Portable Impedance Tomography Platform

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CPE 621, Fall 2017

Introduction

- The impedance of an object can provide meaningful insight into the composition of a particular object.

- Tomography is a technique for displaying a representation of a cross section though a human body or other solid object.
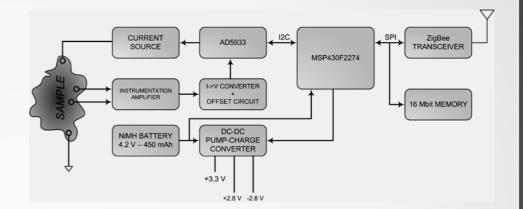
Project Goals

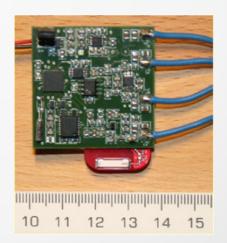Demonstrate a portable solution for bioelectrical impedance measurements.

Features:

- Single Frequency Impedance Measurement
- Frequency Swept Impedance Measurement
- Two-Dimensional Impedance Measurement
- Wireless Connectivity

AD5933 in the wild (Bogonez et. al)

- Zigbee Communication
  - -10dBm
  - Interface to PC with Application
- Multi-frequency 0.1-200kHz
  - Effective out to 60kHz
- 35 day runtime, 5 min sample rate
- Assess temperature impacts on measurements. Negligible
- Studies RF Implantable Solution
- Tested/Installed into farm animals. RF levels required were lower than ICNIRP regulations
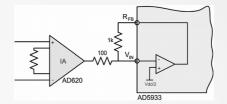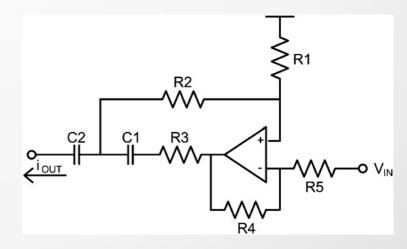
P. Bogónez-Franco, R. Bragós, A. Bayes-Genis, and J. Rosell-Ferrer, "Implantable bioimpedance monitor using ZigBee," in Engineering in Medicine and Biology Society, 2009. EMBC 2009. Annual International Conference of the IEEE, 2009, pp. 4868–4871.

P. Bogónez-Franco, L. Nescolarde, C. Gálvez-Montón, R. Bragós, and J. Rosell-Ferrer, "An implantable bioimpedance monitor using 2.45 GHz band for telemetry," Physiological measurement, vol. 34, no. 1, p. 1, 2012.

AD5933 in the wild (Bogonez et. al)

- Voltage Sense

  – AD820 differential amplifier

- Uses modified Howland current source

  – 10uA 100Hz to 200kHz

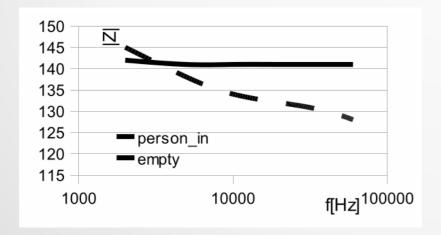- Errors at low frequency due to high electrode contact resistance.

P. Bogónez-Franco, R. Bragós, A. Bayes-Genis, and J. Rosell-Ferrer, "Implantable bioimpedance monitor using ZigBee," in Engineering in Medicine and Biology Society, 2009. EMBC 2009. Annual International Conference of the IEEE, 2009, pp. 4868–4871.
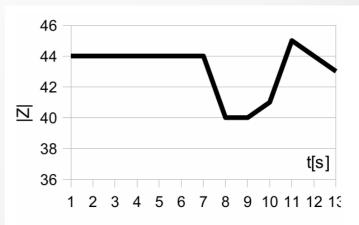
P. Bogónez-Franco, L. Nescolarde, C. Gálvez-Montón, R. Bragós, and J. Rosell-Ferrer, "An implantable bioimpedance monitor using 2.45 GHz band for telemetry," Physiological measurement, vol. 34, no. 1, p. 1, 2012.

