INTRACRANIAL PRESSURE SENSOR: DETECTION OF SHUNT MALFUNCTION IN HYDROCEPHALUS PATIENTS

Brad Lindevig, Nicholas Shiley, Evan Flink, Luke Juckett

Department of Biomedical Engineering

Advisor: Professor Dennis Bahr & Elena Bezrukova **Client:** Dr. Joshua Medow, M.D.

Abstract

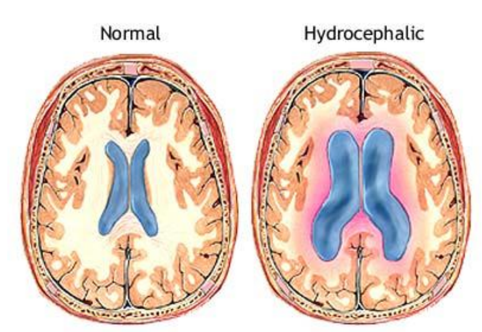
Currently, our client, Dr. Medow is working with Professor John Webster and Elena Bezrukova in developing a sensor that will monitor intracranial pressure without the need for an internal power supply. This sensor will notify medical personnel when a cerebral spinal fluid drainage shunt has failed.

Our team contributed to this project by designing and manufacturing a to-scale prototype and a user interface system that takes the signal from the sensor and translates it into pressure.

Background/Motivation

Hydrocephalus

- Condition of excessive accumulation cerebrospinal fluid in the brain [1]
- Results in abnormal widening of spaces in the brain ventricles [1]
- Can cause seizures, mental disability, enlargement of head, and death [1]



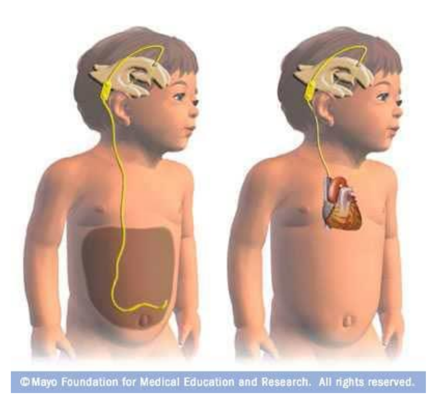
[1]

Ventriculoperitoneal Shunt System

- Relieves pressure in skull
- Dispenses spinal fluid from ventricles to abdominal cavity

Problems with Shunt System

- 50% of shunts fail within the first 2-3 years
- Infection
- Obstruction
- Outgrowing the shunt
- Requires frequent medical evaluations



Current Intracranial Pressure Sensor

- Monitors the shunt system
- Detects increases/decreases in intracranial pressure [1]
- Limited to temporary implantation
- Hazardous

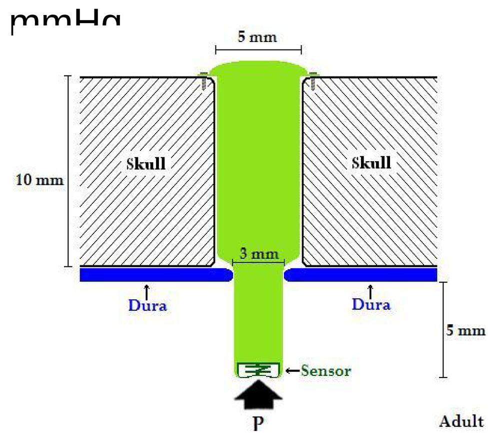
Design Criteria

Capsule

- Material must be biocompatible, and non-metal
- Capsule must be a maximum 3 mm in width and 15 mm in length
- Needs to be implanted and removed easily
- Must have a lifetime between 10-20 years
- Pressure readings can not drift more than 0.5 mmHg per year

User Interface

- Must display a pressure graph in real time
- Should store past test results
- Must display pressures between -30-100 mmHg
- Must be user friendly



