San Francisco State University

School of Engineering

Course Outline for ENGR 451 - Digital Signal Processing

Bulletin Description:

ENGR 451 Digital Signal Processing (4)

Properties of discrete-time systems. Convolution. Difference equations. Sampling and reconstruction of analog signals. Z-transforms and inverse z-transforms. Design of FIR and IIR filters. Discrete Fourier transform. Fast Fourier transform algorithms. Classwork, 3 units; laboratory, 1 unit.

Textbook:

Holton, Thomas (2021): *Digital Signal Processing: Principles and Applications*. Cambridge University Press.

References:

Oppenheim, A.V., Schafer, R.W.: *Discrete-time Signal Processing, 3rd Edition*. Prentice-Hall.

Mitra, S. K. (2005): *Digital Signal Processing: A Computer-Based Approach*. *3rd edition*. McGraw-Hill.

Proakis, J.G. and Manolakis, D.G. (2006): *Digital Signal Processing, 4th Edition*. Macmillan.

Prerequisites by Topic:

1. Complex number representations and algebra.
2. Calculus and analytic geometry.
3. Analog signal processing: Fourier series and Fourier transform. Laplace transform. Pole-zero plots.
4. Analog filter design (recommended): Chebyschev, Bessel, R-C.

Course Objectives*:

1. To give students a working knowledge of the major concepts and methods in digital signal processing. [A.1, A.2, B.1, B.3]
2. To develop a student's ability to analyze problem requirements and translate them into efficient computer programs. [A.1, A.2, A.3, B.1, B.2, B.3]

* numbers in brackets refer to goals and objectives of the School of Engineering.

Topics:

1. Properties of linear time-invariant systems.
2. Convolution.
3. Linear constant-coefficient difference equations.
4. Frequency-domain representation of discrete-time signals.
5. Discrete-time Fourier transform (DTFT).
6. Frequency response of linear time-invariant systems: system functions, magnitude and phase, phase unwrapping.
7. The z-transform: properties of z-transforms, region of convergence, inverse z-transforms.
8. Relation between the z-transform and the frequency response
9. Sampling theorem: sampling of continuous-time signals and reconstruction

of a signal from its samples. Aliasing. Upsampling, downsampling, resampling.
10. Basic structures for discrete-time systems: FIR and IIR representations, block diagrams, canonical and transposed representations.
11. Minimum-phase, maximum-phase and all-pass systems.
12. Design of FIR filters: windowing and optimal design.
13. Design of IIR filters from analog filters: e.g., Butterworth, Chebyshev, inverse Chebyshev.
14. Discrete Fourier Transform (DFT): Fourier transform of periodic and finite-duration signals, properties of the DFT, circular shift and convolution.
15. Fast Fourier Transform (FFT): decimation-in-time and decimation-in-frequency FFT algorithms, mixed-radix algorithms.

Evaluation:

1. Two 50-minute tests 35%
2. One final exam 25%
3. Weekly homework assignments.................. 10%
4. Laboratory projects.......................... 30%

Performance Criteria*:

Objective 1

- 1.1 The student will demonstrate the ability to analyze discrete-time systems to determine their linearity, time invariance, causality and stability.[1-4]
- 1.2 The student will demonstrate the ability to perform convolution.[1-4]
- 1.3 The student will demonstrate the ability to determine the frequency response of a discrete-time system. [1-4]
- 1.4 The student will demonstrate the ability to determine the impulse response of a discrete-time system. [1-3]
- 1.5 The student will demonstrate the ability to design and analyze sampled-data systems. [1-3]
- 1.6 The student will demonstrate the ability to analyze discrete-time upsampling and downsampling systems [1-4]
- 1.7 The student will demonstrate the ability to compute z-transforms, inverse transforms and regions of convergence. [1-3]
- 1.8 The student will demonstrate the ability to determine the block-diagram representation of FIR and IIR systems from z-transform, impulse response or difference equations. [1-3]
- 1.9 The student will demonstrate the ability to design IIR discrete-time filters based on analog filters. [1-4]
- 1.10 The student will demonstrate a knowledge of circular correlation and fast Fourier transforms. [1-3]

Objective 2

- 2.1 The student will design, debug and test MATLAB algorithms to carry out design and analysis of specified discrete-time problems. [4]

***** Numbers in brackets refer to evaluation methods used to assess student performance.

Course Administration:

Instructor:	Tom Holton
Office:	HH807E
email:	tholton@sfsu.edu

Scheduled Coverage: (75 min lectures)

Lectures are keyed with chapters in the book.

