Basic Biological Circuit Engineering, ENGS162 (Winter Term)

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Office Hours: 12.45 to 1.45 p.m. Monday.
Lecture Timings: Mondays, Wednesdays, and Fridays, 11.30 a.m. to 12.35 p.m.
Laboratory Timings: One 3 hr. slot every week with students typically choosing either a Tuesday or Wednesday slot, depending on their schedule, often from 1 p.m. to 4 p.m. 7 labs with a Tutorial, and two 3-lab-sequence modules.
X-hours: Occasional use when instructor is out of town.

Course Catalogue Description

This course will provide a comprehensive introduction to the design, modeling, and experimental implementation of synthetic bio-molecular circuits in living cells. Simple but sophisticated synthetic biological circuits will be implemented and tested in microbial cells in the laboratory including those involving molecular amplification, regulatory feedback loops with biological nonlinearities, and robust analog circuits. Computer aided design, modeling, and simulation will use CADENCE, an industry standard electronic circuit design tool showing how to design, model, and fit actual experimental biological data such that engineering circuit theory and biological experiment agree.

Course Rationale

This course will teach students a uniquely interdisciplinary and unifying approach to both electronic and biological circuit design, currently missing in both the teaching and research communities.

1. This course will provide an introduction to synthetic biology, an important new field that is missing in the Dartmouth curriculum.
2. Students taking this course will learn valuable circuit and feedback-loop design and modeling skills, useful in all research, as well as how to instantiate such circuits in living organisms, useful in many applications in biotechnology and medicine.
3. It is amongst the first or very few interdisciplinary courses at Dartmouth that has been successfully taken by students across three of its schools of Arts and Sciences, Medicine, and Engineering with only basic prerequisites and background common to students from all these schools (A high 1.3 evaluation by undergraduates and 2.3 by graduate students in the very first offering with 15 students).

Learning Outcomes: 1. Understand the fundamental principles of biological circuit engineering and synthetic biology including feedforward, feedback, analog, and digital circuit design; 2. Hands-on exposure and ability to use and understand quantitative modeling approaches and software tools relevant to biological circuit engineering; 3. Introduction to fundamental and modern techniques of molecular biology, necessary for practical instantiation of biological circuits in living cells.

Pre-Requisites: MATH 3 or MATH8 or equivalent experience in Basic Calculus, CHEM5, BIOL13. Experience in Molecular Biology is useful (e.g. ENGS 35, BIOL 45, & BIOL 46 or equivalent) but not necessary. Experience in Signals and System Modeling is also useful (e.g. ENGS 22) but not necessary.

Teaching Methods or Teaching Philosophy:

During a typical class period, I will lecture for 45 min. with the remaining time devoted to questions, either at the end if there is time, or as the lecture proceeds. Such questions often serve to help engineers understand the biology better and biologists to understand the engineering background better. I encourage questions right as I am lecturing with interruption since it is useful for all students.

The emphasis is not on prerequisites but on the ability of advanced undergraduates (juniors/seniors) and graduate students to learn, which has now been successfully proven, based on prior student ratings and feedback. I will often use pictorial and intuitive techniques, which are then later followed by more rigorous mathematical analysis. The biologists and engineers are often paired up together in lab as partners such that they help the other in disciplines that they are less familiar with.

One teaching assistant typically aids with a dry circuit design lab, i.e., with CADENCE biological circuit modeling and design & one aids with wet molecular-biology experiments in biological cells. A senior Thayer wet-lab instructor and lab manager is always present during the experiments in lab. The lecture schedule is coordinated to be synchronized well with the labs.

Grading
33% Module I (Molecular Amplifier) Report; 17% Module I Associated Problem Set; 33% Module II (Log-Linear Positive-Feedback Circuit Presentation); 17% Module II Associated Problem Set.

Grades will be based on the content, clarity, quality of experimental data and experiments, fit of theory to experimental data, originality and creativity in identifying and solving problems when experimental data is not in accord with theory, quality of the circuit simulation, model and design, and the thoroughness of the lab report or presentation. The problem sets will be graded based on the correctness of the answer and on the approach to the correct answer. Late work and incompletes require prior permission of the instructor and, in fairness to other students, will likely lead to a reduced grade depending on circumstances.

