Biomedical Instrumentation

BIOE 414

Fall/2024

Everitt Laboratory 1306

Location:
Everitt Laboratory 1306
Class Time:
Mondays, Wednesdays, and Fridays
11 – 11:50 AM
Instructor:
Dr. Ali Ansari, Bioengineering Department
Office Location: **Everitt Lab Room 3244**
Email: **aansari2@illinois.edu**
Office Phone: **217-333-5333**
Drop By/Office Hours:
Please feel free to come by whenever you need to, I am usually in my office if you need something super important or really quick. Please send me an email if you need me for something a little more time intensive because I now have a class with 200 students in it and I am doomed in terms of time. I will also schedule certain hours that I will be in my office for sure, so if you forget to send an email, I should be there for these. *Scheduled Wednesday 3-4 PM, knock on my office door. Can also be via Zoom if need be, just let me know.*

Course Description:

Biomedical Instrumentation is one of the most iconic and easily recognized applications of our discipline. When you describe to a layperson what bioengineering is, instrumentation is one of the most obvious places to start. But Bioengineering is more than just fancy electronic gadgets and gizmos with complicated and sophisticated calculations, it is a science which fuses many of the concepts you have already mastered with the architecture of biology that you have yet to fully explore. In this course, you will learn how to interpret many different circuits and calculate many different things in order to start to develop tools that will help you design your own devices. Just like last year, many of these concepts may sound very intimidating and overwhelming, but the intent is still to give you a set of tools to work with. Perhaps you won't use every tool in your bag for every situation in your careers, but knowing what each tool is and how to use them is always going to be useful. Please try to frame this course in that way, and I hope that you will find this course to be interesting, useful, and hopefully fun.

Learning Objectives

By the end of this course, you will be able to:

1. Understand the limitations of instrumentation in terms of accuracy, resolution, precision, and reliability.
2. Analyze and design operational amplifier and instrumentation amplifier circuits to amply biosignals.
3. Analyze and design filter circuits unwanted signals from biosignals.
4. Understand the origin of cardiac and muscle biosignals and how they are acquired using ECG and EMG electrodes.
5. Understand electrode circuit models and how they affect signal acquisition.
6. Understand the physical modes of operation of various biosensors (amperometric, enzymatic, optical, resistive, capacitive)
7. Describe and compare methods and instrumentation needed to measure pressure and flow in the body.
8. Determine and characterize the factors that limit medical imaging methods in biological tissue.
9. Describe the requirements and limitations of bioinstrumentation in the clinical environment.
10. Function and interact cooperatively and efficiently as a team member in completing a project.
11. Present work in both written and oral reports.

Method of Instruction

This class will be lecture and in class activity driven predominantly. There will be quizzes and tests to ascertain mastery, as well as a final exam which will cover the greatest hits of the material that you have already seen. The intent of these is to show that you understand the material and can solve problems if given enough information, as *that's the whole point.*

Class Structure (units, topics, periods, texts, divisions):

Weeks 1-3: Introduction to Circuit Concepts and Basics! (Chapters 1-3, and Chapter 5 in Alexander text)
Weeks 3-5: Circuit Problem Solving and Design (Chapters 4 and 6 in Alexander text)
Weeks 5-8: Filtering, Capacitance, and Amplifiers! (Chapter 9 in Alexander text)
Weeks 10-13: Instrumentation basics! (Chapters from Webster text)
Weeks 14-16: Medical Applications and design parameters (Webster text)

Assignments/Activities:

Formative Activities (Lesson based Learning): Homework, In-Class Exercises
Summative (Cumulative) Activities: Project, Quizzes Tests, Final Exam

This course focuses on two main objectives: the first is familiarizing the students with the idea that the field is an intersection of a variety of different tracks and topics which are all equally viable, and then contextualizing them with the skills to be able to take that representation and use it to interact and measure certain phenomena.

Textbook:

This time we have two different textbooks. Let me know if you need me to help you find them. The Alexander text is the more primary one and the one that we will focus on for a large component of the course. The secondary text is the Webster text which is also available, I believe from the library. You should be able to get it digitally from the library for free, so don't feel like you have to buy it if you are hurting for funds.

