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Automated Resuscitator Bag for Critically Ill Patient

Faheemuddin Khan
Biomedical Engineering
Vidyalankar Institute of Technology
Wadala, Mumbai- 400037

Shraddha Pagare
Biomedical Engineering
Vidyalankar Institute of Technology
Wadala, Mumbai- 400037

Priya Bawane
Biomedical Engineering
Vidyalankar Institute of Technology
Wadala, Mumbai- 400037

Abstract
The COVID-19 pandemic has highlighted a critical global shortage of ventilators. This paper presents the development of a low-cost, efficient, and easy-to-use mechanical ventilator. The aim is to design a simple, portable device that can be used even by individuals with minimal training, while also addressing some limitations found in current ventilator systems. A key feature of this project is an automated Ambu bag compressor powered by solar energy and rechargeable batteries. The system is capable of transmitting real-time health updates to medical personnel, enhancing patient monitoring. This solution provides an affordable and practical option for emergency respiratory support, particularly for COVID-19 patients and those with similar respiratory conditions.

Keywords **– COVID-19, affordable ventilator, Ambu bag automation, solar-powered resuscitator, emergency breathing aid**

INTRODUCTION

In March 2020, the World Health Organization (WHO) officially declared COVID-19 a global pandemic (WHO Director-General's briefing on COVID-19, March 11, 2021). This announcement marked the beginning of an overwhelming surge in demand for medical infrastructure worldwide—an issue that remains relevant even today. Low- and middle-income countries have been disproportionately affected due to their limited healthcare resources. In many of these nations, access to quality medical care is restricted to a few hospitals, and the cost of such care is often beyond the reach of the average patient. On average, across 183 countries, there are only 8.73 intensive care unit (ICU) beds available per 100,000 individuals. High-income countries report a better ratio, averaging 12.79 ICU beds per 100,000 people (Sen-Crowe et al., 2021).

In critical medical scenarios, providing sufficient respiratory support to patients unable to breathe unaided is vital. Typically, an Ambu bag (Artificial Manual Breathing Unit) is used for manual ventilation during emergencies or while transporting patients. However, manual use demands continuous effort, and human limitations can result in inconsistent ventilation, increasing the risk of complications. To overcome these issues, the development of an automated Ambu bag system has become increasingly significant. Additionally, such systems should be capable of monitoring blood oxygen saturation and exhaled air pressure to prevent issues caused by under- or over-inflation of the lungs.

I. AIM AND OBJECTIVES

Aim

To design and build an automated Ambu bag system capable of delivering consistent and controlled ventilation for critically ill patients, particularly in emergency scenarios and areas with limited medical resources.

OBJECTIVES

- Create a mechanical mechanism to automate the compression of the Ambu bag, ensuring uniform and accurate delivery of air.

- Integrate a microcontroller-based control system that can regulate ventilation according to individual patient requirements.
- Incorporate real-time monitoring and feedback mechanisms to adjust ventilation parameters dynamically for optimal respiratory support.
- Ensure the overall device is compact and lightweight, allowing for easy mobility and use in ambulances or temporary medical setups.
- Utilize low-cost, easily available components to keep the design affordable and accessible, especially in low-income regions.
- Design an intuitive user interface that allows healthcare professionals to operate the system with minimal training.

II. LITERATURE SURVEY

In this literature review, we examine key studies and findings relevant to our project, highlighting recent advancements and critical insights in the field.

K. H. H. Cong Toai Truong *et al.* [1], in their 2021 study presented at ICIUS in Vietnam, investigated how the angle of paddle compression affects the air volume delivered by bag-valve-mask (BVM) ventilators. Their experimental analysis revealed that the volume of expelled air does not increase proportionally with the paddle's squeezing angle. This finding underscores the importance of incorporating accurate control systems in ventilator design to ensure consistent and appropriate airflow.

R. S. P. R. R. S. Swati Patel [2], in a 2024 pilot study, evaluated the effectiveness of an automated Ambu bag-based ventilator (RC Device) for patients needing mechanical ventilation. The paper references the work of Al Husseini *et al.* (2010), who developed an affordable, portable ventilator using a motor-driven bag-valve-mask (BVM) compression system. Their design featured assist-control functionality, adjustable tidal volume, and safety alarms for overpressure, all at a prototype cost of $420, with the potential for bulk manufacturing under $200—ideal for low-resource settings. Similarly, Williams *et al.* (2010) proposed a pneumatically powered ventilator design that operates efficiently without relying on electricity or pressurized gas supplies. These units focus on oxygen conservation and can be produced at an estimated cost below £200. Both studies emphasize cost-effective solutions with consistent airflow delivery. The cam-driven BVM compression mechanism (Al Husseini) ensures efficient air output, while the oxygen-recycling pneumatic system (Williams) supports longer use and broader therapeutic applicability.

