ICP Monitor

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Outline

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- Design Requirements
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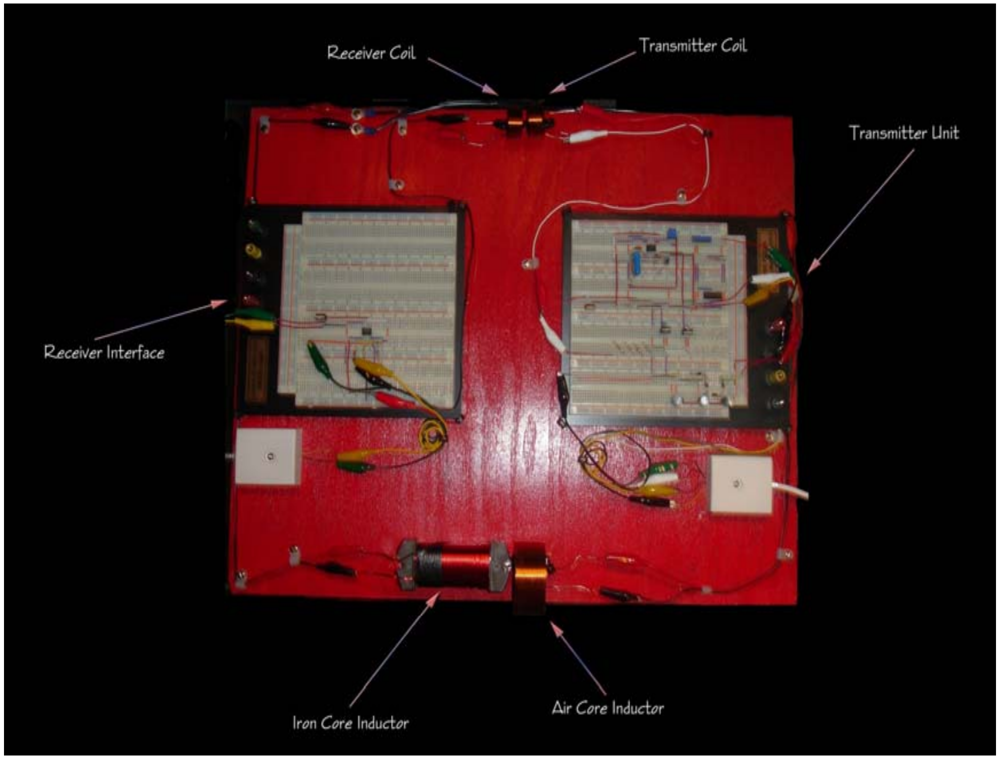
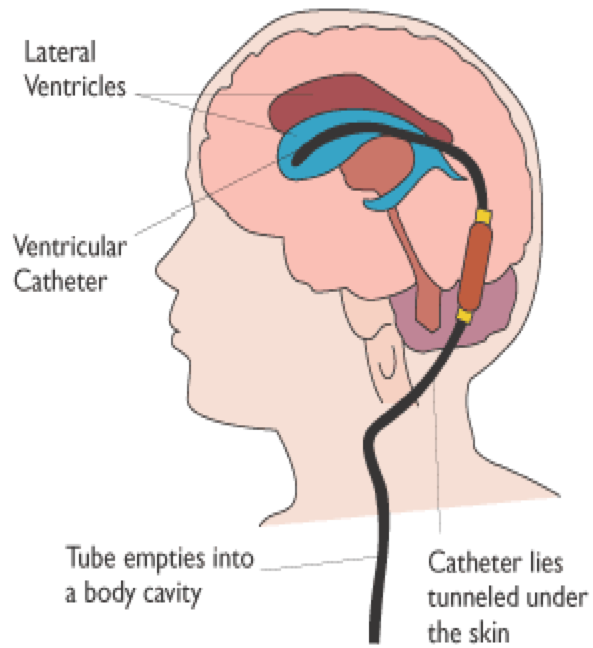
  - Medtronic & Radionics
- Power Supply
  - Design Alternatives
  - Design Matrix
- Transducer
  - Design Alternatives
  - Design Matrix
- Future Research & Calculations



(Josh Medow, MD)

Shunt Purpose and Function

- Regulation of pressure
- Hydrocephalus
- Drainage of cerebrospinal fluid
- Incidence rate of 1%



(http://www.cancerhelp.org.uk/cancer_images/brain-shunt.gif)

