Portable Turbine Spirometer

A Mini Project Report submitted to Department of Biomedical Engineering in partial fulfilment of the laboratory course Microcontroller Lab (BME 3261)

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ABSTRACT

Medical instruments are growing more expensive day by day, and there is a need to find low-cost alternatives. We are looking for a design for a low-cost, dependable spirometer in an effort to extend access to spirometric equipment on a worldwide scale. The project entails the creation of a low-cost spirometer using commonly available materials, capable of measuring Lung volumes and flow rates.

Spirometry attempts to examine the proper functioning of the lungs. The parameters are calculated from measurements of flow and/or pressure. Breath by breath, patient spirometry evaluates the patient's airway's pressures, flows, volumes, compliance, and resistance. The gas flow is calculated. We've used a single, lightweight IR sensor, and the parameters are measured.

The volume of the exhaled air is recorded by the spirometer, which is displayed as numerical data which can be analysed to assess the mechanical characteristics of the lung. Rotation velocity is used to measure the flow rate while integrating the flow rate for a given time interval provides us with the volume of gas passing through the tube.

Finally, we'd like to draw a conclusion to this abstract by stating that spirometry, a vital tool in the medical field for predicting many pulmonary diseases (COPD), tends to be very costly to use. As such, we try to make a cheap, portable device for the common man. Spirometry can show airflow restrictions, but it cannot identify the cause. The functionality can be expanded to measure various other parameters.

Keywords: Spirometer, Flow rate, Lung Volume, Low-cost, COPD (Chronic Obstructive Pulmonary Disease)

LIST OF FIGURES

LIST OF ABBREVIATIONS

COPD	Chronic Obstructive Pulmonary Disease
IR sensor	Infrared sensor
AARC	American Association for Respiratory Care
TV	Tidal Volume
FRC	Functional Residual Capacity
IRV	Inspiratory Reserve Volume
ERV	Expiratory Reserve Volume
TLC	Functional Residual Capacity
FV	Flow Volume
PEFR	Peak Expiratory Flow Rate

CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Introduction

From the years 129 to 200 A.D, the first attempts at measuring lung capacities were made. The Roman physician and philosopher Claudius Galen was the first to do a volumetric experiment on human breathing. The respiratory system is one of the most crucial organs for breathing, distributing oxygen throughout the body, and eliminating carbon dioxide. Our primary goal is to create a fully functional, straightforward spirometer with all the necessary sensors, including a flow meter, that we can programme using an Arduino UNO Rev3 Microcontroller.

1.2 Motivation

The most significant challenge in medicine is disease prevention or early treatment. The goal of this mission must not come at a high price. Over 500 million individuals have been diagnosed with COPD, which is the fourth leading cause of death worldwide [American Association for Respiratory Care (AARC)]. Unfortunately, many patients with diagnoses live in developing nations, where the exorbitant cost of spirometric equipment prevents healthcare practitioners from buying it. Spirometry can identify asymptomatic patients who risk suffering from chronic diseases such as COPD (Chronic Obstructive Pulmonary Disorder). We have used plastic bottles to design our spirometer, thus adopting the ideology of sustainability.

1.3 Objectives of the work

- The main objective is to develop a simple, low-cost spirometer capable of measuring lung volumes.
- To accurately display the obtained numerical values to the user immediately after use.

1.4 Target Specifications

The flow rate may be determined by calculating the turbine's rotational speed.

Integrating the flow rate over a specified amount of time makes it possible to determine the volume of gas that moves through the pipe.

We may also determine some of the various lung volumes and capabilities by repeating the experiment at various time intervals.

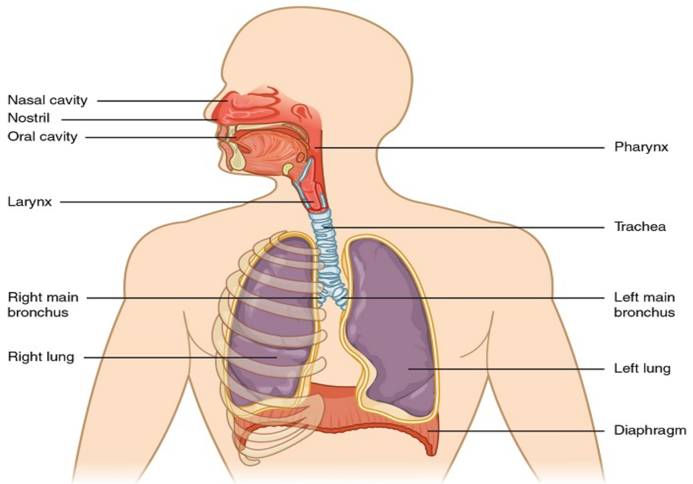
CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This section will go through all the prerequisites required for the calculations, understanding flow rate and spirometer, and how they can be linked with COPD. Also, we will be going through the entire pulmonary system and seeing how it works.

