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DESIGN AND IMPLEMENTATION OF A LOW COST AUTOMATIC VENTILATOR BASED ON BLOOD OXYGEN LEVEL DEFICIENCY MEASUREMENT

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Abstract

This work aims to design and develop an automatic ventilator system which will continuously monitor blood saturation level and initiate process to supply oxygen in required amount to the patient. Considering the contagious nature of Covid-19 disease, the medical health workers and doctors are required to physically monitor the patient and supply the oxygen based upon the requirement of patient. The system developed in this work is fully automatic which senses the blood oxygen level deficiency and automatically presses the Bag Valve Mask (BVM) to supply the oxygen to the patient. The system is designed around the Arduino nano microcontroller, it monitors the blood oxygen level of patient and based upon the deficiency sufficient amount of oxygen is provided to the patient. The system developed here is a low cost system and automatically works without human intervention.

Keywords- Automatic ventilator system, oxygen blood level monitoring, electro-mechanical ventilator system.

1. INTRODUCTION

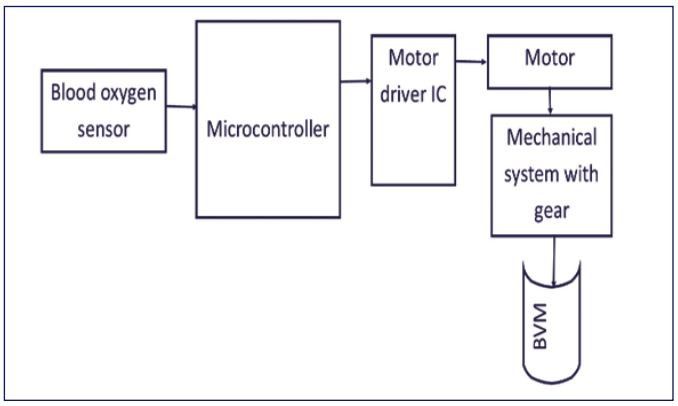
During 2020 to 2022 Covid 19 virus spread worldwide and serious consequences were generated. Doctors and other medical staff also suffered due to direct physical contact of the patient with medical staff. Medical staff was required to continuously visit the Covid patients' ward or ICU units. This resulted in spread of Covid-19 among the health workers. The engineering community tried to find the solution on this issue. Considering this critical situation many systems were developed to avoid direct contact with patient. The oxygen ventilator system was proved to be very significant for Covid-19 patients. Hence much attention was given to development of automatic ventilators for patient to avoid intervention of health workers. The review of some automatic ventilators is discussed in this section. In ref. [1] a low cost and compact mechanical system is developed in which pressure plate is used to press the Ambu bag to supply oxygen to patient. In this the DC servo motor is used to move the pressure plate. Manual control mode, adult and child modes are also provided. The system is equipped with facility of controlling the respiratory rate and oxygen volume. The system is operated using microcontroller. Ref. [2] describes the design of microcontroller based smart ventilator in which bag valve mask (BMV) resuscitator is controlled using the DC motor and mechanical rod. The keypad is used to enter the details for BVM control. The review of the evolution of the mechanical ventilators is presented in [3]. It is informed [3] that the first generation (year 1900 to 1970) mechanical ventilators were volume controlled, second generation (1970 to 1980) ventilators were patient triggered, third generation (1980 to 1990) ventilators were controlled by microprocessors and fourth generation (1990 to 2011) ventilators belonged with different facilities. The fifth generation (after 2011) ventilators were predicted with having decision support mechanism which can be seen to be true nowadays. The constructional details [3] of ventilators in every generation are presented and in future trends it is clearly mentioned that decision support based electronics controlled systems will appear. The compact and handy ventilator is presented [4] considering the Covid- 19 issue. This ventilator is designed using Arduino microcontroller, stepper motor, crank slider system, BVM, peep valve etc. It senses the pressure and accordingly the BVM flow rate is controlled. A mechanical ventilator system is mathematically modeled, simulated in MATLAB-Simulink, and prototype is developed [5]. A low cost ventilator system is designed [6] around Arduino microcontroller. In this system pressure is sensed using pressure sensor by Arduino microcontroller. Arduino and Raspberry Pi microcontroller in this system work in coordination. Servo motor is used which drives the mechanical gear system to press the BVM in to and fro direction. A rapidly deployable ventilator system for Covid-19 disease is developed [7]. Due to Covid-19 disease various systems were developed for respiration, the review of these systems is presented in [8]. The performance of ventilator systems are compared considering their mechanism, features, drawbacks and cost. The factors required for good ventilators and common difficulties are also discussed in [8]. Prototype of low cost ventilator is designed [9] in which actuators are used to press the BVM. A low cost ventilator system is designed and developed [10] using Arduino microcontroller. Automatic ventilator system is discussed in [11] and review of automatic ventilator systems is presented in [12]. Considering the literature review it can be seen that after Covid 19 pandemic many researchers have focused on design and development of automatic, low cost, compact automatic ventilator systems. In this research work an electro-mechanical system prototype is designed and developed which senses the patients' oxygen saturation level and automatically presses the BVM bag with

