EEL 6935
Analog and Mixed-Signal Electronics for Biomedical Applications
Fall 2010
Section: 7812

Lecture 0: Introduction

- Course Outline
- *In vivo* biomedical devices

Practical Information

- Instructor
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Practical Information

- 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 (password protected)
  - Instructor Office Hours: MW 12:35 - 1:20pm
- TA
  - Chris Dougherty (chrisdoc@ufl.edu)
  - Office hours: TBA

Class Material

- Required Textbooks
  - Title: Medical Instrumentation Application and Design
  - Author: John G. Webster
  - Publication date and edition: 4th ed, John Wiley & Sons, 2010
  - ISBN: 0471676004; ISBN-13: 9780471676003
- Reference Textbooks
  - Microelectronic Circuits, A.S. Sedra & K.C. Smith, 5th ed, Oxford University Press, 2004
  - Analog Integrated Circuit Design, D. Johns, K. Martin, John Wiley & Sons
  - Low Noise Electronic System Design, C.D. Motchenbacher, J.A. Connelly, John Wiley & Sons
  - Neil H.E. Weste, David Harris, "CMOS VLSI Design, A Circuits and Systems Perspective," 3rd Edition, Pearson, Addison-Wesley, 2005. ISBN 0-321-14901-7

  - PSPICE or LT SPICE: available in the ECE PC lab

Class Material

- Journal/Conference References
  - Journal of Solid State Circuits (JSSC), TVLSI, CAS-I and II
  - ISSCC, VLSI Symposium, CICC, ISCAS
- Web Links
  - IEEE Explorer

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.

Course Goals

- This course is intended to introduce the basic electronic circuits, techniques and considerations for the development of biomedical implantable devices.
- Several case studies of implantable assistive and therapeutic devices will be presented.

Tentative Course Outline

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

Tentative Course Outline

Topic	Chapters
Digital Signal Processing	Notes
Basic Sensors and Principles	Ch 2 JG Notes
Portable Power Supplies and Circuits	Notes
Wireless Power Transfer	Notes
Energy Harvesters	Notes
Wireless Data and Modulation Schemes	Notes
Assembly and Packaging	Notes
Regulation of Medical Devices	Ch. 1 JG Notes
Electrical Safety	Ch 14 JG
Therapeutic and Assist Devices	Ch 13 JG Notes

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

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

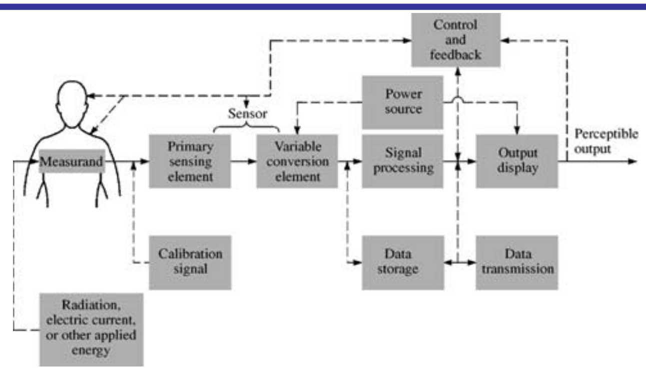
Academic Honesty

- 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



Generalized instrumentation system The sensor converts energy or information from the measurand to another form (usually electric). This signal is the processed and displayed so that humans can perceive the information. Elements and connections shown by dashed lines are optional for some applications.

Generalized Composition of Biomedical Instrumentation

- 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

Measurement	Range	Frequency, Hz	Method
Blood flow	**1 to 300 mL/s**	**0 to 20**	**Electromagnetic or ultrasonic**
Blood pressure	**0 to 400 mmHg**	**0 to 50**	**Cuff or strain gage**
Electrocardiography	**0.5 to 4 mV**	**0.05 to 150**	**Skin electrodes**
Electroencephalography	**5 to 300 μ V**	**0.5 to 150**	**Scalp electrodes**
Electromyography	**0.1 to 5 mV**	**0 to 10000**	**Needle electrodes**
Electroretinography	**0 to 900 μ V**	**0 to 50**	**Contact lens electrodes**
pH	**3 to 13 pH units**	**0 to 1**	**pH electrode**
Respiratory rate	**2 to 50 breaths/min**	**0.1 to 10**	**Impedance**
Temperature	**32 to 40 °C**	**0 to 0.1**	**Thermistor**

