

**Course Title:** Bioen 303 – Bioengineering Signal Processing

**UW General Catalog Course Description:**

Introduction of signal processing techniques necessary to record and analyze medical and biological data. Students use transform calculus to analyze differential equations and develop approximations to functions. Introduces sampling and applies it to biological data.

**Instructor:** Gao, XH

**Instructor's Detailed Course Description:**

Bioen 303 – (4 credits). This course introduces the tools to develop a fundamental understanding of Digital Signal Processing (DSP) theory. It covers the essential mathematics and engineering techniques by explaining the meaning and significance of the key DSP equations. The course also introduces a variety of applications of DSP, in particular, in processing biological signals. The course covers fundamental signal processing techniques that are essential to record and analyze medical and biological data. Using examples from medicine, biology and engineering, the students learn to use transform calculus to analyze differential equations and develop approximations to functions. The sampling theorem is introduced. The students also learn some basics of linear time invariant (LTI) system.

**Prerequisites by Topics:**

calculus, linear algebra, differential equations, basic biomechanics and anatomy, and basic instrumentation.

**Textbooks:**

- Understanding Digital Signal Processing, by Richard G. Lyons, Prentice Hall PTR, 2004 (Second Edition).
- Digital Signal Processing Using MATLAB, by Vinay K. Ingle and John G. Proakis, Brooks/Cole, Thomson Learning, 2000.

**Course Objectives:**

This course introduces junior bioengineering students to modern DSP techniques that are fundamental to a wide variety of biomedical applications. Course will integrate the mathematical basis of discrete-time signal analysis with biomechanics; discuss the design and implementation of digital filters.

**Topics Covered:**

1. introduction of biological and bioengineering signals and statistical analysis; 2. signal categorization and characterization; 3. signal sampling theorem; 4. frequency domain biological signal analysis; 5. digital filter designs; 6. MATLAB practice using simulated or acquired physiological signals.

**Class Schedule:**

- Lectures 1hr20min/lecture, meet twice a week
- Labs one 3-hour session/week

**Computer Use:**

A major component of lectures and lab exercises is the use of MATLAB for algorithm design, implementation, and signal processing. This course involves intensive use of computers.

**Laboratory Projects:**

Laboratory exercises will reinforce critical concepts provided in lectures. Specific studies will include: biological signal reorganization and feature detection; signal noise and interpatient variability; signal frequency domain analysis in MATLAB; design of digital filters and window; and speech analysis.

### **Course Outcome and Assessment:**

This course presents modern DSP techniques and their applications in biology and medicine through lectures, laboratory exercises, home assignments and student presentations, and addresses the following ABET outcome criteria.

Specific outcomes in Bioen 303 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.* (Homework assignments and examinations on discrete convolution and discrete Fourier transforms require students to develop procedural knowledge of underlying mathematical principles. Exemplary lab exercises include peak detection in electrocardiograms and pulse oximetry, drug clearance simulation, spectrograms, and Fourier domain analysis of ECGs; these exercises require knowledge of biosignal properties. Exercises in finite- and infinite-response filter design are used to assess student's ability in using engineering mathematics, such as Laplace and Z transforms.)

□ (c) *an ability to design a system, component, or process to meet desired needs.* (Student's ability is assessed by homework exercises, such as design and implementation of digital filters for signal processing. In addition, all weekly lab exercises assess the

students' ability to design software (MATLAB code) to perform a specified task.)

☐ (k) *computer use*. (All weekly lab exercises and part of the homework assignments assess the students' ability to design software (MATLAB code) to perform a specified task.)

☐ (l) *an understanding of biology and physiology*. (Physiological sources of biological signals, fundamentals of electrocardiograms and pulse oximetry, biological signal noises and etc. are introduced in the lecture series, and the students' understanding is assessed through the weekly lab exercises and term projects (examples include electrocardiograms, pulse oximetry and voice spectrograms))

☐ (m) *the capability to apply advanced mathematics, science, and engineering to solve the problems at the interface of engineering and biology*. (Weekly lab exercises assess the students' ability to derive mathematically the following biosignal features: peaks in electrocardiograms and pulse oximetry waveforms, parameters describing drug clearance rates, time-varying voice spectra, and beat-to-beat signal variability in ECGs. The students' capability is also evaluated by the term project topics, such as using modern DSP techniques for detection of right and left branch bundle block (RBBB and LBBB), speech recognition and etc.)

Additional outcomes and their assessment mechanisms considered of **high relevance** to ABET criteria by the department for Bioen 303 are:  
none

Those specific outcomes and their assessment mechanisms considered of **medium relevance** by the department for Bioen 303 are:

□ (b) *An ability to design and conduct experiments, as well as to analyze and interpret data* (In the weekly lab exercises, students are given a goal and they must design a programming strategy and test it experimentally. In the lecture series, students are given problems to test their ability in analyzing and interpreting data using the techniques they learned in the lecture. For example, after introducing pulse oximetry, they are asked to solve the multispectral imaging problem using a similar mechanism.)

□ (d) *Teamwork* (In one set of the homework assignments, students form their own teams and study modern instruments, which are commonly used in medicine and biological research labs, and their related signals. This case study is done in teams of 3 students. Weekly lab projects are done in teams of two students, with co-authored reports. Term projects are done in teams of 4-5 students, with co-authored reports and team presentations.)

□ (e) *an ability to identify, formulate, and solve engineering problems* (The students' ability is assessed by the homework sets and term projects. For example, in one homework set the students propose their methods to evaluate digital filter's frequency responses. In the term projects, the students are evaluated by their abilities to develop and test algorithms to solve bioengineering problems, such as detection of branch bundle block and speech recognition.)

□ (g) *an ability to communicate effectively* (The students' ability is evaluated by the homework sets, lab reports and presentations. Homework solutions describe mathematical principles behind digital biosignal processing informally; Weekly lab reports discuss methods, results and implications of actual biosignal analysis. Student

presentations of term projects provide an opportunity to interact with an audience while presenting technically advanced topics.)

□ (n) *the ability to make measurements on and interpret data from living systems and non-living materials and systems* (The lecture series discuss the fundamentals of signal collection, discretization and quantization. For one weekly project and one term project option, data from living systems such as voice and pulse oximetry signals will be collected. Measurements of electrocardiograms made in the concurrent physiology course are interpreted in two weekly exercises and one term project option.)

### **Relationship of Course to Departmental Objectives:**

Bioen 303 is designed to introduce modern DSP technology to junior level Bioen students after their previous exposure to calculus, biology, biomechanics and instrumentation in freshman and sophomore years. The course first reinforces the critical concepts in mathematics, engineering, biology and computing, and then integrates them to analyze and solve medical and research problems. For example, the course covers mathematical transform functions and MATLAB computing techniques, which are then used to study electrocardiogram, patient speech and electromagnetic spectrum. Through this multidisciplinary training, the students are expected to develop an ability to apply engineering logic and design principles to collect, sample, analyze, process and manipulate biological signals, and thus prepared for graduate level educations and industrial challenges.

In summary, Bioen 303 complies with the departmental objectives by:

- build on a solid foundation in mathematics, physics, chemistry, computing, engineering and biology.
- integrate engineering concepts and use design and quantitative analysis to solve biomedical problems.
- work in multidisciplinary teams and communicate problems and their solutions effectively with physicians, biologists, and other engineers.