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LOW-COST PORTABLE VENTILATOR

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Abstract: This paper discusses the idea of the designing a low-cost portable mechanical ventilator. The conceptual design is aimed at attaining control on different parameters like inspiration-to-expiration ratio, breaths per minute, tidal volume. COVID-19 patients with other respiratory disorders are facing a worldwide shortage of mechanical ventilators, which prompted the development of a low-cost portable ventilator. In the current crisis, mechanical ventilation plays an important role in treating patients suffering from several diseases in the absence of definitive treatment. This type of ventilator can be manufactured quickly and easily in small quantities or on mass at low cost. This paper also shows method of controlling ventilator using an android application. The method considers pressure measurements from the inspiratory limb and alerts clinicians.

Keywords - Ambu bag, Ventilator, Pandemic, Covid-19, BMP280 pressure sensor, Android application.

I. INTRODUCTION

Both the worlds of sophisticated and technologically advanced countries as well as backward and semi-advanced countries experience enormous stress due to respiratory system failure and diseases brought on by various types of traumas. For the representatives of these countries, a constant source of discomfort and worry comes in the shape of asthma and chronic obstructive lung disease. The general belief is that catastrophic calamities occur more frequently due of smoke imitation, widespread use of toxic gases, and continued depletion of natural resources to meet energy needs. In cases of lung failure, the disorders listed above necessitate mechanical ventilation. This prototype will enable a patient to breathe in and out so that carbon dioxide and oxygen may be exchanged, enabling the patient to maintain artificial respiration.

In the recent several months, there has been an increase in the need for ventilators to treat COVID-19 patients, which has resulted in a global ventilator shortage. This shortage has disastrous consequences, particularly in areas of poverty. Sharing the same ventilator between two patients is a controversial practice since it raises the risk of not only spreading bacterial and viral loads across patients but also inducing unintended injury. Even well-equipped hospitals have devised procedures for this practice, due to shortage of ventilators. Researchers have launched a project to produce low-cost, open-source ventilators in an effort to address the global issue of a lack of ventilators. This paper contributes to this initiative.

A ventilator is a device that mechanically ventilates an individual by circulating breathable air into and out of the lungs. A patient who is physically unable to breathe or is not breathing enough receives breaths through a ventilator. The average amount of air that can be inhaled or expelled during one respiratory cycle is known as tidal volume (TV). The I:E (inspiration-to-expiration) ratio refers to the proportion of each breathing cycle that are spent in the inhalation and exhalation phases. This ratio and the overall respiratory rate will determine how long each phase lasts. The respiratory frequency (FR) refers to the number of breaths a person takes in one minute. The ventilation apparatus relies upon the parameters FR, I:E, and Vt, which should be set by the clinicians.

The ventilator is appropriate for patients of all ages and will be helpful for a variety of respiratory tract congestions, notably the elderly. This project's main goal is to build a low-cost, open-source ventilator for people with COVID-19 and other respiratory conditions. Ventilator should deliver the air to the patients by compressing the Ambu bag by using stepper motor driver mechanism. Users should be able to set (i) the respiratory frequency (FR); (ii) the ratio of inspiration-to-expiration at each respiratory cycle (I:E); and (iii) the air volume supplied to the patient (Vt). Based on these settings the air should reach the patient's lung. By monitoring the pressure measurements from the inspiratory limb, the system must assist the clinicians.

II. METHODOLOGY

The ventilation apparatus relies upon the parameters: Respiratory frequency (FR), The inspiratory to expiratory ratio(I:E) and the tidal volume supplied to the patient(Vt), which should be set by the clinician. The air and oxygen supply flows through the corresponding limb and reach the patient's lungs.

