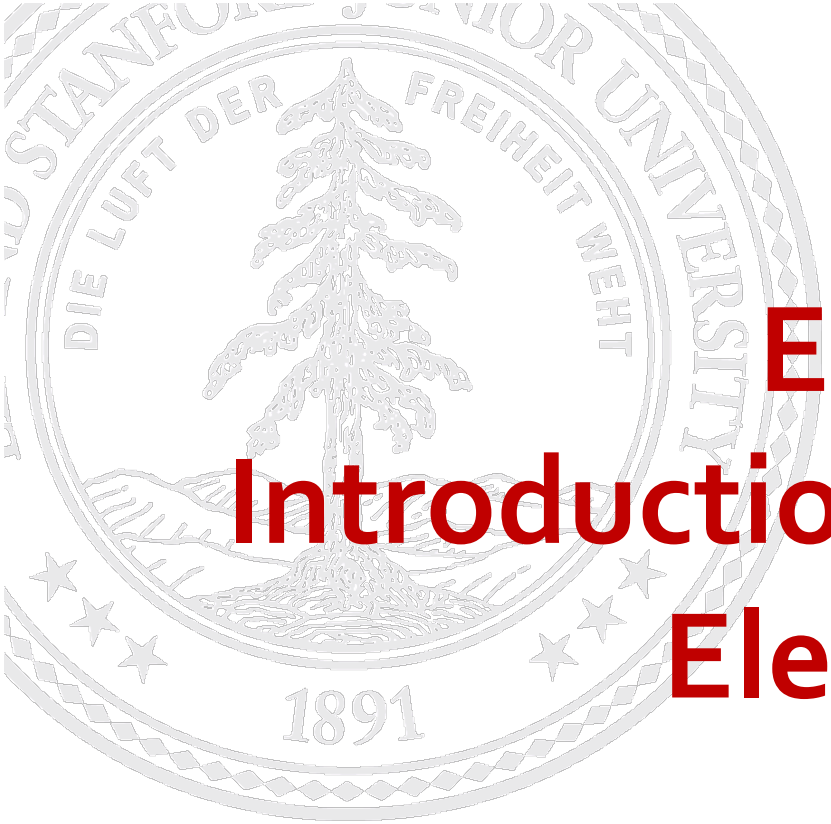


STANFORD
UNIVERSITY

EE122B
Introduction to Biomedical Electronics

Greg Kovacs, Laurent Giovangrandi

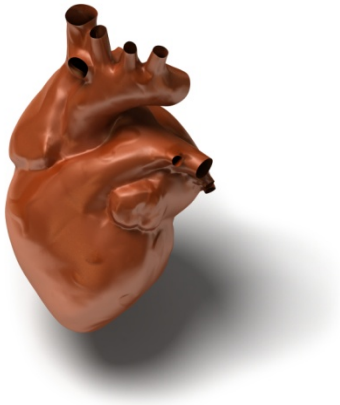
Spring 2015

Department of Electrical Engineering
Stanford University

Biomedical Electronics

Bio

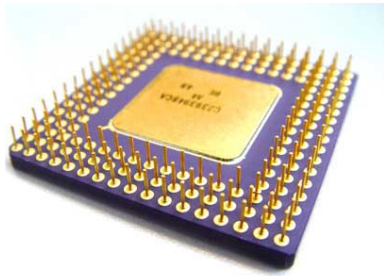
Molecules cells, organs, organisms



Medical

Related to practice of medicine

Electronics



You must already know the fundamentals if you are taking EE122B


Medtronic
Sensia
SEDRO1
OMRON
HEM-780
SYS
DIA
PULSE
140
88
86
THIS WEEK
SET
MEMORY
START
STOP
WelchAllyn
80
125
73

Course Philosophy

- Continuing in the spirit of EE122A (prerequisite) – practical, applied.
- Hands-on, laboratory learning – you get out what you put in.
- Lectures on practical subjects – require EE122A knowledge – if you don't have the background, please drop the class.
- Small-team-based approach to learning.
- Preparation for laboratories will involve some research and analysis.
- Labs are a key component of the learning experience. Lab work is recorded in lab books (one per team, both must make entries) and summarized in short lab reports.
- Grading is based on laboratory notebooks, reports, teamwork, and final project.
- Multi-week final project of your choosing with our approval, but we can help decide.
- Mandatory final demos given by each team to the entire class.
- Final write-up is an "Instructable."

EE122B Course Goals

- Overview of practical biomedical electronics.
- Provide necessary physiology background.
- Understand and apply basic concepts of biological and physiological sensing (and actuation).
- Give first-hand experience in designing and testing simple biomedical **systems**.
- Teach a system approach to biomedical electronics, including signal sensing, conditioning, conversion, analysis, calibration.

