O_2 and CO_2 Sensor Integrated Mask for Aiding Cardiothoracic Surgeons in Assessment of Patient Risk and Recovery

Brianna Myers, Jaskaran Atwal Nahal, Chai Yang, Zibran Chaus, Soheil Ghiasi, and André Knoesen: Department of Electrical & Computer Engineering
Lisa Brown: Department of Surgery

Summary

A compact, low energy mask system was developed to help cardiothoracic surgeons in patient assessment. The mask contains integrated oxygen and carbon dioxide sensors that monitor the concentrations in the user's breath. An onboard accelerometer also measures the activity levels of the user during use. These measurements are collected and sent over Bluetooth to a smartphone for viewing. This system was designed to be a compact and simple alternative to current methods of assessment. The data collected can then be used to more efficiently and effectively determine preoperative risk factors of lung resection patients

Hardware

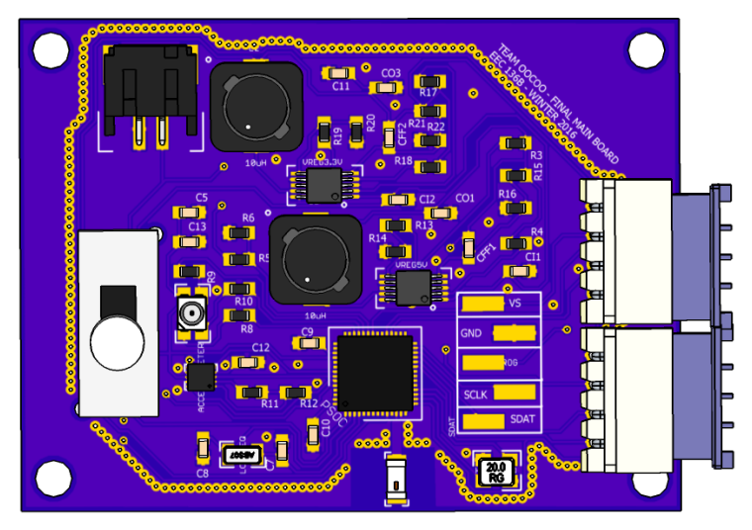
Programmable System on Chip 4 (PSoC4) CY8C4247LQI-BL483 microcontroller

