Master Course Description for EE4xx/EE5xx (ABET sheet)

Title: Electronic-Photonic Integrated Systems

Credits: 4

UW Course Catalog Description

Merges electronic and photonic technologies effectively to design large-scale integrated systems. Students will understand critical aspects from fabrication and integration platforms to system and circuit-level design and architecture.

Coordinator: Sajjad Moazeni, Assistant Professor, Electrical and Computer Engineering

Goals: This course provides seniors, and graduate students who have an interest in electronics and photonics with the integration of electronic and photonic technologies to engineer advanced integrated systems with applications in communications, computation, and sensing/imaging. Topics include mixed-signal electronic design, photonics basics and building blocks, integration methodologies, CAD tools, and applications such as optical interconnects, LiDAR systems, imaging/bioelectronic-photonic integrated, and quantum photonics. All students also learn how to simulate and model devices, systems, and circuits related to these topics.

Learning Objectives: At the end of this course, students will be able to:

1. Understand the principles and fundamentals of mixed-signal electronic design and state-of-the-art CMOS technologies.
2. Comprehend the basics and building blocks of photonics, including passive and active components.
3. Apply integration methodologies to merge electronic and photonic systems effectively.
4. Utilize EDA/CAD tools for design, simulation, and co-simulation of electronic-photonic integrated systems.
5. Analyze and design applications such as optical interconnects, LiDAR systems, imaging/bioelectronic-photonic integrated, and quantum photonics using electronic-photonic integration.
6. Formulate project goals, conduct research, and develop methodologies or CAD tools at the system-level for specific applications.

7. Present project proposals, progress, and final results effectively, both orally and in written IEEE format publications.
8. Collaborate effectively in teams, leveraging complementary backgrounds and expertise to address complex design challenges in electronic-photonic integration.

These learning objectives are aligned with the course's goal of providing students with the knowledge and skills necessary to design practical large-scale integrated systems with unprecedented capabilities in communications, computation, and sensing/imaging.

Textbook: *Class notes, textbook excerpts, and journal articles.*

Prerequisites:

1. Devices and Circuits I(E E 331), or Introduction to Photonics (E E 487) or Instructor Permission

Prerequisites by Topic:

1. Understanding of fundamental concepts in circuits and devices, including circuit analysis and electronic components.
2. Proficiency in mixed-signal electronic design and state-of-the-art CMOS technologies.
3. Familiarity with the basics of photonics, including passive and active components, and their behavior in integrated systems.
4. Knowledge of integration methodologies for merging electronic and photonic systems effectively.
5. Experience with EDA/CAD tools for design, simulation, and co-simulation of electronic-photonic integrated systems.

Topics:

1. Course Logistics & Introduction + Basics of Mixed-signal Electronic Design & State-of-the-art CMOS (0.5 week)

2. Photonics Basics and Building Blocks (Passives) (1week)

3. Photonic Building Blocks (Actives) (1 week)

4. Integration of Electronics & Photonics & Silicon Photonics Processes (0.5 week)

5. EDA/CAD Tools for design and co-simulation & Lasers (0.5 week)

6. Application 1: Optical Interconnects (2 weeks)

7. Application 2: LiDAR Systems (2.5 weeks)

8. Application 3: Imaging/Bioelectronic-photonic integrated & Visible/NIR Photonics (0.5 week)

9. Application 4: Quantum Photonics & Course Summary & Future Directions (0.5 week)

One week is left as a buffer for potential extension of any of the topics, project discussions, and presentations.

The topics covered in this course provide a comprehensive understanding of electronic-photonic integrated systems, from fundamental principles to practical applications across various domains.

Course Structure: The class meets for either two 110-minute or four 50-minute lectures per week. The sessions consist of short lectures on related topics. Grading for the course includes formative assessment (homework and class participation) and summative assessment (project presentations, and a final report).

Computer and Laboratory Resources: Design projects and homework will require standard software packages (Matlab), programming languages (Python) and simulation tools such as Cadence, Lumerical, and Comsol. Students will typically use MS Word/PowerPoint and Latex for project presentation and final report.

Grading:

Undergraduate Students: Class participation make up 15% of the grade (5% of which will be attending lectures and 10% will require active engagement in class discussions); homework assignments make up 45% of the grade; Project proposal presentation make up 20% of the grade; and final presentation make up 20% of the grade. The focus of undergraduate student presentations will be on the quality of presentation, logical reasoning, and problem solving rather than technical rigor or novelty of the project details.

Graduate Students: Class participation make up 15% of the grade (5% of which will be attending lectures and 10% will require active engagement in class discussions); homework assignments make up 35% of the grade; Project proposal presentation make up 20% of the grade; and final presentation along with report make up 30% of the grade. The design project will be constrained to the theme/application focus of the course but will otherwise allow for students to make open-ended design choices. For graduates, in addition to required presentation quality the technical details of the proposed project will be assessed. Graduates also required to write a professional report/paper with proper formatting and references in this course.

ABET Student Outcome Coverage: This course addresses the following outcomes:

H = high relevance, M = medium relevance, L = low relevance to course.

(1) *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics* (**H**) The analysis and design of electronic-photonic integrated systems requires basic (science) understanding of the governing mechanisms of both electronic-photonic integrated and transduction techniques. The interaction between electronics and photonics must also be understood mathematically (including parasitics, noise analysis). The electronic-photonic integrated system design problem presents itself as a series of interconnected engineering problems. Students are expected to use mainstream math processing, data acquisition, and data presentation software to design, analyze, characterize, and summarize electronic-photonic integrated and electronic-photonic integrated system performance. Students must also use general purpose test equipment and electronic interface circuits to extract system performance from their designs. Evidence of this outcome will emerge from open-ended homework and exam problems.

(3) *An ability to communicate effectively with a range of audiences* (**M**) Students will complete homework in teams. Teams must prepare assignments using high level technical writing skills that produces explanations and solutions that can be readily understood by technical layman.

(5) *An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives* (**M**) Students work in teams of 2-3 individuals to complete homework assignments and (where relevant) design projects. Students offer heterogeneous expertise to the team and are expected to articulate their contributions and value to the team.

(6) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions* (**M**). The last two weeks of the course focus on analyzing experimental data from electronic-photonic integrated and summarizing relevant performance metrics of electronic-photonic integrated systems to establish the goodness of those electronic-photonic integrated relative to commercial technologies (used as benchmarks).

Prepared By: Sajjad Moazeni

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