Introduction to Signal Processing
ECE 421 – Spring 2021

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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.

Prerequesites:
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 tests from previous years are posted on the course website. Note that previous offerings of the course often had two tests, a midterm and final exam, and learning objectives for those will be spread over a larger number of 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. In deciding whether to study ECE 421 or another elective course, you may want to consider how developing a more rigorous command of the material can benefit you in the future.

Policies and Procedures:
Academic integrity: Academic integrity is important in ECE 421, because many of you will be applying signal processing to real-world data sets in several years. If you cut corners in your future professional work, it could lead to lawsuits, you could be fired, and in extreme cases people could be injured or die. (If these comments seem far fetched, recall that multiple autonomous car makers have had to explain to the public why their vehicles crashed.)

Students should refer to the University policy on academic integrity. Here are some specific expectations we have.

- When working on homeworks and projects (you are encouraged to submit in pairs or triples), students can certainly work together (while socially distancing) and submit together; each student should make sure that they understand different aspects of the problems being worked through, and that the assignment helped them grasp concepts taught in class.

- When working on tests, no cooperation or "collaboration" between students is allowed. Especially during an online course experience, it could be tempting to text or email a friend. This is not allowed. You will be allowed to use your notes, books, a browser, and software such as Matlab.[1] While working on the test you should not text, email, or communicate with other people (certainly not other students) in any way, unless you are consulting with the course staff. **By submitting the test, you will be acknowledging that you completed the work on your own without the help of others in any capacity.** Any such aid would be unauthorized and a violation of the academic integrity policy.

All cases of academic misconduct will be submitted to the Office of Student Conduct; the recommended penalty will be a failing grade for the entire course.

[1] You can use the browser to access Moodle, the course webpage, and look up technical topics. Similar to a normal test, you must not communicate with other people.

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 *in pairs or triples* (all names should be on the project); projects will be submitted electronically by one of the team members 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.[2] A student who wishes to submit an assignment late **must write to the TA and receive permission to do so at least 48 hours before the assignment is due**. While requesting to submit something late 2–3 days ahead of the deadline is reasonable, doing so the morning it is due is not. As a guiding principle, please try to be nice to the course staff just like you want us to be nice to you. Students who submit late without prior permission will receive zero credit. Eceeptions (permitting late submissions without advance notice) will only be made in emergency situations, of course.

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: We will have multiple tests during the semester. Details about the test schedule will be published on the course webpage. The tests will be open-book, open-notes. Owing to the online nature of the course, computers will be allowed. See comments about intellectual integrity on page 2. (The aforementioned guiding principle also applies here. Students who are taking multiple courses with tests scheduled at inconvenient times should consult with Dr. Baron early on during the semester. In contrast, special circumstances will be handled with greater flexibility.)

Tests will be on Moodle, and available during a 24 hour window. Once you start working on a test, you should submit your work within 90 minutes (a standard class is 75 minutes; plus 15 minutes to scan your work, upload it, and so on). **There have been past cases where a student who submitted last-minute thought that they had submitted, but Moodle did not store the file.** To prevent these problems, in case you have problems submitting the test or do so as time is expiring, you should contact us immediately. A student who submits late (after more than 90 minutes) without having contacted us will be penalized

[2]Moodle submissions up to midnight (or a few minutes before) will be allowed.

1% per minute late. For example, a student who submitted after 2 hours (30 minutes late) and scored 90% will lose $30\% \times 90\% = 27\%$, resulting in a grade of 90-27=63%. (There will be no penalty if you emailed us promptly with an explanation and copy of your submission.)

Quizzes: During normal semesters there are quizzes, but the online format motivated us not to have quizzes this semester.

Extra credit: Extra credit of up to 3% will be allowed. Extra credit will be allocated based on factors such as class participation, feedback about assignments, attendance of office hours, and overall contributions to the course. Details about how much extra credit is allocated to different activities will not be published. Note, however, that in an average semester the average student receives roughly 1% extra credit. The bottom line is that you are encouraged to contribute to a pleasant and productive course experience!

Grading:

Homework (WebWork)	10%
Quizzes (WebWork)	no quizzes
Projects	40%
Tests	50%
Extra credit	3%

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 office hour discussions 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 if needed; 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:

A detailed tentative schedule appears on the course webpage. As we progress through the semester, the schedule will be updated periodically. The final exam is scheduled by the university for May 3, 2021. That said, it is expected that the final exam will have the same

format and weight as other tests.

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.

Continuity plan: A continuity plan was created in March 2020 and updated in January 2021, in response the coronavirus pandemic. The formal plan appears on the course webpage, and the changes highlighted here in colored font.