2.2 Literature Review

The lungs contain many bronchioles, which branch into alveolar ducts and sacs until the alveoli, which end up with numerous vesicles lined with very thin mucus. The respiratory system protects human body cells from carbon dioxide (the product of the oxidation process) and supplies them with oxygen that is necessary for their activities.



Lung Volumes

Tidal volume:

The entire volume of air inhaled/expelled during normal or relaxed breathing. In a healthy guy, typical respiration uses about 500 ml of air.

Inspiratory Reserve Volume:

An additional volume of air ranging from 2500 to 3100 ml might be effectively inhaled following the inspiration of a conventional tidal volume.

Expiratory Reserve Volume

The additional 1200 ml of air that can be forcibly exhaled out after a conventional tidal volume has expired.

Residual Volume/ Reserve Volume

The residual volume is the air that remains in the lungs after the reserve volume has been expelled or breathed out, roughly 1100 to 1200 ml.

Lung Capacities

Total Lung Capacity
The total volume of air that has been pumped into the lungs. The lung volume in a healthy man is about 6000 ml.

TLC = TV + ERV + IRV + RV

Vital Capacity

The amount of air a person can inhale at their vital capacity after reaching their maximal exhalation. It is equivalent to the total of the inspiratory, tidal, and expiratory reserve volumes. It roughly corresponds to Forced Vital Capacity.

VC = TV + ERV + IRV

Inspiratory Capacity

The most amount of air that can be inspired following a typical, silent expiration.

IC = TV + IRV

Functional Residual Capacity:

The space which is still occupied by air in the lungs following a typical, passive exhale.

FRC = ERV + RV

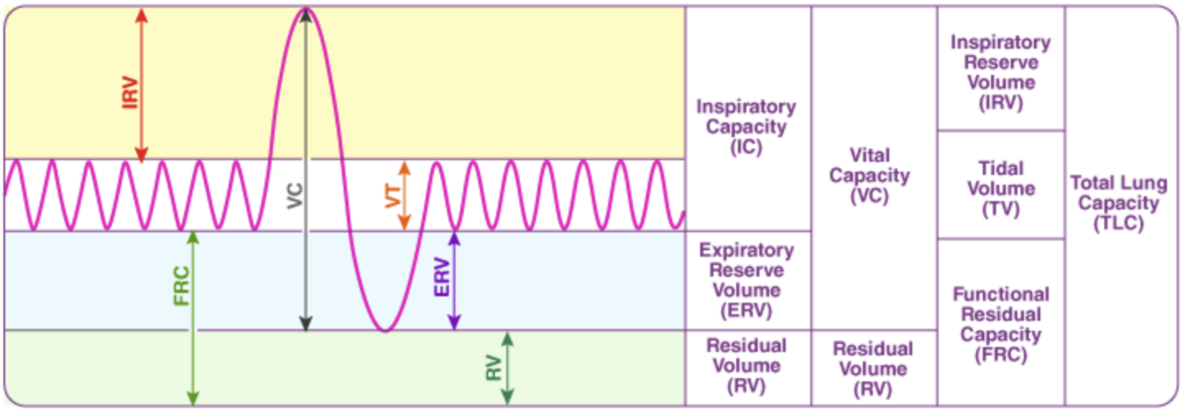


Figure 1: Spirogram

Respiratory system diseases
One of the most prevalent diseases and health issues worldwide is lung and respiratory disease. Lung and respiratory disorders affect tens of millions of individuals worldwide. Most lung conditions are caused by a combination of smoking, infections, and genes. The lungs are a sophisticated organ that expands and contracts hundreds of times daily to deliver oxygen to

the body and remove carbon dioxide. Additionally, any flaw or issue in any component of this intricate system might cause lung illness. Here is a detailed list of lung and respiratory conditions and their signs.

Spirometer
The most popular pulmonary function test is spirometry, which involves a series of evaluations of the respiratory systems under controlled conditions. By monitoring the volumes of air mobilised by respiratory movements and ventilatory fluxes, spirometry aims to regulate the ventilatory function. Normal values in healthy individuals aged 20-60 vary from 4.5 to 3.5L, and for healthy females, it ranges from 3.25 to 2.5L.

