

BME 650: Biomedical Measurements and Instrumentation Units: 4 Fall 2023 — Mondays and Wednesdays, 12:00-1:50 pm

Location: KAP 166 & ONLINE

Instructors:

Prof. Maral Mousavi, DRB-170, <u>Mousavi.maral@usc.edu</u> Prof. Gerald Loeb, DRB-B11, <u>gloeb@usc.edu</u> Office Hours: Immediately following each lecture and by email appointment

Teaching Assistant: TBD Office Hours: TBD

Course Description

This class will introduce basic concepts in medical measurements and diagnostic devices. The class is designed for students with multidisciplinary and diverse educational backgrounds and is typically populated by PhD and MS students (with backgrounds in biomedical engineering, electrical engineering, chemical engineering, sciences such as biology and chemistry, etc.). Only general science and engineering knowledge is required prior to this class. The course is designed to cover the engineering concepts required for biomedical applications. This course will cover: (i) basic principles of analog signal acquisition and processing, (ii) design of different transducers to measure physiological parameters, (iii) digital signal acquisition and processing, (iv) architecture of electronic instruments used to measure physiological parameters and analysis of major process functions integrated in these instruments, (v) design of diagnostic devices and methods for detection of biomarkers in biological fluids (blood, sweat, saliva), (vi) regulatory aspects of diagnostic devices, and (vii) safety in biomedical measurements.

NOTE: This course is focused on clinical measurement. Medical devices that emit electrical energy such as cardiac pacemakers and neural prostheses are covered in BME 620L Applied Electrophysiology, which may be taken concurrently. Specialized imaging methods (ultrasound, magnetic resonance, etc.) are covered in various other BME courses.

Learning Objectives, Specific Outcomes of Instruction, and Relationship to Program Outcomes

1. Learning objectives

- Understand the principles and concepts of biomedical measurements and origins of biopotentials
- Understand the principles and concepts of design of medical electronics and signal processing for biomedical measurements
- Understand the principles and concepts of transducers and their application in biomedical devices and biomedical measurements
- Understand different aspects involved in development of medical devices (design of transducer, signal measurement, conditioning and processing, and regulatory aspects of device development)
- Understand fundamentals of diagnostic devices and biomarker testing in biological fluids
- Understanding the technical and societal factors involved in point-of-care diagnostics and wearable sensors
- 2. Course outcomes
 - Outcome 1: Apply principles and concepts of electronics to analyze input and output signals in medical electronics

- Outcome 2: Apply principles and concepts of electronics to design filters for de-noising of medical measurements
- Outcome 3: Recognize different types of transducers, ongoing progress in improving their design, and their application in medical measurements
- Outcome 4: Apply principles and concepts of engineering to quantify and model measurements of biopotentials
- Outcome 5: Apply principles and concepts of sensing and engineering to (i) design diagnostic devices for detection of markers in biofluids, and (ii) be able to evaluate quality of diagnostic devices
- Outcome 6: Apply engineering tools to evaluate parameters needed for point-of-care health screening and mobile-health, and design of appropriate point-of-care diagnostic devices

Prerequisite(s): Fundamental knowledge of general biology and basic electronic circuits (EE 202 or equivalent courses or practical experience) is required for this course.

Co-Requisite(s): None

Concurrent Enrollment: None

Recommended Preparation: BME 513 Signal and Systems Analysis, general physics (PHYS 152L or equivalent courses), and general chemistry (CHEM 105 A or equivalent courses). Experience with electronic schematic capture and SPICE simulation is helpful or can be acquired through practice tutorials.

Textbook: Chan, A.Y.K., Biomedical Device Technology, Charles C. Thomas, 2023 (3rd ed.). Accessible overview of transducers and signal processing, medical safety and regulation, examples of clinical instrumentation. 2nd edition (2016) is also acceptable.

Tools: Some homework assignments will use NI Multisim, an electronic schematic capture and SPICE-based simulation program similar to the computer-aided engineering (CAE) tools used throughout the electronics industry. A student license version can be downloaded free of charge (instructions will be provided by the class TA). If you have never used such a tool, it is strongly recommended that you work through the tutorial that comes with it.

