Engineering World Health: Infant Apnea Monitor

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Overview

- Client
- Problem
- Background and Constraints
- Design Options
- Design Specifications
- Preliminary Design
- Future Work

Engineering World Health

"Non-profit organization that mobilizes the biomedical engineering community to improve the quality of health care in hospitals that serve resource-poor communities of the developing world"

Infant Respiratory Monitor – EWH Legacy Project

Problem Statement

- 23% of infant death worldwide attributed to asphyxia related causes [1]
- Highest neonatal mortality rates (NMR) found in developing world [1]
- Risk of dying from asphyxia is 8 times higher in countries with high neonatal mortality rates [1]
- Economic and social barriers inhibit effective monitoring & prevention

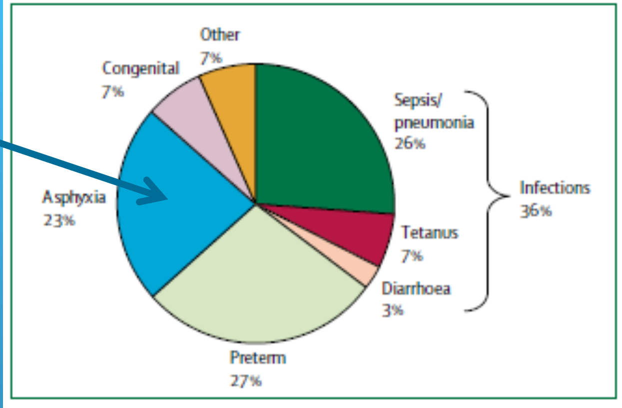


Figure 1: Causes of infant death worldwide [1]

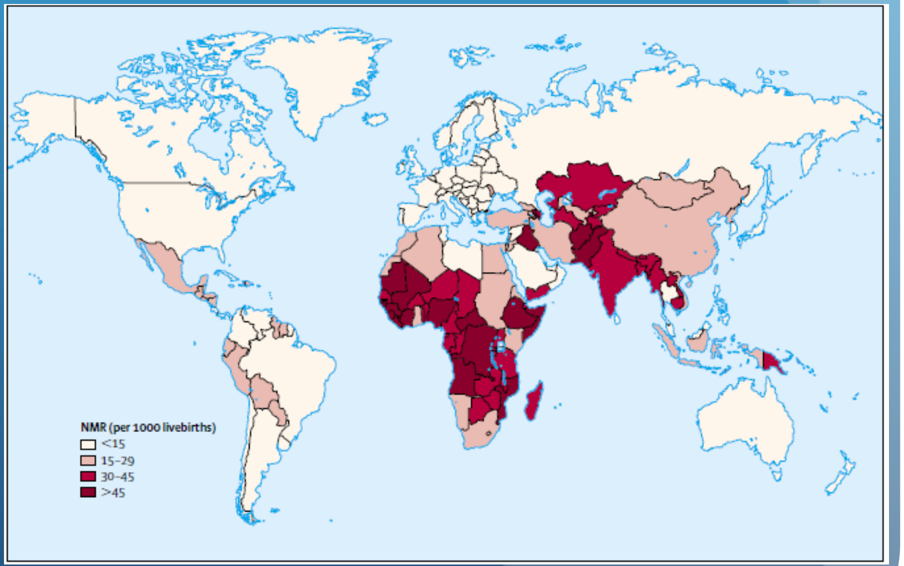


Figure 2: Occurrence of NMR worldwide by country [1]

Problem Statement

Task: Design and construct a low cost, easy to operate prototype that will warn of an apneic event after a specified duration of respiratory arrest in infants.

Apnea & SIDS

- **Sudden infant death syndrome** (SIDS): The unexpected, **sudden death** of a child under age 1 in which an autopsy does not show an explainable cause of **death**
- **Infant Apnea:** Cessation of Breathing
- Monitor for apneic events in order to reduce the number of infant deaths.
  - Apnea is an indicator of a possible SIDS case

Apnea monitoring in the U.S.

