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# Design and Development of Internet of Thing Based Ventilator System

**Ankit Haseeja[1],Pratyush Sinha[2],Faiz Beg[3], Varun Saxena[4], and Sovan Mohanty[5]**

Department of Electronics and Communication Engineering, SRMS College of Engineering and Technology, Bareilly, U.P., India.

***Abstract:*** In this paper, we propose the design and development of an Internet of thing based ventilator system. The ultimate vision of IoT is to upscale communication mechanisms with a highly distributed and significantly dense heterogeneous devices network. Recently world is under stress due to the COVID-19 pandemic, which causes severe respiratory distress. Therefore, it is essential to develop low-cost and high-efficiency technologies for real-time health detection and continuous treatment system. The IoT-based ventilator is a low-cost, respiratory monitoring, and controlling system. The designed and developed ventilator delivers breaths by compressing a conventional Ambu bag with the help of a fixed arm connected to a servo motor. It eliminates the need for a human operator for the bag valve mask. Tidal volume and number of breaths per minute are set via user-friendly input modes, which help in customizing the pressure according to the real-time requirements of the patient. It has a safety mode that is when the power supply goes down; the backup battery automatically kicks in. A built-in alerts system is embedded to activate and warn the local and the remote locations about any malfunctioning for immediate attention.

***Index Terms*** **- Internet of thing,health care,real time patient monitoring,ventilator, ambu bag,big valve mask.**

## I. INTRODUCTION

The last few years have seen exponential growth in wireless communication technologies with the emergence of 5G, artificial intelligence, robotics, cloud computing, wireless sensor networks, and radiofrequency and microwave devices [1]. These technologies have an enormous impact on the medical and health care industries. 'Health is the ultimate wealth'. Therefore, humanity must develop low-cost, smart services in health care such as remote health monitoring systems, elderly care, treatment of chronic diseases, various fitness and health awareness program, etc. Communication and information technologies can alter the dimension of health care industries by bringing low latency, enhanced and fast services, location awareness, notification services, etc.

A ventilator is a machine that provides mechanical ventilation by moving breathable air into and out of the lung, to deliver breaths to a patient who is physically unable to breathe or breathing insufficiently [2]. Modern ventilators are expensive. These ventilators are so expensive that for a country of 1.3 billion people there were only 47,000 ventilators. A few of the available ventilators are working overtime and are very susceptible to malfunction. Most of the government hospitals have very low budgets so they cannot be equipped with a ventilator. They have a very high maintenance cost. These machines look very small but are very expensive. And if they are not maintained properly, they can be more of a death sentence than a lifesaver. Most of the ambulances are not equipped with ventilators. Even they are so expensive that developed countries like the USA and UK are facing a shortage. Ventilators are chiefly used in intensive care medicine, home care, and emergency medicine (as standalone units), and in anesthesiology. Children and adults may need a medical ventilator for a short time while recovering from an illness or other issue.

There are numerous applications of the ventilator in the treatment process. During surgery, a ventilator can temporarily do the breathing for the patient while the patient is under general anesthesia. While recovering from surgery ventilator is required to breathe for hours or even days after surgery. So a ventilator can help to pump up air for ease in breathing if breathing is difficult or impossible due to infection.

The history of mechanical ventilation begins with various versions of what was eventually called the iron lung, a form of non-invasive negative-pressure ventilator widely used during the polio epidemics of the twentieth century after the introduction of the "Drinker respirator" in 1928. Most recently, Covid-19 saw a widespread that it has been categorized as a pandemic, and India is the second most affected county in the world. The COVID-19 pandemic has cast a spotlight on ventilators but is in acute shortage mainly due to the cost of it. Not everyone can afford it.

With the current times, we need a safe and inexpensive alternative to handle a respiratory emergency. The key to designing a simple and inexpensive ventilator. It is an alternative to a hand-operated plastic pouch called a bag-valve resuscitator, or Ambu bag. Every hospital has in its inventory in large quantities. It is a hand-on device that means to be operated by hand, by a medical professional or emergency technician. It is to provide continuous breaths to a patient in situations like cardiac arrest until an intervention such as a ventilator becomes available. The pumping of air into the lung is done by squeezing and releasing the flexible pouch [3]. This is a task of a skilled person, trained in how to evaluate the patient, and adjust the timing and pressure of the pumping accordingly. Since this is not something that a person could be expected to do for an extended period. However, it is crucial for such a system not to damage the bag and to be controllable so that the amount of air and pressures being delivered can be tailored to the particular patient.

In this paper, we present the design and development of an IoT-based ventilator system. It delivers air to breathe by compressing a conventional Ambu bag with the help of a fixed arm connected to a servo motor. Tidal volume and number of breaths per minute are set via user-friendly input modes. It regulates the temperature and the input pressure can be customized according to the real-time requirements of the patient. The safety mode initiates the backup mechanism without any delay. A built-in alerts system warns during an emergency. This system will improve the quality of life by saving time and resources.

