Non-Invasive Ventilator Mask Fitting Feedback System

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121

Abstract

Healthcare workers affix ventilator masks in their treatments of pediatric patients daily. However, due to the current design, problems arise because masks are occasionally affixed too tightly to the face which causes a skin rash and irritation over time. Proximity sensing capabilities along with a real-time fitting information system would assist in minimizing potential skin irritation. Two methods were used to enable proximity capabilities, the first a flexible solution, and the second a rigid approach. A data acquisition system was designed to obtain real-time data. The experimental results of both designs show evidence of a displacement zone that through code, led to the development of an LED based fitting system.

Introduction and Background

- Pediatric Ventilator Mask
  - Fig. 1 shows a non-invasive ventilator mask used in respiratory therapy
  - Black marks indicate main pressure/contact points on patients face. Sensing information about the distance of these points from the skin is desired
- Lack of Available Solutions
  - No commercially available solution able to provide mask fitting information to respiratory therapist
- Capacitive Sensing Approach
  - Capacitive sensing technology commonly seen in touch and proximity applications
  - Changing capacitance seen by sensors used to establish displacement
  - Sensors printed via Aerosol Jet (conductive silver ink)

Fig 1: Main contact/pressure points indicated on mask

System Design

Design 1: Flexible Solution

- Flexible Sensor Design
  - Aerosol Jet printed
  - Conductive silver ink
  - 3.5mm square
  - Printed on flexible Kapton tape

Fig 2: Flexible Sensors Affixed to Mask

- Flexible Hardware and Output System
  - Breadboard containing MTCH112 provides sensor readings from flexible mask
  - MTCH112s provide raw capture data to an Arduino that controls output system
  - 3D printed enclosure holds output system

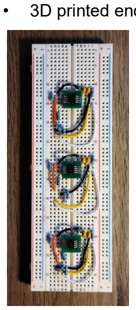

Fig 3: Evaluation hardware on breadboard

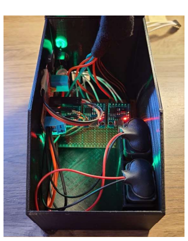

Fig 4: Output System Enclosure

Design 2: Rigid Solution

- Rigid Printed Circuit Board
  - Un-obtrusive frame attachment
  - 10mm copper sensor pads
  - Guard ring surrounding sensors helps control sensing direction and reduce external noise

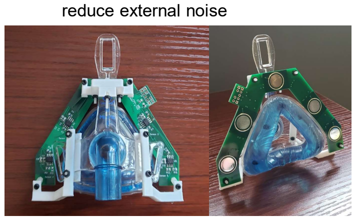

Fig 5: Rigid PCB Frame and Mask

- Circuit for Rigid PCB
  - Sensors connected to individual MTCH112 on printed circuit board as shown in Fig. 6
  - LC filter on input partially removes high frequency noise

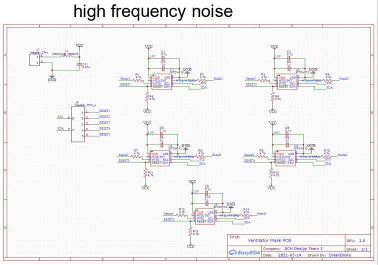

Fig 6: Rigid Data Acquisition Schematic

Experimental Results

- Testing System
  - 3D printed pediatric patient
  - Conductive copper coat used to simulate human skin

Fig 7: 3D Model with Conductive Layer

- Testing System Apparatus
  - Stepper motor driven by Arduino Mega 2560
  - Conductive element affixed to controlled platform for testing with accuracy of ±0.03mm

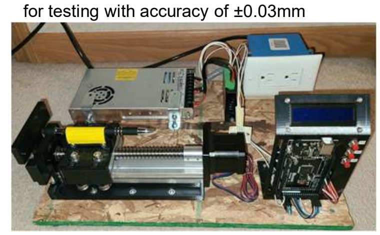

Fig 8: Linear Rail Testing Apparatus

Sensor Proximity Detection Range Testing

Displacement Zone

- Fig. 9 shows plots of evaluation hardware readings from flexible and rigid sensors
- Values seen in 0mm – 0.5mm range of the flexible sensors provide data used to tune LED output system

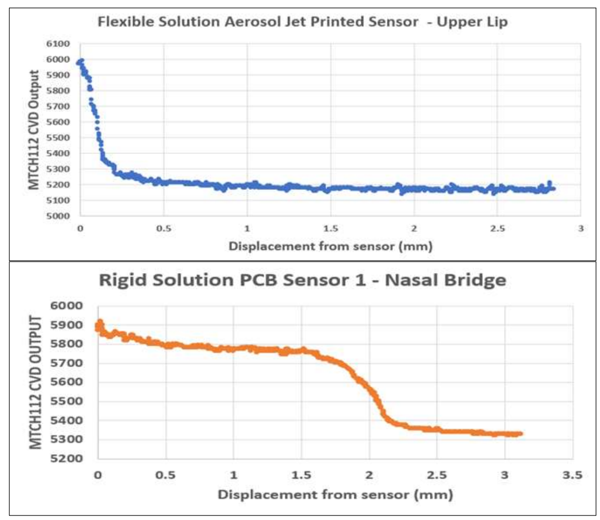

Fig 9: Testing of Flexible (Top) and Rigid (Bottom) Sensors

Output System in Action

Visual Output System

- LED Display House
  - Easily convey mask fitting information to medical staff
  - Houses 3 RGB LEDs arranged to correspond with affixed sensor location
- Specs
  - Internal 9V battery power source
  - Three Arduino ATTINY85 interpret data from MTCH112 chips via I²C
  - PWM output scheme controls color of LEDs as skin approaches each sensor

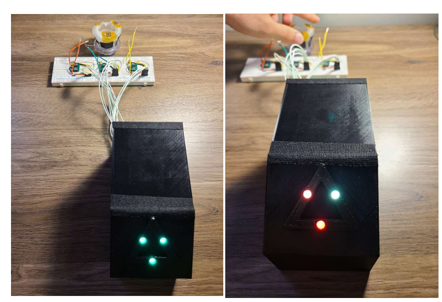

Fig 10: LED Output System. LEDs Gradually Change Color as Objects Approach

Conclusion and Future Recommendations

Conclusion

- Successful implementation of rigid and flexible capacitive sensing systems
- Capable of detecting small distance adjustments (mm) presenting a suitable solution to the design sensitivity
- Results verified through simulation and quantitative testing

Future Recommendations

- Due to COVID, we were unable to test on-site in a real-world application
- Adjustments to proximity sensing code based on field testing
- Implementation of flexible covering
- Automation of sensor fabrication process