Course Title: BIOEN 302 – Introduction to Biomedical Instrumentation

Instructor: Christopher Neils

Credits: 4

UW General Catalogue Course Description: Introduces students to the fundamentals of electrical and optical signals in measurements of biological variables. Transient, periodic and non-periodic signals, operational amplifiers, Fourier analysis, Diffraction, Optical microscopy. Some sensors and actuators used to test biomedical systems. Prerequisite: BIOEN 301; CSE 142; EE215. Co-requisite: BIOEN 304. Offered: A

Instructor's Detailed Course Description:

This course introduces students to the fundamentals of electrical and optical measurements in biomedical systems. The topics include: 1) Transient and steady-state system response; 2) Phasors; 3) Fourier Series; 4) Fourier Transforms; 5) Transfer functions; 8) Feedback control systems; 9) LTI systems and system linearization; 10) Microscopy for Biomedical Applications; 11) Biosensors and photometers. If time permits, the course will also discuss electromagnetic field interaction, transistors, digital logic, and digital circuits.

Prerequisites by Topics:
Circuit Analysis, Elementary Physics, Basic Calculus (Differential Equations, e.g. Harmonic Oscillator, Integration and Differentiation).

Textbooks:
Electric Circuits (Nilsson and Riedel), Physics of the Human Body (Irving Herman). Supplemented by course notes (Albert Folch, Trevor Fowler, Chris Neils).

Learning Objectives:
Introduces students to the principles that allow engineers to make precise electrical and optical measurements. Teaches students how to interpret and manipulate the output of a sensor in terms of its frequency response and frequency content, how to determine the filtering properties of a circuit, and how to detect light emission from or diffraction through biomedical samples.

Topics Covered:
1) Transient and steady-state system response; 2) Phasors; 3) Fourier Series; 4) Fourier Transforms; 5) Transfer functions; 8) Feedback control systems; 9) LTI systems and system linearization; 10) Microscopy for Biomedical Applications; 11) Biosensors and photometers. If time permits: EM field interaction; Active and digital electronic components.

Class Schedule:
Lectures (3 hours/week), Labs (one 3-hour session per week).

Computer Use:
Requires knowledge of online access for lecture notes and course assignments. Laboratories require the use of Excel or MATLAB for data analysis and plotting. One lab requires students to generate a data acquisition system using Labview, and others require students to use

Labview to analyze system response (e.g. pole-zero plots for control system design). Another lab uses ImageJ to process a digital micrograph.

Laboratory Projects:
Laboratory exercises reinforce critical concepts provided in lectures. Topics vary by year but include most of the following: amplification of electrical signals obtained using pipette microelectrodes; oscillatory behavior of electronic circuits and ultrasound transducers; Fourier series decomposition of acoustic signals; diffraction of coherent (laser) light; photometry with LEDs and photodetectors; phase contrast and fluorescence microscopy; and quantitative fluorescence microscopy of dye diffusion in a microfluidic channel.

Course Outcomes and Assessment:
BIOEN302 presents, in interactive lectures, weekly laboratory exercises, and assignments, the fundamentals of electrical and optical signal analysis. As such, this course addresses certain ABET outcome criteria at a variety of levels.

Specific outcomes in BIOEN 302 and their assessment mechanisms to be used by the department for **program assessment** are:

(a) An ability to apply knowledge of mathematics, science and engineering. Concepts and techniques are presented in lecture, practiced in homework, explored in lab, and reinforced with biweekly quizzes. Student competency is assessed primarily with a comprehensive final exam.

(c) An ability to design a system, component, or process to meet desired needs. In the weekly lab exercises students are introduced to the process of team-based design. Throughout the quarter, students from an entire lab section collaborate to design, build, and test a complex bioengineering instrument, which then is used for data collection late in the quarter. Outcome achievement is assessed on the basis of students' project demonstrations and comprehensive written reports.

(d) An ability to work in teams. All laboratory exercises involve students working in teams. The teams must collectively build the devices or setups, troubleshoot, analyze data, and write the lab reports. For the term design project, the lab section is divided into teams that must cooperate on the overall device design. Teamwork is assessed by peers, by instructor observation, and by each team's achievement of their goals.

(g) An ability to communicate effectively. Students write lab reports and receive extensive critiques. Students are also encouraged to participate in lecture and lab discussions. Written communication is assessed via one or more lab reports. Oral communication is assessed via a design presentation.

(k) An ability to use computers and analytical equipment. Most lab exercises require the use of computers to control a scientific apparatus, to acquire data from devices, to process the data, and to produce graphs and other quantitative outputs. Outcome achievement is assessed via the methods, results, and discussion presented in lab reports, and may also be assessed with in-lab practical exams or demonstrations.

(m) An ability to apply advanced mathematics, science and engineering to solve the problems at the interface of engineering and biology. Examples in lecture, homework, and lab are framed around biomedical measurements, so students relate the biomedical need for the measurement with the applied formulas and the performed calculations. Outcome achievement is assessed via written lab reports, in which students apply complex mathematics, differential equations and statistics, and may also be assessed using questions on the final exam.

Relationship of Course to Departmental Objectives:
The course serves to introduce junior-level BioE students to fundamentals of signal analysis and manipulation. This course also reinforces mathematical agility in differential calculus and complex calculus, adding universal quantitative analysis tools such as Fourier analysis. Overall, the course increases the students' *quantitative agility* in the analysis of electrical and optical signals that are ubiquitous in biosensing, as well as their *quantitative understanding* of the performance of RCL circuits (e.g. filters) and optical systems (e.g. interferometers, lenses, microscopes).

In Summary, BIOEN302 complies with departmental objectives by:

- Coupling mathematics, engineering, and biology (through lectures, in-class interactive discussions, and laboratory exercises).
- Having students work in teams (in laboratory exercises).
- Developing an ability to communicate problems and their solutions effectively with physicians, biologists, and other engineers (lab reports and examinations).