The design methodology is explained in Section II followed up by the hardware requirements in Section III. Result analyses are presented in Section IV. At the end, conclusions are given in Section V.

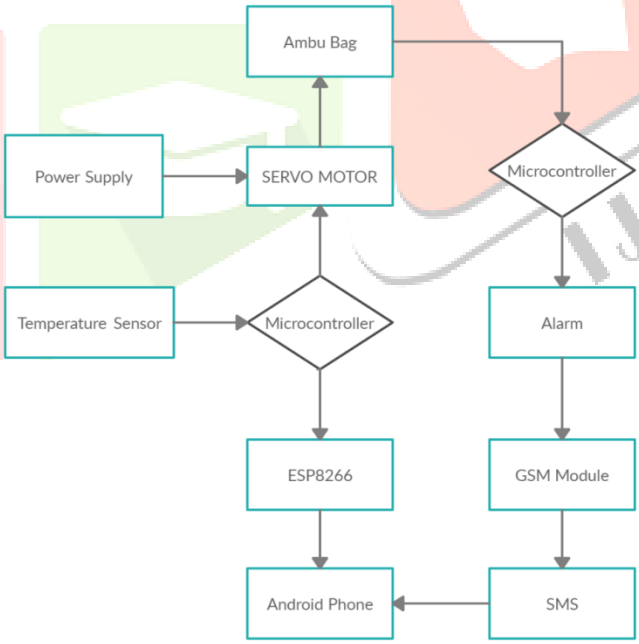


**Fig.1. Fundamental block diagram of the IoT based ventilator system**

## II. DESIGN METHODOLOGY AND ANALYSIS

Two main areas are concentrated for the ventilator's air releasing system. The first technique uses a constant pressure source to release the air continuously. The other method is to release air by compressing an Ambu bag which acts as a simplified air reservoir. The second method reduces the power requirements and eliminates the need for expensive and difficult repairing of the pneumatic components [4].

Where most emergency and portable ventilators are designed with all custom mechanical components, this design takes an orthogonal approach by building on the inexpensive Ambu bag, an existing technology that is the simplest embodiment of a volume-displacement ventilator. Due to the simplicity of their design and their production in large volumes, BVMs are very inexpensive and are frequently used in hospitals and ambulances. They are also readily available in developing countries. Equipped with an air reservoir and a complete valve system, they inherently provide the basic needs required for a ventilator. The main drawback with BVMs is their manual operation requiring continuous operator engagement to hold the mask on the patient and squeeze the bag [5]. This operating procedure induces fatigue during long operations and effectively limits the usefulness of these bags to temporary relief. Moreover, an untrained operator can easily damage a patient's lungs by over-compression of the bag. Our methodology, therefore, was to design a mechanical device to actuate the Ambu bag. This approach results in an inexpensive machine providing the basic functionality required by mechanical ventilator standards [6].

Fig. 1. shows the fundamental block diagram of the IoT-based ventilator system. The ATmega microcontroller is powered by a 9V battery. It controls the servo motor which eventually controls the Ambu bag to release the desired air pressure as required by the patient. A feedback system constituted by the temperature sensor DHT 11 controls the input data to the microcontroller. Further, a wireless network is accomplished by ESP 8266 microchip, which provides the ventilator status information to the outside world. Actuating the BVM is similar to the hand motion for which the bag was designed and it is being determined by the rpm of the servo motor. There are three modes for frequency and three modes for volume. These are not fixed and can be changed while file tuning the ventilator. The modes can be used to change the volume and frequency of the ventilator as required [7]. When the modes have pressed the speed and volume are decided by the pre-defined parameters and it sends signals according to that to the servo motors. ESP 8266 module is used with the temperature sensor DHT 11 which senses the temperature from our hand and sends it to ESP 8266 which transmits the data to the Blynk IoT platform which shows the data on our phone [8]. A buzzer is installed in the system so that whenever the power goes down, It automatically sounds to alert the attendant that the power supply is down and the ventilator has stopped working and urgent attention is required. It is powered by a portable battery which is installed in the device to power the buzzer.