Course Content

- Biomedical instrumentation specifics
  - Safety
  - Noise
- Basics of data acquisition (used in labs)
- Cellular Electrophysiology
- Surface biopotentials (ECG, EEG, EOG,…)
- Tissue impedance (plethysmography, ICG,…)
- Sound, pressure, acceleration (phonocardiography, blood pressure)
- Optical sensing (photoplethysmography, SpO_2,…)
- Electrochemical sensing (oxygen, glucose,…)
- Projects (deeper exploration in teams)

Prerequisites

- EE122A or no-kidding equivalent from another institution is a prerequisite for EE122B.
- You need to know these things from EE122A:
  - Practical understanding of Fourier and Laplace.
  - Op-amp configurations (negative and positive feedback)
  - Active filters (op-amp, switched capacitor, DSP)
  - Op-amp-based oscillators
  - Basic test equipment (multimeter, scope, frequency analyzer, signal generator)
  - Circuit simulation (any package – LTSpice, Multisim,…)
  - Analog breadboarding / prototyping (hands-on experience)
  - Arduino programming and hardware fundamentals.

Grading Breakdown (Subject to Change)

- Laboratory notes (PDF, turned in at end) 20%
- Formal write-ups 20%
  - Prelab (10%)
  - Lab write-up (10%)
- Final project (demo + instructable write-up) 40%
- TA evaluation of laboratory skills (individual) 10%
- Faculty evaluation of knowledge (individual) 10%

100%

Grading

- EE122B is a hands-on, laboratory class.
- CR/NC grading is not offered.
- Auditing is only offered under exceptional circumstances, since this is a laboratory class.

Circuit & Filter Simulation

- Some of the pre-labs will require circuit simulation, as will the project.
- The class assumes prior exposure to circuit and filter simulation.
- Multisim (from EE122A), or LT Spice (http://www.linear.com/designtools/software/, free) should cover most of the needs.
- For filter design, FilterCAD (Linear) or FilterPro (TI) work great:
  - FilterCad: http://www.linear.com/designtools/software/#Filter
  - FilterPro: http://focus.ti.com/docs/toolsw/folders/print/filterpro.html

Data Acquisition and Analysis

- We will use Matlab® to record data on the computer, analyze and plot.
- A basic introduction (if necessary) will be given at the first review session.
- Matlab® is available on campus, and is installed on all lab computers.

Lab Notebook – Good Practices

- For each new lab:
  - Identifiers: name, date, title
  - Objective(s) for the project
  - Record of work done in the lab:
    - Schematics
    - Test conditions (voltages, currents, etc.) to allow someone else to reproduce what you did.
    - Observations
    - Inventions and ideas
    - Pasted in data, plots, photos, as needed (glued, ideally)
    - Other important details.
- The goal is to fully document your work. This is a vital document for inventions (http://otl.stanford.edu/inventors/resources/labnotebooks.html)
- **Keep it neat**
- Bound notebooks or date-stamped electronic notekeeping must be used.
- Only one set of notes is required per team.
- **Again: Keep it neat**.
- Lab notes are collected at the end of the quarter only as a PDF file.

Prelabs

- Prelabs are meant to **save you time** in the lab.
- Prelabs are due **at the start** of the related lab.
  Please bring it completed to the lab:
  - You cannot start your lab before handing out the pre-lab!
  - A **penalty of 25%** of the prelab grade will be applied if late.
- Students are expected to work together on all aspects of each prelab.
- Splitting ("You do part one, I'll do part two.") or rotation ("You do this week, I'll do next") is ***not acceptable.***

Labs

- One weekly session of four hours (to be arranged, usually Wednesday or Thursday)
- Come prepared!
- Curiosity is strongly encouraged.
- Student are expected to work together at each lab, **arrive promptly**, and attend consistently.
- Students who are consistently late will have their grades adjusted downward.

Lab – Safety and Respect

- Some labs requires to apply electrodes on the skin. You do NOT have to do it if you are uncomfortable with this. You can simply ask someone else (e.g., your partner, the instructor or the TA) to serve as a test subject.
- While putting electrodes on, respect the other students, please (can do it privately in the restroom).
- ***Nobody – no exceptions – can be bodily connected to any circuit without instructor (not TA) approval.***
- All labs are **SAFE** if you follow the rules, but some are ***NOT PERMITTED*** for anyone with a pacemaker or other life-support device (ICDs,…). If so, please tell the instructor (this will remain confidential).
- All students must complete the Safety Agreement for the class or be removed from the course roster.

Lab Write-Ups

- Lab write-ups are due the **Monday** after the corresponding lab. PDF is preferred, hardcopy ok (due in class to your TA or by arrangement).
- Lab write-up guidelines:
  - Complete info on methods (voltages, currents, etc.).
  - Data and plots as necessary.
  - No unnecessary "fluff" like datasheets, paragraphs of poetry, etc.
  - Schematics - clear and readable, all pin numbers shown - as needed.
  - Conclusions clear and supported by data.
  - Keep the whole thing concise, neat, and organized.
  - Use of good grammar is important.

