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Green Electronics Project

Arduino-based oxygen ventilator for COVID-19 patients

Submitted to Dr. Mohamed Youssef

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Abstract

For the past two years, the whole world has been facing a new enemy, the covid 19 virus also known as corona virus. These global crises have created shortage of crucial equipment in hospitals across the world. Most importantly ventilators needed to save patients struggling to breathe and as engineers it is our duty to build in times of need.

Motivation:

The new coronavirus behind the pandemic causes a respiratory infection called COVID-19. The virus, named SARS-CoV-2, gets into the airways and can make it hard to breathe. Estimates so far show that about 6% of people who have COVID-19 get critically sick. And about 1 in 4 of them may need a ventilator to help them breathe. But the picture is changing quickly as the infection continues to spread around the globe and so one important device for which demand has ramped up is ventilators [1]

Design and development of a low-cost portable ventilator could be a possible way that can help pneumonia cases of COVID-19 patient and struggling health care systems around the world. Even though A DIY ventilator may not be efficient as that of a medical grade ventilator but it can act as a good substitute.

Introduction:

According to the World Health Organization (WHO), about 80% of persons who contract Covid-19, a coronavirus-related condition, recover without the need for hospitalization. However, one out of every six people falls critically ill. The virus damages the lungs in these extreme cases, causing the body's oxygen levels to plummet and making breathing difficult. To help with this, a ventilator is used to force air into the lungs with higher oxygen levels. [2]

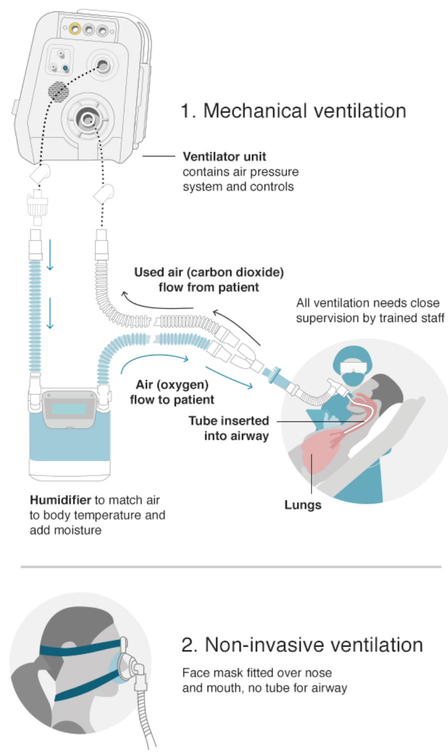

Figure 1:types of ventilators

There are 2 types of ventilators

1. Mechanical ventilator
2. Non- invasive ventilator

Mechanical ventilation is a life-saving therapy that catalyzed the development of modern intensive care units. The origins of modern mechanical ventilation can be traced back about five centuries to the seminal work of Andreas Vesalius. A Ventilators a machine that helps you take breaths if you can’t do it on your own it mechanically helps pump oxygen into your body. The air flows through a tube that goes in your mouth and down your windpipe. The ventilator also may breathe out for you, or you may do it on your own. This report represents an Arduino based ventilator with pulse oximeter sensor and servomotor.

Mechanism of the ventilator:

A ventilator uses pressure to blow air into the lungs. This pressure is known as positive pressure.

The amount of oxygen the patient receives can be controlled through a monitor connected to the ventilator. If the patient's condition is particularly fragile, the monitor will be set up to send an alarm to the caregiver, indicating an increase in air pressure. The machine works by bringing oxygen to the lungs and taking carbon dioxide out of the lungs. This allows a patient who has trouble breathing to receive the proper amount of oxygen. It also helps the patient's body to heal, since it eliminates the extra energy of labored breathing. The machine blows air into the airway through a breathing tube. One end of the tube is inserted into patient's windpipe and the other end is attached to the ventilator. The breathing tube serves as an airway by letting air and oxygen from the ventilator flows into the lungs. Depending on the patient's medical condition, they may be able to use a respiratory mask instead of the breathing tubes. [3]

Automatic inflated bag:

Automatic inflated bag, also known as bag valve mask (BVM), ventilation is a critical skill for emergency providers. BVM ventilation is a technique that restores breathing in patients who are not spontaneously breathing. In most settings, a BVM is an emergency procedure carried to tide over until intubation is done.

