Wireline Communications is an indispensable part of the today computing industry, including a very wide range of applications, including Machine Learning, Artificial Intelligence, Signal Processing, Autonomous Vehicles, 3D high-performance computing systems. As a conclusion, there is a growing demand for engaging skillful designers with good background in this field.

To address these issues, this course plans to address some of the most fundamental concepts related to High-Speed Communication CAS. The course will cover some basic concepts, such as channel modeling, s-parameters, amplifier topologies, very wide-band circuits, and line drivers, as well as more advanced topics such as equalizers, jitter, noise, and analog-to-digital converters. Moreover, the course will present an advanced design algorithm, to be used for implementing very high frequency and low-power circuits. We will extensively use modern circuit simulation tools, such as Cadence, supported by dedicated and carefully designed homework and project activities. In summary, the main objectives of this course are:

- Provide a thorough introduction and overview on real applications of high-speed communication circuits,
- Overview the fundamental concepts, such as wide-band amplifiers, equalizers, slicers, and develop more complex architectures based on that,
- Introduce some advanced topics such as clock and data recovery, phase-locked loops, and clock generators,
- Study some advanced design algorithms to achieve high-performance and low dissipation, simultaneously,
- Introduce and use advanced design and simulation tools (Cadence Virtuoso). There will be exercises on layout, using an advanced technology node (FinFET 16 nm).

Course Format: This course will be offered in both *in-person* and *on-line* formats. There will be dedicated office hours for both class formats (two hours per week). All the course material, including the lecture recordings, will be published on Canvas.

Contact: Armin Tajalli: armin.tajalli@utah.edu. See also: https://lcas.ece.utah.edu
Course Description

High-Speed Communication Circuits and Systems (ECE 5960/6960)

University of Utah
Department of Electrical and Computer Engineering
Professor Armin Tajalli

November 14, 2020 (v1)

Course Description and Objectives
This course is an introduction to design of very high-speed communication circuits targeting applications such as memory links, processor-to-processor data movement, and data centers. The aim is to prepare students to actively and efficiently participate in design of such circuits in their future industrial or academic career. More specifically, the class focuses on the following topics:

- Review design and analysis of elementary building blocks such as equalizers, synchronizers, amplifiers, and matching networks,
- Review different receiver and transmitter architectures,
- Noise and jitter analysis techniques,
- Perform simulations, design, optimization, using Cadence, Matlab, and Spreadsheets.
- We will use a standard FinFET 16nm technology for homework as well as project in this course. Project will include both circuit design and layout practices.

Prerequisites

- ECE3110, ECE5720/6720 or equivalent experience (with instructor’s consent).
- Students should have had previous exposure to signals and linear systems theory, semiconductor device physics (ECE 3200 is recommended), MOS transistors, and basic MOS circuits (e.g. current mirrors, simple amplifier stages, and noise).
- Students should already have basic experience with circuit simulators (PSPICE, HSPICE, LTSPICE, or other SPICE variants), and basic Linux commands and programming ideas (variables, loops, conditional statements). Previous experience with MATLAB is helpful, but is not absolutely required.

Textbook
Some (but not all) parts of this course can be found in the following textbook. Depending on topic, other references will be introduced to students.

**Syllabus**

<table>
<thead>
<tr>
<th>No</th>
<th>Date</th>
<th>Topic</th>
<th>Assignment</th>
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<tbody>
<tr>
<td>1</td>
<td>J20</td>
<td>Introduction to Wireline communication</td>
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<td>2</td>
<td>J25</td>
<td>Communication Channel Characteristics</td>
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<td>3</td>
<td>J27</td>
<td>Communication Channel Modeling</td>
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<td>4</td>
<td>F01</td>
<td>Signaling Scheme</td>
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<tr>
<td>5</td>
<td>F03</td>
<td>Signaling Scheme</td>
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<td>F08</td>
<td>Termination and Matching Network</td>
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<td>F10</td>
<td>Equalization: Receiver Linear Equalizer</td>
<td>HW3</td>
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<td>F15</td>
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<td>16</td>
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<td>M17</td>
<td>Transmitter: Architecture</td>
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<td>Transmitter: Output Driver</td>
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<td>M24</td>
<td>Transmitter: Serializer</td>
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<td>M29</td>
<td>Clock: Architecture</td>
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<td>21</td>
<td>M31</td>
<td>Clock: Tx Clocking</td>
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<td>A07</td>
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<td>HW11</td>
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<td>A12</td>
<td>Clock: Rx Clocking and CDR</td>
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<td>A14</td>
<td>Link Budget: Sources of Noise and Jitter</td>
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<td>26</td>
<td>A19</td>
<td>Link Budget: Sources of Noise and Jitter</td>
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<td>27</td>
<td>A21</td>
<td>State-of-the-Art</td>
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<tr>
<td>28</td>
<td>A21</td>
<td>Final Exam</td>
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</tbody>
</table>

**Note 1.** HWs will be due on every Sunday at 8:00pm.
Grading

- Quiz (in class): 10%
- Homework: 20%
- Mid-term exams: 20% (one mid-term)
- Design projects: 30% (one project)
- Final exam: 20%

Also:

- Letter grade thresholds will be A (>95), A- (>90), B (>85), B- (>80), C+ (>75), C- (>65), and D (otherwise).
- Exercises and the project reports have to be delivered on time. Delivery not later than 24 hours incurs -50%. Delivery after 24 hours will be -75% (you’ll receive up to 25% if you eventually deliver the solutions).
- Class attendance is necessary. One or two absences might be tolerated. More than three absences will affect the grad (-2% per session).

