Engineering Faculty Document No. EFD 22-22

November 2, 2021

TO: The Faculty of the College of Engineering

FROM: The Faculty of the Weldon School of Biomedical Engineering

RE: New Undergraduate Course, BME 20700, Bioinstrumentation and Circuit Theory

The Faculty of the School of Biomedical Engineering has approved the following new undergraduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

BME 20700: Bioinstrumentation and Circuit Theory
Term Offered: Spring, Lecture 1, Lab 2, Cr. 3
Pre-requisites: PHYS 24100 or PHYS 27200
Concurrent prerequisites: MA 26200 or MA 26600
Major Restriction: Biomedical Engineering only

Description: Introduction of laboratory instruments used to measure physiological events. Stimulation and conduction of electric signals within the mammalian nervous system and other excitable tissues are demonstrated. Fundamental circuit elements and concepts include resistance, capacitance, inductance, op-amps, impedance, voltage, current, power, and frequency. Fundamental analog measurement concepts include adequate bandwidth and amplitude and phase linearity. An integrative design project emphasizes the practical aspects of quantitative physiological measurements. Students are introduced to programming (using Python) to deepen the understanding of the basic concepts and learn basic skills in data processing. SPICE software will be used throughout the course to design/simulate various analog circuits.

Reason: This course replaces a Junior-level introductory circuit theory lab that was designed as a co-requisite to BME 301 Bioelectricity. This new course is designed to stand alone, and will expose the student to basic skills, such as programming, simulation, and physiological signal acquisition at the sophomore level, preparing students for two of the four pathway choices in our curricular redesign. Half of this course has been piloted successfully as a temporary 8-week BME 29500 course in Spring 2021 with 16 students and is now being submitted as a full-semester course for a permanent course number.

David M. Umulis
Dane A. Miller Head and Professor
Weldon School of Biomedical Engineering

Course Information

Course # and title: BME 20700: Bioinstrumentation and Circuit Theory

Instructional modality: Face-to-Face

Course Credit Hours: 3

Pre-requisites: PHYS 241 Electricity and Optics **or** PHYS 272 Electric and Magnetic Interactions
Concurrent pre-reqs: MA 262 Linear Algebra and Differential Equations **or** MA 266 Differential Equations

Instructors' Contact Information

Course Instructors: Dr. Yunjie Tong — Office: MJIS 2019
Email: tong61@purdue.edu — Phone: (765) 494-0198
Office Hours: by appointment via email

Lab Coordinators:
Mr. Asem F. Aboelzahab (aboelzahab@purdue.edu)
Office: MJIS 1084
Ms. Daniela Nkama (dnkama@purdue.edu)
Office: MJIS 1055
Office Hours: Open-door / by appointment

Course TAs:
Ms. Mrunmayi Angane (mangane@purdue.edu)
Mr. Agudemu Borjigin (aagudemu@purdue.edu)
Mr. Hao-Cheng Gao (gao561@purdue.edu)
Ms. Brianna Kish (kishb@purdue.edu)
Ms. Chandana Kodumuri (ckodumur@purdue.edu)
Mr. Ryan Olson (olson119@purdue.edu)
Office Hours: BME Resource Center MJIS 1097 7-9pm (M & W)

Course Description

Introduction of laboratory instruments used to measure physiological events. Stimulation and conduction of electric signals within the mammalian nervous system and other excitable tissues are demonstrated. Fundamental circuit elements and concepts include resistance, capacitance, inductance, op-amps, impedance, voltage, current, power, and frequency. Fundamental analog measurement concepts include adequate bandwidth and amplitude and phase linearity. An integrative design project emphasizes the practical aspects of quantitative physiological measurements. Students are introduced to programming (using Python) to deepen the understanding of the basic concepts and learn basic skills in data processing. SPICE software will be used throughout the course to design/simulate various analog circuits.

