Course Title: BIOEN 302 – Introduction to Biomedical Instrumentation

Instructor: Albert Folch, Credit: 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) **Basic bioelectricity and electronics concepts** (Basic review of components (I, V, R, C, L), Kirchhoff's Laws, and differential equations); 2) **Transient responses of electrical circuits** (First-order circuits (RC or RL) and Second-order circuits (RLC)); 3) **AC electronics**: Impedance and AC responses of electrical circuits (Impedance, Phasors, First- and Second-order circuits, Filters); 4) **Amplifiers:** Basic op-amp concepts, Inverting/Non-inverting/Differential Amplifiers, Integrator, Differentiator, and Comparator; 5) **Fourier Analysis:** Analog Fourier Transform, Fourier analysis of RLC circuits, Fourier analysis of diffraction spectra; 6) **Biosensors:** Fluid handling (microfluidics), Surface analysis (overview & case study); 7) **Photometry fundamentals:** Photon/wave duality, Coherence/Monochromaticiy, Interferometry, Beer's law, Spectrophotometer; 8) **Optics fundamentals:** Reflection, Refraction, Refractive index, Magnification; Diffraction and Resolution using Fourier analysis; 9) **Microscopy for Biomedical Applications:** Phase-contrast microscopy and Fluorescence microscopy; 10) **Advanced Microscopy for Biomedical Applications:** Electron microscopy (SEM, TEM), Confocal microscopy, Scanning Probe Microscopies (STM, AFM, NSOM). Laboratory exercises will reinforce critical concepts provided in lectures.

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

Textbooks:
None. Comprehensive handouts have been developed by Albert Folch and contain multiple exercises and all the theory needed to understand the lectures.

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) Basic bioelectricity; 2) Basic electronic components; 3) Transient responses of electrical circuits; 4) Phasors; 5) Operational Amplifiers; 6) Fourier Series; 7) Fourier Transforms; 8) Biosensors; 9) Light emission and absorption; 10) Light propagation and interference; 11) Lenses and Interferometers; 12) Microscopy for Biomedical Applications.

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 for data analysis and plotting. One lab requires the use of Labview for Fourier Series visualization. Another lab uses ImageJ to process a digital micrograph.

Laboratory Projects:
Laboratory exercises will reinforce critical concepts provided in lectures. Topics could include: 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)*** To apply knowledge of mathematics, science and engineering *(homework, lab exercises, and exams)*. All written exercises require the use of math to predict or analyze electrical/optical phenomena and measurements covered in the lectures or labs (such as Fourier series decomposition of acoustic signals).
- ***(c)*** To design a system, component, or process to meet desired needs *(lab exercises)*. The students are lectured on the need for a particular biomedical measurement, asked to put together a device or setup (such as a photometer with LEDs) to carry on the measurement, and required to provide a comprehensive report of their activities.
- ***(d)*** To work in teams *(lab exercises and reports)*. 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.
- ***(g)*** To communicate effectively *(in-lecture discussion, lab reports, and essay-type questions in exams)*. The students are encouraged (directly by the instructor and indirectly by the grading system) to participate in lecture discussions. In all written exercises, clarity in writing is part of the grade.
- ***(k)*** To use computers and analytical equipment *(for data acquisition and analysis in lab exercises)*. Most labs require the use of computers to control a scientific apparatus, to collect (read) data from devices, to process the data, and to produce graphs and other quantitative outputs that illustrate the data.
- ***(m)*** To apply advanced mathematics, science and engineering to solve the problems at the interface of engineering and biology *(homework and exams)*. All written questions are framed around a biomedical measurement, so the students relate the biomedical need for the measurement with the applied formulas and the performed calculations.

Additional specific outcomes and their assessment mechanisms (in parentheses) considered **of high relevance** by the department for BIOEN302 are: None

Additional specific outcomes and their assessment mechanisms (in parentheses) considered **of medium relevance** by the department for BIOEN302 are: None

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).