Portable Ventilator Using Ambu Bag for Patient Care and Mobility

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ABSTRACT

The global demand for accessible, affordable, and portable respiratory support systems has intensified, especially in emergency and low-resource settings. This project presents the design and development of a compact, portable ventilator that automates a manual resuscitator Ambu bag (Artificial Manual Breathing Unit) to provide life-saving ventilation support for patients in need of respiratory assistance. The system integrates a microcontroller-controlled mechanism to compress the Ambu bag at adjustable rates and volumes, ensuring customizable ventilation according to patient needs. Emphasis is placed on affordability, ease of use, and mobility, making it suitable for use in ambulances, rural clinics, and disaster zones. Key features include battery operation, simple user interface, pressure monitoring, and fail-safe mechanisms to ensure patient safety. The proposed solution bridges the gap between manual ventilation and expensive hospital ventilators, offering a practical alternative for both emergency response and continuous patient care during transport or in remote areas.

Keywords: Ambu Bag, Patient Care, Healthcare.

I. INTRODUCTION

1.1 Overview

A portable ventilator using an Ambu bag is an innovative, low-cost, and compact respiratory support system designed to assist patients who require mechanical ventilation during critical conditions. This type of device is particularly useful in emergency scenarios, patient transportation, rural or resource-limited environments, and even during global health crises such as the COVID-19 pandemic. Unlike traditional, complex, and often expensive hospital ventilators, this design utilizes a standard Ambu bag (Bag-Valve-Mask or BVM), which is mechanically compressed to deliver a consistent supply of air to the patient's lungs.

The core functionality of this system lies in automating the manual process of squeezing the Ambu bag, ensuring consistent and controlled airflow. A key component of this automation is the use of a microcontroller-based system, particularly the Arduino Uno, which serves as the brain of the device. Through precise programming and integration with sensors and actuators, the Arduino Uno controls the rhythm and intensity of the Ambu bag's compression, effectively simulating human intervention with accuracy and reliability.

1.2 Motivation

The outbreak of the COVID-19 pandemic revealed deep vulnerabilities in global healthcare infrastructure, especially in terms of access to life-saving equipment like mechanical ventilators. In many parts of the world, especially in rural or underdeveloped regions, hospitals faced a severe shortage of ventilators. Even when available, their high cost, complex operation, and dependence on trained professionals limited their usage. This posed a life-threatening challenge for patients in need of immediate respiratory support. The Ambu bag, being a simple and widely available tool for manual ventilation, plays a crucial role in emergency respiratory care. However, its operation requires continuous manual effort from medical personnel or caregivers, which is not always feasible particularly for prolonged durations. This situation inspired the development of an automated Ambu bag-based ventilator system using Arduino Uno, which brings together cost-effectiveness, mobility, and automation in a single device.

The Arduino Uno, an open-source, easy-to-program microcontroller, provides a robust and flexible platform for automating medical devices like ventilators. It can be integrated with servo motors, sensors (such as pressure or oxygen sensors), and display modules to monitor and regulate the airflow. This makes it possible to build a user-friendly, customizable solution that can adapt to different patient needs while operating with minimal human supervision. The goal is to empower healthcare workers and save lives, even in the most challenging environments.

1.3 Objectives

The main objectives of this project are as follows:

1. **Affordability**: To develop a cost-effective alternative to traditional mechanical ventilators using readily available components such as the Arduino Uno, servo motors, and basic mechanical parts. This helps ensure the device is accessible to hospitals and clinics in low-income or resource-limited settings.
2. **Emergency Use**: To provide a rapidly deployable, portable ventilation system that can be used during emergencies, natural disasters, pandemics, or mass casualty events where hospital-grade ventilators are either unavailable or insufficient.
3. **Automation Using Arduino Uno**: To eliminate the need for continuous manual operation by automating the compression of the Ambu bag. The Arduino Uno microcontroller is programmed to control a motor-driven mechanical system that mimics the hand-squeezing of the bag at precise intervals and volumes. Parameters such as breath rate, compression strength, and cycle timing can be adjusted as needed for individual patients.
4. **Open-Source and Educational Value**: To encourage innovation and collaboration, the design and Arduino code may be shared as an open-source project. This allows other developers, students, engineers, and healthcare professionals to further improve or adapt the system for different applications.

II. LITERATURE SURVEY

1. Pravin S Yele, Kaustubh B Ahire," *Health Monitoring System with Ventilator Using Arduino*", DOI:10.32628/IJSRST2293154.