Learning Resources, Technology & Texts

Required Text: Hayt, Kemmerly, Phillips, & Durbin. *Engineering Circuit Analysis* (9th ed.)
McGraw-Hill, 2019. ISBN-13: 9780073545516/9781259989452/9781259989513
Note: Previous editions are acceptable

Required Materials:
- Paper or printable electronic notebook
  (e.g., Microsoft Word; remember that MS Office is free for all students)
- One component kit per lab group (provided; no purchase necessary)

Course Web Page: https://purdue.brightspace.com
Access the course via Purdue's Brightspace learning management system. Begin with the Start Here tab, which describes how the course Brightspace is organized. It is strongly suggested that you explore and become familiar not only with the site navigation but with content and resources available for this course. See the Student Services widget on the campus homepage for resources such as Technology Help, Academic Help, Campus Resources, and Protect Purdue.

Learning Outcomes

Upon completion of the course, you will be able to:

1. Appraise the validity of established bioelectricity hypotheses and circuit models based on quantitative physiological measurements.
2. Document procedures, measurements, and subsequent data analysis in clear and cohesive laboratory reports.
3. Design an analog bioinstrumentation measurement system meeting prescribed specifications to accurately record a physiological event.
4. Design and simulate analog circuits using SPICE.
5. Create simple Python code to plot, analyze, and denoise physiological data. Build functions to simulate a simple bioinstrumentation system.

Assignments

Laboratories	*breakdown:*		55 %
	Pre-lab problems (individual)	*25 %*	
	Notebook (group), Jupyter Notebook (individual)	*5 %*	
	Post-lab analysis (individual)	*25 %*	
Design laboratory	*see Design Lab supplementary material* #		15 %
Exams	*breakdown:*		30 %
	Exam I (Midterm)	*15 %*	
	Exam II (Final)	*15 %*	
Total			**100 %**

* *All assignments are collected, but only select sets (randomly selected) are graded.*

\# *For full credit, you must complete online course evaluations and submit evidence of survey completion. Furthermore, TA/Peer Review (individual) may reduce an individual's grade by up to 15 % of the group grade.*

For each lab, you will be required to complete a pre-lab assignment and either a post-lab assignment or a formal lab report. In addition, you are expected to maintain a laboratory notebook throughout the course of the semester. Following is a description of what is expected for each.

- **Pre-lab:** Prior to each laboratory session, students are expected to read over the laboratory material and the assigned textbook reading. Pre-labs can be found on Brightspace but will require students to refer to their lab manual/text for more information. **Pre-lab exercises are to be completed and submitted online before coming to lab.** By completing this assignment, you will better understand the lab and lecture concepts and form expectations for the lab activities. Please note that although pre-labs are completed online, you should keep a notebook showing your work for all calculations. **IMPORTANT:** Students who do not turn in a Pre-lab assignment will be awarded a zero for that assignment.

- **Pre-lab Quizzes:** To ensure students come prepared to class, there may be a pre-lab quiz at the beginning of laboratories. The quizzes will be in the format of short answer, true/false, and multiple-choice questions. The intent of the quiz is to encourage students to come prepared for that day's laboratory exercise. The score achieved on the quiz will be factored into the pre-lab grade associated with that laboratory.

- **Notebook:** During the laboratory exercises, each team will be expected to keep a notebook, either electronic or handwritten. The entries should follow the standard notebook layout with a brief statement of the **Objective** of the activity, the **Procedure** followed, and any **Results** obtained. The circuits in the lab will also be simulated and tested in the LTSpice. **Conclusions** must also be provided for each part of the lab activity. The procedure must include a record of all circuits constructed. The results section should include all relevant observations and data. These observations/thoughts may be important in the post-lab analysis. Calculations and numerical information used or obtained in the experiment must be explicitly included in the notebook, including the simulated results from LTSpice. If hand-written, all entries in the lab notebook are to be written in ink; if you make a mistake, simply cross out the mistake by making an X through the area and make the correction next to it. It is expected that all work is well organized. The notebook entries will be graded for their organization and content. **Notebook entries will be submitted with the post-lab assignment.**

  Note: Late pre-labs and notebooks will <u>not</u> be accepted.

