EECE 2150 - Circuits and Signals: Biomedical Applications
Fall 2018 - Section 3
Course Information and Syllabus

Joint Lectures and Labs

- Location: 9 Hayden Hall (Basement)
- Time:
  - Mondays 3:20PM - 5:40PM
  - Wednesdays 3:20PM - 5:40PM
  - Thursdays 3:20PM - 4:25PM

Instructor

- Charles A. DiMarzio, Associate Professor, Electrical and Computer Engineering, MIE, BioE
- Email: dimarzio@ece.neu.edu

- Office Hours: Mondays 10:00 to 12:00 in 302 Stearns or by appointment

I'm a moving target so the probability of finding me sitting in my office and not being busy is vanishingly small. However, if you send an email I can almost always arrange a time to meet within 24 hours. Please include "EECE2150" in the subject line of your email, so that it will get my prompt attention.

Teaching Assistants

There will be one graduate student TA and one undergraduate Hourly Course Assistant (HCA) to help with this course.

Note also that there are 5 sections of this course, taught by 4 instructors, each with its own pair of TA/HCA (some of whom are working with 2 sections). We will make some

aspects of the course shared across sections – in particular we plan to have office hours / lab makeup times every day **in the lab from 6PM-8PM**, staffed by the TAs and HCAs, and open for all students in any section. Also keep in mind that Mathworks supports a University-wide MATLAB TA and that the HKN honor society will be organizing tutor time to help students in this course.

Required Texts

- Nilsson/Riedel, Electric Circuits with Pearson Mastering Engineering (see below)
- Schaum's Outlines of Signals and Systems, 3rd Edition, Hwei P. Hsu, McGraw-Hill, ISBN 9780071829465

Course Website

I will post information on the course website, http://www.ece.neu.edu/courses/eece2150/2018fa/. I will update the site with files used in class, announcements, and helpful hints as appropriate. I will use Blackboard for grading, posting information that is not owned by me, and probably not for much else.

Mastering Engineering

It is an on-line system for homework, study, quizzes and (optionally) text access. We will discuss options to get access to Mastering Engineering in class. We will officially be using the 10th edition of the text. However, previous editions of either text are fine for the course and are available inexpensively if you want a paper copy, and you might find other options! Note that you may be able to find cheaper codes for the Mastering Engineering on-line access from third-party vendors such as Amazon. **However if you purchase from anyone other than the bookstore or the publisher Pearson, our representatives at Pearson have warned us that they will not be able to support you if you have trouble getting access, and that they have had this happen in the past. Note also that you must register individually for Mastering Engineering as soon as possible.** An information sheet on how to do this is provided by the publisher. Note that no text is required for biomedical components of the course; all required information will be provided in class notes.

Other Required Purchase

You are required to purchase a blank quad-ruled (graph paper) notebook, which we will refer to as your **Course Notebook** and will be used for all aspects of the class. Normal

8.5x11 size is fine. Please buy this notebook now, before the second class of the semester, and please use it for this class only! If this requirement does not fit your normal way of using notebooks you are free to discuss this with me but you can expect me to push you pretty hard to do as required.

Recommended Reference Texts

Note that there are many texts on each of these topics, and these are just two representative texts that have been or are being used in courses in our department.

- Circuits, 2nd Edition Fawwaz T. Ulaby & Michel M. Maharbiz, NTSPress. ISBN 978-1- 934891-19-3.
- Signals and Systems 2nd Edition, Alan Oppenheim and Alan Willsky with S. Hamid Nawab, Prentice Hall, ISBN 013098566X.

- The Art of Electronics Paul Horowitz and Winfield Hill, Cambridge Press
- Medical Instrumentation: Application and Design, John G. Webster, Wiley
- PSPICE for Basic Circuit Analysis, Joseph Trout 4. MATLAB – An Introduction with Applications, Amos Gilat

What This Course Is About

On one level, our goal in this course is to measure electrical signals from the surface of the body that have their origin in the functional activity of the heart, transfer those signals to a computer, and process those signals to extract information about the function of the heart. On another level, our goal is to establish a strong background in two of the most fundamental subjects in electrical and computer engineering: 1) circuits and 2) signals and systems. On a third level, the goal is to introduce you to the expectations and atmosphere in ECE courses. Throughout the semester we will go back and forth among theory, physical experiment, and computational experiment. (This is the way most research and development is carried out in science and engineering, although often of course on a much larger scale.) We will discuss the physiological origin and informational content of the signals (why we are interested in them), ways in which we can design, analyze, and build circuits to measure those signals and get them onto a computer, and ways in which we can design, analyze, and build computer programs to process those signals computationally and extract information of interest. The course will include elements of circuit theory and

electronics, signal and system theory, circuit design, circuit building and troubleshooting, signal analysis through computation, and program design and troubleshooting.

