HOW TO MAKE AC CIRCUITS RELEVANT TO PRE-HEALTH AND LIFE SCIENCE STUDENTS
TWO LAB ACTIVITIES: EKG AND BIA

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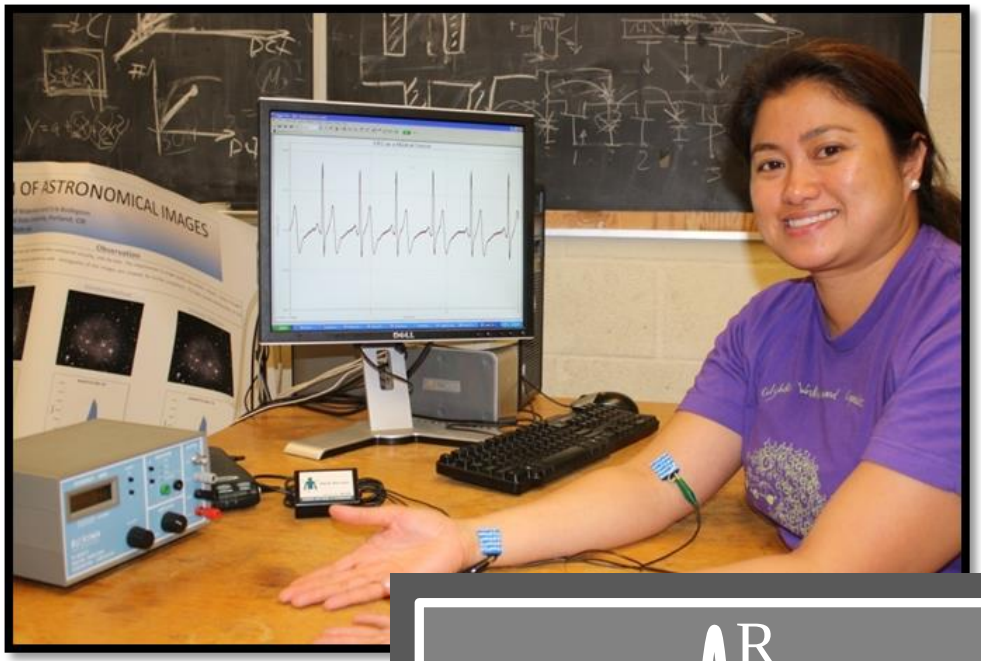
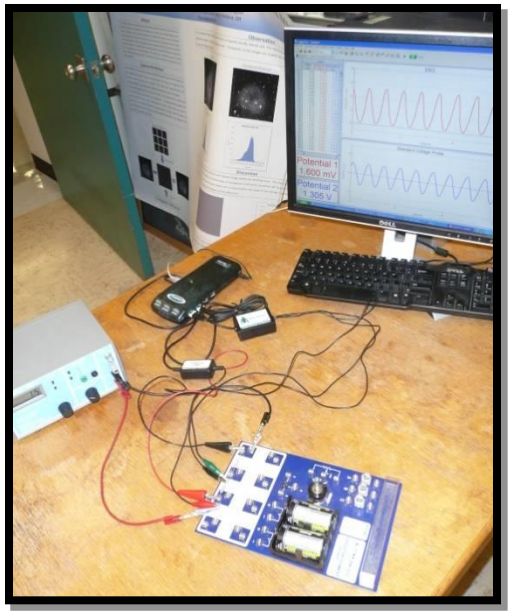
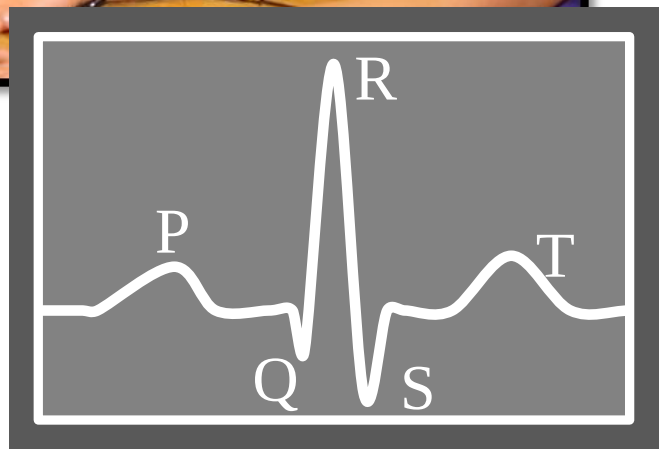
The Electrocardiogram (EKG or ECG)