- **Post-Lab Analysis:** Post-lab analyses will **always** include the analysis and interpretation of the data obtained during the laboratory exercises. A Jupyter Notebook based on Python will be given for each lab, which will help you understand the relevant concepts of the lab. You will be expected to run the examples in Google Colab and make your own python programs as asked. A few textbook problems that cover the lecture topics may be assigned. In addition, you will be expected to answer questions posed involving application and integration of the relevant concepts covered in that lab. *All post-lab assignments may be typed or handwritten (as long as you print clearly); the post-lab should **not** be embedded within your in-lab notebook observations and data.* Please note that you must show work for all calculations and **circle or box your final solution**. Each person in the class is to complete and turn in his/her own post-lab assignment for grading.

  Note: If the post-lab analysis is not turned in <u>within the first 15 minutes</u> of lab, it will be considered late, and the assignment will be automatically assigned a 20% grade deduction.

- **Exams:** There will be two closed book exams that will take place mid-semester and during finals week at the end of the semester. These exams will cover all topics addressed in the lecture and may include laboratory topics.

Grading Scale

The following grading scale is guaranteed; final grades may be curved at the instructors' discretion.

Letter Grade	Percentage	GPA score
A+	≥ 100	4.0
A	≥ 94	4.0
A-	≥ 90	3.7
B+	≥ 87	3.3
B	≥ 83	3.0
B-	≥ 80	2.7

Letter Grade	Percentage	GPA score
C+	≥ 77	2.3
C	≥ 73	2.0
C-	≥ 70	1.7
D+	≥ 67	1.3
D	≥ 63	1.0
D-	≥ 60	0.7
F	< 60	0

Re-grade Policy: Students have the right to contest any grades throughout the semester. If a student feels an assignment has been inappropriately graded, the student must submit one typed page indicating the source of the problem and an explanation for the re-grade submission. Along with this document, the original assignment must be returned. Students have one week after the return of a graded assignment to protest a grade; after this time, grade disputes will not be accepted. Papers submitted for a re-grade will be completely re-evaluated (i.e., the entire paper will be re-graded, not only the portion under protest), which means that students may lose additional points for mistakes missed during the first grading process.

Topics Covered

1. Fundamentals of electrical measurements and properties, Ohm's law (1 lecture, 1 lab)
2. Resistive models of biological systems (1 lecture, 1 lab)
    - KCL, KVL, nodal analysis, conductivity of physiological solutions
3. Generation and measurement of bioelectric signals (1 lecture, 1 lab)
    - Linearity, Thevenin equivalent, practical circuit models of voltage sources and voltmeters
4. Time varying bioelectric signals (1 lecture, 1 lab)
    - Capacitors, step response of RC circuits
5. Bioelectric amplifiers (1 lecture, 1 lab)
    - Operational amplifiers
6. Sinusoidal response of linear circuits (1 lecture)
    - Lead/lag networks, phasor notation
7. Frequency response of RC models & frequency content of physiological signals (1 lecture, 2 labs)
    - Phasor analysis of RC circuits, Fourier series
8. RLC model of the cochlea (1 lecture, 1 lab)
    - 2^{nd} order linear systems, step response, frequency response
9. Recording and stimulating electrodes (1 lecture, 1 lab)
    - electrodes, circuit models of electrodes, Wheatstone bridge circuit
10. Stimulation of nervous system (1 lecture, 1 lab)
    - Impulse function, convolution in time domain
11. Action potential propagation in nervous and muscle tissue (1 lecture, 1 lab)
    - Convolution in frequency domain, high pass and low pass filtering
12. Recording of physiological signals (1 lecture, 1 lab)
13. Differential and Instrumentation amplifiers, common mode rejection ratio
14. Instrumentation design (2 lectures, 2 labs)
15. Adequate magnitude and phase linearity and bandwidth, signal distortion, filtering