AD5933 in the wild (Bujnowski et. al)

- Detecting bathtub presence
  - Characterized tap water, soap, salts.
  - Active vs inactive
  - Single vs multi frequency
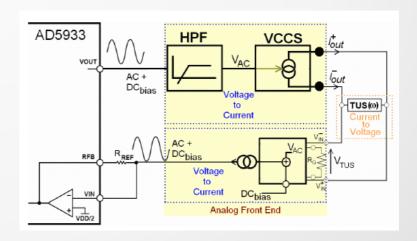- Howland Current Source Drive

A. Bujnowski, A. Palinski, P. Koscinski, L. Skalski, A. Skurczynska, and J. Wtorek, "Detection of person presence and its activity in the bathtub," in Journal of Physics: Conference Series, 2013, vol. 434, p. 012035.

AD5933 in the wild (Pena)
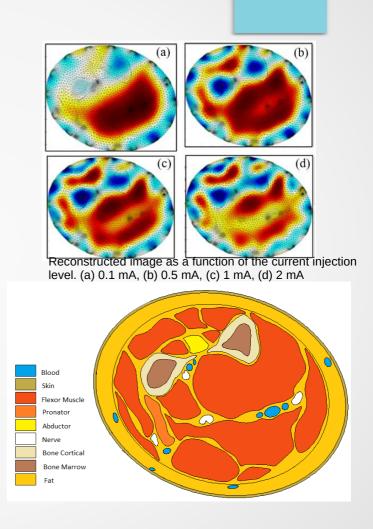
- Masters Thesis

  - Compares AD5933 to ImpediMed SFB7

  - Evaluated against

    - Arm-Arm

    - Respiration Rate

    - Leg-Leg

    - Lung Composition

    - Total Body Composition

    - Trunk-Trunk

TABLE 5.1 RELATIVE ERROR: SFB7 VS. AD5933+4-AFE

SFB7/AD5933	Ri		Cm		Re		Fc	
AA	0.01%	1.36%	1.47%	1.65%	0.06%	0.31%	1.52%	1.11%
RR	0.08%	1.63%	1.50%	2.14%	0.29%	1.03%	1.70%	2.42%
LL	0.20%	1.20%	0.78%	0.94%	0.14%	0.19%	0.80%	0.48%
LC	0.44%	3.63%	2.16%	2.97%	0.16%	0.53%	2.24%	2.68%
TBC	0.14%	1.64%	2.22%	1.47%	0.04%	0.36%	2.31%	1.01%
TT	0.04%	2.13%	7.19%	8.25%	0.11%	0.36%	7.82%	8.54%

A. Ansede Pena, "A Feasibility Study of the Suitability of an AD5933-based Spectrometer for EBI Applications," 2009.
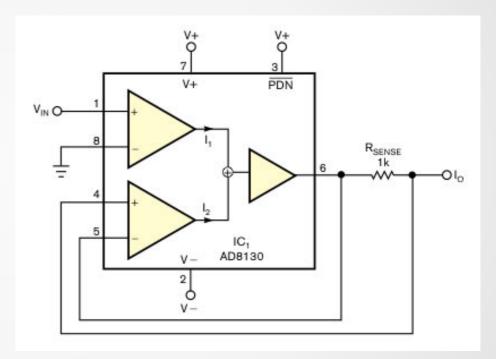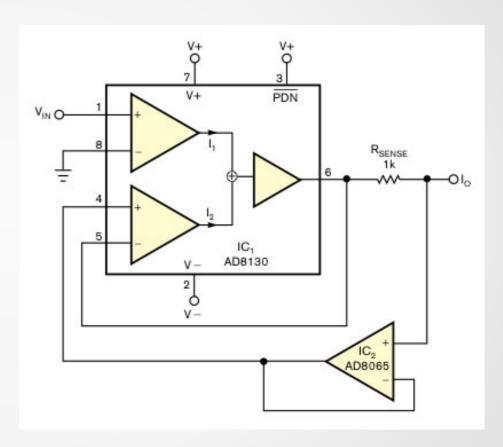
Image reconstruction (Vilchez-Monge et al.)