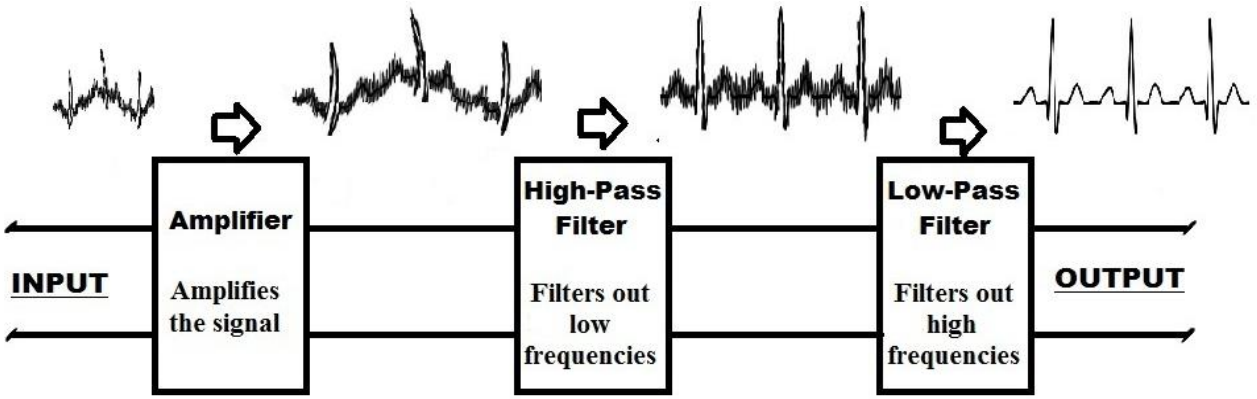






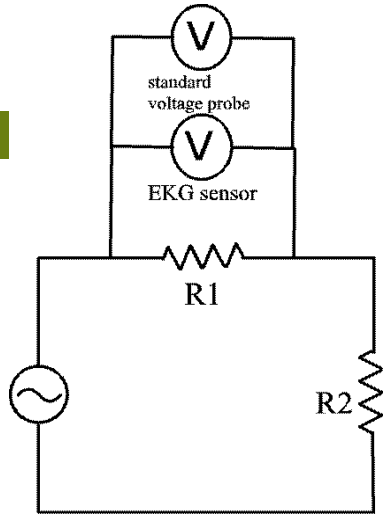
The EKG sensor

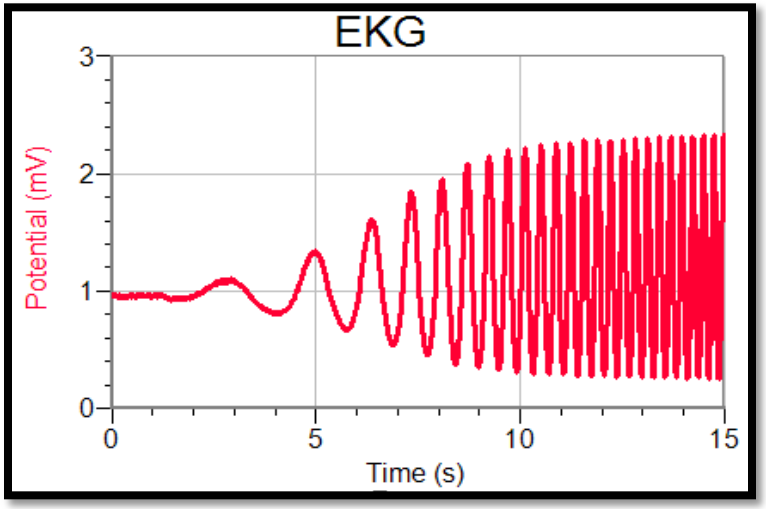
- Amplifies signals
- Acts as a band-pass that filters high and low-frequency noise and bias offsets
- Nine experiments in three Parts
  - Part One- The EKG
  - Part Two- The EKG as a voltage probe
  - Part Three- Noise reduction in the EKG



Noise reduction in the EKG

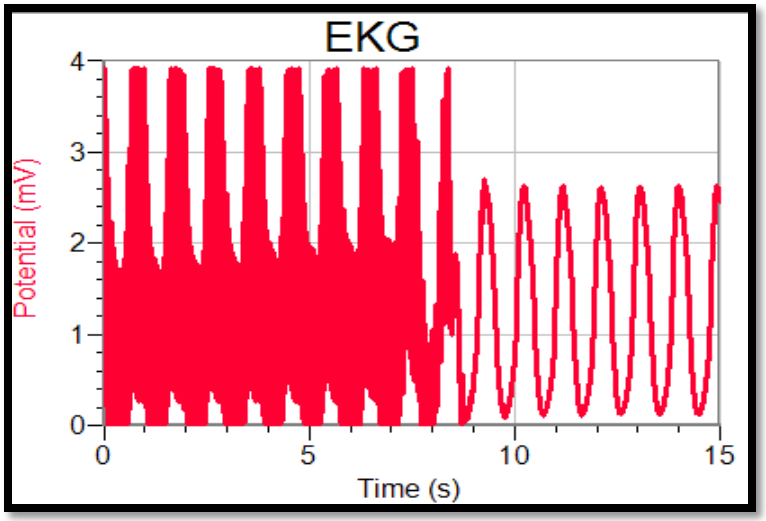
- Range of filtered frequencies are explored