Course Instructor, Lecture Notes, and Course Website

- Prof. Armin Tajalli
- E-mail: armin.tajalli@utah.edu
- Phone: (801) 581 4840
- Office: MEB 2224
- Office hours: Mon 11:00 – 12:00 / Thu 11:00 – 12:00 (also possible with appointment). Both in-person and online office hours will be offered. There will be Zoom sessions dedicated to each office hour.
- Course Website: on Canvas
- Handouts: can be found on Canvas
- Discussion: Please use the Canvas site Discussions page for questions about the material, so that answers and explanations will benefit the whole class.

Course Hours and Room

- Course hours: Monday/Wednesday, 12:25 to 11:45 (class recording will be uploaded the same day).
- Room: None (IVC/on-line)
- First class session: Monday, January 19, 2021
- Last class session: Monday, April 27, 2021
- Mid-terms: March 1, 2021.
- Final exam: April 21, 2021.
- No classes will be held on: February 15 and April 5.
TAs

- TAs: TBD
- TA Hours: TBD

Exam Policy

- No electronic device with possibility of networking is allowed.
- A simple old-school calculator can be used during the exam sessions.

Differences between 5960 and 6960:

The 5960 section is meant for undergraduates, while the 6960 section is meant for graduate students. Talk to Prof. Tajalli if you are not sure of which section to enroll in. Homework sets will have some problems assigned for both sections, and some problems that are only required for 6960 students. 5960 and 6960 students take different exams. 6960 students are assigned more work on the final design project. Overall course grades as well as grades for course components shown above are curved across two separate pools of students, one for 5960 and one for 6960.

Other Important Items

- **College of Engineering Guidelines:** Refer to these for course add/drop information on: [https://www.coe.utah.edu/students/current/semester-guidelines/](https://www.coe.utah.edu/students/current/semester-guidelines/)

- **Wellness Statement:** Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student’s ability to succeed and thrive at the University of Utah. For helpful resources contact the Center for Student Wellness: [http://wellness.utah.edu/](http://wellness.utah.edu/) Ph. 801-581-7776.

- **Safety:** Please also check: [https://attheu.utah.edu/home-page/adding-safety-to-the-syllabus/](https://attheu.utah.edu/home-page/adding-safety-to-the-syllabus/)
Academic Misconduct

Academic misconduct, which includes but is not limited to “cheating,” is a serious issue at the University of Utah. Sanctions can include a grade reduction for an assignment/exam, a failing grade for the course, and even dismissal from the ECE program and the University as a whole.

Homework Policy (specific to this course): Students are encouraged to discuss homework problems with each other, but each student must write up and understand their own solutions. Exchanging and/or directly reusing solutions in any form (hardcopy, electronic, etc.) is strictly prohibited. If you think what you’re doing might be against the rules: 1) don’t do it, 2) ask the instructor. Detailed homework solutions will be provided to students after due dates as a service to help learning. The assignments and solutions are for current ECE 6960 students only and are not to be shared with anyone else. Providing friends with solutions is not good for them and it is not good for you — don’t do it!

Exam Policy (specific to this course): As discussed above, students need to bring an “old-school” calculator to the exam (e.g. TI-89). No laptops, smart phones, or similar devices (nothing capable of network access). The exam will be closed-book, but students will be allowed one single side of a 8.5 × 11 inch piece of paper for notes for the midterm — no magnifying glasses or microscopes allowed in exams. The exam and solutions are for current ECE 6960 students only and are not to be shared with anyone else. Providing friends with solutions is not good for them and it is not good for you — don’t do it!

Common Sense (all courses): If you think that what you’re doing might be against the rules: 1) don’t do it, 2) ask the instructor. Students sometimes feel pressured to cut corners when time is tight, but the penalties of academic sanctions for misconduct hugely outweigh any saved time. Talk to the instructor if you get into disruptive situations that are affecting your ability to complete the course, many University resources are available to help!

