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LOW-COST VENTILATOR WITH VARIABLE BPM AND SPO_2 SETTINGS

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Abstract: The global health crisis has underscored the urgent need for this affordable, scalable ventilator which can be of great use where the patient needs constant monitoring. This paper presents the design and development of a low-cost ventilator capable of monitoring and adjusting BPM and SpO2 levels. The ventilator integrates basic mechanical ventilation principles with electronic sensors to ensure safe and effective respiratory support. It allows healthcare providers to adjust BPM settings based on patient needs and continuously monitor SpO2 levels, ensuring real-time oxygen management. The system is designed to be easy to use, power-efficient, and suitable for rapid deployment in emergency scenarios. Through cost-effective components and minimal maintenance requirements, this ventilator aims in providing a reliable solution for critical care management According to preliminary testing, this device satisfies critical medical requirements for patient monitoring and non-invasive ventilation, which makes it an acceptable substitute for low-resource environments in times of medical emergency. This project gives comfortable treatment to the patient, and monitors and controls the pressure of oxygen level.

***Keywords*- Ventilation, BVM (bag-valve-mask), Arduino Uno, LCD**

1.Introduction

Ventilator is a mechanical device that helps people breathe by moving air into and out of their lungs and one essential physiological function for human life is respiration. However, a number of conditions, including illness, trauma, infections, neuromuscular abnormalities, etc., might interfere with normal physiology and necessitate outside assistance in order to perform this function. Mechanical or aided breathing becomes essential in certain situations and may even save lives. An estimated 20,000 individuals with India need ventilator support every day due to head traumas, chronic respiratory disorders, an allergic reaction and other injury-related illnesses. Sadly, the lack of ventilators frequently requires caregivers to manually compress AMBU bags for extended periods of time, underscoring the urgent need for additional ventilators in the nation.

The demand for ventilators is anticipated to far outstrip the available supply given the anticipated number of people who will be expected to get the illness in India and the proportion of these patients who would probably need assisted ventilation. Physicians worldwide are being forced to make tough triage decisions about which patients to treat and which to release due to the shortage of ventilators. The intricacy and expense of conventional intensive care unit ventilators, which are made greater by the pandemic's disruption of normal supply chains, make expanding the number of ventilators more difficult. Ensuring safe and dependable production while satisfying the unique needs of patients is the main goal of the automatic Ambu bag operating mechanism for the low-cost ventilator design. This design strategy aims to decrease the device's part count, complexity, and expense while also lessening or doing away with its need on limited resources and components. Additionally, the design places a high priority on its adaptability to various healthcare systems while making sure that healthcare workers with little to no ventilation experience and no past contact with this kind of ventilator system can follow its easy assembly, testing, and usage instructions. The automatic Ambu bag operating device design prioritizes simplicity in both operation and installation, in contrast to current intensive care unit ventilators that provide a variety of breathing modality and complex feedback loops for different respiratory parameters. The operation of modern ICU ventilators necessitates highly skilled personnel, and the regulations are understandably tight. Medical equipment makers have had trouble meeting emergency ventilator orders during the pandemic because of supply chain disruptions and the difficulty of quickly increasing manufacturing of highly sophisticated ventilators. One unique feature that sets our project apart is the automation of compression settings in the ambu bag compression. In contrast to other projects that depend on manual settings, ours uses automatic compression, which improves accuracy and efficiency. By automating the compression process, we limit the chance of human error and assure constant and optimal compression levels. Our project also has the ability to collect data by data gathering systems to record and examine a variety of characteristics during compression, whereas other initiatives might only concentrate on the ambu bag's mechanical components. Better patient care and more effective emergency decision-making may result from the data-driven insights our initiative produced.

