ECE/BIOM 527B Signal and Noise in Biosensors

Fall 2023 (middle 5 weeks)

10:00 – 10:50 am MWF in Engineering B4

Instructor: Kevin Lear
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Important note: You must include "ECE527B" as part of the subject line for all emails regarding this class, or else my email filters will not move them to a higher priority inbox.
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Office: Scott 346
Office Hours: See Canvas webpage

This course is a module in the GAUSSI series, developed in part to support the NSF-sponsored GAUSSI program. Courses in this series include:
Cells as Circuits - ECE 527A (Lear)
Signal and Noise in Biosensors - ECE 527B (Lear)
Sensor Circuit Fundamentals - ECE 527C (Chen)
Affinity Sensors – ECE 527D (Chen)
Electrochemical Sensors - ECE 527E (Chen)
Biophotonic Sensors Using Refractive Index - ECE 527F (Lear)

COURSE DESCRIPTION: Quantitative treatment of concepts of noise, interference, and signal including noise types and spectra, filtering, and limitations imposed by noise. Example applications to Biosensors.

COURSE OBJECTIVES: Upon successful completion of this class, students will be able to:

- Describe major types of noise and their spectral dependence.
- Describe quantization error and its dependence on analog-to- digital convertor parameters.
- Relate signal to noise ratio to measurement confidence and limit of detection.
- Determine appropriate analog and digital filtering methods for improving signal to noise ratio.
- Distinguish between interference and noise.

PREREQUISITES: PH142; MATH340 or MATH345, may be taken concurrently.
Students in this class are expected to be able to do detailed engineering computations and data analysis on a platform, such as R, Matlab, or Excel, that is capable of FFTs, calculating correlations, random number generation, and graphing. Students will probably find prior exposure to Fourier transforms helpful.

REQUIRED MATERIALS: There is no required textbook for this class. Readings and notes will be provided as needed.

Canvas: canvas.colostate.edu will have the syllabus, links, homework, course grades and other postings. It is your responsibility to check the course website each week for new postings.

COURSE TOPICS: The planned topics for this course are:

Week 1	• Introduction, motivation, course material and policy overview • Review of basic statistical calculations and their relationships • Shot, thermal, and flicker (telegraph) noise: physical origins, spectra, calculation of magnitude. Units for characterizing noise amplitude e.g. dBm/Hz, V/sqrt(Hz), noise-equivalent power. • Distinction between noise and interference, background subtraction, electromagnetic interference, drift, environmental variables, benefit of differential measurement.
Week 2	• Brief review of Fourier transform and frequency domain concepts including transform pairs, scaling, Bode plot representation of simple filters • Fast Fourier transform (FFT) application, scaling, padding, artifacts • Filtering methods: averaging, integration time, analog filter functions, digital filtering functions, impact on time-domain waveforms, impact of bandwidth.
Week 3	• Practical issues in applying analog-to- digital converters including range, number of bits, sampling rate, dithering, and quantization noise • Amplifier noise, impact of amplifiers on signal-to- noise ratio, noise figure, design choices impacting noise.
Week 4	• Impact of noise and interference on sensitivity, limit of detection, measurement confidence. • Biosensing examples possibly including EEGs, patch clamp of neuron, single molecule fluorescence, photon counting.
Week 5	• Basic methods for characterizing noise; use of oscilloscopes, spectrum analyzers, noise meters, amplifiers. • Sensor performance metrics and the relationships between them; International Union of Pure and Applied Chemists (IUPAC) definitions; Final exam or Project

GRADING:

Quizzes / participation in discussions 10%
Homework assignments 45%
Final exam or project 45%

Homework will be due at the start of class one week after it is assigned, typically each Tuesday, but check the website for updates. Links to the homework can be found on Canvas. I request that you record the time spent on each question on your paper.

The final exam for this course will may occur either during the last class session (a Thursday), or if this course is during the last five weeks of the semester, during the usual time scheduled during finals week. (No out-of-class time is typically scheduled for a final exam for classes ending before the semester.)

Final grades will be determined by the following scale:

≥ 90% A	80-83.99% B	70-73.99% C
87-89.99% A-	77-79.99% B-	60-69.99% D
84-86.99% B+	74-76.99% C+	≤ 59.99% F

ACADEMIC INTERGRITY: Students are expected to adhere to the Academic Integrity Policy of Colorado State University, outlined in the CSU General Catalog. Students are also expected to follow the Student Conduct Code which can be found at www.conflictresolution.colostate.edu. Academic dishonesty is not accepted in this course, and any form of cheating (including plagiarism) will be reported. Penalties may include a lowered course grade, loss of course credit, and expulsion from the university.

Students are **not allowed to copy another past or current student's work or access any prior solution on homework or exams**. Students must cite the sources they use on all work done outside the classroom, including discussions with other students. Students are encouraged to discuss course topics and approaches to problems with each other or other knowledgeable sources, but should not collaborate when writing up their solutions. Work duplicating that of another student is likely to result in a significant academic penalty.