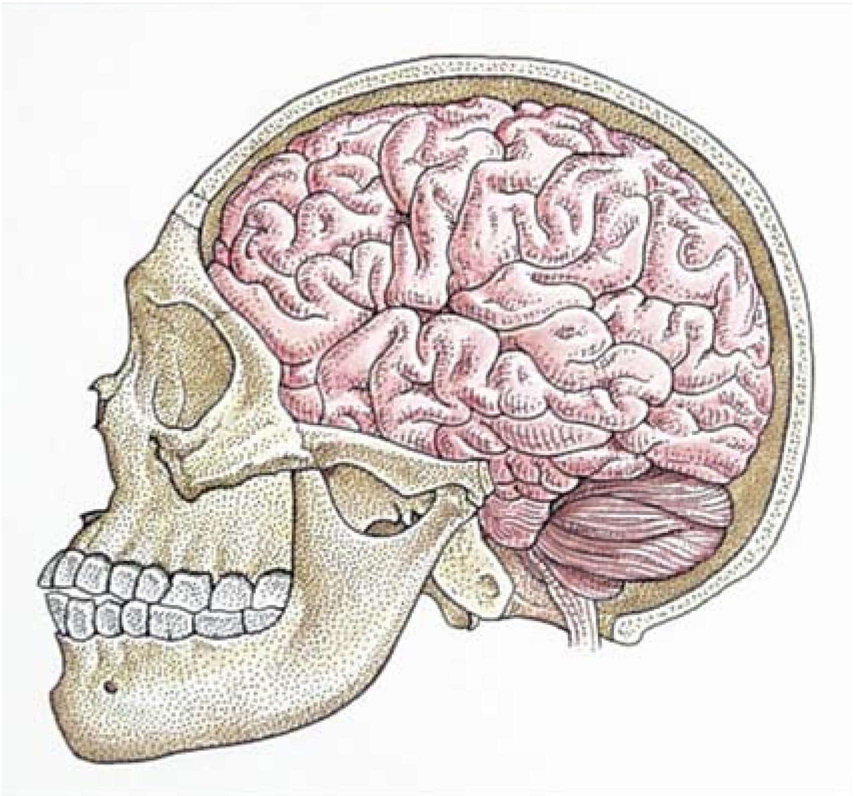
Inspiration for ICP Monitor

- Shunt failure rate
  - 50% failure rate in first 2-3 years
- Shunt malfunctions
  - Invasive diagnosis
    - Surgery & Shunt Tap
  - Noninvasive diagnosis
    - Physical Exam
    - MRI / CT Scan

(Joshua Medow, MD)

Design Requirements

- Noninvasive method to measure intracranial pressure
  - Effective power transmission across 1.5 cm gap
  - Implanted pressure gauge transducer
  - Signal transmission & interpreted externally



(http://www.dkimages.com/discover/previews/832/20112875.JPG)

Specifications for ICP Monitor

- Performance Requirements
  - 5 Volts
  - Current < 100 mA
- Accuracy & Reliability
- Materials
  - Biocompatibility
  - MRI – no ferrous materials
- Pressure ranges
  - Average: 10 – 15 mmHg
  - Gauge range: -3 – 30 mmHg

