WIRELESS AIRWAY MANAGEMENT SYSTEMS FOR EMERGENCY MEDICAL APPLICATIONS

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stryker

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Objective

Capnography is a non-invasive measurement of partial pressure of CO2 from the airway, as shown in Figure 1. Existing capnography devices utilize side-stream technology which is inconvenient, messy, bulky, and does not provide Emergency Medical Technicians (EMTs) with the best possible real-time feedback. We worked to create a portable mainstream capnography device that is capable of two main objectives:

1) Measuring End-Tidal CO2 (EtCO2) from the exhaled breath of a patient
2) Measuring inspiratory/expiratory flow rate and airway pressure

With the two main objectives in mind to create waveforms such as Figure 2, additional functionality such as bluetooth connectivity with existing Stryker products and sensor software integration must also be targeted for a complete commercial product.

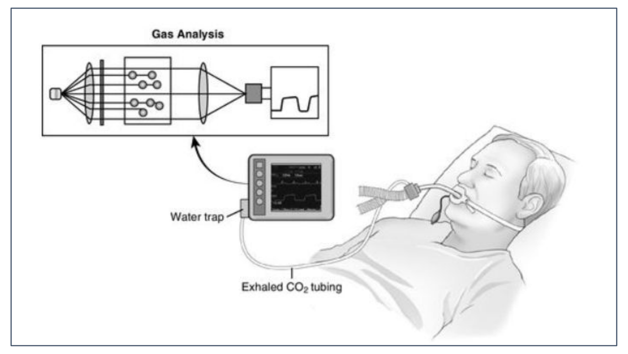


Figure 1: Example capnography monitoring

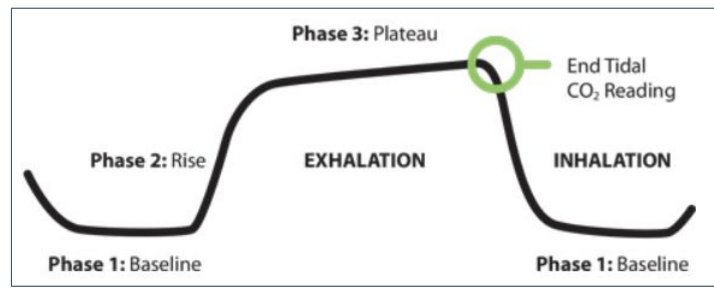


Figure 2: A normal capnograph

Design Concept

The Wireless Airway Management module in Figure 3, is intended to be:

- Light, compact, wireless, and robust device
- Utilize mainstream capnography instead of a sidestream method for compact form factor
- Display values using UART, an asynchronous serial communication, on a GUI that is representative of a future LCD display

Broken down into two submodules:

1) End-Tidal CO2
2) Lung Pressure & Flow Rate

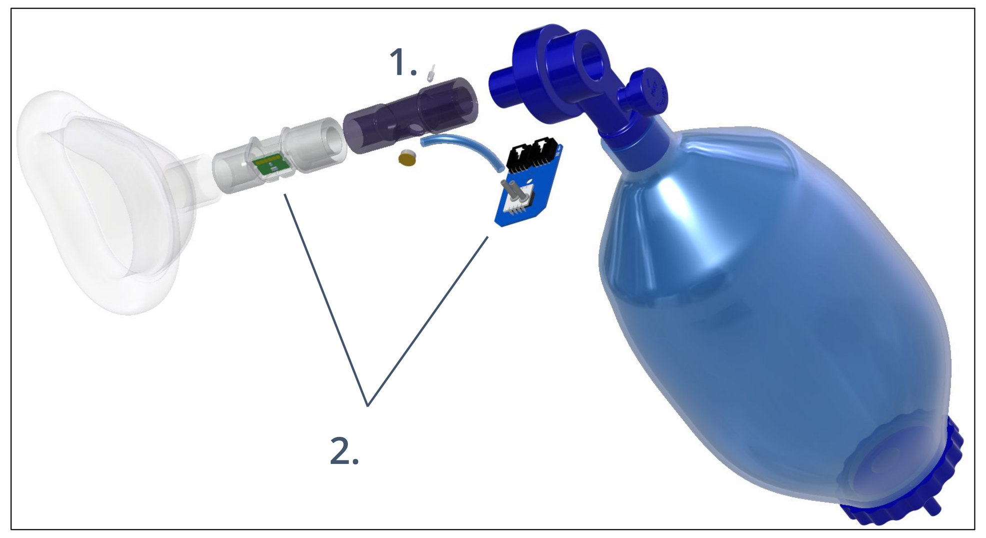


Figure 3: Breakdown of integrated module

Pressure & Flow Rate Hardware

This submodule is able to read pressure and flow rate values using two verified sensors powered by TM4GX123XL microcontroller in Figure 4

A. Sensirion SFM3300-D, Flow Sensor for respiratory devices
B. AMS5915-0100-D Amplified Low Pressure Sensor

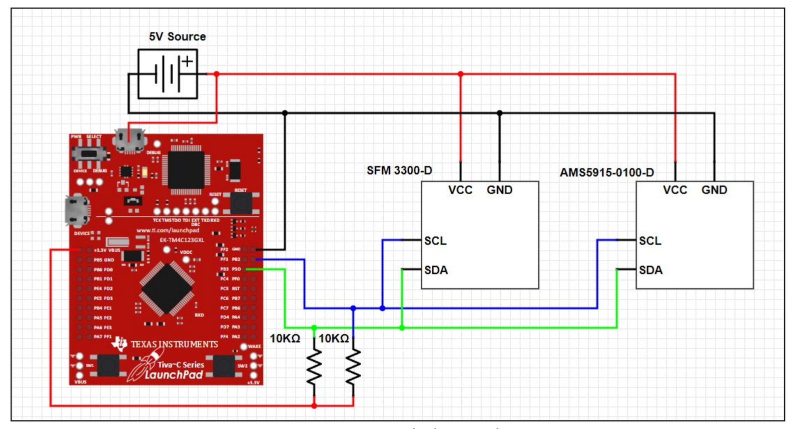
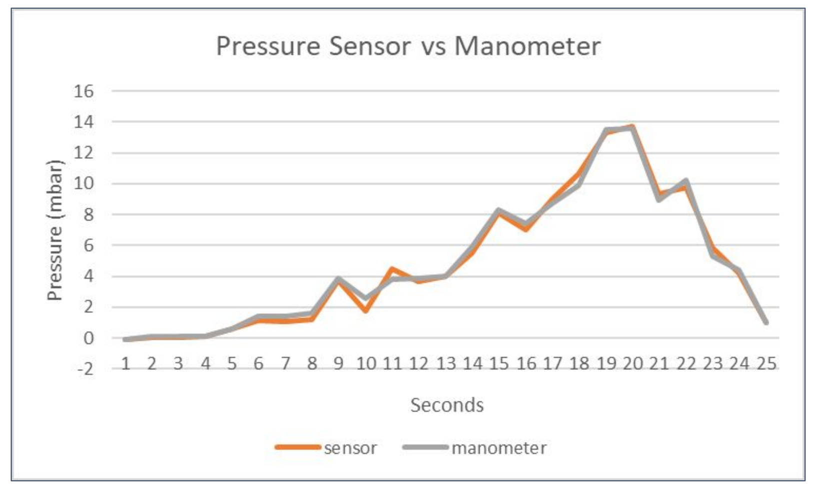