Frequency is varied from 0.1 to 5 Hz

Varying frequency to determine band-pass limits of the EKG

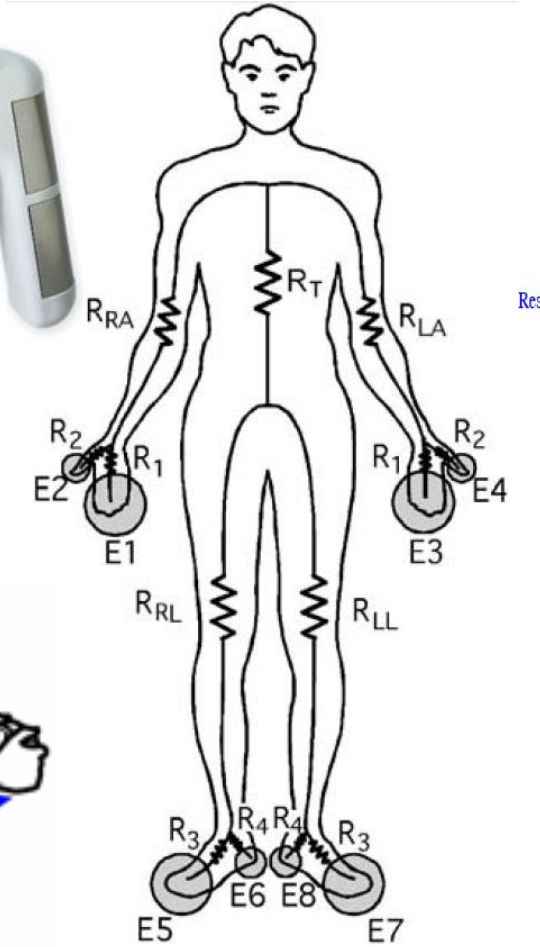


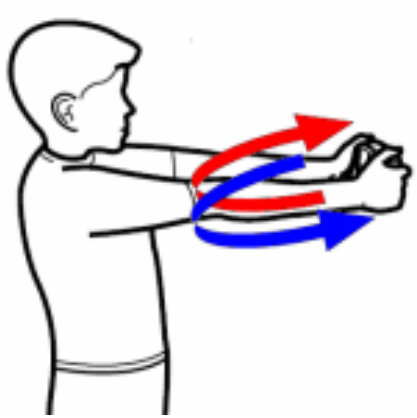
High frequency noise set at 60 Hz and 433 Hz. Signal at 1 Hz.

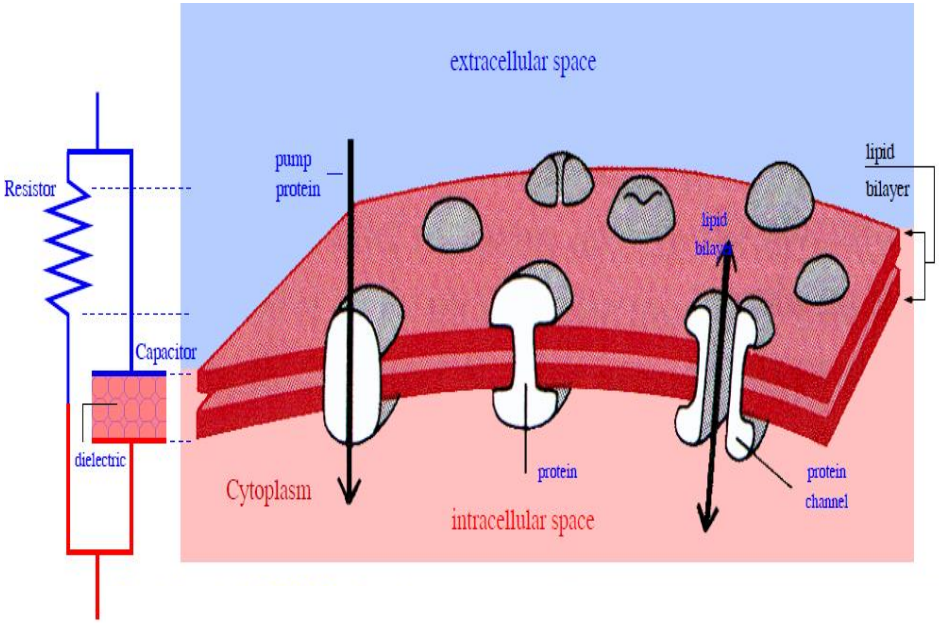
Introducing and filtering high and low-frequency noise sources.

Bioelectrical Impedance Analysis

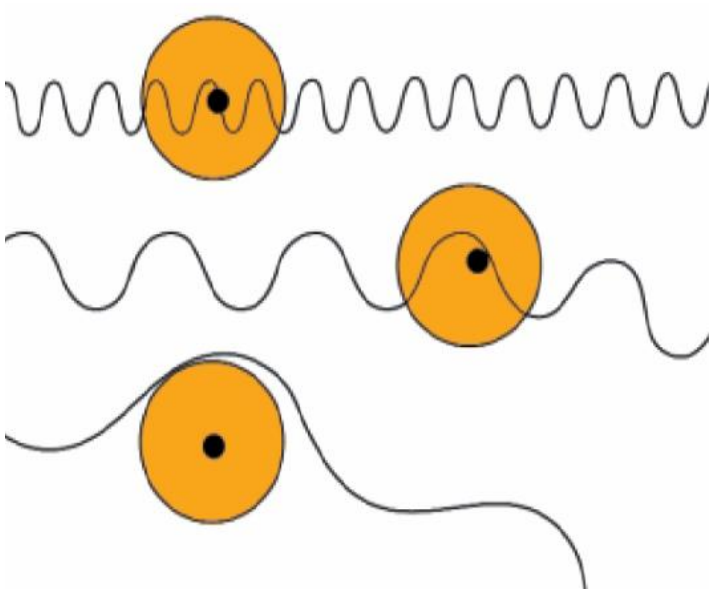
OMRON Body Fat Analyzer (healthgoods.com)