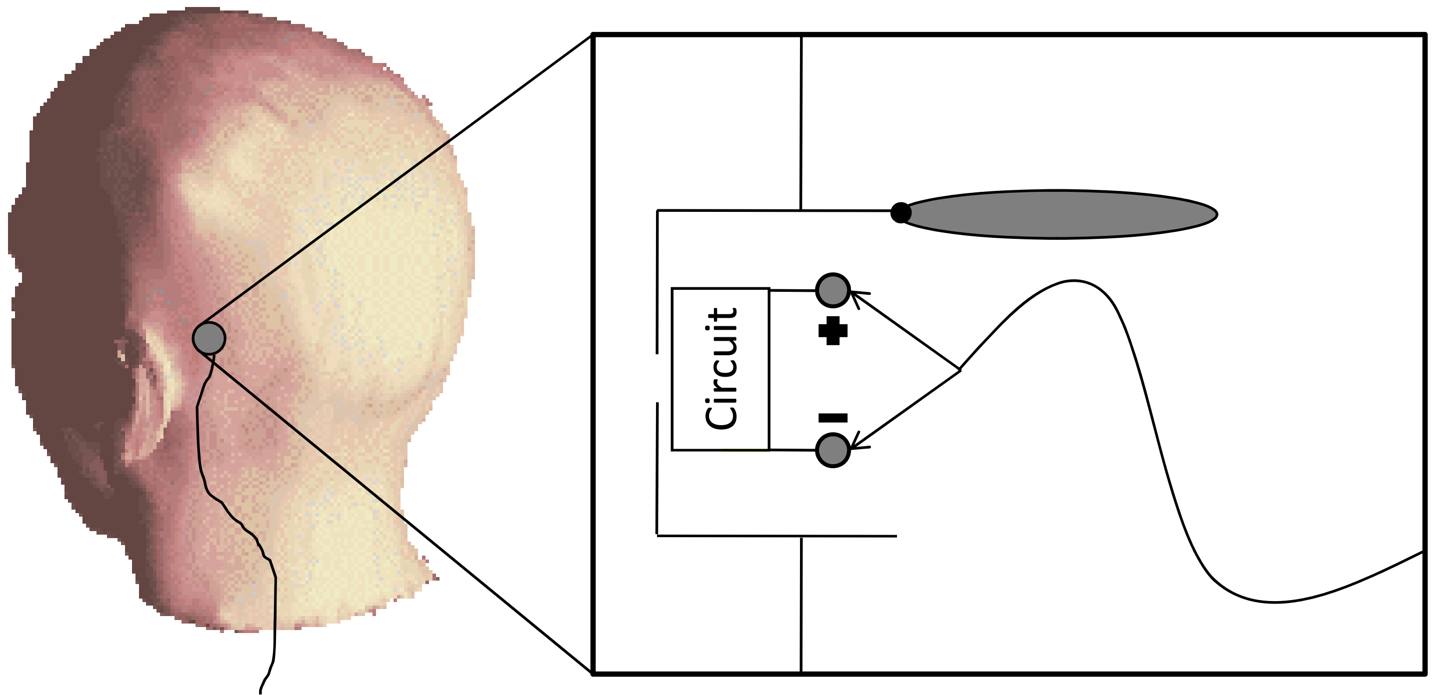
Existing ICP Monitors

- Medtronic – Insite Monitor
  - Decent accuracy
  - Expensive
  - Large battery implanted in chest
  - Finite power supply
- Radionics – TeleSensor
  - Indicate high & low pressure
  - Solenoid moved with changes in pressure

External Power Supply

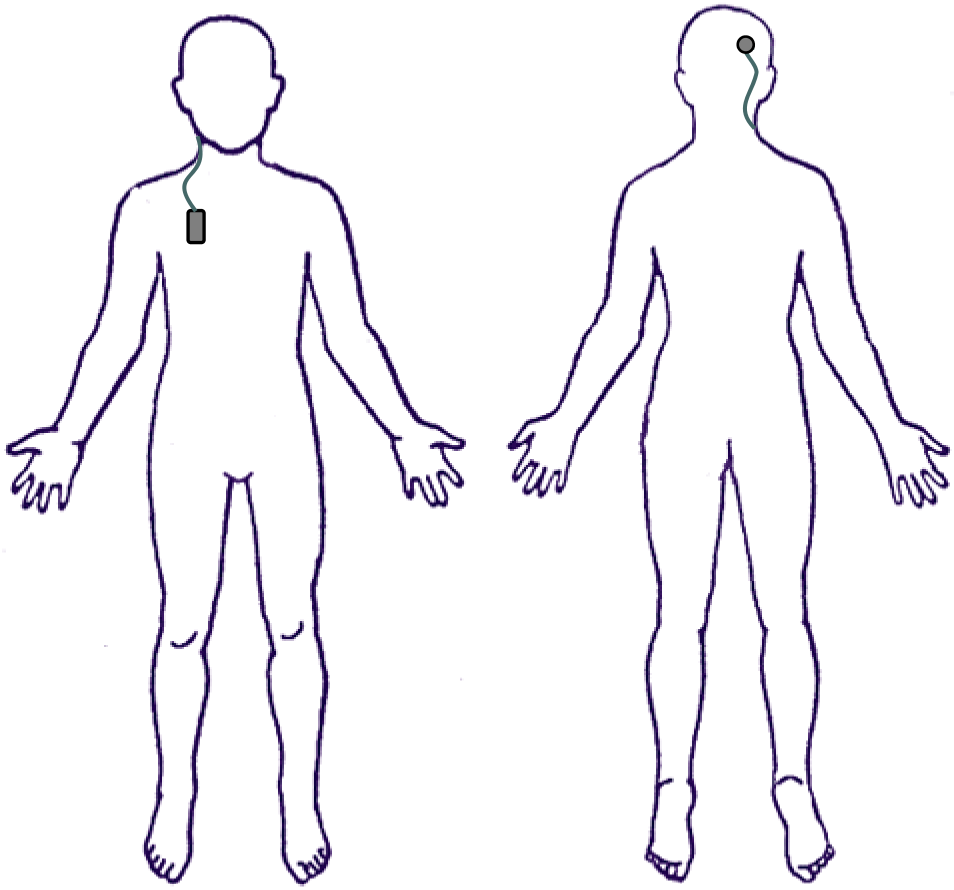
- 3 Designs
  - Direct Hook-up
  - Battery
  - Solenoid
- Design Matrix

