ECSE 4530 Digital Signal Processing

Course Syllabus

Basic Overview

Course Instructor: Derya Malak, JEC 6038, malakd@rpi.edu

Office Hours: Wednesday 4pm-6pm on Webex.

Class Schedule and Location:

- Lecture: Monday & Thursday, 10:10 am-11:30 am, JONSSN 4104 (i.e., JEC-4104)
  - Attribute: Hybrid:Online/In-Person Course, Undergraduate
  - All lectures will be recorded. Links to each lecture will be available on the **course website**.

Teaching Assistant: Hongji Guo, guoh11@rpi.edu **Office Hours** Monday 2pm-4pm on Webex.

Teaching Assistant: Alex Belsten, belsta@rpi.edu **Office Hours** Tuesday 5pm-7pm on Webex.

Overview: The main objective of this course is to provide a comprehensive treatment of the theory, design, and implementation of digital signal processing algorithms. In the first half of the course, we will emphasize frequency-domain and Z-transform analysis. In the second half of the course, we will investigate advanced topics in signal processing, including multirate signal processing, filter design, adaptive filtering and quantizer design. The course is intended to be fairly application-independent, to provide a strong theoretical foundation for future study in communications, control, or image processing. *3 credit hours*

Student Learning Outcomes: Students will be able to have an understanding of: (1) discrete-time signals and input-output relationships in discrete-time, linear time invariant systems, (2) the use of the Fourier transform, Fourier series, Discrete-Time Fourier Transform, Discrete Fourier Transform, Z-transform, and when to use them, (3) the sampling theory and how to reconstruct signals, (4) the design and implementation of FIR/IIR digital filters, (5) adaptive digital filtering, signal estimation and prediction, and (6) the recent advances in sparse signal processing.

Student Assessment Measures:

Component	Date	Learning Outcome(s)	Weight
Homeworks (6 in total)	Every 4-5 lectures	1-6	20 %
Midterm Exam 1	October 8	1-2	25 %
Midterm Exam 2	November 16	3-4	25 %
Final	TBD, online	1-6	30 %

Prerequisite Courses: ECSE 2410 Signals and Systems, ECSE 2500 Engineering Probability, MATH 2010 Multivariable Calculus and Matrix Algebra, or permission of instructor.

Texts:

- J. G. Proakis and D. G. Manolakis, Digital Signal Processing: Principles, Algorithms, and Applications, 4th Edition, Prentice-Hall, 2006 (Textbook).
- A. Oppenheim and R. Schafer, Discrete-Time Signal Processing, 3rd edition, Prentice-Hall, 2009.
- M. Hayes, Schaum's Outline of Digital Signal Processing, 2nd Edition, McGraw Hill, 2011.

Online Tools: The following online tools will be used to support this course. If you do not have access to any of these tools, please inform the instructor or the TA as soon as possible.

- Piazza Course Website: **https://piazza.com/rpi/fall2020/ecse4530/home**
  - Primary use is for class announcements, class discussion, and posting questions.
  - Contains all course information and links to Gradescope and MATLAB Grader Platforms.
  - Contains lecture notes, homework assignments, solutions and back exams; you are responsible for knowing any information that appears there. RPI LMS will only be used for grades.
- **Cisco Webex Meetings and Teams**.
  - Webex Meetings will be used to host lectures, with invites provided for each lecture. Webex Teams will be used for Office hours.
- Gradescope: **ECSE 4530**
  - Submission and grading of assignments will be done through this platform.

Policy Detail

FERPA Statement: The online tools in the table provide a service designed to assist schools, teachers and other educational partners to improve student learning outcomes. In some circumstances, these online tools may receive personally identifiable information about students ('Student Data') from the instructor in the course providing this service. For example, an instructor will provide a class roster, email addresses of all students in the class, as well as coursework data that may be linked to a particular student. All listed online resource companies used by the instructor consider Student Data to be strictly confidential and have physical, administrative and technical security protections in place to protect such data. They do not use personally identifiable Student Data for any purpose other than to provide the services to the instructor, and they do not share personally identifiable Student Data with any third party except as authorized or required by the instructor. The online tools above may collect, analyze, and share anonymized or aggregated data or data derived from Student Data for certain purposes, but only if the disclosure of such data could not reasonably identify a specific individual or specific School. Collection and use of Student Data provided by the instructor is governed by Terms of Service for each platform and by the provisions of the Family Educational Rights and Privacy Act (FERPA). Student Data is provided and controlled by the instructor. If you have questions about reviewing, modifying, or deleting personal information of a student, please contact the Office of the Registrar.

Students will be asked to sign this statement to agree to the use of these online tools and to acknowledge understanding of their use to facilitate online content for the course.