BVM ventilation is needed in the following conditions:

- Respiratory (lung) failure
- Failed intubation (insertion of an artificial ventilation tube into the trachea)
- Patients undergoing anaesthesia for elective surgery
- Apnoea (slowed or stopped breathing)

Patients who use a breathing machine (ventilator) can also use a resuscitator bag if there is a need to disconnect from the ventilator due to a power failure or when there is a problem with the ventilator. [4]

Mechanism of the BVM:

- Connect the bag mask and oxygen tube to the BVM.
- Use an airway adjunct to keep the tongue out of the way. Otherwise, the tongue may block the airway and force air into the oesophagus or stomach.
- Position the mask on the patient's face and hold it in place firmly over the nose and mouth.
- To achieve a good seal, pull the chin up (rather than pushing the forehead down) to keep the airway open.
- Squeeze the bag until the chest rises, count six seconds between bag squeezes, about 10-12 times per minute on an adult or 30 times in case of infants.

- Avoid squeezing too quickly and over-ventilating the patient. [5]

So, our motivation is to implement an automatic BVM to do the same process and be more efficient. This was done using a servo motor and an arm to press on the bag.

First, an oxygen level sensor is used to measure the oxygen level in the patient's blood. If the level was below 94% and servo motor starts rotating an arm to press on the mag mask in order to provide the necessary breathing aid to the patient. When the oxygen level stabilizes the arm stops rotating. [6]

In the following part, a detailed explanation of the components and the circuit connections is carried out.

Components and supplies:

1. ARDUINO UNO REV3:

Figure 2:Arduino kit

- Arduino Uno is a microcontroller board developed by Arduino.cc which is an open-source electronics platform mainly based on AVR microcontroller Atmega328.
- Arduino Uno comes with USB interface, 6 analog input pins, 14 I/O digital ports that are used to connect with external electronic circuits. Out of 14 I/O ports, 6 pins can be used for PWM output.

2. MAX30100 Pulse Oximeter Sensor:

The MAX30100 is a Pulse Oximetry and heart rate monitor sensor solution. The sensor combines a pulse oximetry and heart-rate monitor sensor in one package. It detects pulse and heart rate signals using two LEDs, a photo detector, optimized optics, and low-noise analog signal processing. It runs on 1.8V and 3.3V power sources and can be turned off by software with very little standby current, allowing the power supply to be connected at all times.

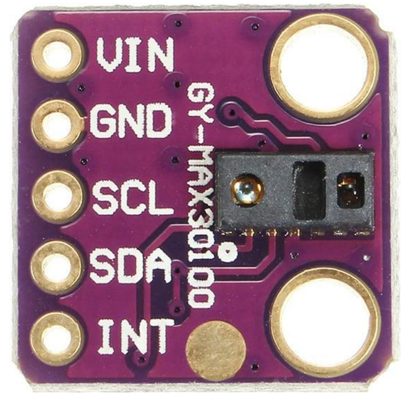

Figure 3:MAX30100 pulse oximeter IC

- How does the Pulse Oximeter Sensor work?

Oxygen enters the lungs and then travels via the bloodstream. The blood transports oxygen to all of our body's organs. Hemoglobin is the principal carrier of oxygen in our bloodstream. A little clamp-like device is put on a finger, earlobe, or toe during a pulse oximetry reading. As shown in Figure 4

