited signals and describe the consequences of undersampling (aliasing).
5. Analyze filters—Calculate the magnitude and phase response and analyze the properties of basic filters in continuous and discrete-time using appropriate transforms.
6. Numerical programming for signal processing—Use modern programming languages to describe signals and systems for computer-based analysis, processing, and visualization.

Learning Resources

Required Learning Materials

OWN: *Signals and Systems*, 2nd Ed., A. V. **O**ppenheim and A. S. **W**illsky, with S. H. **N**awab, Pearson Education, Upper Saddle River, NJ, 1997, ISBN: 978-0138147570.

Schaum's: *Schaum's Outlines Signals and Systems*, 4th Ed., Hwei P. Hsu, McGraw-Hill Education, New York, NY, 2017, ISBN: 978-1260454246.