This paper refers to the problems faced of shortage of ventilators and comes with a reliable and homemade ventilator which is easy to use. During the pandemic year's like covid 2019 diseases arrived and during this we were out of oxygen ventilators and we lost many lives. To overcome this situation, we built homemade electronic machine using Arduino which works like oxygen ventilator. The ventilator develop here is somehow similar to the ventilator used today at various hospital's ICU, but comes with low cost and are made for only emergency purposes

2. Arnon Jumlongkul," *Automated AMBU Ventilator with Negative Pressure Headbox and Transporting Capsule for COVID-19 Patient Transfer*", DOI: 10.3389/frobt.2020.621580.

It is now clear that the COVID-19 viruses can be transferred via airborne transmission. The objective of this study was to attempt the design and fabrication of an AMBU ventilator with a negative pressure headbox linked to a negative pressure transporting capsule, which could provide a low-cost construction, flexible usage unit, and also airborne prevention that could be manufactured without a high level of technology.

3. Carles Domènech-Mestres, Elena Blanco-Romero*," Design for the Automation of an AMBU Spur II Manual Respirator*", https://doi.org/10.3390/machines9020045.

This article shows the design of a device to automatize an Ambu Spur II manual respirator. The aim of this compassionate medicine device is to provide an emergency alternative to conventional electric respirators which are in much shortage during the present COVID-19 pandemic. To develop the device, the classical method of product design based on concurrent engineering has been employed.

4. Vishal Kumar, Ravinder Kumar," *Recent advances in low-cost, portable automated resuscitator systems to fight COVID-19*", DOI: 10.1007/s12553-021-00629-4.

World is fighting one of its greatest battles against COVID-19 (a highly infectious disease), leading to death of hundreds of thousands of people around the world, with severe patients requiring artificial breathing. To overcome the shortage of ventilators in medical infrastructure, various low-cost, easy to assemble, portable ventilators have been proposed to fight the ongoing pandemic. These mechanical ventilators are made from components that are generally readily available worldwide.

5.Rajeev Chauhan, Summit Bloria, Priya Thappa, Raman Sharma," *Assessment of the Efficacy of an Automated AMBU Bag Operating Device (RC Device) in Patients Requiring Mechanical Ventilation: A Pilot Study*", DOI:10.1055/s-0043-1777675.

Obtaining the goal of high-quality healthcare within a resource-constrained environment is desirable in developing countries, but it is fraught with many challenges. Critical care is still in itsnascent stages in many developing countries, where health care technology is limited and high cost is a major constraint to the availability of ventilators in hospitals.1There is a lack of reliable epidemiological data, and there is a significant disparity in the quality of care across developing countries. In such countries, obtaining a ventilator upon arrival of a patient in an emergency or trauma centre is a true struggle.

III. METHODOLOGY

The methodology behind the design and development of this portable ventilator focuses on creating a life-saving device that is easy to operate, cost-effective, and reliable in emergency situations. This ventilator is intended for short-term use during emergencies such as sudden respiratory failure, transportation of patients, or field situations where access to professional medical equipment is limited. However, when there is a need to use it for longer durations, it is essential that the ventilator be operated under a medical professional's strict guidance and prescription. The system has been designed to simplify user interaction so that even individuals with basic technical understanding can operate it safely in critical moments.

The functionality of the ventilator is centred around essential respiratory parameters such as the patient's breathing rate, oxygen saturation, the balance between inspiration and expiration, and the volume of air delivered per breath. To capture and respond to these variables effectively, we have used the Arduino Uno microcontroller as the brain of the entire system. The Arduino Uno, based on the ATmega328P chip, offers simplicity, programmability, and compatibility with various sensors and motor control modules. Its central role is to read data from the sensors, process the information, and control the mechanical actions required to assist or mimic breathing.