These developments are especially valuable in crisis scenarios like mass casualty incidents and temporary medical facilities. Future improvements are likely to incorporate components such as Positive End-Expiratory Pressure (PEEP) valves, moisture exchangers, and advanced safety features to enhance overall clinical performance. The reviewed systems represent a major step forward in making mechanical ventilation more affordable and accessible worldwide.

N. V. A. N. V. Leonardo Acho *et al.* [3], in a 2020 study published by MDPI, introduced an open-source, low-cost mechanical ventilator aimed at assisting COVID-19 patients. Their system uses an actuator connected to a shaft to automate the compression of an Ambu bag for breath delivery. In addition, they proposed a numerical monitoring approach that evaluates lung function by analyzing pressure data from the inspiratory circuit. This method provides real-time alerts to healthcare providers regarding the patient's respiratory status. Simulations representing both healthy and compromised lung conditions were conducted, demonstrating the device’s effectiveness in different clinical scenarios.

S. F. R. T. J. D. D. Williams [4], in a 2010 *Euro* anaesthesia publication from Denmark, explored the development of cost-efficient pneumatic ventilators tailored for use during respiratory health crises. Conventional ventilators often prove too costly and complex for low-resource environments. To address this, Williams *et al.* created three progressively advanced models of gas-powered ventilators that consume low amounts of oxygen, each priced below £200. The initial prototype demonstrated oxygen efficiency three times higher than the widely used Dräger Oxylog 1000. Subsequent models included enhancements such as self-inflating bags and integrated nitric oxide systems to aid in treating conditions like ARDS. These ventilators showed promising results in trials, offering better oxygen utilization and flexibility, making them ideal for deployment in rural, emergency, and low-income healthcare settings. Further clinical evaluation was suggested to validate their use at scale.

III. METHODOLOGY

A. Hardware Requirements

- Arduino Nano - The Arduino Nano is a compact, open-source microcontroller board designed for easy integration with breadboards. It is powered by the Microchip ATmega328P chip and was first introduced by Arduino.cc in 2008. Functionally similar to the Arduino Uno, it offers the same input/output features and connectivity, but in a smaller form factor. The board includes 30 male I/O pins arranged in a DIP-30 layout. Programming can be done using the Arduino IDE, which supports both online and offline platforms. The board can be powered via a mini-USB Type-B cable or a 9V battery.

- 20x4 LCD Display - LCD stands for Liquid Crystal Display and works by using liquid crystals to control the passage of light. This display technology is widely used in various electronic devices such as mobile phones, laptops, televisions, and computer monitors. LCDs come in different sizes and configurations, with the 20x4 model displaying 20 characters per line across four lines. The rise of LCDs brought significant advancements to the electronics industry, allowing them to replace older technologies like CRT (cathode ray tubes), LEDs, and gas plasma displays. Additionally, LCDs are known for their lower power consumption compared to LED and plasma screens.

- Potentiometer (10K) - A 10K potentiometer is a type of variable resistor with three terminals. It features a rotating or sliding contact (called the wiper) that adjusts the output voltage, effectively forming an adjustable voltage divider. When only two terminals are used—typically one end and the wiper—it operates as a variable resistor or rheostat. The potentiometer gets its name because it's often used to measure or regulate electrical potential (voltage), applying the voltage divider principle.

- Push Button - A push button is a simple mechanical switch used to control a device or trigger a specific action. Made usually from durable materials such as plastic or metal, push buttons are designed for easy pressing, with surfaces shaped to accommodate the human finger or hand. Most push buttons are spring-loaded, meaning they return to their original position after being released. While many are biased (they naturally return), some designs require a spring to reset.

- Servo Motor (TD-8125) - The TD-8125MG is a high-torque digital servo motor designed for demanding applications in robotics and remote-controlled systems. It delivers a peak stall torque of 26.8 kg·cm, making it ideal for projects such as DIY robots, robotic arms, and RC vehicles that require both strength and precision.

- NodeMCU (ESP8266) - NodeMCU stands for Node Microcontroller Unit, a development board that combines both hardware and software capabilities. It is built around the affordable ESP8266 chip from Espressif Systems. The ESP8266 features built-in Wi-Fi, a CPU, RAM, and support for an operating system and SDK, making it a solid foundation for a wide range of Internet of Things (IoT) applications.

- MAX30100 Sensor - The MAX30100 is a compact sensor that combines heart rate monitoring and pulse oximetry into a single module. It contains two LEDs, a photodetector, and efficient analog signal processing components to accurately measure heart rate and blood oxygen levels. It operates at 1.8V or 3.3V and supports a low-power standby mode, allowing continuous connection to power without excessive energy use.

