Instructor

Sreeraman Rajan
Office: Mackenzie 4480
Telephone: 613-520-2600 ext 4169
Email: sreeramanr@sce.carleton.ca

Office Hours
TBD

Course Objectives

The course provides an introduction to digital signal processing (DSP). It covers the basic DSP concepts and methods, such as sampling, discrete-time systems, FIR filters, IIR filters and DFT/FFT algorithms. Emphasis will be on digital infinite impulse response (IIR) and finite impulse response (FIR) filters and applications of the fast Fourier transform (FFT). Students will learn different ways of implementing DFT. The relationship between discrete-time and continuous-time signals and systems is emphasized throughout the course. Students will understand different ways of describing a filter: time domain response, signal flow graphs, difference equations, pole-zero descriptions, frequency domain descriptions and frequency domain response. Students will have the opportunity to apply the theory in several design and implementation of basic DSP functions such as FIR and IIR filters as well as spectral analysis using the FFT. Students will learn different filter structures including multirate systems and will learn to choose appropriate structures for implementation in DSP systems. Students will get an exposure to rudimentary power spectral estimation techniques.

Learning Outcomes

At the end of this course, students should be able to:

a) Apply DSP concepts to practical systems, convert a continuous time system into a discrete time system through sampling process. Recommend a sampling technique based on the contents of the signal.
b) Design linear phase filters given the specifications. Describe filters using signal flow graphs, difference equations, pole-zero forms and through pole-zero plots, time and frequency domain responses.

c) Design IIR filters given the specifications.

d) Analyze the filter properties in time domain and frequency domain, describe filters in time domain and frequency domains

e) Construct different filter structures and convert one structure to another structure.

f) Analyze the frequency components of a discrete signal and provide power spectral estimates.

g) Describe windowing effects on spectral estimates and in design of DSP systems.

Course Web Site

CU Learn will be used as the course website:  https://culearn.carleton.ca

Textbook and References

Optional Textbook:


Alternative Textbook:


Links to Software, libraries, additional resources

CU Learn will be used as the course webpage. All Announcements, assignments, and additional materials will be posted on CU Learn. CU Learn is accessible at http://culearn.carleton.

Evaluation and Marking Scheme

Assignments: 15%

Midterm Test: 35% (Date TBD)

Final Examination: 50% (Scheduled Exam)

Important things to note:
1. To obtain a final grade higher than F, students must obtain a passing grade on the final exam. B- is the passing grade for Carleton University graduate students while B is the passing grade for University of Ottawa graduate students.

2. Under cases where re-evaluation of midterm needs to be done, it would be performed without student’s presence. Any re-evaluation may lead to either increase or decrease of marks. By agreeing to re-evaluation, students agree that they are okay with both increase or decrease. Once re-evaluated, the re-evaluated marks will prevail. No more appeal would be entertained.

3. The web page will list your official assignment, midterm grades throughout the semester.

4. It is your responsibility to double check that the grades are recorded correctly for your work and if any discrepancy is noticed, it should be brought to the notice of the instructor so that appropriate changes can be made.

5. Check the course web page regularly for announcements and postings.

6. Use of cell phones is strictly prohibited during lectures/exams/quizzes/tests/labs. If you are seen using the cell phones during the lectures, you will be asked to leave the lecture room.

7. Final Exam and Midterm will be closed book. Duration of final exam will be 3 hours. Only non-programmable calculating devices will be allowed.

8. No Cheat sheets will be allowed in the midterm or final exam. If there are changes to this policy during the semester, then it will be announced in the class, especially before the midterm or the final exam.

9. Late Assignments will not be evaluated.

10. Midterm may be in-class or out of class hours depending on the availability of the class room. An announcement to this effect will made as soon details of room are available.

11. Extra classes may be held outside the prescribed hours whenever needed. Announcement will be made in advance in the class as and when required.

Exams

The final examination is for evaluation purposes only and will not be returned to students. You will be able to make arrangements with the instructor or with the department office to see your marked final examination after the final grades have been made available.

General Regulations

- **Copyright on Course Materials**: The materials created for this course (including course outline, slides, posted notes, labs, project, assignments, quizzes, exams and solutions) are intended for personal use and may not be reproduced or redistributed or posted on any web site without prior written permission from the author(s).

- **Deferred Term Work**: Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for making alternate arrangements with the instructor and in all cases this must occur no later than three (3.0) working days after the term work was due. Consult the section 9.3 of the Graduate Calendar for more information.

- **Academic Integrity**: Students should be aware of their obligations with regards to academic integrity. Please review the information about academic integrity at: https://carleton.ca/registrar/academic-integrity/ This site also contains a link to the complete
Academic Integrity Policy that was approved by the University's Senate.

- **Academic Accommodations**: Requests for Academic Accommodation You may need special arrangements to meet your academic obligations during the term. For an accommodation request, the processes are as follows:
  - Pregnancy obligation
    Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, visit the Equity Services website: carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf
  - Religious obligation
    Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, visit the Equity Services website: carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf
  - Academic Accommodations for Students with Disabilities
    If you have a documented disability requiring academic accommodations in this course, please contact the Paul Menton Centre for Students with Disabilities (PMC) at 613-520-6608 or pmc@carleton.ca for a formal evaluation or contact your PMC coordinator to send your instructor your Letter of Accommodation at the beginning of the term. You must also contact the PMC no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with your instructor as soon as possible to ensure accommodation arrangements are made. carleton.ca/pmc
  - Survivors of Sexual Violence
    As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and is survivors are supported through academic accommodations as per Carleton’s Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: carleton.ca/sexual-violence-support
  - Accommodation for Student Activities
    Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf

**Additional Information**

**Prerequisites:**

A good knowledge of the continuous-time Fourier transform, Laplace transform, impulse response, frequency response, and probability and statistics, as well as a basic understanding of computer architecture. Understanding of discrete-time Fourier transforms, sampling, and basic digital signal processing is an asset and also preferred.

**Tentative Week-By-Week Schedule**
Course Content:

Time permitting, the following topics will be covered:

- Review of discrete-time signals and systems
- Representation in time, frequency, and z-domains
- Impulse response, frequency response
- Shannon sampling theorem, Nyquist rate
- z-transform, region of convergence, inverse z-transform
- Linear discrete-time convolution
- Pole-zero diagrams, stability, causality
- Generalized linear phase filters, group delay
- Frequency selective filters, ideal filters, digital resonators, nulling filters, comb filters
- All-pass, minimum-phase, and maximum-phase filters
- z-domain, frequency domain relationship
- Discrete Fourier transform (DFT), fast Fourier transforms (FFT)
- FIR filter design, Gibbs’ phenomenon
- Windowing, Kaiser filter design
- Equiripple FIR filters, Parks-McClellan filter design
- IIR filter design, impulse invariance, bilinear transformation
- Filter structures, quantization effects
- Picket fence effect, spectral leakage, frequency resolution
- Circular convolution, linear filtering with DFT, overlap-add and overlap-save methods
- Random signals, correlation functions, system identification
- Multi-rate signal processing, digital-to-digital rate conversion, decimation, interpolation, polyphase realizations
- Power spectrum estimation, periodogram, Bartlett method, Welch method, Blackman-Tukey method
- Introduction to joint time-frequency analysis, spectrograms
- MATLAB/Octave implementations