Projects

- EE122B projects are the occasion to design and build something not doable in one lab.
- Projects will span the last several weeks, but earlier starts are good.
- Start thinking about it early. You may need parts that we need to order.
- Properties of good projects:
  - Relevant to the course material (bio/medical)
  - Sufficiently complex to be significant (we will help you)
  - Carefully designed - not copied from a book or the web.
  - Fairly divided workload between team members.
  - Short, clear and organized presentation and demo.
- Not strictly limited to analog design – can use Arduino, our DSP shield, etc.
- Project proposals due in class, date TBD (around end of April)

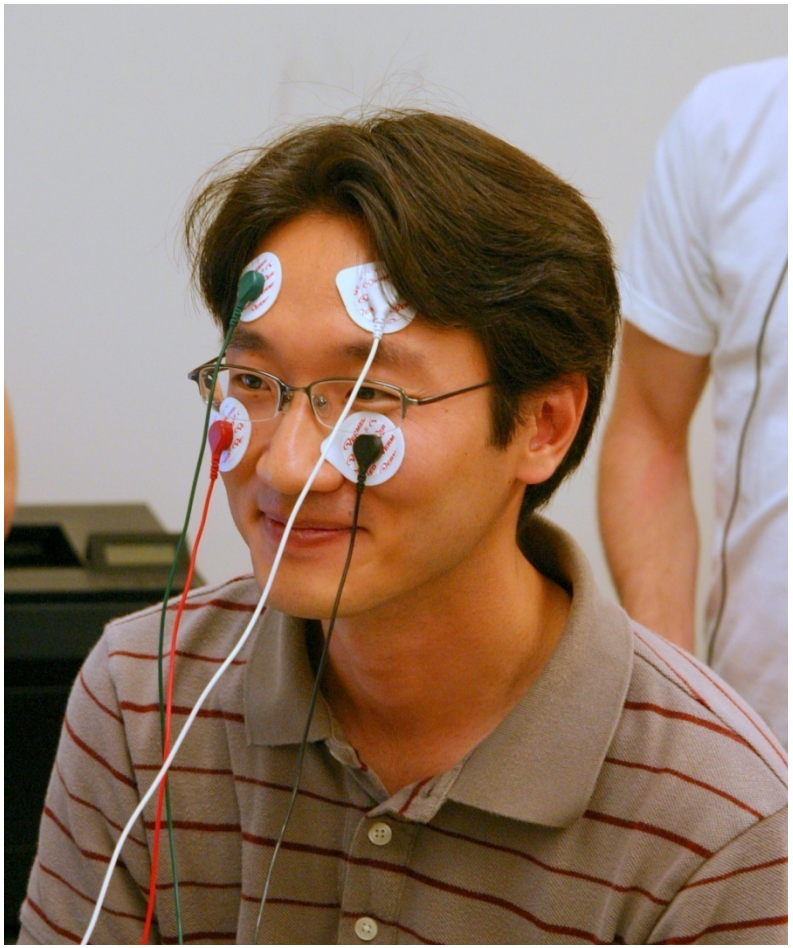
Demo & Write-Up

- EE122B demo day (mandatory – this is the "final exam") is scheduled for Monday, June 1st. Students must attend the entire session (normal class time, 2:15 – 4:05 pm.
- Nobody leaves until the lab is cleaned up completely.
- Write-ups are to be in "Instructables" format, with careful inclusion of all necessary elements (schematic, code, libraries, etc.) so that the work could be replicated.

