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Ventilator Using Arduino with Blood Oxygen Sensor for Covid19

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Abstract: This paper describes the design and prototyping of a low-cost portable mechanical ventilator for use in mass casualty cases and resource-poor environments. The ventilator delivers breaths by compressing a conventional ambu bag with a pivoting cam arm, eliminating the need for a human operator for the ambu bag. An initial prototype is driven by an electric motor powered by a 12 VDC battery and features an adjustable tidal volume up to a maximum of 750 ml. Tidal volume and number of breaths per minute are set as per the default conditions. Future iterations of the device will include a controllable inspiration to expiration time ratio, a pressure relief valve, an LCD screen and an alarm to indicate over pressurization of the system. Through this prototype, the strategy of automated ambu bag compression is proven to be a viable option to achieve low-cost, low-power portable ventilator technology that provides essential ventilator features at a fraction of the cost of existing technology.
Keywords: Ambu Bag, Arduino, Blood Oxygen Sensor, Low-Cost, Low-Power, Portable and Automatic

I. INTRODUCTION

Total 1,769 ventilators in Our State, which means an average of one ventilator available for every 93,273 persons. The most pressing shortages facing hospitals during the COVID-19 emergency is a lack of ventilators. These machines can keep patients breathing when they no longer can on their own and they can cost around **$30,000** each. Design and development of a low-cost portable ventilator could be a possible way, that can help pneumonia cases of COVID-19 patient in Our State.

Respiratory diseases and injury-induced respiratory failure constitute a major public health problem in both developed and less developed countries. Asthma, chronic obstructive pulmonary disease and other chronic respiratory conditions are widespread. These conditions are exacerbated by air pollution, smoking, and burning of biomass for fuel, all of which are on the rise in developing countries[1,2] Patients with underlying lung disease may develop respiratory failure under a variety of challenges and can be supported mechanical ventilation. Additionally, these ventilators are often fragile and vulnerable during continued use, requiring costly service contracts from the manufacturer.

One example of this shortage occurred during Hurricane Katrina, when there were insufficient numbers of ventilators and personnel were forced to resort to manual BVM ventilation Measures to improve preparedness have since been enacted; most notably the Center for Disease Control and Prevention (CDC) recently purchased 4,500 portable emergency ventilators for the strategic national stockpile. However, considering the low number of stocked ventilators and their currently high cost, there is a need for an inexpensive portable ventilator for which production can be scaled up on demand.

II. METHODS AND MATERIAL

1. EXISTING SYSTEM

A. TRADITIONAL VENTILATOR SYSTEM:

The main drawback with the regular ambu bag is their manual operation requiring continuous operator engagement to hold the mask on the patient and squeeze the bag. 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.

2. PROPOSED SYSTEM

To overcome the challenges faced by the existing systems, two main strategies were identified for the ventilator's air delivery system. One strategy uses a constant pressure source to intermittently deliver air while the other delivers breaths by compressing an air reservoir. The latter approach was adopted as it eliminates the need for the continuous operation of a positive pressure source. This reduces power requirements and the need for expensive and difficult to repair pneumatic components.

Where most emergency and portable ventilators are designed with all custom mechanical components, we chose to take an orthogonal approach by building on the inexpensive BVM, an existing technology which is the simplest embodiment of a volume-displacement ventilator. Due to the simplicity of their design and their production in large volumes, ambu bags are very inexpensive (approximately $10) 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.

A. HARDWARE

Components used are as follows:

i. Arduino Uno

The Arduino Uno is a ATmega328 based microcontroller. It features 14 digital I/O pins, among which 6 can be used as PWM outputs, the rest of the pins include 6 analog inputs, a 16MHZ crystal oscillator pin, power jack point, USB connection port, an ISCP header pin, and a reset button. It can be powered either by using a USB cable or with an AC- to -DC adapter or a battery. Though this board can accept voltages between 7 to 20 V, its operating voltage is 5V. This board can be programmed using an open-source software tool Arduino IDE. It has 32 KB of memory which is used for the bootloader, 2 KB of SRAM, and 1 KB of EEPROM.

Figure 1: Arduino Uno

ii. Pressure Sensor

A pressure sensor is a device for pressure measurement of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed. Pressure sensors are used for control and monitoring in thousands of everyday applications.

Pressure sensors can be classified in terms of pressure ranges they measure, temperature ranges of operation, and most importantly the type of pressure they measure. Pressure sensors are variously named according to their purpose, but the same technology may be used under different names.

