Low Cost Portable Ventilator[1]

Prof. Trima P. Fernandes e Fizardo, Prof. Anisha Cotta, Jane Fernanades, Myola Dias, Skylia Estibeiro

Department of Electronics and Telecommunication,
Don Bosco College of Engineering, Fatorda-Goa

DOI:10.37648/ijrst.v13i01.002

Received: 21 November 2022; Accepted: 13 January 2023; Published: 14 January 2023

ABSTRACT

The COVID-19 pandemic has produced critical shortages of ventilators worldwide. This aim of this paper is to build mechanical ventilators with low cost. This project is based on the development and validation of a simple, portable and low-cost ventilator which overcome few limitations offered by the mechanical ventilators. This device is very simple to operate so any less experienced person will be able to operate with ease. Designing portable, solar powered and rechargeable battery operated Ambu bag compressing machine, which sends real time cloud messages to the doctors and other medical authorities about the patient. The shortage of ventilators is met effectively by developing this project. This project is a low cost yet effective ventilating system for the people affected with COVID-19 and other respiratory diseases.

Keywords- *Solar Panel, Ultrasonic Sensors, Autonomous, Grass Cutter*

INTRODUCTION

According to medical knowledge, viruses have a significant negative impact on how well the lung function and can evencause a patient's life to end. The presence of viscous pulmonary mucus frequently causes the patient's respiratory system to collapse and causes the patient finds it challengingto breathe on his own. Thus, it is crucial to provide patients with ventilation and recovery devices. Beginning in 2020, the global was exposed to the COVID-19 pandemic, which is the corona virus, and needed ventilation to assist patients in breathing and resuscitation tools were required. Hospitals have a limited supply of sophisticated, pricey, and expensive cardiac resuscitation equipment. Additionally, supplying a significant number of these tools to handle emergency circumstances (as is the case with the global Corona pandemic) in a brief amount of time is challenging. Hence the significance of producing ventilators and resuscitation equipment that is both economical and simple to operate in order to assist patients. The intricately designed mechanical ventilators used in intensive care units require com pressed air to deliver the best possible lung ventilation. It is necessary to outfit the ambulance with a mechanical ventilator device that is suitable in terms of size, external power needs, and average gas consumption while transporting patients who require ventilation support. Portable ventilators are made to offer mechanical ventilationusing preset parameters and are compact and lightweight. The development of diagnostic and therapeutic medical devices has greatly benefited from developments in computer technology. These days, it is feasible to create portable ventilators that are comparable to the classic intensive care ventilator. In order to give the best advanced breathing modes, this technology in the ventilators also caused a qualitative change in the relationship between the ventilator and the patient. The ability to interact between theoperator and the patient's needs was made possible by the graphical user interface.

[1] *How to cite the article:* Fernanades J., Dias M., Estibeiro S., Fizardo T.P.F., Cotta A., Low Cost Portable Ventilator, IJRST, Jan-Mar 2023, Vol 13, Issue 1, 14-24, DOI: http://doi.org/10.37648/ijrst.v13i01.002

MOTIVATION AND OBJECTIVE

Motivation

The COVID-19 epidemic has caused severe ventilator shortages throughout the world. Rapidly deployable, emergency-use ventilators are required in order to handle COVID-19 patients with severe acute respiratory distress syndrome, but this requirement is unmet.

Objective

- To meet the increasing demand of mechanicalventilators due to COVID -19.
- To provide low cost alternative to ventilators.
- To develop a very easy to operate system so that any less experienced person must be able to operate it with ease.

MECHANICAL VENTILATOR

The primary indications for mechanical ventilation are:

1) Airway protection in patients with obtunded or dynamic airways, such as those who have undergonetrauma or who have an oropharyngeal infection.
2) Hypocapnic respiratory failure brought on by a reduction in minute ventilation.
3) Hypoxemic respiratory failure brought on by an oxygenation failure.
4) Cardiovascular distress, where mechanical ventilation can relieve breathing's energy demands.
5) Expected course, such as an approaching transfer or expected patient deterioration.

