ECEN 3300: Linear Systems
Spring 2014
Syllabus

Instructor:
Professor Hughes
Office: Engineering Center Office Tower (ECOT) 336
Office hours: Mondays 4-5:30pm and Fridays 12:30-2pm
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Course Overview

Catalog Description: Characterization of linear and time-invariant systems in time and frequency domains. Continuous time systems are analyzed using differential equations and Laplace and Fourier transforms. Discrete time systems, which can be implemented using a modern digital signal processing framework, use difference equations, z-transforms and discrete time Fourier transforms for their analysis and design. Applications of linear systems include communications, signal processing, and control systems.

Credits: 3 credit hours. Required core course for EE program, selected elective course for ECE program.

Prerequisites: ECEN 2260, Circuits as Systems

Textbook: Alan V. Oppenheim and Alan S. Willsky with S. Hamid, *Signals and Systems,* 2nd edition, Prentice Hall, 1996. ISBN-13: 978-0138147570.

Additional Suggested Online Reference: Richard Baraniuk, *Signals and Systems*, Online open-source textbook, http://cnx.org/content/col10064/

Coursework Description

Homeworks: Homework problems will be assigned throughout the semester. Typically, each homework set will be assigned on Monday and due the following Monday at the beginning of class.

Quizzes: Instead of large midterm exams, there will be frequent small in-class 25 minute quizzes throughout the semester covering approximately 2 weeks worth of new material each. These are scheduled for alternating Wednesdays starting Feb. 5th. In all, this means that the quizzes will be held on **Wednesdays 2/5, 2/19, 3/5, 3/19, 4/9, and 4/23**. The quizzes will tend to focus on new material, but are cumulative, meaning that you may be asked to use material from any point in the semester on each quiz.

Final Exam: There will be a 2.5 hour final exam. The registrar's office has scheduled this for Monday, May 5, 1:30pm-4:00pm.

Grading Policies

Final Average: Your final average will be calculated using the maximum of the following two averages:

Quizzes	45%	35%
Final Exam	35%	55%
Homeworks	20%	10%

Dropping the Lowest Homework Grade: The lowest homework grade will be dropped when calculating the homework average.

Dropping the Lowest Quiz Grade: The lowest quiz grade will be dropped when calculating the quiz average.

Penalties for Late Work: Late homework will be penalized at a rate of 15% of the points possible for each day late. The penalty is assessed at the start of each day late (e.g. 2:00pm). For those who prefer math, late homework will receive the grade g_L given by:

$$g_L = \max((1-.15\ d_L)g_O, 0)$$

where g_O is the grade the homework would have received had it been turned in on time and d_L is the number of days it is late (rounded up). We recommend that late homework be scanned into PDF and emailed to the grader so that we have a timestamp of when it was submitted. Alternately, we recommend making arrangements with the grader to submit the homework. Late homework submitted under Prof. Hughes's door will be counted as submitted when it is found, which might not be for a day or two after it was delivered, depending on timing.

Homework solutions will always be posted at least 24 hours prior to any quiz or exam covering the associated material, and no late homework will be accepted after solutions have been posted.

Conflicts with Quizzes/Exams: Quizzes and the final exam ***cannot be taken late unless arranged prior to the scheduled quiz/exam time*** with Prof. Hughes, due to extraordinary circumstances such as a medical or family emergency. In this case, ***documentation of the extraordinary circumstances will be required.*** See the class extension policy for details.

Homework Grading Policies: It is expected that homework solutions will be neatly written with each step to the solution clearly explained. Homework solutions that are unreadable or unclear may fail to receive full points, even if the final answer is correct.

Other Course Information and Policies

Collaboration on Homework: You are allowed and encouraged to discuss the homework problems with other students. However, your final submitted written solution should reflect only your own understanding of the problem. You should write this and work through the calculations yourself without looking at others' work. Identical, word-for-word, or eerily similar solutions should never arise from this process. Checking your final answer with that of others is fine.

Extension Policy on Coursework: This class has a generous penalty policy on late work and ability to drop one homework grade without penalty. Thus, penalty-free extensions will be granted only in the case of an extraordinary, unforeseen circumstance, for example a significant medical or family emergency. In this case, documentation to support the claimed circumstance will be **required**. Please keep this in mind and plan well in advance for deadlines for the course. It is also recommended that you save your option to drop the lowest homework score and lowest quiz score for unexpected circumstances.

Quiz/Exam Rules: Quizzes and exams are closed book and closed notes. However, for the first two quizzes, you will be allowed one **"cheat sheet"**, an 8.5" x 11" sheet of paper on which you may ***handwrite*** any information that you would like to have access to during the exam (writing on both sides is allowed). For the third and fourth quizzes, you may bring 2 "cheat sheets", and for the 5th and 6th quizzes, 3 "cheat sheets". For the final exam, you will be allowed 4 "cheat sheets". You may, and ideally will, reuse your cheat sheets from earlier quizzes as part of your "cheat sheet" allotment for each quiz/exam.

Apart from your "cheat sheets", you may only bring writing implements, a standard watch (no smart watches or cell phones), and if you wish a drink or small snack into quizzes or exams. *No textbooks, other notes, study aids, calculators, cell phones, MP3 players, or electronic devices of any kind are allowed*. Scratch paper will be provided for you in each quiz/exam if requested.

Feedback: Please feel free to let me know your feedback about the course at any time. If you don't feel comfortable talking to me directly, there is a form for anonymous feedback on the course webpage on Desire2Learn under the Survey tab.

