Lecture 0: Introduction

- Course Outline
- *In vivo* biomedical devices

Practical Information

- **Instructor**
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- **Admin**
  - Janet Sloan, 526 NEB
  - (352) 392-2723, [holman@ece.ufl.edu](mailto:holman@ece.ufl.edu)

- **Class**
  - Meeting time: MWF 11:45-12:35 (period 5)
  - Location: NEB 202
  - Website: [http://www.icr.ece.ufl.edu/teaching/EEL6935-F10/F10-6935.htm](http://www.icr.ece.ufl.edu/teaching/EEL6935-F10/F10-6935.htm) (password protected)
  - Instructor Office Hours: MW 12:35 - 1:20pm

- **TA**
  - Chris Dougherty ([chrisdoc@ufl.edu](mailto:chrisdoc@ufl.edu))
  - Office hours: TBA
Class Material

• Required Textbooks
  – Title: Medical Instrumentation Application and Design
  – Author: John G. Webster

• Reference Textbooks
  – PSPICE or LT SPICE: available in the ECE PC lab

Course Goals

• This course will focus on advanced topics of mixed signal circuit design for in vivo wireless biomedical devices.
• We will cover topics such as low power low noise amplifiers, A/D converters, power management circuits and communication techniques.
• You will be introduced to specific issues associated with the electrical environment of living organisms, bioelectric signal characteristics and the acquisition of physiological signals.
### Pre-requisites

- **EEL3308 Electronic Circuits I**
- **EEL5320 Bipolar Analog IC Design** (or taken concurrently)

- **For Biomedical Engineering students**
  - Biomedical Instrumentation class or equivalent
  - Will need to review Opamps, Signals and MOS transistors

### Tentative Course Outline

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<th>Topic</th>
<th>Chapters</th>
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<td>Orientation</td>
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<td>Implantable Systems</td>
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<td>Opamp review</td>
<td>Ch 1, 2, 4, 7 S&amp;S</td>
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<td>MOS review</td>
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<td>Basic amplifiers review</td>
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<td>Noise Fundamentals</td>
<td>Ch 1, 2 M&amp;C</td>
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<td>Feedback</td>
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<td>Origin of Biopotentials</td>
<td>Ch 4 JG</td>
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<td>Physiological measurement variables</td>
<td>Ch 1 JG</td>
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<td>Biopotential Electrodes</td>
<td>Ch 5 JG</td>
</tr>
<tr>
<td>Biopotential Amplifiers and Analysis</td>
<td>Notes</td>
</tr>
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<td>High Impedance Techniques and interference reduction</td>
<td>Notes</td>
</tr>
<tr>
<td>ADC Fundamentals</td>
<td>Ch 11, 12, 13 J&amp;M</td>
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</table>

### Grading Policy

- **Student research papers: 50%**
  - about 4-5; at least 1 individual student paper
  - Student papers must be written according to IEEE paper guidelines. Paper templates and guidelines are available in the following link:
  - Grading will be based on a peer review process based on well defined review criteria.

- **Student presentations: 50%**
  - In class presentation of selected research paper topics. These will be mostly group presentations that will last 10-20mins depending on topic and class size. Presentation templates will be provided.

- **NO MIDTERMS OR FINAL EXAM**

- **Grading Scale**
  - A > 90; 85 < B+ < 90; 80 < B < 85; 75 < C+ < 80; 70 < C < 75; D+, D, E < 70

*Grading policy is subject to change*
Academic Honesty

- All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action.

- This statement is a reminder to uphold your obligation as a student at the University of Florida and to be honest in all work submitted and exams taken in this class and all others.

- Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide documentation to the instructor when requesting accommodation.

Lecture 1: Introduction

- **In vivo biomedical devices**

Generalized Biomedical Instrumentation System

- **Measurand:**
  - Physical quantity measured by the instrument

- **Sensor:**
  - A device that converts measurand to electric signal

- **Signal Conditioning:**
  - Amplification, filtering, etc

- **Analysis and Display:**
  - Digitizing, analysis of electric signals. Calibration. Output Result

- **Data Transmission**
  - Wired (external) or wireless (implant)

- **Power Supply**
### Common medical measurands

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Range</th>
<th>Frequency, Hz</th>
<th>Method</th>
</tr>
</thead>
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<tr>
<td>Blood flow</td>
<td>1 to 300 mL/s</td>
<td>0 to 20</td>
<td>Electromagnetic or ultrasonic</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>0 to 400 mmHg</td>
<td>0 to 50</td>
<td>Cuff or strain gage</td>
</tr>
<tr>
<td>Electrocardiography</td>
<td>0.5 to 4 mV</td>
<td>0.05 to 50</td>
<td>Skin electrodes</td>
</tr>
<tr>
<td>Electroencephalography</td>
<td>5 to 300 μV</td>
<td>0.5 to 150</td>
<td>Scalp electrodes</td>
</tr>
<tr>
<td>Electromyography</td>
<td>0.1 to 5 mV</td>
<td>0 to 10,000</td>
<td>Needle electrodes</td>
</tr>
<tr>
<td>Electroretinography</td>
<td>0 to 900 μV</td>
<td>0 to 50</td>
<td>Contact lens electrodes</td>
</tr>
<tr>
<td>pH</td>
<td>3 to 13 pH units</td>
<td>0 to 1</td>
<td>pH electrode</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>2 to 50 breaths/min</td>
<td>0.1 to 10</td>
<td>Impedance</td>
</tr>
<tr>
<td>Temperature</td>
<td>32 to 40 °C</td>
<td>0 to 0.1</td>
<td>Thermistor</td>
</tr>
</tbody>
</table>