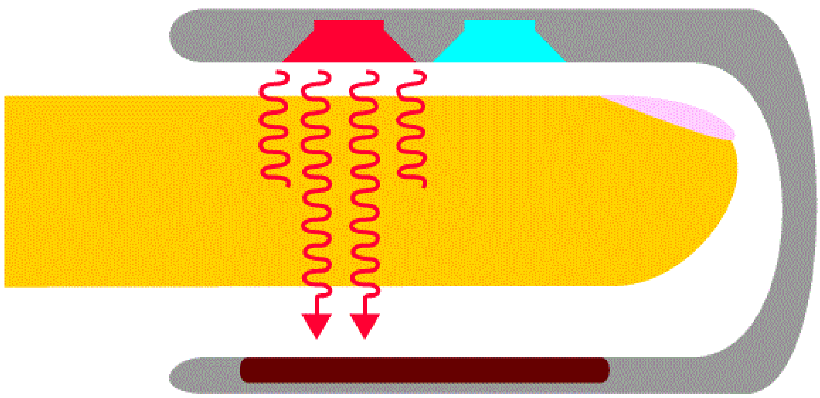

Figure 4:the outer mechanism of the oximeter

The amount of oxygen in the finger is measured by little beams of light passing through the blood. It does that by detecting variations in light absorption in oxygenated and deoxygenated blood. [7]

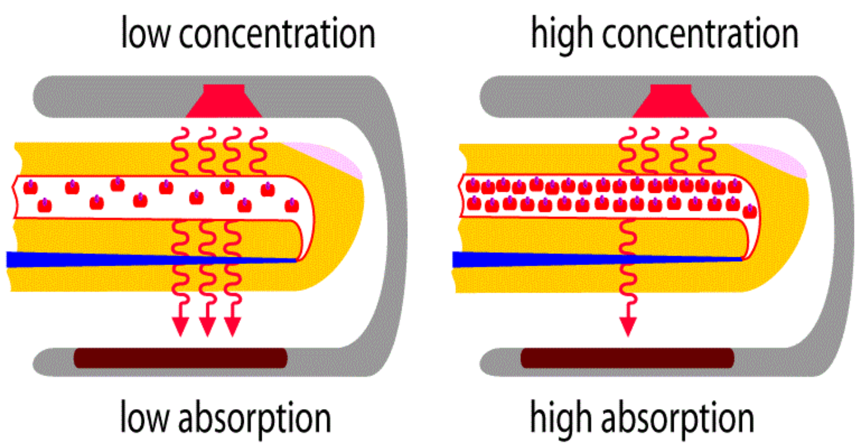

Figure 5: the inner mechanism of the oximeter

3. LCD Display:

JHD162A 16X2 LCD Display

Figure 6: JHD162A 16X2 LCD Display

a) LCD schematic:

The JHD162A lcd module has 16 pins and can be operated in 4-bit mode or 8-bit mode. Here we are using the LCD module in 4-bit mode. The schematic of a JHD162A LCD pin diagram is given below.

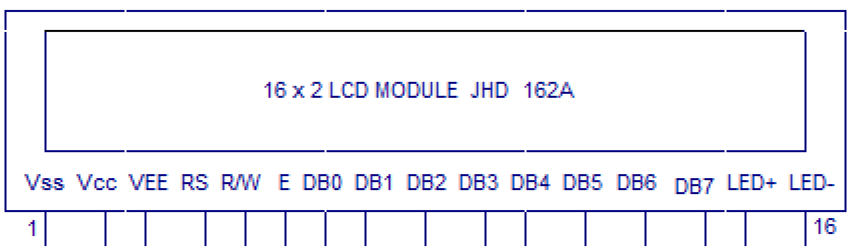

Figure 7: The LCD schematic

- **Pin1(Vss)**: Ground pin of the LCD module.
- **Pin2(Vcc)**: Power to LCD module (+5V supply is given to this pin)
- **Pin3(VEE)**: Contrast adjustment pin. This is done by connecting the ends of a 10K potentiometer to +5V and ground and then connecting the slider pin to the VEE pin. The voltage at the VEE pin defines the contrast. The normal setting is between 0.4 and 0.9V.
- **Pin4(RS)**: Register select pin. The JHD162A has two registers namely **command register** and **data register**. Logic HIGH at RS pin selects data register and logic LOW at RS pin selects command register. If we make the RS pin HIGH and feed an input to the data lines (DB0 to DB7), this input will be treated as data to display on LCD screen. If we make the RS pin LOW and feed an input to the data lines, then this will be treated as a command (a command to be written to LCD controller – like positioning cursor or clear screen or scroll).
- **Pin5(R/W)**: Read/Write modes. This pin is used for selecting between read and write modes. Logic HIGH at this pin activates read mode and logic LOW at this pin activates write mode.