- Home vs. hospital monitoring
- Multi-sensor monitors: ECG, impedance, pulse oximeter
- Differences in size, output

Figure 3: Dummy newborn with apnea monitor

Figure 4: Team testing respiration monitors at Meriter Hospital

Design Constraints – Haitian Mobile Hospital

- Intended for use in typically impoverished regions
- Distribution through non-profit organization (EWH)
  - Must be low cost ($10-$20)
  - Theft concerns for expensive/rare components
- Cannot introduce additional risk of harm to the infant
  - Infrastructure varied and substandard compared to U.S.
  - batteries vs. distribution grid
- Human element untrained or unskilled
  - Assembly, operation, and repair must be straightforward

Existing Methods of Monitoring

- Most clinical monitors implement multiple methods
  - Redundancy decreases # of false positives/negatives

Method/Device	Measuring Parameter	Sensor type and placement
Thermistor (change in temperature)	Breath temperature	Electrode placed over mouth
Chest Force Sensor Resistor (FSR)	Force produced by chest movement	Attached to chest
Impedance Pneumograph (IP)	Transthoracic impedance	Skin electrodes on chest
Pulse Oximetry (PO)	$\%O_2$ saturation in blood	Attached to wrist, ankle, or toe
Inductance Plethysmography	Chest circumference via inductance	Coiled wire-elastic band around chest
Electromyography	Venous return	Fiber-optic sensor

Changes in Breath Temperature

- Design Specifics
  - Uses three thermistors placed in nasal cannula
  - Thermistors measure change in temperature
- Advantages
  - Easy to use (hard put in wrong location)
  - Relatively reliable
- Disadvantages
  - Requires wires on and around the head
  - Potential for infection spread

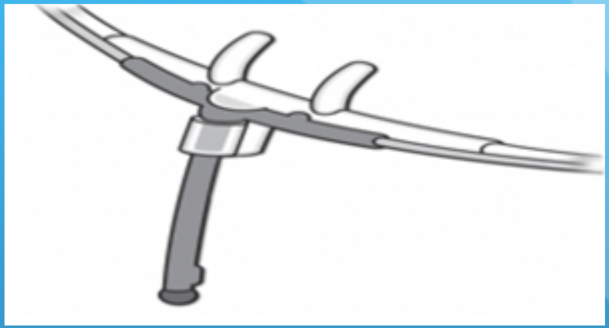


Figure 5: Infant nasal cannula thermistor [2]

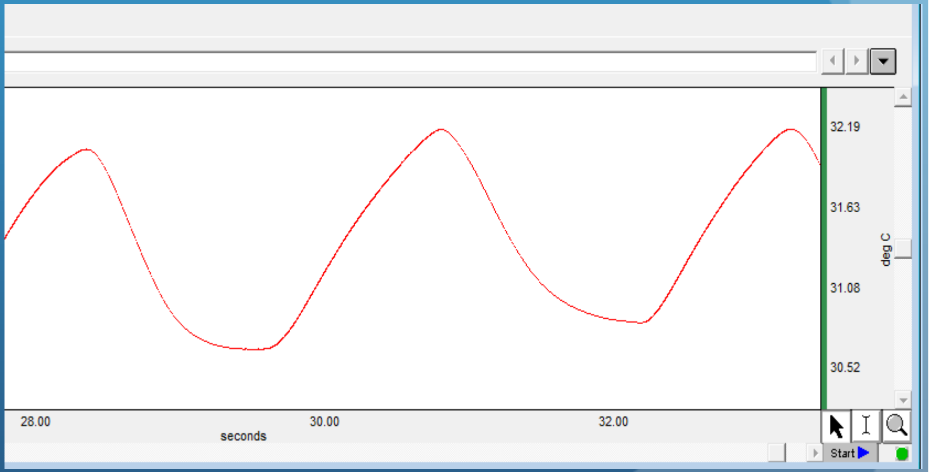


Figure 6: Preliminary testing using BioPac SS5LB Thermistor

Force Sensing Resistor (FSR)

- Design Specifics
  - Measures variation of force of chest wall through resistance
  - Either directly attached (chest) or under mattress
- Advantages
  - Non-invasive (under mattress)
- Disadvantages
  - Proper placement of resistor plate imperative
  - Higher propensity for false positives [3]
  - Expensive