SST LuminOx LOX-2, 25% oxygen sensor

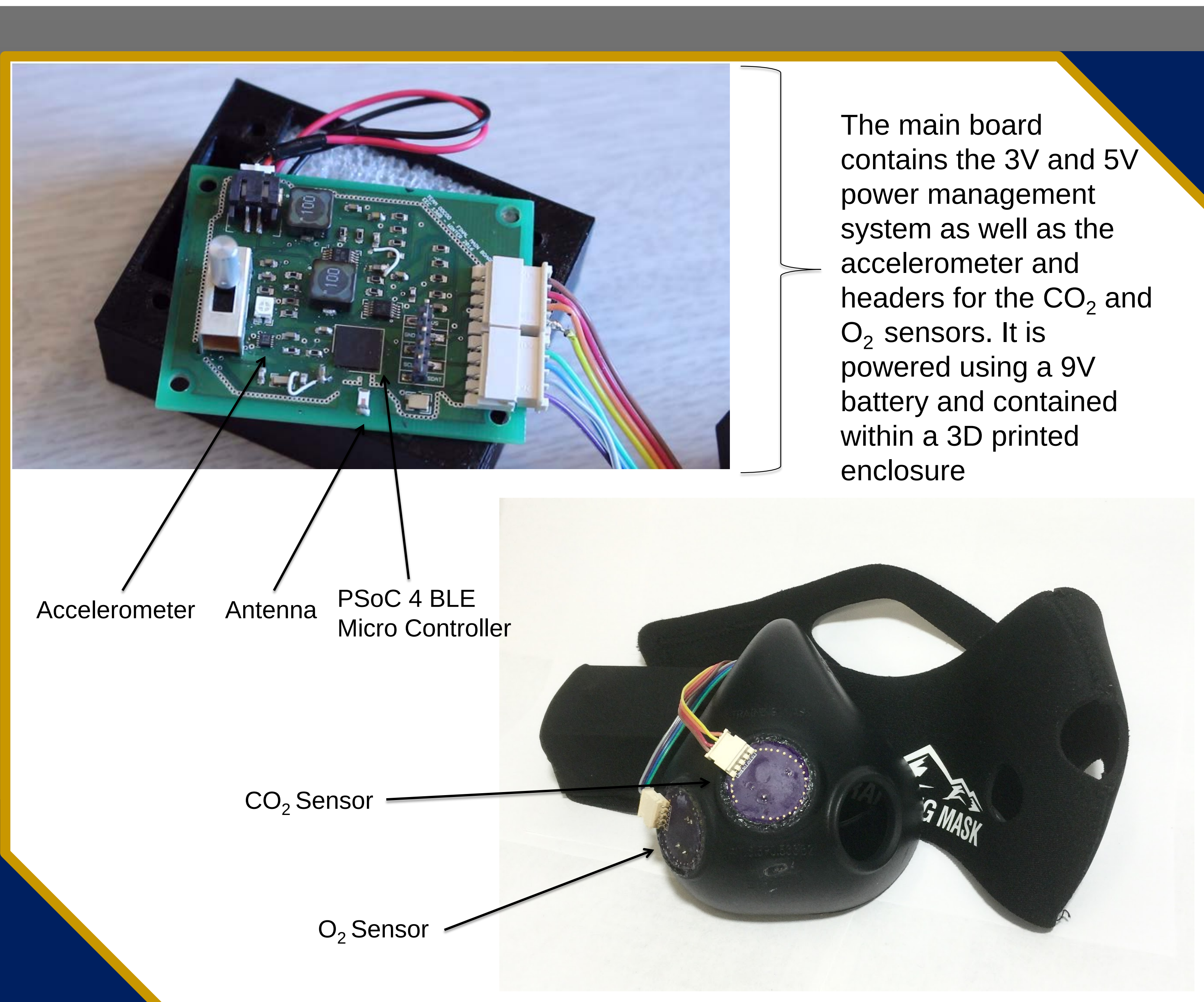
MinIR 100% GC-0025 carbon dioxide sensor

NXP/FreeScale MMA8652FCR1 12-bit, 3-axis accelerometer 2g/4g/8g

Training Mask 2.0



Printed Circuit Board layout designed in Eagle CAD



The main board contains the 3V and 5V power management system as well as the accelerometer and headers for the CO_2 and O_2 sensors. It is powered using a 9V battery and contained within a 3D printed enclosure

Methodologies

The system uses the Training Mask 2.0 with two integrated gas sensors. The mask has three circular holes in which two are occupied by the sensors and one is left open for free airflow. The diameter of this hole is 30mm and this measurement is important as a diameter smaller than the human trachea (25mm on average) will introduce air resistance during use. These two sensors are routed to the back of the head where the enclosure is mounted. The enclosure contains the main board, the accelerometer, and the battery. The carbon dioxide and oxygen sensor measures the expired gas levels of the user (in ppm) and the accelerometer measures the activity level of the user. This data is then sent to a smartphone for viewing via Bluetooth.

O2[%]	CO2[%]	Activity
20.27	0.22	0

Figure 1. System Overview. The data gathered from the sensors are sent to the smartphone application via Bluetooth.

The system begins in the search state where the gas sensors and accelerometer are initialized. Once the user chooses to pair the Qt Android Mobile Application with the PSoC 4 BLE on the mask, the gas sensors and accelerometer send real-time data from the PSoC 4 BLE to the phone application over Bluetooth Low Energy. The phone application then displays this live data as the oxygen, carbon dioxide, and activity levels of the user along with the current battery level of the mask. Once the user chooses to disconnect, the system returns to the search state.

Results

To verify the mask design and functionality of the two gas sensors, two tests were completed. This first test performed served to establish a baseline reading for the sensors and acted as the control. The volunteer wore the mask for a session of 20 minutes and was told to remain sitting. Data was recorded every three minutes. After establishing the resting data, the volunteer then performed a running test. The test was ran for 15 minutes: 10 minutes of running on a treadmill plus 5 minutes of rest. Data was recorded every minute to establish the trend. The volunteer's height, weight, age, sex, and average running speed were also collected.