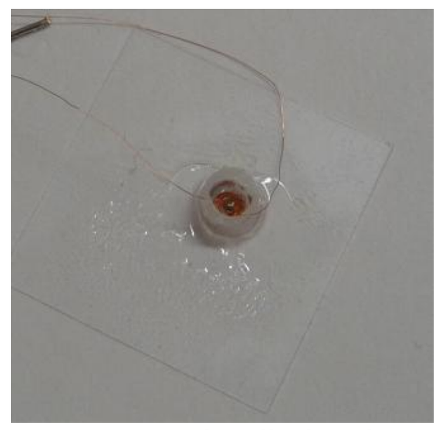
Prototype design

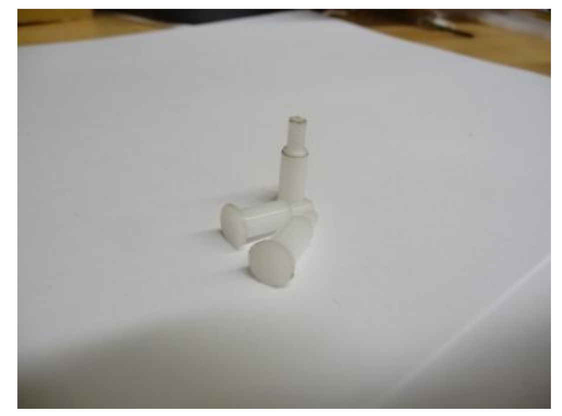
Final Design

Fabrication

Capsule and Spacer

- Made of acetyl copolymer
  - Spacer is lathed to 4 mm in diameter
  - Center hole is drilled with 3 mm diameter drill bit
- Spacer glued to cellulose acetate transparency
- Both coils and 2 connecting wires are sealed within spacer
- Spacer is glued to capsule


Spacer and coil glued to membrane

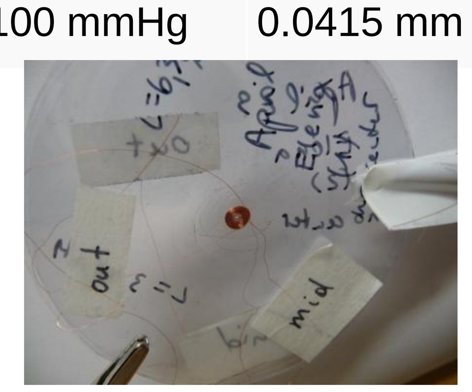

Capsules

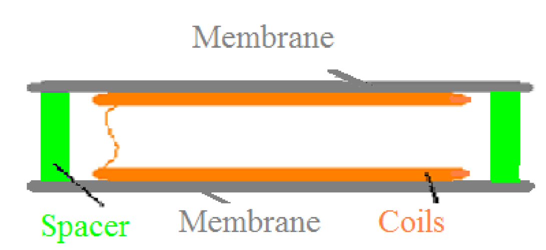
Membrane

- Cellulose acetate transparency
- 0.1 mm thick

Membrane Deflection Values

Pressure	Membrane Deflection	Expected change in capacitance	Expected resonant frequency
-30 mmHg	0.0125 mm	-84.8 fF	45.7 MHz
100 mmHg	0.0415 mm	94.8 fF	43.22 MHz


Cellulose Acetate wrapped around coil



Cross-sectional view of sensor

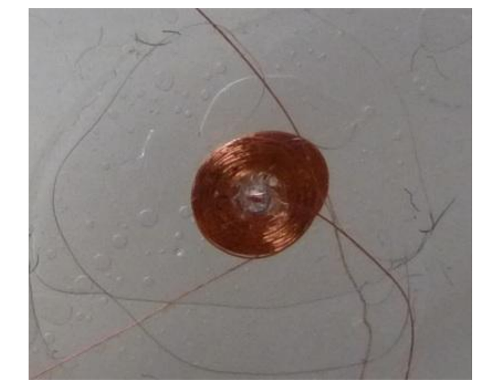
User Interface

- Created on LabView 8.2
- Detects power drop from the interrogating device
- Calculates the distance from start of the sweep to resonant frequency peak
- Tracts the rectified sweep of 42 – 46 MHz which matches coil response
- ICP pushes the coils closer together thus changing the resonant frequency
  - Increase in ICP moves the resonant frequency peak to the right
  - Decrease in ICP moves the resonant frequency peak to the left
- Saves data to specified file

Coils

- 44 Gauge wire and base wire are fed through plastic disks
- Glued between 2 thin (1.5 inch diameter) plastic sheets
- Pressed between 2 additional 1.5mm thick (1.5 inch diameter) plastic disks
- Wire is then wound around the base wire until desired diameter is achieved
- Base wire is removed

