ALow Cost Portable Mechanical Ventilator

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Abstract—In light of global health crises, such as the COVID-19 pandemic, there is an urgent need for accessible and affordable medical equipment, particularly ventilators, to support patients experiencing respiratory distress. However, many regions, especially those with limited resources, face challenges in procuring ventilators due to high costs and logistical constraints.The challenge is to design a low-cost portable ventilator that meets medical standards for efficacy and safety while remaining affordable and accessible to healthcare facilities worldwide. This ventilator should be capable of delivering controlled oxygenation and ventilation to patients with varying degrees of respiratory failure, and should be suitable for use in both clinical settings and field hospitals. The proposed technique uses a potentiometer to vary input BPM which controls the movement of motor leading to control the pressure applied to the ambu bag. Hence the controlling of the respiratory frequency makes the ventilator to be used for any patient with respiratory issues. And this can be affordable as it requires less equipment and is also portable.

INDEX WORDS- Mechanical ventilator, Volutrauma, Atelectrauma, respiratory frequency, Bag Value Mask (BVM), Positive-End-Expiratory-Pressure(PEEP).

I. INTRODUCTION

Artificial respiration plays a vital role in the hospitals and ambulances for the patients suffering with respiratory problems. Over the past few years, the requirement for the mechanical ventilation has been rapidly increasing due to the COVID-19 pandemic[1]. These ventilators are not only used for COVID patients but also people suffering with asthma, chronic obstructive pulmonary and other chronic respiratory conditions. Such diseases maybe increased due to smoking, air pollution, occupational risks and lot more. These diseases may lead to acute respiratory problems[3]. As to reduce the shortage of ventilators in hospitals a low cost, open source and easily accessed ventilators.

According to some studies mechanical ventilation can be supplied in two ways that isthrough positive and negativepressure ventilation. In the 19th century the negative pressure ventilation has been discovered in which the patient is supplied with less pressure when compared to the atmospheric pressure in order to increase the work done by respiratory muscles.

Whereas the positive pressure ventilation is done by supplying the excess pressure than the atmospheric pressure.

But by using mechanical ventilation the patient may suffer with atelectrauma and volutrauma. Volutrauma occurs when ventilation in excess distends the airways. This may cause an inflammatory reaction, which eventually leads to rupture of alveolar walls and edema [4].

On the other handatelectrauma occurs due to the less air pressure which leads to alveolar reopen and damage. To avoid the atelectrauma experts suggest positive pressure ventilation or Positive End-Expiratory pressure [PEEP][1].

Studies also say that using PEEP may cause lung inflammation and edema formation yet mechanical ventilators are used inemergency situations to help patients from respiratory problems. But using PEEP is far better than negative pressure ventilation because negative pressure collapses the airway for breathing [5].

II. LITERATURE SURVEY

The Literature Survey involves reviewing existing research, publications, and projects related to web-based notice boards, smart technologies, and related areas.

The raspberry pi is given 3 inputs namely respiratory frequency(FR), inspiration-to-expiration ratio(I:E) and tidal volume(Vt) which then acts accordingly to the given inputs and controls the movement of the motor which in turn controls the pressure applied to Bag Value Mask(BVM)[1].

The ventilator breath delivery system works on the principle of discontinuous gas delivered by compression of a gas reservoir with an eccentric disc cam, reducing the need for expensive pneumatic components. The resulting portable volume-displacement ventilator can thus be operated with existing, inexpensive, technology. The gas reservoir is a bag-valve-mask (BVM), which is already frequently used in hospitals and ambulances. This is equipped with an air reservoir and a complete safety valve system [2].

A single ventilator in pressure control mode was used with flow control valves to simultaneously ventilate two patients with different lung compliances. The system was first evaluated using high-fidelity human patient simulator mannequins. Patients were matched on positive end-expiratory pressure, fractional inspired oxygen tension, and respiratory rate. Tidal volume and peak airway pressure (P_{MAX}) were recorded from each patient using separate independent spirometers [6].

The novel ventilator consists of an inspiratory limb composed of an elastic flow-inflating bag encased within a non-compliant outer sheath and an expiratory limb composed of a series of two, one-way bidirectional splitter valves derived from a self-inflating bag system. An Arduino Uno microcontroller controls a solenoid valve that can be programmed to open and close to produce a set respiratory rate and inspiratory time [7].

The proposed system uses an Arduino Nano controller with a digital display, pressure blower, its drivers and two transducers. Pressure and flow were continuously measured at the outlet of the ventilator and fed into the controller which was provided with a custom-made code to detect inspirations and expirations and toaccordinglytriggerthe inspiratory and expiratory pressures generated by the blower [8].

The ventilator uses a self-inflating bag-based mechanical ventilation system, combining its intrinsic simplicity with instrumented sensing of the pressure produced by the system to continuously control the ventilator in a closed feedback loop, creating airflow sensors in favour of calibrated determination of how bag volume varies with mechanical compression. This allows the ventilator to reach precise pressure targets within a prescribed inspiratory time while setting safety alarmed thresholds on the volume delivered per breath utilizing an inexpensive and rapidly devised design [9].