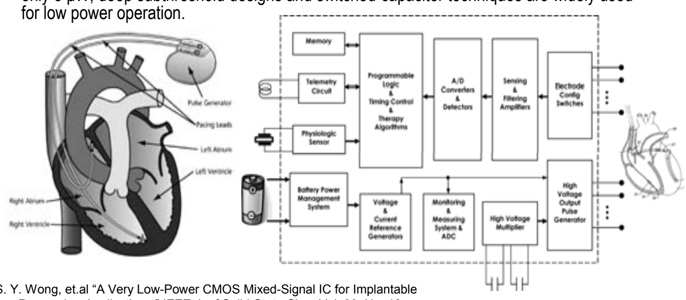
100mmHg=1.93psi=13.3kPa

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
- 200k transistor IC fabricated in a 0.5µm 3P-3M process occupies 49 mm^2 and consumes only 8 µW; deep subthreshold designs and switched-capacitor techniques are widely used for low power operation.

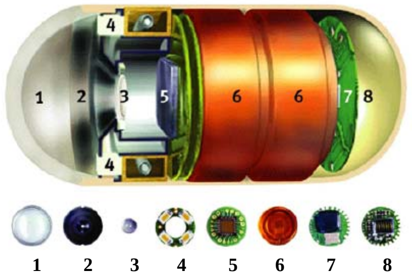


L. S. Y. Wong, et.al "A Very Low-Power CMOS Mixed-Signal IC for Implantable Pacemaker Applications," IEEE J. of Solid-State Circ., Vol. 39, No. 12, pp. 2446- 2456, Dec. 2004.

Camera in a pill

- Wireless Endoscopy Capsule

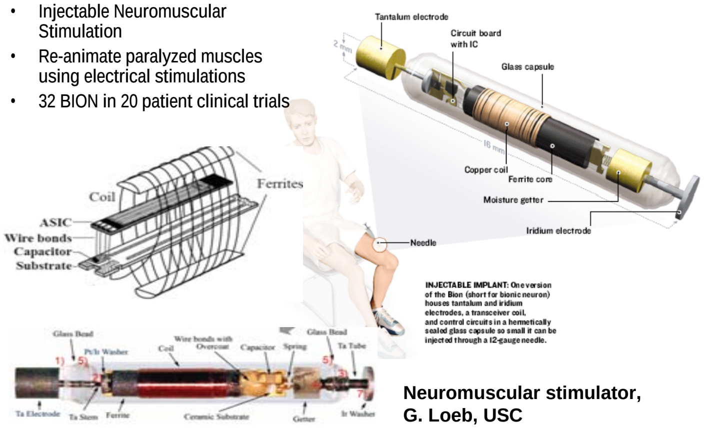
Pill capsule with integrated Camera for Endoscopy
26x11mm, 5.2mW, 8hrs, Two 1.5V batteries;
14 images/sec, or 2,600 images, 402-405MHz MICS



Given Imaging

Implantable Neuromuscular Stimulator

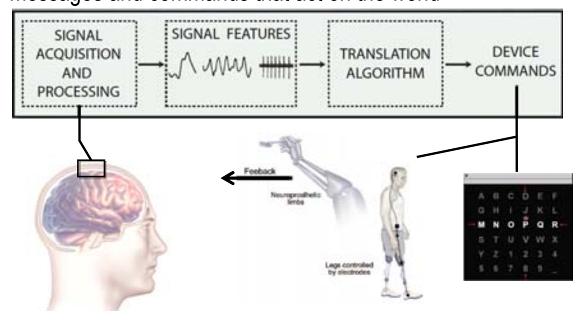
- BION (Bionic Neuron)
- Injectable Neuromuscular Stimulation
- Re-animate paralyzed muscles using electrical stimulations
- 32 BION in 20 patient clinical trials



Neuromuscular stimulator, G. Loeb, USC

Brain Computer Interfaces

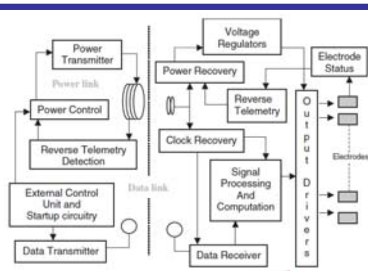
- Decode human intent from brain activity
  - create an alternate communication channel (completely new output pathway) for people with severe motor impairments
  - messages and commands that act on the world

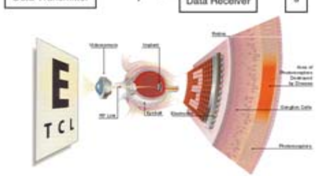


[Walpow, Clin Neurophysiol, 2002]

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.