Design 1: Direct Hook-Up



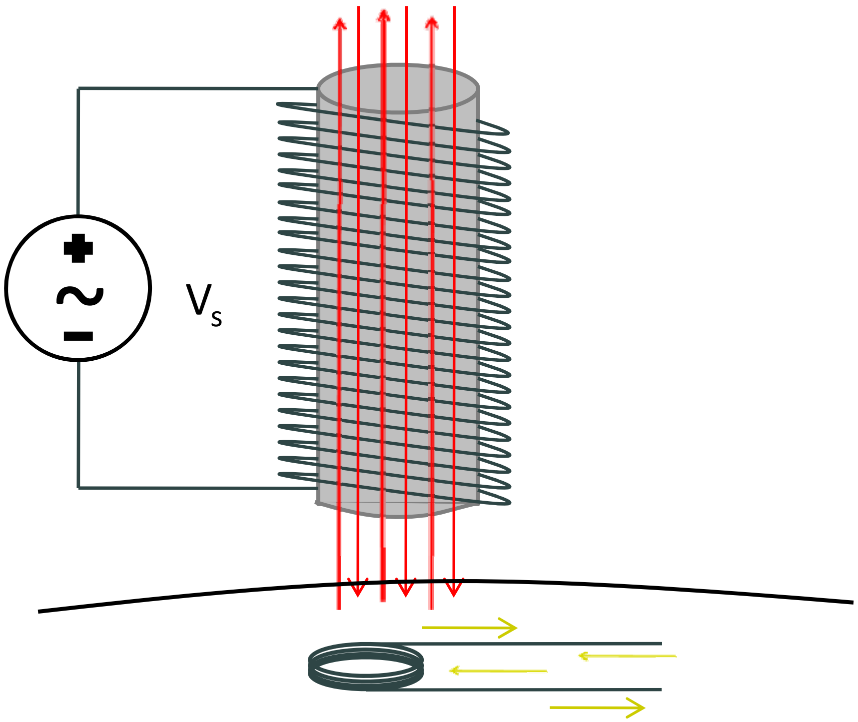
(http://www.mathworks.com/matlabcentral/files/647/head_big.gif)

Design 2: Battery



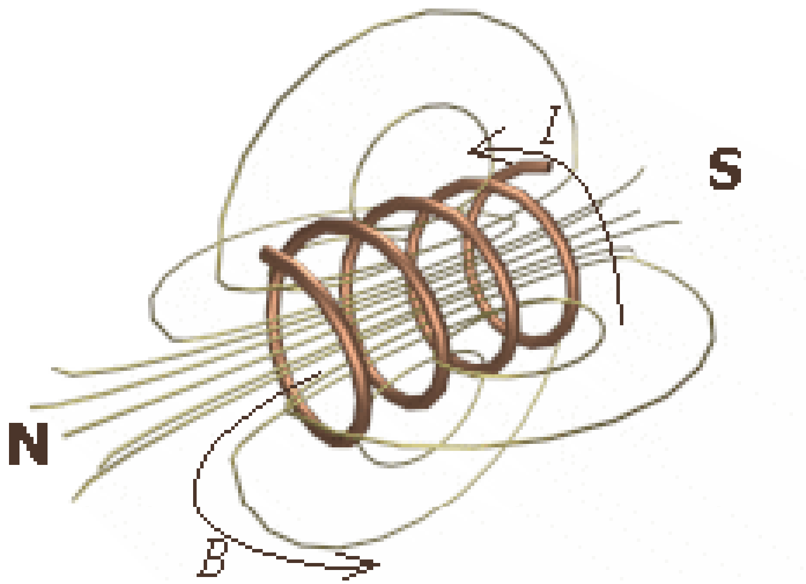
(http://www.bfawu.org/images/bakers-union-body.gif)

Design 3: Solenoid



(Josh Medow, MD)