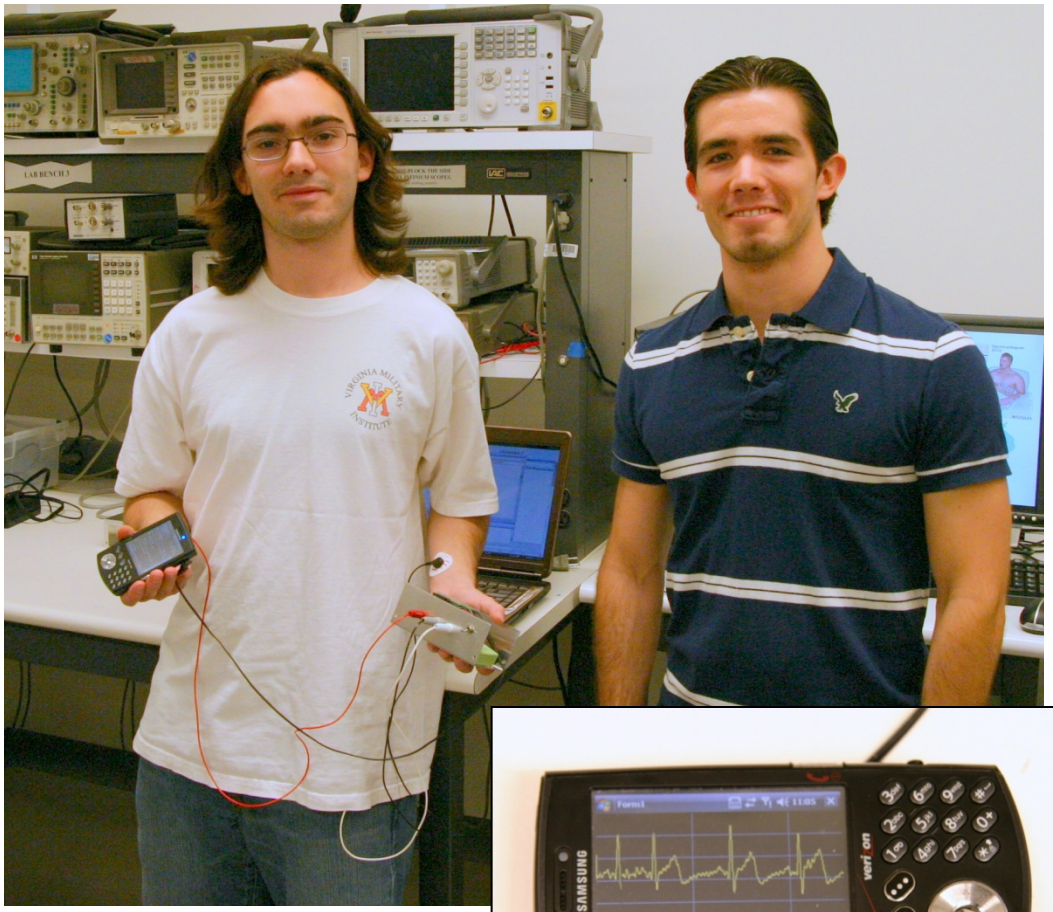
Projects Ideas

- Rate-dependant pacemaker (simulated…)
- Spyrometer (calibrated)
- ECG for cell phone (heart rate-based playlists!)
- Accelerometer-based doze detector
- Eyeblink-based sleepiness monitor
- Inductively-powered hearing aid
- Sensing via piercings
- SpO_2 sensor (dual-wavelength photoplethysmograph)
- Automated blood pressure cuff
- Emotional state estimation via sensor fusion
- Sleep optimization system
- Glucose sensor
- EEG-based games
- …

Examples Projects from Spring 2009

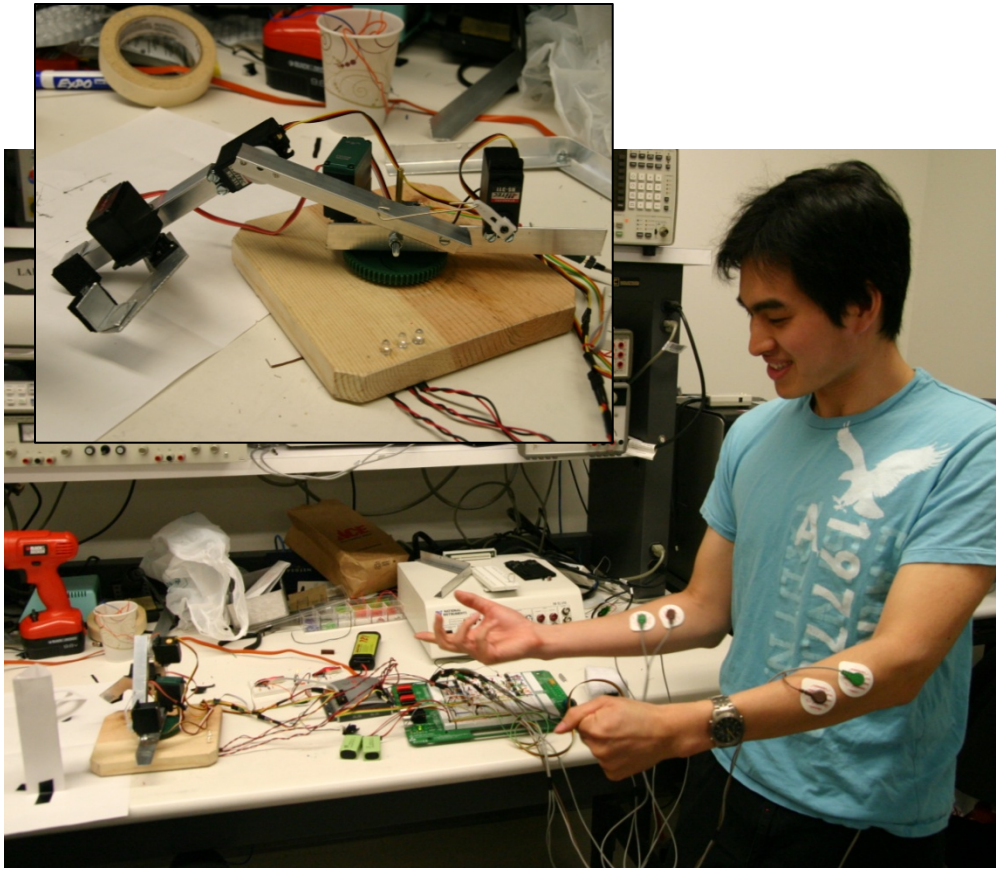


Electro-oculogram (EOG)-based input device

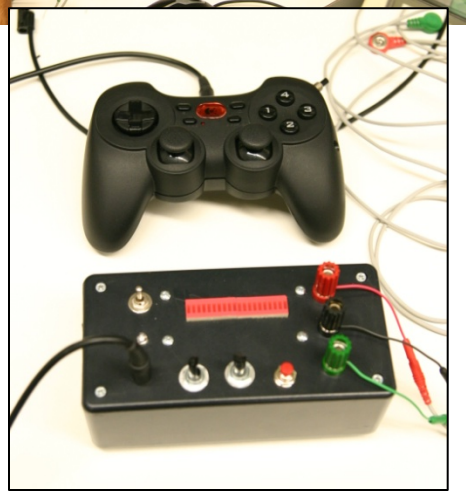


Cell phone-based Electrocardiograph (ECG)