Figure 2: Pressure Sensor

iii. 16x2 LCD Module

LCD stands for Liquid Crystal Display. The LCD screen is an alphanumeric electronic display and it has various applications in different fields. This display is a very basic module and is most commonly used in devices and circuits. A 16 x 2 LCD means it can be used to display a maximum of 16 characters per line, and there are two such lines. Each character in this LCD is displayed in a 5x7 pixel matrix format. The alphanumeric display is capable to display 224 various characters and symbols in two modes like 4-bit and 8-bit. It consists of 16 pins. This can be operated between 4.7 V to 5.3 V [7].

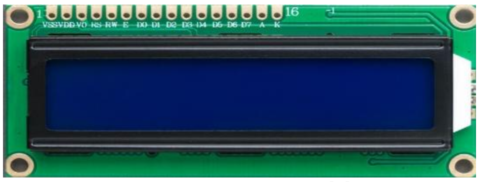

Figure 3: 16x2 LCD Module

iv.Stepper Motor

A stepper motor is an electro-mechanical device it converts electrical power into mechanical power. Also, it is a brush-less, synchronous electric motor that can divide a full rotation into an expansive number of steps. The motor's position can be controlled accurately without any feedback mechanism, as long as the motor is carefully sized to the application. Stepper motors are similar to switched reluctance motors. The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided. The stator has eight poles, and the rotor has six poles. The rotor will require 24 pulses of electricity to move the 24 steps to make one complete revolution. Another way to say this is that the rotor will move precisely 15° for each pulse of electricity that the motor receives.

Figure 4: Stepper Motor

V. Ambu Bag

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.

Figure 5: Ambu Bag

B. SOFTWARE

The software used is Arduino IDE. The Arduino IDE (Integrated Development Environment) is open-source software and a cross-platform application that is written in the programming language Java. It is useful in writing and uploading programs to Arduino Compatible Boards. The Arduino IDE software supports c and c++ languages by following the special rules for code structuring. It can be implemented within the Windows, Mac, and Linux operating systems.

The components are mainly written in JavaScript for easy editing and compiling. The main advantage of using this software is writing codes for Arduino. But several other features are worth noting. The software is equipped with a means to share any details easily with other stakeholders of the project. The internal layouts and schematics can be easily modified by the user when required. Some guides are helpful during the process of installation.

Figure 6: Arduino IDE

Vi. Blood Oxygen Sensor

Small beams of light pass through the blood in the finger, measuring the amount of oxygen. It does this by measuring changes of light absorption in oxygenated or deoxygenated blood. This is a painless process. In medical situations, blood oxygen monitoring can be critical. SpO2 is an important metric for monitoring patients afflicted with respiratory illnesses like sleep apnea, emphysema, COPD, or Covid-19.

Figure 7: Blood Oxygen Sensor

III. WORKING

An IoT based motor drive of clockwise and counter clockwise will provide the required motion for the arm movement to maintain an automatic air flow with a controlled pressure rate. The figure shows the working process of this proposed automatic ventilation machine.

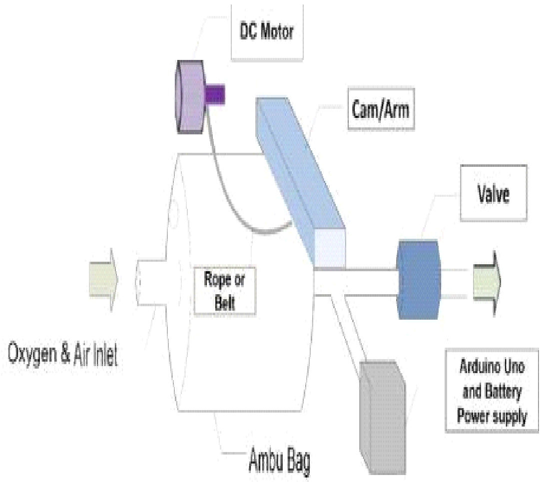

Figure 8: Working Process of Setup

An actuator requires a control signal and a source of energy. The control signal is relatively low energy and may be electric voltage or current, pneumatic, or hydraulic fluid pressure, or even human power. Its main energy source may be an electric current, hydraulic pressure, or pneumatic pressure. When it receives a control signal, an actuator responds by converting the source's energy into mechanical motion. In the electric, hydraulic, and pneumatic sense, it is a form of automation or automatic control.