OVERVIEW OF A MECHANICAL VENTILATOR

The effectiveness of mechanical ventilation depends on the compliance and resistance of the airway system, which is influenced by how much pressure must be produced by the ventilator to achieve a specific tidal volume. Mechanical ventilation operates by applying a positive pressure breath (TV). The amount of air that enters the lung during inhaling is known as the tidal volume (TV.) The illness state(s) that required intubation may have an impact on compliance and resistance since they are dynamic. Mechanical ventilation has four stages. The trigger phase, inspiratory phase, cycling phase, and expiratory phase are all present. The beginning of an inhalation, which is triggered by either a patient effort or by mechanical ventilator parameters, is known as the trigger phase. The inspiratory phase is defined by the patient taking a breath. The brief period after inhalation has ended butbefore exhalation starts is known as the cycling phase. The patient's passive exhalation of breath is the expiratory phase. The doctor may be given a variety of alternatives for setting up the ventilator after deciding to put the patient on mechanical ventilation. There are many different types of ventilation techniques, including pressure support ventilation, synchronized intermittent mechanical ventilation (SIMV), and assist-control ventilation (AC) (PSV). After that, the ventilator can be configured to deliver a specific volume or pressure. Volume assist control (VAC), which is accessible on all ventilators and is recommended for usageby several prominent experts in emergency medicine andcritical care, is easy to use and safe. Additionally, it offers whole ventilator support, which reduces exhaustion in critically ill patients. The remaining ventilator settings must be set after selecting the mode. The respiratory rate (RR), inspiratory flow rate (IFR), percent of inspired oxygen (FI02), and positive end-expiratory pressure (PEP) are these parameters (PEEP).

(IJRST) 2023, Vol. No. 13, Issue No. I, Jan-Mar **e-ISSN: 2249-0604, p-ISSN: 2454-180X**

HARDWARE REQUIREMENTS

- **ATmega2560 Arduino**

The ATmegA2560, which powers the Arduino Mega 2560, isa microcontroller board. It contains 34 digital input/output pins in total, with 15 of them supporting all PWM output. 16 pins for analogue input. a USB connector, a reset button, andfour ART Ports. It is simply connected to a PC using a USB cable or a DC adapter with a 12V rating. The Mega 2560 board has multiple component shields built in. Other uses include motor driver protection, GSM module protection,etc. Simply enter the code, build it, and upload the result are required. The Arduino Mega doesn’t require further programming after being uploaded.

Figure 1: ATmega2560 Arduino

- **Buzzer**

A beeper or buzzer, for example, could be electromechanical,piezoelectric, or mechanical in design. The signal is converted from audio to sound as its primary function. It is often powered by DC voltage and used in timers, alarm clocks, printers, computers, and other electronic devices. It can produce a variety of sounds, including alarm, music, bell,and siren, according on the varied designs. The buzzer’s pin configuration is displayed below. It has two pins: a positive pin and a negative pin. The ”+” sign or a longer terminal is used to indicate the positive terminal. The negative terminal is represented by the ”-”symbol or short terminal and isconnected to the GND terminal, whereas this terminal issupplied by 6 volts.

Figure 2: Buzzer

- **Force Sensitive Resistor**

An inexpensive piezoresistive sensor known as a force sensorresistor (FSR) changes resistance when pressure or force is applied. When the sensor is not loaded, its resistance is high, and it decreases as force is applied. This prototype detects weight and physical pressure on the patient's chest using an FSR 402 sensor.

Figure 3: Force Sensitive Resistor

- **ATmega328 Arduino Uno Board**

This board includes digital I/O pins-14, a power jack, analog i/ps-6, ceramic resonator-A16 MHz, a USB connection, an RST button, and an ICSP header. All these can support the microcontroller for further operation by connecting this board to the computer. The power supply of this board can bedone with the help of an AC to DC adapter, a USB cable, otherwise a battery.

