Introduction to Signal Processing
ECE 421
Spring 2020

Instructor: Dror Baron
Email: dzbaron@ncsu.edu
Office hour: Wednesday 1-2 PM in EB2 2097
http://people.engr.ncsu.edu/dzbaron

Teaching assistants: to be determined

Course Text: Digital Signal Processing - Principles, Algorithms, and Applications by Proakis and Manolakis. Changes between editions have been minor, and any relatively recent edition should be fine. Some of you may want to download an electronic version.

Prerequisites:
ECE 301 (linear systems) and familiarity with Matlab.

Course purpose: ECE 421 will familiarize students with the basic elements of signal processing. It will teach you key concepts in discrete- and continuous-time signals and systems including frequency domain analysis, linear time invariant systems, Fourier transforms, and filtering. You will also learn how to sample analog signals and later reconstruct them. Finally, you will learn to solve signal processing problems numerically using the Matlab software package, and in particular you will be able to apply a methodology to signal processing problems that involves looking at the problem, translating it to mathematics, proposing an algorithm, and implementing it in Matlab.

Course Objectives: By the end of the semester, students should be able to:

• Analyze and implement digital signal processing (DSP) systems in the time domain.
• Compute the Fourier series and the discrete time Fourier transform (DTFT) of discrete-time signals.
• Analyze digital signal processing systems using the Z-transform and the DTFT.
• Design frequency-selective digital filters.
• Design digital filters using windows.
• Sample and reconstruct analog signals.
• Compute circular convolution and the discrete Fourier transform (DFT) of discrete-time signals.
• Analyze and implement digital systems using the DFT and the Fast Fourier Transform (FFT).
• Use Matlab for DSP system analysis and design.

More detailed objectives that are relevant to specific chapters covered in the midterms and final exam will be posted on the course website prior to these tests.

**Expectations:**
Per conversations with students who took the course in previous years, Dr. Baron’s course includes more open ended projects and test questions than some other courses. There will be less emphasis on plugging numbers into formulas and producing numerical results, and more emphasis on using your understanding for tasks such as evaluating trade-offs critically, deriving new results, and applying concepts you learned to problems you haven’t seen before. Some students have indicated that this educational style helped them build a strong foundation in signal processing. Before choosing another course, you should consider how developing this methodology can benefit you in the future. In any case, it’s your choice, because ECE 421 is an elective course.

**Policies and Procedures:**
*Academic integrity:* Students should refer to the University policy on academic integrity found in the Code of Student Conduct. Authorized aid on an individual assignment includes discussing the interpretation of the problem statement, sharing ideas or approaches for solving the problem, and explaining concepts involved in the problem. Any other aid would be unauthorized and a violation of the academic integrity policy.

Here are examples of student interactions: 
(i) students submitting a project together in pairs are certainly allowed to work and submit the project together; 
(ii) students submitting homeworks or projects separately can discuss the problem together, but must work out the details and submit separately; and 
(iii) cooperation during tests is forbidden. All cases of academic misconduct will be submitted to the Office of Student Conduct.

*Role of TAs:* The teaching assistants (TAs) will be the main points of contact for homeworks and projects. You can copy Dr. Baron, but he should be a secondary point of contact. Personal and other sensitive matters can be directed to Dr. Baron.

*Homework:* Students will submit electronic WebWorK homework individually. Assignments and the schedule for submitting them will be posted on the course web site.
Projects: Projects will involve a mathematical component, programming component in Matlab, and commentary on your results. The projects can be submitted individually or in pairs (both names should be on the project if submitting in pairs); projects will be submitted electronically via Moodle. Assignments and the schedule for submitting them will be posted on the course web site.

Late submissions: Completed WebWork assignments should be turned in by the due date electronically. Projects should be turned in electronically on the due date. A student who wishes to submit an assignment late must write to the TAs and receive permission to do so at least 48 hours before the assignment is due. Students who submit late without prior permission will receive zero credit. Exceptions will only be made in emergency situations.

Matlab: The projects will involve Matlab programming. A free Matlab download is available on the EOS website:

http://www.eos.ncsu.edu/software/downloads/

Students can learn Matlab from a tutorial available on the course webpage. Several Matlab scripts available on the course webpage as examples should also be informative; and you can always ask instructional staff.

Tests: There will be two midterm tests in class during the semester, and a comprehensive final exam at the end of the semester. All tests will be open-book, open-notes. Computers are absolutely not allowed; basic calculators are allowed. Any device that can communicate is not allowed. Students who are unable to take the test at those times must inform the instructor at the beginning of the semester; and an alternate arrangement will be formulated. In the past, students have written to the instructor a few days before tests about the timing being inconvenient. Please keep in mind that it is impossible to change the schedule during the semester in a way that is convenient for everybody. Consequently, changes at the last moment are impossible. That said, problems do happen, and if you consult with us well ahead of time, we will try to be flexible.