	Introduction	1 lecture
Ch 1	Discrete-time signals and systems	2
Ch 2	Impulse response	3
Ch 3	Discrete-time Fourier transform	3
Ch 4	z transform	3
Ch 5	Frequency response	2
Ch 6	A/D and D/A conversion	3
Ch 7	FIR filters	2
Ch 8	IIR filters	2
Ch 9	Filter architecture	2
Ch 10	Discrete Fourier transform	2
Ch 11	Fast Fourier transform	1

Use of MATLAB will be introduced and used in laboratory sessions. Up to ten laboratory projects will be assigned, about one a week, + or -.

Notes on Copyright of Course Material:

All material for this course, whether made available to you on the course website or posted is copyright © 2021 Thomas Holton. Copyright law forbids the reproduction or distribution of copyrighted work to others, including on file-sharing sites. It also prohibits downloading scanned copies of the textbook from unauthorized sites. Penalties for copyright infringement include civil and criminal penalties: https://its.sfsu.edu/guides/copyright-law

Notes on Evaluation:

All exams are closed-book and closed-notes. One (1) handwritten, single-sided page of formula is allowed per exam. **Absolutely no make-up exams or incomplete grades will be given for any reason.** Missed exams count as zero. Homework and projects are assigned approximately weekly and solutions will be available after the assignment is handed in. No late homework will be accepted. Grading scale is as follows: $A- \geq 88$ $B- \geq 70$ $C- \geq 52$ $D- \geq 34$.

Notes on Cheating:

The School of Engineering has an academic dishonesty policy, here: http://engineering.sfsu.edu/academic_dishonesty.html.

You are responsible for reading, and understanding it. Students who cheat, whether they give or receive answers from others, will receive a failing grade in the course and be reported to the appropriate people in the University. Cheating also includes soliciting or accepting answers from the Internet.

Notes on Courtesy:

Please refrain from the following behavior in the classroom: eating, texting, checking cellphones, tablet and other devices. Recording audio and video of lectures is not permitted. Be nice.

Notes on Prerequisites:

Engineering students must have appropriate prerequisites or have a copy of the course approval form signed by the instructor on file in the Engineering Office. Students lacking the prerequisites are subject to being administratively withdrawn from the course without notice by the instructor.

Notes on Disability:

Students with documented accommodation from DPRC for testing will take their exams at the same time as the rest of the class at the DPRC facility. The DPRC is located in the Student Service Building (voice/TTY 415-338-2472). Email (dprc@sfsu.edu). It is the student’s responsibility to arrange their accommodation with DPRC in a timely manner.

Notes on Communication:

Communication for this course will be done via e-mail sent to the SFSU e-mail account associated with your name. You are required to check this regularly. If you normally use an external e-mail account, make sure that your SFSU account is set to forward mail to your external account.

Notes on Safety:

This course includes a mandatory computer laboratory. Despite the fact that this “just” involves working with computers, observing laboratory safety precautions is more important than anything else you do in the laboratory. Your life may depend on it.

The most dangerous safety problem in a computer laboratory is the possibility of electric shock, for example from a broken computer. The effect of an electric shock varies from individual to individual and is a function of both current and time. In case of electric shock,

1. Immediately remove the power source from the victim if you can do so without endangering yourself.
2. Do not touch the victim with your bare hands while the victim is still connected to the power source, or you may become a victim, too.
3. Alert the instructor and call 911 right away. Don’t wait.
4. If the victim has stopped breathing, administer artificial respiration until directed otherwise by medical professionals.

General electrical safety practices:

1. Keep all equipment properly grounded.
2. Avoid handling of exposed leads and conductors.
3. Shut off all power sources before touching any part of a circuit.
4. Keep yourself and particularly your hands dry.
5. Wear a pair of shoes and avoid wearing anything metal, including jewelry.
6. Know what you are doing and pay attention to what you are doing and what your lab partners are doing.

Relationship to Other Courses:

This course extends the student's knowledge in basic continuous-time signal processing from the prerequisite course, ENGR 305, to encompass discrete-time signal processing.

The University requires the following notice to be included in all syllabi:

SF State fosters a campus free of sexual violence including sexual harassment, domestic violence, dating violence, stalking, and/or any form of sex or gender discrimination. If you disclose a personal experience as an SF State student, the course instructor is required to notify the Dean of Students. To disclose any such violence confidentially, contact:
The SAFE Place - (415) 338-2208; http://www.sfsu.edu/~safe_plc/
Counseling and Psychological Services Center - (415) 338-2208; http://psyservs.sfsu.edu. For more information on your rights and available resources: http://titleix.sfsu.edu.