Examples Projects from Spring 2010



Electromyogram (EMG)-based robotic arm controller



Electro-oculogram (EOG)-based game controller

Your Teaching Staff

- Greg Kovacs, Laurent Giovangrandi
  - Office: CISX-202 (Kovacs)
  - Office hours:
    - After lecture (typically group coffee in Packard lobby)
    - By appointment - please email and we'll set a meeting up.
    - TBD as needed during quarter.
  - Email (preferred): kovacs@cis.stanford.edu , giovan@stanford.edu
  - Phone: (650) 725-3637

- Bill Esposito
  - Email: wespo@stanford.edu

Two important persons who are here to help you with EE122B.

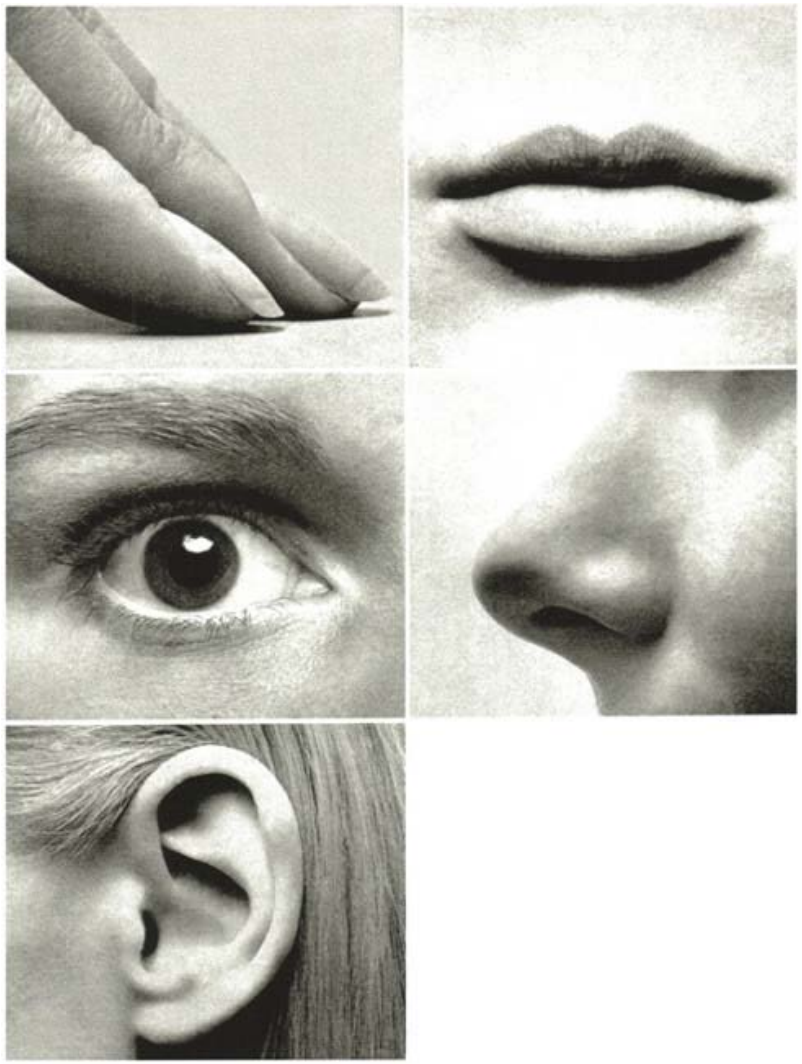
Steven Clark
Lab Manager
Packard 112, 723-1660
smclark1@stanford.edu

Claire Nicholas
Administrative Assistant
claireni@stanford.edu

Symptoms & Signs

- Symptoms are things a patient tells you (e.g., “my nose is running,” “I feel hot,” “my toe hurts”).
- Signs are things we detect that the patient is not aware of (e.g., high viral load of influenza, temperature of 102.4 °F, pus oozing from toe when squeezed).