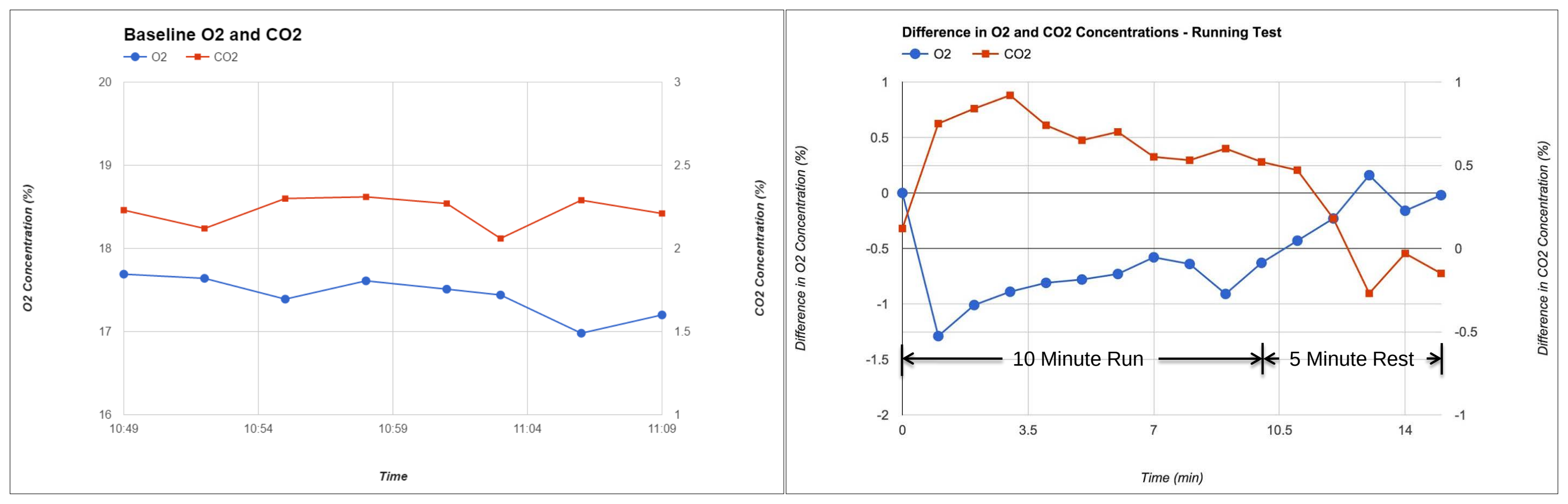


Figure 2. Test 1 results. The left graph shows the established baseline of the volunteer. The right graph shows the difference in O_2 and CO_2 concentrations from the baseline during exercise.

The baseline resting test results yielded an average of 18.1% oxygen and 2.35% carbon dioxide in respiration at rest. Figure 2 (right) displays the observed trends in carbon dioxide and oxygen levels resulting from the running test. The values graphed in Figure 2 (right) are the change in oxygen and carbon dioxide values from the baseline values observed in the initial test. When the volunteer began to run at one minute, their carbon dioxide levels increased, while oxygen levels decreased. At ten minutes when the users stopped running and began the resting period, oxygen and carbon dioxide respiration levels returned to the resting levels observed at the start of the testing period. As expected during exercise, the O_2 concentration decreased due to the body's increased oxygen consumption which resulted in the increase of CO_2 concentration.