Basic Organization

This course will have classroom, laboratory, computational, and problem solving components, which will be interspersed in a flexible way as we work through the material. You will be expected to record your activity in the Course Notebook mentioned earlier, as described in more detail below, and this Notebook will become one component of your grade.

Mutual Expectations

The instructor's basic expectation is that students are willing to take responsibility for their own learning and to put in the effort required to achieve that goal. Our experience is that this course may require you to take a significantly higher degree of such responsibility than many of you are used to from previous courses. You may find some of this material difficult to learn, but we firmly believe that all of you are capable of learning the material. What may be harder for many of you is to understand what it means to take this responsibility and actively pursue it. We will attempt to spend as much time as feasible in class actively working on both hands-on and paper exercises. For this to be possible you must do the necessary work outside of class. The Mastering Engineering on-line system offers us a lot of opportunities and options along these lines, but this can only work if you make it work. Thus you have a responsibility not only to yourself and me but also to your colleagues to take the preparation seriously.

How To Do Well In This Course

In particular, meeting our expectations of you requires that you be active participants in the learning process. You will be expected to:

- Prepare for class, by some combination of reading the text, watching videos on-line, doing the on-line preparatory work in Mastering Engineering, and diligently preparing for labs.
- Do the homework on time. Start in plenty of time to resolve problems, conceptual or practical (such as dealing with the Mastering Engineering interface). Use your resources as necessary - friends, professor and all office hours.
- Attend class regularly, including being on time and prepared with questions and comments on assigned reading and material presented in class, If you don't do well

on a quiz, that means you should get help on that material and keep practicing it within no more than one week if at all possible until you are confident in your ability to do a similar quiz well.

- Do the homework on time. The quizzes are based on the homework so do all the homework yourself - not without help, but make sure you do the problems yourself.
- Engage actively in in-class activities including labs and exercises, and discuss your progress and your frustrations with the professor and the TA / HCAs
- **Ask questions in class if you do not understand. Feel free to slow me down.**

To do well in this course it is essential to keep up to date.One specific expectation is that students will keep up with email sent out to the class or individual students by the instructor or the TAs. We will use email to communicate with each idividual, and the course website to communicate with the whole class. It is your responsibility to monitor the website. Finally students are expected to behave appropriately in class. This includes getting to class on time, not using your phone or the computer during class for non-class activities, not engaging in excessive side conversation, and not leaving class in the middle of a discussion or activity. During lab periods you are free to leave and return if you need to, but during other types of class activity you are expected to wait until we have a formal break period (which we will generally have in the long classes if we are not doing a lab). Also, you need to respect that, because of the lab equipment in the classroom, **NO EATING OR DRINKING IS ALLOWED IN THE ROOMS!**

In return for fulfilling this expectation, students in turn can expect that they will gain useful knowledge and skills and be able to earn good grades. Grades in this course will be based on a combination of achievement and effort and students should expect that the instructor will give them fair opportunities to demonstrate their success in both areas. Finally, you should expect that the instructor will take your educational needs seriously and respond appropriately when you articulate those needs.

Course Work

- **Homework**: Homework will be assigned approximately weekly. Much of it will be within the Mastering Engineering system but there may also be some more traditional paper-based homeworks. Some assignments may include problems designated as math problems rather than ECE problems. The material they cover is essential to the course and including those problems is a technique we have found helps students to engage with the math and succeed in the course. Those problems will be graded separately from the ECE parts of the homework. There may be some assignments or parts of assignments that will be designated as Supplementary or Optional: responses

to this will be used to help determine grades at the upper end of the grade range, as explained below.

- **Quizzes**: There will be approximately 10 weekly quizzes. These are a significant component of the final grade. They are intended to provide students and the instructor with regular feedback on understanding of the course material. There is no mid-term exam, so quizzes should be treated as small tests.

