International Journal of Research in Engineering, Science and Management
Volume 8, Issue 4, April 2025
https://www.ijresm.com | ISSN (Online): 2581-5792

Low-Cost Respiratory Aid for Chronic Obstructive Pulmonary Disease (COPD)

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***Abstract*: This paper outlines various studies conducted in the field of respiratory assistance. Human lungs function by a push-pull mechanism during inhalation and exhalation. The DIY respiratory aid designed in this study aims to support individuals during critical times such as the COVID-19 pandemic. It is highly affordable and accessible. This device can be used for patients suffering from lung or breathing disorders, especially in emergency or critical care situations. The core component of the respiratory aid is a Stepper Motor, which is used to compress an Ambu bag (manual resuscitator) to simulate natural breathing. A LED display is integrated to show vital parameters such as the breathing rate and pulse levels. When abnormal breathing patterns or low pulse levels are detected, a buzzer is activated to alert caregivers. Additionally, the system is equipped with a pulse oximeter sensor to monitor blood oxygen saturation and a pressure sensor to measure the exhaled lung pressure, ensuring that the device does not deliver excessive or insufficient air pressure. The respiratory aid is built using Atmega Microcontroller, which serves as the central controller for all components, making the design both reliable and cost-effective. Potential applications include use in rural clinics, emergency response units, home care settings, and temporary field hospitals, particularly when access to commercial ventilators is limited.**

***Keywords*: ATmega microcontroller, respiratory aid, bag valve mask, pneumatic, COVID-19.**

1. Introduction

Human lungs utilize the opposite pressure produced by the compression movement of the diaphragm to draw in air during respiration. An inverse mechanism is employed by a respiratory aid to inflate the lungs through a pumping-type motion. A respiratory aid system should be capable of delivering between 10–30 breaths per minute, with the flexibility to adjust in increments of two. Additionally, it should regulate the air volume delivered to the lungs with each breath. Another important parameter is the ability to control the inhalation-to-exhalation time ratio. Furthermore, the respiratory aid should monitor the patient's blood oxygen level and exhaled lung pressure to prevent over- or under- pressurization. The respiratory aid developed in this work, based on Atmega Microcontroller control, meets these essential requirements to ensure reliable and cost-effective respiratory support during medical crises.

A silicon-based manual resuscitator is actuated using DC motors with a dual-side push mechanism. An electric switch is used for power control, and a variable potentiometer adjusts the breath duration and BPM settings for the patient. The system integrates a blood oxygen sensor and a sensitive pressure sensor to monitor critical patient vitals, which are displayed on a compact screen. An emergency buzzer is incorporated to provide alerts in case of irregularities. The entire system is governed by an ATmega Microcontroller to ensure responsive operation in pandemic and emergency scenarios.

During global health crises such as the COVID-19 pandemic, hospitals and healthcare facilities have reported shortages of essential medical equipment. In such circumstances, engineers and researchers have a responsibility to address these gaps by developing open- source alternative solutions. While under lockdown, innovation remains active. One such critical device is the respiratory aid, which provides mechanical ventilation for patients unable to breathe adequately due to respiratory complications. Although not equivalent to a clinical-grade ventilator, this system serves as a viable substitute with control over essential respiratory parameters.

The design prioritizes affordability, scalability, and ease of deployment, making it suitable for use in remote or under-resourced areas. Future enhancements may include remote monitoring, data logging, and integration with telemedicine platforms to further improve patient outcomes and extend accessibility.

- *Tidal volume*: it is the volume of air delivered to the lungs with each breath by the ventilator - typically 500ml at rest.
- *BPM (Breaths per minute)*: this is often the set rate for delivering breaths. Range is 10-30.
- *Inspiratory*: Expiratory ratio (IE Ratio): refers to the ratio of inspiratory time: and expiratory time.
- *Flow rate*: is that the most flow at which a set tidal volume of breath is deliver by the ventilator
- *Peep (Positive end-expiratory pressure)*: it's the pressure within the lungs above gas pressure that exists at the top of expiration.

2. System Overview

The proposed system is designed to monitor and support the

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breathing of the patient. The setup includes a respiratory aid unit, a BPM (breaths per minute) monitoring circuit, user input switches, and control toggles. The primary objective of this project is to develop a cost-effective respiratory aid using readily available components and implement it in a rapid and practical manner. The hardware implementation involves the construction and testing of a functional prototype capable of delivering controlled respiratory support. The system leverages basic electromechanical components and sensors to ensure regulated airflow, vital sign monitoring, and responsive control mechanisms to aid patients with compromised respiratory function.