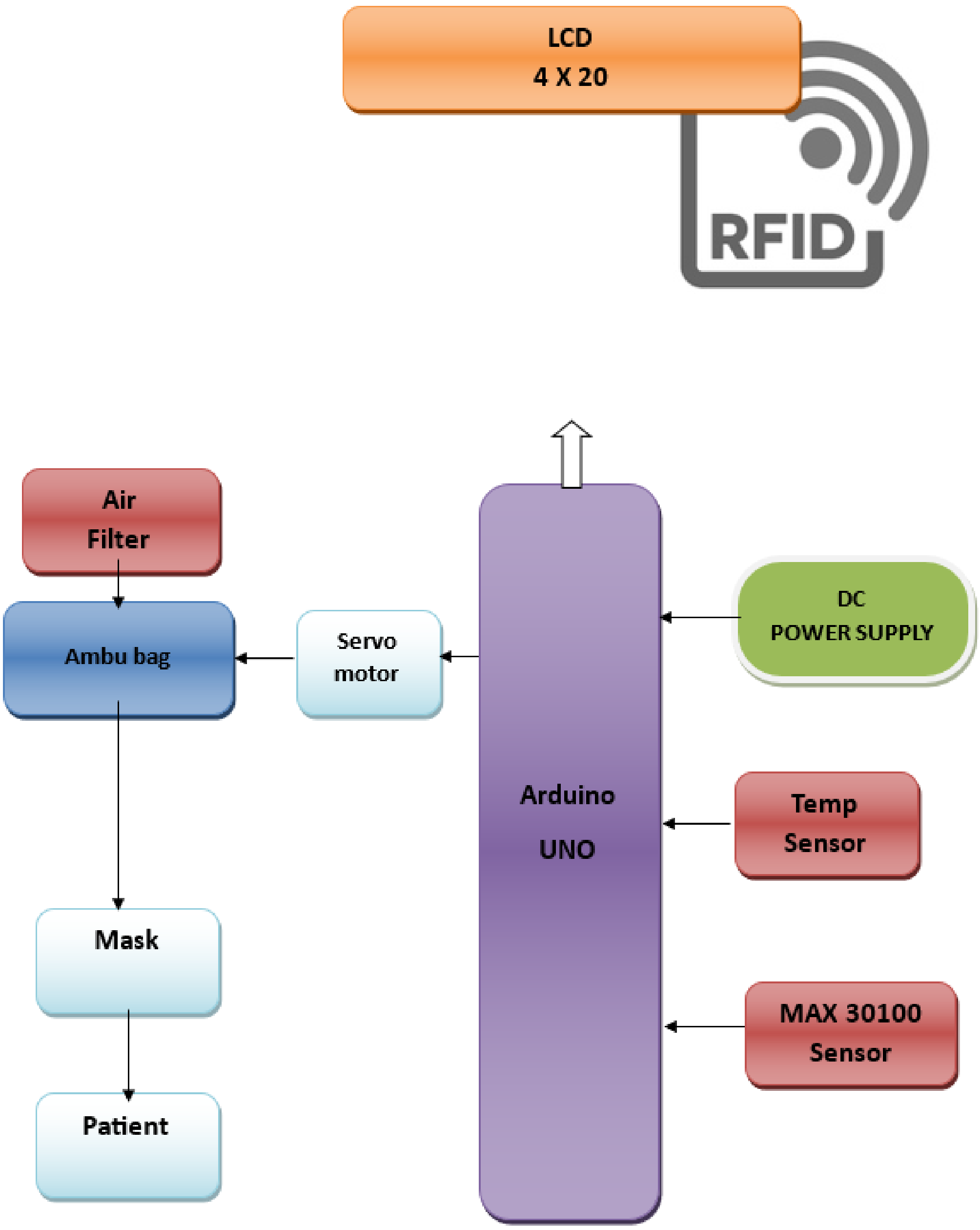
One of the most critical components in monitoring the patient's condition is the MAX30102 sensor, which is capable of measuring both the heart rate (BPM) and oxygen saturation levels (SpO2). This sensor is interfaced with the Arduino Uno using the I2C protocol. The data from this sensor is continuously read by the microcontroller and displayed on a screen to help the operator keep track of the patient's vitals. Moreover, the ventilator's breathing mechanism is designed to be responsive to this sensor data, so that the rhythm of the artificial respiration can be adjusted according to the patient's needs.

The actual air delivery to the patient is managed through the use of a standard Ambu bag, which is compressed and released in a rhythmic cycle to simulate natural breathing. The Arduino Uno controls a motor that compresses the bag using a mechanical lever or pressing mechanism. The timing of the motor—how long it compresses, how fast it moves, and how long it rests between compressions—is controlled through the program uploaded into the Arduino. This program is calibrated to maintain a proper inspiration-to-expiration ratio based on general medical guidelines or as per manual adjustments. To make the system user-friendly, we incorporated a single control knob that adjusts key parameters such as the motor speed and compression rate. This knob is connected to a potentiometer, and its analog values are read by the Arduino Uno to determine how fast or slow the motor should operate. This ensures that even non-technical users can manage basic settings without complex interfaces.