Academic Dishonesty and the Honor Code: "All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Other information on the Honor Code can be found at http://www.colorado.edu/policies/honor.html and at http://honorcode.colorado.edu"

In this class, cheating includes any attempt to present another's work as your own. *This includes copying directly from another student's homework, another student's quiz or exam, online solution, or other source*. In this course, the expected academic sanction I will give for cheating is a *zero on the assignment that was cheated on*. You will also be reported to the Honor Code Council.

Other Campus-Wide Policies Pertaining to this Course

Policy on Students with Disabilities Needing Special Accommodation: If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines

accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary Injuries under Quick Links at Disability Services website (http://disabilityservices.colorado.edu/) and discuss your needs with your professor.

Policy on Religious Observances: Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, you should notify me as soon as possible of any potential deadlines that you feel you might have trouble meeting due to religious observances. Reasonable requests for accommodation due to religious observances will be granted *if they are made at least 2 weeks prior to the scheduled deadline*. See full details at http://www.colorado.edu/policies/fac_relig.html

Policy on Classroom Behavior: Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. See policies at http://www.colorado.edu/policies/classbehavior.html and at http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

Policy on Discrimination and Harassment: The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. The University of Colorado does not discriminate on the basis of race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status in admission and access to, and treatment and employment in, its educational programs and activities. (Regent Law, Article 10, amended 11/8/2001). CU-Boulder will not tolerate acts of discrimination or harassment based upon Protected Classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "Protected Classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, or veteran status. Individuals who believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550. Information about the ODH, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at http://hr.colorado.edu/dh/

Detailed Outline of the Course (with Recommended Reading)

Unit 1: Signals and Systems Overview
- Complex Numbers Review
- Basic Signal Categories (OW 1.1.1)
- Complex Exponentials (OW 1.3)
- Discrete- and continuous-time impulse and unit step functions (OW 1.4, also 2.5)
- System Properties: linearity, time-invariance, causality, stability, memory (OW 1.6)

Unit 2: Time-Domain Analysis of LTI Systems
- Impulse Response (OW 2.1 and 2.2)
- Discrete-Time Convolution (OW 2.1)
- Continuous-Time Convolution (OW 2.2)
- Circular Convolution for Periodic Signals (Baraniuk under DTFS and CTFS sections)
- Convolution Properties (OW 2.3.1-3)
- Tests of the Impulse Response for Causality and Stability (OW 2.3.6-7)

Unit 3: Linear Algebra Preliminaries (for all, see Baraniuk Appendix A)
- Linear Algebra Basics: Vector Space, Inner Product, Norm, Linear Operator
- Orthonormal Basis (ONB)
- Eigenvectors and Eigenvalues
- Matrix/Operator Diagonalization
- Using the Matrix/Operator Diagonalization for System Analysis

Unit 4: Frequency Domain Analysis of LTI Systems on Discrete-Time Periodic Signals (OW 3.6-8,11)
- Eigenfunctions of Discrete-Time LTI Systems (OW 3.8)
- The Discrete Fourier Transform (DFT) ONB for Periodic Signals (OW 3.6)
- Frequency Response/Transfer Function (OW 3.8)
- LTI System Analysis using the DFT (OW 3.8)
- DFT Basic and Symmetry Properties (OW 3.7)
- Relationship of Frequency Response and Impulse Response
- DFT Coefficients of Common Signals (OW 3.6)
- Case Study: Analyzing Linear Constant-Coefficient Difference Equations with the DFT (OW 3.11)

Unit 5: Frequency Domain Analysis of LTI Systems on Continuous-Time Periodic Signals (OW 3.2-5,10)
- Eigenfunctions of Continuous-Time LTI Systems (OW 3.2)
- Continuous-Time Periodic Functions as a Vector Space and the L^2 Inner Product (Baraniuk Appendix B)
- Continuous-Time Fourier Series (OW 3.3)
- CTFS Convergence Concerns and Gibbs Phenomena (OW 3.4)
- LTI System Analysis using CTFS (OW 3.2)
- CTFS Basic and Symmetry Properties (OW 3.5)
- CTFS Coefficients for Common Signals (OW 3.3)
- Case Study: Solving Differential Equations with CTFS (OW 3.10)

Unit 6: Frequency Domain Analysis of LTI Systems on Aperiodic Signals
- The Discrete-Time Fourier Transform (DTFT) (OW 5.1)
- The Continuous-Time Fourier Transform (DTFT) (OW 4.1)

- DTFT and CTFT Properties (OW 4.3-6 and 5.3-6)
- DTFT and CTFT Common Transform Pairs (OW 4.6 and 5.6)
- Revisit Case Studies Above for Aperiodic Signals (OW 4.7 and 5.8)

Unit 7: System Analysis Using the Frequency Response

- Magnitude and Phase (OW 6.1)
- Lowpass, Highpass, Bandpass, and Bandstop Filters

Unit 8: Case Studies: Practical Examples in Applications

Case Study 1: Modulation for AM Radio

- Signal Modulation in Time and Frequency (OW 8.1.2)
- Signal Demodulation (Recovery) in Time and Frequency (OW 8.2)

Case Study 2: Analog-to-Digital and Digital-to-Analog Conversion

- Sampling in Time and Frequency (OW 7.1)
- Signal Reconstruction in Time and Frequency (OW 7.2)
- Interpolation Using the Sinc Function (OW 7.2)
- Aliasing and the Nyquist Rate (OW 7.3)

If Time: Z-Transforms (OW 10), Case Studies for Other Applications such as Finance, Controls, Image Processing