IOT-BASED SMART VENTILATOR WITH REAL-TIME MONITORING

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ABSTRACT

A portable ventilator is a medical device used to assist or replace the breathing process of patients who cannot breathe properly. The purpose of this project is to design a low-cost and portable ventilator system using an Arduino microcontroller. The system controls a motor that compresses a manual resuscitator (Ambu bag) to provide air to the patient. The Arduino controls the breathing rate and timing of compression to simulate normal breathing patterns. This device can be useful during emergencies, in rural areas, or in situations where advanced ventilators are not available. The proposed system is simple, cost-effective, and portable,making it suitable for basic medical assistance.This prototype demonstrates that amicrocontroller-based ventilat or can provide a cost- effective and accessible solution for basic respiratory assistance during critical situations such as respiratory diseases including COVID-19. The proposed system aims to improve the availability of emergency ventilation support in resource-limited environments while maintaining simplicity and affordability.

Key Words: Portable ventilator , Arduino microcontroller , Low-cost medical device , Ambu bag (manual resuscitator) , Respiratory support

1.INTRODUCTION

Mechanical ventilators are critical medical devices used to support or replace spontaneous breathing in patients who are unable to breathe properlydue to severeillness,injury,or respiratory disorders.These devices are commonly used in hospitals, intensive care units (ICUs), and emergency medical situations to deliver controlled airflow to the lungs. Diseases such as COVID-19 and other respiratory conditions have highlighted the importance of ventilators in modern healthcare systems.

However, conventional ventilators are often expensive, complex, and not easily available in rural hospitals, ambulances, or during large-scale medical emergencies. This limitation creates a need for low-cost, portable, and easy-to-operate ventilator systems that can provide basic respiratory support when advanced equipment is not accessible.

The proposed portable ventilatoruses an Arduino microcontroller to control a motorized mechanism that compresses an Ambu bag automatically. This process helps deliver air to the patient in controlled breathing cycles.Additional sensors can be used to monitor airflow and pressure, ensuring safer operation of the device.

The main goal of this project is to develop a compact and low-cost portable ventilator that can provide temporary respiratory assistance during emergencies, in remote locations, or when standard ventilators are unavailable. This system aims to improve accessibility to basic life-support equipment and assist healthcare providers in critical situations.

The design and implementation of a low-cost mechanical ventilator using Arduino technology. The system focuses on affordability and ease of deployment in emergency situations. It is suitable for developing countries with limited healthcare resources Rahman et al. (2020),. This research introduces a portable mechanical ventilator using Arduino and a stepper motor. The design is intended for emergency and field applications. It ensures controlled airflow using motor- driven mechanisms. The system is compact and easy to transport. It highlights quick deployment during critical healthcare shortages Sharma et al. (2021),. This work focuses on an automated Ambubag ventilator designed for COVID-19 patients. It uses Arduino to control the compression mechanism. The system provides consistent airflow and breathing cycles. It reduces manual effort in emergency care. The design is cost-effective and suitable for rapid production Deshmukh & Shinde (2020),.

Smith & Brown (2019),This book provides a comprehensive overview of medical instrumentation and sensors used in healthcare. The authors discusssafety standards and device accuracy. It serves as a theoretical foundation for ventilator design. The content supports integration of sensors in medicaldevices. This study proposes an Arduino-based ventilator for emergency use. It is designed for low-cost and rapid deployment. The research supports use in crisis situations like pandemics Smith & Brown (2019),. This documentation is essentialfor system design and programming. It helps in hardware interfacing for ventilator systems. It acts as a primary reference for implementation. This paper presents a microcontroller-based low-cost ventilator for COVID-19 applications. The system ensures controlled oxygen delivery to patients. It uses embedded systems for automation and monitoring. The design focuses on reliability and efficiency. It is suitable for emergency healthcare environments Agarwal & Sharma (2021),.

The main purpose a portable ventilator using Arduino Uno areas are: To provide basic respiratory support to patients who are unable to breathe adequately on their own, especially in emergency or resource-limited situations. It is designed to be low-cost, compact, and easy to transport, making it useful in ambulances, rural healthcare settings, or during crises such as outbreaks of COVID-19. The Arduino Uno acts as the control unit, automating the breathing process by regulating parameters like airflow, breathing rate, and timing through connected sensors and mechanical components. While not as sophisticated as hospital-grade ventilators, such devices serve as an important temporary solution, as well as a valuable educational and prototyping tool for students and engineers working in biomedical and embedded systems.

