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Design and Development of Mechatronic Emergency Ventilator for Treating Breathing Ailments

Hemanth R K[1], Sudir P[2], Ganesh K[3], Deepika B[4]

Electronics and Communication Engineering, SJC INSTITUE OF TECHNOLOGY, Chickballapura, INDIA[1]

Associate Professor, Electronics and Communication Engineering, SJC INSTITUE OF TECHNOLOGY, Chickballapura, INDIA [2]

Electronics and Communication Engineering, SJC INSTITUE OF TECHNOLOGY, Chickballapura, INDIA [3-4]

Abstract: This paper presents the design and development of a mechatronic emergency ventilator for treating breathing ailments. The system was developed to address the increasing demand for ventilators due to the COVID-19 pandemic. The ventilator consists of a mechanical system that provides the necessary air pressure and volume to the patient, and an electronic control system that regulates the respiratory rate and tidal volume. The system was designed with simplicity, portability, and cost-effectiveness in mind, using off-the-shelf components whenever possible. The stepper motor is interfaced with a stepper drive in order to impose a "PUSH-PULL" mechanism to run the AMBU bag, and Arduino is used to interface all of the sensors, motor, and supply. The "PUSH-PULL" technique is used to equalize air pressure. This meets every demand and requirement for the patient with Covid-19.

Keywords: Covid-19, Ventilators, PUSH-PULL, Stepper motor, Stepper drive, Arduino.

I. INTRODUCTION

The severe acute respiratory syndrome coronavirus 2 is the cause of the infectious disease known as Covid-19 [1]. Common cold, cough, headache, fever, body aches, and a loss of taste and smell are the typical symptoms of Covid-19 [2] and it is easily transmitted from one person to another by direct personal contact or through the spit of the sick person. The intensity of COVID-19 symptoms varies greatly, from hardly perceptible to potentially fatal. Low oxygen levels in the afflicted patient are the major cause of the highest death rate. Only the use of a ventilator can remedy this problem, but for a variety of reasons including high cost, poor output, difficult operation, and others the affected individual is not given access to a ventilator at the appropriate time. Use the enter key to start a new paragraph. The appropriate spacing and indent are automatically applied. In layman's terms, we can simply say that a ventilator normalizes air pressure in accordance with the patient's condition because its primary purpose is to increase the patient's oxygen levels [4]. Taking this into consideration, the use of AMBU bags (Bag-Valve-Mask Ventilation) brought about a novel option for fixing the issue encountered in this dire circumstance [5].

The Arduino Nano, a stepper motor, stepper drive, Bluetooth module, pressure sensors, blood oxygen sensor and motor which detect I:E ratio, and tidal volume, breath per minute are all used in the construction of the ventilator. Configuring the stepper motor interface with the drive that enforces the "PUSH - PULL" mechanism for compressing and extending the AMBU bag is the fundamental for the electrical circuiting phase. So that the necessary air pressure may be produced. Stepper drive is equipped with DIP switches that are labelled S1 to S6, and these switches may be used in one of two ways to change the air pressure that is generated. The stages of the motor that power the push-pull mechanism are managed by the switches S1 to S3. And S4 to S6 are utilized when the stepper motor is not functioning properly even though all of the settings are accurate. By building a pipe line that is connected to the AMBU bag, we are able to utilise two sensors to monitor the motor's air pressure, which is known as barometric pressure and is sensed by the sensor. The specific sensor and meter to measure the parameters are set as a result to ensure correct compression and expansion of the bag. The output is then routed into the Mobile display through Bluetooth Module. After completing the circuitry, the code is created using the Arduino IDE program after verifying the connections. Finally understanding the criteria and parameter can be easily modified.