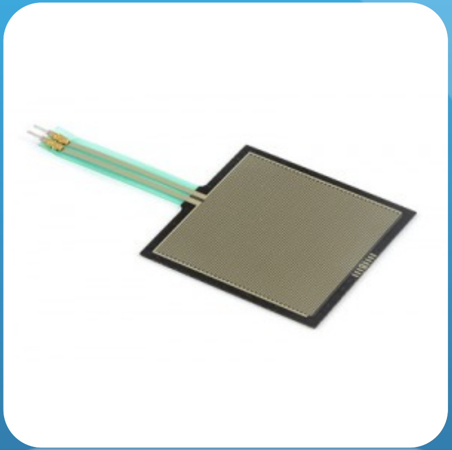


Figure 7: Example of a square force sensitive resistor [4]

Impedance Pneumograph (IP)

- Design Specifics
  - Works on principle of increased resistance of air
    - Resistivity of air is 1.3×10^{16} to 3.3×10^{16} Ω·m compared to cardiac tissue (175 Ω·cm) and lung tissue (157 Ω·cm) [5]
  - Current passed through four leads on body
- Advantages
  - Directly measures tidal volume
  - Very reliable
  - Relatively low cost
- Disadvantages
  - Current applied to body
  - Many wires attached to body

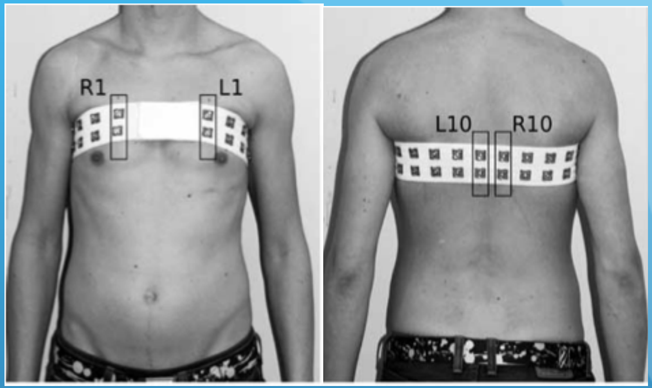


Figure 8: Bodily lead placement for IP [6]

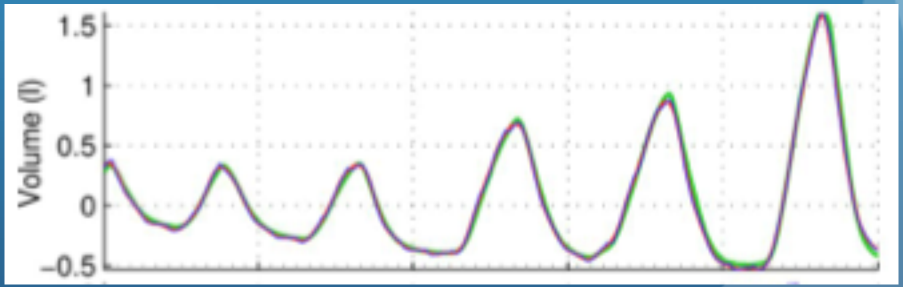


Figure 9: Impedance pneumograph waveform during respiration [6]

Pulse Oximetry (PO)

- Design Specifics
  - LED emits light through body, photodiode measures light output
  - Difference in output measures blood's change in absorption of red and infrared light
    - More O_2 →less red absorption, more infrared absorption
- Advantages
  - Non-invasive with several attachment points
  - Measures both pulse and oxygen saturation
- Disadvantages
  - Data averaging delays readings
  - Misplacement can lead to poor readings

Figure 10: Pulse oximeter attached to infant's toe [7]

Design Matrix

- OBJECTIVE: Design shall combine *two* measurement methods into one feedback loop

	Weight	Temp	FSR	IP	PO
Cost	.25	8	6	8	3
Safety	.30	5	8	4	6
Durability/Lifespan	.15	7	5	6	7
Ease of assembly/use/repair	.05	7	7	5	6
Signal reliability	.25	5	3	8	4
Total	1	6.2	5.8	6.3	4.9