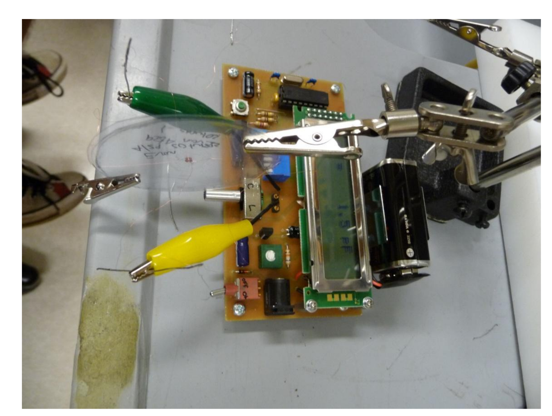

Fabrication of coil

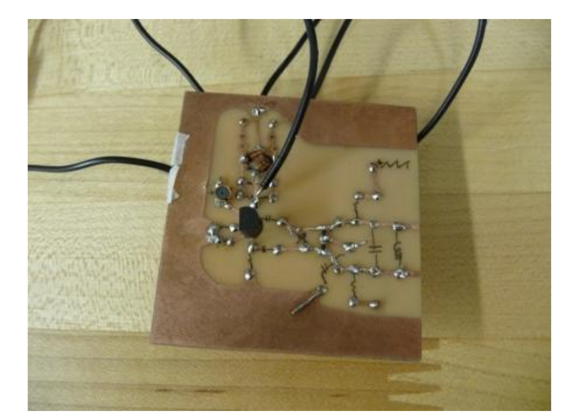

Final coil product

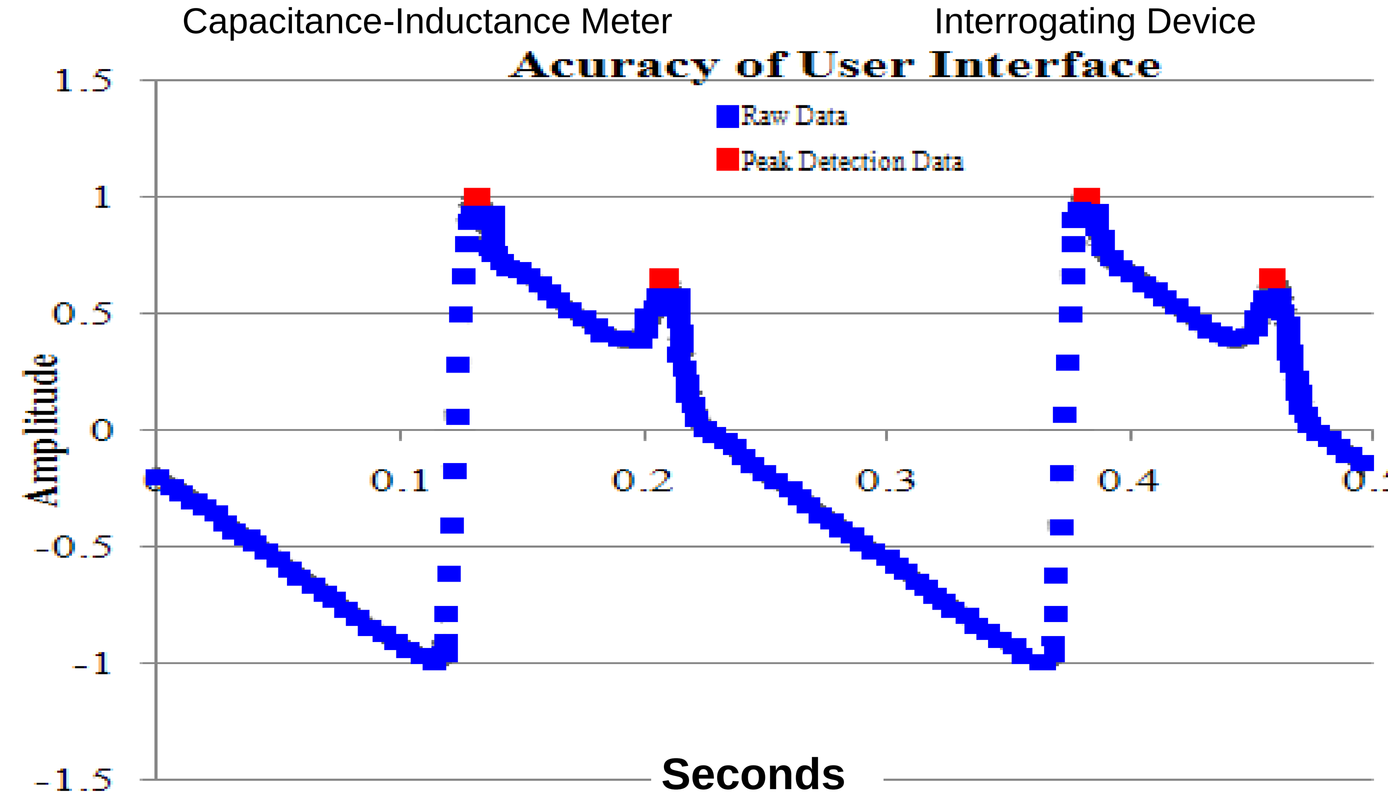
Testing

- Measured the resistance and inductance of each individual coil
- Measured inductance and capacitance of best pair of coils