2. Literature Survey

A low-cost ventilation is a surgical instrument used to give patients who have trouble breathing artificial ventilation, usually as a result of respiratory conditions or after surgery. Low-cost ventilators are made to be simpler and less expensive than typical hospital ventilators, which makes them suitable for usage in places with limited resources, including rural regions or healthcare facilities with little funding. In order to deal with the growing need for respiratory therapy in various parts of the world during the COVID-19 epidemic, these ventilators proved very crucial. Low-cost ventilators are designed to save lives when traditional ventilators are unavailable, even though they do not have all the latest capabilities. To help patients, Rouf-ul Aalam, Afshan Amin Khan, and Dr. Liyaqat Nazir suggested a ventilator design which is simple to produce and incorporate into a hospital setting. In essence, the suggested ventilator uses electronically controlled mechanical breathing, which is accomplished by carefully calculating the periodic expansion and compression of an easily accessible ambulatory bag [1]. The resilience and functionality of the ventilator, which is not only easily transportable but also extremely affordable and economically friendly, were designed by Muhammad Jawad Ghafoor and Mustafa Naseem. Its primary concept is to be integrated into massive human emergencies in areas with limited resources. By compressing a conventional bag valve mask, it distributes breaths without the need for a human operator [2]. Gisela Pujol-Vázquez, Leonardo Acho, and Alessandro N. Vargas [3] created and built an open-source, inexpensive mechanical ventilator. To provide breaths, the ventilator uses a motor and its shaft to compress the ambu bag. The potential advantages of the derived mechanical ventilator are demonstrated by laboratory experiments that simulated both healthy and sick people. Hency Subha Jose P, K. Rajasekaran, P. Rajalakshmy, and P. Manimegalai, [4] created a device prototype employing the fewest possible parts to help patients who are only partially able to breathe on their own. Abdul Mohsen Al Husseini, Heon Ju Lee, Justin Negrete, Stephen Powel son, Amelia Servi, Alexander Slocum, and Jussi Saukkonen [5] created a low-cost compact mechanical ventilator that compresses an ambu bag so that air can enter the patient's lungs using a cam-type actuation mechanism. Providing decision support is the primary function of this new generation of ventilators. A list of possible causes and therapies will be provided for each alerting state. The doctor will be informed of any changes in ventilator variables, along with any likely reasons and potential remedies. From the ventilator's operating handbook to the data demonstrating a suggested method of action, a library of information will be readily available from the screen. There will be closed-loop venting control for every ventilation mode. To enhance patient ventilator synchronization, these new ventilators will have the ability to modify gas supply. In order to guarantee that gas supply is in harmony with the patient's preferences, they will be able to automatically adjust the flow waveform, peak inspiratory flow, rise time, and termination criteria in addition to interpreting the airway pressure and flow waveform during both volume and pressure ventilation. Given that asynchrony [6, 7] may have a significant impact on patient outcomes, this is a component that is becoming more and more significant in ventilator functioning. At least one ventilator already has the ability to automatically modify the termination standards [8].

3. O_2U Ventilator Simulation

The ventilator was connected to pressurized sources of air and oxygen gas. Using a gas mixer, the necessary fraction of inspired oxygen (FiO2) was combined with medical-grade air before going into the ventilator. Similar to previous CPAP or High Flow Nasal Cannula systems, this gas combination was permitted to continually flow through the device during non-invasive operation modes, entering and leaving the patient's respiratory circuit. The expiratory and inspiratory valves stayed open in this state, and the system monitored the pressures for leaks, obstructions, or any other threat to the patient's or the device's safety. During aided or necessary intensive ventilation modes, the inspiratory and expiratory valves were used to allow or prevent the flow of incoming and departing gas, respectively, in order to enforce the patient's breathing cycle. Because there were no flow-measuring sensors, the ventilator's flow rate was adjusted manually using a control valve known as a Thorpe Tube. Additionally, the inspiratory time was adjusted so that each inspiration phase supplied a known volume of gas. A spirometer-based [9] expiratory volume sensor was utilized on the expiration side of the circuit to measure exhaled volumes in addition to this table for establishing the desired delivered volume because volume calculations are still essential to patient care. The O2U ventilator prototype is shown in Figure 1.

