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ES106: PROJECT REPORT: Team 1049

SPIROMETER

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ABSTRACT:

The highly contagious coronavirus disease (COVID-19) was first detected in Wuhan, China in December 2019 and consequently spread to 212 countries and territories around the world, infecting millions of people. The World Health Organization declared the outbreak a Public Health Emergency of International Concern on 30 January 2020, and a pandemic on 11 March 2020.

Spirometry is a common office test used to assess how well your lungs work by measuring how much air you inhale, how much you exhale, and how quickly you exhale. Spirometry is used to diagnose asthma, chronic obstructive pulmonary disease (COPD), and other conditions that affect breathing.

Since Covid 19 directly impacts the lungs and damages the alveoli (tiny air sacs), a Spirometry test can be carried out to get an idea of how your lungs are functioning.

1. INTRODUCTION:

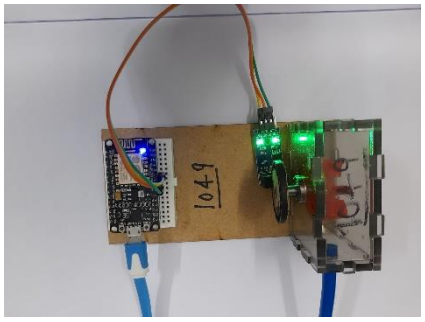


Fig: Spirometer

A spirometer is an apparatus for measuring the volume of air inspired and expired by the lungs. A spirometer measures ventilation, the movement of air into and out of the lungs.

It helps in detecting the symptoms of COVID-19 as well as many other diseases such as asthma, chronic obstructive pulmonary disease (COPD), and other conditions that affect breathing.
The spirometer consists of an impeller enclosed in the housing. A blow tube is attached to the housing, wherein the person blows in, which then rotates the impeller. Accordingly, the shaft and the slotted disk rotates.
The LM393 Speed Sensor is basically an Infrared Light Sensor integrated with LM393 Voltage Comparator IC.
This sensor is mounted on the base plate in front of the slotted disk. A light-emitting device is placed at a suitable position such that when the holes of the slotted disk coincide with the light ray, it is detected by the LM393 Speed Sensor, which then gives the output as 1, and at other times the output is 0. The LM393 Speed Sensor transfers the output to the nodeMCU, which then converts this output in the frequency form that is used to understand the condition of the lungs.

2. Design

The dimensions of the base plate are 65mm x 110mm.

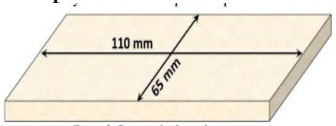
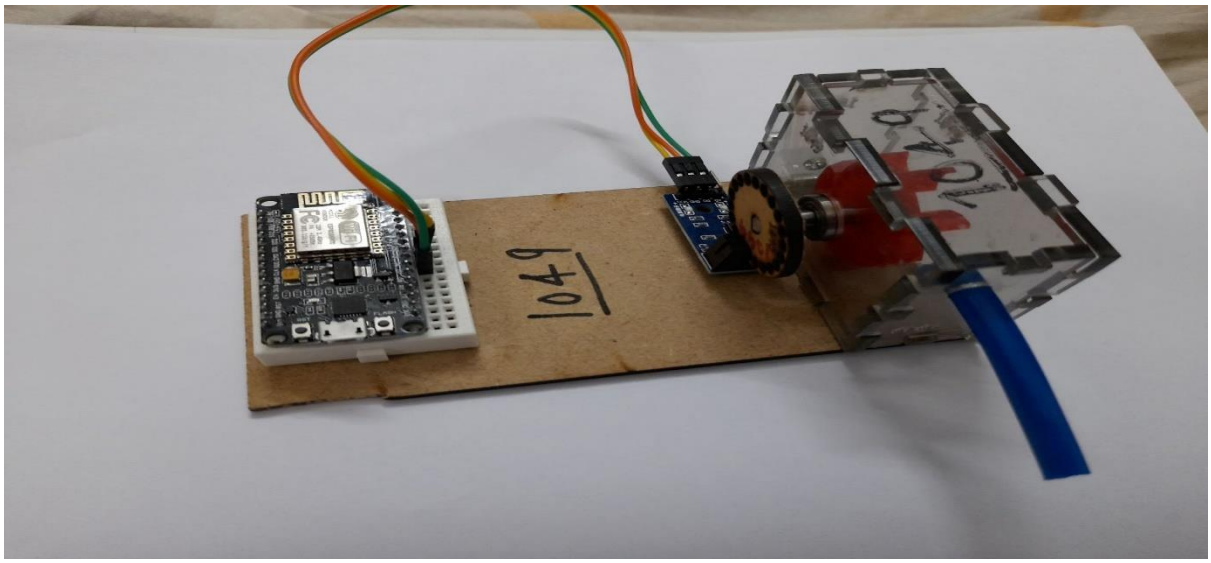


Figure 3: Rectangular base plate

To create components that require the laser cutting machine, we were given the choice to select among the 3mm and 5mm thick acrylic sheet. We chose the 3mm thick sheet.

