Course Outline (W2023)

ELE863: VLSI Circuits for Data Communications

Instructor(s)	Dr. Fei Yuan [Coordinator] Office: ENG 433 Phone: (416) 979-5000 x 556100 Email: fyuan@torontomu.ca Office Hours: Mon. 9-10 am via ZOOM
Calendar Description	An advanced course on design of VLSI circuits for data communications over wire channels. The theoretical component consists of: switching noise and grounding of mixed analog-digital circuits, modeling of wire channels, clock generation and distribution, power distribution on chip, ESD protection, channel equalization, clock and data recovery. The laboratory component consists of design of clock and data recovery circuits using state-of-the-art CMOS technology and CAD tools.
Prerequisites	ELE 727 or ELE 734
Antirequisites	None
Corequisites	None
Compulsory Text(s):	1. ELE 863 Lecture Notes from Dr. Fei Yuan (available from D2L). 2. Laboratory manual: ELE 863 Laboratory Manual (available from D2L).
Reference Text(s):	1. W. Dally and J. Poulton, Digital Systems Engineering, Cambridge University Press, 1998. 2. B. Razavi, Design of Integrated Circuits for Optical Communications, McGraw-Hill, 2003 3. H. Johnson and M. Graham, High-speed digital design - A handbook of black magic, Prentice-Hall, 1993. 4. F. Yuan, CMOS Current-Mode Circuits for Data Communications. Springer, 2006. 5. Stojanovic, Channel-limited high-speed links: modeling, analysis and design, PhD Dissertation, Stanford University, 2004. 6. Published peer-reviewed scientific papers in scientific journals and conference proceedings.
Learning Objectives (Indicators)	At the end of this course, the successful student will be able to: 1. Improve their capabilities of using the technical knowledge of VLSI circuits to design a transceiver for data communications. (**4b**) 2. Utilize computer-aided design tools for integrated circuit design to iteratively design a transceiver for data communications over wire channels. (**4c**) 3. Proficiency in use of computer-aided design tools from Cadence Design Systems for integrated circuit design to design and analyze a transceiver for data communications over wire channels. (**5a**) 4. Write professionally prepared laboratory reports. Laboratory reports are evaluated on their correctness, completeness, English, and quality of graphics. (**7a**), (**7c**)

	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	Ian Perczak. Email : iperczak@torontomu.ca	

Course Evaluation

Theory	
Midterm Exam	30 %
Final Exam	30 %
Laboratory	
Lab Projects	40 %
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	1. 3-hour closed-book midterm exam during regular lecture time on Feb. 22. 2. 3-hour closed-book final exam during university exam period with date/time set by the university. Only course materials covered AFTER the midterm exam will be tested.
Other Evaluation Information	None
Other Information	None

Course Content

Week	Hours	Chapters / Section	Topic, description

1-2	6	Distributed lecture notes	Module 1 - Modeling of wire channels
			   1) Components of wire channels
			   2) Scaling of wire channels
			   3) Resistance of wire channels
			   4) Capacitance of wire channels

			5) Inductance of wire channels 6) Modeling of wire channels at low, intermediate, and high frequencies 7) Transmission-line effect (perfect/under/over termination) 8) Termination schemes

3	1.5	Distributed lecture notes	Module 2 - Electrical signaling
			  1) Single-ended signaling
			  2) Fully differential signaling
			  3) Pseudo-differential signaling
			  4) Voltage-mode incremental signaling
			  5) Current-mode signaling
			  6) Current-mode incremental signaling

3	1.5	Distributed lecture notes	Module 3 - Fundamentals of serial links
			  1) Data encoding for serial links
			  2) Data modulation for serial links
			  3) Eye diagrams
			  4) Inter-symbol interference (ISI)
			  5) Bit-error rate
			  6) Test of serial links

4	3	Distributed lecture notes	Module 4 - Pre-emphasis
			  1) Channel equalization
			  2) Pre-emphasis strategies
			  3) Basic idea of pre-emphasis
			  4) Pre-emphasis algorithms
			  5) Pre-emphasis algorithms : A zero/pole perspective
			  6) Pre-emphasis algorithms : A frequency response perspective
			  7) Pre-emphasis waveforms
			  8) Implementation of pre-emphasis FIR filters
			  9) Advantages of pre-emphasis
			  10) Limitations of pre-emphasis

5	3	Distributed lecture notes	Module 5 - Continuous-time linear equalization
			  1) Channel impairments
			  2) Channel equalization
			  3) Continuous-time linear equalization
			  4) Continuous-time linear equalization - Source degeneration
			  5) Continuous-time linear equalization - Negative capacitors
			  6) Continuous-time linear equalization - Inductor shunt-peaking
			  7) Continuous-time linear equalization - Complete design

6	3		Mid-term examination during normal lecture time on Feb. 22.