- **Pin6(E)**: This pin is meant for enabling the LCD module. A HIGH to LOW signal at this pin will enable the module.
- **Pin7(DB0) to Pin14(DB7)**: These are data pins. The commands and data are fed to the LCD module though these pins.
- **Pin15(LED+)**: Anode of the back light LED. When operated on 5V, a 560-ohm resistor should be connected in series to this pin. In Arduino based projects the back light LED can be powered from the 3.3V source on the Arduino board.
- **Pin16(LED-)**: Cathode of the back light LED. [8]

4. MG996R Servo Motor

The MG996R is a servo motor with a maximum stall torque of 11 kg/cm and metal gears. The motor rotates from 0 to 180 degrees based on the duty cycle of the PWM wave given to its signal pin, just as other RC servos.

Figure 8: MG996R Servo Motor

a) Wire Configuration

Table 1:wire configuration of the motor

Wire Number	Wire Color	Description
1	Brown	Ground wire connected to the ground of system
2	Red	Powers the motor typically +5V is used
3	Orange	PWM signal is given in through this wire to drive the motor

b) MG996R Servo Motor Features

- Operating Voltage is +5V typically
- Current: 2.5A (6V)
- Stall Torque: 9.4 kg/cm (at 4.8V)
- Maximum Stall Torque: 11 kg/cm (6V)
- Operating speed is 0.17 s/60°
- Gear Type: Metal
- Rotation: 0°-180°

- Weight of motor: 55gm
- Package includes gear horns and screws

c) How does it work?

To make this motor rotate, we have to power the motor with +5V using the Red and Brown wire and send PWM signals to the orange color wire. Hence, we need something that could generate PWM signals to make this motor work, we used Arduino.

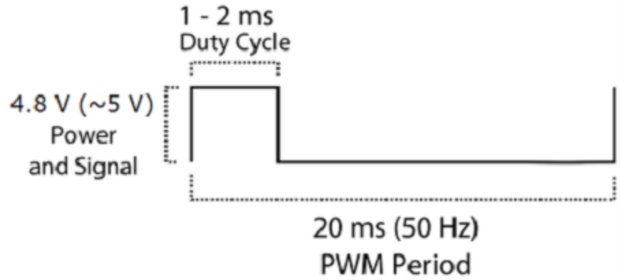

Figure 9: the motor cycle

The PWM signal produced should have a frequency of 50Hz, which means the PWM period should be 20ms, as shown in the diagram. The On-Time might range from 1 to 2 milliseconds. When the on-time is 1 millisecond, the motor will be at 0 degrees, 1.5 milliseconds, 90 degrees, and 2 milliseconds, 180 degrees. The motor can be controlled from 0° to 180° by adjusting the on-time from 1ms to 2ms. [9]

5. 12v to 5v converter using 7805 IC

Figure 10:7805 Voltage Regulator IC

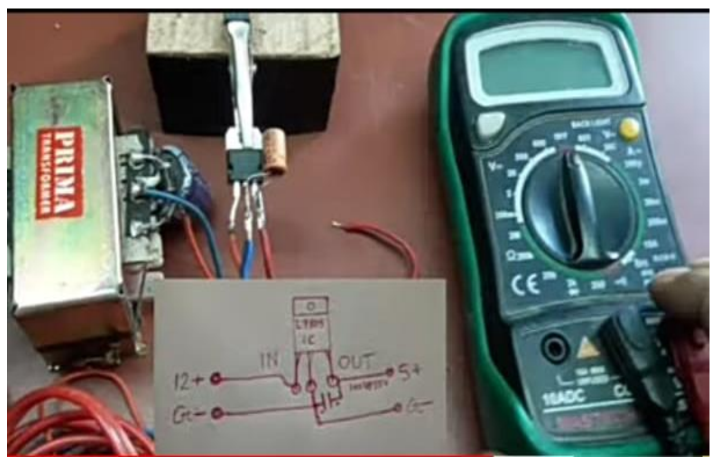

Figure 11: connections of the converter

Connecting port 3 to port 2 with a 100 uF capacitor, then port 1 represents the input power supply voltage (12v) and the output is the (5v) as shown in Figure 11