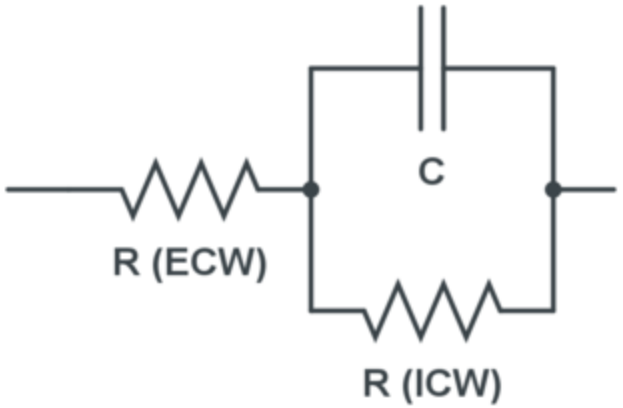




Series Equivalent Circuit



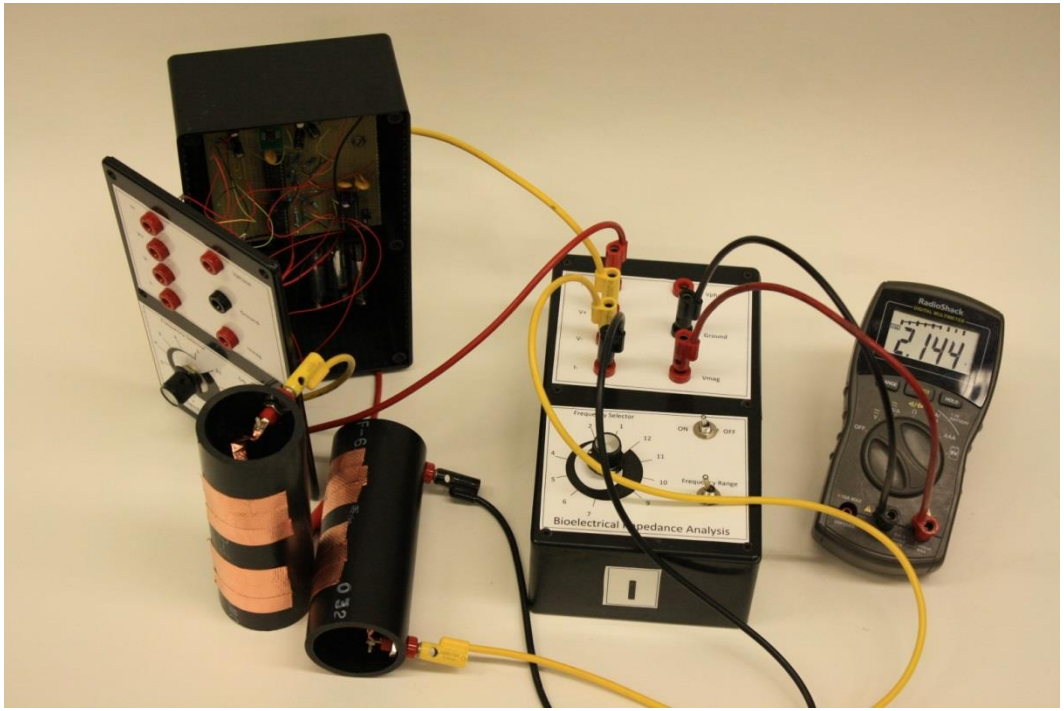
Bio-Impedance Analysis BIA
Evaluation of Nutrition and Hydration Status Using Vectorgram and BiaGram, (rjlsystems.com)

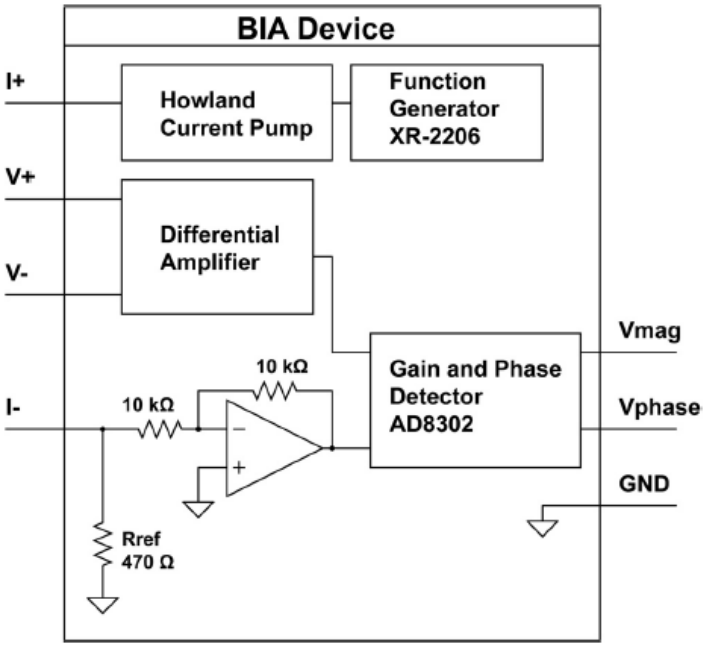


Single Frequency Series Equivalent

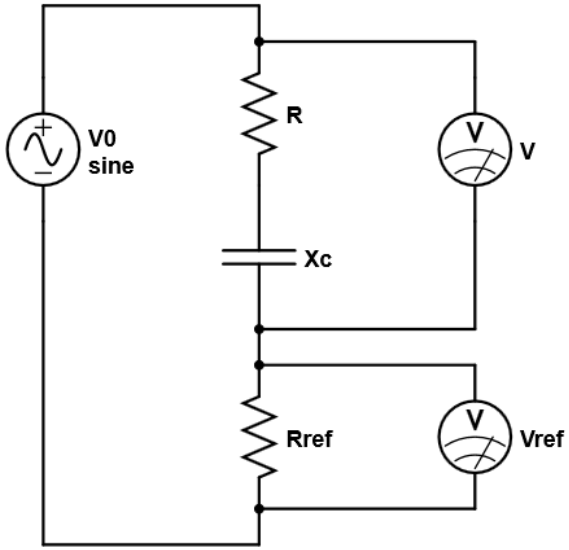
- Body impedance frequency dependent
- For a single frequency, intricate body model circuits are approximated with simple series circuit
- Single Frequency BIA uses 50kHz