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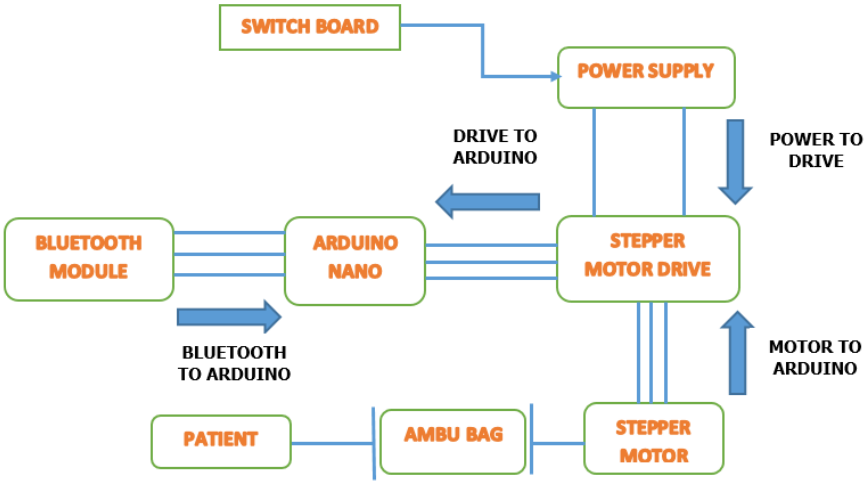
II. METHODOLOGY

The primary circuitry section begins with the motor interface. Arduino Nano, Bluetooth module, a stepper motor, an appropriate stepper motor drive, a 12V voltage controlled power supply, and an external power source are needed for this. First, the appropriate Arduino pins are connected to the Bluetooth module.



The output is shown on the mobile display which is transferred through the Bluetooth module. After the Bluetooth module and Arduino have been connected, the stepper motor and stepper drive are connected, and then the stepper drive is connected to an Arduino pin. The power supply is linked to the drive, where switches deliver external current to the power supply. Once the circuit is complete, an appropriate program is loaded onto the Arduino to obtain output.

III. COMPONENTS

A. *Hardware components*

1. Arduino Nano

A crystal oscillator with a 16 MHz frequency is included with the Arduino Nano [6]. It is used to generate an accurate clock with a steady voltage. One drawback of utilizing an Arduino Nano is that it lacks a DC power connection, which prevents you from using a battery as an external power source.

2. Stepper motor (NEMA 23)

Stepper motor NEMA 23 has a faceplate of 2.3 by 2.3 inches (58.4 by 58.5 mm) with a 1.8-degree step angle (200 steps per revolution). A holding torque of 19 kg-cm is possible with each phase using 2.8 A at 3.2 V [7]. Hard drives, printers, CNC machines, and linear actuators all often employ NEMA 23 stepper motors.

3. Stepper Drive (TB6600)

A professional stepper motor driver that is simple to use and could operate a two-phase stepping motor is the TB6600 Arduino Stepper Motor Driver [8]. It can produce a 5V digital pulse signal, making it compatible with Arduino and other microcontrollers. The stepper driver allows for both direction and speed control.

4. Power Supply

One of the most popular power sources in use today is the 12V power supply (sometimes known as a 12V DC power supply). A dissipative regulating circuit is used by linear regulated 12VDC power supply to control the output. They don't have any switching frequencies that could produce EMI, have very low ripple, and are incredibly stable.

5. Bluetooth Module (HC-05)

The HC-05 is a widely used Bluetooth module that is commonly used for wireless communication between electronic devices. It is a highly integrated module that includes a Bluetooth transceiver and a serial communication interface. The HC-05 is designed to operate in the 2.4GHz ISM frequency band, which is available for industrial, scientific, and medical use.