2.3 Conclusions

This chapter dealt with the respiratory system, various lung volumes, and capacities. The respiratory system provides human body cells with oxygen that is required for daily activities. The respiratory system consists of the trachea, bronchi, bronchioles and alveoli.

Lung volumes include TV, IRV, ERV and RV, while lung capacities include IC, VS, FRC and TLC.

Smoking, infections and genes are all the main culprits of lung diseases. Lung diseases are one of the most prevalent diseases worldwide.

CHAPTER 3

METHODOLOGY

3. 1 Introduction

We can get the parameters regarding lung volume and capacities by using IR sensors in our turbine-type spirometers. As one blows air into the turbine positioned vertically, the air stream also rotates due to this rotating airflow. A pair of optical sensors may determine the flow direction and rate by counting rotations. We will see the technique used in volume calculations and how we tackled various problems.

3. 2 Detailed Methodology

```
#include <LiquidCrystal.h>

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

// Pin configurations.
int OUTPIN = 2;

// Variable initialisations.
int detected, lastDetected;
unsigned long startMillis, currentMillis, timeDelay;
const unsigned long period = 10;

void setup() {
 // Setup code to run initially.
 pinMode(OUTPIN, INPUT);
 lcd.begin(16, 2);
 Serial.begin(9600);
 detected = LOW;
}

void loop() {
 // Main code to run repeatedly.
 detected = digitalRead(OUTPIN);

 if (lastDetected == LOW && detected == HIGH) {
    // Take off phase. Obstacle detected previously, and not detected now.
    startMillis = millis();
 } else if (lastDetected == HIGH && detected == LOW) {
    // Ending phase. Obstacle not detected previously, and detected now.
    currentMillis = millis();

    timeDelay = currentMillis - startMillis;
    if (timeDelay >= period) {
```

```
    Serial.print("Time delay: ");
    Serial.println(timeDelay);
  }
 }

 lastDetected = detected;

 lcd.clear();
 lcd.setCursor(0, 0);
 lcd.print("Spirometer: ");

 lcd.setCursor(0, 1);
 lcd.print("Value : ");
 lcd.setCursor(10, 1);
 lcd.print(timeDelay);
}
```