Figure 4: Pressure and Flow Subcircuit

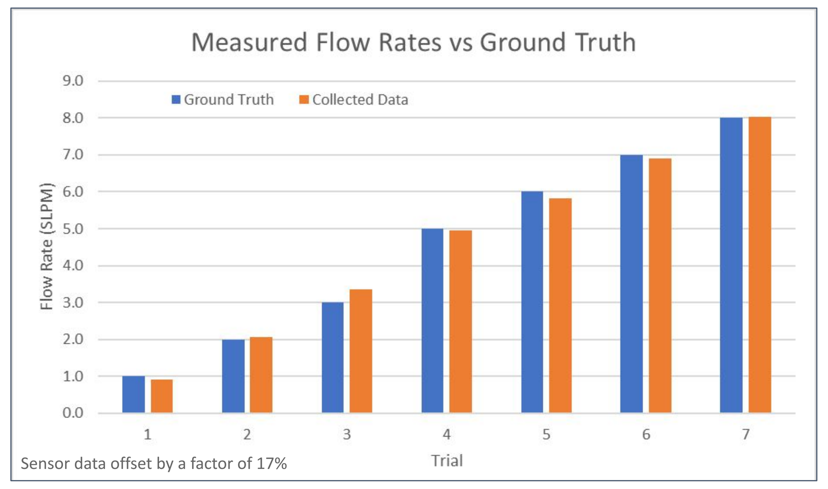
Pressure & Flow Rate Data Analysis

Physiological characteristics of breathing indicate that pressure during ventilation ranges from 5 cmH2O to 40 cmH2O. The current pressure is calculated using the equations in Figure 5 to convert from digital pressure readings. We tested the dynamic range against a ground truth manometer to confirm that our setup was accurate displayed in Figure 5. Similarly, flow rate in the airways should not exceed 150 SLPM. The flow rate displayed was calculated using equation in Figure 6 to convert the digital reading to a flow reading in SLPM. We tested our sensor using pressurized nitrogen gas and a single stage gas regulator from a range of 1 to 8 SLPM shown in Figure 6.



$$p = \frac{Digoutp(p) - Digoutp_{min}}{Sensp} + p_{min} \quad \text{with} \quad Sensp = \frac{Digoutp_{max} - Digoutp_{min}}{p_{max} - p_{min}}$$

Figure 5a. Pressure ground truth testing & conversion equations



$$flow\ [\text{slm}] = \frac{measured\ value - offset\ flow}{scale\ factor\ flow}$$

Figure 6a: Flow rate ground truth testing & conversion equations

EtCO2 Hardware

This submodule measures ETCO2 using an IR emitter and PY0234 CO2 sensor powered by TM4GX123XL microcontroller

A. The bandpass filter in Figure 7 is used to amplify the AC output of the CO2 sensor
B. The DMOS based circuit in Figure 7 is used to drive the IR emitter at a 10 Hz frequency

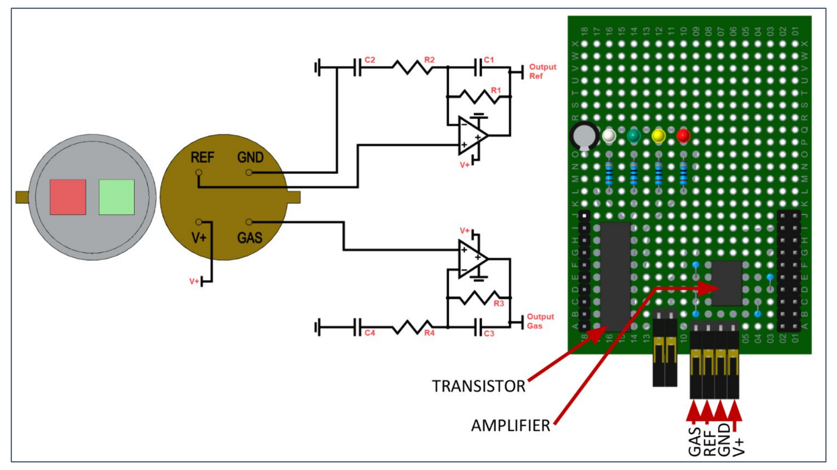


Figure 7: Bandpass/amplifier and DMOS based circuit

EtCO2 Data Analysis and Calibration

The PY0234 sensor subsystem was calibrated using CO2 gas cylinders of varying concentrations from 0-65% CO2. Figure 8 shows the raw analog-to-digital converter values plotted over multiple IR emitter periods.