2.1 Casing/Housing

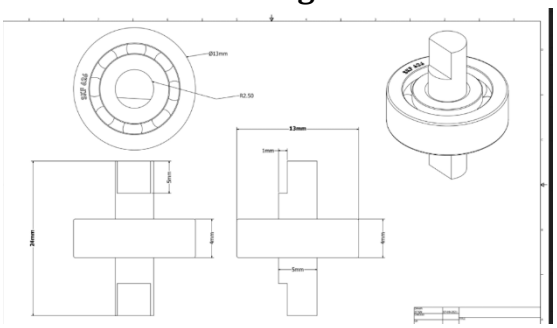


The dimensions of the housing plates are 65 x 30 x 45 mm.

The project charter said," Each team is required to design a spirometer that can fit inside a 120 mm (L) X 70 mm (W) X 50 mm (H) box". Also since the thickness of

the acrylic sheet is 3mm in itself. Therefore, we took a height a little less than that of the box and as per the thickness of the acrylic sheet.

2.2 Shaft and Ball Bearing

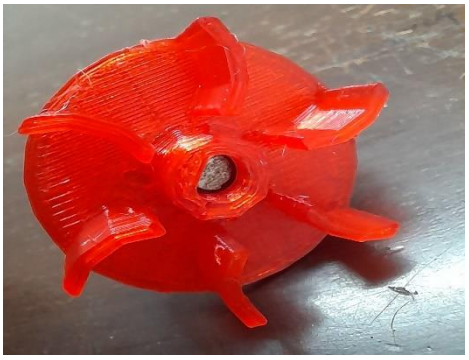


The shaft is circular in cross-section. From the orthographic projection above, the diameter of the shaft is 5mm. Each of the ends of the shaft will have slots of 1mm in the radial direction and a length of 5mm.
The ball bearing has a diameter of 13mm, and a thickness of 4mm.
The slots (cuts) on the ends of the shaft ensure proper alignment of the impeller and the slotted disk onto the shaft.

2.3 Slotted Disk

The diameter of the slotted disk is 30 mm. There are 20 small holes on the periphery of the slotted disk, each with a diameter of 3 mm. The hole in the middle has the same diameter as that of the shaft such that the shaft can pass through it suitably.
The smaller holes are made since they are used to measure the rotational speed of the impeller attached to the shaft.

2.4 Impeller



The base diameter of the impeller is 30mm. The hole in the center has the same dimension as that of the shaft. There are 6 impeller blades, each of which is part of a circle of 11mm. The blades lie on the periphery of a circle of 15mm which is concentric to that of the hole.
The shape of the blades was suitably made such that they experience minimum air resistance and rotate smoothly.

3. Materials and Methods

3.1 Housing/Casing

The housing plates are made from acrylic sheets. Acrylic sheets are transparent glass. This property of transparency is useful so that one could see the impeller rotating inside the casing. Acrylic sheets were cut with the help of laser cutting.

Laser cutting explained:

Laser cutting uses a high-power laser which is directed through optics and computer numerical control (CNC) to direct the beam or material. Typically, the process uses a motion control system to follow a CNC or G-code of the pattern that is to be cut onto the material. The focused laser beam burns, melt, vaporizes, or is blown away by a jet of gas to leave a high-quality surface finished edge.
The laser beam is created by the stimulation of lasing materials through electrical discharges or lamps inside a closed container. The lasing material is amplified by being reflected internally via a partial mirror until its energy is enough for it to escape as a stream of coherent monochromatic light. This light is focused at the work area by mirrors or fiber optics that direct the beam through a lens that intensifies it.
At its narrowest point, a laser beam is typically under 0.0125 inches (0.32 mm) in diameter, but kerf widths as small as 0.004 inches (0.10mm) are possible depending on material thickness.

3.2 Base Plate

The base plate is made from medium-density fibreboard(MDF).
Medium-density fibreboard is an engineered wood product made by breaking down hardwood or softwood residuals into wood fibers, often in a defibrillator, combining it with wax and a resin binder, and forming it into panels by applying high temperature and pressure. MDF is generally denser than plywood.

3.3 Shaft and Bearing Assembly

Shaft and Ball Bearings are made from high carbon chromium steel. This is used for reasons of cost and durability. Bearings can also be made from other materials such as stainless steel, ceramics, and plastic.

3.4 Slotted Disk

The slotted disk is made up of the same material as that of the housing, i.e. acrylic sheet of 3mm thickness.