Course Procedures

During a typical week there will be one lecture and one laboratory. The *lecture* will introduce and cover the circuit analysis techniques to be utilized in one or more of the accompanying laboratories. The *laboratories* have been designed to provide a hands-on learning environment to explore and relate the circuit analysis concepts to bioelectricity (BME 301) and measurement of physiological events. As such, an attempt was made to create lab activities that contain either a wet lab experiment or a measurement of a physiological event on a living subject. Students successfully completing this course will obtain understanding of the criteria required to faithfully reproduce a physiological event as well as the ability to design, construct, and test simple measurement circuits.

Format of lecture period: The lecture period is devoted to covering the week's topics through traditional lecture and active learning activities.

Format of laboratory period: The pre-lab assignments are due online before coming to lab. There will be a brief introduction (5 – 15 minutes) to the lab provided by the Teaching Assistants at which time a brief quiz may be given. Students then execute the lab.

- *Laboratory Attire:* Safety regulations require that you wear long pants (or equivalent) and closed-toe shoes while working in the laboratory.
- *Lab Group Composition:* At the start of the lab, students will be paired into lab groups. Most lab groups will contain two students. No lab group will contain more than 3 students. The instructor of the course reserves the right to reassign lab partners at any point during the semester.

Completion of every lab is required to pass. Make-up work will be considered and assigned on a case-by-case basis. ***To receive credit for the lab, a student must be in the lab on time, no more than 15 minutes late. A student who is more than 15 minutes late and who does not have an excused reason may receive a zero on the lab.***

See Brightspace for up-to-date COVID lab use protocols, general safety protocols, and weekly lab content (including lab protocols, safety information, and lab introductory videos and tutorials).

Format of office hours: Lab office hours will be held twice a week via Zoom. The link is available on the course web page. If you are unable to attend the assigned office hours, please consult with a TA to set up alternative arrangements. Instructor office hours are made by appointment as indicated on the first page of the syllabus.

Attendance Policy during COVID-19

Students are expected to attend all classes in-person unless they are ill or otherwise unable to attend class. If they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus, students should stay home and contact the Protect Purdue Health Center (496-INFO).

In the current context of COVID-19, in-person attendance cannot be a factor in the final grades. However, timely completion of alternative assessments can certainly be part of the final grade. Students need to inform the instructors of any conflict that can be anticipated and will affect the timely submission of an assignment or the ability to take an exam.

Laboratory engagement is extremely important and associated with your overall success in the course. The importance and value of course engagement and ways in which you can engage with the course content even if you are in quarantine or isolation, will be discussed at the beginning of the semester. Student survey data from Fall 2020 emphasized students' views of in-person course opportunities as critical to their learning, engagement with faculty/TAs, and ability to interact with peers.

Only the instructors can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructors of the situation as far in advance as possible. For unanticipated or emergency conflicts, when advance notification to the

instructors is not possible, the student should contact the instructors as soon as possible by email, through Brightspace, or by phone. In cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via email or phone at 765-494-1747. Our course Brightspace includes a link to the Dean of Students under Campus Resources.

Academic Guidance in the Event a Student is Quarantined/Isolated

If you must quarantine or isolate at any point in time during the semester, please reach out to the instructors via email so that we can communicate about how you can continue to learn remotely. Work with the Protect Purdue Health Center (PPHC) to get documentation and support, including access to an Academic Case Manager who can provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Your Academic Case Manager can be reached at acmq@purdue.edu. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify the instructors via email. We will make arrangements based on your particular situation.

Classroom Guidance Regarding Protect Purdue

The Protect Purdue Plan, which includes the Protect Purdue Pledge, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask in classrooms and campus building at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace before and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not properly wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss the next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Incidents of academic misconduct in this course will be addressed by the course instructor and referred to the Office of Student Rights and Responsibilities (OSRR) for review at the university level. Any violation of course policies as it relates to academic integrity will result minimally in a failing or zero grade for that assignment, and at the instructor's discretion may result in a failing grade for the course. In addition, all incidents of academic misconduct will be forwarded to OSRR, where university penalties, including removal from the university, may be considered.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under University Policies.