Biomedical Instruments: Basics



www.ehumanbiofield.wikispaces.com

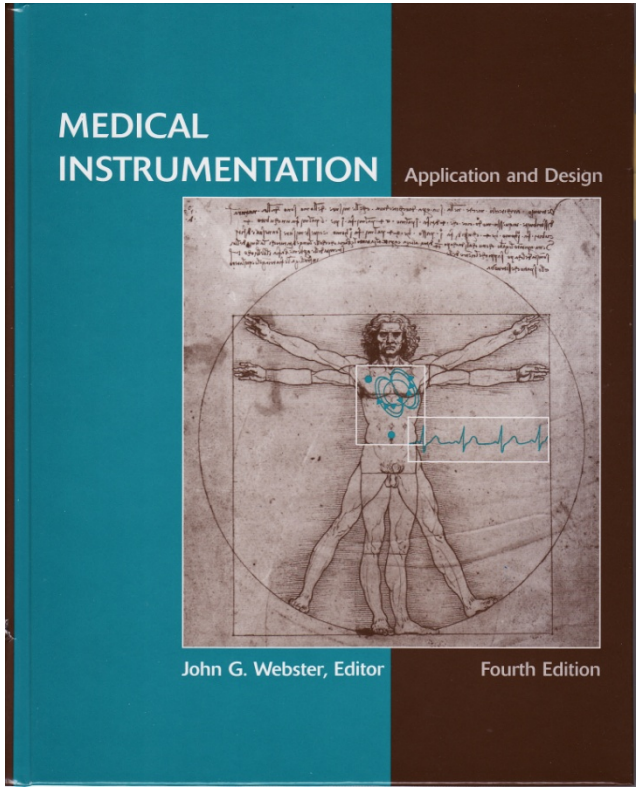
www.dentalorg.com

Safety Issues

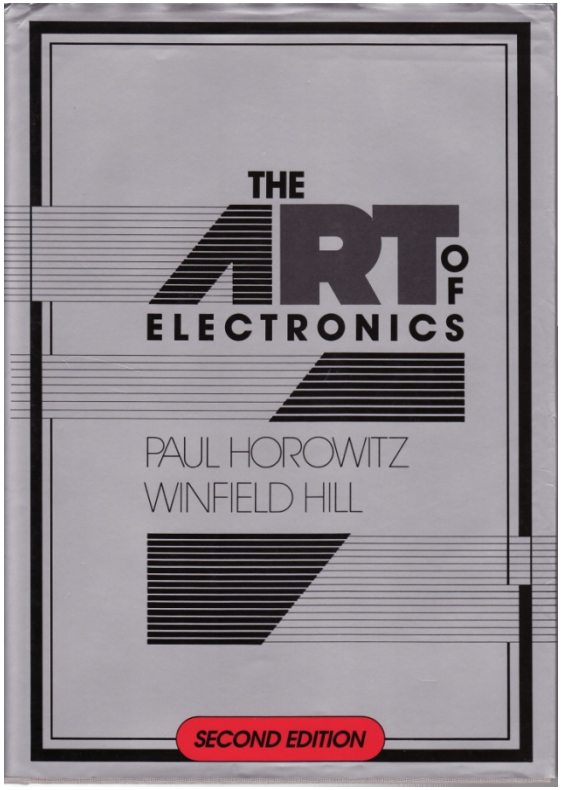
- No students can work in the lab without a TA present. ***No exceptions.***
- Always keep voltages below +/-15 V unless specifically authorized.
- No line-powered projects please. Use the bench power supplies, or batteries.
- Any circuits contacting the body must:
  1. Run on battery (±9V max).
  2. Be fully isolated (more on that later).
  3. Have been cleared by Greg or Laurent *BEFORE* use.

Resources for EE122B

Books, References



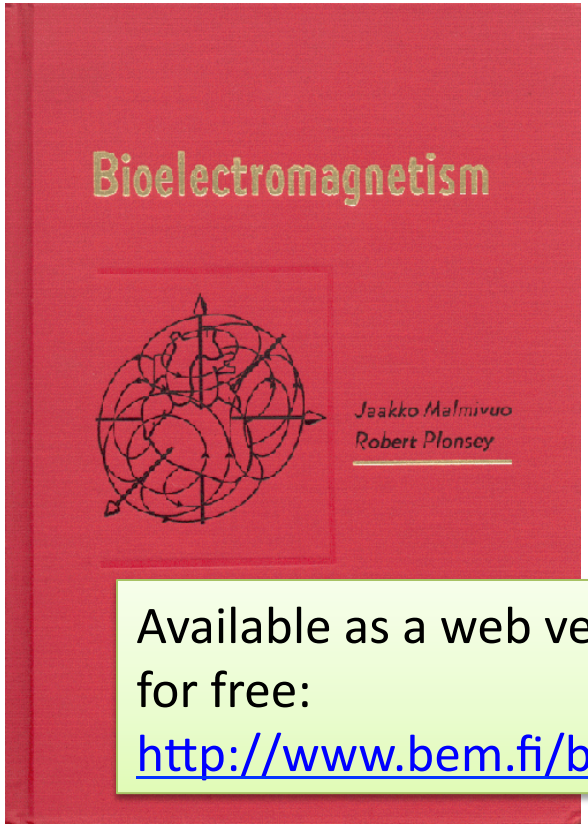
Medical Instrumentation,
J. Webster, 4th Ed., 2009,
Wiley