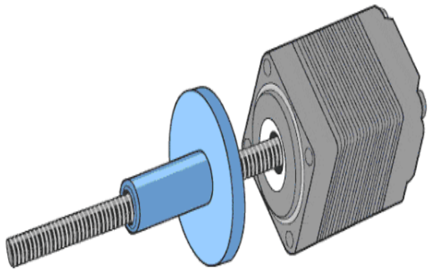

Figure 9: Actuation Mechanism

Control over ventilation parameters can be achieved by varying;
No. of rotations (stroke) ----> Tidal volume

- Speed of rotation----->Flow rate
- Steps in clockwise :steps in anti-clockwise direction--->IE Ratio
- Frequency of direction change per minute---->BPM

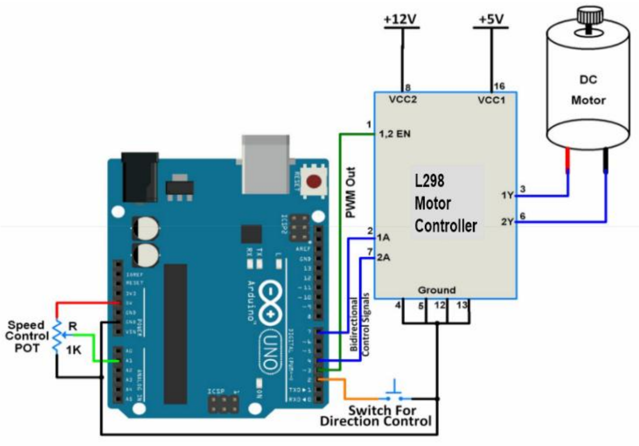

Figure 10: Circuit Diagram

The connections presented by the unit to external input/outputs will follow hospital standards. The supply pressure is reduced by a pressure regulator to approximately 200mbar. The system concept is based around a buffer volume (ambulatory bag) of approximately 1.6liters. The filling of this buffer is controlled by the input valve (valve in). By controlling of the opening time, one can achieve the desired target pressure in the buffer after which the valve (valve in) is shut. This buffer filling occurs during the respiratory part of the breath cycle. If the buffer pressure is within tolerance of the required pressure, the output valve (valve out) is then opened, initiating the respiratory cycle. The respiratory rate, inspiratory time (corresponding to the open time of valve out) and pause time are all controllable.

If a PEEP pressure is set, then the pressure in the lungs will have the minimum of the PEEP pressure. In the case where the tidal volume is not achieved at a particular pressure setting, due to changes in the patient's airway resistance this can then be gradually adjusted. SIMV mode will allow the patient to take spontaneous breaths, and will assist the breathing when the spontaneous breath is taken.

1. Design Considerations:

A set of mechanical, medical, economic, user interface and repeatability functional requirements were developed. These include the ASTM F920-93 standard requirements[9], and are summarized in Table 1.

Medical	- User-specified breath/min - insp./exp ratio, tidal volume - Assist control Positive end-expiratory pressure (PEEP)

	- Maximum pressure limiting - Humidity exchange - Infection control - Limited dead-space
Mechanical	- Portable - Standalone operation Robust - mechanical, electrical and software systems - Readily sourced and repairable parts - Minimal power requirement - Battery-powered
Economic	- Low-cost (<$500)
User interface	- Alarms for loss of power, loss of breathing circuit integrity, high airway pressure and low battery life - Display of settings and status - Standard connection ports
Repeatability	- Indicators within 10% of correct reading - Breath frequency accurate to one breath per minute

IV. RESULT

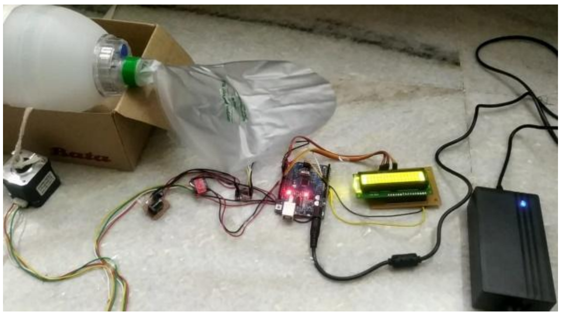

Figure 11: Prototype of the project

Figure 11: Prototype of Project

V. CONCLUSION

This paper proposes, **"Ventilator using Arduino with blood oxygen sensor for covid19"**, which automizes the manual operation of the ambu bag. There is a great advancement in technology due to its features like low cost and ease of use. In addition, this system reduces the manpower in the hospitals. The mistakes done by nurses and doctors while performing the manual operation can be reduced using this system. A Menu can be updated every time based on the availability of food present in the kitchen. This is an effective system to improve the performance of medical system. Finally, we can conclude that this system will work perfectly and efficiently by solving all issues faced by doctors and patients.

VI. FUTURE SCOPE

Designed and developed a prototype of automatic ventilator to support pneumonia cases for COVID-19 patients. It has a controlled breath rate of 12 RR/min and 500-600mL tidal volume. It features assist control and provide a constant air flow to the lungs. Power requirement is very low and running for 3.5 hours on one battery charge at its most demanding setting. Battery backup also need to be checked. It is low cost, portable, light weight and able to run 2 DC motors at the same time. Further development includes pressure sensor, air flow meter, over pressure alarm another safety features to make it more user friendly.

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