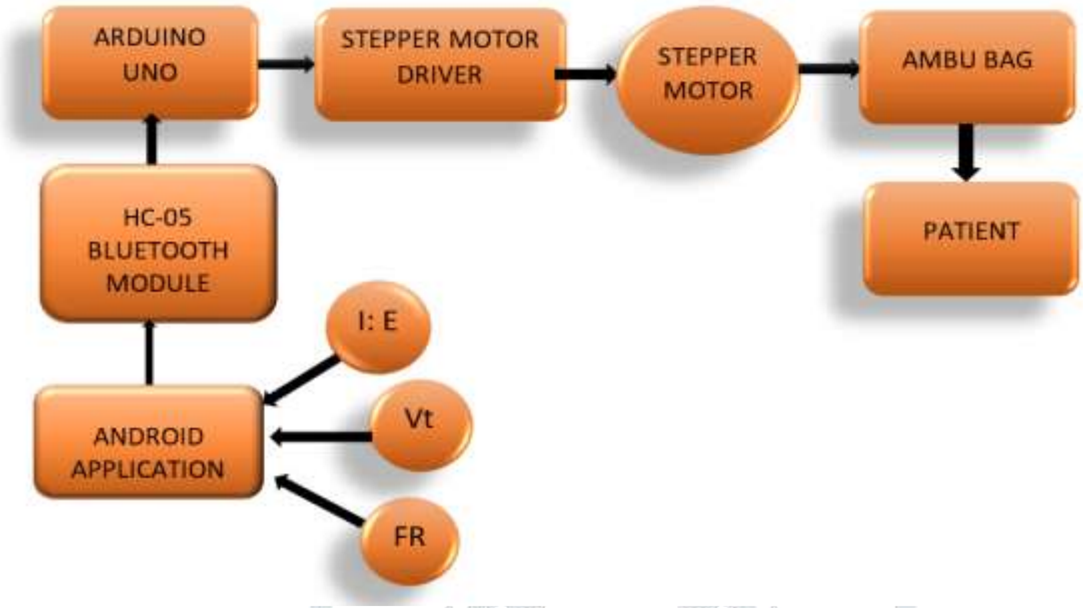

Figure 1: Scheme of the mechanical ventilator. Based on the input given by the user using android application, Arduino triggers the stepper motor and the shaft compresses Ambu bag accordingly.

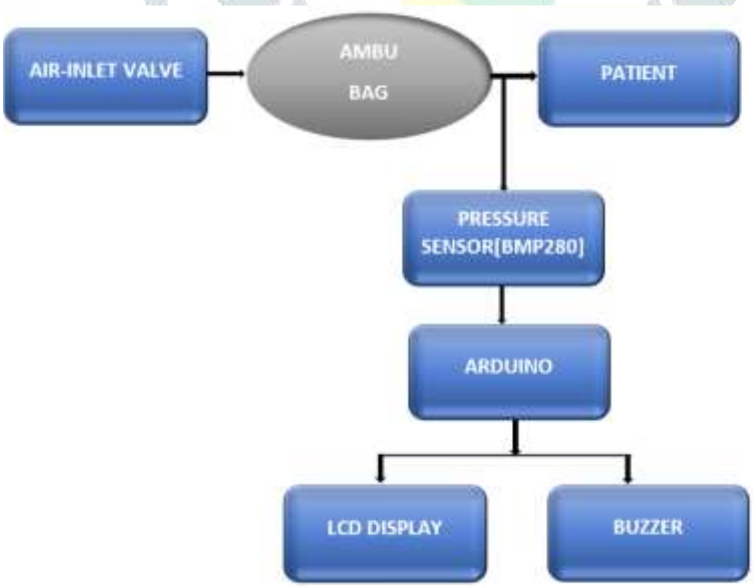

Figure 2: Obtaining pressure sensor data from inspiratory limb. BMP280 Pressure sensor reads the airway pressure and the data is displayed in LCD, if the pressure diverges from the normal range buzzer generated alarm.

Figure 3: Top view of ventilator model

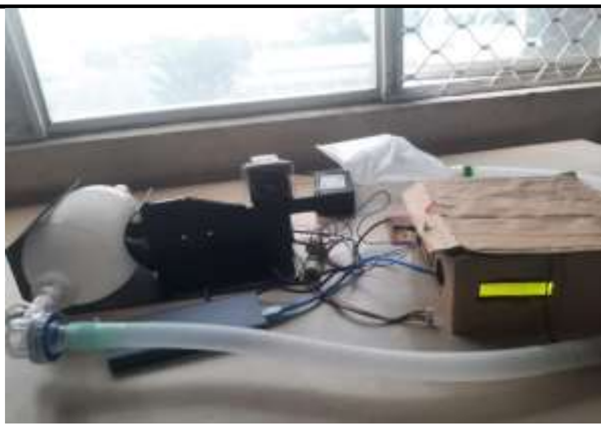

Figure 4: Front view of ventilator model

Respiratory Frequency (BPM)	I:E Ratio (1:2)		I:E Ratio(1:3)	
	Inspiration Time(sec)	Expiration Time(Sec)	Inspiration Time(sec)	Expiration Time(Sec)
5	4	8	3	9
10	2	4	1.5	4.5
15	1.3	2.6	1	3
25	0.8	1.6	0.6	1.8