- **Labs**: The laboratories in this course will be closely integrated with the lectures.

  - Lab preparation: Key to success in the labs, and thus in the course, is proper preparation before the labs. The more you think through what a lab requires before you start it, the better you are likely to do and the more you are likely to get out of it.
  - Lab Reports: You will be required to hand in a report for some lab experiments. The report should reflect the goal of each lab, how you planned to do each task with reporting the results and a brief discussion about the results. The report is not supposed to be too long with all the details, but it should include all the important information emphi.e. it should be brief and at the same time thorough report.
  - After-lab exercises: For some labs the material covered is essential for later on in the course. If we have concerns about the degree to which students have learned this material we may give after-lab exercises to assess learning and diagnose topics that need more work.

  "When you have finished the lab work on a Lab or ALE, you should have your Course Notebook signed off by a TA or the instructor who will ask a few questions to help you be sure that you have understood what you have done."

- **Course notebook**: As noted earlier, before the second class you are required to purchase a quad-ruled course notebook specifically for this course. This notebook should be used to keep as complete a record as feasible of your experience during work for the class, outside of what you do on-line in Mastering Engineering and what you hand in on paper, and should include class notes, questions and confusions as well as insights about class material, and a record of your experience during the labs. Having a good record of measurements and observations is really important. The course notebook is not intended to contain a pre-defined set of "right answers"; it is intended to be a useful record of your experience. Note that this kind of record-keeping is important, even critical, in many engineering settings, especially in the medical device industry where it is essential documentation in submissions to regulatory agencies (*e.g.* the FDA in the US). More detail on what to write in the notebook during the

lab will be given in the lab descriptions. Your notebook will supplement your lab reflections as a record of your lab experience. Your notebook will be checked and signed off on frequently by the TAs and instructor and you will be given occasional feedback. Notebooks will be collected at the end of the semester for review as part of the grading process.

Grade Breakdown

- Quizzes: 25%. We will drop the lowest quiz grade.
- Homework: 25%. We will drop the lowest homework grade.
- Labs: 25% (Specifically, participation and attendance: 15%, Lab work as documented in your notebook: 10%. For students who score in the upper range of grades, B+ or better, responses to any Supplemental or Optional HW assignments will contribute to their final grade.
- Final: 25%

Academic Honesty

There is no restriction on discussions, use of texts, or use of library materials while doing any assignment in this course. Indeed students are encouraged to help each other learn! However every student is expected to submit his or her own work, working through the student's own analysis or modeling. It is not permissible to present another student's work as one's own, nor to copy computer code. With computer programming there can at times be a fine line between collaboration and copying/duplication of work. However although this line may be fine, it is generally pretty easy to tell where it is. Ultimately you are responsible for any work you hand in and may be asked to explain it to the instructor, so do not hand in anything you do not understand! In the case of improper collaboration, penalties may be assessed to all students involved. Plagiarism and cheating will be dealt with under the policies described in the student handbook. If you are tempted to cheat, it probably means that you are not ready to carry out the required activity and in that case you should talk to the instructor / TAs about the material, rather than attempting to bluff your way through by cheating. If you have doubts in a specific situation about what level of collaboration is acceptable, ask!

Course Description In Detail

A combined lecture/laboratory course in which students learn elements of circuit theory, signal processing, and MATLAB programming, and apply their knowledge to build an

ECG system that acquires and processes electrical signals generated by the heart. In the circuits area, the course introduces basic device and signal models and basic circuit laws used in the study of linear circuits. The course proceeds to the analysis of resistive and complex impedance networks including the Thevenin and Norton theorems. Op-amp circuits are studied using the ideal operational amplifier model with a particular emphasis on differential amplifiers and active filter circuits. In the signal processing area, the course introduces the basic concepts of linearity and time-invariance for both continuous and discrete-time systems. Concepts associated with Analog/Digital Conversion (ADC), such as sampling and quantization are introduced, discrete-time linear filter design and application is demonstrated on the acquired signals in the MATLAB environment.