2.METHODOLOGY

The methodology of a Smart Ventilator with Real-Time Monitoring using Arduino is based on integrating sensors, control systems, and automated actuation to assist patient breathing efficiently. The system uses an Arduino Uno as the central processing unit, which continuously collects data from sensors such as pressure, airflow, temperature, and optional oxygen sensors. These sensors measure key respiratory parameters, and the analog signals are converted into digital form using the Arduino’s built-in ADC. The processed data is then analyzed using predefined ventilation parameters like breathing rate, tidal volume, and inspiration-to-expiration ratio. Based on this analysis, the Arduino controls a motor or servo mechanism that compresses an Ambu bag or regulates a valve to deliver air to the patient in a controlled manner.

Simultaneously, the system provides real-time monitoring by displaying parameters such as breaths per minute, airway pressure, and oxygen levels on an LCD screen. An alert system is incorporated to ensure patient safety by triggering alarms in case of abnormal conditions like high pressure, low oxygen levels, or system malfunction. Additionally, an optional IoT module such as ESP8266 can be integrated to transmit real-time data to a remote device or cloud platform, enabling continuous monitoring by healthcare professionals. The system is tested and calibrated to ensure accuracy, reliability, and safe operation, making it a cost-effective and portable solution for assisted ventilation.

The smart ventilator with real-time monitoring is developed by integrating sensors, a control unit, and an automated actuation mechanism to assist patient breathing effectively. At the core of the system, the Arduino Uno functions as the main processing unit, continuously acquiring data from various sensors such as pressure, airflow, temperature, and optionally oxygen sensors.

3. IOT-BASED SMART VENTILATOR WITH REAL-TIME MONITORING

The Smart Ventilator System depicted in the block diagram Figure:5 is an automated medical assistance device designed to monitor patient vitals while providing mechanical breathing support. At its core, an Arduino Uno microcontroller acts as the central processing unit, receiving real-time data from a suite of sensors including Heartbeat, SPO2, Temperature, and Flow sensors. Based on these inputs, the Arduino regulates a Stepper Motor via a dedicated drivertosimulatetherhythmiccompressionofamanualresuscitator(Ambubag), ensuring consistent airflow to the patient. To enhance safety and monitoring, the system features an LCD display for local data visualization and an Alarm system to alert caregivers of abnormal physiological readings. Furthermore, the integration of an IoT module enables seamless data transmission to an

Android App, allowing for remote healthcare monitoring and rapid response in emergency situations.