The BMP280 piezoresistive pressure sensors provide a very accurate and linear voltage output, directly proportional to the applied pressure. The pressure sensor is connected in the circuitry in such a way that it sends measurements and transmits the processed data to the Arduino Uno. The Arduino Uno takes these measurements and feeds the pulmonary monitoring algorithm. Stepper motor is a high-precision mechanical-rotary position system. The gear is then attached to the stepper motor rod. The radius of this gear is about 2.5 cm, and each gear's teeth was separated from each other in about 1 degree. Tidal volume must be delivered by the Ambu bag at various rates. Users can increase the I:E ratio, which does increase the inspiration time throughout the respiratory cycle and results in more oxygen reaching the lung. 5, 10, 15, or 25 breaths per minute are the options the clinician has for FR values. There are some commercial mechanical ventilators that enable clinicians to choose this number from the continuous interval [5, 25]. However, in order to keep things simple, we chose to limit the selection of the FR values to those discrete values only. The user can additionally set Vt (air volume supplied to the patient). The Vt value is influenced by the pathological state of the patient and other variables. To control parameters like Vt, FR and I:E, we are using a mobile application called MIT app inventor. These parameters can be cordially controlled by the user as per the patient's requirements.

III Results:

Building a mechanical ventilator that will take pressure readings from the inspiratory limb into account and allow users to alter parameters using an Android application in accordance with the patient's breathing pattern. When real-time measurements reveal results that are different from the reference value, such as when pressure exceeds 40 cm H2O and falls below 5 cm H2O, the system should notify clinicians. It can deliver appropriate amount of air to the patient's lungs by setting parameters(FR, Vt, I:E) according to the patient's health condition.

Respiratory Frequency (BPM)	**I:E Ratio (1:2)**		**I:E Ratio(1:3)**	
	Inspiration Time(sec)	Expiration Time(Sec)	Inspiration Time(sec)	Expiration Time(Sec)
5	3.6	9.02	2.1	7.65
10	1.10	3.24	1.0	4.11
15	1.23	2.01	0.72	2.64
25	1.0	1.02	0.89	0.98

Figure 4: Display of pressure data, obtained from BMP280 pressure sensor connected to inspiratory limb of the ventilator

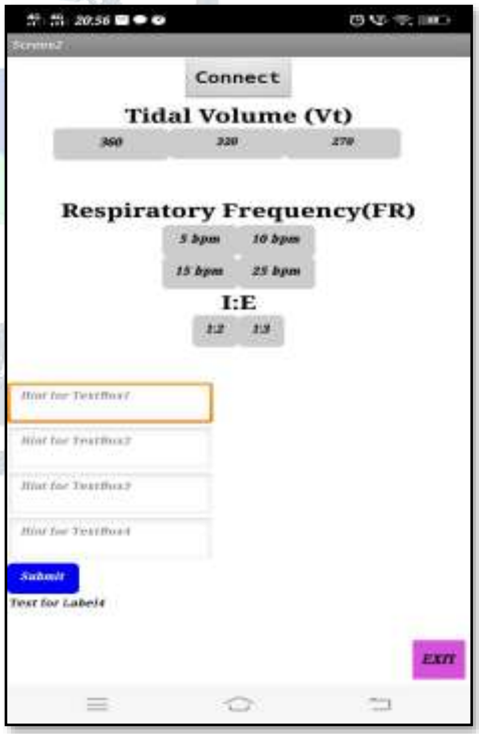

Figure 5: Screen 1-Front page of the application

Figure 6: Screen 2-Contains options to control ventilation

An Android application is built to control ventilation where it allows user to set parameters according to the patient's needs. Figure 5, shows front page of the application, on selecting the 'Control Ventilation' option, it takes to screen 2. In screen 2, the 'Connect' option shows a lists of Bluetooth module where we select 'HC-05'. Only after successful connection to the desired module, the app interface shows the text 'Connected'. On selecting appropriate parameters and submitting, it triggers the motor driver, hence rotation of stepper motor is controlled.

IV Conclusion

Constructing a mechanical ventilator, that aims to consider pressure measurements from the inspiratory limb and allows user to change parameters using an android application according to the patient's respiratory pattern. For acceptable deployment of this ventilator in the clinical environment, future work has to be made.

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