



microMedic  
2013 National Contest

# Pulmonary Capacity Analyzer

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microMedic Project Number micro13MM250

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## 1 Project Summary

### 1.1 Overview

The Pulmonary Capacity Analyzer is intended to measure a user's lung capacity. By measuring the velocity of air moving through a breathing device, the microcontroller can calculate the volume of air that was moved during the time of inhalation. Pulmonary related diseases or injuries would typically result in reduced lung capacity; by comparing the output from this device to a known baseline, medical personnel have additional knowledge to aid in diagnosis and/or treatment.

This project was developed with the Propeller Board of Education received from Parallax upon submission of the project proposal. Also used was the mouth-piece component of the nebulizer found in the microMedic kit. By sheer coincidence, the wind sensor fit perfectly into the mouth piece.

The Wind Sensor was obtained from Modern Device (<http://shop.moderndevice.com/products/wind-sensor>).

### 1.2 Technical Design Overview

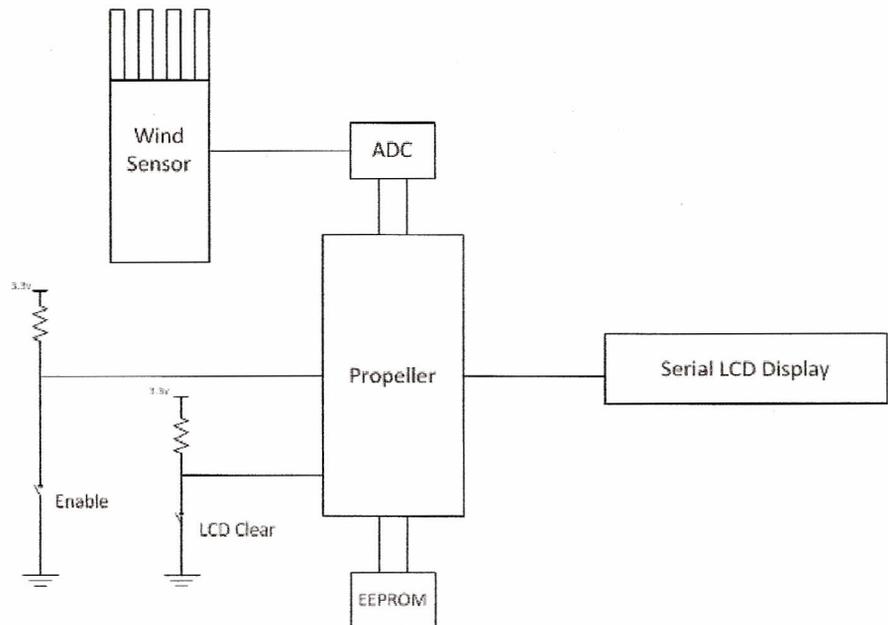


Figure 1 - System Diagram

Figure 1 depicts the high-level architecture of the system. The Propeller microcontroller takes input from the Wind Sensor via a 12 bit A/D converter and performs the necessary mathematical calculations. The output is displayed on a serial LCD display. One momentary contact switch is used to clear the display for subsequent measurements while a second switch is used to enable the system to take the measurements from the Wind Sensor.

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The Wind Sensor is the central component to the system. It is a thermal anemometer which uses the "hot-wire" technique for measure air flow velocity. This technique involves heating an element to a constant temperature and then measuring the electrical power that is required to maintain the heated element at temperature as the wind changes. This measured electrical input is then directly proportional to the square of the wind speed.

The output of the Wind Sensor is an analog voltage value that ranges from approximately 1.8 volts (no air movement at room temperature) to 5 volts (maximum air movement). This value is converted to a digital representation via the on-board A/D converter (on the Propeller Board of Education) or a MCP3204 A/D converter (on a Propeller Project Board).

In order to calculate the volume, the system needs to know not only the velocity (measured in meters/sec) but the cross-sectional area of the tube where the air is measured (measured in square centimeters). Multiplying these values (taking into account the different units of measurement) yields a result measured in cubic centimeters/sec.

Finally, it is necessary to know the duration (measured in seconds) that air was flowing past the sensor, or, how long the individual was inhaling a breath of air. In this project, an enabler switch was introduced. When the user presses (and holds) it, the Propeller starts a timer; when the switch is released, the timer stops. So to properly use this system, the user must depress the switch as he begins inhaling, and release at the completion of the inhale. This time value (measured in milliseconds) is then multiplied by the volume flow data previously calculated to finally yield a volume of air, or cubic centimeters. The information is displayed on the LCD display which can be cleared by the "LCD Clear" switch.

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## 2 Problems Encountered

Fortunately, throughout the course of this project, I did not encounter any significant problems. However, there were a few worth noting here.

### 2.1 Wind Sensor Documentation

There is very little documentation available on this particular wind sensor; what exists is limited to the one page on the Modern Device web site. The issue came with trying to understand completely how to map the voltage outputs to the actual air velocity, and do so accurately. The information that is available states that the voltage is proportional to the square of the wind speed. However experimentation showed some degree of error with that formula (note this same question/concern was posted on a couple of forums; some people resorted to calibrating their sensor by using expensive CFM equipment used by air conditioning technicians; I did not have access to such equipment so my conversion formula produces results that are likely not as accurate as they should be).

### 2.2 Wind Sensor Inaccuracies

The original design was to have the Propeller and the Wind Sensor together determine when the “breath” both started and ended and automatically determine the duration. This proved to be highly inaccurate. A part of the issue is that when air movement stops, it stops suddenly (you reach the limit of your breath, you suddenly stop, you don’t slow to a gradual stop). The wind sensor doesn’t react that quickly and was showing a velocity reading even after the breath had stopped. While this lasted a mere second or so, the resulting error was much too great to produce a useful output.