Fundamentals of Electric Circuits 7th Edition, Charles Alexander and Matthew Sadiku, McGraw Hill,
ISBN: 978-1-260 57079-3

Medical Instrumentation: Applications and Design 4th or 5th Edition, John G. Webster, Wiley, ISBN: 13-978-0471-67600-3

Homework:

The intent is to have most if not all homework assignments be a combination of questions that you will be expected to solve in relation to the tests and final exams, but also a small "lab" like one for each core concept which may be more fun than a set of questions.

Tests:

In order to assess how well you know your stuff, and also to keep this in line with previous iterations, there will be two tests and one final exam. The maximum points possible is more than the 100 points allotted for the test, which should help to buffer your scores. I will also try to make it a point to give you the opportunity to do practice problems as well. :) There will be a final exam at the end, which will be over the material that we cover and will be cumulative over some of the material, but that's because it all builds off itself.

Projects:

There will be one LTSpice/MultiSIM/Simulink Project that you will be doing in creating a model of a biological system. That will be assigned later in the semester. I will give you a rubric and outline when we get there.

Scoring:

I wanted to try something a little different and new and make each point awarded equivalent. That means instead of having homework average being a certain percentage of the score, instead, it is weighed equivalently with a grand total of 650 points being awarded throughout the course. That means that there be 2 tests with 125 points each, one final with 125 points each, one project worth 100 points, 25 points allotted for Professionalism and Participation, 50 points for In-class activities, with the last bit being 100 points for homework.

Assignments	**Points**
Participation and Professionalism	40
Quizzes	115
Homework	100
Project	100
Test 1	115
Test 2	115
Final Exam	115
In Class Assignments	50
Total	**750**

Grading:

The performance of a student in each course is evaluated on the grade report by the use of the following symbols:

Grade	Point Range
A+	727.5-750
A	697.5-727
A-	675-697
B+	652.5-674.5
B	622.5-652
B-	600-622
C+	577.5-599.5
C	547.5-577
C-	525-547
D+	502.5-524.5
D	472.5-502
D-	450-472
F	0-449.5

Tentative **Course Schedule:**

	Date		Lecture Topics Covered	Assignments Due
1	Mon.	August 26th	Introduction, Course Outline, Basics of Biomedical Instrumentation	Day 1 Survey Assigned!
	Wed.	August 28th	Circuit Basics and Modeling Circuits	
	Fri.	August 30th	Energy, Power, and Ohm's Law!	Day 1 Survey Due!
2	Mon.	September 2nd	HOLIDAY!	
	Wed.	September 4th	Basic Circuit Calculations	
	Fri.	September 6th	Filters and Practice Problems	
3	Mon.	September 9th	Nodal Analysis, Basic Filters, Quiz #1	
	Wed.	September 11th	Active Filters	
	Fri.	September 13th	Frequency Response and Filters	
4	Mon.	September 16th	Norton and Thevenin Equivalents	
	Wed.	September 18th	Practice Exam Review	
	Fri.	September 20th	Exam Review/ Quiz 2	
5	Mon.	September 23rd	Exam 1	
	Wed.	September 25th	Exam 1 Recap!	
	Fri.	September 27th	Neurons and Basic Biology	
6	Mon.	September 30th	Biological Circuit Model	
	Wed.	October 2nd	Linearity and Superposition	
	Fri.	October 4th	Norton and Thevenin Equivalency	
7	Mon.	October 7th	Practice Problems and ECG and Hearts	
	Wed.	October 9th	EEG and Epilepsy, and Medical Instrumentation Applications!	
	Fri.	October 11th	/Quiz 3	
8	Mon.	October 14th	Pacemakers	Project Assignment
	Wed.	October 16th	Electrode and Half-Cell Potential	
	Fri.	October 18th	Exam Review and Remote Assignment!	Remote Assignment
9	Mon.	October 21st	BMES Conference!	
	Wed.	October 23rd	BMES Conference!	
	Fri.	October 25th	BMES Conference!	Remote Assignment Due
10	Mon.	October 28th	Practice Problems Exam 2 Review	
	Wed.	October 30th	Exam Review	

	Fri.	November 1st	Exam 2	
11	Mon.	November 4th	Exam 2 Recap	
	Wed.	November 6th	Polarization	
	Fri.	November 8th	Electrodes	
12	Mon.	November 11th	Electrode Practice Problems	
	Wed.	November 13th	Project Work	
	Fri.	November 15th	Volume Conductor Model/ Quiz 4	
13	Mon.	November 18th	Block Diagram of ECG and Common Interferences / Project Work	
	Wed.	November 20th	ECGs and Interference, ECG Example Problems/ Project Work if time	
	Fri.	November 22nd	Decreasing Interference and ECG Preamplifiers/ Project Work if time	
14	Mon.	November 25th	Fall BREAK	
	Wed.	November 27th	BE FREE	
	Fri.	November 29th	REST UP!	
15	Mon.	December 2nd	Final Presentations!	
	Wed.	December 4th	Presentations	
	Fri.	December 6th	Presentations	
16	Mon.	December 9th	Presentations	
	Wed.	December 11th	Overflow Presentation/Final Exam Review with Food maybe?	