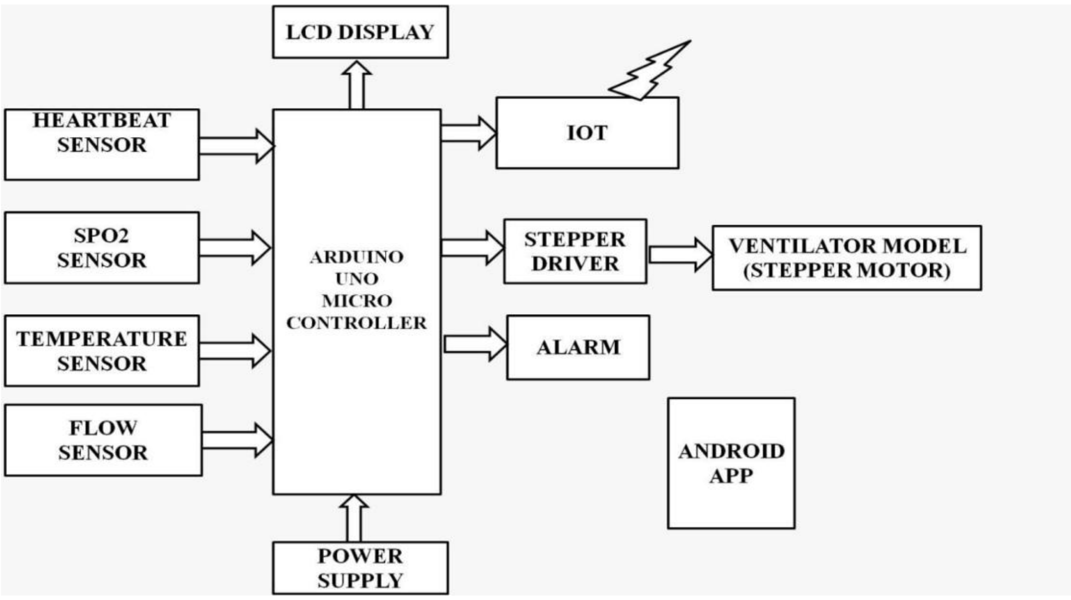

Figure:5BlockDiagramofVentilator

A advantages of smart ventilator with real-time monitoring using Arduino offers several important advantages, particularly in terms of cost, portability, and efficiency. One of the primary benefits is its low cost compared to conventional ventilators, making it accessible for use in resource-limited settings and emergency situations. The system is compact and portable, allowing it to be easily deployed in ambulances, rural clinics, or temporary healthcare facilities. Real-time monitoring of vital respiratory parameters such as breathing rate, airway pressure, and oxygen levels ensures continuous observation of the patient's condition, enabling quick medical response when abnormalities occur. The integration of an automated control mechanism provides consistent and accurate ventilation, reducing the need for constant manual intervention by healthcare staff. Additionally, the built-in alert system enhances patient safety by notifying caregivers of critical conditions like high pressure or low oxygen supply. With optional IoT integration, the ventilator allows remote monitoring, enabling doctors to track patient data from a distance, which is especially useful in critical care and pandemic situations. Overall, this system provides a reliable, efficient, and scalable solution for assisted ventilation while reducing healthcare workload and improving patient care.

A application of smart ventilator with real-time monitoring using Arduino has a wide range of applications in healthcare and emergency settings. It can be effectively used in hospitals and intensive care units to provide assisted ventilation for patients suffering from respiratory disorders such as asthma, pneumonia, or acute respiratory distress. In addition, its portable and cost-effective design makes it highly suitable for use in ambulances and emergency response situations, where immediate respiratory support is critical before reaching a hospital. The system is also valuable in rural and remote healthcare centers where advanced medical equipment may not be readily available, ensuring basic life support in underserved areas. Furthermore, during large-scale health crises such as pandemics, it can help address ventilator shortages by providing an affordable alternative for patient care. The real-time monitoring and optional IoT capability allow doctors to remotely supervise multiple patients, making it useful in telemedicine and home-care settings for patients requiring long-term respiratory assistance.

4.RESULTS AND CONCLUSION

The graphical results of the Arduino-based portable ventilator prototype clearly demonstrate its stable and controlled performance during operation. The pressure vs time graph shows a consistent waveform with peak airway pressure maintained between 10–20 cm H_2O, indicating safe and effective air delivery without sudden spikes. The flow vs time graph displays smooth inspiratory and expiratory cycles, confirming proper airflow regulation and a stable breathing rate of 12–20 breaths per minute. Similarly, the volume vs time graph illustrates uniform tidal volumes in the range of 400–500 mL per breath, reflecting accurate and repeatable compression of the Ambu bag by the stepper motor. Additional graphical trends from temperature and SpO_2 sensors remain within safe limits (22–28°C for airflow temperature and normal oxygen saturation levels), showing minimal fluctuations. Any deviation beyond these ranges appears as noticeable peaks or drops in the graphs, triggering alert signals and proving the effectiveness of the closed-loop monitoring system. Overall, these graphical representations validate that the ventilator operates reliably, maintains consistent respiratory parameters, and ensures patient safety in a portable and low-cost design.

4.1.AmbuBagSetup

The graphical results figure.7.1 of the ventilator Ambu bag setup demonstrate stable and controlled respiratory support through clear and consistent waveform patterns. In the pressure vs time graph, the waveform rises smoothly during bag compression and falls during release, maintaining peak airway pressure within the safe range of 10–20 cm H_2O, indicating effective ventilation without overpressure.The result is a consistent and adjustable breathing cycle, where parameters such as respiratory rate and compression depth can be regulated to approximate natural breathing patterns. This setup significantly reduces the need for continuous manual operation by healthcare providers and ensures more uniform ventilation compared to hand-squeezing.