Recommended References:

- Northrop, R.B., Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation, CRC Press, 2012. Detailed examples of circuits and equations for instrumentation, including telemetry. (Available for 3 hr check-out in Science and Engineering Library)
- Philbrick classic op-amp manual: <u>https://www.analog.com/en/education/education-library/applications-manual-computing-amplifiers.html</u> A very good way to develop an intuitive understanding of analog circuit behavior.

Course Notes: This course is designed to introduce you to different aspects of biomedical instrumentation and diagnostics. Through classroom discussion, homework assignments, exams, and critical reading of primary literature students will learn design of biomedical instruments and diagnostic systems. The timeline on which the material will be covered is provided below and is subject to change at the instructor's discretion.

Web page: A class website will be setup on Backboard containing information about the course: syllabus, reading handouts, homework assignments, grades, information about class activities, solutions to the homework sets, and an email directory of all students in the class. Use it as much as you find it useful. The web page can be accessed at: https://Blackboard.usc.edu.

Office Hours: Time and location for office hours will be identified at the beginning of first session of the class. Students are encouraged to take advantage of office hours.

Course Schedule: A Weekly Breakdown

	Lecturer	Topics Covered {chapter in Chan textbook}	Quiz	Homework
Week 1 Aug. 21, 23	Loeb Loeb	 Introduction, System Characteristics, Types of Medical Measurements {1,14} Review of Electronics, Signals, Precision, Accuracy, Noise and Filters {2} 		
Week 2 Aug. 28, 30	Loeb Loeb	 Operational Amplifiers, Analog Filters, Instrumentation Amplifiers {Philbrick} Analog-to-digital Sampling, Digital Filtering, Telemetry {A-2} 	Q Q	
Week 3 Sept. 6	Loeb Loeb	(Labor Day) • Temperature Transducers {5,29,30}	Q	#1 due
Week 4 Sept. 11, 13	Loeb Loeb	 Strain gauges and bridge circuits {4} Mechanical Transducers for Motion and Force {6} 	Q Q	
Week 5 Sept. 18, 20	Loeb Razaviyayn	 Tactile sensing Introduction to Machine Learning and Data Analysis (recording) 	Q	#2 due
Week 6 Sept. 25, 27	Loeb Loeb	 Measurement of Fluid Pressure and Flow (liquids and gases) {7,18,19,25,26} Electrodes for Bioelectric Signals {10} 	Q Q	
Week 7 Oct. 2, 4	Loeb Loeb	 Instrumentation for Bioelectric Signals – Electrocardiogram {15} Biocompatibility, Safety and Regulation of Medical Instrumentation {12} 	Q Q	
Week 8 Oct. 9, 11	Loeb Loeb	Exam 1Discussion of Exam 1		
Week 9 Oct. 16, 18	Mousavi Mousavi	 Introduction to biochemistry and disease diagnosis, Introduction to Biosensors Biosensors continued, Biomolecules used in biosensors 		
Week 10 Oct. 23, 25	Mousavi Mousavi	 Structure of Matter, Chemical equilibrium, 2nd law of thermodynamics Nernst Equation, electrochemistry, biopotential electrodes, Electrochemical Measurements {9} 	Q Q	
Week 11 Oct. 30, Nov. 1	Mousavi Mousavi	 Electrochemical diagnostic devices, active and passive techniques Clark Electrode and Glucose Sensing 	Q Q	#3 due
Week 12 Nov. 6, 8	Mousavi Mousavi	 Impedance Spectroscopy and applications Interaction of matter with light, optical sensors, spectrophotometry {8} 	Q Q	
Week 13 Nov. 13, 15	Mousavi Mousavi	 Spectroscopy Instrumentation, Types of Spectroscopy Light Sources, Pulse oximetry {31} 	Q Q	#4 due
Week 14 Nov. 20, 22	Mousavi Mousavi	 Spectroscopy in Diagnostic Devices, Colorimetric biosensors Immunosensors, colorimetric detection in immunosensors 	Q Q	
Week 15 Nov. 27, 29	Mousavi Mousavi	Exam 2Discussion of Exam 2		
Final Week		No activities or submissions		

<u>Class Format and Grading Policy:</u> There will be two 110-minute lectures per week. Both exams and the project presentations will be given in regularly scheduled class sessions. Each exam will be followed by an in-class discussion of potential answers.