3.3 Circuit layout and Block diagrams

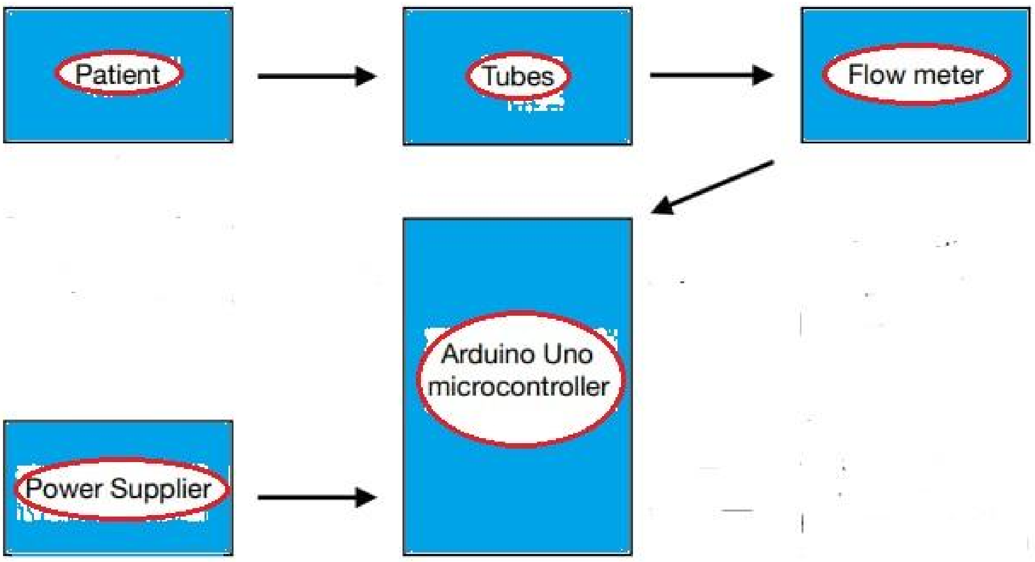


Figure 02: Circuit layout

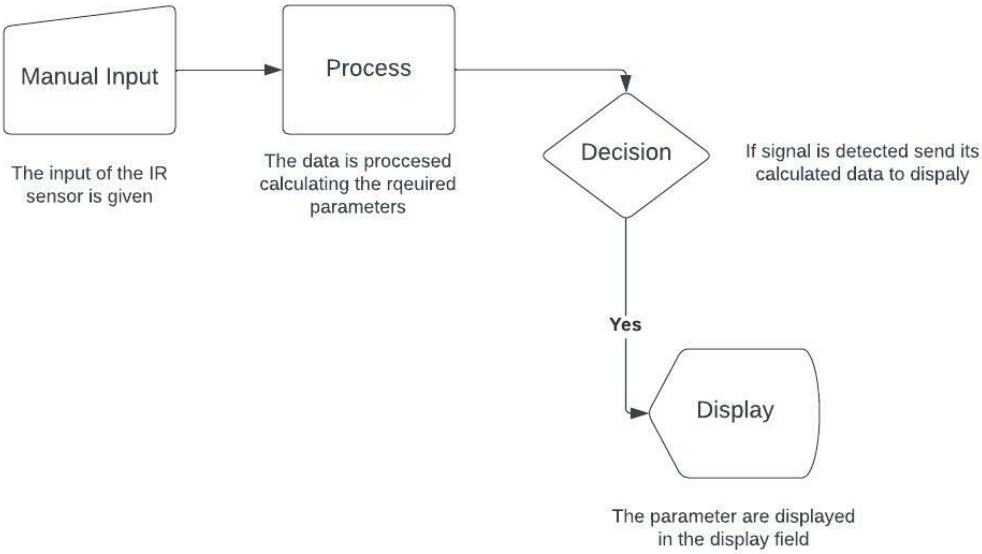


Figure 03: Flow diagram

3.4 Component specifications

- IR sensor module for sensing the tip of the fan.
- Arduino UNO Rev3 Microcontroller for the interface.
- 9v Battery power supply

3.5 Justification for comport selection

- *IR sensor module*

  The IR Sensor module has excellent ambient light adaptation capabilities. It consists of a infrared emitting pair of tubes and a receiver tube. The infrared emitting tubes emit a specific frequency when an obstacle is detected. The green LED illuminates when this frequency is reflected back to the receiver tube, which processes the signal. The signal output then outputs a digital signal. To adjust the detection distance, the sensor's detecting range may be altered using a potentiometer, through a potentiometer knob. It has minimal interference, is simple to install and use, and is suitable for various applications, including black-and-white line tracking, obstacle avoidance for robots, and counting cars on production lines.

  The effective distance range ~2-10 cm working voltage of about 3.3V-5V.
- *Arduino UNO Rev3 Microcontroller for the Interface*