For supplying oxygen-enriched air when needed, the ventilator can be connected to an external oxygen cylinder. The oxygen flow is controlled using a valve, which is manually adjusted in this prototype. However, in future iterations, this valve can be automated and integrated with the Arduino to provide precision control based on patient requirements. The Arduino Uno also allows for the integration of alarms and safety mechanisms. For instance, in case of abnormal BPM or low SpO2 values, the microcontroller can trigger a buzzer to alert the user.

The mechanical frame that holds the Ambu bag, motor, and control system is designed to be sturdy yet compact. Materials such as aluminium and acrylic are used for durability, while the enclosure for electronic components protects the circuits from accidental damage. The Arduino Uno, along with the motor driver circuit and sensors, is safely housed in this enclosure, with a small display mounted externally for easy readability of the patient's real-time health parameters. Powering the device is made flexible by supporting a 12V DC power input, which can be sourced from an adapter, power bank, or battery, making the ventilator truly portable. The low power consumption of the Arduino Uno ensures that the device can operate for extended periods, especially in scenarios where grid power is unavailable.

3.1 BLOCK DIAGRAM:



3.2 WORKING

The proposed system is designed to be **portable and cost-effective**, making it easy to transport and use in various environments. Unlike commercial medical ventilators that are often bulky and expensive, this system offers an affordable alternative for emergency patient care, especially in remote or resource-limited settings.

At the heart of this system lies the **Arduino Uno microcontroller**, which acts as the brain of the entire operation. It is responsible for reading sensor data, processing it, and controlling the servo motor and display modules accordingly. The Arduino Uno operates on a 5V DC power supply and requires three essential components for smooth functioning: a regulated power source, a reset circuit, and an oscillator unit.

The power supply section includes a **step-down transformer**, a **rectifier**, input and output filters, and a **voltage regulator**. The transformer reduces the main AC supply (240V) to a lower voltage, which is then converted into pulsating DC by the bridge rectifier. Capacitors are used for filtering, providing a smooth DC voltage. The **5V DC regulated output** powers the Arduino Uno, LCD display, and various sensors.

Multiple biomedical sensors are interfaced with the Arduino Uno:

- A **temperature sensor** to detect the patient's body temperature,
- A **pressure sensor** to monitor airflow and mask pressure,
- A **heartbeat sensor** to check the patient's pulse rate,
- And a **blood oxygen (SpO2) sensor** to measure oxygen saturation levels.

The Arduino processes this real-time data and displays the vital parameters on an **LCD module**, enabling caregivers to continuously monitor patient health. A **servo motor**, controlled by the Arduino, is used to operate a silicon ventilator bag with a two-sided pushing mechanism. This simulates the breathing cycle by adjusting the airflow based on the patient's needs. To ensure precise control, a **potentiometer** is included to manually adjust the breath rate or BPM (breaths per minute). Additionally, an **emergency buzzer** is integrated into the system to alert caregivers of any abnormalities or critical values detected by the sensors.

3.3 COMPONENTS REQUIRED

1. AMBU BAG: A bag valve mask (BVM), sometimes referred to as an Ambu bag, is a handheld tool that is used to deliver positive pressure ventilation to any subject with insufficient or ineffective breaths used for ventilators. It consists of a self-inflating bag, one way valve, mask, and an oxygen reservoir.

