Toronto Metropolitan University

Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

Course Outline (F2022)

ELE792: Digital Signal Processing

Instructor(s)	Anwar Mirza [Coordinator] Office: TBA Phone: TBA Email: anwar.mirza@ryerson.ca Office Hours: Online (zoom)
Calendar Description	The topics covered in this course include fast algorithms for the computation of DFT, fast Fourier transform (FFT), finite length discrete transforms, Discrete Cosine transform (DCT), estimation of spectra from finite-duration observations of signals, implementation of discrete-time systems, floating-point and fixed-point representations, multi-rate signal processing, adaptive filters and applications.
Prerequisites	ELE 632 and ELE 635 and (COE 538 or ELE 538)
Antirequisites	None
Corerequisites	None
Compulsory Text(s):	1. A.V. Oppenheim and R.W. Schafer, Discrete-Time Signal Processing, 3rd Edition, Pearson Higher Education Inc., 2010.
Reference Text(s):	1. L. Tan and J. Jiang, Digital Signal Processing, Fundamentals and Applications, Third Edition, Academic Press, 2019. 2. J.G. Proakis and D.G. Manolakis, Digital Signal Processing: Principles, Algorithms, and Applications, fourth edition, Prentice Hall, Upper Saddle River, New Jersey, 2007. 3. S.K. Mitra, Digital Signal Processing: A Computer-Based Approach, third edition, McGraw-Hill Inc., New York, 2005. 4. E.C. Ifeachor and B.W. Jervis, Digital Signal Processing: A Practical Approach, second edition, Prentice-Hall Inc., Essex, 2002. 5. D. S. Reay, Digital Signal Processing Using the ARM Cortex M4, Wiley, John Wiley & Sons, Inc., Hoboken, New Jersey, 2015.
Learning Objectives (Indicators)	At the end of this course, the successful student will be able to: 1. Develops a good understanding of modeling and analysis discrete-time signals and systems. Works with mathematical tools (z-Transform, difference equations) to have an in-depth understanding of discrete-time signals and systems. (**1c**) 2. Uses spectral analysis (Fourier analysis: DTFT, DFT) to analyze signals and systems. Studies, understands and works with A/D, D/A conversion processes. Studies digital filter design techniques. (**1d**) 3. Investigates techniques for efficient and real-time implementation of signal processing algorithms. Studies discrete-time system structures. (**2a**) 4. Studies algorithm complexity to measure the viability of different implementation techniques with respect to real-time processing constraints. (**3b**)

5. Applies signal processing and real-time implementation techniques to formulate feasible alternatives. Proposes solutions to design problems that will satisfy various design criteria. (**4c**)
6. Works with specialized engineering tools to develop DSP code which in turn is used to obtain experimental results and correlate the results with the theoretical understanding. (**5a**)

NOTE: *Numbers in parentheses refer to the graduate attributes required by the Canadian Engineering Accreditation Board (CEAB).*

Course Organization	3.0 hours of lecture per week for 13 weeks 2.0 hours of lab per week for 12 weeks 0.0 hours of tutorial per week for 12 weeks
Teaching Assistants	Randy Tan (randy.tan@ryerson.ca)

Course Evaluation

Theory	
Lecture: Midterm Examination	25 %
Lecture: Final Examination	35 %
Laboratory	
Laboratory: Project	16 %
Laboratory: Experiments [8 (Lab1) + 8 (Lab2) + 8 (Lab3)]	24 %
TOTAL:	100 %

Note: In order for a student to pass a course, a minimum overall course mark of 50% must be obtained. In addition, for courses that have both **"Theory and Laboratory"** components, the student must pass the Laboratory and Theory portions separately by achieving a minimum of 50% in the combined Laboratory components and 50% in the combined Theory components. Please refer to the **"Course Evaluation"** section above for details on the Theory and Laboratory components (if applicable).

Examinations	Midterm Examination: Tentatively week 7, 2 hours duration; problem & theory based, close book; covers weeks 1–7. Final Examination: During exam period; 3 hours duration; problem & theory based, close book; covers the entire course material. Online exam(s) within this course may use a virtual proctoring system.
Other Evaluation Information	Midterm Exam:- A single Midterm Exam will be held. No make-up exam will be provided for missing the Midterm Exam for a valid reason, instead its weight will be shifted to the Final Exam for eligible cases. Labs and Project are individual [all in-person]:- To be done by each student.
Teaching Methods	1. Lectures will be delivered in-person during the scheduled class hours. 2. Notes/slides from the class lectures will be posted on D2L. 3. Practice problems sets and their solutions will be provided on the course web page from time to time. These problem sets will neither be collected nor graded; they are provided only as a study guide. You are strongly recommended to attempt to solve the problems on your own without looking at the solutions first. 4. If you have any question about the lecture or the sample problems (or its respective solution),

please consult the course instructor during the consulting hours.
 5. Class lectures should not be recorded (for voice or video), to ensure privacy concerns of everyone in the classroom. Also video accessed via Zoom should not be recorded, for voice or video.