Solenoid Basics

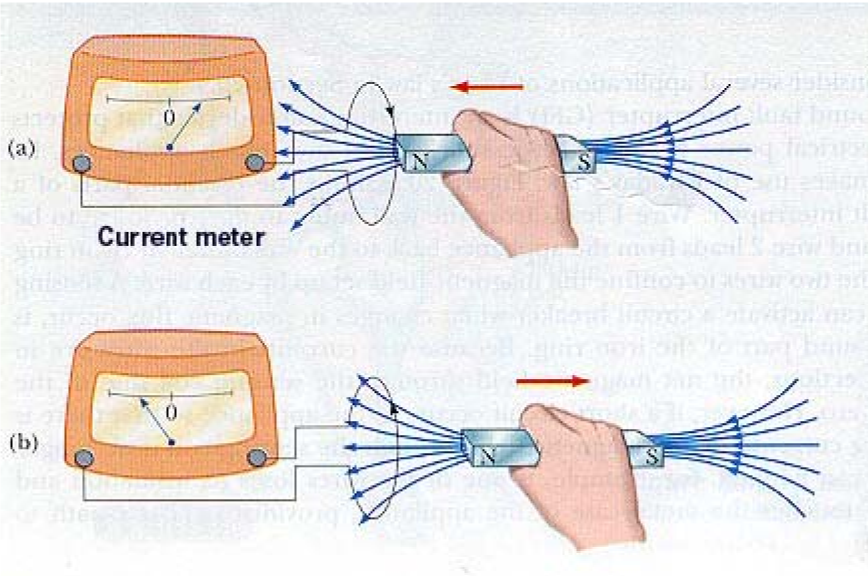


$$B_1 = \frac{\mu_0(1 + \aleph)N_1 I_1}{L_1}$$

(http://library.thinkquest.org/16600/intermediate/solenoid.gif)

- Magnetic field primarily within solenoid
- Proportional to:
  - Length
  - Number of windings
  - Core material
  - Current

Faraday's Law and Lenz's Law



$$E_2 = -N_2 A_2 \frac{dB_1}{dt}$$

(http://sol.sci.uop.edu/~jfalward/electromagneticinduction/barcoilgalvonometer.jpg)

- Faraday:
  - Secondary Voltage
  - Change in flux
  - Changing magnetic field
- Lenz:
  - Resists change in flux
  - Negative sign