Figure 4: ATmega328 Arduino Uno Board

- **12V Solar Panel**

The 12V solar panel is seen as the best option formotorhomes, car, vans, and even boats. They provide just theright amount of power to help keep all of your basic appliances and electrical items running – from phone chargers to fridges and lightbulbs. If you are planning on going on holiday in one of these vehicles, then choosing a solar panel to help keep everything running is a much greener option. Plus, it's often a cheaper option in the long run. Even if you are holidaying in a cloudy location, your solar panels will still be able to gather charge.

- **Spirometer or Pressure Sensor MPX5010dp**

An instrument called a spirometer is used to measure how much air is inhaled and expelled by the lungs. The flow rate was determined by inserting a pressure sensor into the bag valve mask's output and applying the spirometer's operating principle. The flow rate is directly related to the differentialin pressure on either side of the constriction (for laminar flow). The MPX5010 sensor was used to determine the tidal volume after detecting the device's pressure output. It produces a strong, proportionate analogue signal to the applied pressure.

Figure 5: Force Sensitive Resistor

- **Drive Module L298**

Based Motor Driver Module is a high power motor driver perfect for driving DC Motors. It uses the popular L298motor driver IC and has the onboard 5V controller which it can supply to an external circuit. It can control up to 4 DC motors, This motor driver is perfect for controlling motors from microcontrollers, switches, relays, etc. An H- Bridge is a circuit that can drive a current in either opposition and be controlled by Pulse Width Modulation(PWM). palpitation range Modulation is a means of controlling the duration of anelectronic palpitation. Motors are rated at certain voltages and can be damaged if the voltage is applied to heavily or if it's dropped snappily to decelerate the motor down. therefore PWM. Motors will last much longer and be more dependable if controlled through PWM. Features- motorist chip L298 dual H- bridge driver chip. Operates up to 35V DC Drivepart of the peak current Io 2A/ Bridge Logical part of the terminal power supply range Vss4.5V-5.5 V Logical part of the operating current range 0 36mA Maximum power consumption 20W .

Figure 6: Motor Drive Module

- **LCD 16x2**

The LCD 16x2 is a type of electronic display that shows information and messages. As implied by the name, it has 16 Columns and 2 Rows, allowing it to display 32 characters in total (162=32), each of which is built up of 5x8 (40) Pixel Dots. Therefore, the total number of pixels on this LCD can be estimated as 32x40, or 1280 pixels. The majority of 16X2 displays rely on multi-segment LEDs. The LCD 16x2 is widely used in devices, DIY circuits, and electronic projects because it is less expensive, programmable friendly, and easyto access. Other types of displays with different combinations include 8x2, 8x1, 16x1, and 10x2.

Figure 7: Display, LCD 16 seg X 2 Lines

- **WIFI Module**

A low-cost Wi-Fi module with a full TCP or IP stack and a microprocessor capable of being used in Internet of Things applications is the ESP8266. For wireless connection withthe medical facility or the specialist, it is utilised in this project.

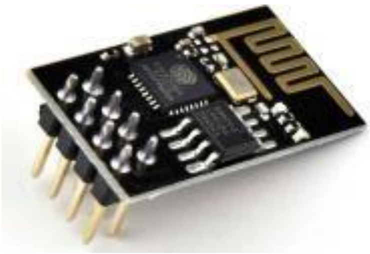

Figure 8: WIFI Module

- **Bag Valve Mask (BVM)**

A bag valve mask (BVM) is a hand-held device that is frequently used to provide positive pressure ventilation to patients who are not breathing or are not breathing adequately. It is also occasionally referred to by the proprietary name Ambu bag or more generally as a manual resuscitator or ”self-inflating bag.” The tool is a necessary component of resuscitation kits for trained personnel in out of-hospital settings (such ambulance crews) and is widely used in hospitals as a piece of standard equipment found on acrash cart, in emergency rooms, or in other critical care settings. When a mechanical ventilator needs to be checked for potential problems or when patients who require mechanical ventilation are being relocated inside the hospital, manual resuscitators are also used to provide interim ventilation for patients who require them. There are primarily two different kinds of manual resuscitators; one is self-filling with air, though additional oxygen (O2) can be added without making the device functional. In nonemergency situations in the operating theatre, the other main type of manual resuscitator (flow-inflation) is frequently employed to ventilate patients throughout the induction and recovery of anesthesia.