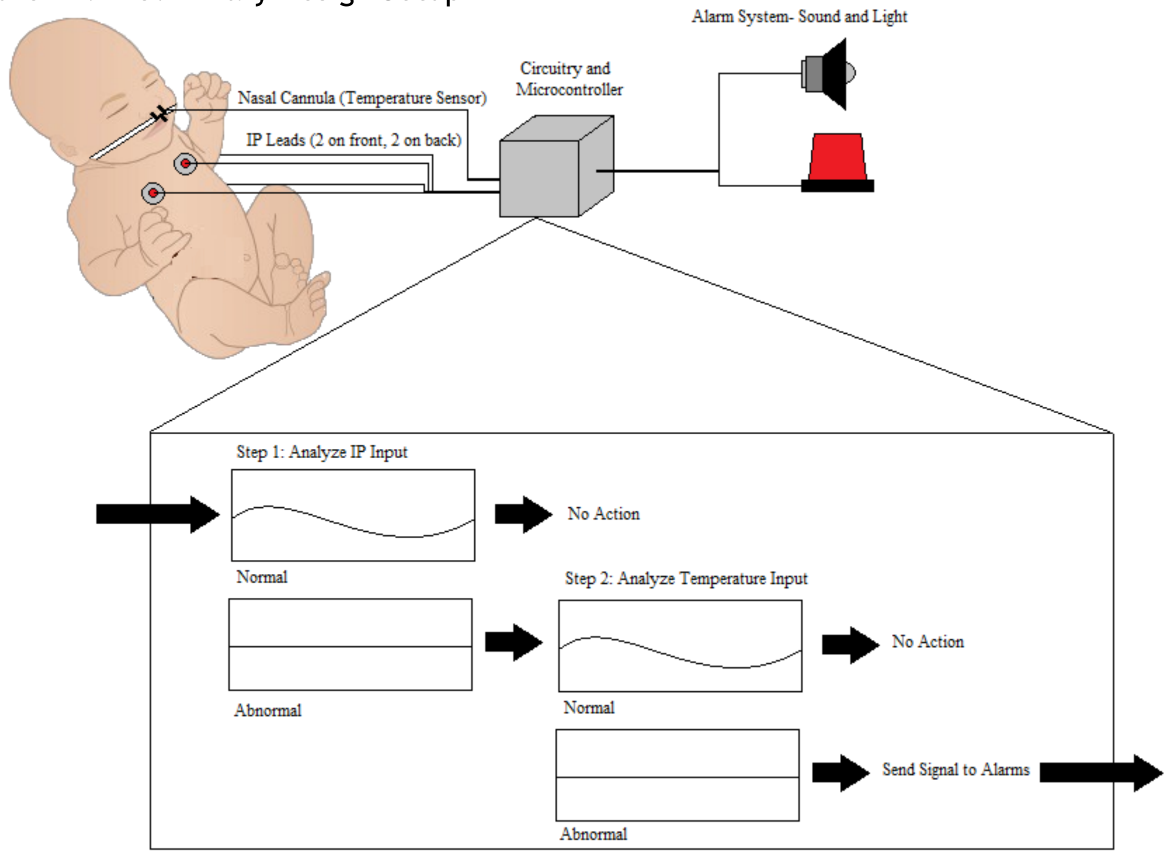
Design Specifications

- Kit distribution
  - Training/instructions included
  - Low cost ($10-$20)
- Continuous monitoring necessary
  - ~12 hours uninterrupted operation
- Alert of apneic event after ~20 seconds of respiratory arrest
- Rely on 12V power source with less than 100mA drain during operation
- Small portable form factor preferred
  - Circuitry housing no larger than 10 cm x 10 cm x 10 cm

Preliminary Design

- Integrate impedance pneumograph and thermistor
  - Feedback loop

Figure 11: Preliminary Design Setup



Future Work

- Determine optimal lead and sensor placements
- Assemble two input circuits (IP & Thermistor)
- Develop alarm output circuit (speaker & LED)
- Choose a low cost microcontroller for control, pattern recognition, and processing.
  - Develop algorithm for apnea detection
- Determine expected implementation environment
  - Determine source of power
    - Batteries or distribution grid

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- Amit Nimunkar
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