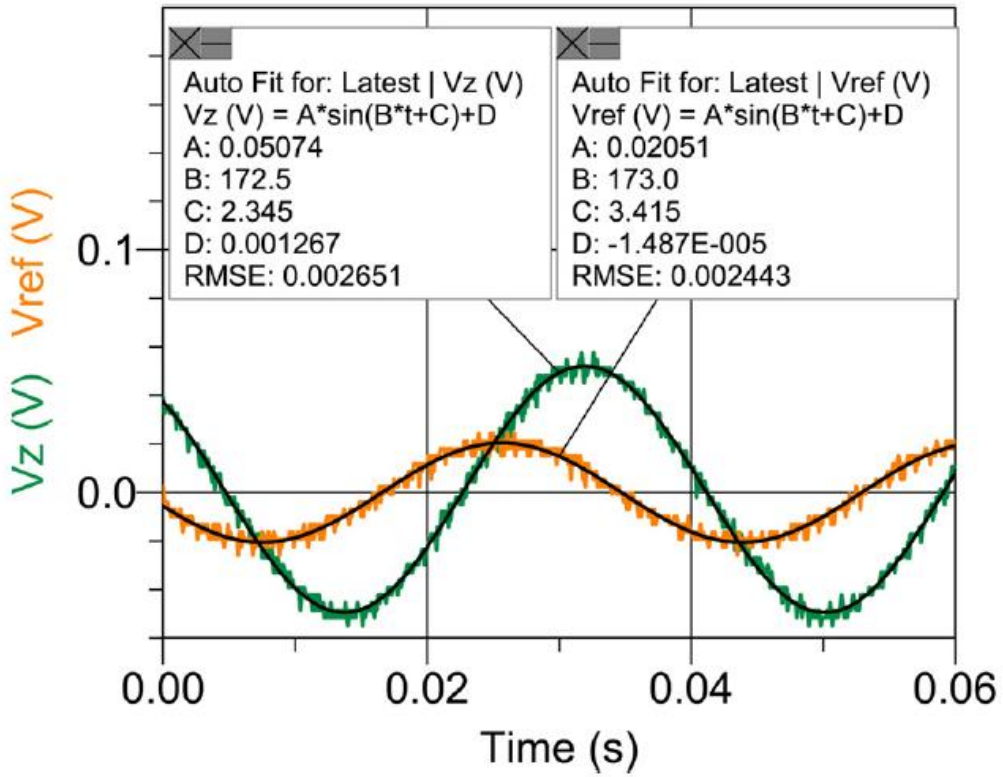
BIA device


RadioShack
2144
Bioelectrical Impedance Analysis


BIA Device
I+
V+
V-
I-
Howland Current Pump
Function Generator XR-2206
Differential Amplifier
Gain and Phase Detector AD8302
10 kΩ
10 kΩ
Rref 470 Ω
Vmag
Vphase
GND