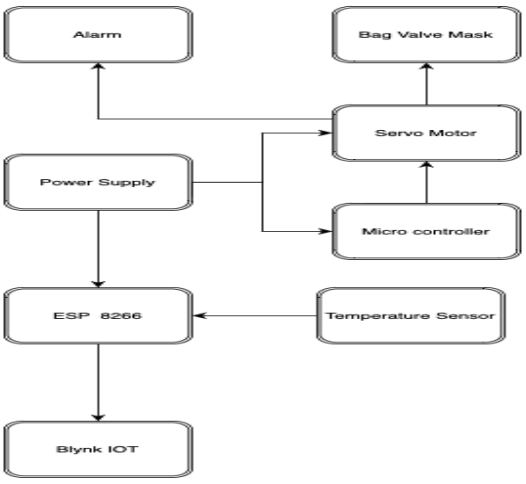


**Fig.2. Modified block diagram of the IoT based ventilator system**

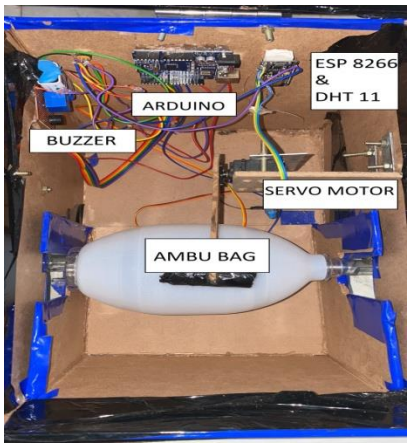


**Fig.3. Top view of the developed prototype of the ventilator system**

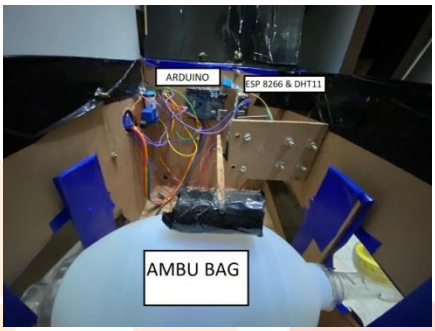


**Fig.4. Side view of the developed prototype of the ventilator system**


**Fig.5. Setting up various modes of the developed prototype**

**Table 1: Time difference and tidal volume for different set**

| SET | SET 1 | SET 2 | SET 3 | SET 4 | SET 5 | SET 6 |
|---|---|---|---|---|---|---|
| Time Difference | 17 | 16 | 15 | 14 | 13 | 12 |
| Tidal Volume | 350 | 375 | 400 | 425 | 450 | 500 |

## III. HARDWARE REQUIREMENTS

This design uses following hardware:

i. Arduino UNO
ii. ESP 8266
iii. Servo Motor
iv. Temperature Sensor
v. Power Supply
vi. Bag Valve Mask

### 3.1 Arduino UNO

The **Arduino Uno** is an open-source microcontroller board based on the Microchip ATmega 328P microcontroller and developed by Arduino. cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be an interface to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE ), via a type B USB cable. It can be powered by a USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is similar to the Arduino Nano and Leonardo.

### 3.2 ESP8266

The ESP8266 is a low-cost Wi-Fi microchip, with a full TCP/IP stack and microcontroller capability, produced by Espressif Systems in Shanghai, China.The chip first came to the attention of Western makers in August 2014 with the ESP-01 module, made by a third-party manufacturer Ai-Thinker. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands. However, at first, there was almost no English-language documentation on the chip and the commands it accepted. The very low price and the fact that there were very few external components on the module, which suggested that it could eventually be very inexpensive in volume, attracted many hackers to explore the module, the chip, and the software on it, as well as to translate the Chinese documentation.The ESP8285 is an ESP8266 with 1 MiB of built-in flash, allowing the building of single-chip devices capable of connecting to Wi-Fi.

### 3.3 Servo Motor

A servo motor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity, and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor, although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system. Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

### 3.4 Temperature Sensor

A temperature sensor is an electronic device that measures the temperature of its environment and converts the input data into electronic data to record monitor or signal temperature changes. There are many different types of temperature sensors. Some temperature sensors require direct contact with the physical object that is being monitored (contact temperature sensors), while others indirectly measure the temperature of an object (non-contact temperature sensors).

### 3.5 Power Supply

An AC/DC converter can be used to power the ventilator directly from a wall outlet or a vehicle inverter. When external power is unavailable, the ventilator can run off of any battery capable of delivering 12-15 volt at least 3.5 Amps. For the prototype, we used a 14.8 volt, four-cell Li-Ion battery pack capable of 4.2 Amps (limited by protective circuitry), with a capacity of 2200 mA-hr.

### 3.6 Bag Valve Mask

A bag valve mask (BVM), sometimes known by the proprietary name Ambu bag or generically as a manual resuscitator or "self-inflating bag", is a hand-held device commonly used to provide positive pressure ventilation to patients who are not breathing or not breathing adequately. The device is a required part of resuscitation kits for trained professionals in out-of-hospital settings (such as ambulance crews) and is also

frequently used in hospitals as part of standard equipment found on a crash cart, in emergency rooms, or other critical care settings.

## IV. CONCLUSION

In this paper, a working prototype of IoT based ventilator is designed and developed. The prototype has a user-controlled breath rate and tidal volume. The Arduino along with suitable algorithm controls the motor speed and instructs the motor about the directions of rotation. It will set the proper compressions and expansions of the bag. The compression frequency and the tidal volume both are decided by the pre-decided modes with the help of which a user can customize the flow of air according to the patient. Based on efficiency, cost, mean time between failure, and affordability this system will improve the quality of life by saving time, money, and resources. The number of variables in the feedback system can be increased to make the system more effective in handling active cases in the real-time system.

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