3. System Design

The system diagram of the respiratory aid using At mega Microcontroller and integrated blood oxygen sensing is shown in the figure above. Rapid prototyping techniques were employed to develop a functional and efficient medical respiratory aid. The simulated mechanical breathing component is connected to a wall-mounted oxygen source through a flow meter, which acts as an air reservoir. This setup enables controlled delivery of oxygen-enriched air to the patient, while real-time sensing modules monitor key parameters such as blood oxygen saturation and pressure to ensure safe operation. The design prioritizes modularity and scalability for quick deployment in emergency healthcare situations.

4. Software Application

Upon execution, the Arduino runs the embedded program, which initiates the motor to perform a series of controlled clockwise and counterclockwise rotations. This motion simulates the compression and decompression of the resuscitator bag, ensuring that the respiratory aid mechanism operates smoothly and reliably. The software is designed to manage the breathing rate by controlling the motor timing based on user-defined input or preset values. In addition to motor control, the program continuously reads data from the pulse oximeter and pressure sensor to monitor blood oxygen levels and airway pressure in real time. This information is processed and displayed on an LED screen for continuous observation by healthcare personnel. The code also includes safety protocols that trigger a buzzer alarm if abnormal conditions, such as low oxygen levels or overpressure, are detected. User inputs from switches and potentiometers are read and interpreted by the microcontroller to dynamically adjust parameters such as breaths per minute (BPM) and inhalation/exhalation ratio. Overall, the software serves as the central controller, integrating sensor feedback, user control, and actuator operation to provide safe and adaptive respiratory assistance [1].

5. Literature Survey

This text shows the event of a novel IoT-based mechanical ventilator system intended to support COVID-19 patients. The system is capable of collecting real-time data to improve clinical decision-making. It uses sensors and an internet-connected platform to monitor vital parameters and control respiratory assistance accordingly. The integration of IoT allows remote tracking of patient vitals and system status, making it suitable for isolation wards or rural settings. One of the major concerns of this system is the possibility of cybersecurity threats, dependence on stable internet, and risk of malfunctions that may affect patient safety. It also carries the limitation of possible data breaches due to real-time transmission. The study proposes a cloud-based dashboard and remote alert mechanism for improved usability.

M. N. Mohammed, Halim Syamsudin, Mnel A. H. Abdelgnei, (Toward a Novel Design for Mechanical Ventilator System to Support Novel Coronavirus (Covid-19) Infected Patients Using IoT-Based Technology) [1].

This text shows the simulation and validation of a non-invasive mechanical ventilator using MATLAB, where PI and LQR approaches are used to control pressure and volume. The method offers improved accuracy in handling ventilation parameters, providing better stability in the patient's breathing cycles. The study uses control theory to regulate air pressure and flow rate, ensuring optimal gas exchange and patient safety. However, the system requires powerful computing hardware to perform real-time control, and increased system complexity could introduce delays or instability in dynamic conditions. The controller's performance was evaluated through step response, rise time, and settling time analysis, showcasing its potential for real- time deployment.

Sergio Morales, Styven Palomino, Ricardo Terreros, Victor Ulloque, (Pressure and Volume Control of a Non-invasive Mechanical Ventilator: A PI and LQR Approach) [2].

This text shows the development of a low-cost, portable, and automated mechanical ventilator for use in developing countries. The system uses open-source hardware and software to allow for easy replication and affordable deployment. The design prioritizes cost-efficiency and accessibility while maintaining key respiratory features such as tidal volume control and breath rate regulation. Though cost-effective, the device offers limited functionality compared to standard ventilators and may not be suitable for patients in critical respiratory failure. There are also concerns regarding durability and regulatory approval. The prototype was tested for reliability under simulated patient load, and its modularity makes it adaptable for future upgrades.

Saad Pasha, Eesha Tur Razia Babar, Jack Schneider, (A Low-cost, Automated, Portable Mechanical Ventilator for Developing World) [3].

This text shows the design of a portable emergency ventilator based on a bag valve mask (BVM), intended for fast deployment in urgent scenarios. The device is lightweight and easy to transport, making it ideal for emergency and field use. The mechanism operates using a pivoting arm powered by a low-voltage motor to provide manual-like compression to the BVM. Despite its portability, the system is not designed for long-term ventilation and may exhibit inconsistent performance due to its dependency on manual component resupply.

Jozef Zivcak, Michal Kelemen, Ivan Virgala, (A Portable BVM-based Emergency Mechanical Ventilator) [4].

