

## Foundations of Digital Signal Processing

EEL 4750 / EEE 5502

**Class Periods:** M, W, F | Period 9 (4:05 PM - 4:55 PM)

**Class Location:** Zoom

**Academic Term:** Fall 2020

**Website:** <http://smartdata.ece.ufl.edu/eee5502/>

### Instructor

Name: Joel B. Harley

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Office Phone Number: 352-392-2692

Office Location: NEB 441

Zoom Room: Find on Slack / Canvas

Office Hours: W, F 5:00 PM – 6:00 AM

### Supervised Teacher(s)

- Name: Daniel Alabi, E-mail: [dalabi@ufl.edu](mailto:dalabi@ufl.edu), Office Hours: TBA
- Name: Ayobami Edun, E-mail: [aedun@ufl.edu](mailto:aedun@ufl.edu), Office Hours: TBA
- Name: Joseph Melville, E-mail: [joseph.melville@ufl.edu](mailto:joseph.melville@ufl.edu), Office Hours: TBA

### Course Description

This course covers topics related to the foundations of digital signal processing. After completing this course, students should understand the essential properties of discrete-time signals and systems; understand the sampling and reconstruction of signals; be able to perform transform analysis of digital signals and systems, and apply filter design techniques; as well as understand the fundamental principles of multi-rate signal processing.

### Course Pre-Requisites / Co-Requisites

Prerequisite: EEL 3135 (Introduction to Signals and Systems) or equivalent

### Course Objectives

At the conclusion of this course, you should be able to:

- Apply discrete-time systems to discrete-time signals
- Explain aliasing caused by under-sampling data
- Apply convolution and correlation to modify and locate signals
- Create a Fast Fourier transform algorithm
- Analyze data with the short-time Fourier transform / spectrogram
- Design FIR & IIR filters for modifying time-domain signals
- Analyze data with a multi-channel filter bank

### Recommended Materials

- Digital Signal Processing, 4th edition
  - Authors: John G. Proakis and Dimitris K. Manolakis
  - Publisher: Prentice Hall, 2006
  - ISBN: 0131873741
- EEL 4750/EEE 5502 Course notes
  - Author: Joel B. Harley

### Recommended Software

- MATLAB

## Course Schedule

The first half of EEL 4750 / EEE 5502 has two key objectives.

### Objective 1: Normalize Signals and Systems Knowledge

Since this is an introductory graduate course, you may start the class with a different signals and systems knowledge relative to other students. As a result, this half of the course aims to normalize knowledge across the class. Hence, parts of this half of the course may be a review of signals and systems material for you.

### Objective 2: Increase Depth of Signals and Systems Knowledge

While some topics may not be new for students, the course aims to give you a more in-depth, mature understanding of the theory and implementation of digital signal processing. This may require you to see old topics from new perspectives and with new mathematics.