Figure 9: Bag Valve Mask (BVM)

- **MAX30100**

The MAX30100 is a sensor solution with integrated pulse oximetry and heart rate monitoring. To detect pulse Oximetry and heart-rate signals, it incorporates two LEDs, a photodetector, improved optics, and low-noise analogue signal processing. Ambient light cancellation (ALC), a 16-bitsigma delta ADC, and a custom discrete temporal filter makeup the SpO2 subsystem of the MAX30100. A continuous time oversampling sigma delta converter with a maximum resolution of 16 bits is the SpO2 ADC. From 50Hz to 1kHz can be configured as the ADC output data rate. A patented discrete temporal filter is built into the MAX30100 to eliminate residual low-frequency environmental noise and interference at 50Hz and 60Hz.

Figure 10: MAX30100

- **12V 4RPM Rectangular gearbox**

DC motor 12V, 4RPM, rectangular gearbox The DC motor has a high torque rating of 846.2 N-cm and a gear ratio of 1166K. This motor's 8mm-diameter, 27mm-long shaft with M4 tapping is its distinguishing feature. A central air conditioning valve, entertainment equipment, coin-return machines, grills, and ovens are just a few applications for this motor. Additionally, it can be used for peri static pumps,ATM bank machines, office supplies, home appliances, medical devices, and other items. features for a powerful, portable, and small motor. specialized shaft with a 27mm length for easy attachment. The wheel/coupling design issimple because the shaft is a D-type.

Figure 11: 12V 4RPM Rectangular gearbox DC motor

SOFTWARE REQUIREMENTS

- **Arduino Software**

The IDE is a specialized computer programme that enables you to create sketches for the Arduino board in a straightforward language that is based on the Processing language. The crucial step occurs when you choose to upload the sketch to the board: your written code is completely converted to C before being sent to the compiler, which completes the process of translating it intoa form that the microcontroller can understand. When the upload is finished, the successfully submitted code is shown.

- **TinkerCAD**

On the website Tinker cad, you may model and prototype Arduino circuits or your own designs. This can also be used as a preliminary simulation to confirm that everything is operating as expected before moving further with the hardware.

- **SolidWorks**

SolidWorks is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) application. SolidWorks is a solid modeler that builds models and assemblies using a parametric feature-based method thatwas first developed by PTC (Creo or Pro-Engineer). Software is created using the Parasolid-kernel platform.

METHODOLOGY

The methodology flow diagram in this chapter's fig. displays the project's overall process flow, the entire hardware block diagram, and the process flow chart. The requirements and design of the hardware model were completed after the problem definition and study into wireless and hardware technology.

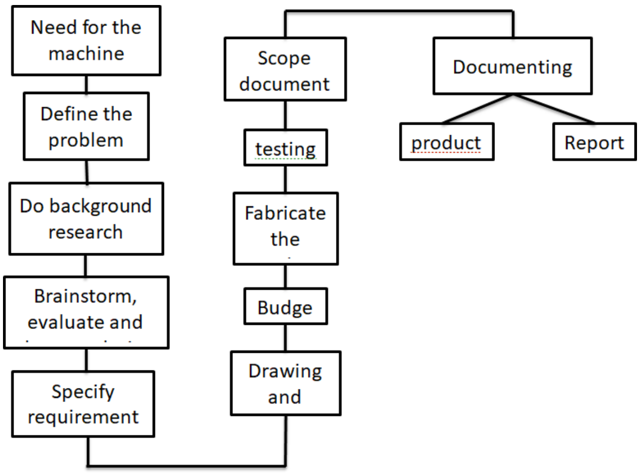

Figure 12: Methodology

WORKING

The **Hardware** block diagram demonstrates the many parts that were used to create the ventilator model. An ambu bag, apressure sensor, a moving arm, a microcontroller, a gear motor, a speed regulator, a SpO2 sensor, an LCD display, and a Wi-Fi module make up this model.