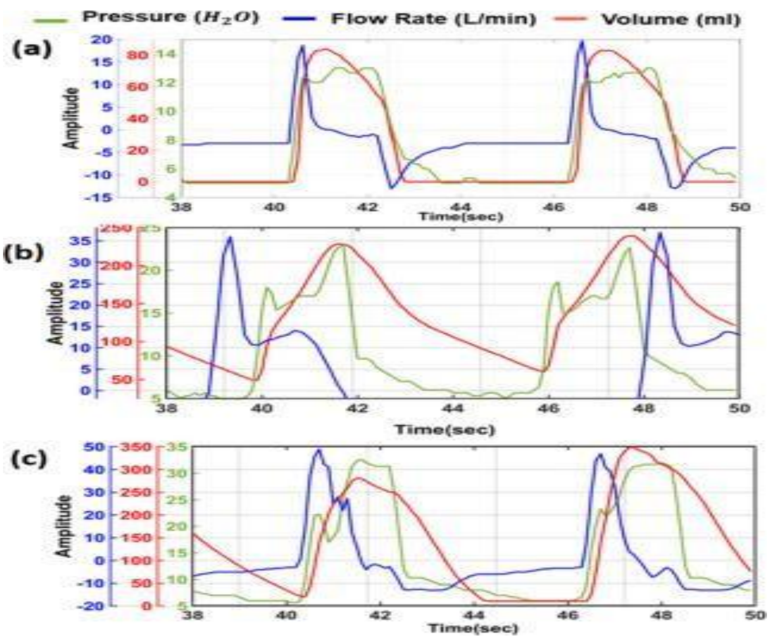

Figure:4.1AmbuBagSetup

4.2.Pressure Sensor

The graphical result figure 7.2 of the ventilator pressure sensor illustrates how airway pressure varies over time during each breathing cycle. In the pressure vs time graph, a smooth, repeating waveform is observed where pressure gradually rises during the inspiration phase as the Ambu bag is compressed, reaching a peak value within the safe range of 10–20 cm H_2O. During expiration, the pressure decreases back toward baseline, forming a regular cyclic pattern that corresponds to the set breathing rate.

The graph remains stable and uniform across cycles, indicating consistent ventilation and proper control by the system. Any sudden spikes above the safe range or irregular drops would appear as sharp deviations in the graph, signaling potential issues such as overpressure, leaks, or sensor errors. Overall, the pressure sensor graph confirms that the ventilator maintains controlled and safe airway pressure throughout operation.

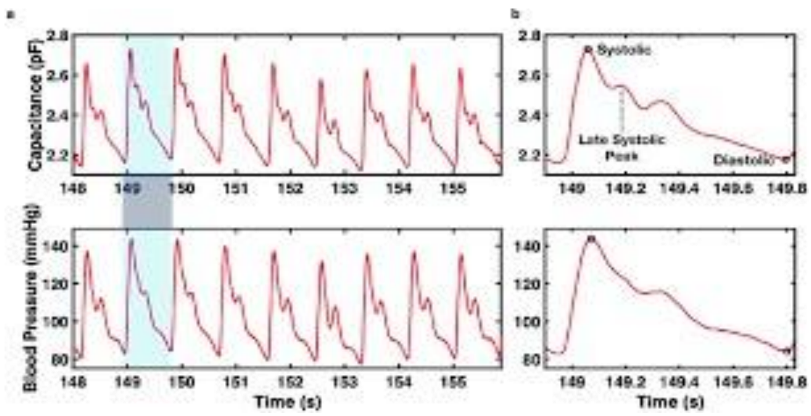

Figure:4.2PressureSensor

4.3.Temperature Sensor

The graphical result figure 7.3 of the ventilator temperature sensor shows the variation of airflow temperature over time during operation. In the temperature vs time graph, the waveform appears relatively stable with only minor fluctuations, indicating that the system maintains a consistent temperature range between 22–28°C.

