Syllabus: Digital Signal Processing

Jeffrey Yepez

University of Hawaiʻi Maui College
Science, Technology, Engineering and Mathematics Department
310 Kaʻahumanu Ave, Kahului, HI 96732-1617
yepez@hawaii.edu

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I. COURSE DESCRIPTION

This is a 4 credit one-semester course on discrete signal processing, part 2 of a year long course on signal processing for computer and electrical engineering students. Part 1 is ETRO 360, Signals and Systems taught in the preceding Spring term.

A. Overview

The course introduces digital signal processing, discrete-time signals and systems, linear time-invariant systems, linear system transformation theory, finite difference equations, the discrete time Fourier transformation and inverse transformation (including Discrete Fourier Transform (DFT) and Fourier Sequence Transform (FST)), the Z transformation and inverse transformation, and their derivations. The students are given the basic concepts and mathematical preparation to comprehend the signal transformations and signal spectrums in reciprocal space. The course material includes impulse response, frequency response, system function, transform analysis of linear systems in both frequency space and z space (building on concepts introduced in ETRO 360), sampling theory and the Nyquist-Shannon sampling theorem, structures for discrete time linear systems, diagrammatic circuit representations, signal flow graph representations. Time permitting, the course introduces lattice filters, filter design, and implementation/coding of computational algorithms for the DFT and fast Fourier transform (FFT). Finally, the course provides laboratory hands-on applications of the concepts and theories presented each week throughout the semester.

B. Course plan

Students will gain a facility with complex analysis as well as a symbolic mathematics language. Presented is an introduction to the concept of contour integration as its applies to the inverse Z transformation. Intuition about contour integration is conveyed to the student by using a comprehensible approach based on fluid flow in the complex plane. Demonstrations in the class will use symbolic mathematics (including Mathematica and SciPy) — the use of a symbolic mathematics software application is highly recommended for the students as an aid to accomplishing the assigned weekly problem sets.

Each student will select a digital simulation topic of their choosing for a Final Project.

The Final Project will entail:

1. building an electrical or optoelectrical digital system for testing
2. obtaining experimental discrete time series data
3. analyzing the digital system with mathematical tools and methods presented in the class
4. and comparing analytical predictions about the digital systems behavior with the observed experimental behavior.

Each student will summarize his or her digital system experiment in written Technical Report form for turn in as a final report.

A basic review/refreshers for differential and integral calculus and Fourier series representations of continuous periodic functions is reviewed at the outset as needed.

The class meets Monday 3:00-5:45pm and Wednesday 3:00-5:45pm (via VTC as needed)

Office Hours: Immediately following class Wednesday and by appointment

Prerequisites: ETRO 360 with grade C or better. — This prerequisite cannot be waived.

C. Mathematical skill set

Complex numbers, linear (matrix) algebra and symbolic mathematics for computers

II. PROSPECTUS

1. Introduction
   - Introduction to digital signal processing, transform space, the course outline and mathematical foundations
2. Introduction to discrete linear systems
   - Impulse response of linear time-invariant systems
   - Finite difference equations
   - Frequency-domain response of linear time-invariant systems
3. Introduction to transformation theory
   - Kronecker's Delta and Dirac Delta function and the representations as series and integrals
   - Pathway from Discrete Fourier Transform (DFT), Fourier Sequence Transform (FST), and Fourier Transform to arrive at the form of the Z Transform and inverse Z Transform
4. Z transform
   - Developing an intuition for complex functions and a signal's spectrum in z-space
   - Important examples of Z transformations
   - Z transformation and the system function
   - Transform analysis of linear time-invariant systems
5. Midterm
   - Midterm exam (October)
   - In-class review of the solution set
6. Sampling theory
   - Dirac comb (periodic sampler)
   - Nyquist-Shannon sampling theorem
   - Signal deconstruction and reconstruction
7. Signal graphs for discrete-time systems
   - Introduction to signal flow graphs
   - Graphical representations of finite difference equations
8. Applications (time permitting)
   - Lattice filters and filter design
   - Computational algorithms for the discrete Fourier transform (DFT) and fast Fourier transform (FFT)
9. Final
   - Final exam (mid December) and Student Project submitted in Technical Report format

III. PROBLEM SETS

Problem sets are assigned weekly and tailored to the classes progress. Student generally have one week to complete any given assigned problem set.

Selected Problem Sets will be submitted in Technical Report format using scientific typesetting software. Students will be provided with the scientific writing preparation and help.

IV. COURSE REQUIREMENTS AND EVALUATION

Problem sets, labs, written exercises, and computer problems: 30%
(assigned Wednesday and due the following Wednesday)
Midterm examination: 30%
Final exam: 30%
Class participation: 10%

V. METHOD OF INSTRUCTION

- Internet-based video teleconference
- SciPy and Mathematica demonstrations
- Class discussions
- Weekly office hours following the class end and can be scheduled on a weekly basis by e-mail request

VI. RESOURCES

- Text book:
  Alan V. Oppenheim and Ronald W. Schafer, "Discrete-Time Signal Processing", 3rd Ed., Prentice Hall
- Additional reference books:
  B. P. Lathi, "Linear systems and signals," 2nd Ed., Oxford University Press (2005)
  Charles L. Phillips and H. Troy Nagle, Jr., "Digital control system analysis and design," Prentice Hall (1984)
- In class demonstrations: Mathematica notebooks
- Additional resources and weekly updates will be provided in class.

VII. DISABILITY STATEMENT

1. If you have a disability and have not voluntarily disclosed the nature of your disability and the support you need, you are invited to contact Lisa Deneen - Disabilities Coordinator at 984-3227 or Telecommunication Device for the Deaf (TDD) 984-3325 or the Text Telephone (TT) replay service at 643-8833.

2. Reasonable accommodations will be provided for students with documented physical, sensory, systemic, cognitive, learning and psychiatric disabilities. If you believe you have a disability requiring accommodations, please notify Lisa Deneen - Disabilities Coordinator at 984-3227 or Telecommunication Device for the Deaf (TDD) 984-3325 or the Text Telephone (TT) replay service at 643-8833. The Disabilities Coordinator will verify your disability and provide the course instructor with recommendations for appropriate accommodations.