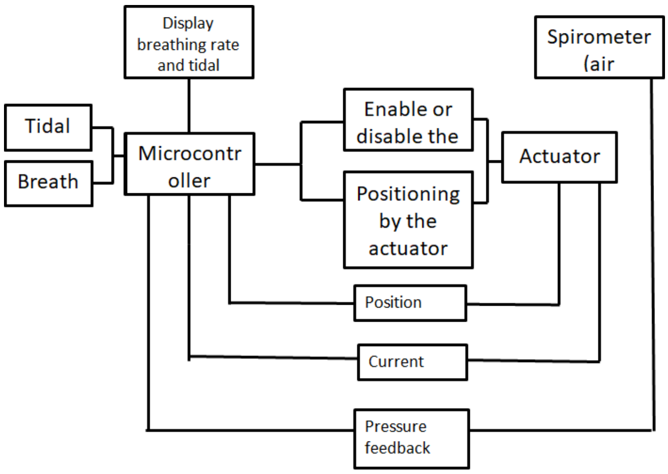

Figure 13: Hardware block diagram

Process Flow Chart

At the beginning of the operation, the arm position is modified to be in the initial (or starting) position. This meansthat when the arm is in its ultimate position, it supplies 1.5 milliliters and contacts the bag to supply 100 milliliters. But it is advisable to change these placements in order to make the treatment process simpler and ensure high accuracy. The calibration procedure is based on two feedback signals generated by the pressure sensor and SpO2 sensor. The pressure sensor is used to determine the lowest andmaximum positions of the arm. The pressure sensor chooses the position that will produce a volume of 100 milliliters at the lowest pressure and the position that will produce the most at the greatest pressure (1.5 liters). SpO2 level and temperature is measured and it is the input to calculate theI:E ratio and the breathing rate. Further the height and weight is used to calculate the tidal volume. If the tidalvolume required is more than the arm will be pressed at a greater angle.

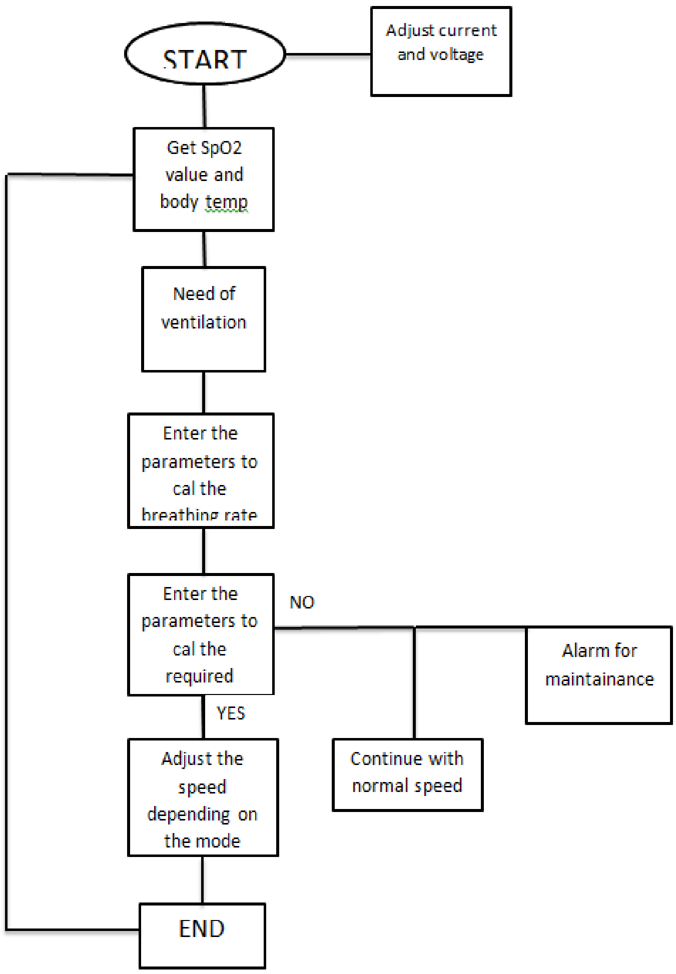

Figure 14: Process flow chart

The ventilator will mimic how the respiratory system moves oxygen via tubes into our lungs, where it diffuses into the circulation, while carbon dioxide is transported through other tubes and into our body. This ventilator can be used for the adults, children's and infants, just by changing the mask size and the setting of the breathing parameters without any change for the internal components of the device. Tidal volume and breathing ratewill be taken into account when controlling the mechanical ventilator's operation. These two parameters can be determined according to the patient's medical data including gender, weight and medical condition. Hence, the ventilation system in this project can be used for all ages.