Quizzes: There will be quizzes during the semester roughly every week. Quizzes will be on the date that a homework is due, and the quiz will typically involve re-solving a modified version of one of the homework questions. The quizzes will be electronic and use the WebWorK software platform, which will grade your responses automatically. Each such quiz will be short and receive a relatively small grade weight (probably less than 1% of the total grade). For WebWork-based quizzes, computers (laptops, tablets, or smartphones) can be used to access the quiz. Please make sure to bring appropriate electronic devices to class on days when a quiz is scheduled. There will be no make-up quizzes; exceptions will only be

\footnote{Moodle submissions up to midnight (or a few minutes before) will be allowed.}
made in emergency situations.

Extra credit: Up to 2% of extra credit will be allowed. Extra credit will be allocated based on factors such as class participation, and feedback about assignments.

Precise guidelines for how extra credit is computed will not be provided. Extra credit is entirely up to the instructor and TAs, and the amount of extra credit will not be published.

Grading:
- Homework (WebWork): 5%
- Quizzes (WebWork): 5%
- Projects: 25%
- Midterm1: 20%
- Midterm2: 20%
- Final: 25%
- Extra credit: 2%

Weighted averages of 90, 80, and 70 will guarantee minimal letter grades of A-, B-, and C-, respectively. Realistically speaking, most semesters a bit of curving has gotten the class average to roughly 3.4.

Instructors’ commitment: You can expect your instructor to be courteous, punctual, well organized, and prepared for lecture and other class activities; to answer questions clearly and in a non-negative fashion; to be available during office hours or to notify you beforehand if they are unable to keep them; to provide a suitable guest lecturer or post pre-recorded lectures online when they are traveling; and to grade uniformly and consistently according to the posted guidelines.

Students with disabilities: North Carolina State University is subject to the Department of Health, Education, and Welfare regulations implementing Section 504 of the Rehabilitation Act of 1973. Section 504 provides that: “No otherwise qualified handicapped individual in the United States . . . shall, solely by reason of his handicap be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance.” This regulation includes students with hearing, visual, motor, or learning disabilities and states that colleges and universities must make “reasonable adjustments” to ensure that academic requirements are not discriminatory. Modifications may require rescheduling classes from inaccessible to accessible buildings, providing access to auxiliary aids such as tape recorders, special lab equipment, or other services such as readers, note takers, or interpreters. It further requires that exams actually evaluate students’ progress and achievement rather than reflect their impaired skills. This may require oral or taped tests, readers, scribes, separate testing rooms, or extension of time limits.

Schedule:
Midterm1: February 12, 2020
Midterm2: March 23, 2020
Final: May 4, 2020, 8:00–11:00 AM

Outline of Material Covered
Relevant chapters in the textbook are listed in parenthesis.

• **Introduction and Review. Discrete-Time Signals and Systems and Z-Transform.** (Chapters 1, 2, 3)
  We will learn about the advantages and some applications of digital signal processing, and properties of discrete-time signals and systems. Implementation techniques for discrete-time systems and the correlation of discrete-time signals will be introduced. We will also review the Z-transform and how to solve difference equations using the one-sided Z-transform.

• **Frequency Analysis of Signals and Systems and Digital Filter Design** (Chapters 4, 5, 10)
  We will compute the Fourier series and the Fourier transforms of discrete-time signals, analyze linear time invariant systems in frequency domain, design frequency selective filters, and investigate filter design using windows.

• **Sampling and Reconstruction of Signals.** (Chapter 6)
  Review ideal sampling and reconstruction of continuous-time signals, and consider the implementation of analog-to-digital and digital-to-analog converters.

• **The Discrete Fourier Transform (DFT) and the Fast Fourier Transform (FFT).** (Chapters 7, 8)
  We will review the DFT and its properties, compute circular convolution of discrete-time sequences, and learn linear filtering methods and analysis of signals using the DFT. Efficient computation of the DFT using the FFT algorithm will be introduced.

In order to give students a taste for some timely topics, we will spend some time surveying some modern signal processing topics. A detailed road map of the class appears on the course website.

**Class Evaluations:** Online class evaluations will be available for students to complete in April. (Dates will be announced at that time.)

Students will receive an email message directing them to a website where they can login using their Unity ID and complete evaluations. All evaluations are confidential; instructors will never know how any one student responded to any question, and students will never know the ratings for any particular instructors.