#### Part 1: Signals, Systems, and Transforms (18 Classes)

DATE	LECTURE	READING	ASSIGNMENTS	QUIZZES
<b>Chapter 2: Discrete-Time Signals and Systems</b>				
MON	Aug 31	Motivation, Policies, DSP	Ch. 1	Quiz #1
WED	Sep 02	Continuous and Discrete-Time Signals	Ch. 2.1	
FRI	Sep 04	Continuous and Discrete-Time Systems	Ch. 2.2	
<b>Chapter 2: Discrete-Time Signals</b>				
MON	Sep 07	(Holiday)	--	
WED	Sep 09	Impulse Responses and Convolutions	Ch. 2.3	HW #1 Quiz #2
FRI	Sep 11	Difference Equations and System Implementations	Ch. 2.4-2.6	
<b>Chapter 3: The Z-Transform</b>				
MON	Sep 14	The Z-Transform	Ch. 3.1-3.3	HW #2 Quiz #3
WED	Sep 16	The Inverse Z-Transform	Ch. 3.4	
FRI	Sep 18	Poles and Zeros / Causality / Stability	Ch. 3.5	
<b>Chapter 4: Frequency Analysis of Signals</b>				
MON	Sep 21	Continuous-Time Fourier Transforms	Ch. 4.1	HW #3 Quiz #4
WED	Sep 23	Discrete-Time Fourier Transforms	Ch. 4.2	
FRI	Sep 25	Fourier Transform Properties	Ch. 4.3-4.4	
<b>Chapter 5: Frequency Domain Analysis of LTI Systems</b>				
MON	Sep 28	The Frequency Response	Ch. 5.1-5.2	HW #4 Quiz #5
WED	Sep 30	Frequency Selective Filters	Ch. 5.4	
FRI	Oct 2	(Homecoming)	--	
<b>Chapter 6: Sampling and Reconstruction of Signals</b>				
MON	Oct 05	Sampling (Continuous Time to Discrete Time)	Ch. 6.1-6.2	HW #5 Quiz #6
WED	Oct 07	Reconstruction (Discrete Time to Continuous Time)	Ch. 6.3-6.4	
FRI	Oct 09	Fourier, Periodicity, and Sampling	--	
<b>Chapter 2-6: Exam 1</b>				
MON	Oct 12	Review	--	HW #6 Quiz #7
WED	Oct 14	Exam 1 (Take-home: Identify systems in MATLAB)	--	
FRI	Oct 16	Short-Time Fourier Transforms	--	

The second half of EEL 4750 / EEE 5502 has two objectives.

### Objective 1: Design and Implement Filter Systems

In the second half of the course, we will design filter systems to satisfy specific requirements. Our focus will emphasize on stable, causal, linear phase filter systems that remove and retain specific frequencies. We will also briefly investigate how to design filter with other phase or magnitude requirements.

### Objective 2: Multi-Resolution Signal Processing

The final part of the course will delve into multi-resolution signal processing (i.e., filters operating at multiple sampling rates). These systems allow us to simultaneously process data at both coarse and fine timescale. This allows far more flexible capabilities than what available to typical filtering techniques.

#### Part 2: Filter Design and Implementation (19 Classes)

DATE	LECTURE	READING	ASSIGNMENTS	QUIZZES
<b>Chapter 7-8: The Discrete Fourier Transform &amp; The Fast Fourier Transform</b>				
MON	Oct 19	Frequency-Domain Sampling / Time-Domain Periodicity	Ch. 7.1-7.2	Take Home #1
WED	Oct 21	The Fast Fourier Transform Algorithm	Ch. 8.1-8.2	
FRI	Oct 23	Filtering with DFT / FFT	Ch. 7.3-7.4, 8.3	
<b>Chapter 9: Implementation of Discrete-Time Systems</b>				
MON	Oct 26	FIR Filter Structures	Ch. 9.1-9.2	HW #7 Quiz #8
WED	Oct 28	IIR Filter Structures	Ch. 9.3	
FRI	Oct 30	Implementation Considerations	Ch. 9.4-9.6	
<b>Chapter 10: Design of Digital Filters</b>				
MON	Nov 02	Challenges / Desirable Filter Properties	Ch. 10.1	HW #8 Quiz #9
WED	Nov 04	Designing FIR Filters	Ch. 10.2	
FRI	Nov 06	Designing IIR Filters	Ch. 10.3	
<b>Chapter 10: Design of Digital Filters</b>				
MON	Nov 09	Filter Transformations	Ch. 10.4	HW #9 Quiz #10
WED	Nov 11	(Veteran's Day)	--	
FRI	Nov 13	Filtering Short-Time Fourier Transforms	--	
<b>Chapter 11: Multirate Digital Signal Processing</b>				
MON	Nov 16	Downsampling / Decimation	Ch. 11.2	HW #10 Quiz #11
WED	Nov 18	Upsampling / Interpolation	Ch. 11.3	
FRI	Nov 20	Sample Rate Conversions	Ch. 11.4-11.8	
<b>Chapter N/A: Speech Enhancement Methods</b>				
MON	Nov 23	Signal Enhancement Methods	--	HW #11 Quiz #12
WED	Nov 25	(Thanksgiving)	--	
FRI	Nov 27	(Thanksgiving)	--	
<b>Chapter 11: Multirate Digital Signal Processing</b>				
MON	Nov 30	Two-Channel Filter Banks	Ch. 11.10-11.11	
WED	Dec 02	M-Channel Filter Banks	Ch. 11.12	
FRI	Dec 04	Multi-Resolution Applications	--	
<b>Chapter 7-11: Exam 2</b>				
MON	Dec 07	Review	--	HW #12 Quiz #13
WED	Dec 09	Exam 2	--	
FRI	Dec 11	(No Class)	--	
MON	Dec 14	(No Class)	--	Take Home #2