6. Manual resuscitation bag

Figure 12: manual resuscitation bag

- Used for resuscitation in emergency situations, available at local chemists.
- Compressible self-refilling ventilation bag with non-re breathing patient valve with pressure limitation valve to minimize the risk of over inflating.
- 100% latex free.

7. Breadboard
8. Two Leds and one buzzer
9. 10k Potentiometer
10. 4.7k ohm resistors

Ventilator circuit:

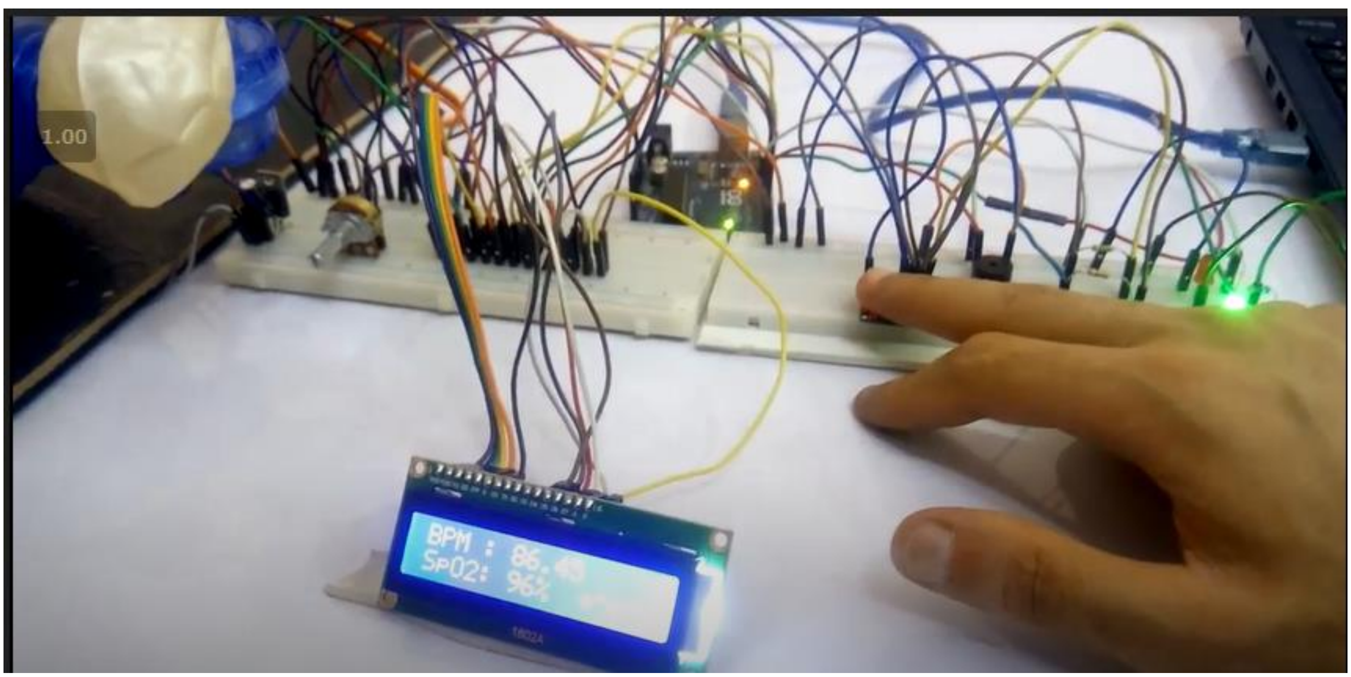

Figure 13: live screenshot of our project circuit

Components interfacing with Arduino:

1. MAX30100 Pulse Oximeter Sensor interface

MAX30100 Pulse Oximeter Sensor interface with Arduino, the circuit diagram and connection are shown in Figure 14 below. [10]

- Vin pin of MAX30100 is connected to Arduino 5V or 3.3V pin
- GND pin of MAX30100 is connected to Arduino GND.
- I2C Pin, SCL & SDA of MAX30100 is connected to A5 & A4 of Arduino.