Circuit Analysis – Method I

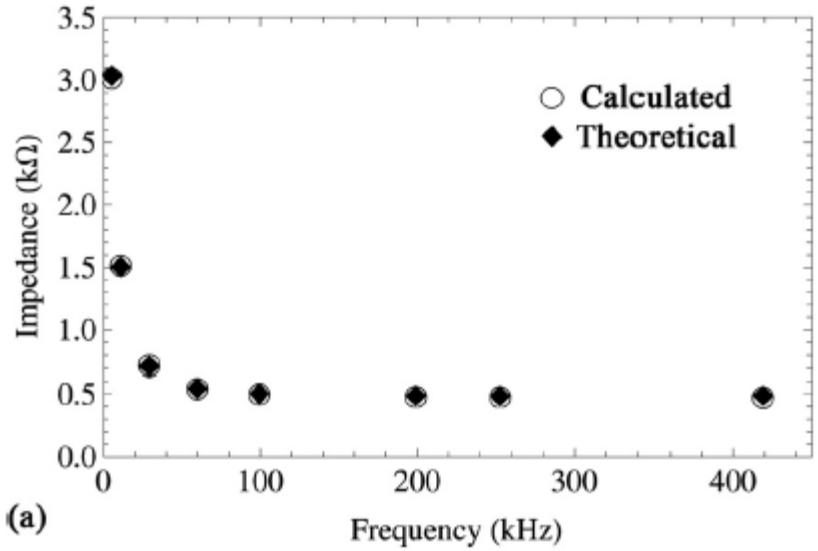


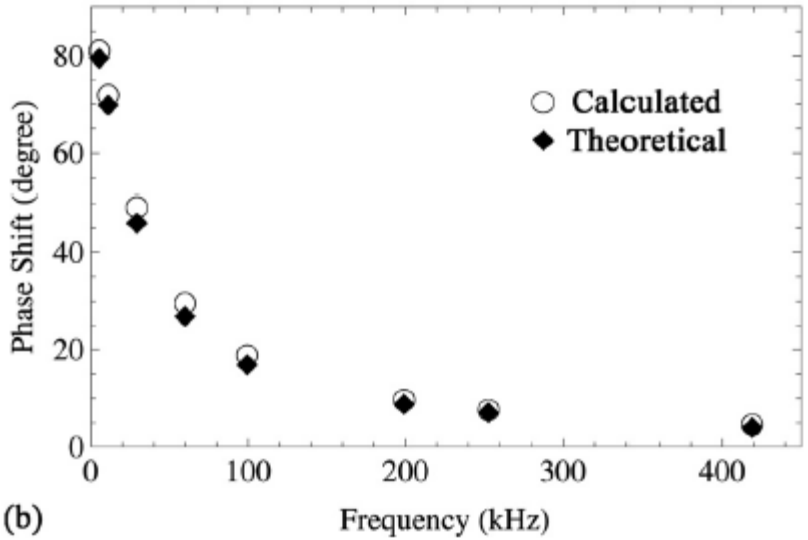


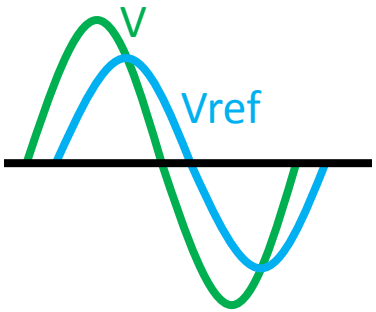
$$V_{ref} = V_{pp2} sin(2\pi f t + \varphi_2)$$

$$V = V_{pp1} sin(2\pi f t + \varphi_1)$$

Circuit Analysis – Method II





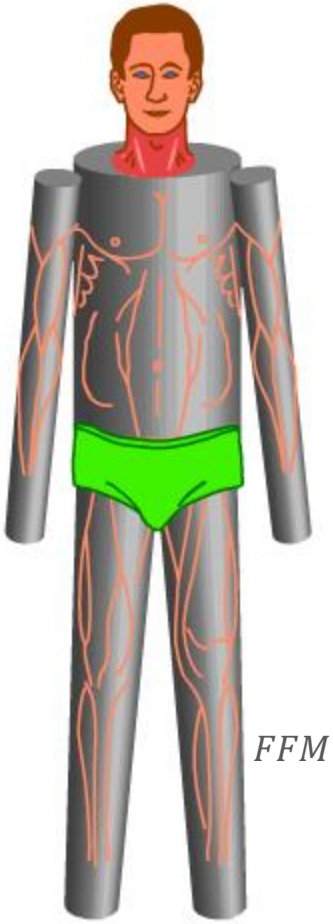


Gain & Phase Detector

$$V_{mag} \propto \log_{10} \frac{Z}{R_{ref}}$$

$$V_{phs} \propto \varphi$$

Mass Calculation – Fat Free Mass (FFM)



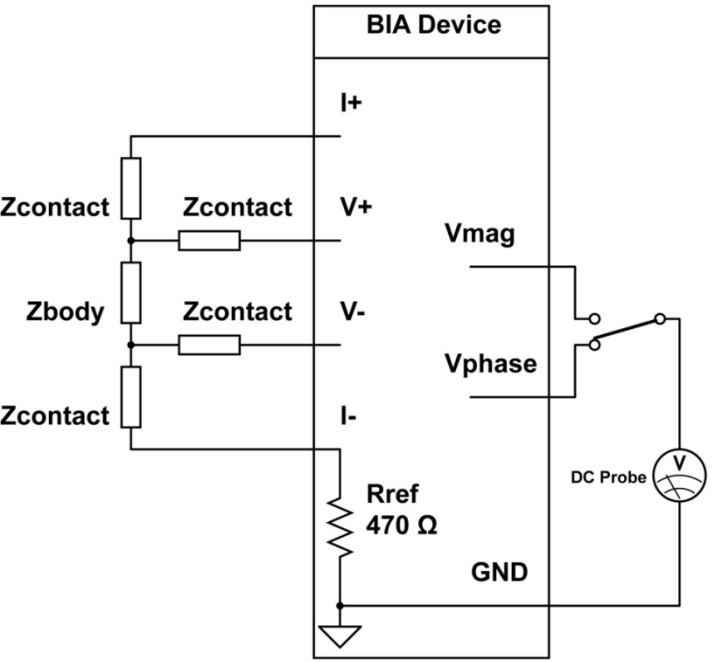
- In human testing
  - Cylinder model
  - Density approximately equal to that of water
  - Coefficients and fitting factors empirically derived
  - Fat mass not measured
- Reactive components due to cellular walls
- Resistive components due to both intra- and extracellular fluid
- Current flows primarily through Fat Free Mass