## Attendance and Participation Policies

### *Attendance & Participation:*

While attendance is not graded, lectures will include regular homework help and in-class discussions and demonstrations on the subject material. While participation is not graded, it is an integral part of each class that can help you learn the material.

### *Slack Page:*

We have a Slack page for the course: <https://uf-eee5502-SP2019.slack.com/>. This is an *optional* resource for students to discuss the course amongst each other and occasionally with the Professor and TAs. This resource is intended to supplement office hours and student interactions. **No official communication / submission happens over Slack.** No assignments submissions will be accepted over Slack.

### *Online Course Recording:*

Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

## Evaluation Methods and Criteria

The following section discusses the policies for each of the graded assessments in this course. You should look here first for answers to any general, course-related inquiries.

### *Group Quiz (13 in total)*

**When:** Assigned roughly once a week (see course schedule). Completed during class.

**What:** Relatively straightforward multiple choice and true/false problems solved together with other students.

**Why:** These quizzes are intended to be low-stakes assessments. They keep you up to date with the class and ensure that I know everyone is following along.

**Grading:** Quizzes will be graded on a scale from 0 to 10. How points are assigned will vary with the assignment.

**Late policy:** No late quizzes can be turned in.

**Submission:** Quizzes will be completed on canvas during class.

### *Homework (12 in total)*

**When:** Assigned roughly once a week (see course schedule).

**What:** Three parts: (1) Analytical problems that can be solved by hand, (2) theory assignments that can be solved by hand, and (3) implementation problems solve thru MATLAB.

**Why:** Homework guides you through course material and presents you with questions that will require time to think about and complete. Homework assignments are not meant to be completed in a single day.

**Grading:** Each of the three homework parts is graded separately. Homework is graded on a scale from 0 to 10. How points are assigned will vary with the assignment.

**Late policy:** Late assignments can be submitted one day late and can receive a maximum grade of 8/10.

Assignments will not be accepted after one day. This policy allows us to post solutions before an exam.

**Submission:** Homework will be submitted on canvas before class (4:00 PM) on the due date. Please ensure that your submission is readable.

### *In-Class Exams (2 in total)*

**When:** There are two non-cumulative exams covering each part of the course and one cumulative final exam.

**What:** Questions will be similar to homework concept problems

**Why:** Exams are an opportunity to show what you know about the course

**Calculators/Open Book:** Exams will be open book but time constrained, so do not rely on them

**Grading:** Exams are graded on a 100-percentage scale.

**Final/Makeup exams:** Each part of the final exam acts as a re-take or make-up exam. If you perform poorly on an in-class exam, you will have the opportunity to take one or more final exam parts to replace your grade(s). You will receive the highest grade from each midterm/final part pair.