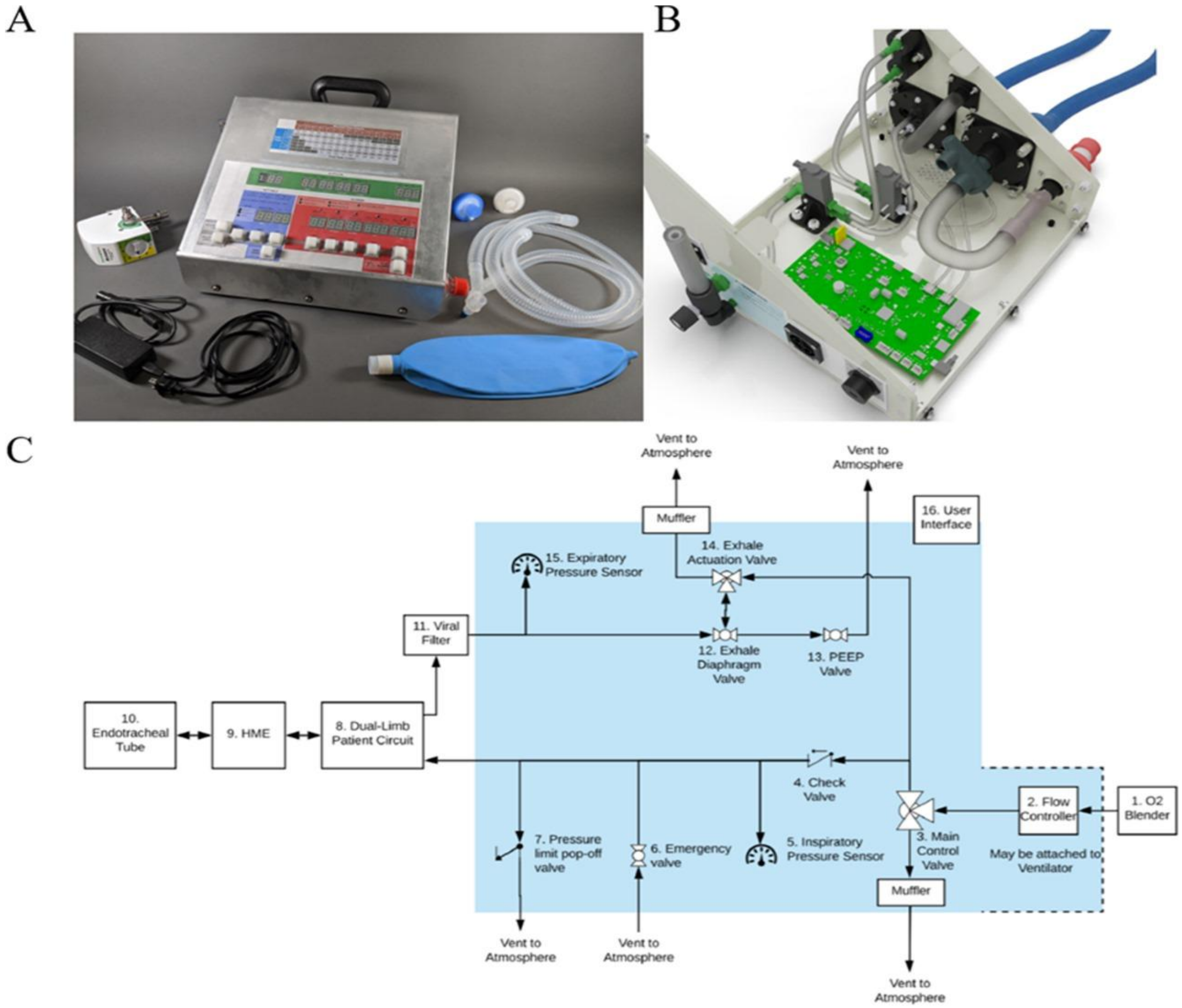

Figure 1: SpO_2 ventilator prototype

4. Control Implementation

Control design: This ventilator uses an assist-control (AC) mode to offer guaranteed tidal volumes. The operator chooses the tidal volume based on the patient's optimal body weight and minimum respiratory rate, which is typically 6–8 mL/kg. A minimum ensured minute ventilation (Ve) is therefore provided. The ventilator will supply the set tidal volume if the patient's breathing rate is higher than the set inspiratory pressure, which is exceeded by a vacuum of 2 cmH20. User Interface: Three potentiometer knobs are used to adjust the three user inputs (tidal loudness, bpm, and I: E ratio). An LCD display will be added to future versions of the device to show the battery power status, airway pressure level, and input parameters.