Course Mechanics:

Policies:

As far as I am currently aware, these classes are intended to be in person for the time being. As such, your attendance is strongly recommended and expected. You are all full adults here, so if you will be missing, **you have to let me know in advance.** If you want to provide a reason, then that is fine, but if you warn me, I can prepare for it. If for some reason, the university moves back to digital formats, I shall upload all the material to the class website and it will be available to all students, whether on campus or attending remotely. Honestly, your safety is paramount to me, so please do whatever makes you feel safest.

For make up assignments and homework, please contact me **IN ADVANCE,** so I can prepare an assignment for you. If something unforeseen occurs, please contact me and we can figure out how best to address it. I also would like to meet with you in office hours/Zoom if a class is missed in this way. If unexcused absences start becoming a problem, then we may need to meet to discuss solutions, as they will make it difficult to successfully complete the projects and will definitely impact your overall experience and grade.

If you are seriously ill or experiencing a family emergency that will impact two classes or less, contact Dr. Ansari via e-mail as soon as possible. If you need an extension on an assignment, arrangements must be made with Dr. Ansari before the assignment due date. If your illness or emergency lasts longer than three days (or two classes), you should request an absence letter from the Office of the Dean of Students: https://odos.illinois.edu/community-of-care/resources/students/absence-letters . Letters should be requested within 10 days of returning. If you test positive for COVID-19 at an on-campus testing facility it will be automatically recorded.

Expectations:
All assignments will have a reasonably-allotted window of time for completion/participation. If at any time you feel you can not access course materials or complete an assignment in the allotted time, please contact me via email with any requests for deadline extensions or assistance. I will hold weekly "office hours" and if you have classes during those times, I can be free other time periods as long as you let me know in advance. If you cannot make either of those, or feel uncomfortable meeting in person, you can contact me directly in Zoom via Office hours w/ Prof. Ali Ansari: Zoom ID:352 339 1708. Students may also email me to request specific meeting times and my current schedule and availability are posted in my Google Calendar. Any students who do not attend live/synchronous course meetings or events are expected to attend at least one "office hours" session (or one they schedule) within 7 days of missing the meeting/event. Please email me if this presents any issues and we will work together to find a mechanism that works better for you.

Class Participation:
Students are expected to engage with the course material to the extent possible based on their location and situation. We aim to foster an inviting and open environment that everyone can feel comfortable sharing in. As such, students are all expected to read/view all posted materials, and complete all assigned work and assessments in a timely manner to best facilitate this environment.

Inclusion and Disability Statements:
To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the DRES office as soon as possible. To ensure that disability-related concerns are properly addressed from the beginning, students with disabilities who require assistance to participate in this class should contact Disability Resources and Educational Services (DRES) and see the instructor as soon as possible. If you need accommodations for any sort of disability, please speak to me after class, or make an appointment to see me or see me during my office hours. DRES provides students with academic accommodations, access, and support services. To contact DRES you may visit 1207 S. Oak St., Champaign, call 217-333-4603 (V/TDD), or e-mail disability@illinois.edu , http://www.disability.illinois.edu/
Please note that if you turn in your application too late, then it may not be possible for us to implement the proper facilities, such as getting you a room for you to have different times for testing. Please factor in at least a week prior to make sure that the office can help you out. :)

Mental Health:
Mental health is extremely important for everyone here, and I urge to take it into account. Significant stress, mood changes, excessive worry, substance/alcohol misuse or interferences in eating or sleep can have an impact on academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings which are covered through the Student Health Fee. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do for yourself and for those who care about you. Please also feel free to chat with me if there is anything I can do to try to help. You all deserve the absolute best, and I want you to treat yourself that way. :)

- Counseling Center (217) 333-3704
- McKinley Health Center (217) 333-2700
- National Suicide Prevention Lifeline (800) 273-8255
- Rosecrance Crisis Line (217) 359-4141 (available 24/7, 365 days a year)
  If you are in immediate danger, call 911.