- DHT11 Sensor - The DHT11 is a commonly used digital sensor designed to measure both temperature and humidity. It incorporates a thermistor (NTC) to detect temperature changes and uses an 8-bit microcontroller to transmit the readings as serial data output.

- Resuscitator Bag - A resuscitator bag, also known as a bag-valve mask (BVM), is a manual breathing device used in emergencies to assist individuals who are not breathing effectively or at all. It is an essential tool found in ambulances, emergency rooms, and first aid kits for providing ventilation support.

B. Block Diagram Description

The Arduino Nano is powered with a 5V supply through a Nano cable, which is then distributed to various components, including the I2C LCD converter, LCD, and other modules. The LCD screen displays essential

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parameters such as volume, pressure, age group, and breath rate. A red LED indicates that the system is powered on by blinking when the circuit is activated. Two push buttons are integrated into the system: Push Button 1 is used to change the age group parameter, while Push Button 2 starts the operation of the MG990 servo motor. When the servo begins its looping action, a green LED lights up to indicate its active state.

The device also includes two potentiometers—Potentiometer 1 is used to regulate the pressure, and Potentiometer 2 adjusts the volume. The values controlled by these potentiometers are displayed on the LCD screen. In addition to the Arduino Nano, a second microcontroller, the NodeMCU (ESP8266), is employed to handle specific sensor data. It controls the MAX30100 sensor, which measures the user's heart rate (BPM) and blood oxygen saturation (SpO2) when a finger is placed on the sensor. It also monitors environmental conditions using the DHT11 sensor to track temperature and humidity levels. The readings collected by the ESP8266 are transmitted to the Blynk IoT mobile application, allowing real-time monitoring and visualization on a smartphone.

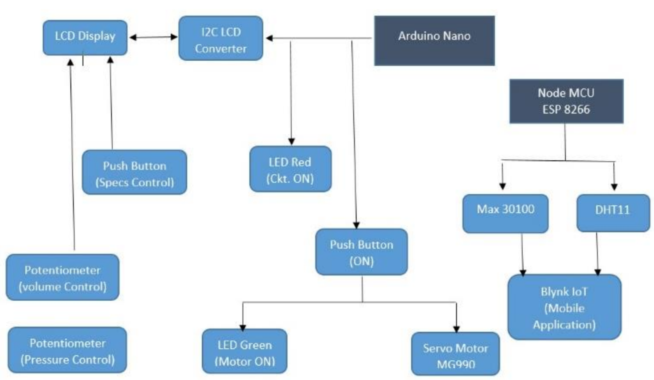

Figure 1.1: Block Diagram

C. Circuit Diagram

The circuit design includes a 20×4 LCD connected to the Arduino UNO for parameter visualization. The connections are as follows: GND to GND, VCC to 5V, SDA to analog pin A4, and SCL to analog pin A5. For monitoring vital signs, the MAX30100 sensor is interfaced with the ESP8266 (NodeMCU) microcontroller. The sensor connections are made with VCC to 5V, GND to GND, SDA to D2, SCL to D1, and the interrupt pin (INT) to D0.

To handle the mechanical actuation, a TD-8125 servo motor—chosen for its high torque—is connected to digital pin D4 of the Arduino. Volume and pressure control is achieved using two 10k potentiometers, connected to analog pins A0 and A1, allowing manual adjustment through simple rotation.

System status is indicated using two LEDs: a red LED connected to pin D7 lights up when the system is off, and a green LED on pin D8 turns on when the system is active. Additionally, a push button is used for selecting the age group and to start or stop the system, sharing the same digital pins (D7 and D8) through proper input handling logic.

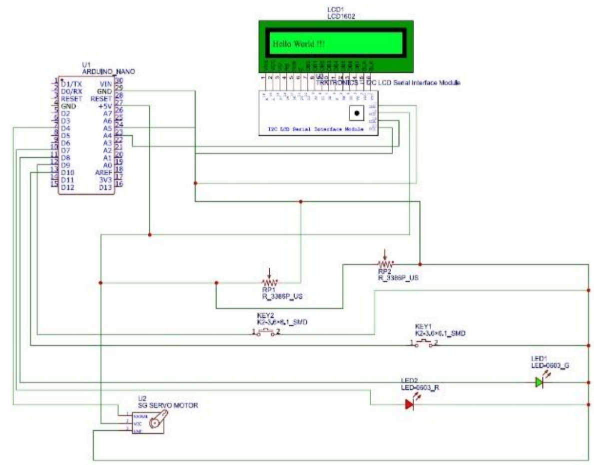

Figure 1.2: Circuit 1 (Arduino Nano)

