PediO2meter

Pediatric Pulse Oximeter for the Developing World

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Abstract

The PediO2meter is a pediatric pulse oximeter designed to address critical medical challenges of the developing world by providing a vital tool in the assessment of respiratory disease in young children. Conventional pulse oximeters, although widely used in the developed world, do not meet the special needs of the developing world and its pediatric population. Consequently, clinicians are unable to accurately and objectively diagnose respiratory function and thus determine appropriate treatment for patients. The PediO2meter meets these needs with a self-powered and self-contained design that accommodates pediatric physiology.

Diagnosing Respiratory Disease

Pulse oximetry is a noninvasive, accurate method of diagnosing the severity of respiratory disease.

Visual symptoms are insufficient for determining illness severity, particularly in the case of children.

• 22% of pediatric deaths in Sub-Saharan Africa are due to acute respiratory infection

Pulse oximetry non-invasively determines blood oxygen saturation (SaO_2) by utilizing the unique optical properties of oxygenated and deoxygenated hemoglobin.

• SaO_2 is a strong indicator of respiratory disease

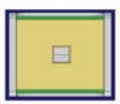
Design Criteria

Challenge: Unreliable power supply
Solution: Hand-powered energy generation

>> Energy for the pulse oximeter is supplied by a hand crank and stored in a rechargeable Ni-MH 3.6 V battery.

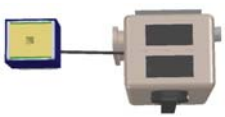
Challenge: Impractical sensors for pediatric patients
Solution: Reusable 'Raspberry' sensor

>> The reusable sensor can accommodate a range of finger diameters in pediatric patients while maintaining a durable construction



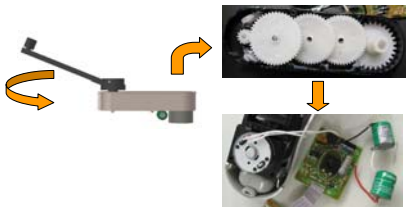
Challenge: Prevalent theft
Solution: Personal and portable pulse oximeter

>> The pulse oximeter is contained within one unit, and the sensor is connected permanently to the body.

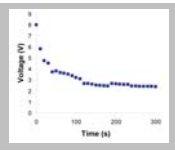


PediO2meter Design

Power Generation

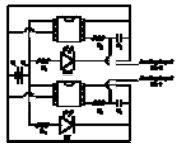


• Handle modeled after Garrity® Light (4.5" in length)
• Connected to gear box (gear ratio = 12.5)
• AC to DC bridge rectifier circuit charges battery
• 7.2 V Ni-MH rechargeable battery powers:
  •LEDs (2.3 V)
  •Operational amplifier (6 V)
  •Display (5 V)



Hand crank powered NiMH battery powers circuit for 100-120 seconds.

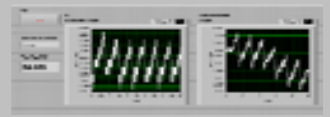
Signal Processing/Calculations



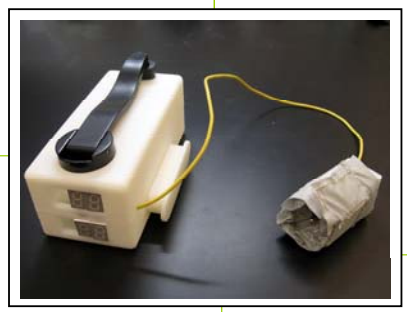
• LED / photodiode circuit
• Amplification with single-supply operational amplifier
• Low-passfiltering

• LabVIEW algorithm utilizes AC and DC components of signals from photodiodes receiving infrared and red light
• SaO_2 is calculated:

$$\frac{\varepsilon_{HbO_2,\lambda 1}\left(\frac{AC_{\lambda 2}}{DC_{\lambda 2}}\right)R - \varepsilon_{Hb,\lambda 2}}{\left(\varepsilon_{Hb,\lambda 1} - \varepsilon_{HbO_2,\lambda 1}\right) - \left(\varepsilon_{Hb,\lambda 2} - \varepsilon_{HbO_2,\lambda 2}\right)R}$$

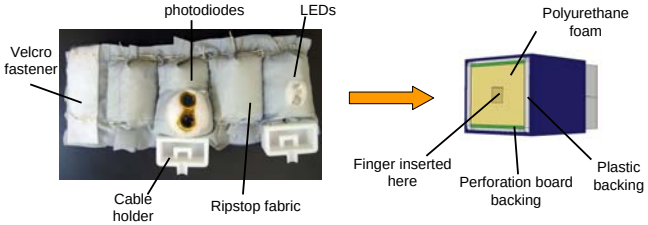


• LabVIEW testing environment gives graphical view of voltage signal from red and infrared LEDs.
• Calculations result in reasonable pulse rate and SaO_2 values



Raspberry Sensor

• Polyurethane foam interior conforms to finger diameters 0.7 – 1.1 cm
• Foam embedded with IR and red wavelength LEDs and two OPT101 op-amps with embedded photodiodes
• Ripstop fabric exterior is resistant to tears, waterproof, and inhibits bacterial growth
• Sensor can be 'unrolled' for easy access to interior



Displaying SaO_2 and Pulse

SaO_2 and heart rate displayed on the front of the pulse oximeter using low-power 7-segment LEDs

• Low power, common anode 7-segment LED display
• Calculated results travel as digital outputs and are translated by NTE 2024 2-digit BCD 7-segment decoder
• 7-segment LED common anode powered by hand crank battery
• 7 segments turned on and off by BCD translated digital outputs
• Result updates every five seconds

Conclusion

The PediO2meter is a self-powered, self-contained pediatric pulse oximeter that meets the needs of the developing world.

• Current prototype
  • Successfully detects cardiac-synchronous pulsatile signal with hand-powered circuit
  • Ni-MH battery (charged by hand crank) maintains adequate voltage to power circuit
  • 'Raspberry' sensor is reusable and appropriate for the pediatric patient population
• Future work directed toward:
  • Embedding SaO_2 calculation logic to microcontroller
  • Testing accuracy and feasibility for use on pediatric patients
  • Optimizing signal detection and processing

References

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2. Mendelson Y. Pulse oximetry: theory and applications for noninvasive monitoring. Clin Chem. 1992 1992 Sep;38(9):1601-7

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