Coil Size	Inductance	Capacitance	Resonant Frequency
2.5 mm diameter (20 turns)	8.0 µH	1.6 pF	44.5 MHz

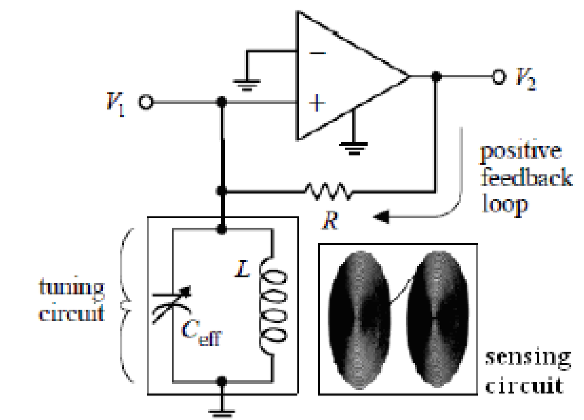

Capacitance-Inductance Meter


Interrogating Device

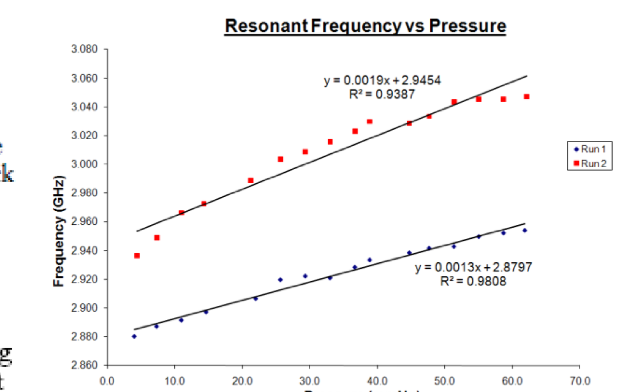


Accuracy of User Interface Peak Detection algorithm. SD of peak detection points are no more than .004.

Theory



Schematic of interrogating device



Frequency vs. pressure

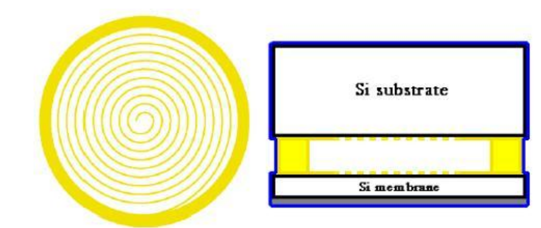
$$y_c = \frac{3(m^2-1)r^4P}{16m^2E_yt^3}$$

Membrane deformation equation

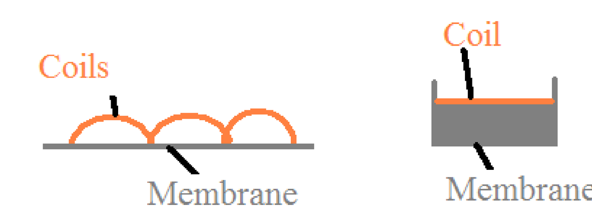
Future Work

Photolithography

- Uses acid and light to etch grooves into substrate
- Mass producible
- More reliable and repeatable than hand-wound coils



Top view of coil (left) and cross-sectional view of sensor (right)



Hand wound coils (left) vs. photolithography coils (right)

Saline Solution

- Plot frequency vs. pressure
- Biomimetic
- Acts as a capacitor

Testing Negative Pressure

- Connect to vacuum trap and aspirator
- Vary the negative pressures within the column by changing the rate of water flow of the aspirator
- Record data

Testing Positive Pressure

- Calculate density of water used to fill water column
- Fill column with water to reach height that correlates with desired increment in pressure
- Record data


Phantom tester

References

"Neurological Disorders - Hydrocephalus." *Schneider Children's Hospital Home Page*. Web. 09 Mar. 2010. <http://www.schneiderchildrenshospital.org/peds_html_fixed/peds/neuro/hydro.htm>. [1]

C. Collins. Miniature Passive Pressure Transensor for Implanting in the Eye. IEEE Transactions on Biomedical Engineering 14-2 (1967), 74-83. [2]

Professor Dennis Bahr
Dr. Joshua Medow, M.D.
Elena Bezrukova
Professor Thomas Yen
Lacey Halfen
Professor Sergei Bezroukov