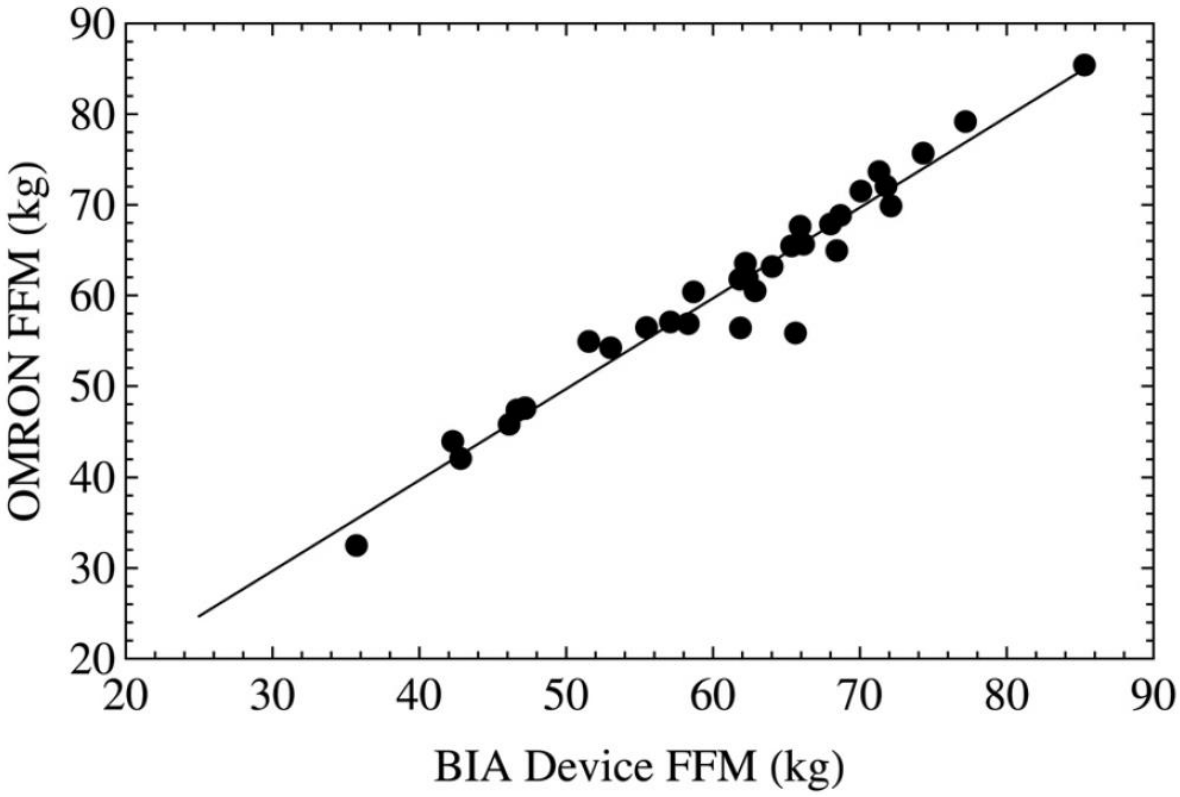
$$FFM = 0.360 \cdot \frac{Height^2}{R} + 0.162 \cdot Height + 0.289 \cdot Weight - 0.134 \cdot Age + 4.83 \cdot Gender - 6.83$$

Gender: Female = 0, Male = 1

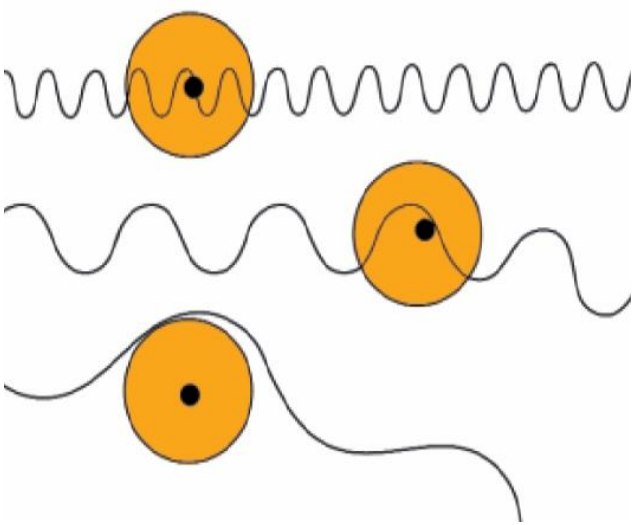
http://nutrition.uvm.edu/bodycomp/bia/lesson4.html