- Tomography of forearm

- Inverse Problem - Voltage is used to predict base model

- Forward Problem – Uses conductivity base and current applied to predict voltage fields.

- Image Reconstruction – open source EIDORS

Reconstructed image as a function of the current injection level. (a) 0.1 mA, (b) 0.5 mA, (c) 1 mA, (d) 2 mA

Blood
Skin
Flexor Muscle
Pronator
Abductor
Nerve
Bone Cortical
Bone Marrow
Fat

M. Vilchez-Monge, D. Canales-Vasquez, and R. Rimolo-Donadio, "Image Reconstruction of the Human Foearm by Electrical Impedance Tomography," in 2017 International Conference and Workshop on Bioinspired Intelligence (IWOBI), 2017, pp. 1–6.

Constant Current Source (Birkett)

- 2005 Birkett Article Explains Constant Current Source

A. Birkett, "Bipolar current source maintains high output impedance at high frequencies," Design Idea, 5-2005. [Online]. Available: https://www.edn.com/design/analog/4324499/Bipolar-current-source-maintains-high-output-impedance-at-high-frequencies.

Constant Current Source (Birkett)
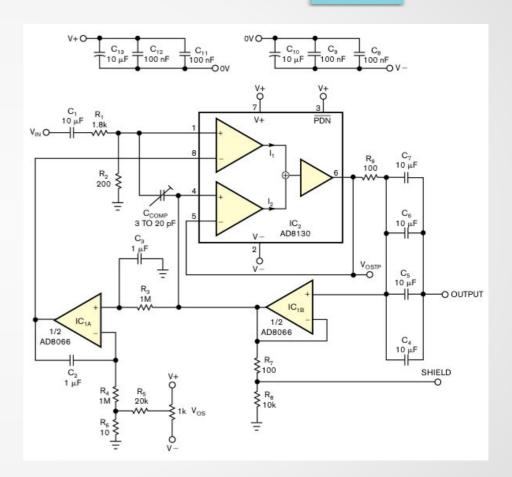
- Adds Voltage Follower due to high input bias current

A. Birkett, "Bipolar current source maintains high output impedance at high frequencies," Design Idea, 5-2005. [Online]. Available:
https://www.edn.com/design/analog/4324499/Bipolar-current-source-maintains-high-output-impedance-at-high-frequencies.

Constant Current Source (Birkett)
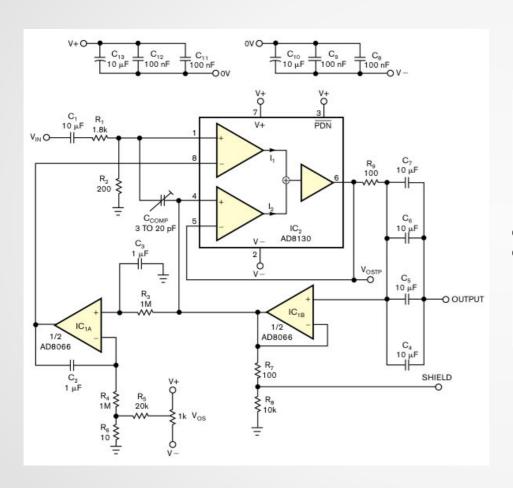
- Add a DC servo loop to stabilize operating point and decouples output.

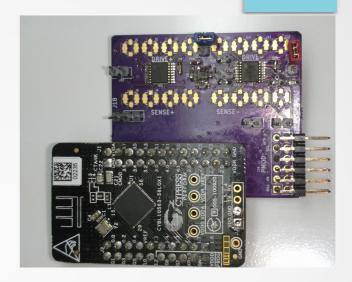A. Birkett, "Bipolar current source maintains high output impedance at high frequencies," Design Idea, 5-2005. [Online]. Available: https://www.edn.com/design/analog/4324499/Bipolar-current-source-maintains-high-output-impedance-at-high-frequencies.