The design is made in such a way that, by switching on the motor causes the wire to bend. This pulls the bottom circle upwards, which pressurizes the air inside the tank which corresponds to inspiration cycle. And when turned off the tension in the wire is released and thus the bag restores to it's initial position and thus creating expiration cycle[10].

The ventilator delivers breaths by compressing a conventional bag-valve mask (BVM) with a pivoting cam arm, eliminating the need for a human operator for the BVM.It is driven by an electric motor powered by a 14.8 VDC battery and features an adjustable tidal volume up to a maximum of 750 ml. Tidal volume and number of breaths per minute are set via user-friendly input knobs. The prototype also features an assist-control mode and an alarm to indicate over-pressurization of the system. Future iterations of the device will include a controllable inspiration to expiration time ratio, a pressure relief valve, PEEP capabilities, and an LCD screen [11].

III. METHODOLOGY

A. Block diagram of the work

For the development of this work we have used Node MCU, motor driver(L298), DC motor, ambu bag or Bag Value Mask(BVM), Temperature and humidity sensor(DHT11), Blood oxygen sensor(MAX30100) and a LCD display.

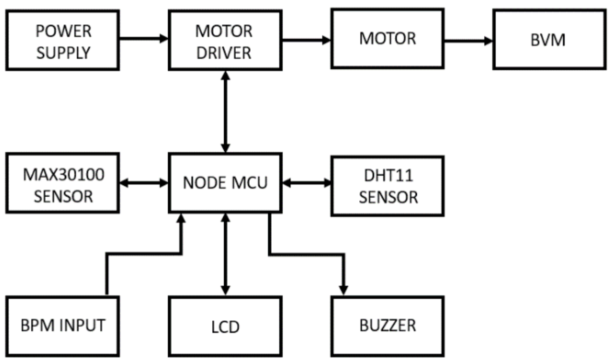


Fig. 1. Block Diagram of Hardware Implementation

Fig. 1. shows the block diagram of the low cost portable mechanical ventilator. NodeMCU, an economical open-source platform built around the ESP8266 Wi-Fi module, holds significant promise for enhancing low-cost portable ventilators. With its wireless connectivity capabilities, NodeMCU enables seamless communication between the ventilator and external devices or a central monitoring system, eliminating theneed

forcumbersome physical connections. Moreover, its integration facilitates data logging of critical ventilation parameters and allows for remote monitoring, empowering healthcare professionals to track and adjust ventilator settings in real-time. The platform's compatibility with various sensors further enhances the ventilator's functionality by enabling the monitoring of crucial metrics such as pressure, airflow, and temperature. NodeMCU's cost-effectiveness is particularly noteworthy, contributing to the overall affordability of the portable ventilator system. Leveraging an open-source community for support, ease of programming through the Arduino IDE, and a compact form factor, NodeMCU emerges as a versatile and practical solution for the development of low-cost, yet technologicallyadvanced, portable ventilators.

Microcontroller

Node-MCU (Node Microcontroller Unit) is an open-source software and hardware development environment built around an inexpensive System-on-a-Chip (SoC) called the ESP8266. The ESP8266,designed and manufactured by Espressif Systems, contains the crucial elements of a computer: CPU, RAM, networking (WiFi), and even a modern operating system and SDK. It is a self-contained WiFi networking solution offering as a bridge from the existing microcontroller to WiFi and is also capable of running self-contained applications.

LCD Display

An LCD (Liquid Crystal Display) is a flat-panel technology that uses liquid crystals to modulate light and produce images on a screen. It consists of layers with electrodes and liquid crystal molecules sandwiched between them. When an electric current is applied, the liquid crystals align to control the passage of light, creating the display. LCDs are commonly used in TVs, monitors, and electronic devices for their thin profile and energy efficiency.

MAX30100 Sensor

The MAX30100 sensor is a compact, integrated pulse oximeter and heart-rate monitor. It efficiently measures blood oxygen levels and heart rate, making it widely used in wearable devices for health monitoring. The sensor combines red and infrared LEDs with a photodetector to analyse light absorption in blood vessels, providing accurate physiological data.

DHT11 Sensor

The DHT11 sensor is a low-cost, digital temperature and humidity sensor commonly used in electronic projects. It provides real-time readings and operates via a single-wire digital communication protocol. With its simplicity and affordability, the DHT11 is popular for monitoring environmental conditions.

Motor Driver

TheL298 motor driver consists 4 input pins, 4 output pins and 2 enable pins. It is used to drive the high power motors by providing sufficient power to the motor.

DC Motor

The proposed system consists of a 60RPM 5kg motor which is used to press the BVM while considering the commands from Node MCU. The Node MCU is controlled through code written and helps the motor to press the arm according to the input given from the potentiometer.

Power Source

The system consists of three 3.7V batteries for providing biasing to the motor driver. Each of the batteries can generate 1200mAh current.

BVM

An Ambu bag, also known as a bag-valve-mask (BVM) or self-inflating bag, is a medical device used to provide positive pressure ventilation to individuals who are unable to breathe on their own or require assistance with breathing. The device is commonly employed in emergency medical situations, during anesthesia administration, or in other scenarios where respiratory support is needed.