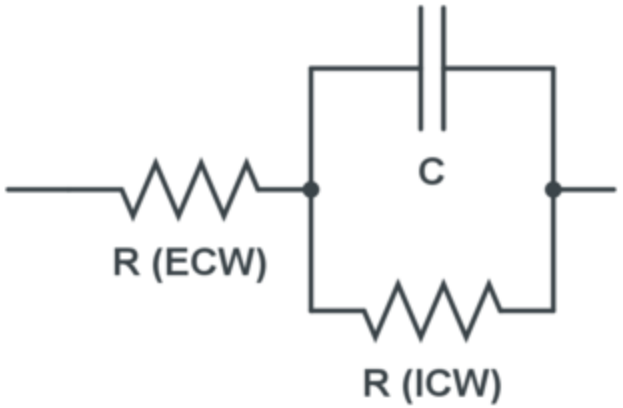
OMRON vs. our BIA device

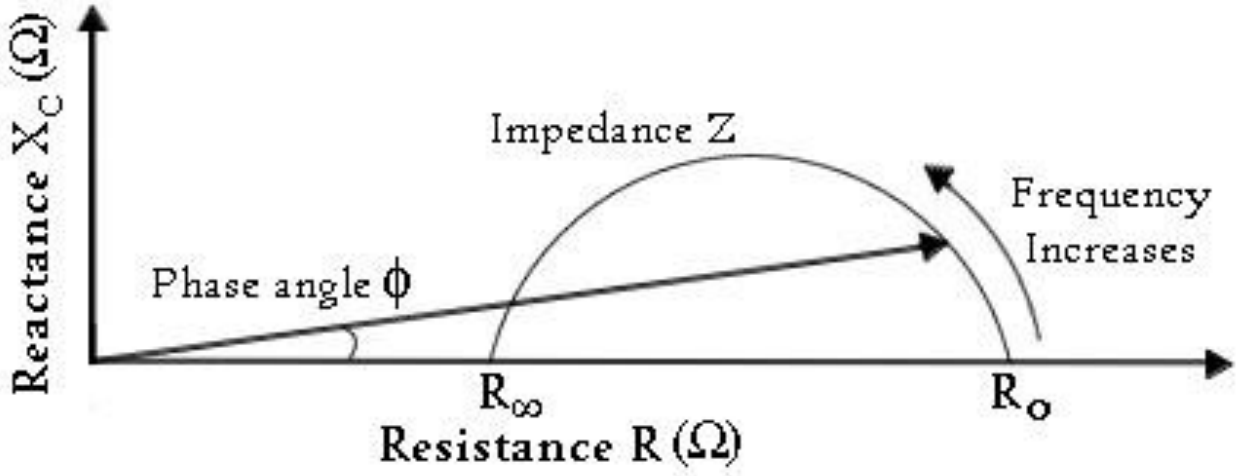




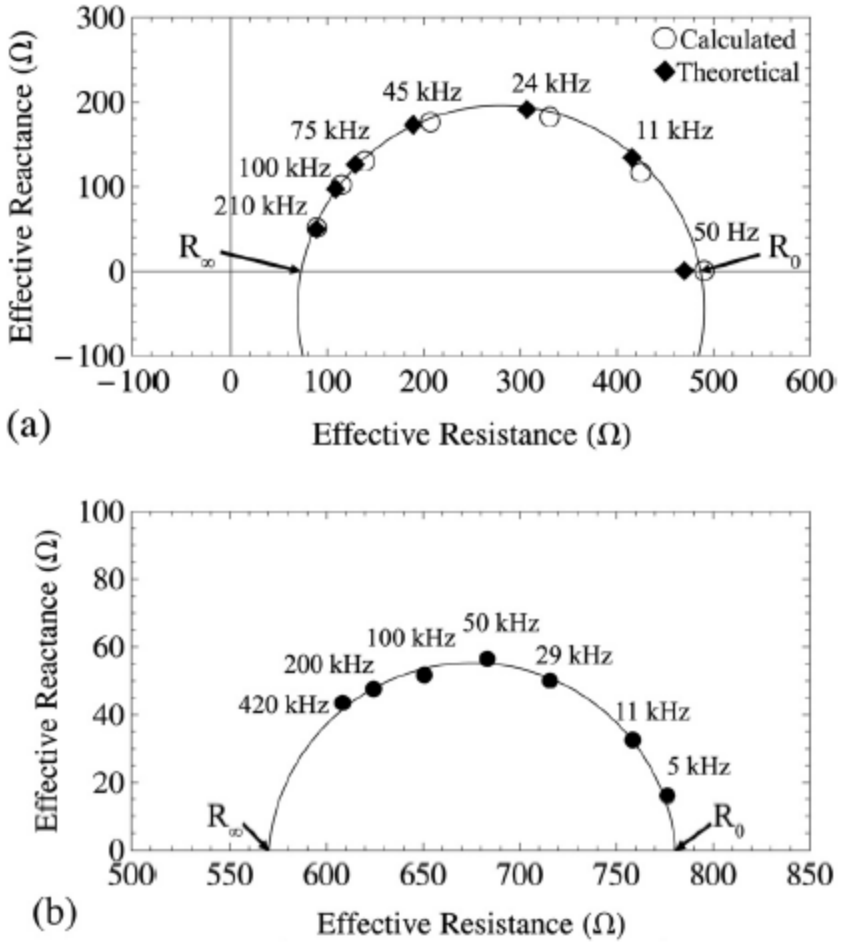
Multi-frequency BIA







Multi-frequency data



Resources

The labs are part of a series of activities designed to improve understanding of medical instrumentation as well as the human body:

Elliot E. Mylott, Justin C. Dunlap, Ryan Klepetka, Ralf Widenhorn , An easily assembled laboratory exercise in computed tomography, 2011 Eur. J. Phys. 32 1227

G. R. Van Ness and Ralf Widenhorn. Engaging the community through an undergraduate biomedical physics course. American Journal of Physics 80, 1094-1098 (December 2012).

Warren Christensen, James K. Johnson, Grace R. Van Ness, Elliot Mylott, Justin C. Dunlap, Elizabeth A. Anderson, and Ralf Widenhorn, Developing and Assessing Curriculum on the Physics of Medical Instruments, CBE Life Sci Educ. 2013 Jun 1;12(2):250-61

Ellynne Kutschera, Justin C. Dunlap, Misti Byrd, Casey Norlin, Ralf Widenhorn, Pulse oximetry in the physics lab: a colorful alternative to traditional optics curriculum, The Physics Teacher,Vol. 51, 495-497, November 2013

Elliot Mylott, Ellynne Kutschera, and Ralf Widenhorn, Bioelectrical Impedance Analysis as a laboratory activity: at the interface of physics and the body, American Journal of Physics 82 (5), 521-528, May 2014

http://web.pdx.edu/~ralfw/bia.html

http://web.pdx.edu/~ralfw/ekg.html

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Thank you for your attention!