Expectations
Students are expected to attend every lecture and lab and inform the instructor in advance if they cannot. If a lab is missed, then the student will coordinate with the instructor to makeup. The use of laptops and phones is discouraged during class since it is distracting to all. You can take notes on the lecture printouts, with space on the handouts for you to do so. Participation is actively encouraged since it is good for learning and enlivens the class.

Texts and Resources
Approximately 10 journal papers, printouts of every lecture, a laboratory manual including a list of videos and links for tutorials, and 5 book chapters, some from the instructor's own book, will be handed out. These resources are comprehensive such that other material is not necessary. Some of these materials will be posted on Canvas including the 13 techniques necessary for giving a good scientific talk.

Academic Honor
The Academic Honor principle is explained in http://www.dartmouth.edu/judicialaffairs/honor/index.html. Proper citation of sources is explained in http://www.dartmouth.edu/judicialaffairs/honor/index.html.

Paired lab-partner students can collaborate on writing the joint lab report and preparing the joint lab presentation. They can consent amongst themselves on how to divide the labor involved. But, each student must write up his or her problem set individually.

It is acceptable to ask teaching assistants for guidance on the problem sets and labs. It is also acceptable to ask other students in the lab for help during the experiments or on matters having to do with technical issues such as computer or software technicalities.

Mental Health
The academic environment at Dartmouth is challenging, our terms are intensive, and classes are not the only demanding part of your life. There are a number of resources available to you on campus to support your wellness, including your: Undergraduate Dean (http://www.dartmouth.edu/~upperde/);Counseling and Human Development (http://www.dartmouth.edu/~chd/); and the Student Wellness Center (http://www.dartmouth.edu/~healthed/).

Religious Observances
Some students may wish to take part in religious observances that occur during this academic term. If you have a religious observance that conflicts with your participation in the course, please meet with the instructor before the end of the second week of the term to discuss appropriate accommodations.

Student Accessibility Needs
Students with disabilities who may need disability-related academic adjustments and services for this course are encouraged to see the instructor privately as early in the term as possible. Students requiring disability-related academic adjustments and services must consult the Student Accessibility Services office (205 Collis Student Center, 646-9900, Student.Accessibility.Services@Dartmouth.edu).

Once SAS has authorized services, students must show the originally signed SAS Services and Consent Form and/or a letter on SAS letterhead to the instructor. As a first step, if you have questions about whether you qualify to receive academic adjustments and services, you should contact the SAS office. All inquiries and

discussions will remain confidential.

Additional Support for your Learning

Academic Skills Center (http://www.dartmouth.edu/~acskills/)
The Academic Skills Center is open to the entire Dartmouth Community. Here are some common reasons why you might visit the ASC:

- You're getting B's but you want to get A's
- You don't feel comfortable talking in class
- You're attending class regularly but you feel like you're missing important points
- You feel like you're a slow reader
- You're having trouble completing tests in the allotted time
- You feel like you don't have enough time to get everything done
- You're not sure how to take notes
- You want to sign up for a tutor or study group
- You're not sure if you should get tested for a learning disability

The Research Center for Writing, and Information Technology (RWiT http://writing-speech.dartmouth.edu/learning/support-writing-research-and-composing-technology/rwit)

Located in **Berry 183,** RWIT is a free service dedicated to helping members of the Dartmouth community develop more effective strategies for generating and organizing their ideas, finding and evaluating research sources, and presenting and revising compositions in a variety of media. Through informal dialogue, RWIT tutors assist writers in developing better compositions and more effective composing strategies. A collaboration between the Institute for Writing and Rhetoric, the Library, and Academic Computing, RWIT brings together faculty, administrators, staff, and students to focus on the art and science of composition.

Dartmouth College Library (http://library.dartmouth.edu/)
Dartmouth College Library A key to successful research is the use of reliable, high-quality information sources. While some information can be found on the open web, the best place to start your research is at the Library's Research Guides, researchguides.dartmouth.edu/guides. These research guides have categorized and organized the library's key resources - including books, databases, scholarly articles, and data sources - for your convenience. The Library's website also has information on useful research tools and services. In addition to the online information, a librarian has been assigned to this class to answer research questions, help you find appropriate resources, and assist with search techniques. Please contact your subject librarian (http://researchguides.dartmouth.edu/subjectlibrarians) for specialized help.