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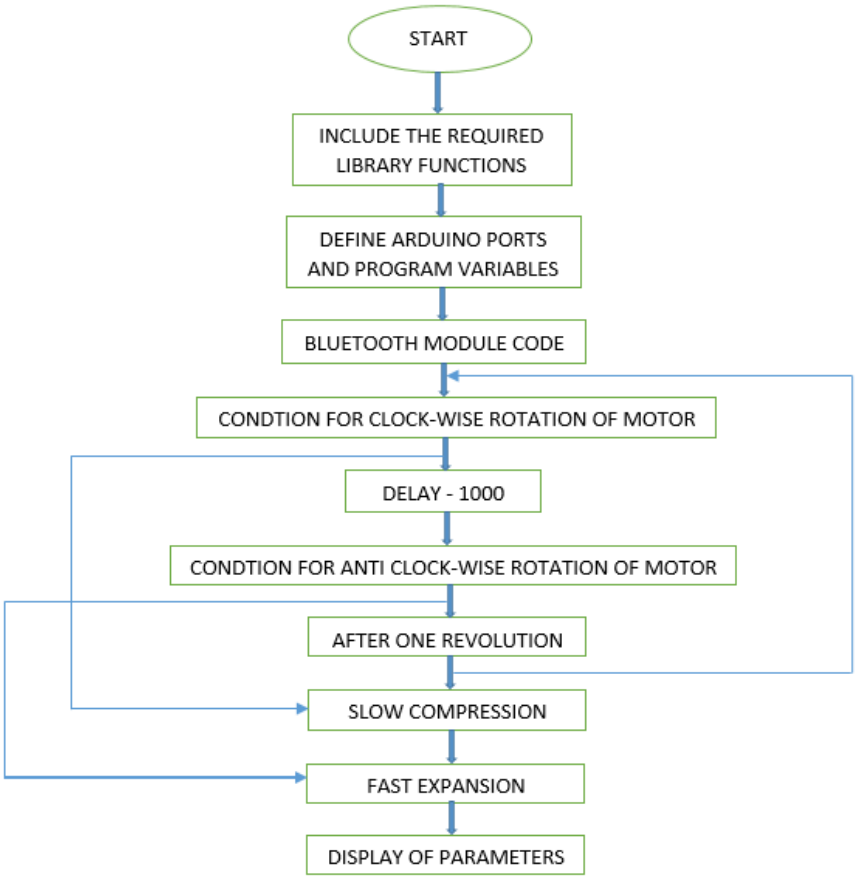
B. *Software*

The code is uploaded to the Arduino board using the Arduino IDE software. It is an open source software that makes coding simple. The Arduino IDE is derived from the Processing IDE. It contains all the necessary libraries for writing code for any type of Arduino.

Steps for uploading code:

- Download Arduino IDE Software.
- Power up your board.
- Launch Arduino IDE.
- Open your first project.
- Select your Arduino board.
- Select your serial port.
- Upload the program to your board.

IV. WORKING PROCEDURE



In order for the statements connected to those functions to stay active throughout runtime and for there to be no mention of errors, the necessary library functions must first be included. Then, along with the program variables, the Arduino ports from which the out is to be extracted must be mentioned. The information must then be shown on the mobile display using a different piece of code. Once the display portion is complete, the code and conditions for the stepper motor's clockwise rotation are defined, and a delay of 1000 is specified to allow for slow compression. The stepper motor's code and state must then be established, but without a wait to allow for quick growth. The control returns to the clockwise condition and repeats itself after one rotation. The control shifts to the gradual compression when the antilock rotation condition is fulfilled, when the AMBU bag is compressed. The control switches to the quick expansion when the anticlockwise condition is carried out, expanding the AMBU bag there. The closed loop supply chain network is created by this [9]. Lastly, the Mobile displays the parameters, which include the I:E ratio, breaths per minute, and tidal volume.

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V. RESULT

Figure 5.1: Project prototype.

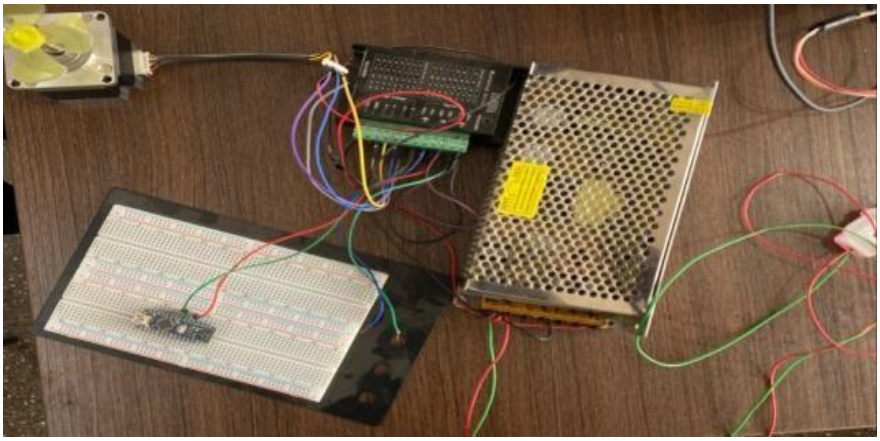

Figure 5.2: Rotation of stepper motor.

100% building up the electrical part shown in figure 5.2 results in rotation of stepper motor helps in pumping of ambu bag which results in supply of sufficient air to a patient.