1. **User Interface:** Three potentiometer knobs are used to adjust the three user inputs (tidal loudness, bpm, and I:E ratio). An LCD display will be added to future versions of the device to show the battery power status, airway pressure level, and input parameters.
2. **Safety Features:** A pressure sensor attached to a sensor output on the BVM is used to monitor the airway pressure in order to make sure the patient is not hurt. If the pressure increases too much, the same pressure sensor that initiates assist control also sounds an alarm, warning the doctor to treat the patient. A mechanical pressure relief valve will be incorporated into subsequent versions of the gadget as an additional safety precaution against over-inflation.
3. **Control loop:** The inspiratory stroke is started at the start of the control loop, which is started by the internal timer that is set by user input. The actuator puts the cam back in its starting position and holds it there until the next breath is taken after the specified tidal volume is attained. After that, the loop is repeated to produce irregular breaths. The ventilator instantly delivers a breath, breaking the loop and resetting the timer if the patient attempts to breathe (as detected by the pressure sensor). This loop is depicted in a diagram in Figure 2 **.**

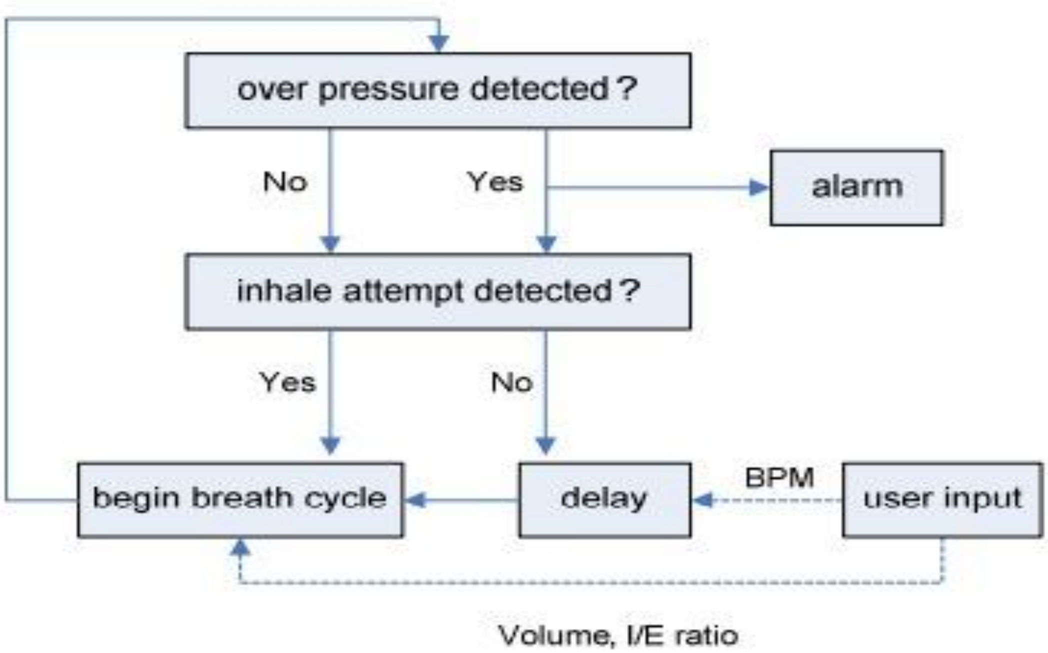

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Figure 2: Ventilator Control loop

5. Hardware Implementation

The different parts of the design are shown in the table below to depict the specification of the component used in the design. At first, Arduino Uno is mounted on the PCB board and then the LCD display is connected with the help of jumper wires from SCL→A5 and SDA→A4, with a 5v supply and other set of wires from LCD is connected to servo motor and Arduino Uno. After that, the code is inserted with the help of Arduino IDE software. At last, the AMBU bag is fastened to the PCB board with the help of a Wooden Flap.