Constant Current Source (Birkett)
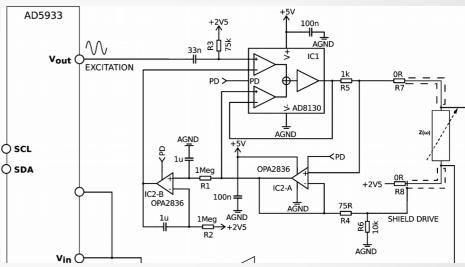
- Adds Ccomp to provide additional stabilization.

- Add shield drive

- 20Hz to 10MHz Bandwidth

A. Birkett, "Bipolar current source maintains high output impedance at high frequencies," Design Idea, 5-2005. [Online]. Available: https://www.edn.com/design/analog/4324499/Bipolar-current-source-maintains-high-output-impedance-at-high-frequencies.

Constant Current Source (Birkett) vs (Harder)

A. Birkett, "Bipolar current source maintains high output impedance at high frequencies," Design Idea, 5-2005. [Online]. Available: https://www.edn.com/design/analog/4324499/Bipolar-current-source-maintains-high-output-impedance-at-high-frequencies.

R. Harder, A. Diedrich, J. S. Whitfield, M. S. Buchowski, J. B. Pietsch, and F. J. Baudenbacher, "Smart Multi-Frequency Bioelectrical Impedance Spectrometer for BIA and BIVA Applications," IEEE Transactions on Biomedical Circuits and Systems, vol. 10, no. 4, pp. 912–919, Aug. 2016.
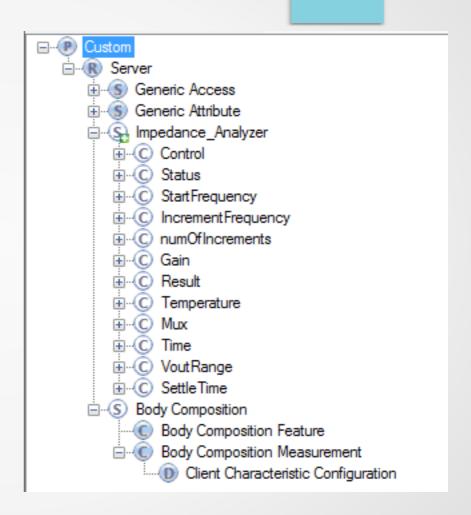
Project Status

- Board Assembled

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- Platform Software Completed & Tested

- Testing In Process
    - Testing AD5933 I/O
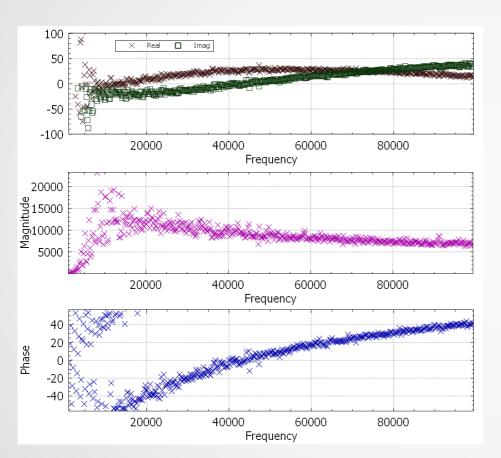   - AFE looks 'stuck', requires further investigation.