The alternate solution was to implement the “enable” switch, relying on the user to indicate when breathing started/stopped. While this is obviously not an accurate (or desirable) solution, the accuracy was much greater this way.

Another inaccuracy with measuring the air velocity is that it’s not always linear. I noticed that when a breath began, there was an acceleration factor which was exacerbated by the wind sensor “catching up” to the start of air movement. I chose to ignore this “acceleration effect”. The Propeller code instead takes a measurement every 100 milliseconds, and at the end of the cycle (when the “enable” button is released) calculates the *average* velocity.

### 3 Project Images

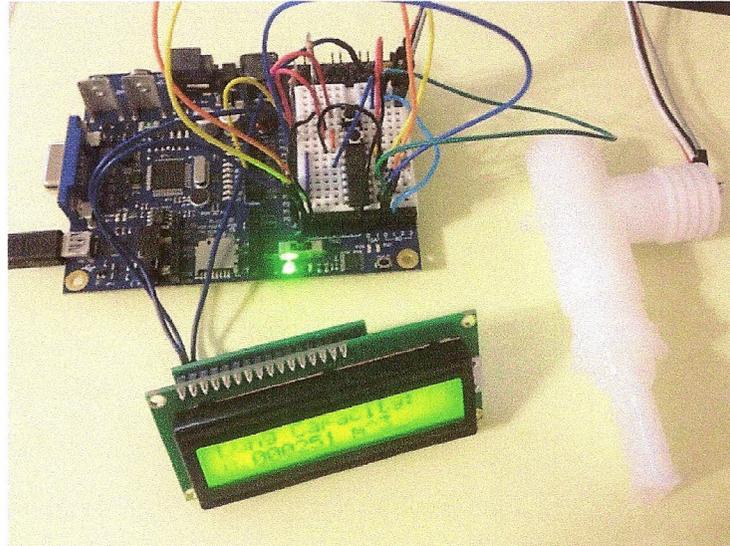


Image 1 – Overall project setup on Propeller Board of Education with breathing tube from the nebulizer in the microMedic Inspiration Kit.

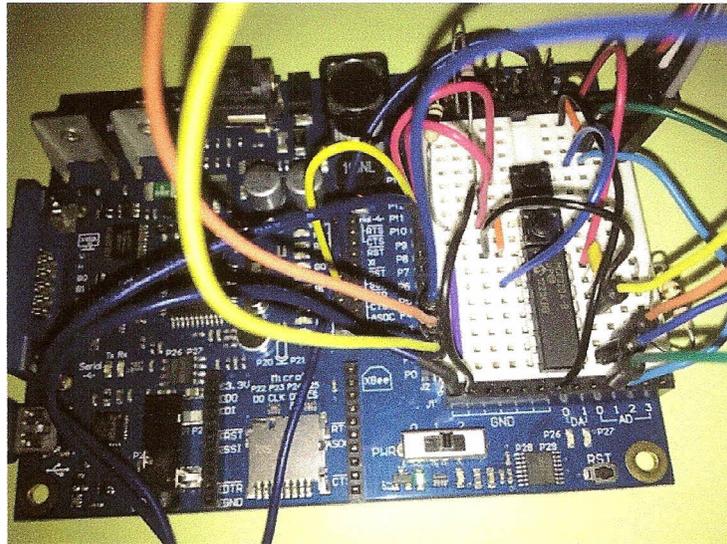


Image 2 – Close-up of the BOE. Chip at the bottom of the breadboard is the MCP3204 ADC, needed for future relocation of project to a Propeller Project Board.

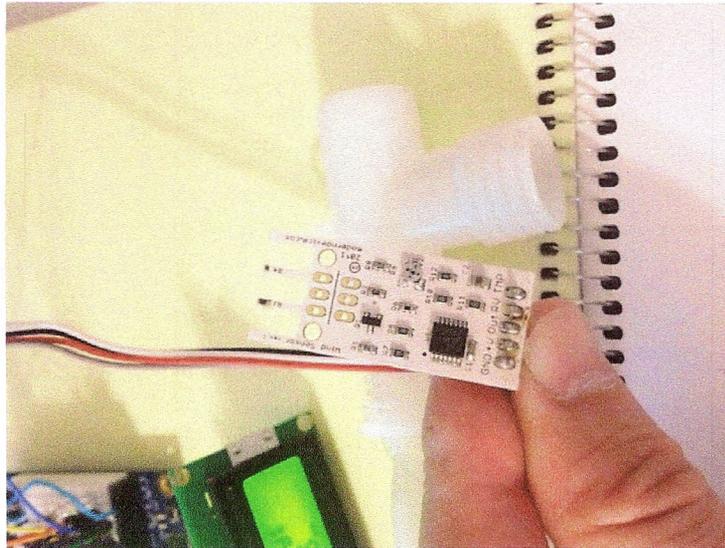


Image 3 – The Wind Sensor. Air movement through the tabbed end (left side) causes slight temperature fluctuations which are picked up by the circuitry and relayed as voltage changes.



Image 4 – The Wind Sensor coincidentally fits perfectly into the bottom of the breathing tube with only the tabbed end exposed in the horizontal chamber. The user breathes on the left end, and air flows through the length of the tube passing the Wind Sensor.



Image 5 – LCD display showing the calculated lung capacity, measured in cubic meters.