required pressure. The pressure is determined from the blood oxygen level. Whenever the blood oxygen level goes below the threshold level of 95 the system supplies the oxygen to the patient till it reaches to 100. Thus the developed system continuously tries to keep the oxygen saturation level between 95 to 100.

2. SYSTEM BLOCK DIAGRAM

Figure 1 shows the system block diagram. In this the blood oxygen sensor is used to monitor the SpO_2 i.e. oxygen saturation level in the body of a patient. Microcontroller continuously senses the SpO_2 using sensor, whenever the SpO_2 level drops below certain level, the microcontroller signals the motor driver IC so that motor starts to rotate. The mechanical assembly of the rotating plate and shaft is used which pushes the BVM to and fro so that the BVM generates pressure and air oxygen is supplied to the patient automatically. This process last longer till the oxygen saturation level of the person reaches to 100. Once it reaches 100, the microcontroller stops this mechanism and again monitors the saturation for lower level.

Fig. 1 : System block diagram



3. HARDWARE IMPLEMENTATION

The system components used for this work are described below.

3.1 Microcontroller: Arduino Nano microcontroller is used. It is 8 bit controller with facilities of general purpose I/O, PWM pulse generator, I2C pins etc. which are required for this application. It is light weight and low cost device.

3.2 Blood Oxygen sensor: MAX 30100 blood oxygen sensor module is interfaced to the microcontroller with I2C protocol. It also provides temperature sensing facility. Due to I2C protocol only two pins viz. SCL and SDA are required and serial data can be sent through SDA pin to microcontroller. This is low power consuming device and suitable for battery powered handy equipment.

3.3 Bag Valve Mask (BVM): Bag Valve mask of 0.5 liter size is used. The bag is always connected to oxygen cylinder. Manually this bag can be pressed to supply oxygen. In this work mechanical assembly of revolving plate and rod is used to press the bag to create pressure and to supply the oxygen.

3.4 Motor Driver: L298 motor driver IC is used to drive the Johnson DC motor. It consists of in built H-bridge circuit.

3.5 Johnson DC Motor: It is geared DC motor having 30 RPM and 12 V power supply. It is suitable to handle the mechanical rod used in this application.

3.6 Mechanical System: The design of mechanical system to push BVM is shown in figure 2. The mechanical components are A- Johnson motor, B- revolving plate, C- push pull plate, D- rod, E- support, F- pressing plate, G- BMV. The shaft of the Johnson motor revolves the revolving plate B. Due to revolution of this plate B, the push pull plate moves the rod D in to and fro direction due to which the pressing plate F presses the BMV and oxygen is supplied from the oxygen source.