Topics Covered

- R, L, C, sources, Kirchoff's Laws
- Basic signals and systems
- Equivalent circuits
- Operational amplifier circuits
- Complex impedance, Phasor notation, Phasor domain analysis
- Euler's Formula and complex notation
- Basic system properties and transfer functions
- Fourier Transform, frequency domain analysis of signals and systems
- Sampling and analog-to-digital conversion
- Designing, building, characterizing and testing an ECG amplifier
- Designing, coding, and testing signal processing algorithms to identify ECG signal features
- Basic bioelectric physiology, with emphasis on cardiac bioelectric activity

Course Outcome

Student should:

- Be able to analyze and build R,L,C circuits
- Be able to find the Thevenin or Norton equivalents of resistive circuits with sources

- Be able to analyze and build op-amp amplifier circuits
- Be able to determine the transfer function of simple passive and active filter circuits
- Be able to analyze the frequency content of signals and explain the importance of matching amplifier frequency response
- Be able to apply knowledge of MATLAB to solving circuit problems and carry out basic signal processing tasks
- Be able to analyze circuits using PSPICE
- Be able to recognize the basic components of an ECG signal and relate them to the cardiac cycle

Tentative Schedule

Week	Dates	Topics
1	9.5	Introduction, Circuit Variables (Nilsson-Riedel, Ch 1)
	9.6	Sources and Resistances (Nilsson-Riedel, Ch 2) / Lab 1
2	9.10	Parallel and Series Circuits (Nilsson-Riedel, Ch 3) / Lab 2
	9.12	KVL, KCL / Lab 3a – Diodes and PSpice
	9.13	Quiz 1 / Lab 3 (Spice, resistance, simple AC circuit)
3	9.17	Node-Voltage Method (Nilsson-Riedel, Ch 4 + Classroom Problems)
	9.19	21Mesh Current Method (Nilsson-Riedel, Ch 4 + Classroom Problems)
	9.20	Quiz 2 / Lab 4 (Frequency Basics)
4	9.24	Source Transformation, Thevenin Equivalent. Class problems.
	9.26	Lab intro, lab 5. (not finished)
	9.27	Quiz 3, Finish lab 5, Introduce Op-Amps, Nilsson, Ch. 5.
5	10.1	Op-Amps Nilsson, Ch. 5, Lab 6: Basic Op-Amps
	10.3	Op-Amp circuits, Sinusoids
	10.4	Quiz 4, Sinusoids and Complex Numbers, Lab 7: Sinuosoids & Sound
6	10.8	Columbus Day – No class
	10.10	Sampling & A/D Conversion
	10.11	Quiz 5, Lab 8, A/D Conversion
7	10.15	Capacitors and Inductors, First-Order Transient Response (Nilsson-Riedel Ch 6, 7) Lab 9, RC Circuits in the Time and Frequency Domains
	10.17	First Order Time Dependent Circuits (Nilsson-Riedel, Ch 7)
	10.18	Quiz 6, Sinusoidal Steady State Analysis (Nilsson-Riedel, Ch 9)
8	10.22	Sinusoidal Steady State Analysis, Phasor Problems, Transfer Function
	10.24	Transfer Function brief comments, Lab 10, PSpice analysis of Op-Amp filters
	10.25	Quiz 7, Lab 11, Op-Amp Filters
9	10.29	Power with Phasors, Finish Lab 11 if necessary
	10.31	Fourier Series (Nilsson-Riedel, Ch. 15)
	11.1	Quiz 8, Lab 12, Frequency Content of Signals
10	11.5	Frequency Components, FFT, and Filtering, Lab 13
	11.7	Lab 13 Continued
	11.8	Quiz 9, Instrumentation Amplifier, ECG Lab 1
11	11.12	Veterans Day Holiday
	11.14	Biopotentials / ECG Lab 1 / 2
	11.14	Biopotentials/Fourier Transform of ECG signal discussion
	11.15	Quiz 10, Transfer function of filters discussion, ECG Lab 2
12	11.19	Transfer function brief discussion, homework discussion, ECG Lab 2 (close to acquiring signal)
	11.21	Thanksgiving
	11.22	Thanksgiving
13	11.26	ECG Lab 2, Some groups start Digital Signal Processing Lab
	11.28	Digital Signal Processing
	11.29	Quiz 12, ECG Lab 2, Digital Signal Processing Lab
14	12.3	Digital Signal Processing Lab
	12.5	Last day of classes – Make-up and review for Final Exam