Table 1: Components used for hardware

Sl No.	COMPONENTS	SPECIFICATIONS
1.	Arduino uno	ATmega328P
2.	Power supply	12 volts
3.	Ambu bag	1 unit
4.	Servo Motor	GS5515 Mg
5.	Bread Board	1
6.	Jumper wire	15 units
7.	LCD used	16 x 2 LCD
8.	Potentiometer	10 K ohms

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6. Block Diagram of Low-Cost Ventilator

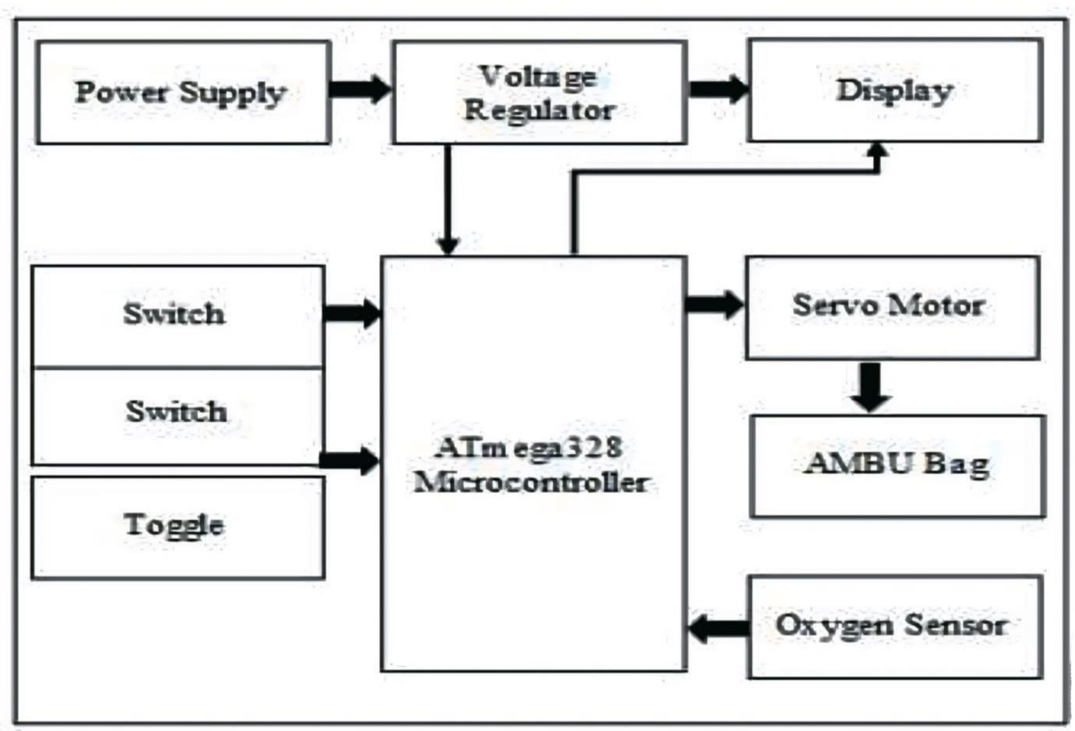

Figure 3: Block Diagram of low-cost ventilator

7. Software Implementation

The Arduino interface interacts with sensors to receive inputs, monitor the system's state as feedback, and provide output to motor. Arduino Uno boards are used in the system to guarantee streamlined operation and value computation. Potentiometers are used to program the master Arduino to allow parameter changes. Every time there is a change in input, the master Arduino connects to the auxiliary Arduino and sends the motor control settings. The auxiliary Arduino's sole purpose is to control the motors, it modifies its motor control in response to the updated data. A motor driver is employed because the microcontroller is unable to supply the stepper motor with sufficient power. To activate the stepper motor, the motor driver receives signals from the auxiliary Arduino. The pressure sensor provides pressure values to the main Arduino, which uses a transducer to transform physical data into electrical impulses and provide an analog output. The analog values are converted to digital format using an analog-to-digital converter (ADC) and then transmitted to the Arduino Uno. The flow rate is determined using these sensory values, using a simplified version of Bernoulli's equation. The calculated values are then displayed to the users on an LCD screen.