The Art of Electronics,
Horowitz & Hill, 2nd Ed.,
1989, Cambridge

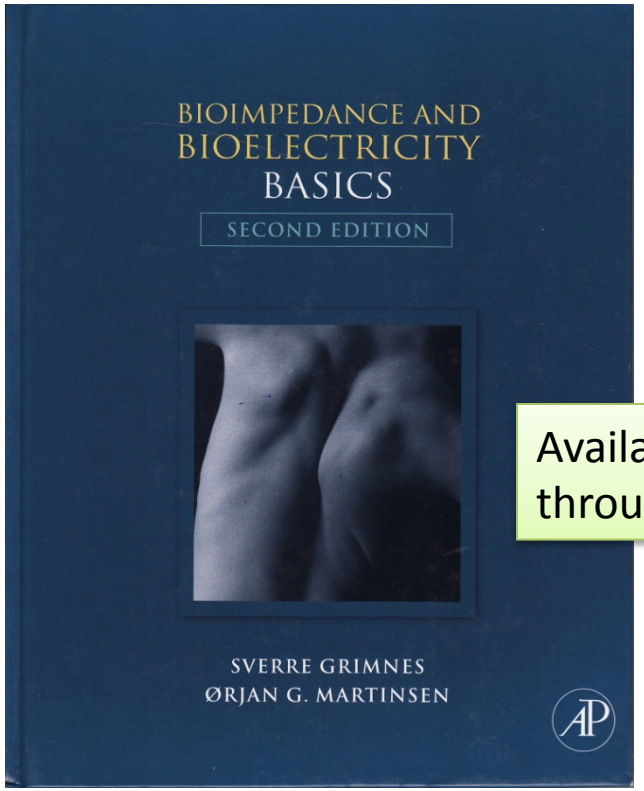
Copies on hold at Engineering Library

Books, References



Available as a web version for free: http://www.bem.fi/book/

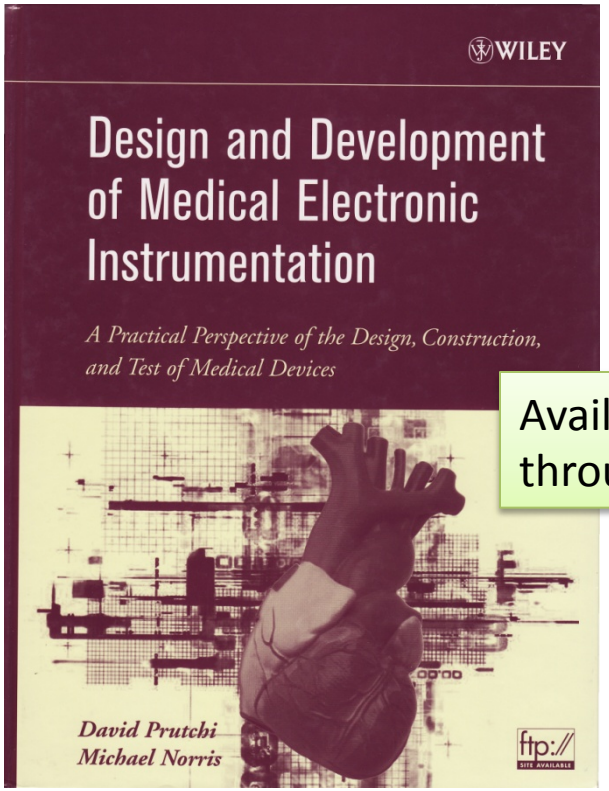
Bioelectromagnetism - Principles and Applications of Bioelectric and Biomagnetic Fields, Malmivuo & Plonsey, 1995, Oxford University Press, New York



Available online through Stanford

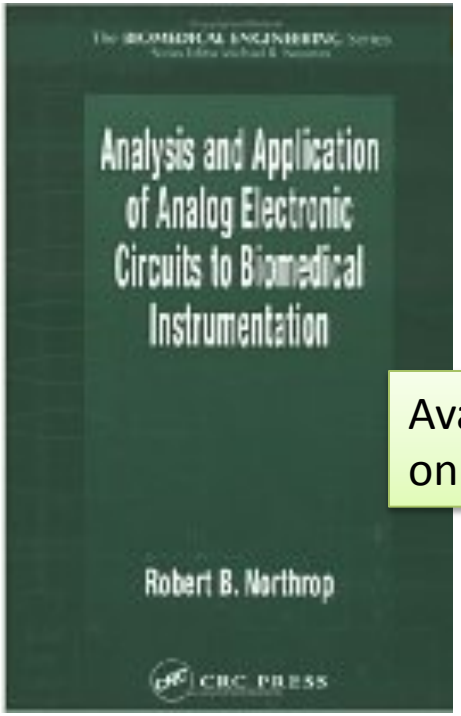
Bioimpedance and Bioelectricity Basics, Grimnes & Martinsen, 2nd Ed., 2008, Academic Press

Books, References



Available online through Stanford

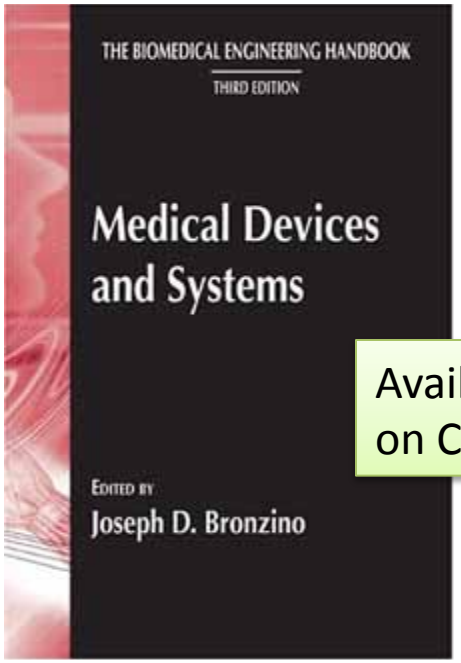
Design and Development of Medical Electronic Instrumentation: A Practical Perspective of the Design, Construction, and Test of Medical Devices, Prutchi & Norris, 1st Ed., 2004, Wiley