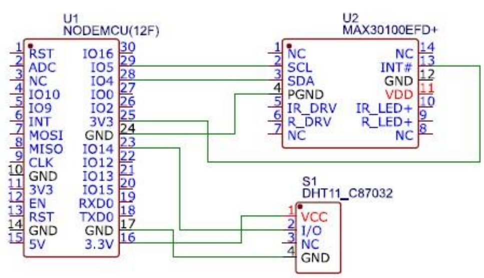

Figure 1.3: Circuit 2 (ESP Microcontroller)

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D. Experimental Setup

This project involves the design and implementation of a low-cost, portable, and microcontroller-driven automated resuscitator system, intended for use in emergency medical scenarios, especially in resource-constrained environments or during health crises such as pandemics. The system integrates an Arduino Nano and an ESP8266 Wi-Fi module to form a compact ventilator unit that supports both local and remote functionality.

A silicone resuscitator bag (Ambu bag) is mechanically compressed using a servo motor attached to a linear arm mechanism. Activation of the system is triggered by a push button, after which the device operates automatically. The user can fine-tune the tidal volume and airway pressure using variable potentiometers connected to the controller.

The system also includes safety monitoring features to ensure proper ventilation. It continuously checks vital indicators such as lung pressure and oxygen saturation (SpO_2), helping to avoid conditions like over-pressurization or insufficient inflation of the lungs. The entire setup is compact, suitable for battery operation, and controlled by the Arduino Nano, making it highly suitable for deployment in field hospitals, ambulances, or emergency response situations.

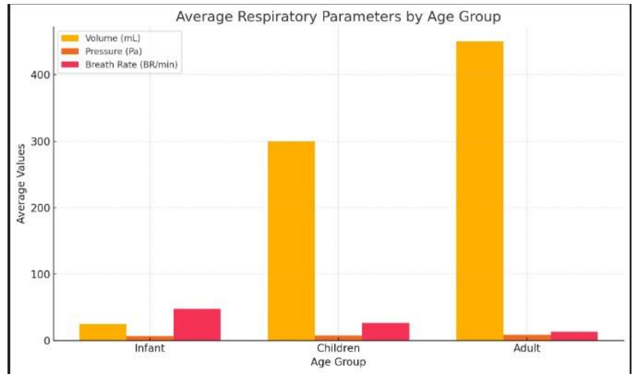
E. Results

We conducted circuit testing across a range of respiratory parameters corresponding to different age groups—infants, children, and adults.

Age group	Volume(ML)	Pressure (Pa)	Breath Rate (BR/Min)
Infant	15-35	3-10	44-51
Children	200-400	5-10	23-30
Adult	350-550	7-10	10-17

Table 1: - Age group parameters

The age group classification is based on the physiological differences that influence lungs function.



Graph of table 1

Respiratory Parameters by Age Group

Infants (0–1 year)

- Volume: 15–35 mL
  Due to their immature respiratory system and small lungs, infants require minimal tidal volume.
- Pressure: 3–10 Pa
  Low pressure is sufficient but must be precisely managed to avoid lung injuries such as barotrauma.
- Breath Rate: 44–51 breaths per minute
  Their breathing rate is significantly high, driven by rapid metabolism and higher oxygen demand.

Children (1–12 years)

- Volume: 200–400 mL
  As the lungs grow with age, they can handle larger volumes of air during each breath.
- Pressure: 5–10 Pa
  A moderate increase in pressure is required to ventilate the expanding lung capacity.
- Breath Rate: 23–30 breaths per minute
  While slower than in infants, the breathing rate remains elevated compared to adults.

Adults (12+ years)

- Volume: 350–550 mL
  Adults reach full lung capacity, though values can differ based on body size and sex.
- Pressure: 7–10 Pa
  A higher pressure range is typically needed to ensure full lung expansion.
- Breath Rate: 10–17 breaths per minute
  Breathing stabilizes at a normal resting rate in healthy adults.

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IV. REFERENCES

Truong, K. H. H. C. T. (2021). Characteristic of paddle squeezing angle and AMBU bag air volume in Bag Valve Mask Ventilator. *Presented at* ICIUS, Vietnam.

Chauhan, R. S. D. (2024). Assessment of the efficacy of an automated AMBU bag operating device. Neurotrauma Conference, India.

Acho, L. (2020). Low-cost open-source mechanical ventilator with pulmonary monitoring for COVID-19 patients. MDPI, Vazquez.

Williams, D. S. R. (2010). A low oxygen consumption pneumatic ventilator for emergency construction. Presented at Euroanaesthesia, Denmark.

Ort, N. H. T. (2021). MIT Emergency-Vent: An automated resuscitator bag for the COVID-19 crisis. IEEE Engineering in Medicine and Biology Society, Massachusetts.