WIRELESS AIRWAY MANAGEMENT SYSTEMS FOR EMERGENCY MEDICAL APPLICATIONS

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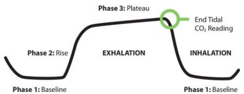
Background

- Capnography - The waveform that shows how much CO_2 is present at each phase of the respiratory cycle. [1]
- End-Tidal CO2 (ETCO2) - The partial pressure of CO2 detected at the end of exhalation. The value is normally 35-45 mmHg. [1]

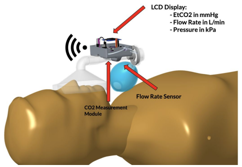


Problem Statement

- Existing capnography devices utilize side stream technology which is inconvenient, messy, and bulky.
- We need to eliminate the wiring of current capnography technology and provide more information to EMTs (Emergency Medical Technicians) in a prehospital setting.
- Manual ventilation bags without real-time feedback fail to tell an EMT whether they are ventilating a patient properly, or if they might be damaging the patient's lungs.
- Our goal is to create a portable capnography device that is capable of measuring End-Tidal CO2 from the exhaled breath of patient, as well as inspiratory and expiratory flow rate and airway system pressure.

Design Concept

- The Wireless Airway Management module is a light, compact, wireless, and robust device that is designed to have minimally intrusive components to reduce complications that occur during the transport of patients.
- The device utilizes mainstream capnography instead of a sidestream method in order to maintain a compact form factor.



- The three core functions of the device are ETCO2 measurement, pressure measurement, and flow rate measurement.
- Our team researched the physics that would allows us to measure ETCO2 and built circuits to do the same. Our team had also researched ways of measuring flow of gases and integrated a flow rate sensor in-line with with the ETCO2 module.

Implementation

- ETCO2 measurement - To measure CO2 concentration through the mainstream method, Nondispersive Infrared Spectroscopy (NDIR) is used. An IR lamp along with a thin film pyroelectric dual channel sensor is used to filter light at the 4.26um and 3.70um wavelengths.
- When light passes through a stream of gas containing CO2, the gas absorbs energy from the light at the 4.26um wavelength, as CO2 has a dominant absorption band at 4.26um. Since no gas absorbs light at 3.7um, a reference channel with a light filter of 3.7um wavelength is used.

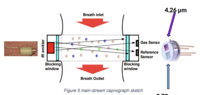
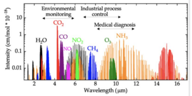
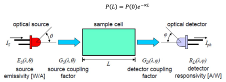


Figure 5 main-stream capnograph sketch

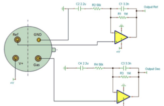


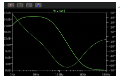


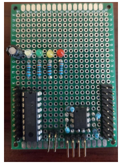
- Flow rate measurement - Both the inspiratory and expiratory flow rate is necessary for providing the EMT with proper volume measurement, we chose to measure flow bidirectionally using a thermal method. This is much more suited to our goals than the traditional pressure differential method of detecting flow rate, which only measures unidirectionally.
- We chose the Sensirion i2c SFM3300 for our flow rate measurement technology. It has a central heater with a heat sensor on either side of the heater. When air passes from the female to male part of the sensor, it registers a positive flow rate, and vice versa.

Hardware Setup

- A bandpass filter is used to amplify the raw signals from the IR sensor.
- A DMOS based circuit is used to drive the IR lamp.
- The sensor readings are then digitized by the ADC of the TIVA TM4C123GXL and over sampled to increase resolution of the data and distinguish microvolt level changes in data.

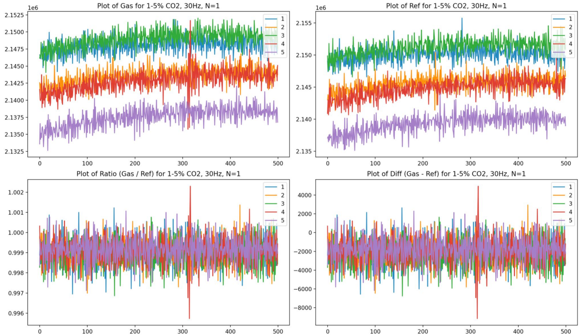






Data Analysis and Calibration

- To calibrate the ETCO2 sensor subsystem, CO2 gas cylinders of varying CO2 concentrations (1% CO2 - 5% CO2) were used. Below are the plots of various sensor readings that were gathered in a controlled experiment.



- From the above data we see that our system is performing in accordance with the Beer-Lambert law. As the concentration of CO2 increases, the intensity of the light decreases, which is shown in the linear decrease in voltage readings. Here, CO2 at 3% concentration is an outlier.
- Performing data analysis on these readings should allow us to create a mapping from voltage readings to gas concentrations, finalizing our ETCO2 module.

Future Work, Acknowledgments and References

In the future, teams should:

- Integrate pressure sensing & complete calibration to a greater degree.
- Merge the ETCO2, flow rate, and pressure sensing into a single prototype.
- Create standalone prototype with energy management electronics.

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[1] "5 things to know about capnography," EMS1, 08-Jul-2020. [Online]. Available: https://www.ems1.com/ems-products/capnography/articles/5-things-to-know-about-capnography-Hr5ETRdXzCoU3fLH/.
[2] Person, "Complete Gas Sensor Circuit Using Nondispersive Infrared (NDIR)," Complete Gas Sensor Circuit Using Nondispersive Infrared(NDIR)|Analog Devices.[Online]. Available: https://www.analog.com/en/analog-dialogue/articles/complete-gas-sensor-circuit-using-nondispersive-infrared.html#.

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