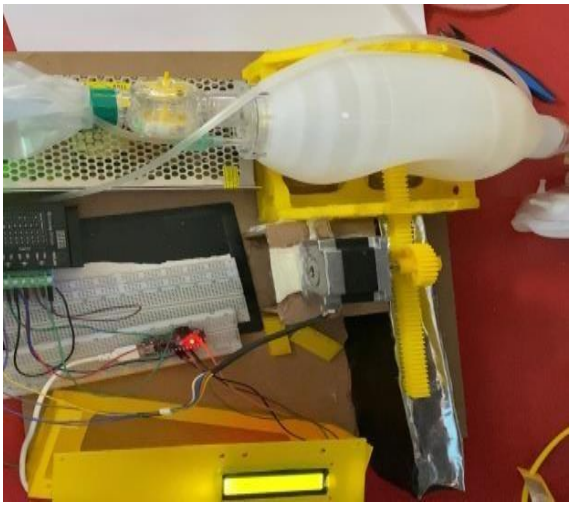

Figure 5.3: Implementation of 3D printings.

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In Figure 5.3 shows the Implementation of 3D printing, Printing material is polylactic acid (PLA) or glycol modified polyethylene terephthalate(PETG).

To place and support of ambu bag the printed material is bag support and arduino, Bluetooth module, bread board and few other components placed in closed bread box base and control box panel printed material also for push and pull of an ambu bag which is done by the rotation of stepper motor, the stepper motor fixed by Rack and pinion printed material.

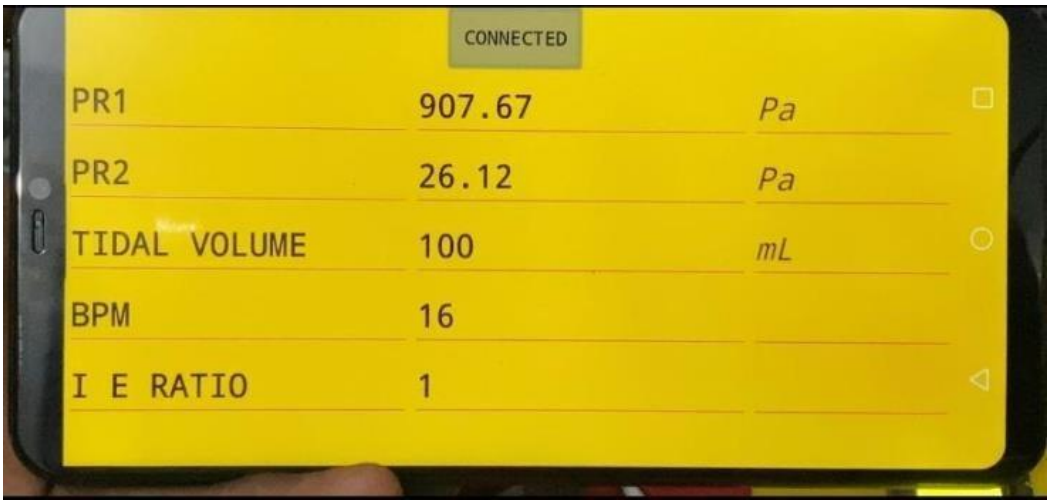

Figure 5.3: Display of parametric values in mobile application

The reading of the output will be displayed in the mobile application developed in using the open-source software. Where the application should be downloaded in laptop or smart phones and connected thought Bluetooth with the help of Bluetooth module which is part of circuit.

The required values of I:E ratio of 1:1 to 1:4 ratio and tidal volume from100 to 800 milliliters, breathing rates from 5 to 40 breaths/min are set by manually as per patient condition. In Figure 5.3 shows that the value of pressure sensor 1 and pressure sensor 2 as 907.67 pascals and 26.12 pasacals and the respective I:E ratio as 1:1, breathing rate as 16 breaths/min and tidal volume as 100 ml at the initial point.

VI. CONCLUSION

In this article, we have covered all the necessary aspects of a mechanical emergency ventilator. This explains the simple "PUSH-PULL" operation and AMBU bag functionality of the ventilator. The report makes plain the primary prerequisite for the AMBU bag's functioning mechanism and includes examples of it, along with confirmation of the experiment's success.

The Mechatronic Emergency ventilators can operate as a stop-gap device to provide some relief to the patients prior to receiving professional medical treatment, though, in circumstances when standard ventilators are not immediately accessible or while patients are being transported to hospitals in ambulances.

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