$$B_1 = \frac{\mu_0 (1 + \aleph) N_1 I_1}{L_1}$$

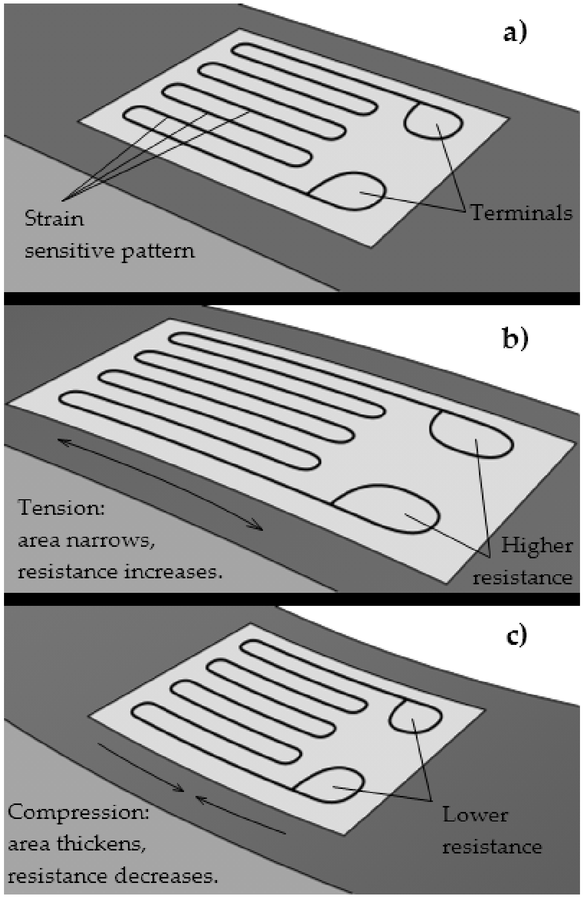
Power Supply Design Matrix

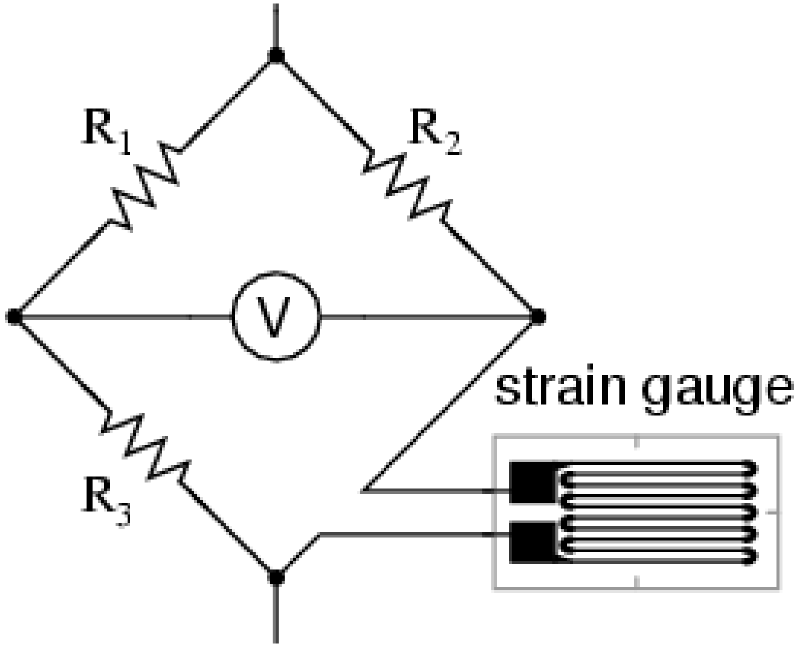
	Adequate Power (0.3)	Lifespan (0.25)	Cost (0.05)	Patient Safety (0.3)	Size (0.1)	Total
Solenoid	**6 (1.8)**	**6 (1.5)**	**6 (0.3)**	**6 (1.8)**	**7 (.7)**	**5.1**
Direct Power Supply	7 (2.1)	5 (1.25)	6 (0.3)	1 (0.3)	6 (0.6)	4.55
Battery	4 (1.2)	2 (0.5)	2 (0.1)	5 (1.5)	4 (0.4)	3.6