Project Status

- BLE Custom Service
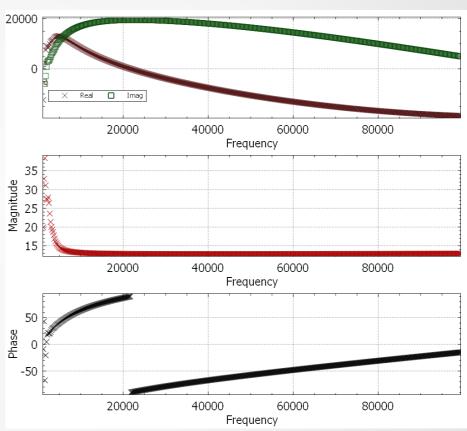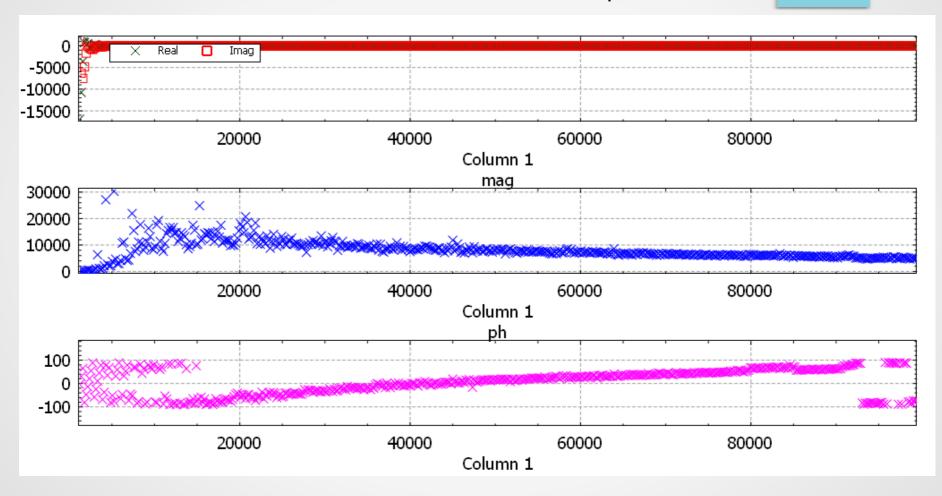
Preliminary Results

10k Resistor

100nF Capacitor
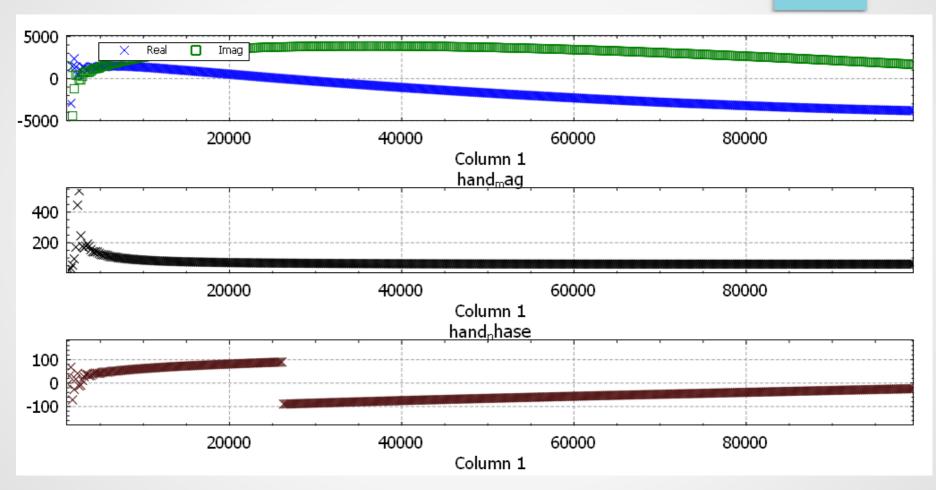
Preliminary Results

10k Resistor + 100nF Capacitor

Preliminary Results

Hand-Hand Measurement

Lessons Learned

- Human Body Interfacing can be difficult to understand.

- In-line breaks between circuits is a good idea.

- Don't take 2 classes, work full time, and have a newborn baby.