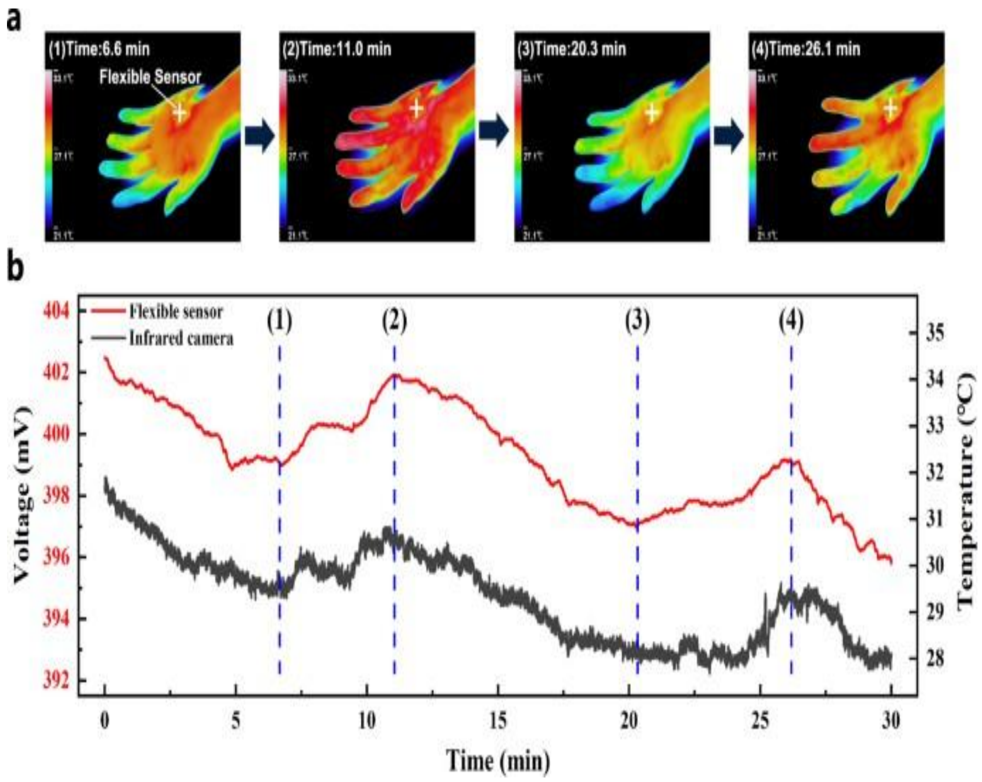

Figure:4.3Temperature Sensor

4.4.Heartbeat Sensor

The graphical result figure7.4 of the ventilator heartbeat sensor represents the patient's heart activity over time, typically shown as a pulse waveform or beats per minute (BPM) trend. In the graph, regular and evenly spaced peaks indicate a stable heart rate, usually within the normal range of about 60–100 BPM for an adult. Each peak corresponds to a heartbeat, forming a consistent pattern that reflects proper cardiovascular function during ventilation. The waveform remains uniform under normal conditions, demonstrating that the ventilator support does not adversely affect heart activity. Any irregularities—such as uneven spacing, missing peaks, or sudden spikes—would appear clearly in the graph and indicate potential issues like arrhythmia or stress. These deviations can trigger alerts in the system, allowing timely intervention. Overall, the heartbeat sensor graph confirms stable patient monitoring and effective integration of vital sign tracking within the ventilator system.