Internal Pressure Gauge

- 2 Designs
  - Stain gauge
  - Capacitor
    - Cylindrical
    - Flexible Dome
- Design Matrix

Design 1: Strain Gauge





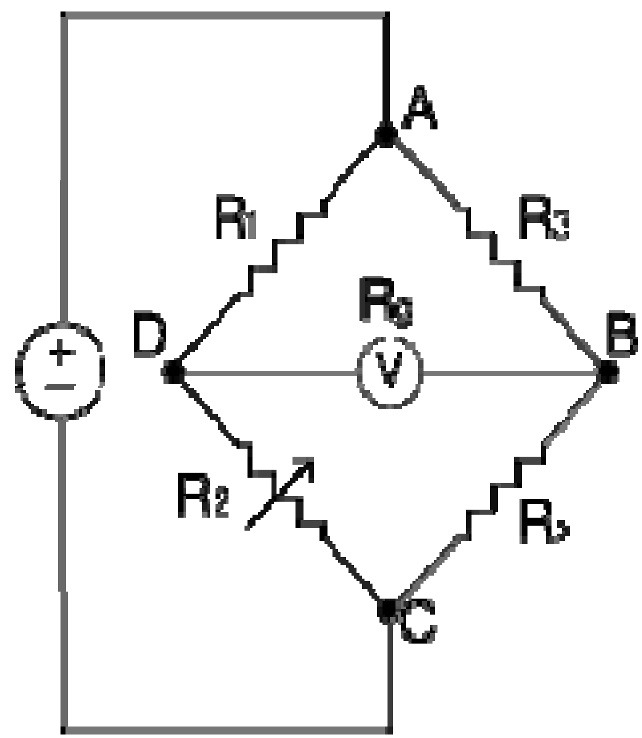
(http://www.allaboutcircuits.com/vol_1/chpt_9/7.html)

(http://www.answers.com/topic/straingaugevisualization-png)

Wheatstone Bridge

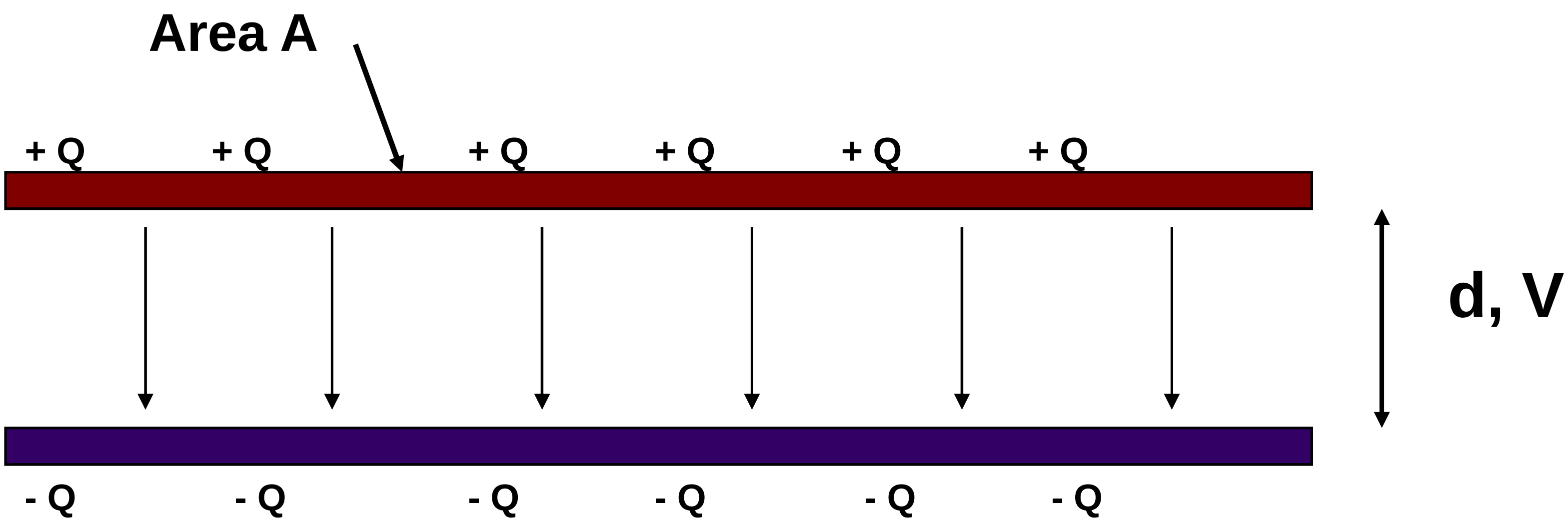
- *R*2 / *R*1 = *Rx* / *R*3
  - Balance point V=0
  - Changes in Rx disrupt voltage