Equity & Inclusion Statement:

This classroom has a zero tolerance for any kind of discrimination or intolerance. It has no place here or anywhere else on campus let alone outside of it. As you all have the right to fully respected and treated fairly and kindly, if at any point you do not feel welcome or comfortable, please tell me immediately and we will work together to make sure that is remedied as soon as possible. If you don't feel comfortable speaking to me, please don't hesitate to reach out to any of the other professors or deans or even the Director of Graduate Studies who may be able to help you. Additionally, I intend on making this an inclusive and accepting environment that hinges on your comfort in the classroom. This means, if there are issues that affect your learning, as perhaps learning English as a second or so language, and thus requiring more time in reading, presenting, or difficulties in hearing, or anything else, please do not hesitate to talk to me, as I can possibly help deal with this.

The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to Campus Belonging Resources (https://diversity.illinois.edu/diversity-campus-culture/belonging-resources/). Based on your report, Members of the Office of the Vice Chancellor for Diversity, Equity & Inclusion staff will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Behavior that persistently or grossly interferes with classroom activities is considered disruptive behavior and may be subject to disciplinary action. Such behavior inhibits other students' ability to learn and an instructor's ability to teach. A student responsible for disruptive behavior may be required to leave class pending discussion and resolution of the problem and may be reported to the Office for Student Conflict Resolution (https://conflictresolution.illinois.edu ; conflictresolution@illinois.edu ; 217-333-3680) for disciplinary action.

Accommodating Religious Holidays:
Additionally if you have a religious holiday that is placed during the semester please let me know ahead of time so I can also accommodate that as well. This does not count as an unexcused absence, but you will have to make up anything that you may miss, but we can discuss it if it does happen. Religious observances are an example of a planned absence. Students should complete the Request for Accommodation for Religious Observances form (https://cm.maxient.com/reportingform.php?UnivofIllinois&layout_id=19). In order to best facilitate planning and communication, please requests for absence letters as early as possible.

Academic Integrity:
The University of Illinois Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: https://studentcode.illinois.edu/article1/part4/1-401/
Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Masking Policy:
In accordance with the University's rule that makes masks optional, please feel free to make your own discretion on whether to mask or not. I will most likely be masked as to prevent me from getting you all sick, but in return for the freedom to choose, I only request one thing. DO NOT COME IN TO CLASS SICK. If you take your entire class out with a disease, we all suffer. Send me an email before class and let me know what is happening. If you are sick and come in, I reserve the right to ask you to leave. Anything due we can discuss at a later point. Your health and wellbeing is paramount, and I intend to maintain it as much as possible.

Sexual Reporting Obligations:
The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX and Disability Office. In turn, an individual with the Title IX and Disability Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.
A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: https://wecare.illinois.edu/resources/students/#confidential
Other information about resources and reporting is available here: https://wecare.illinois.edu

Use of Generative AI Technology:
Generative AI, such as ChatGPT, Bard, and Microsoft Copilot/Bing Chat, can answer questions and generate text, images, and other media. The appropriate use of generative AI varies from course to course. In BIOE414, there are times when generative AI may be useful in the course. If you choose to use generative AI as permitted below, you must document and attribute all AI contributions to your coursework and take full responsibility for the contributions including the accuracy of the information and reliability of sources. When using generative AI, keep a journal documenting prompts, AI responses, and your usage. Your instructor may ask you to provide this documentation.

You may use generative AI in BIOE414 for the following:
- Revising your own text for spelling and grammar
- Creating study aids (e.g., flashcards) for quizzes or exams
- Testing and practicing your knowledge of course topics
- Conducting basic research on the course and assignment topics

You MAY NOT use generative AI in BIOE414 for the following:
- Generating data for experiments conducted in the course
- Writing entire sentences, paragraphs, or papers to complete class assignments
- Solving technical design problems.

If you have a question about the use of Generative AI, please reach out to your instructors. Failure to abide by these guidelines is a violation of academic integrity. We will investigate suspected uses of generative AI that do not follow these guidelines and apply sanctions as outlined in the Illinois Student Code.

Thank you very much for reading this far, I am extremely excited to teach you all and wish you all a wonderful semester! :)