### Take-Home Exams (2 in total)

**When:** There are two non-cumulative exams covering each part of the course and one cumulative final exam.

**What:** Questions will be similar to homework theory / implementation problems

**Why:** Exams are an opportunity to show what you know about the course.

**Calculators:** No calculators are allowed or necessary

**Grading:** Exams are graded on a 100-percentage scale.

**Late policy:** Late take-home exams will receive a 0 grade. Please turn everything in on time.

### Evaluation of Grades

Assignment	Percentage of Final Grade (EEL 4750)	Percentage of Final Grade (EEE 5502)
Group Quizzes (best 8 out of 12)	5%	5%
Concept Problems (best 11 out of 12)	10%	10%
Theory Problems (best 11 out of 12)	12%	12%
Code Problems (best 11 out of 12)	13%	13%
Midterm Exam 1	15%	15%
Midterm Exam 1 (Take home)	15%	15%
Midterm Exam 2	15%	15%
Midterm Exam 2 (Take home)	15%	15%
Final Exam	See section on exams	See section on exams
	100%	100%

### Grading Policy

Percent	Grade	Grade Points
93.3 - 100.0	A	4.00
90.0 - 93.3	A-	3.67
86.6 - 90.0	B+	3.33
83.3 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.6 - 80.0	C+	2.33
73.3 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.6 - 70.0	D+	1.33
63.3 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
00.0 - 60.0	E	0.00

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

## Course & University Policies

### *Modifying Syllabus by Class Vote*

**When:** If you and/or other students believe the course would be improved by a change in the syllabus and I agree that it would be a reasonable change. **What:** The proposed change will be put to an anonymous vote with the entire class. If the majority of the class agrees to this change, it becomes part of the syllabus. **Why:** In previous years, changes to the syllabus have been necessary do to unforeseen consequences of certain policies. The class vote ensures the entire class agrees with the change.

### *Collaboration*

**Healthy collaboration:** To solve homework assignments, healthy discussion and collaboration amongst classmates is encouraged. Healthy collaboration includes:

- Discussing and explaining general course material
- Discussing assignments for better understanding
- Providing assistance for general programming and debugging issues

If another student contributes substantially to your understanding of a problem, you should *cite* this student to let myself and the teaching assistants be aware of your similar interpretations of a problem. You will not be judged negatively for citing another student.

**Cheating and plagiarism:** While collaboration is encouraged, you are *expected to submit your own work*. Submitting work completed by another student is considered plagiarism and will be dealt with according to university policy. In general, if you do not fully understand your solution, the work is not your own. Examples of plagiarism or cheating include:

- Copying (or allowing someone to copy), even partially, an assignment solution or program from the course
- Submitting material, particularly code, using material taken from another source without proper a citation
- Obtaining solutions to assignments or exams through inappropriate means

Note that I may elect to use a plagiarism detection service in this course, in which case you will be required to submit your work to such a service as part of your assignment.

**Consequences:** If you are suspected of dishonest academic activity, I will invite you to discuss it further in private. Academic dishonesty will likely result in a grade reduction, with severity depending on the nature of the dishonest activity. I am obligated to report on academic misconduct with a letter to the department, college, and/or university leadership. Repeat offences will be treated with significantly greater severity.

### *Students Requiring Accommodations*

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, <https://www.dso.ufl.edu/drc>) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

### *Course Evaluation*

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at <https://evaluations.ufl.edu/evals>. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at <https://evaluations.ufl.edu/results/>.

### *University Honesty Policy*

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that

facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### **Software Use**

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### **Student Privacy**

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <http://registrar.ufl.edu/catalog0910/policies/regulationferpa.html>

### **Commitment to a Safe and Inclusive Learning Environment**

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, [rbielling@eng.ufl.edu](mailto:rbielling@eng.ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@ufl.edu](mailto:nishida@ufl.edu)

*Sexual Discrimination, Harassment, Assault, or Violence:* If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the Office of Title IX Compliance, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

### **Campus Resources:**

#### Health and Wellness

#### **U Matter, We Care:**

If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) or 352 392-1575 so that a team member can reach out to the student.

**Counseling and Wellness Center:** <http://www.counseling.ufl.edu/cwc>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

#### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

#### Academic Resources

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu).

<https://lss.at.ufl.edu/help.shtml>.

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.ufl.edu/>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.

<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.

<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus:** [https://www.dso.ufl.edu/documents/UF\\_Complaints\\_policy.pdf](https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf).

**On-Line Students Complaints:** <http://www.distance.ufl.edu/student-complaint-process>.