This text shows the implementation of an adaptive control system in mechanical ventilation aimed at improving pressure support. The proposed method reduces the risk of ventilator-induced lung injury by dynamically adjusting the airflow. The system is responsive to real-time patient feedback, modifying the pressure and volume based on current lung compliance and resistance. However, the system relies on high computational capacity and poses challenges in maintaining real-time stability during rapid changes in a patient's condition. The algorithm was implemented using embedded processors and validated in hardware-in-the-loop simulations, showing promising results in adjusting to variable respiratory loads.

Joey Reinders, Bram Hunnekens, Frank Heck, (Adaptive Control for Mechanical Ventilation for Improved Pressure Support) [5].

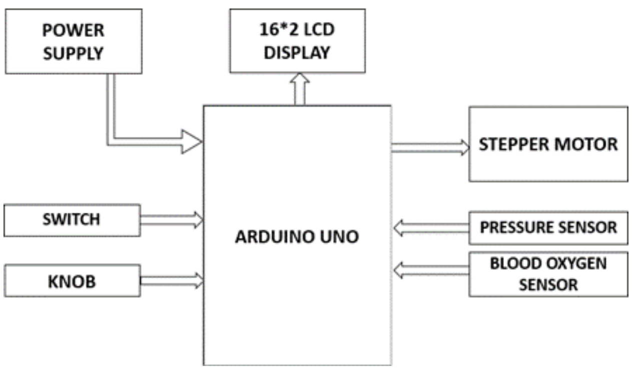

Fig. 1. Block diagram

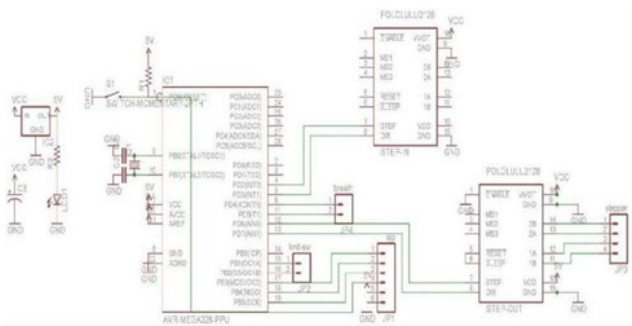

Fig. 2. Circuit diagram

6. Components

A. ATMEGA328P

The ATmega328P is an 8-bit AVR microcontroller used as the core processor in the Arduino Uno. It operates at a clock speed of 16 MHz and features 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM. It supports 23 programmable I/O lines, 6 PWM channels, and a 10-bit ADC with 6 analog input channels. The microcontroller provides reliable performance for embedded applications, low power consumption, and is programmed using the Arduino IDE.

Fig. 3. ATmega328P microcontroller

B. MAX30100 SP02 Sensor

The MAX30100 is an integrated pulse oximetry and heart-rate monitor sensor. It combines two LEDs (red and infrared), a photodetector, optical elements, and low-noise analog signal processing to detect oxygen saturation (SpO_2) and pulse rate. The sensor operates over I²C communication and is suitable for non-invasive patient monitoring. It's compact and power-efficient, making it ideal for wearable and portable health devices.

Fig. 4. MAX30100 SP02 sensor

C. NEMA 23 Stepper Motor

The NEMA 23 is a high-torque stepper motor commonly used in automation and robotics. It provides precise control over angular positioning, ideal for mechanical compression mechanisms in respiratory aids. It typically operates at 2.8V to 3.2V and requires a stepper motor driver for operation. With its rugged structure, it can reliably drive the ambu bag for consistent ventilation cycles.

Fig. 5. NEMA 23 stepper motor

D. LCD Display (20X4)

The LCD display is used to present real-time patient parameters such as oxygen saturation, breath rate, and system status. A standard 16x2 or 20x4 character display is interfaced via a parallel or I2C connection with the Arduino. It operates at 5V and is easily programmable via built-in Arduino libraries. The backlit display ensures visibility in clinical environments.

Fig. 6. LCD display

E. 10K Potentiometer Knob

The 10K potentiometer is a variable resistor used for adjusting parameters such as breath timing and motor speed (BPM control). It is connected to the Arduino's analog input pin and allows dynamic tuning of input values. The knob version provides an intuitive interface for real-time manual control, improving usability for healthcare providers.

Fig. 7. Potentiometer knob

F. HX710B Pressure Sensor

The HX710B is a precision pressure sensor module used to monitor the pressure inside the respiratory system. It provides high-resolution analog-to-digital conversion and supports differential pressure sensing. The module operates at 5V and communicates digitally with the Arduino, helping ensure safe ventilation by detecting overpressure or leakage conditions.

