Syllabus for BIEN 130: Bioinstrumentation

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Spring 2017

Class Schedule

Lecture:	12:40 – 2:00 TR	SPIETH 2200
Discussion:	1:10 – 2:00 M	MSE 003
	12:10 – 1:00 F	MSE 003

Course description

Introduces basic components of instruments for biological applications. Explores sources of signals and physical principles governing the design and operation of instrumentation systems used in medicine and physiological research. Topics include data acquisition and characterization; signal-to-noise concepts and safety analysis; and interaction of instrument and environment. 4 units total: 3 units lecture, 1 unit discussion.

Textbooks

None required, but a reader will be provided on iLearn containing selections from *Bioinstrumentation* by John G. Webster, *The Art of Electronics* by Paul Horowitz and Winfield Hill, and other resources.

Course outline

Introduction to bioinstrumentation. Case study of the Coulter counter. Importance of bioinstruments.

DC circuits. Overview of electronic sensors. Current, voltage, and resistance. Ohm's law. Resistivity. Voltage dividers. Wheatstone bridge. Digital multimeters. Prototyping boards.

AC circuits. Characteristics of AC signals. Capacitors. Case study of the defibrillator and AEDs. Timescales for charging and discharging a capacitor. Building an electronic filter. Low-pass, high-pass, and band-pass filters. Bode plots. Case study of removing 60 or 120 Hz noise due to electrical lines.

Op-amp circuits. Introduction to biopotentials. Case study of electroencephalography (EEG). Nernst equation for membrane potential of a neuron. Case study of the 741 op-amp. Basic function of op-amps. Voltage followers. Comparators. Inverting and non-inverting amplifiers. Gain. Low-pass, high-pass, and band-pass filters with gain > 1. Differential amplifier. Instrumentation amplifier.

Data acquisition. Analog world vs. digital world. Analog inputs and outputs. Analog-to-digital conversion (ADC). ADC resolution. The Nyquist sampling theorem. Case study of recording an electrocardiogram (EKG or ECG) on a computer. Counters for frequency measurement.

Introduction to sensors. Sensor response and dynamic range. Single vs. multi-channel sensors.

Temperature sensors. Thermocouples. Thermistors. Infrared thermography. Case study of medical thermography for detecting breast tumors.

Light sensors. Photoresistors. Photodiodes. Photomultiplier tubes. Charge-coupled devices (CCDs).

Flow sensors. Thermal mass flow meters. Ultrasonic flow meters.

Force, mass, and pressure sensors. Strain gauges. Piezoelectric sensors.

Optical bioinstruments. Light interacting with matter. Deriving Beer's Law. Spectrophotometry. Optical imaging. Dispersive elements. Case study of pulse oximetry. Fluorescence. Light scattering. Raman spectroscopy.

Noise and errors. Thermal or Johnson-Nyquist noise. Shot noise. Quantization errors. Dither. Noise reduction strategies. Ground loops.

Statistics. Normal or Gaussian distributions. Standard deviation. Interquartile range. Box plots. P values. Type I and Type II errors. Sensitivity and specificity. Positive and negative predictive value. Bayes' Theorem.

Biopotentials. Excitable cells. Electrical model of the cell membrane and the origins of the membrane potential. Action potential in neurons. Electrocardiography (ECG or EKG). Action potentials during the heartbeat. The cardiac vector. ECG lead placement and Einthoven's triangle. Circuits for ECG measurements.

Medical imaging. Electromagnetic spectrum. X-rays for medical imaging. X-ray absorption of the elements. Angiography. Esophagography. Fluoroscopy. Case study of shoe store foot fluoroscopes. Tomography. X-ray computed tomography (CT or CAT scan). Drawbacks of radiographic imaging. Nuclear magnetic resonance (NMR). Magnetic resonance imaging (MRI). Functional MRI. Positron emission tomography (PET). Doppler ultrasound. Imaging ultrasound. Case study of diagnosing Down syndrome *in utero* with ultrasound and the "technocratic takeover" of pregnancy.

Separations. Importance and challenge of separations. Mass spectrometry. Affinity-based separations. Chromatography. Gas chromatography (GC). High-performance liquid chromatography (HPLC). Thin-layer chromatography (TLC). Electrophoresis. Electroosmotic flow. DNA sequencing. Sanger sequencing.

Cytometry. Hemocytometer. Coulter counter. Flow cytometry. Fluorescence-activated flow cytometry (FACS). Hydrodynamic focusing and sheath flow. Cell sorting. Case study of inkjet printers and electrostatic cell sorters. Gating in FACS.

Binding assays. Challenge of multiplexed binding assays. Enzyme-linked immunosorbent assay (ELISA). Direct and indirect ELISA. Case study of wellplate HIV diagnostic. Case study of lateral-flow pregnancy test. Microarrays. Case study of Luminex instrument.

Electrochemical detection. Electrochemical cells and batteries. Standard electrodes. Three-electrode cell. Case study of blood glucose meter.

Electrical safety. Effects of voltage and current (AC/DC) on human body. Ground fault interrupter circuits (GFIC). Let-go current. Current density and micro vs. macro shocks. Methods of electrical isolation.

Intellectual property. What is patentable? Prior art. "Person having ordinary skill in the art" (PHOSITA). Provisional patent applications. Public disclosure. Full patent application. Multiple independent discovery. Importance of notebooks. Inventions by students.

Grading

- 40% Homework
- 20% Midterm exam
- 20% Presentation
- 20% Final exam

		A+	$\geq$	97.00
97.00	$>$	A	$\geq$	92.00
92.00	$>$	A–	$\geq$	90.00
90.00	$>$	B+	$\geq$	87.00
87.00	$>$	B	$\geq$	82.00
82.00	$>$	B–	$\geq$	80.00
80.00	$>$	C+	$\geq$	77.00
77.00	$>$	C	$\geq$	72.00
72.00	$>$	C–	$\geq$	70.00
70.00	$>$	D+	$\geq$	67.00
67.00	$>$	D	$\geq$	62.00
62.00	$>$	D–	$\geq$	60.00
60.00	$>$	F		

Homework

- Assigned via iLearn, due one week later by 5pm.
- Solutions posted on iLearn after grading is finished.

Presentations

- Abstracts due in Week 5.
- Presentations to the class in Week 10.
- Critical, in-depth analysis of a commercial bioinstrument, including:
    1. How the instrument works (in terms of the material learned in class)
    2. Assessment of the commercial success/potential of the instrument (how much does it cost, how large is the market for the instrument)
    3. How would you improve it to make it less expensive/more useful/etc.
- Teams of 1, 2, or 3 people.
- Visuals in PowerPoint, Keynote, PDF, Google Docs, or on the chalkboard. No Prezi or similar tools please.