Collaboration and Academic Dishonesty: Intellectual integrity and credibility are the foundation of all academic work. A violation of Academic Integrity policy is, by definition, considered a flagrant offense to the educational process. It is taken seriously by students, faculty, and Rensselaer and will be addressed in an effective manner. If found responsible for committing academic dishonesty, a student may be subject to one or both types of penalties: an academic (grade) penalty administered by the professor and/or disciplinary action through the Rensselaer judicial process described in **this handbook**. Three relevant academic integrity violations to emphasize include:

> **Collaboration:** Collaboration is defined as deliberately facilitating an act of academic dishonesty in any way or form; for example, allowing another student to observe an exam paper or allowing another student to "recycle" one's old term paper or using one another's work in a paper or lab report without citing it as another's work.

Copying: Copying is defined as obtaining information pertaining to a graded exercise by deliberately observing the paper of another student; for example, noting which alternative a neighboring student has circled on a multiple-choice exam.

Plagiarism: Plagiarism is defined as representing the work or words of another as one's own through the omission of acknowledgment or reference. Examples include using sentences verbatim from a published source in a term paper without appropriate referencing, or presenting as one's own the detailed argument of a published source, or presenting as one's own electronically or digitally enhanced graphic representations from any form of media.

The Rensselaer Handbook of Student Rights and Responsibilities defines the full list of forms of Academic Dishonesty and you should make yourself familiar with these. In this class, all assignments that are turned in for a grade must represent the student's own work. In cases where help was received, or teamwork was allowed, a notation on the assignment should indicate your collaboration. If you have any questions concerning this policy before submitting an assignment, please ask for clarification.

Inclusivity and Accessibility Statement: Rensselaer Polytechnic Institute strives to make all learning experiences as accessible as possible. We strive to provide an environment that is equitable and conducive for learning for all students. Please contact the instructor as soon as possible if you:

1. live in a distant time zone and may need accommodations for meetings and exams. For additional help, please be proactive about attending open hours and office hours.
2. have internet accessibility issues where you live at any time during the semester. Contact the instructor directly if events cause disconnection for any important portion of the course. If you know this will be a consistent problem, please contact the instructor early in the semester.
3. anticipate or experience academic barriers based on a disability, please let the instructor know immediately so that alternative options may be discussed and determined early. To establish reasonable accommodations, please register with The Office of Disability Services for Students. After registration, make arrangements with the instructor as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. To receive any academic accommodation, you must be appropriately registered with DSS.

   DSS contact information: dss@rpi.edu; 518-276-8197, 4226 Academy Hall.

Assignments and Exams

Homework: Homework will be assigned every 4-5 classes (about 6 homeworks total) and posted on Piazza. These homeworks will be a mixture of paper-and-pencil problems to hand in, and MATLAB problems to submit online using a system called MATLAB Grader. You may discuss problems with other students, but you must prepare your solution independently.

Homework is due at the start of class (defined as the first 10 minutes) on the date indicated and you will turn in your homework on Gradescope. To do so, you will need to create a PDF of your work and save it to your computer before submitting. Please see the guide for students which is available here: **Get Started**.

For each student, the lowest homework score will not count towards the total homework score. Late homework will not be accepted. The TA will be responsible for homework grading and any questions about grading should be directed to the TA.

Exams: All exams will be closed book. Dr. Malak will assist in grading the exams and handle any questions or appeals.

Course Logistics

Grading Policy: The grade will be based on the average homework grade (worth 20%), two midterm exams in class (worth 25% each), and a final exam (worth 30%).

Attendance Policy: Attendance is expected and required in every class period, unless previously discussed with the instructor, and if necessary, officially documented by the **Student Experience office** (4th floor, Academy Hall). We will cover a lot of ground in this course to build a strong foundation for DSP, so attendance is important. To encourage learning, preparation and participation, the lectures will be complemented by additional reading or review materials, e.g., slides, papers or MATLAB codes, and online course materials to cover some of the basic concepts prior to the lectures.

Regrading Policy: Grade appeals, on homework or exam, must be submitted in writing within 72 hours of its return to the class. No verbal complaints will be considered.

Grade appeals on a homework should be made directly to the TA that graded it within 72 hours of its return to the class. Grade appeals on an exam should be made to the professor within 72 hours of its return to the class. I will not consider appeals immediately after an exam is handed back unless they relate to an error in adding up points. Please take the time to carefully compare your solution to the posted exam/homework solutions before appealing.

Other Course Policies: If you require extra time on exams or another form of accommodation, please contact the Dean of Students Office or the Office of Disability Services for Students. Please do this early in the term so that we have plenty of time to plan.