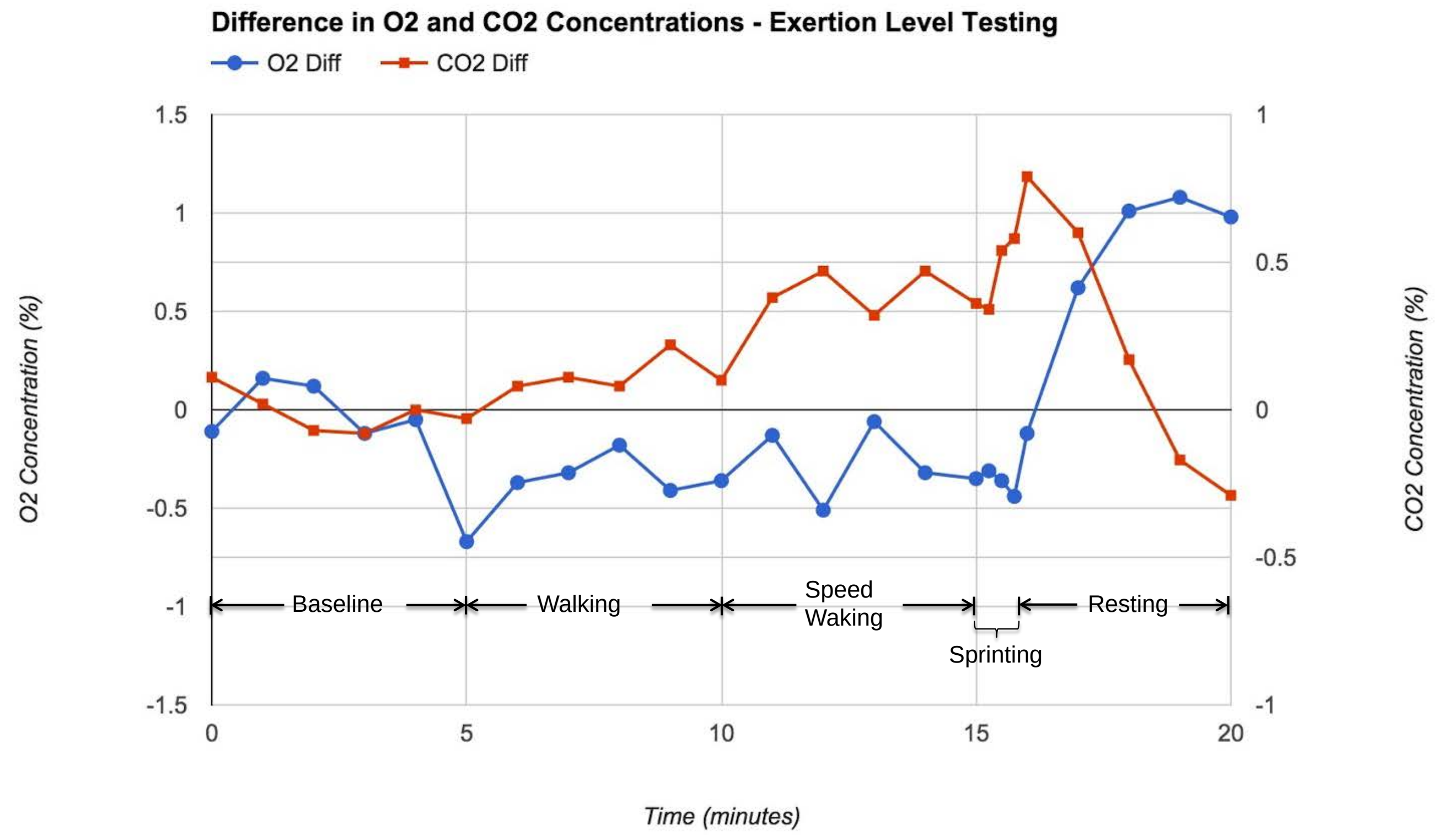


Figure 3. Test 2 results. The graph shows the difference in O_2 and CO_2 concentrations from the baseline hence the first five minutes are around zero percent.

Test 2 tested whether or not the system will be able to differentiate O_2 and CO_2 concentrations during different levels of exertions. The test ran for 20 minutes: 5 minutes baseline, 5 minutes walking, 5 minutes speed walking, 1 minute sprint, and 5 minutes of resting. The results in Figure 3 shows that with increasing exertion levels, the O_2 and CO_2 concentrations will, respectively, decrease and increase accordingly.

Acknowledgements

Texas Instruments
Cypress
Perform