8. Result Analysis

The BPM range should be adjustable, typically between 10–30 BPM for adult patients. The system could use a servo motor to vary the airflow in line with the selected BPM. Then it read SpO_2 values, and maintain steady flow cycles. Integrate an adjustable interface to set BPM. If SpO_2 levels drop, the system could automatically adjust BPM within safe parameters or alert caregivers. The system could plot historical data to see SpO_2 level trends over time or analyze how BPM adjustments affect oxygenation. Testing the ventilator in various scenarios and ensuring that all components respond as expected is essential. Testing under controlled conditions to validate its effectiveness in maintaining BPM and SpO_2 levels within target ranges is critical for ensuring patient safety. The whole setup is show in Figure 4**.**

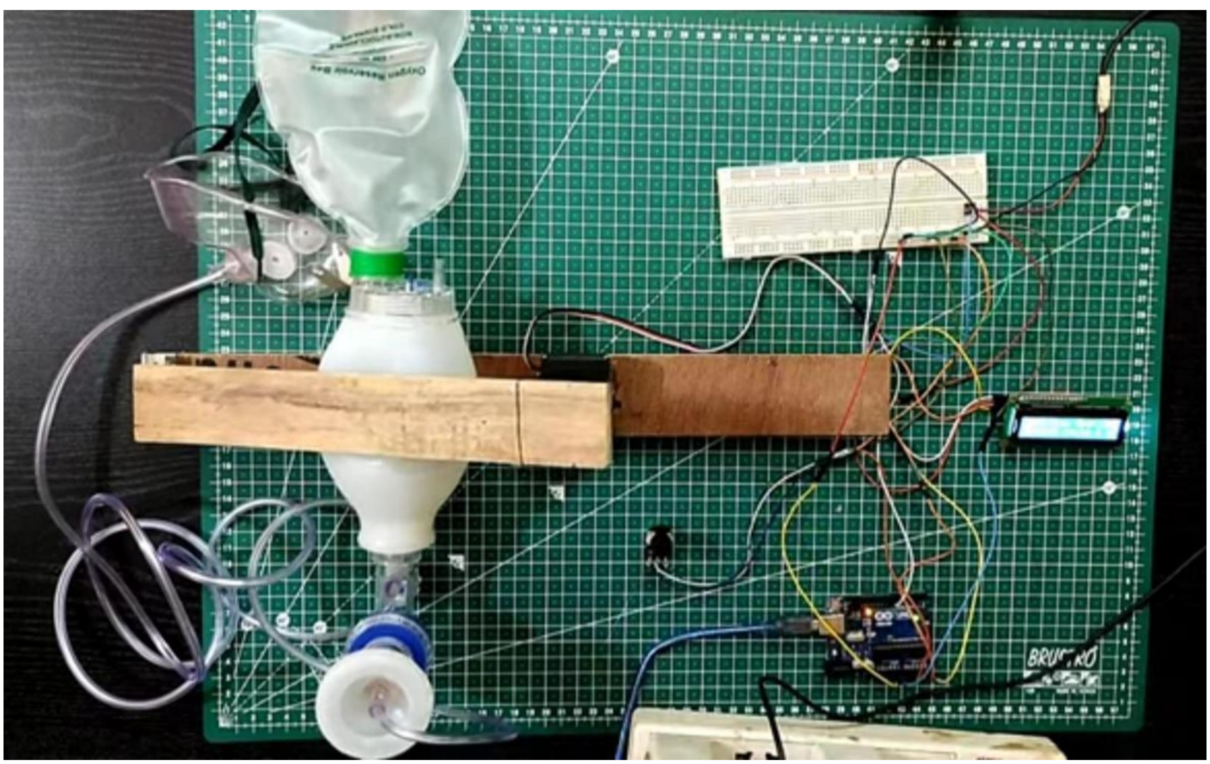

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Figure 4: Testing of final hardware

9. Conclusion

It is our hope that the project will save many more lives and fulfill its intended purpose. People with breathing problems will be able to use this project as artificial lungs. To demonstrate the possible advantages of this ventilator, it imitated both healthy and sick people. Nobody needs a medical expert to operate this task because it is straightforward to use and control, and it can be used both at home and in emergency situations. This device's dependable structure and simple design make it easy for the patient to accept. This project's primary goal is to reduce the device's parts and boost its effectiveness so that the patient can use it with the same level of comfort as they would with a standard ventilator.

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