Breathing rate (BR): is the number of breaths in a minute. As an example, the average breathing rate is 12 bpm (breaths per minute) for adult.

Tidal volume (TV): is the amount of air breathed in with each normal breath. As an example, the average tidal volume is 0.5 liters (for adult).

Minute ventilation (VE): is the total volume of air entering the lungs in a minute. As an example, the averageVE is 6 liters per minute (for adult). The VE can be obtained by multiplying the BR by the TV of the patient.

Age	Breathing rate(per min)	Tidal volume(ml)	Minute ventilation	Weight (kg)
child	20-30	200-270	20*0.2	33
teenager	15-25	330-440	15*0.33	55
adult	12-20	440-580	1280.5	73

Table 1: Parameters of the respiratory system

RESULTS AND ANALYSIS

The concepts of reverse engineering have been used in the design and construction of a low cost portable ventilator and spO2 device for calculating the oxygen level as asupport efforts in providing assistive medical devices. Thework of the first engineering model of the device was tested and gave expected results in its dealings with various scenarios of the patient's condition. The device is distinguished by the following: A battery-powered andsolar panel portable device that can be used in remote areas. The device depends on its work on a group of sensors. The device can be accessed wirelessly to identify the patient's condition. The device can be used as a monitoring tool to help the paramedic in the process of cardiac resuscitation. The overall efficiency of the device can be improved by using a smart control methodology.

Monitoring of force sensor

An inexpensive piezoresistive sensor known as a force sensor resistor (FSR) alters resistance when pressure or forceis applied. The sensor is extremely resistant and drops as force is applied when it is unloaded. This concept uses a sensor to recognize physical the patient's chest is under pressure and weight.

Monitoring of SpO2

In this design we have used MAX30100 palpitationOximeter Sensor with Arduino and lcd. The MAX30100Sensor is able to measuring Blood Oxygen and Heart Rate. We have used display of 16x2 to view the value of SpO2 andBPM. The blood Oxygen attention nominated SpO2 is measured in Chance and Heart Beat and palpitation Rate is measured in BPM

Monitoring of Pressure Sensor MPX5010dp

A spirometer is an apparatus for measuring the volume of air inspired and expired by the lungs. The spirometer principle of operation has been used for calculating the flow rate by connecting a pressure sensor into the output of the bag valve mask. The flow rate is proportional to the difference in pressure on each side of the constriction (for laminar flow). The MPX5010 sensor has been used to detect the pressure output. It provides a high level analog output signal proportional to the applied pressure.

Testing the Final Device

CONCLUSIONS AND FUTURE SCOPE

Conclusion

The oscillatory motion of the motor which moves the arm to and fro is used in the proposed device. The ambu bag which is the main part of the machine provides the required ventilation to the patient. The construction of a low cost portable ventilator and sp02 device for calculating the oxygen level as a support efforts in providing assistive medical devices. The work of the first engineering model of the device was tested and gave expected results in its dealings with various scenarios of the patient's condition. The device is distinguished by the following: A battery- powered and solar panel portable device that can be used in remote areas. The device depends on its work on a group of sensors. The device can be accessed wirelessly to identify thepatient's condition. The device can be used as a monitoring tool to help the paramedic in the process of cardiac resuscitation.

Future Scope

Using a smart control methodology can increase the device's general efficiency. The system can be improved so that it continuously tracks chronic obstructive pulmonary disease. The research team, with the support of Philadelphia University, is working on developing the device by employing fuzzy logic and neural networks in the process of controlling and determining the data for the device.

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