Figure 1.: Ambu bag

2. Arduino UNO: The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

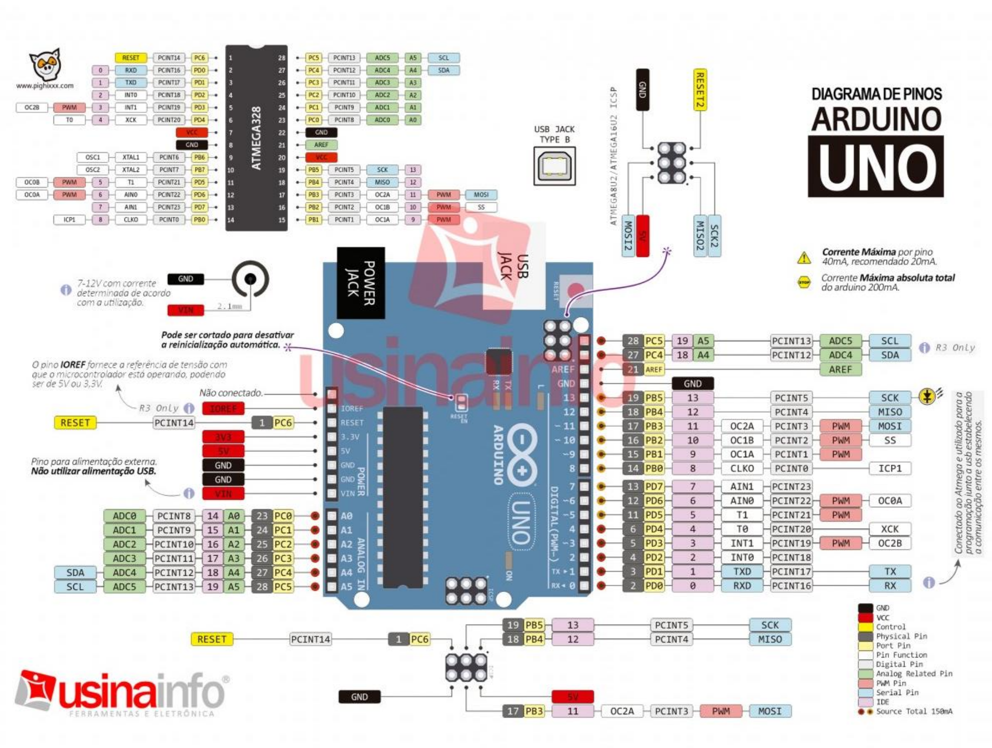


Figure 2.2: Arduino UNO

3. 2 X 16 LCD DISPLAYS: The LCD is much more informative output device than a single LED. The LCD is a display that can easily show characters on its screen. They have a couple of lines to large displays. Some LCDs are specially designed for specific applications to display graphic images. 16×2 LCD (HD44780) module is commonly used. These modules are replacing 7-segments and other multi-segment LEDs. LCD can be easily interfaced with microcontroller to display a message or status of the device. It can be operated in two modes: 4-bit mode and 8-bit mode. This LCD has two registers namely command register and data register. It is having three selection lines and 8 data lines. By connecting the three selection lines and data lines with the microcontroller, the messages can be displayed on LCD.

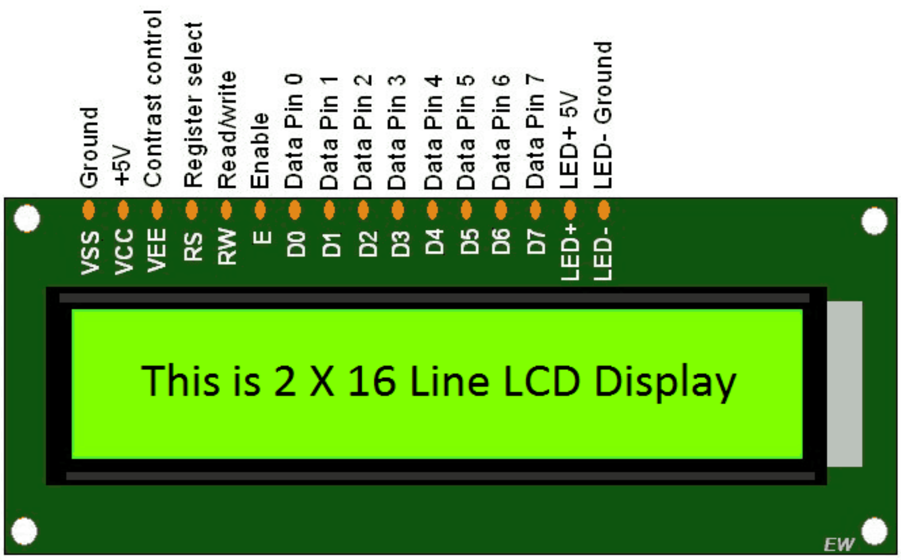


Figure 3: 2x16 Line LCD Display

4.1-Wire Digital Thermometer (DS18B20): Figure shows a block diagram of the DS18S20, and pin descriptions are given in the Pin Description table. The 64-bit ROM stores the device's unique serial code. The scratchpad memory contains the 2-byte temperature register that stores the digital output from the temperature sensor. In addition, the scratchpad provides access to the 1-byte upper and lower alarm trigger registers (TH and TL). The TH and TL registers are non-volatile (EEPROM), so they will retain data when the device is powered down. The DS18S20 uses Maxim's exclusive 1-Wire bus protocol that implements bus communication using one control signal.