Other Information	None	

Course Content

Week	Hours	Chapters / Section	Topic, description
1	3	Chap 4 Sec 1-4, 8 + C.N*	Introduction, Review, Baseband Sampling, Nyquist Criteria, Quantization Lab 1 Review and Discussion
2	3	Chap 4 Sec 7, 9 + C.N	Bandpass Sampling, Oversampling A/D, Multirate Signal Processing, Decimation, Interpolation
3	3	Chap 5 Sec 3–7 + C.N	Transform Analysis of LTI systems, Transfer Function, Frequency Response of filters, Pole, Zero locations and Filter Characteristics, All pass filters, Linear Phase FIR Transfer Functions Lab 2 Review and Discussion
4	3	Chap 6 Sec 1-3, 8 & Ch 7 Sec 1-7 + C.N	Structures of Discrete-Time Systems, Digital Filter Design, IIR filters, Effects of Coefficient Quantization
5	3	Chap 7 Sec 1-7 + C.N	Design of IIR and FIR filters.
6	3	Chap 7 Sec 1-7 & Ch 8 Sec 1-8 + C.N	Design of FIR filters, Introduction to Adaptive Filters, Finite Length Discrete Transforms, DFS, DFT, Circular Convolution Lab 3 Review and Discussion
7	2		Midterm Exam (2 hrs) - Tentatively week 7
7-8	4	Chap 8 Sec 1-	Linear Convolution using DFT, Fourier Analysis of Signals, Application of DCT,

		8 & Ch 10 Sec 1-4 + C.N	Discrete Cosine Transform
9	3	Chap 8 Sec 1-8 & Ch 9 Sec 1-2 + C.N	Discrete Cosine Transform, Fast Fourier Transform Project Review
10	3	Chap 9 Sec 1-2 + C.N	Fast Fourier Transform
11	3	C.N	Short-time Fourier Transform, Spectrograms
12	3	C.N	Introduction to Wavelet Analysis (if time permits)
13	3		Course Review: • Summary and review of the course material • Directions of further investigation/learning (graduate studies)
			C.N*: Course Notes Note1: The duration (hours) versus topics is tentative and is subject to change. Note2: In addition to Chapter/Sections listed above, ALL class notes and materials posted in D2L are included in the syllabus.

Laboratory(L)/Tutorials(T)/Activity(A) Schedule

Week	L/T/A	Description
1	In-person	Students will be introduced to general DSP architecture and processor specific architecture. The first session will also introduce students the general concepts of real-time (r/t) programming. Issues that are critical to r/t programming will be discussed and highlighted.
2-3	In-person	Lab 1: Implementation of Simple DSP Operations
4-6	In-person	Lab 2: Implementation of Digital Filters

7-9	In-person	Lab 3: Block-Processing Algorithm Implementation Many DSP algorithms are based on block processing (e.g. FFT) and while the algorithm operates a block of samples further samples will arrive and need to be stored in a temporary buffer. In this laboratory exercise students will be exposed to r/t considerations in the design of block processing algorithms.
10-13	In-person	Projcect: Media Authentication with Electric Network Frequency Analysis The objective of this project is to investigate the use of various signal processing techniques in extracting Electric Network Frequency (ENF) information from audio signals as a means of media authentication. In this project students use Short-Time Fourier Transform (STFT) to extract time varying ENF information at the line frequency and its harmonics. The ENF information extracted from the audio signal will be compared to a reference ENF signal. Comparison of the two ENF signals can provide valuable clues about the similarity between the two ENF signals and consequently about the authenticity of the audio signal being investigated.

Policies & Important Information:

Students are reminded that they are required to adhere to all relevant university policies found in their online course shell in D2L and/or on the Senate website

1. In accordance with the Policy on TMU Student E-mail Accounts (Policy 157), Toronto Metropolitan University (TMU) **requires** that any electronic communication by students to TMU faculty or staff be sent from their official university email account;
2. Any changes in the course outline, test dates, marking or evaluation will be discussed in class prior to being implemented;
3. Assignments, projects, reports and other deadline-bound course assessment components handed in past the due date will receive a mark of ZERO, unless otherwise stated. Marking information will be made available at the time when such course assessment components are announced.
4. Familiarize yourself with the tools you will need to use for remote learning. The Continuity of Learning Guide for students includes guides to completing quizzes or exams in D2L or Respondus, using D2L Brightspace, joining online meetings or lectures, and collaborating with the Google Suite.
5. The University has issued a minimum technology requirement for remote learning. Details can be found at: https://torontomu.ca/covid-19/students/minimum-technology-requirements-remote-learning. Please ensure you meet the minimum technology requirements as specified in the above link.
6. Toronto Metropolitan University COVID-19 Information and Updates (available https://www.torontomu.ca/covid-19/students) for Students summarizes the variety of resources available to students during the pandemic.
7. Refer to our **Departmental FAQ** page for information on common questions and issues at the following link: https://www.ecb.torontomu.ca/guides/Student.Academic.FAQ.html.