7-9	9	Distributed lecture notes	Module 6 – Phase/frequency-locked loop
			  1) Voltage-controlled ring oscillators
			  2) Noise
			  3) Spectrum (phase noise) of oscillators
			  4) Phase detectors
			  5) Charge pumps
			  6) Loop filters
			  7) Loop dynamics of type-1 phase-locked loops
			  8) Loop dynamics of type-2 phase-locked loops
			  9) Phase noise of phase-locked loops
			  10) All-digital phase-locked loops
			   - TDC-based ADPLL
			   - Delay line TDC
			   - Delay-locked loops
			   - Vernier TDC
			   - Cyclic Vernier TDC
			   - Digital phase interpolation
			   - Digital loop filters (FIR, IIR filters)
			   - Digital controlled oscillators (DCOs)
			  11) Frequency synthesizers
			   - Injection-locked frequency dividers
			   - DFF-based frequency dividers
			   - Frequency difference detectors
			   - Frequency-locking and phase-locking in frequency synthesizers

10-11	6	Distributed lecture notes	Module 7 - Decision feedback equalization (DFE)
			  7.1 Decision feedback equalization
			   1) Postcursor-induced ISI
			   2) Principle of DFE
			   3) Configuration of DFE
			   4) Characteristics of DFE
			   5) Challenges of DFE
			   6) DFE blocks
			
			  7.2 Adaptive decision feedback equalization
			  1) Classification of DFE
			  2) Data-state (DS) DFE
			  3) Data-transit (DT) DFE
			  4) Weighted DS-DFE and DT-DFE
			  5) Adaptive DFE
			  6) Least-mean-square (LMS) adaptive DFE algorithm
			  7) Sign-sign (S^2) LMS adaptive DFE algorithm
			  8) SS-LMS implementation
			  9) Error detection unit for adaptive DS-DFE
			  10) Reference voltages
			  11) Error detection unit for adaptive DT-DFE
			  12) Charge pumps and loop filters

12-13	6	Distributed lecture notes	Module 8 - Clock and data recovery
			  1) Clock recovery
			  2) Frequency drift of receiver PLL
			  3) Direct coupling and AC coupling
			  4) Data encoding
			  5) Classification of clock recovery
			  6) Clock recovery using phase tracking

		7) Clock recovery using phase picking 8) Clock recovery using phase interpolation

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

Week	L/T/A	Description
1/2	Lab 1	Wire channels. Report due : Sunday mid-night of Week 2 if your lab is in Week 1 and Sunday mid-night of Week 3 if your lab is in Week 2.
3/4	Lab 2	Pre-emphasis. Report due : Sunday mid-night of week 4 if your lab is in Week 3 and Sunday mid-night of Week 5 if your lab is in Week 4.
5/6	Labs 3/4	Continuous-time linear equalizer/Phase-locked loop. CTLE report due : Sunday mid-night of week 6 if your lab is in Week 5 and Sunday mid-night of Week 7 if your lab is in Week 6.
7/8	Lab 4	Phase-locked loop. PLL report due : Sunday mid-night of week 8 if your lab is in Weeks 5/7 and Sunday mid-night of Week 9 if your lab is in Weeks 6/8.
9/10	Lab 5	Decision feedback equalizer. Report due : Sunday mid-night of week 10 if your lab is in Week 9 and Sunday mid-night of Week 11 if your lab is in week 10.
11/12	Lab 6	Clock and data recovery. Report due : Sunday mid-night of week 12 if your lab is in Week 11 and Sunday mid-night of Week 13 if your lab is in Week 12.

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.***" <u>**NOTE: You are required to submit all of your pertinent documentation through the University's online Academic Consideration Request system at the following link:**</u> prod.apps.ccs.torontomu.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.torontomu.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)](link) 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)(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](link) or contact aasadmin@torontomu.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](link) provides research [workshops](link) 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](link) 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](link).

3. You can submit an [Academic Consideration Request](link) when an extenuating circumstance has occurred that has significantly impacted your ability to fulfill an academic requirement. You may always visit the [Senate website](link) 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.torontomu.ca/senate)](www.torontomu.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@torontomu.ca
   - Consent Comes First - Office of Sexual Violence Support and Education: 416-919-5000 ext: 553596 or email osvse@torontomu.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](#).