100mmHg=1.93psi=13.3kPa

### In vivo biomedical devices

- A major use of medical electronic instrumentation are **non-invasive** devices used in diagnostic medicine
  - Sense physiological signals, process and display them
- Another class of devices are **invasive**, such as implants, used for therapeutic and/or prosthetic functions
  - Implanted devices are inserted into a surgically formed or natural body cavity and intended to remain there for > 30 days
  - However, some devices are ingested and perform monitoring functions
- In this class we will mainly focus on **in vivo** devices, (devices that reside inside the body, chronically or for a limited amount of time)
  - In vivo devices generally place high demands on electronic components and mixed-signal electronics
  - Some in-vivo devices are presented...

### Pacemakers

- First introduced in the 1950s to treat pathological conditions known collectively as heart block - i.e. cardiac arrhythmias such as bradycardia (slow heart rate) - wherein the heart’s natural pacemaking function is assisted using relatively low voltage stimulation pulses (5-10V)
- Lifetime of 10-12 years from a single battery
- 200x transistor IC fabricated in a 0.5μm 3P-3M process occupies 49 mm² and consumes only 8 μW; deep subthreshold designs and switched-capacitor techniques are widely used for low power operation.


### Camera in a pill

- **Wireless Endoscopy Capsule**
  - Pill capsule with integrated Camera for Endoscopy
  - 26x11mm, 5.2mW, 8hrs, Two 1.5V batteries; 14 images/sec, or 2,600 images, 402-405MHz MICS

![Camera in a pill diagram](image)

Given Imaging
Implantable Neuromuscular Stimulator

- BION (Bionic Neuron)
- Injectable Neuromuscular Stimulation
- Re-animate paralyzed muscles using electrical stimulations
- 32 BION in 20 patient clinical trials

Brain Computer Interfaces

- Decode human intent from brain activity
  - create an alternate communication channel (completely new output pathway) for people with severe motor impairments
  - messages and commands that act on the world

Retinal Implants

- Retinitis Pigmentosa (RP – genetic) – 1 in 4000 incident and 100,000 in US and 12 Million worldwide (peripheral region goes flat followed by gradual loss of central or reading vision)
- Age-related Macular Degeneration (AMD) – 700,000 in US yearly and 10% become legally blind (loss of central vision makes it difficult to impossible to perform detailed work such as reading)
- Elicit electrical activity by artificially stimulating rods and cones.

Cochlear Implants

- A prosthesis which restores hearing by electrically stimulating the nerves in the cochlea
  - First implant in France 1957 (Djourno & Eyries), Single channel devices in 1960s and 70s, Multiple channel 1980s
  - The cochlea (inner ear) is a frequency analyzer
  - The nerves are arranged in tonotopic order


Peter Seligman, Cochlear Ltd

[Walpow, Clin Neurophysiol, 2002]
Passive Microsystems for Medication Compliance

• Passive microchip to measure medication adherence
• Biocompatible antenna with miniaturized µChip under protective coating.
• RFID signaling for in-body communications.

Basic Implant System

- Sensors and Transducers
  - Solid-state (piezo, capacitive, etc), electrochemical (ionic)
- Signal Conditioning
  - Low noise amplifiers, A/D converters, D/A converters, Stimulators
- Signal Processing
  - Signal filtering, signal compression, localized feedback and control, processing circuits for monitoring signals, collecting therapy history and diagnostic files, and monitoring all subsystem functions
- Power management
  - Battery, types of batteries, battery chargers and monitors, voltage regulators, switch-mode power supplies, wireless power transfer, inductive links
What are the common electronic subsystems

- **Wireless Communication**
  - Antenna issues, RF receivers and transmitters, data bandwidth, choice of frequency, body losses

- **Safety**
  - Biocompatibility, RF heating, component reliability, voltage stress, ESD protection, redundancy

- **Assembly and micro packaging**
  - Electrode leads, biological tissue interface, biocompatibility, hermeticity, chronic implantation, mechanical stress

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Parameterization of Hardware Approaches

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General Themes

- **Size and miniaturization**
  - Highly integrated, micropackaging, battery vs. battery-less, number of external components

- **Functionality**
  - Bandwidth, memory, on-chip processing, # of channels, wireless, sensing vs. stimulation, low noise vs. high voltage

- **Low power**
  - Low power circuit techniques, performance power tradeoffs, battery lifetime

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Summary

- **This class will focus on Analog and Mixed-Signal Electronics for Biomedical Applications, specifically for in-vivo devices**

- **Review of basic sensors and transducers, signal conditioning circuits, signal processing, power management circuits, wireless telemetry**

- **Case studies of therapeutic implants**
  - Brain, Vision, Hearing, Heart