What's Left

- AFE Checkout
  - Independent test
  - Drive appears operational, but difficulty overcoming contact resistance.
  - Sense impedance needs increased.
- AMUX Checkout
  - Tested operational (~500ohms)
- Device Calibration
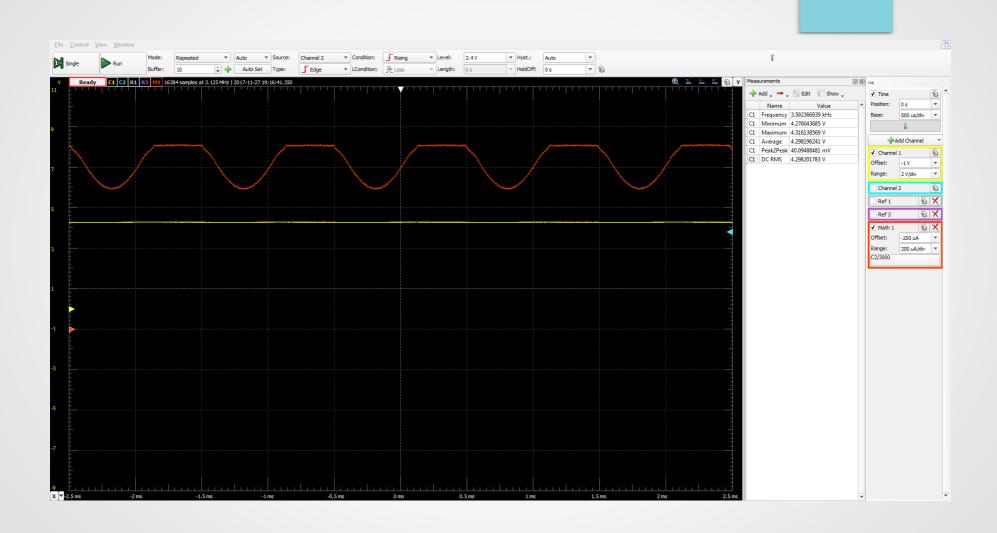- Android App Implementation

Calibration

- Measurement results are not directly usable
    - Much like raw bits from an ADC are not in volts.
    - Have to apply scale factor & unit conversions.
    - Results are in admittance.
- Calibration is required for design specific AFE, or lack thereof.
    - Measurements are performed a known ohmic resistance.
    - Matseiv demonstrates that DC offset at input cause considerable measurement error and should open circuit DC bias measurement results should be factored out of all measurements.
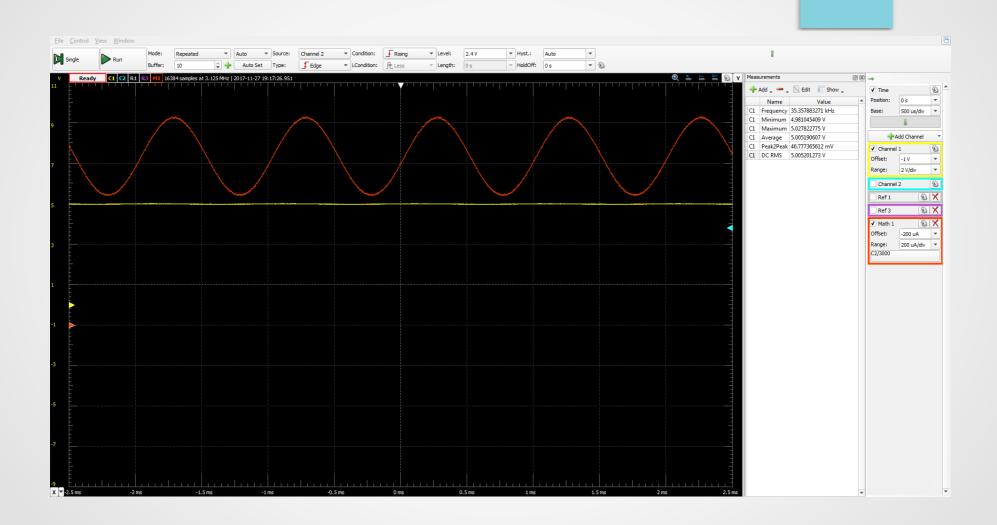
L. Matsiev, "Improving performance and versatility of systems based on single-frequency dft detectors such as ad5933," Electronics, vol. 4, no. 1, pp. 1–34, 2014.

Beyond Semester

- Revise PCB mux control.

    - All use the same address.

- Investigate the Body Composition BLE Service.

    - Impedance Characteristic.

    - Do health apps use it??

- Use EIDOR to construct tomography image.

- Enhance Android Application.

Powered from BLE Pioneer Board

Powered from 5V Supply

AFE Input to Output