All mobile devices (e.g., smartphones, tablets, computers) should be stored securely away during lecture and are not be used unless specifically directed otherwise by the instructor. Use of (or ANY interaction with) a mobile device during an exam without explicit permission of the instructor will be interpreted as the illicit transfer of exam data, will be considered an act of cheating and will be treated as such.

You are expected to approach the instructor with any issue that may affect your performance in class ahead of time. This includes absence from important class meetings, late assignments, inability to perform an assigned task, the need for extra time on assignments, etc. You should be prepared to provide sufficient proof of any circumstances based on which you are making a special request as outlined in **The Rensselaer Handbook of Student Rights and Responsibilities**.

Any letter grade assignment posted before the end of the class should be regarded as tentative and subject to change.

Academic Integrity: Student-teacher relationships are built on trust. For example, students must trust that teachers have made appropriate decisions about the structure and content of the courses they teach, and teachers must trust that the assignments that students turn in are their own. Acts that violate this trust undermine the educational process. The Rensselaer Handbook of Student Rights and Responsibilities and The Graduate Student Supplement define various forms of Academic Dishonesty and you should make yourself familiar with these. In this class, all assignments that are turned in for a grade must represent the student's own work. This is particularly important for the MATLAB-based homework problems.

Submission of any assignment that is in violation of this policy may result in a penalty of an F in the class, and may be subject to further disciplinary action.

If you have any question concerning this policy before submitting an assignment, please ask for clarification.

Course Calendar

Date	Topic	Readings	Assignments	Form
M 8/31	Introduction; Discrete-time signals and their properties; Complex signals/sinusoids	2.1		**Online**
R 9/3	Properties of discrete-time systems	2.2		**Online**
M 9/7	No class (Labor Day)			
T 9/8	MATLAB for Digital Signal Processing; Discrete-time LTI systems; Impulse response of LTi systems (Monday's schedule)	2.3		In class
R 9/10	Convolution; Causality, Linearity, Time-invariance, Stability	2.3		In class
M 9/14	Difference equations, review of the Fourier series and properties	2.4, 4.1.1	HW 1 due	In class
R 9/17	Review of the Fourier Transform and its properties	4.1.2-4.1.3		In class
M 9/21	Frequency response; Eigenvalues and eigenfunctions of LTI systems	5.1-5.2		In class
R 9/24	The Discrete-Time Fourier Transform (DTFT); Relationships between transforms	4.2.3, 4.4		In class
M 9/28	Frequency response; The Z-Transform; The ROC	3.1		In class
R 10/1	Properties of the Z-Transform; poles-zeros	3.2-3.3	HW 2 due	In class
M 10/5	Inversion of the Z-Transform; Review for Midterm 1	3.4		In class
R 10/8	**Midterm 1**			TBD
M 10/12	No class (Columbus Day)			
R 10/15	Filter design (using Z-plane); The Discrete Fourier Transform (DFT)	7.1-7.2		In class
M 10/19	Properties of DFT; Circular convolution; The Fast Fourier Transform (FFT)	7.2, 8.1.3	HW 3 due	In class
R 10/22	FFT; Decimation in time; Decimation in frequency; Radix-2 FFT	8.1-8.2		In class
M 10/26	The Sampling Theorem; Discrete-time processing of CT signals	6.1-6.2		In class
R 10/29	Downsampling and upsampling	6.4-6.5, 11.1-11.4	HW 4 due	In class
M 11/2	Polyphase/Multirate signal processing	11.5-11.10		In class
R 11/5	FIR filter design; Linear phase filters	5.4.1-5.4.2, 10.1-10.2		In class
M 11/9	FIR filter design; Frequency sampling; Least Squares; Chebyshev approximations	10.2		In class
R 11/12	FIR filter design; Remez exchange algorithm; IIR filter design	10.2-10.3	HW 5 due	In class
M 11/16	**Midterm 2**			TBD
R 11/19	Direct digital IIR design; IIR design from Analog IIR filters	10.3		In class
M 11/23	Adaptive filtering; Moving average (MA) and auto regressive (AR) processes; Wiener filters	12.1-12.4, 12.7		In class
R 11/26	No class (Thanksgiving Break)			
M 11/30	Linear MMSE filter design; The Levinson-Durbin algorithm; Steepest descent algorithm	12.4, 12.7		**Online**
R 12/3	The least mean squares (LMS), Least squares (LS), Recursive LS algorithms	13.2-13.3	HW 6 due	**Online**
M 12/7	LS algorithms			**Online**
R 12/10	Sparse signal processing; Quantizers (Last day of class)	6.3, 6.6		**Online**
	Final exam (Online Finals December 15 - 18 and 21)			**Online**