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

- **If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed**, try WellTrack. Sign in and find information and tools at your fingertips, available to you at any time.
- **If you need support and information about options and resources**, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am – 5 pm.
- **If you find yourself struggling to find a healthy balance between academics, social life, stress**, etc., sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.
- **If you are struggling and need mental health services**: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it related to COVID-19, students may submit requests for emergency assistance from the Critical Needs Fund.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructors' control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email. You are expected to read your @purdue.edu email on a frequent basis.

Active Emergency Response: In case of fire, evacuate the building via the east doorways (towards S. Russell St.) if they are free of hazards. Do not use the west doorways as a primary exit as those will be the doors accessed by emergency responders and fire personnel. The primary Emergency Assembly Area location (after evacuating the building) is the outside courtyard and main entrance to Hockmeyer. This entrance faces Martin Jischke Drive. The secondary Emergency Assembly Area location, in case of inclement weather, is the interior main lobby of Hockmeyer.

If “sheltering” owing to a tornado warning, immediately proceed to the MJIS basement hallway via the stairwell. Do not use the elevators. Be prepared to kneel facing a wall and cover your head.

If “sheltering” owing to an active shooter, building intruder, or a civil disturbance on campus, follow police instructions. In the absence of instructions, seek a safe location, preferable a room without windows that can be locked or secured by barriers.

Course Schedule (example)

WEEK OF	WEEK	LAB ACTIVITY	LECTURE TOPIC	ASSIGNED TEXT READING
8/23	1	***No Lab*** (Lab 0 – on your own)	Ohm’s law, Kirchhoff’s circuit laws (KCL & KVL)	Ch. 1, Ch. 2, Ch. 3
8/30	2	Fundamentals of electrical measurements and properties	Equivalent resistance, nodal analysis, mesh analysis	Ch. 4, Appx. 1
9/6	3	Resistive models of biological systems	***Labor Day 9/6 (M)***	
9/13	4	Generation and measurement of bioelectric signals	Linearity, superposition, source transformation, Thévenin and Norton equivalents	Ch. 5, Appx. 2
9/20	5	Time varying bioelectric signals and response times of measurement devices	Capacitors & inductors, RC & RL circuits	Ch. 7.1-7.4, 7.6-7.7, Ch. 8.1-8.8
9/27	6	Bioelectric amplifiers	Operational amplifiers, instrumentation amplifier	Ch. 6 & 7.5
10/4	7	Frequency response of RC models of biological systems	Sinusoids, steady-state response, phasors	Appx. 5, Ch. 10, Ch. 15.1-15.2
		Exam I (Midterm) – 10/7 (Th)		
10/11	8	***No Lab***	***October Break (M-T)***	
10/18	9	Frequency content of physiological signals and bandwidth	Basic filter design, intro to Fourier analysis	Ch. 15.7-15.8, Ch. 17.1-17.3, Appx. 4, Appx. 6
10/25	10	The RLC Model of the cochlea	RLC circuits, resonance, bandwidth, quality factor	Ch. 9, Ch. 15.1-15.6
11/1	11	Recording and stimulating electrodes	Laplace transforms, **s**-domain	Ch. 14.1-14.3, Appx. 7
11/8	12	Design project	Electrodes, point response function, convolution	Ch. 14.4-14.12
11/15	13	Design project	Nerve stimulation	Posted to Brightspace
11/22	14	***Thanksgiving Break (W-F)***	AC circuit power analysis	Ch. 11
11/29	15	Design project	AC circuit power analysis	
12/6	16	Design project	Magnetically coupled circuits, wireless power transfer	Ch. 13
12/13		***Exam II (Final) – date/time TBD***		