Missed Classes and/or Evaluations

When possible, students are required to inform their instructors of any situation which arises during the semester which may have an adverse effect upon their academic performance, and must request any consideration and accommodation according to the relevant policies as far in advance as possible. Failure to do so may jeopardize any academic appeals.

1. **Academic Consideration Requests for missed work** (e.g. missing tests, labs, etc) - According to Senate Policy 134, Section 1.2.3, if you miss any exams, quizzes, tests, labs, and/or assignments for health or compassionate reasons you need to inform your instructor(s) (via email whenever possible) in advance when you will be missing an exam, test or assignment deadline. When circumstances do not permit this, you must inform the instructor(s) as soon as reasonably possible". *In the case of illness, a Toronto Metropolitan Student Health Certificate, or a letter on letterhead from an appropriate regulated health professional*

with the student declaration portion of the Student Health Certificate attached. For reasons other than illness, proper documentation is also required (e.g. death certificate, police report, TTC report). ***ALL supporting documentation for illness or compassionate grounds MUST be submitted within three (3) working days of the missed work.***" **NOTE: You are required to submit all of your pertinent documentation through the University's online Academic Consideration Request system at the following link:** prod.apps.ccs.ryerson.ca/senateapps.

2. ***Religious, Aboriginal and Spiritual observance*** - If a student needs accommodation because of religious, Aboriginal or spiritual observance, they must submit a Request for Accommodation of Student Religious, Aboriginal and Spiritual Observance AND an Academic Consideration Request form within the first 2 weeks of the class or, for a final examination, within 2 weeks of the posting of the examination schedule. If the requested absence occurs within the first 2 weeks of classes, or the dates are not known well in advance as they are linked to other conditions, these forms should be submitted with as much lead time as possible in advance of the absence. Both documents are available at www.torontomu.ca/senate/forms/relobservforminstr.pdf. **If you are a full-time or part-time degree student, then you submit the forms to your own program department or school;**

3. ***Academic Accommodation Support*** - Before the first graded work is due, students registered with the Academic Accommodation Support office (AAS - prod.apps.ccs.ryerson.ca/senateapps) should provide their instructors with an Academic Accommodation letter that describes their academic accommodation plan.

Virtual Proctoring Information (if used in this course)

Online exam(s) within this course may use a virtual proctoring system. Please note that your completion of any such virtually proctored exam may be recorded via the virtual platform and subsequently reviewed by your instructor. The virtual proctoring system provides recording of flags where possible indications of suspicious behaviour are identified only. Recordings will be held for a limited period of time in order to ensure academic integrity is maintained and then will be deleted.

Access to a computer that can support remote recording is your responsibility as a student. The computer should have the latest operating system, at a minimum Windows (10, 8, 7) or Mac (OS X 10.10 or higher) and web browser Google Chrome or Mozilla Firefox. You will need to ensure that you can complete the exam using a reliable computer with a webcam and microphone available, as well as a typical high-speed internet connection. Please note that you will be required to show your Toronto Metropolitan University OneCard prior to beginning to write the exam. In cases where you do not have a Toronto Metropolitan University OneCard, government issued ID is permitted.

Information will be provided prior to the exam date by your instructor who may provide an opportunity to test your set-up or provide additional information about online proctoring. Since videos of you and your environment will be recorded while writing the exam, please consider preparing the background (room / walls) so that personal details are not visible, or move to a room that you are comfortable showing on camera.

Academic Integrity

Toronto Metropolitan University's Policy 60 (the Academic Integrity policy) applies to all students at the University. Forms of academic misconduct include plagiarism, cheating, supplying false information to the University, and other acts. The most common form of academic misconduct is plagiarism - a serious academic offence, with potentially severe penalties and other consequences. It is expected, therefore, that all examinations and work submitted for evaluation and course credit will be the product of each student's individual effort (or an authorized group of students). Submitting the same work for credit to more than one course, without instructor approval, can also be considered a form of plagiarism.