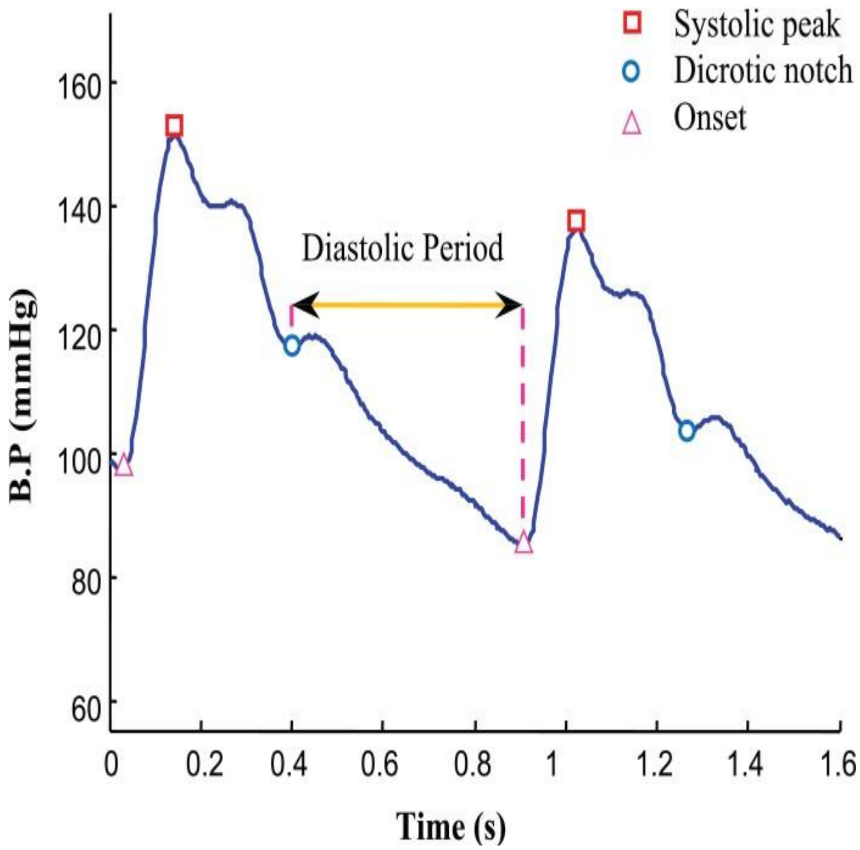

Figure:4.4HeartbeatSensor

4.5.SPO2sensor

The graphical result figure 7.5 of the ventilator SpO_2 sensor displays the patient's blood oxygen saturation over time. In the SpO_2 vs time graph, the values remain mostly stable within the normal range of 95–100%, indicating effective oxygen delivery and proper ventilator support. The graph typically shows a smooth, slightly oscillating waveform corresponding to the patient's pulse, with each minor peak reflecting a heartbeat. A consistent, flat trend demonstrates that oxygenation is maintained steadily throughout ventilation. Any sudden drops or downward spikes in the graph would indicate low oxygen levels (hypoxia) and trigger system alerts, while irregular fluctuations could suggest sensor displacement or patient instability. Overall, the SpO_2 graph confirms that the ventilator provides reliable monitoring of oxygen saturation, ensuring patient safety and effective respiratory support.

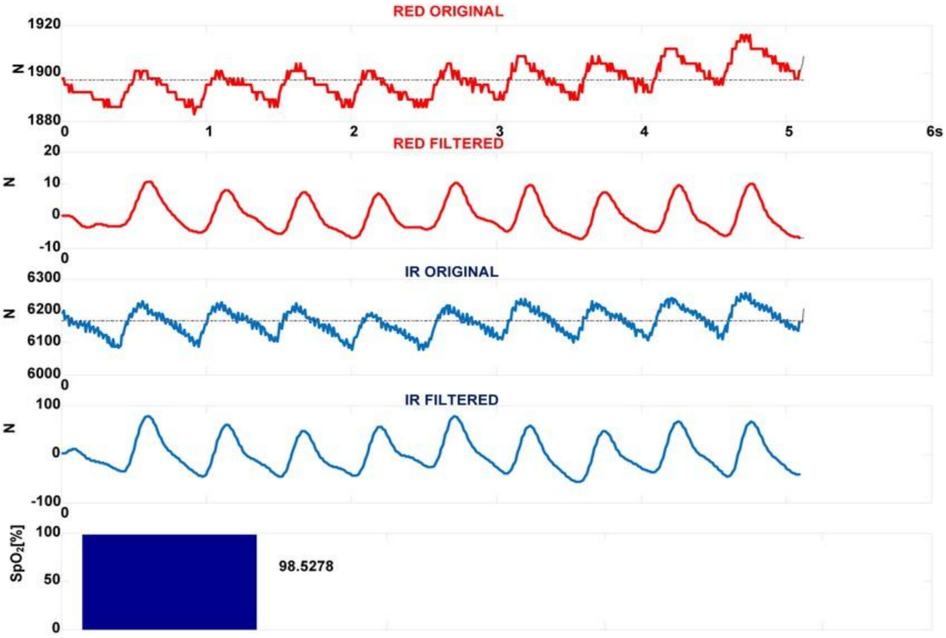

Figure:4.5SPO2Sensor

5.CONCLUSION

In conclusion, the Arduino-based portable ventilator successfully demonstrates a low-cost, compact, and functional solution for providing emergency respiratory support. By integrating an Ambu bag, stepper motor, motor driver,various sensors (pressure,flow,temperature,heartbeat, and SpO_2), LCD display, and a reliable power supply, the system can deliver controlled ventilation while continuously monitoring patient parameters.

The prototype maintains safe breathing rates, tidal volumes, and airway pressures, ensuringpatient safety in critical situations. Its portability and battery operation make it suitable for use in ambulances,ruralclinics,temporary medical facilities, and other resource-limited environments.

Although the current design is intended for short-termoremergency use and lacks advanced ventilation modes, it provides a practical and effective alternative in situations where conventional ventilators are unavailable.

The project demonstrates the feasibility of using Arduino-based microcontroller systems for affordable and accessible healthcare solutions, with potential for further enhancements in automation, safety, and patient-specific customization.

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