Fig. 2: Mechanical system design

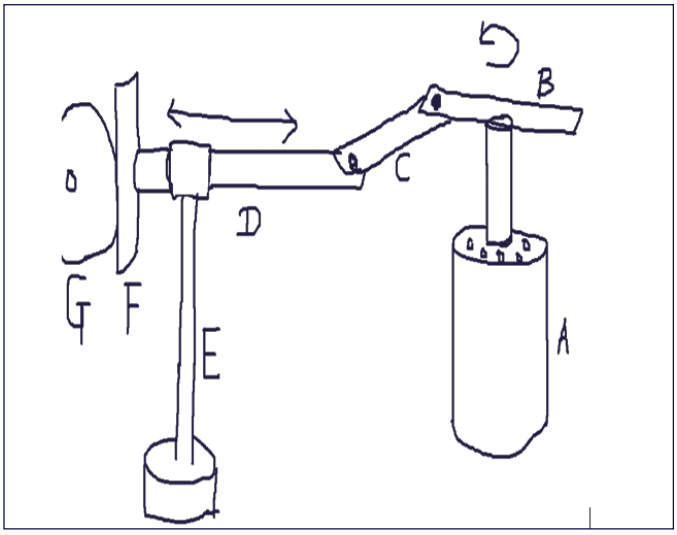
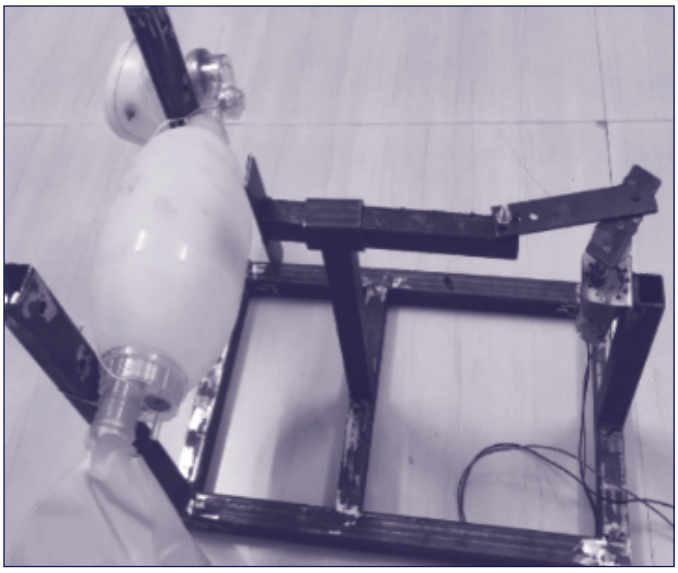


Fig. 3: shows the mechanical assembly developed in laboratory.

Fig. 3: Mechanical system prototype

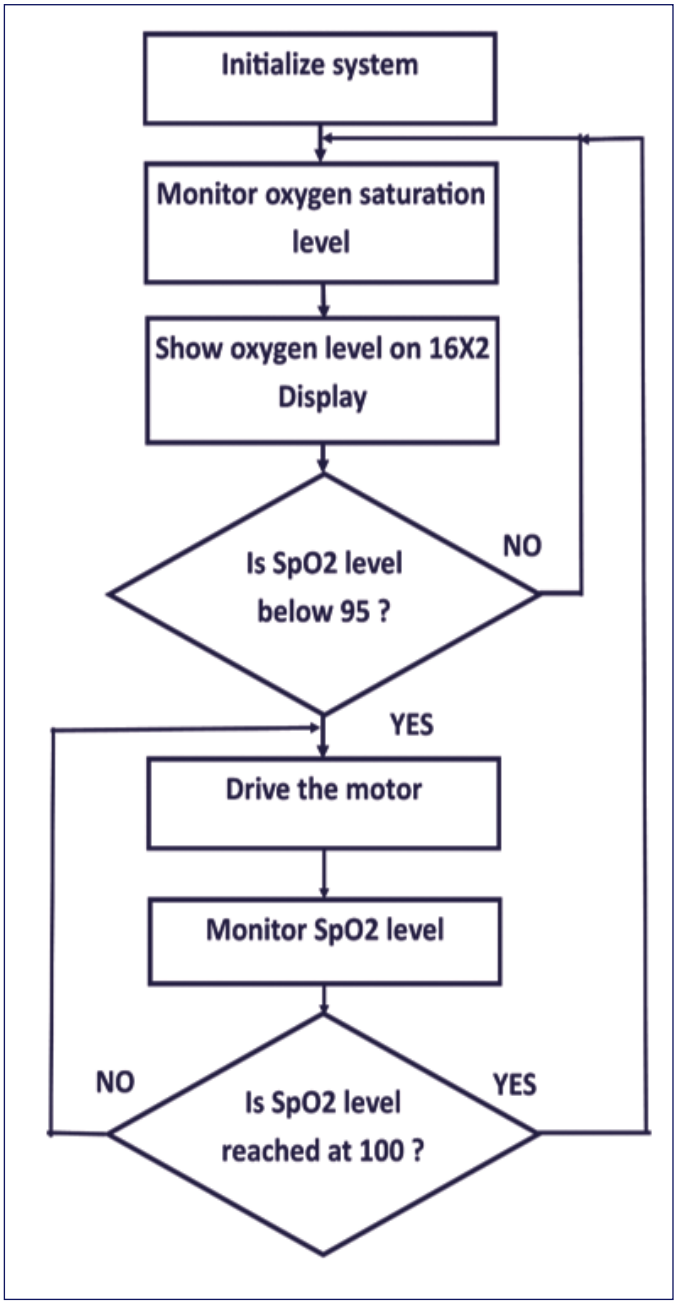


4. SOFTWARE DESIGN

The system follows the flowchart shown in figure 4. The blood oxygen sensor is required to be connected to finger of patient. The BVM mask should be attached to the nose of patient. The BVM should be connected to the oxygen source. Upon power ON, the system checks the SpO_2 level of the patient. If the SpO_2