- Using the root mean squared values for the gas and reference plots, constants for a modified Beer-Lambert equation were determined to relate absorbance and gas concentration, as seen in Figure 9 and 10.

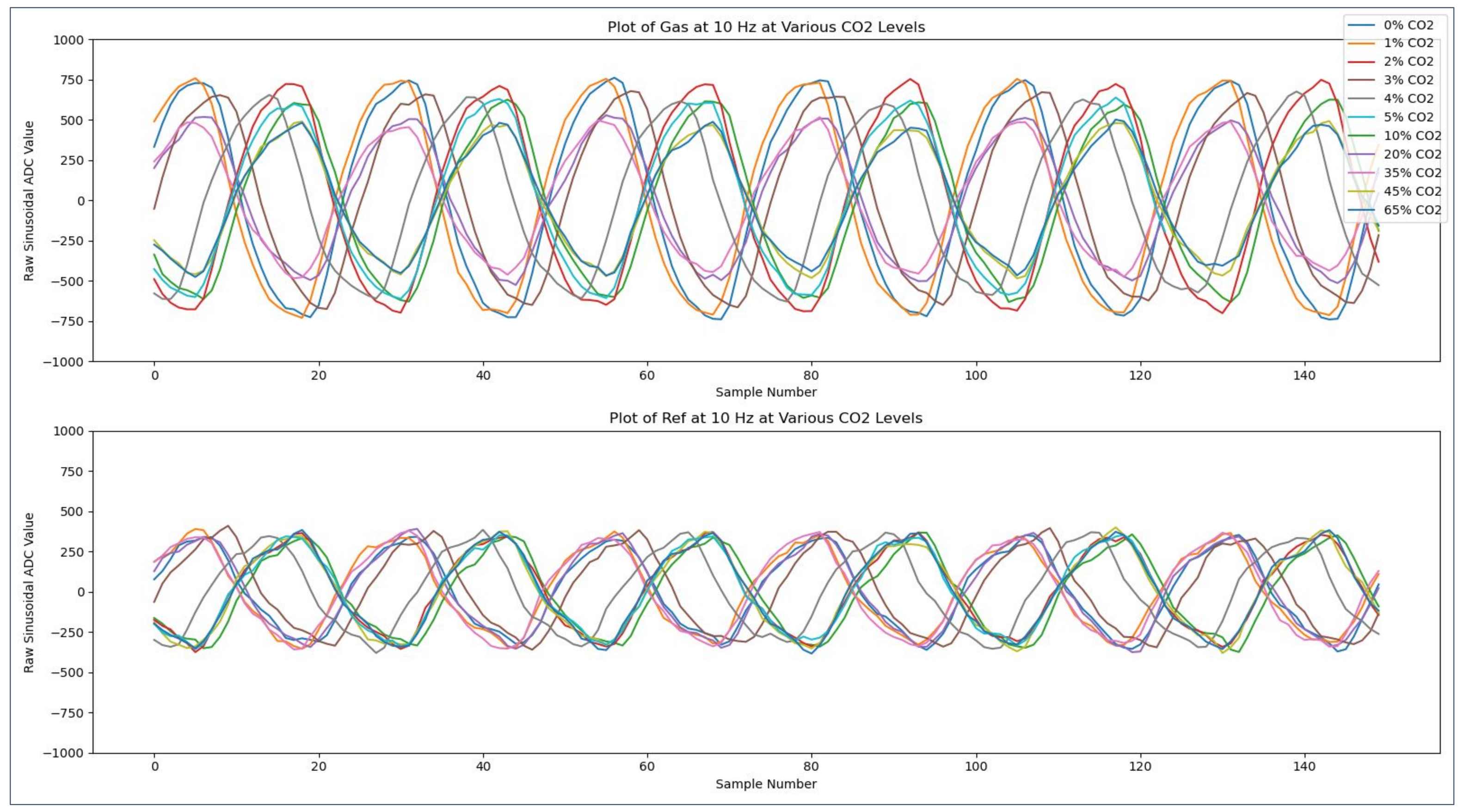


Figure 8: Data plots for gas and reference values from the TM4GX123 ADC (analog-to-digital converter)

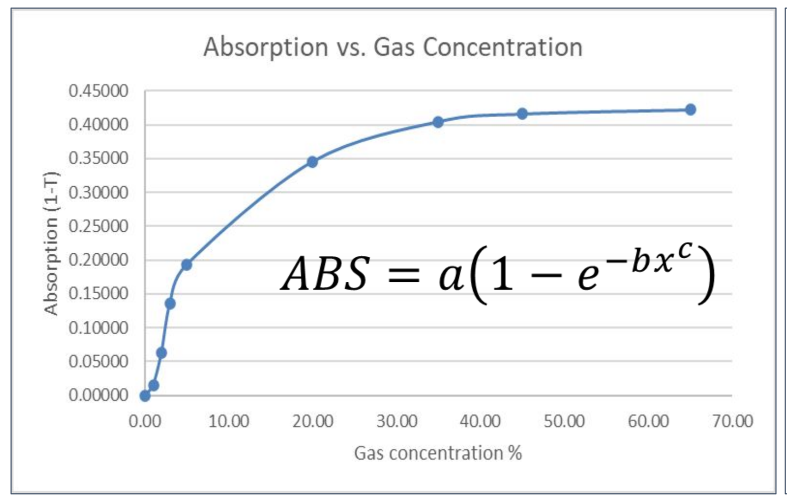


Figure 9: Data plot for absorption against experimental gas concentration

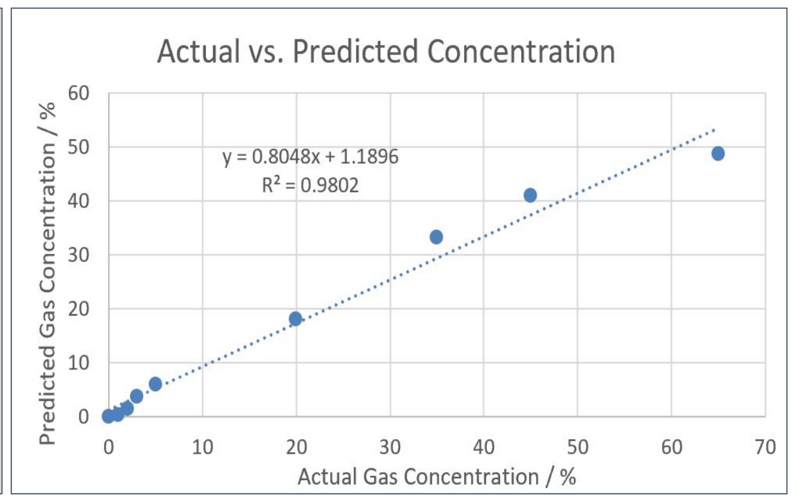


Figure 10: Trendline for calculated and experimental gas calculations

Conclusion, Future Work & References

- Tasks completed
  - Validated and calibrated the EtCO2 module at constant CO2 concentrations
  - Validated and integrated flow rate and pressure modules
- Tasks to be completed
  - Dynamic validation of CO2 sensor with exhaled breaths
  - Integration of flow rate, pressure, and EtCO2 modules
  - Creation of a standalone prototype
  - Implementation of bluetooth functionality with Stryker's LifePak 15

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