3.5 Impeller

The impeller was made by the process of 3D printing. 3D printing, or additive manufacturing, is the construction of a three-dimensional object from a CAD model or a digital 3D model. The creation of a 3D printed object is achieved using additive processes. In an additive process, an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced cross-section of the object.
The impeller was designed in Autodesk Inventor, and a .stl file was created which was then transferred to the 3D printer.
The 3D printer used PLA plastic as the material. ABS filament is the most commonly used 3D printing plastic. It is used in the bodywork of cars, appliances, and mobile phone cases. It is a thermoplastic that contains a base of elastomers based on polybutadiene, making it more flexible, and resistant to shocks.

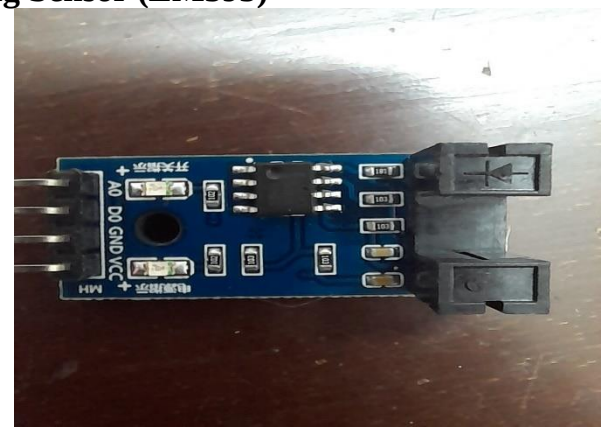
3.6 Blow Tube

We were provided with a polyurethane pipe to use as a blow tube.

Polyurethane explained:

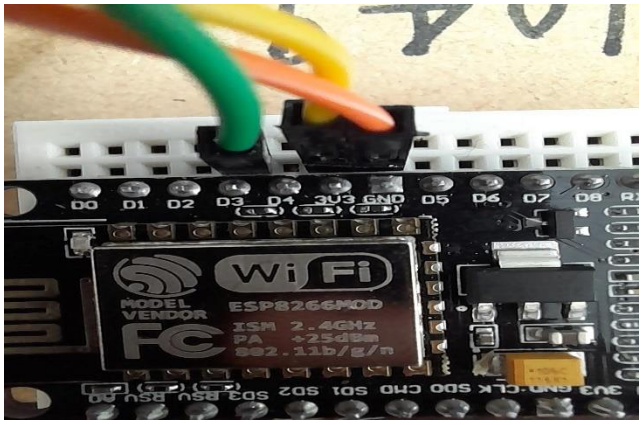
Polyurethane tubing is flexible, kink-resistant, and abrasion-resistant. They are also available in multiple colors for system color coding. They are equipped with medium and high durometers, enabling our tubing to deal with higher pressures and have excellent hydrolytic stability. Parker's polyurethane tubing is flexible easy to assemble on to designated fittings. Polyurethane tubing exhibits similar characteristics to rubber and has chemical resistance associated with plastics. It is, therefore, suitable for use with a wide variety of applications across many of the major industrial markets.

3.7 Speed Measuring Sensor (LM393)



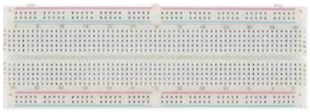
The LM393 Speed Sensor is basically an Infrared Light Sensor integrated with LM393 Voltage Comparator IC.this sensor can also be divided into two parts: the sensor part and the control part.
The sensor part of the LM393 Speed Sensor module consists of an Infrared LED and an NPN Photo Transistor. These two components are placed facing each other is a special housing made of black thermoplastic.
This special housing ensures that the Photo Transistor receives light only from the Infrared LED and all the external source of light is eliminated.

3.8 Node MCU (ESP 8266)



Node MCU is a microcontroller that will be used for reading the output of LM 393 Speed Sensor and displaying it on a computer. The conversion of data into physical signal and all othe computation will be programmed on this Arduino-compatible component.

3.9 Breadboard



Breadboard is a rectangular plastic board with a bunch of tiny holes in it. These holes let you easily insert electronic components to prototype (meaning to build and test an early version of) an electronic circuit, like this one with a battery, switch, resistor, and an LED (light-emitting diode).

3.10 Jumper Wires

A jump wire is an electrical wire, or group of them in a cable, with a connector or pin at each end, which is used to interconnect the components of a breadboard.

4. Algorithms

The basic principle behind the working of a spirometer is that the speed of rotation of the slotted disk is a specification of the breathing capacity of the blower.
The speed of the slotted disk is marked by the number of rotations undertaken per minute(rpm).

