Finger Plethysmograph to Measure Blood Resistivity

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Abstract

Impedance plethysmography can be used to measure arterial volume changes that occur with propagation of the blood pressure pulse in a limb segment. For this measurement, we assume a constant value of blood resistivity. However, blood resistivity may change under both physiological and pathological conditions. Use of an impedance plethysmograph on a finger immersed in a saline filled vessel may yield a method for determining this change in blood resistivity. This may develop into a method that diabetics can use to measure glucose levels noninvasively. The goal of our project is to design a finger plethysmograph to measure blood resistivity.

Background

Diabetes

- A disease characterized by the body's inability to manage glucose levels
- Caused by either the pancreas's inability to produce enough insulin, or the inability to effectively use insulin produced.
- Very high prevalence (and rising)
  - 26.3 million individuals in the US are currently diagnosed with diabetes (8% of total US population)
  - 13.5% increase over by the last 3 years
  - Worldwide: 171 million individuals living with diabetes
- Hypothesized that blood sugar levels may be correlated with blood resistivity

Electrical Theory

- Four electrode impedance plethysmography
  - 2 electrodes pass current through finger
  - 2 electrodes measure voltage
  - Signal processing
  - Calculate impedance and resistivity from voltage output

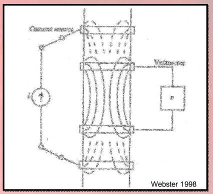


Figure 1: Four Electrode Impedance Plethysmograph

Biological Theory

- High blood flow
  - Red Blood Cells (RBCs) align, current meets little resistance
- Low blood flow
  - RBCs misalign, greater resistance
  - Impedance results from this
- Change in volume of artery
  - Saline solution cancels signal

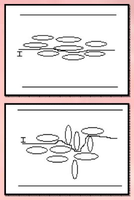


Figure 2: Current flow through vessel with high blood flow (top) and low blood flow (bottom)

Current Devices

Current blood glucose monitors require a small sample of the patient's blood in order to determine glucose levels. This usually needs to be attained through a painful self-induced finger prick. Because of the associated inconvenience and pain of this method, a simpler, more user friendly non-invasive method is desired.

Problem Statement

Statement:
Our goal is to design a finger plethysmograph to measure blood resistivity.

Client Requirements:

- Device must minimize finger mobility
- Must be able to accept a wide range of finger sizes
- Observe voltage changes due to blood resistivity
- Must meet Institutional Review Board for Human Subjects testing
- Budget $250

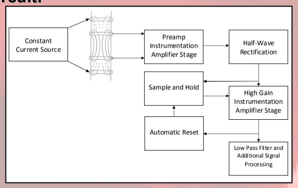
Design Specifications

Design Requirements:

- *Materials*: The materials of the device must be electrically inert where needed and such that they do not harm the human subject or collection of data.
- *Safety*: The device will be designed so that the electricity used will not cause any harm to the user.
- *Performance requirements*: The device will be used extensively in research trials. The device should be able to provide consistent results over an entire research trial.

Design Development

Circuit:



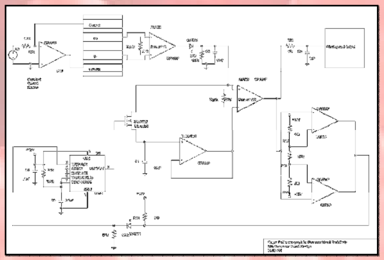


Figure 3: Block diagram (top) and Schematic (right) of finger holder attached to current source and circuit

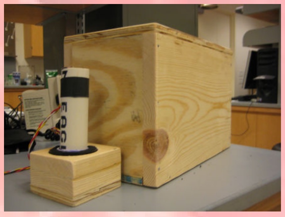
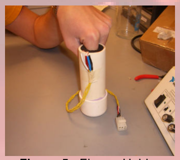


Figure 4: Patient and Finger Holder Stabilizer

Finger Holder:

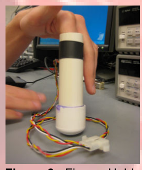
Generation 0



- •PVC outer shell
- •1.5" diameter
- •Three rings of rubber elastomeric foam
- •Four tin electrodes
- •Pliobond adhesive
- •0.9 wt% Saline solution

Figure 5: Finger Holder Generation 0

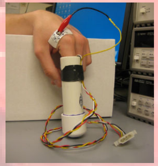
Generation 1A



- •PVC outer shell
- •1" diameter
- •Three rings of rubber elastomeric foam
- •Four tin electrodes
- •Pliobond adhesive
- •0.9 wt% Saline solution

Figure 6: Finger Holder Generation 1A

Generation 1B



- •PVC outer shell
- •1" diameter
- •Two rings of polypropylene, three strips of foam
- •Three tin electrodes
- •1 Skin electrode on finger
- •Pliobond adhesive
- •0.9 wt% Saline solution

Figure 7: Finger Holder Generation 1B

Testing and Results

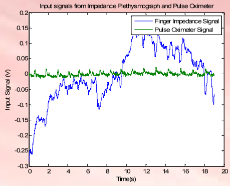


Figure 8: Non-occluded raw data, Gen 1A. Output from our finger plethysmograph and a pulse oximeter (positive control signal). Signals were sampled at 1kHZ. Both signals were normalized to zero.

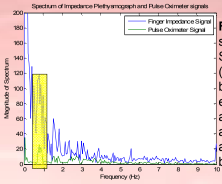


Figure 9: Non-occluded spectrum, Gen 1A. Spectrum of the signal (DC components of both spectrum are eliminated in the adjusted signal). There are two peaks aligned at ~1 that is likely cause by heart beat.

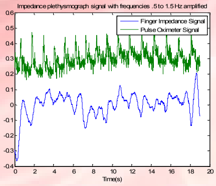


Figure 10: Non-occluded filtered signal, Gen 1A. The signal is boosted from 0.8-1.5 Hz frequencies by a factor of 3. Low frequency signals < |.2 Hz| are attenuated by a factor of 10. Heart beats appear apparent in both.

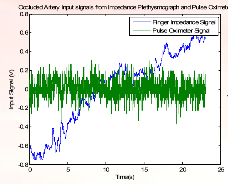


Figure 11: Occluded raw data, Gen 1A. Output from our finger plethysmograph and a pulse oximeter. Signals were sampled at 1kHZ. Both signals were normalized to zero.

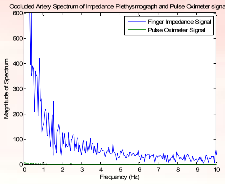


Figure 12: Occluded spectrum, Gen 1A. Spectrum of the signal (DC components of both spectrum are eliminated in the adjusted signal).

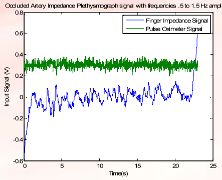


Figure 13: Occluded filtered signal, Gen 1A. Filtered output from our finger plethysmograph and a pulse oximeter.

Finger Model

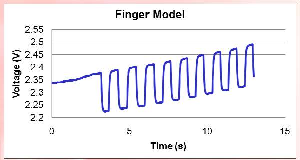
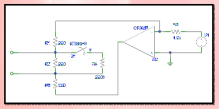


Figure 14: Finger Model Results (top), finger model circuit (below)



- •Mimics 1/1000 change in resistance based on resistance of the blood in the finger to be 660N-cm

Future Work

- Eliminate drift
- Finalize digital filtering stage
- Higher amplitude current
- Apply for IRB approval
- Begin subject testing to determine relationship of voltage output/blood resistivity and glucose levels

Conclusion

With the work done this semester, both with updates to the circuit and the creation of new finger holders, we were able to distinguish the heart beat in the finger. By completing this step, further work can be done toward correlating blood resistivity and glucose levels.

References

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