$$V = \left(\frac{R_x}{R_3 + R_x} - \frac{R_2}{R_1 + R_2} \right) V_s$$



(http://en.wikipedia.org/wiki/Wheatstone_bridge)

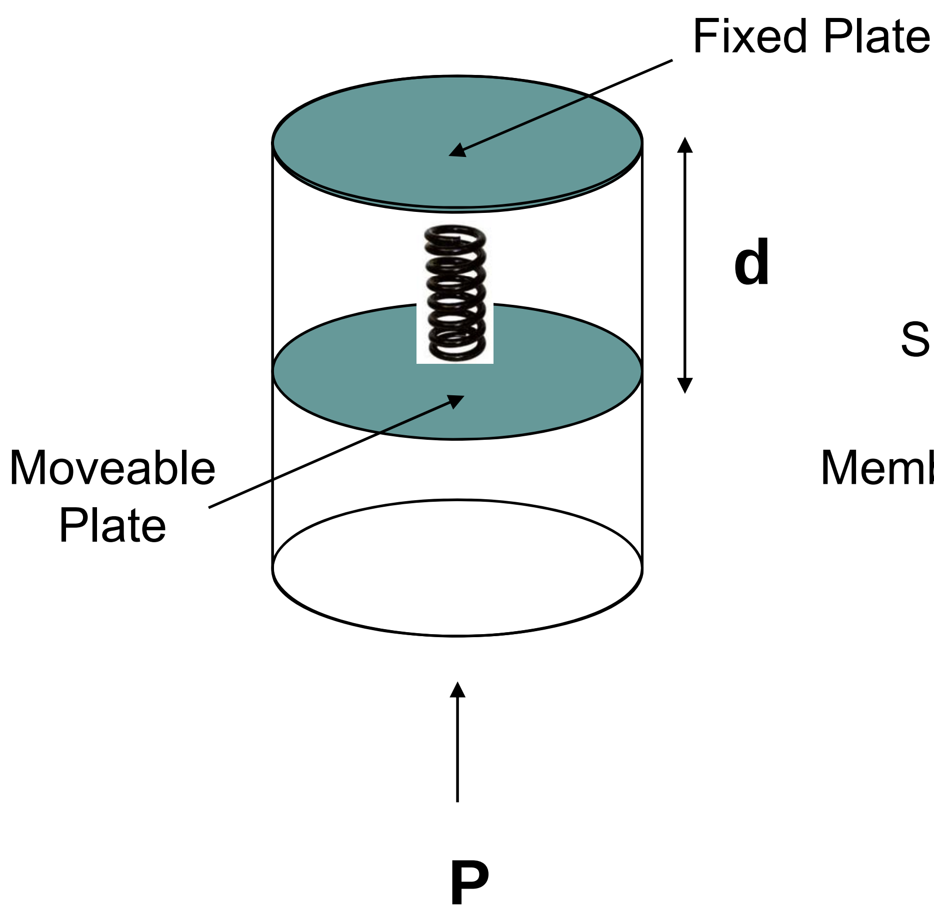
Design 2: Capacitor

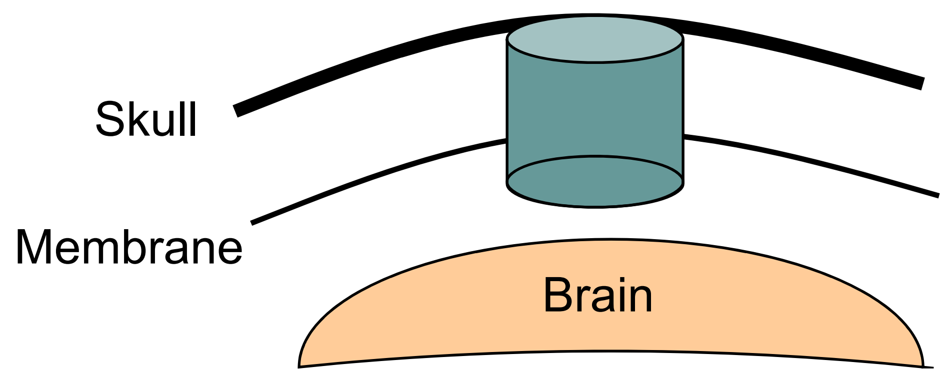


$$C = \varepsilon A / d$$

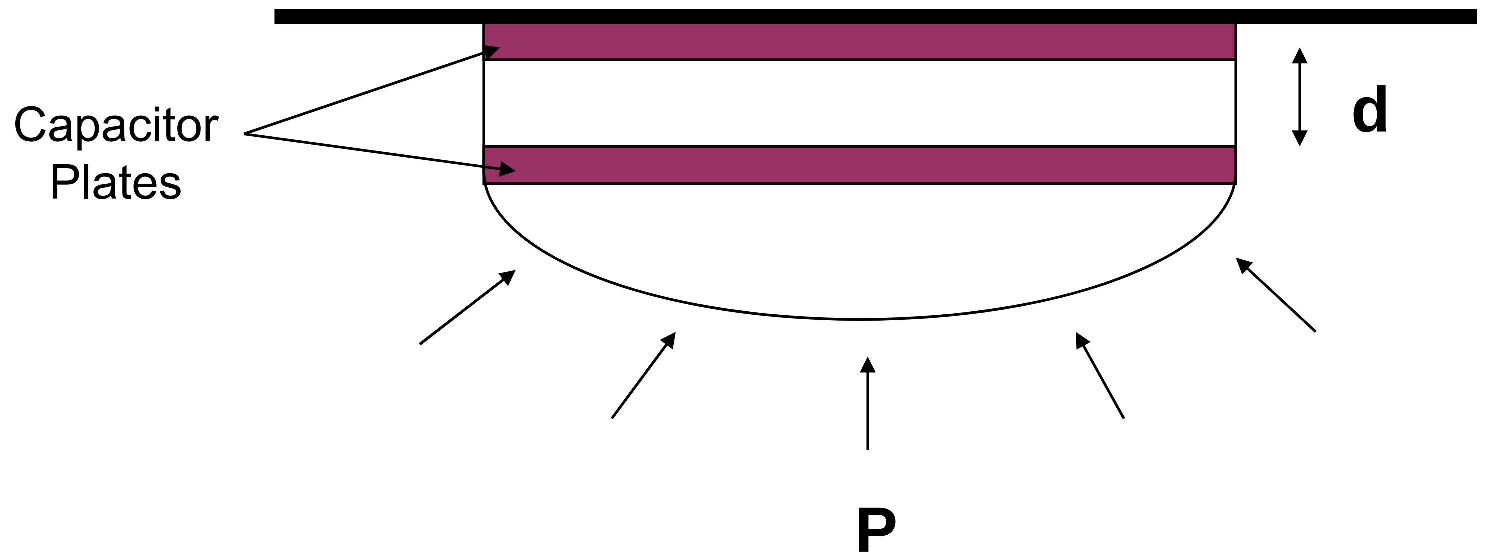
$$C = Q / V$$

Cylindrical Capacitor





Flexible Dome Capacitor



Pressure Gauge Design Matrix

	Accuracy (0.35)	Durability/ Lifespan (0.3)	Biocompatibility (0.2)	Size (0.1)	Cost (0.05)	Total
Strain Gauge	**6 (2.1)**	**5 (1.5)**	**6 (1.2)**	**7 (0.7)**	**7 (0.35)**	**5.85**
Cylindrical Capacitor	4 (1.4)	5 (1.5)	6 (1.2)	4 (0.4)	5 (0.25	4.75
Flexible Dome	3 (1.05)	6 (1.8)	6 (1.2)	5 (0.5)	3 (0.15)	4.7

Future Research & Calculations

- Power Supply
  - Test different frequencies
  - Test different core material
  - Calculations for magnetic flux
- Pressure Gauge
  - Piezoresistive material – quasi-static measurements
  - Change in distance needed for pressure range
  - Deformations of materials