Fig. 8. HX710B pressure sensor

G. Ambu Bag and BiPaP Pipe

The Ambu bag (Artificial Manual Breathing Unit) is a hand-held device used to provide positive pressure ventilation to patients. In this system, it is mechanically compressed using a motorized setup. The BiPAP (Bilevel Positive Airway Pressure) pipe is used to deliver pressurized air from the Ambu bag to the patient's airway. This combination simulates a real-world respiratory support system and forms the core of the mechanical breathing aid.

7. Working

A regulated 5V DC power supply is essential for the operation of core components such as the Arduino microcontroller, the LCD display, and associated sensors. A step-down transformer coupled with a voltage regulator is used to ensure a stable and noise-free 5V DC output. The Arduino serves as the central processing unit of the respiratory aid, handling both control logic and sensor integration. It operates with support from a reset circuit and an onboard oscillator to maintain accurate timing and reliable execution of programmed operations.

The system is equipped with a silicon-based resuscitator (ambu) bag that is mechanically actuated by a dual-sided DC motor-driven compression mechanism. This setup emulates the manual process of ventilation with automated precision. A relay module is used to control the motor operation, while a variable potentiometer allows manual adjustment of breath duration and frequency, effectively setting the BPM (Breaths Per Minute) to suit the patient's condition.

An LCD screen is integrated into the system to provide real-time feedback on critical parameters such as oxygen saturation, breath rate, and airway pressure. The respiratory aid also incorporates a blood oxygen (SpO_2) sensor and a sensitive pressure sensor to continuously monitor the patient’s vitals. These sensors provide essential data inputs to the Arduino for both display and control adjustments.

For enhanced safety, an emergency buzzer system is included to alert healthcare providers in case of abnormal breathing patterns, oxygen level drops, or unsafe pressure conditions. This auditory warning system ensures that anomalies are detected promptly, enabling immediate intervention. The entire unit is designed to be low-cost, portable, and suitable for emergency deployments, particularly during pandemic conditions or in areas with limited access to commercial ventilators.

Overall, this respiratory aid provides a practical, scalable, and efficient solution for temporary respiratory support, combining automation, sensor feedback, and user-adjustable parameters into a single compact system.

8. Results

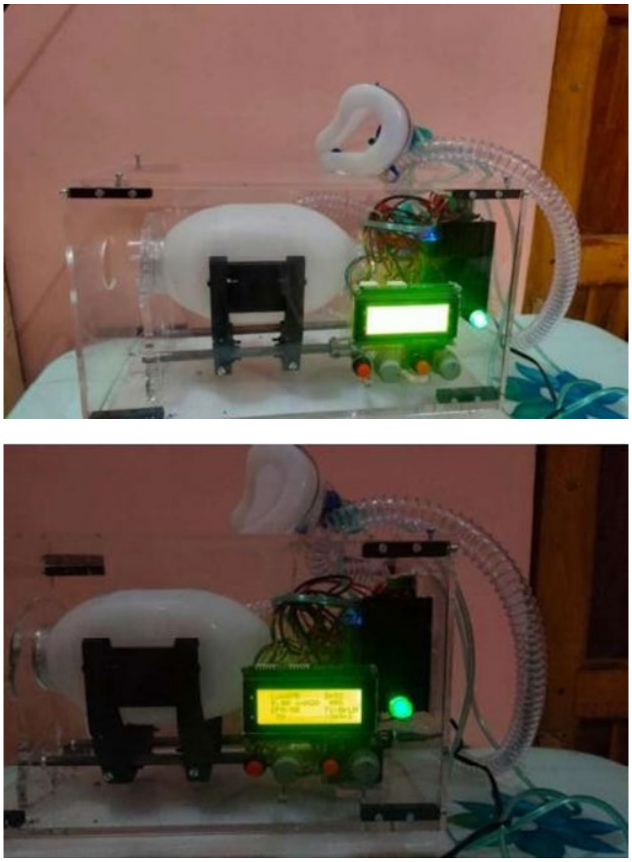

Fig. 9. Hardware setup

9. Conclusion

This work presents a cost-effective solution suitable for emergency situations and the COVID-19 pandemic. It outlines the development of an open-source respiratory aid system designed using distributed manufacturing techniques. The paper provides a detailed explanation of designing and implementing a low-cost, open-source mechanical respiratory support device for patients. While the system is currently in its initial design stages, it shows strong potential for further development and optimization. Future upgrades are required to meet clinical-grade standards. This project can serve as a valuable resource not only during the current global health crisis but also for emergency scenarios and routine use in low-resource environments.

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