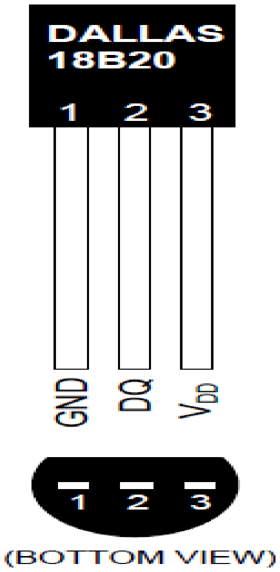


Figure 4: 1-wire digital thermometer (DS18B20)

5.MAX30100 pulse oximeter sensor: In this project we will be Interfacing MAX30100 Pulse Oximeter Sensor with Arduino that can measure Blood Oxygen & Heart Rate and display it on 16x2 LCD Display. The blood Oxygen Concentration termed as SpO2 is measured in Percentage and Heart Beat/Pulse Rate is measured in BPM. The MAX30100 is a Pulse Oximetry and heart rate monitor sensor solution.

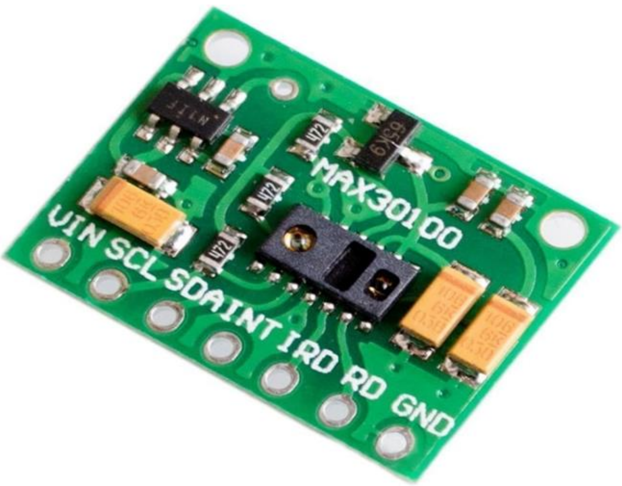


Figure 5: MAX30100 pulse oximeter sensor

III. ADVANTAGES, DISADVANTAGES AND APPLICATIONS

1.1 ADVANTAGES:

- **Low Cost**: Much cheaper than commercial mechanical ventilators, making them accessible in resource-limited settings.
- **Portability:** Lightweight and compact; can be used in ambulances, field hospitals, or during transport.
- **Rapid Deployment:** Can be quickly manufactured and deployed during emergencies (e.g., pandemics or mass casualty events).
- **Simplicity:** Easy to build and operate with minimal training, especially in automated versions.
- **Power Efficiency:** Some versions can operate on battery or manual power, which is useful in areas with unstable electricity.

1.2 DISADVANTAGES:

- **No Feedback Mechanisms:** Most designs do not include sensors or alarms to detect issues like airway blockage or overinflation.
- **Not Approved for Critical Care:** Often not certified for use in intensive care settings, limiting legal and ethical use in hospitals.

1.3 APPLICATIONS:

- **Emergency Response**: Used in disaster zones, accident scenes, or during pandemics when conventional ventilators are unavailable.
- **Low-Resource Healthcare Settings:** Useful in rural hospitals, field clinics, or developing countries with limited access to advanced medical equipment.
- **Temporary Backup Ventilation:** Can serve as a stopgap solution when conventional ventilators are being repaired or are unavailable.
- **Transport Ventilation:** Used in ambulances or during intra-hospital transfers where a compact, portable ventilator is needed.
- **Training and Education:** Helpful for teaching ventilation basics to medical and paramedical students in a cost-effective way.
- **Pandemic or Mass Casualty Events:** Deployed when patient numbers exceed the capacity of traditional ventilators, such as during COVID-19 surges.

V. EXPECTED OUTCOMES

- **Short-Term Life Support**: Maintains oxygenation and ventilation in patients until standard care is available.
- **Increased Access**: Provides basic respiratory support in places or situations where advanced ventilators are unavailable.
- **Reduction in Mortality**: Can help reduce preventable deaths during emergencies or pandemics by offering temporary ventilation.
- **Bridge to Definitive Care**: Keeps patients stable during transport or while waiting for ICU beds or advanced ventilators.

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