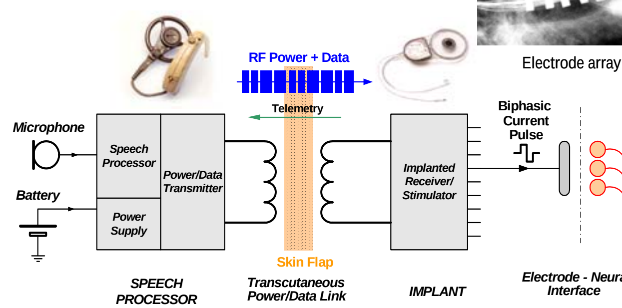


W. Liu, P. Singh, C. DeMarco, R. Bashirullah, M. S. Humayun, and J. D. Weiland, Semiconductor-based implantable Microsystems. CRC Press LLC, 2003.

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

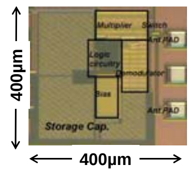
Electrode array in-situ



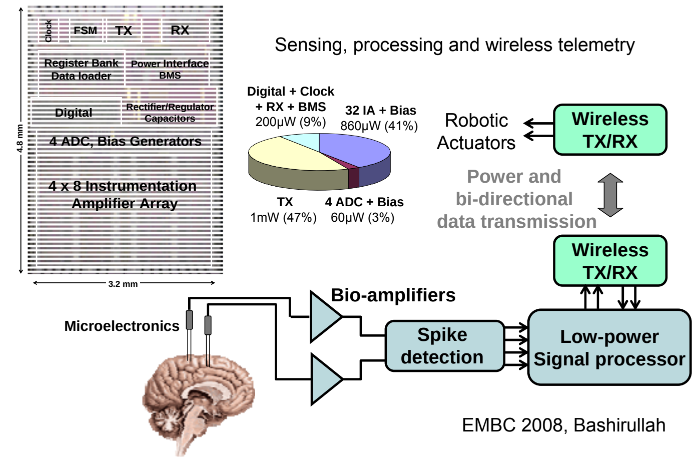
Peter Seligman, Cochlear Ltd

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.

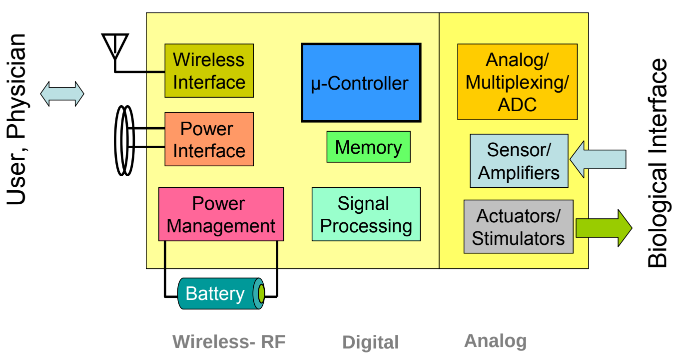


Basic Components of Implant Microsystem



EMBC 2008, Bashirullah

Basic Implant System



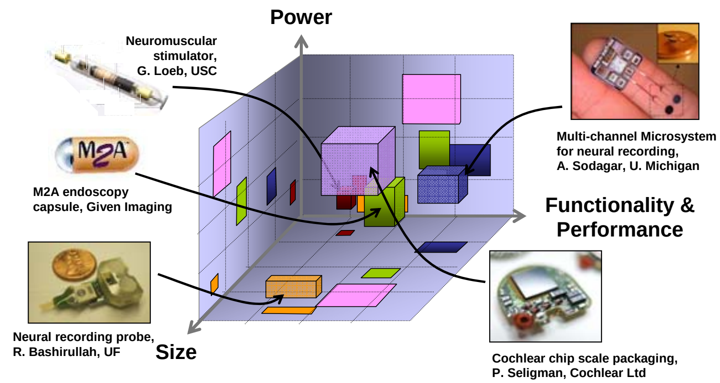
Electronic subsystems

- 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, biocompatability, hermeticity, chronic implantation, mechanical stress

Parameterization of Hardware Approaches



R. Bashirullah, IEEE Microwave Magazine, to appear in Dec issue

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

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