The final grade will be based on the following:

- (1) Homework Assignments (25% total)
 - a. In general, weekly homework is assigned on the first lecture of the week, and due on the first lecture of the following week (at the beginning of the class). Six to ten homework assignments, each specifying various work products, will be posted through the semester. Homework assignments are designed to test your understanding of material presented in class and your ability to apply that knowledge to engineering problems. From time to time, you may also be asked do your own research and discover new material as part of your homework assignment. Appropriate reading (journal articles, reports, etc.) will be assigned to assist in homework and learning of the class content.
 - b. <u>All questions on homework should be posted to the appropriate discussion board on Blackboard.</u>
 - c. Show all work. All derivations must be included with symbols before numbers are "plugged in." Units must accompany numerical results when applicable.
 - d. Collaboration is permitted on HW, however copying is not. Collaboration is highly encouraged and includes discussions of concepts, exchange of information, and working together. Each student is responsible for individually preparing and fully understanding the work they submit. Review the university and course Integrity Policies (links below). They will be strictly enforced. This class has a **no-tolerance** policy on academic integrity violations copying is a form of cheating.
 - e. Late homework is not accepted (only exception is a medical emergency with valid physician's note).
- (2) Exams (60% total)

Our philosophy of exams is that they are an important part of learning to synthesize material rather than just a way to grade students based on how much they have memorized. Both exams will be open book, open notes, no internet or email. Both will be held in the regular classroom during a regularly scheduled session. Possible responses to the questions will be discussed during the next regular classroom session and before exams are graded so everyone will learn from and understand what constitutes appropriate vs. inappropriate responses.

Exam 1 covers weeks 1 through 7 (30% of final grade)

Exam 2 covers weeks 9 through 14 (30% of final grade)

(3) Class Quizzes for in person students (15% total)

May be given at the beginning of class based on assigned readings or during the class as a mini-assignment OR

(4) Written Report for distance students (15% total)

Analyze a medical device (ideally associated with your employment) in terms of its measurement requirements, the current methods by which they are fulfilled and opportunities to improve performance.

Homework/Academic Integrity Policy

Students are reminded that they are preparing for a career in which people's health is at stake and in which your professional preparation and integrity are an essential part of any job. Students are expected to spend approximately eight hours per week on readings and assignments. Students are expected to do their own homework assignments and should completely understand everything that they submit as their own. It is anticipated and expected that students consult one another for clarification of concepts, advice, to compare the final numerical homework solution, etc. It is not acceptable to show someone else your written homework, even if it is easier than explaining a concept verbally. You may also use whatever materials you find on the web, in other texts, or other sources to assist in preparing your homework. Copying another student's work on homework assignments or exams is a violation of the USC standards of Academic Integrity (<u>http://www.usc.edu/student-</u>

affairs/SJACS/docs/AcademicIntegrityOverview.pdf and http://www.usc.edu/student-affairs/SJACS/docs/GradIntegrity.pdf). Violations will result in an **automatic F** in the class and filing of an academic misconduct report to the Office of Student Conduct.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" <u>policy.usc.edu/scampus-part-b</u>. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, <u>policy.usc.edu/scientific-misconduct</u>.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call studenthealth.usc.edu/counseling

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call suicidepreventionlifeline.org

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call <u>studenthealth.usc.edu/sexual-assault</u>

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298 equity.usc.edu, titleix.usc.edu

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298 usc-advocate.symplicity.com/care report

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776 <u>dsp.usc.edu</u>

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710

uscsa.usc.edu

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101

diversity.usc.edu

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 - 24/7 on call

dps.usc.edu, emergency.usc.edu

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call dps.usc.edu

Non-emergency assistance or information.