Available online on CRCnetBase

Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation, Northrop, 1st Ed., 2003, CRC Press

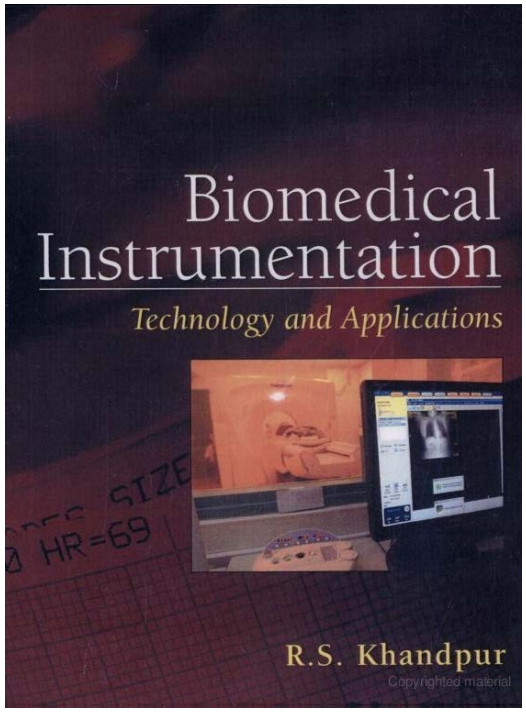
Other Books, References



Available online on CRCnetBase

The Biomedical Engineering Handbook, Joseph Bronzino, 3rd Ed., 2006, CRC Press:

- **Vol 1: Biomedical Engineering Fundamentals**
- **Vol 2: Medical Devices and Systems**
- Vol 3: Tissue Engineering and Artificial Organs



Biomedical Instrumentation: Technology and Applications, Khandpur, 1st Ed., 2004, McGraw-Hill Professional

Electronic References

- Stanford has access to many other electronic resources:
  - Morgan & Claypool Series, *Synthesis Lectures on Biomedical Engineering:* http://www.morganclaypool.com/toc/bme/
    - **A Biosystems Approach to Industrial Patient Monitoring and Diagnostic Devices**, Baura, 2008
    - **Introduction to Biomedical Engineering: Biomechanics and Bioelectricity**, Christensen , 2009
    - **Brain–Machine Interface Engineering**, Sanchez & Principe, 2007
    - **Neural Interfacing: Forging the Human-Machine Connection**, Coates, Jr., 2008
    - **Phonocardiography Signal Processing** , Abbas & Bassam, 2009
    - ...
  - CRC Press (CRCnetBase), *The Biomedical Engineering Handbook*
    - **Biomedical Engineering Fundamentals** http://www.crcnetbase.com.laneproxy.stanford.edu/doi/book/10.1201/9781420003857
    - **Medical Devices and Systems** http://www.crcnetbase.com.laneproxy.stanford.edu/doi/book/10.1201/9781420003864

And many more on Socrates (http://library.stanford.edu/)...

As for EE122A…

- Application notes and books from chip manufacturers like:
  - National Semiconductor
  - Linear Technology
  - Maxim
  - Analog Devices
  - Texas Instruments/Burr-Brown
- Electronics “cookbooks” (various) - check Fry’s and Jameco.

Good (New) Parts Sources

- Digi-Key - www.digikey.com
- Jameco - www.jameco.com (walk-in possible – up 101)
- Fry's - www.frys.com (doesn't list all items in store)
- Radio Shack - www.radioshack.com
- Sparkfun – www.sparkfun.com (specialized parts)
- Allied - www.alliedelec.com
- Newark - www.newark.com
- Hosfelt - www.hosfelt.com

Let us know of any others you find - they will be added to this list!

Surplus Sources

- Halted Specialties, Inc.
  - Great selection of parts.
  - 3500 Ryder St., Santa Clara, (408) 732-1573, www.halted.com
- Alltronics
  - Parts, some instruments, much junk.
  - 2300D Zanker Road, San Jose, (408) 943-9773, www.alltronics.com
- Gateway
  - Cool surplus parts
  - Various cities, (800) 669-5810, http://www.gatewaycatalog.com
- Resources Unlimited
  - can be hard to deal with, but have large selection of optics, lasers, and weird stuff.
  - Manchester, NH, (800) 810-4070
- All Electronics,
  - Van Nuys, CA, (888) 826-5432, http://www.allelectronics.com/
- Foothill and Livermore Swap Meets
  - Livermore 1st Sunday of every month March-November (http://www.livermoreark.org/swap/swap.html)
  - Foothill 2nd Saturday of every month March-October (http://www.electronicsfleamarket.com)