level is normal it displays it on the 16 X 2 LCD. When the level drops below 95, it operates the motor. Due to rotation of motor shaft, the revolving plate get revolved around its own axis, this causes push-pull plate to get rotate, this action generates the to and fro movement of mechanical rod which presses the BVM repeatedly. Due to this the BVM get pressed and the oxygen in required amount is supplied to the patient. The system continuously checks the SpO_2 level, when it reaches above 100, the system stops the motor and again starts to monitor the SpO_2 level continuously. If level is within normal limits then the motor is not driven. Regularly the SpO_2 level get displayed on LCD.

Fig. 4: System flow chart



Arduino IDE is used for programming. In this the functions for LCD, I2C protocol, PWM, sensor are used.

Fig. 5: System circuit hardware

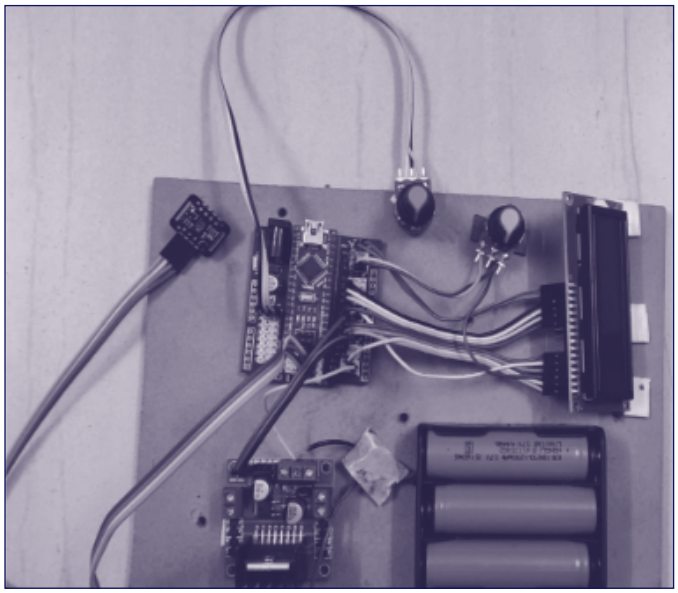
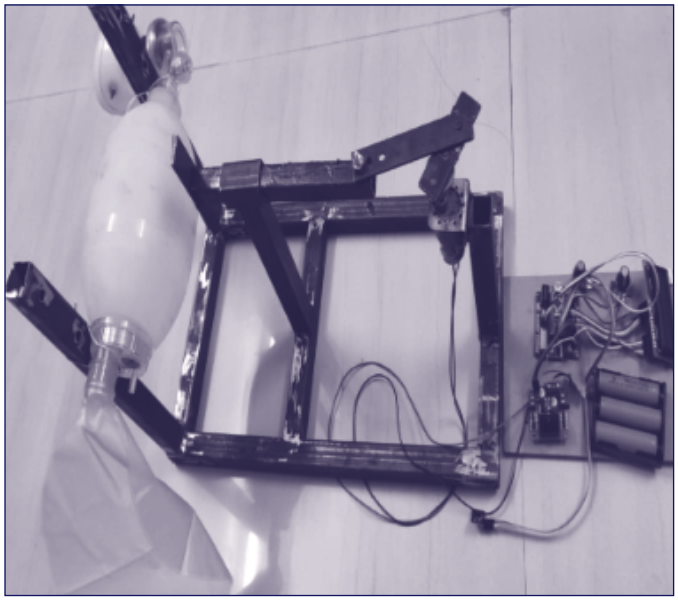


Fig. 6: System prototype developed in laboratory



5. RESULTS AND DISCUSSIONS

The prototype is developed in the laboratory which works as desired. The system is low cost, easy to design, handy and works well without manual intervention. However there is scope to further reduce the system weight by using the aluminum. Additional facility of temperature and heart beat monitoring is provided in it. System is bit noisy due to movement of mechanical parts. As reported in [3], this system belongs to fifth generation ventilators having decision making capability.

6. CONCLUSION AND FUTURE WORK

The automatic ventilator system having facility of automatically sensing the blood oxygen saturation level and operating the BVM is a good solution for contagious disease like Covid-19. It also removes the need of manual intervention. The direct monitoring of health worker of the patient is avoided, hence

in future online remote monitoring system can be added by which the oxygen saturation level, temperature and heart rate of patient can be monitored using IoT technology.

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