- The NodeMCU, functioning as the central controller, interfaces with the MAX30100 sensor to measure heart rate and oxygen levels, crucial parameters for respiratory health. Simultaneously, the DHT11 sensor provides real-time temperature and humidity data, aiding in comprehensive environmental monitoring.
- The NodeMCU enables remote monitoring and control, allowing healthcare professionals to access real-time data and adjust ventilator settings remotely.
- The ability to easily connect to the internet and leverage cloud services enhances the ventilator's functionality, data analysis, and potential integration with healthcare systems.
- Simultaneously, the DHT11 sensor provides real-time temperature and humidity data, aiding in comprehensive environmental monitoring.
- The gathered information is displayed on an LCD screen as well as on the blynk app, offering a user-friendly interface for instant feedback.
- The code is written in such a way thatby giving input that is BPM through potentiometer the

motor rotation increases with increase in BPM and vice versa.

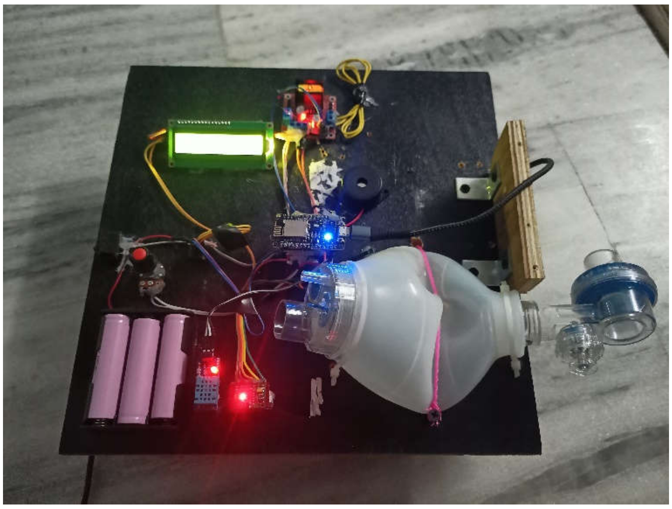
- ➢ If there is rise in temperature abnormally and the temperature is above threshold then the buzzer will be activated. By this we can be aware of the room temperature of the patient.
- ➢ The parameters that are observed on the LCD display can also be observed on the required smart phone by using blynk app.

B. SOFTWARE DESCRIPTION

- ➢ The Arduino IDE (Integrated Development Environment) is a software platform designed for programming and developing applications for Arduino microcontrollers. It provides a user-friendly interface for writing, compiling, and uploading code to Arduino boards. Key features include a text editor with syntax highlighting, a serial monitor for debugging and communication, and a library manager for easily integrating pre-written codes.

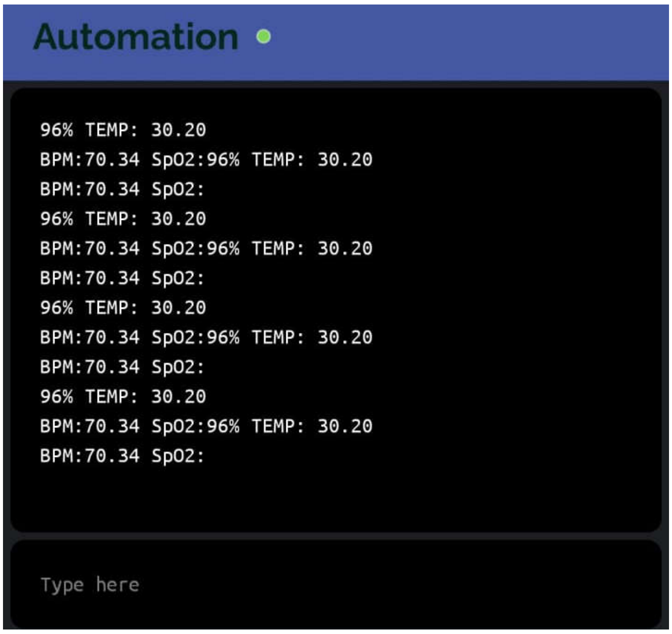
IV. RESULTS AND DISCUSSION

Step1:- The initial phase of the ventilator when the power is given is shown below.



Step 2:- By giving a small value of resistance the motor is rotated slowly and there is small pressure observed on the ambu bag. The temperature, humidity andoxygen level is observed on the LCD display as well as on the blynk app.

Step 3:- By giving the large value of resistance the motor is rotated with high speed and there is large amount of pressure applied on to the ambu bag. The temperature, humidity andoxygen level is observed on the LCD display as well as on the blynk app.



V. CONCLUSION

In conclusion, the NodeMCU based mechanical ventilator has varied the speed of rotation of motor which in turn controls the amount of oxygen supplied to the patient. And this ventilator is of low cost and is suitable for any emergency situations. Since, these ventilators are small in size these can be carried anywhere and operated easily. By using Blynk app the data like oxygen levels, humidity and temperature can be monitored anywhere.

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