Connections:

Encoder Node MCU

D0	D3
A0	3U3
Ground	Ground

Instruction Code:

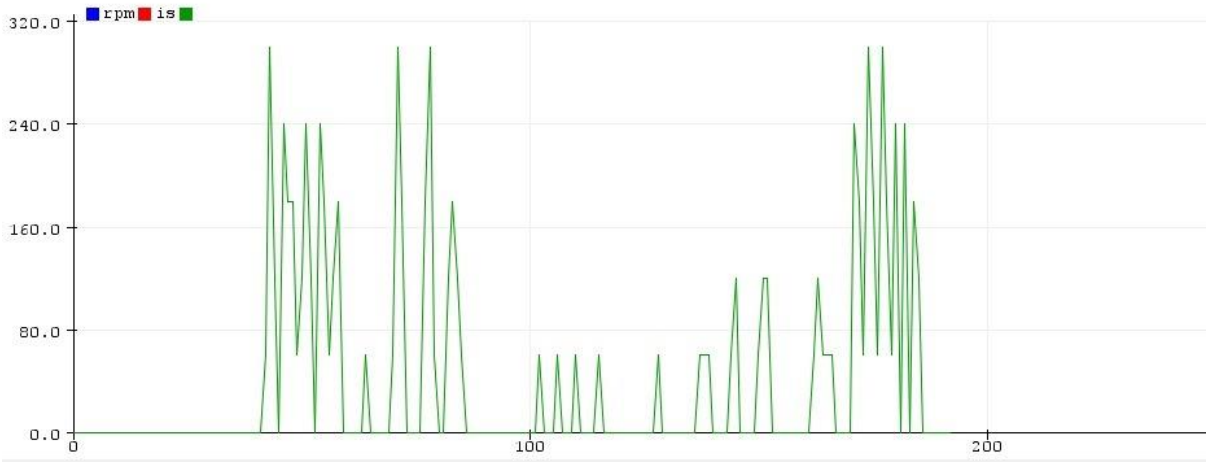
```
#define sensor_pin D3

int sensor_input = 0;
int sensor_input_prev = 0;

int count = 0;
float tl = 0;
float t;
float rpm;

void setup() {

  pinMode(sensor_pin,INPUT_PULLUP);
  pinMode(LED_BUILTIN, OUTPUT);
  Serial.begin(9600);

}
void loop() {


  sensor_input = digitalRead(sensor_pin);
  digitalWrite(LED_BUILTIN, LOW);

  if(sensor_input == 0 && sensor_input_prev == 1){
    count = count + 1;
    digitalWrite(LED_BUILTIN, HIGH);
  }

  t = millis();
  sensor_input_prev = sensor_input;

  if(t - tl >= 1000){
    rpm = (count/20)*(60);
    tl = t;
    count = 0;
    Serial.print("\n RPM is ");
    Serial.println(rpm);
  }

}
```

5. Results and Discussions

The encoder registers the number of holes detected per second, this data is then used to calculate the rotations per second, and this data is averaged to calculate the rotations per minute.

The process:
With Covid infection the capacity of the lungs to pump air is reduced, this system is a simple apparatus to measure the lung capacity of an individual. The data is recorded for peak RPM and prolonged air blowing these two datasets, i.e. Peak RPM and prolonged air blowing RPM average these averages are then compared with those of a healthy individual.

Output:



6. Challenges and problems

6.1 Although the appropriate kerf for assembly design was still taken, the parts were not fitting by friction. We have to file and glue some parts to fit properly.
6.2 The bearing was loose in the hole designed in the assembly wall, although the measurements were perfect with appropriate kerf.
6.3 The blowpipe was not fitting properly in the assembly so it also has to be filed in order to fit it properly inside the assembly.

7. Recommendations and improvements

7.1 The scale of the model was very small so even small errors made it very difficult to assemble and complete the assembly so we had to file and glue small parts to join the assembly which took more than half the time taken for the whole project. It would have been better if the project was chosen so that these minute errors do not

drastically impact the assembly of the model, so that more time can be given to the thought process of the model.
7.2 We also found that there is a major flaw in the model design. If an infected person from Covid-19 is tested the saliva and particles in the mouth are blown into the assembly which stay at the walls, which may spread the disease.
7.3 If the back wall of the housing would have been extruded, it would reduce the resistance to the air flow, and the rpm of the impeller would have been increase, and thus increased the possibility of getting more accurate results.

8. Conclusions

The project is a good example of how simple designs can be incorporated to check the threat level of real-world problems.
But there is a flaw in the design as the saliva and particles which are blown with the exhaled air cling onto the walls of the assembly which can spread the infection of the disease.
We appreciate the fact that most crucial devices such as spirometers have been successfully designed by the techniques such as 3D printing, laser cutting, and programming has once again shown its importance through this project.

9. Acknowledgements

We would like to extend our gratitude to the project instructor Professor Madhu Vadali and our TA Vignesh Ramakrishnan. It would not have been possible without them.

10. References

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