Suspicions of academic misconduct may be referred to the Academic Integrity Office (AIO). Students who are found to have committed academic misconduct will have a Disciplinary Notation (DN) placed on their academic record (not on their transcript) and will normally be assigned one or more of the following penalties:

1. A grade reduction for the work, ranging up to an including a zero on the work (minimum penalty for graduate work is a zero on the work);
2. A grade reduction in the course greater than a zero on the work. (Note that this penalty can only be applied to course components worth 10% or less, and any additional penalty cannot exceed 10% of the final course grade. Students must be given prior notice that such a penalty will be assigned (e.g. in the course outline or on the assignment handout);
3. An F in the course;
4. More serious penalties up to and including expulsion from the University.

The unauthorized use of intellectual property of others, including your professor, for distribution, sale, or profit is expressly prohibited, in accordance with Policy 60 (Sections 2.8 and 2.10). Intellectual property includes, but is not limited to:

1. Slides
2. Lecture notes
3. Presentation materials used in and outside of class
4. Lab manuals
5. Course packs
6. Exams

For more detailed information on these issues, please refer to the Academic Integrity policy(https://www.torontomu.ca/senate/policies/pol60.pdf) and to the Academic Integrity Office website (https://www.torontomu.ca/academicintegrity).

Academic Accommodation Support

Toronto Metropolitan University acknowledges that students have diverse learning styles and a variety of academic needs. If you have a diagnosed disability that impacts your academic experience, connect with Academic Accommodation Support (AAS). Visit the AAS website or contact aasadmin@ryerson.ca for more information.

Note: All communication with AAS is voluntary and confidential, and will not appear on your transcript.

Important Resources Available at Toronto Metropolitan University

1. The Library provides research workshops and individual assistance. If the University is open, there is a Research Help desk on the second floor of the library, or students can use the Library's virtual research help service at https://library.torontomu.ca/ask to speak with a librarian.

2. Student Life and Learning Support offers group-based and individual help with writing, math, study skills, and transition support, as well as resources and checklists to support students as online learners.

3. You can submit an Academic Consideration Request when an extenuating circumstance has occurred that has significantly impacted your ability to fulfill an academic requirement. You may always visit the Senate website and select the blue radial button on the top right hand side entitled: Academic Consideration Request (ACR) to submit this request).

   Please note that the Provost/Vice President Academic and Deans approved a COVID-19 statement for Fall 2022 related to academic consideration. This statement will be built into the Online Academic Consideration System and will also be on the Senate website (www.ryerson.ca/senate) in time for the Fall term:

   Policy 167: Academic Consideration for Fall 2022 due to COVID-19: Students who miss an assessment due to cold or flu-like symptoms, or due to self-isolation, are required to provide a health certificate. All absences must follow Senate Policy 167: Academic Consideration.

   Also NOTE: Policy 167: Academic Consideration does allow for a once per term academic consideration request without supporting documentation if the absence is less than 3 days in duration and is **not for a final exam/final assessment**. If the absence is more than 3 days in duration and/or is for a final exam/final assessment, documentation is required. For more information please see Senate Policy 167: Academic Consideration.

4. TMU COVID-19 Information and Updates for Students summarizes the variety of resources available to students during the pandemic.

5. TMU COVID-19 Vaccination Policy.

6. If taking a remote course, familiarize yourself with the tools you will need to use for remote learning. The Remote Learning guide for students includes guides to completing quizzes or exams in D2L Brightspace, with or without Respondus LockDown Browser and Monitor, using D2L Brightspace, joining online meetings or lectures, and collaborating with the Google Suite.

7. Information on Copyright for [students](#).

8. At Toronto Metropolitan University (TMU), we recognize that things can come up throughout the term that may interfere with a student's ability to succeed in their coursework. These circumstances are outside of one's control and can have a serious impact on physical and mental well-being. Seeking help can be a challenge, especially in those times of crisis.

   If you are experiencing a mental health crisis, please call 911 and go to the nearest hospital emergency room. You can also access these outside resources at anytime:
   - **Distress Line:** 24/7 line for if you are in crisis, feeling suicidal or in need of emotional support (phone: 416-408-4357)
   - **Good2Talk:** 24/7 hour line for postsecondary students (phone: 1-866-925-5454)
   - **Keep.meSAFE:** 24/7 access to confidential support through counsellors via My SSP app or 1-844-451-9700

   If non-crisis support is needed, you can access these campus resources:

   - Centre for Student Development and Counselling: 416-979-5195 or email csdc@ryerson.ca
   - Consent Comes First - Office of Sexual Violence Support and Education: 416-919-5000 ext: 553596 or email osvse@ryerson.ca

   We encourage all Toronto Metropolitan University community members to access available resources to ensure support is reachable. You can find more resources available through the [Toronto Metropolitan University Mental Health and Wellbeing website](#).