  Operating voltage: +5V

  (Recommended) Input Voltage: +7V to +12V

  In/Out Voltage (Limit): + 6V to +20V

  PWM Digital I/O Pins: 6

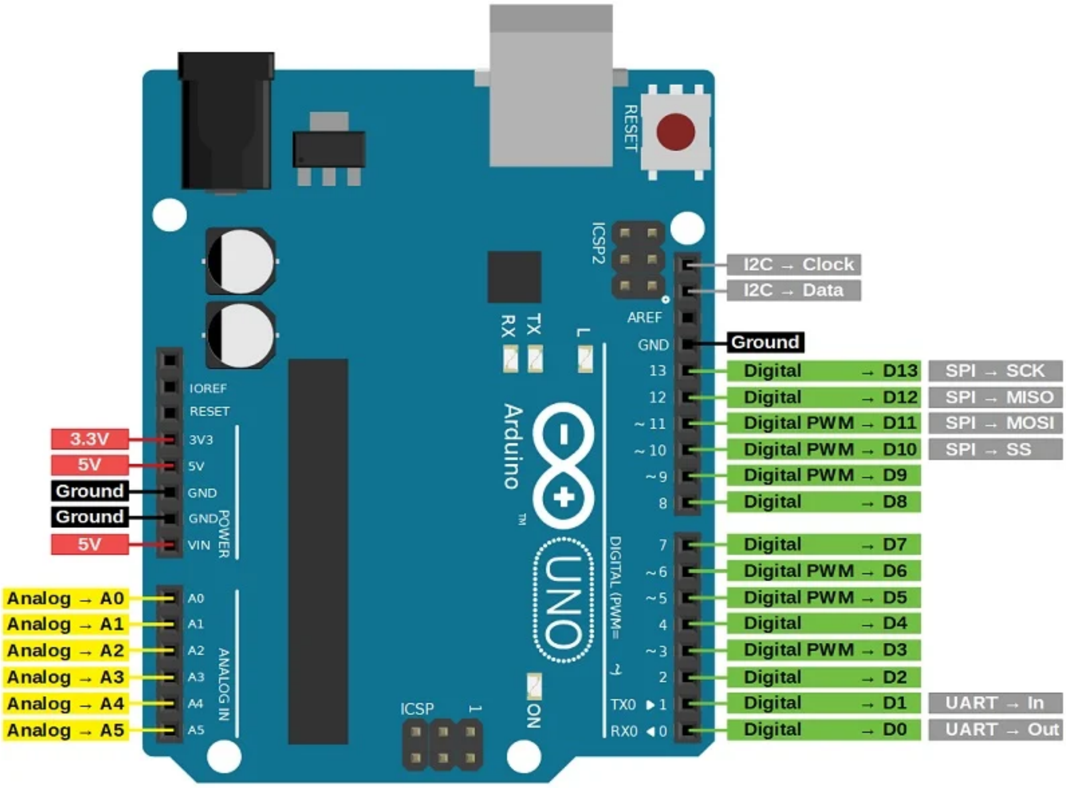
  Analog Input Pins: 6

Digital I/O pins: 14 [6 pins to provide PWM output]

DC Current per I/O pin: 20 mA

It is an excellent and portable device supporting the C language; it is effortless to obtain and very flexible to operate.

3.6 Detailed specification



3.7 Conclusions

Lung volumes and lung capacities are obtained using turbine spirometers containing IR sensors. Flow rates and flow direction are measured by counting the number of rotations of the turbine using optical sensors.

An Arduino UNO, IR sensor module and 9V power supply were the main components used in our project. The IR sensor is used due to various factors such as excellent light adaptation capabilities which have an effective distance range of 2-10cm and a working voltage of 3.3V-5V.

CHAPTER 4
RESULTS AND DISCUSSION

4. 1 Introduction

We have used an IR sensor to calculate the parameters needed. This IR sensor senses the blades of the rotor we used. The design of the apparatus is quite simple and eco-friendly, given our objective of coming up with a cheap, portable spirometer. The blades of the rotor were also made up of waste plastic bottles.

4. 2 Result Analysis

The flow rate can be calculated using the flow velocity. This flow rate can also be integrated to get the volume of the subject.

Healthy young women typically have values between 150 and 200 L/min, and males's and women's normal values decline with age. Peak Expiratory Flow Rate (PEFR) is defined as the highest flow rate that can be reached during an FVC manoeuvre. Young individuals in good health may have normal values that exceed 600 L/min.

Males have a mean tidal volume of 38.9 mL, and females have a mean tidal volume of 46 mL.

4. 3 Significance of the result obtained

When the subject blows into the apparatus, the subject's airflow turns the turbine in the device; the IR sensor detects the time interval between two successive blades giving the speed of the air flown from which the flow rate can be obtained.

$$Q = vA$$

The results are then passed through an integrator to get the volume of the subject's lung, thus getting the parameters required for measuring the flow rate and volume.

Flow rate and volume can be used to identify COPD in the subject.

Subjects having low flow rates can be identified, and proper direction to the subject can be given based on the results obtained from the spirometer.

4.4 Conclusions

Lung volume can be obtained after the integration of sample inputs of flow rate, which is detected by an IR sensor that then gives us information on the individual lung capacities and volume. This further can be used to diagnose the subject with respective COPD.

CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5. 1 Brief summary of the work

The project's main objective is to develop a simple, low-cost spirometer capable of measuring lung volumes.

We adopted a sustainable and eco-friendly design for the spirometer. We measured the volume and flow rate from the rotating turbine set in motion by the subject, from which we got the lung capacities of the subject.

5. 2 Conclusions

We can calculate lung volume and capacities using our portable turbine spirometer to detect COPD. The small device can be easily transported, along with a low-maintenance cost, so the daily person can afford this diagnosis. The affordability of the device inspired this design, and we have tried to make it economical and sustainable.

5. 3 Future scope of work.

Combined muti-purpose oximetry and capnometry can be included with this spirometer. This device can calculate the O_2, CO_2, and volume parameters at once, thus decreasing essential time and cost and increasing the efficiency of the diagnosis.

Also, to design cost-effective design so that the whole population can afford it and critical diagnosis of COPD can be given, which should be highly reliable.

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PAGE 16

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