Student Rights and Responsibilities (all courses): Students are expected to adhere to the policies outlines in Policy 6–400: Code of Student Rights and Responsibilities (“Student Code”). The full Student Code can be accessed at: http://regulations.utah.edu/academics/6-400.php

A few highlights are detailed below:

◊ Academic misconduct includes, but is not limited to, cheating, misrepresenting one’s work, inappropriately collaborating, plagiarism, and fabrication or falsification of information. (Part I.B.2)

◊ A student who engages in academic misconduct as defined in Part I.B. may be subject to academic sanctions including but not limited to a grade reduction, failing grade, probation, suspension or dismissal from the program or the University, or revocation of the student’s degree or certificate. (Part V.B)

◊ Upon discovery of academic misconduct: “... sanctions may include requiring the student to rewrite a paper(s) or retake an exam(s), a grade reduction, a failing grade for the exercise, or a failing grade for the course.” (Part V.B.3)

Here is a link to additional ECE Department Academic Misconduct Policy: https://www.ece.utah.edu/files/2019/01/ECE-Academic-Misconduct-Policy.pdf
Frequently Asked Questions

Can I use other circuit simulators/tools/etc.?
You may use other SPICE-based tools and variants at your own risk. You must use the provided 180nm ECE6720 transistor models.

I cannot attend your scheduled office hours. Are you available at other times?
Feel free to email the instructor to set up a meeting on an as-needed basis.

I think there was a mistake in grading my homework/exam/project/etc., can you re-grade it?
Requests for the reconsideration of a grade on an assignment, exam or project must be made in writing within one week of the day that the item was returned to the majority of the class. Re-grade requests will not be considered after the one-week policy. If a student is not present to receive their returned work, it does not exempt them from the one-week policy. It is the responsibility of the student to obtain returned work outside of class if they were not in attendance during the class period where a graded assignment or exam was initially returned. The entire assignment will be re-graded in full, and may receive a lower grade than the original score.

I need to take the midterm/final exam at other than the scheduled time. May I?
Such arrangements are made on a case-by-case basis, and instructors cannot guarantee flexibility in this matter. The most common acceptable reason is a demonstrable scheduling conflict with another course. As an example, “Being able to catch a cheaper flight” is not a suitable reason. Please alert the instructor as soon as possible. Scheduling for final exams is already set, please plan accordingly:

- [https://registrar.utah.edu/academic-calendars/final-exams-spring.php](https://registrar.utah.edu/academic-calendars/final-exams-spring.php)

I must get a grade of B or higher to satisfy requirements for my employment, or scholarship, etc. Can you guarantee that I will get a B or higher?
No, of course not. Students earn their grades; instructors don’t arbitrarily assign them. To maximize the likelihood of fulfilling your needs, stay current on the homework. Many students who also have jobs find themselves in trouble in terms of time. The best advice is to expect the unexpected. Be sure to budget enough time for this course and all your other courses.

How much time does this course take? The time commitment for upper level courses such as this one depends on your background, e.g. when is the last time you took an electronic circuits course? Undergraduate full time enrollment is 12+ credit hours per semester. If you are enrolled as a full time student, then you should plan on 40+ hours of time per week dedicated to your studies overall.

Here are links to College of Engineering policies for adding, dropping, withdrawing, etc.:

- [https://www.coe.utah.edu/semester-guidelines](https://www.coe.utah.edu/semester-guidelines)
- [https://www.coe.utah.edu/students/academic-affairs/](https://www.coe.utah.edu/students/academic-affairs/)

Student Resources
The University of Utah has a wide array of resources that you are entitled to take advantage of. Reach out if you are struggling with any aspect of University life.

- ECE Department advising and student organizations:
  - [https://www.ece.utah.edu/](https://www.ece.utah.edu/)
  - [https://www.ece.utah.edu/advising](https://www.ece.utah.edu/advising)
  - [https://www.ece.utah.edu/student_orgs](https://www.ece.utah.edu/student_orgs)
Many support services and campus organizations:
https://studentsuccess.utah.edu/resources/student-support/

Center for Student Wellness: https://wellness.utah.edu/

Other resources for all university students:
https://advising.utah.edu/student-resources.php
https://www.utah.edu/students/services.php
https://ugs.utah.edu/student-resources/
https://gradschool.utah.edu/current-students/
https://gradschool.utah.edu/graduate-student-support-services/

Inclusion and Diversity
The ECE Department and the overall University of Utah are committed to diversity and inclusivity, and are guided by the following principles:

We believe that inclusion and diversity are fundamental to the success of the university and its students, staff, faculty, and administrators. A collective commitment to diversity and inclusion enriches learning and prepares students to become actively engaged in our local and global societies as responsible citizens.

We strive to nurture a culture of inclusion that respects the humanity of all people. We do not support acts of intolerance against another’s race, ethnicity, age, sexual orientation, gender, gender identity and expression, ability, socioeconomic status, veteran status, size, national origin, language, religion or any other real or perceived differences based on an individual’s identity.

We aim to promote a climate of respect and shared responsibility that cultivates and sustains transformative practices by forging spaces of possibility where people feel safe, valued, welcomed, and respected. These ideals are intrinsic to collaborative partnerships and our university’s mission “to serve the people of Utah and the world.”

See the Office for Inclusive Excellence for more information: https://inclusive-excellence.utah.edu/

Campus Safety:
The University of Utah values the safety of all campus community members. To report suspicious activity or to request a courtesy escort, call campus police at 801-581-COPS (801-585-2677). You will receive important emergency alerts and safety messages regarding campus safety via text message. For more information regarding safety and to view available training resources, including helpful videos, visit: https://safeu.utah.edu