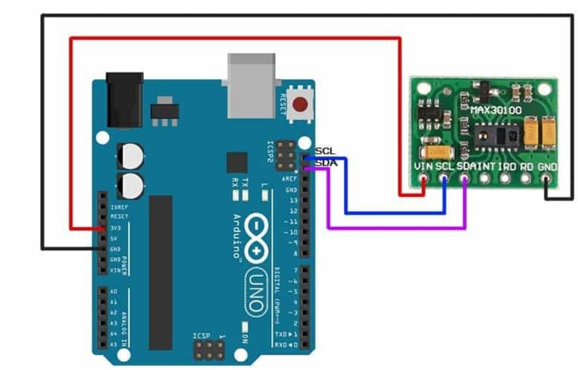

Figure 14: MAX30100 Pulse Oximeter sensor interface with Arduino

The MAX30100 IC uses 1.8V for VDD and this particular module uses two regulators to achieve this voltage. Nothing wrong with that until it is connected with microcontrollers with higher logic levels. The Arduino can detect a minimum HIGH voltage of 2V and the SCL and SDA pins are pulled-up via the 4.7k ohm resistors to 1.8V. This means it won't work well

The solution is to remove the resistors from the board (shown in Figure 15 and attach external 4.7k ohms resistors instead as shown in Figure 16 . [11]

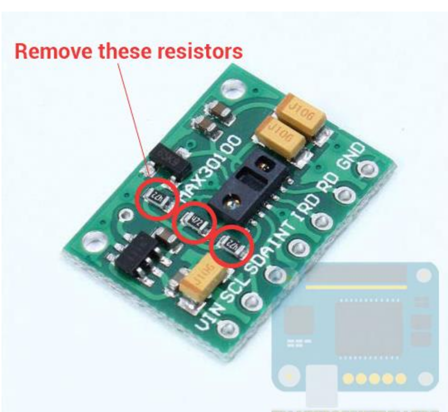

Figure 15:Oximeter internal resistors

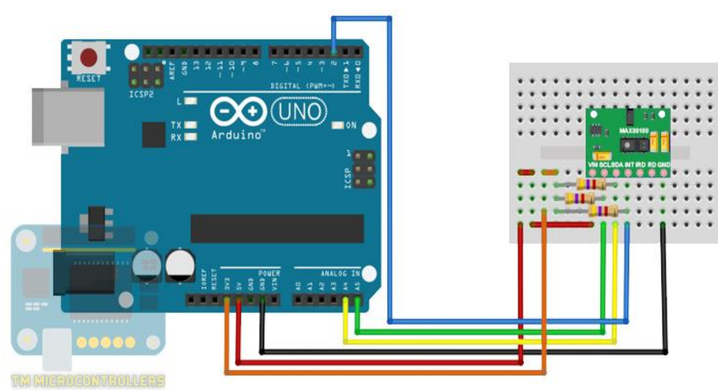

Figure 16:Oximeter sensor interface with Arduino after using external resistors

2. LCD interface

The 16X2 LCD is used to Display the value of BPM & SpO2. The circuit is shown in the circuit diagram below in Figure 17. [12]

- The LCD pin 1, 5, 16 is connected to GND of Arduino
- The LCD pin 2, 15 is connected to 5V VCC of Arduino
- LCD pin 4, 6, 11, 12, 13, 14 is connected to Arduino pin 13, 12, 11, 10, 9, 8
- Use 10K Potentiometer at pin 3 of LCD to adjust the contrast of LCD.

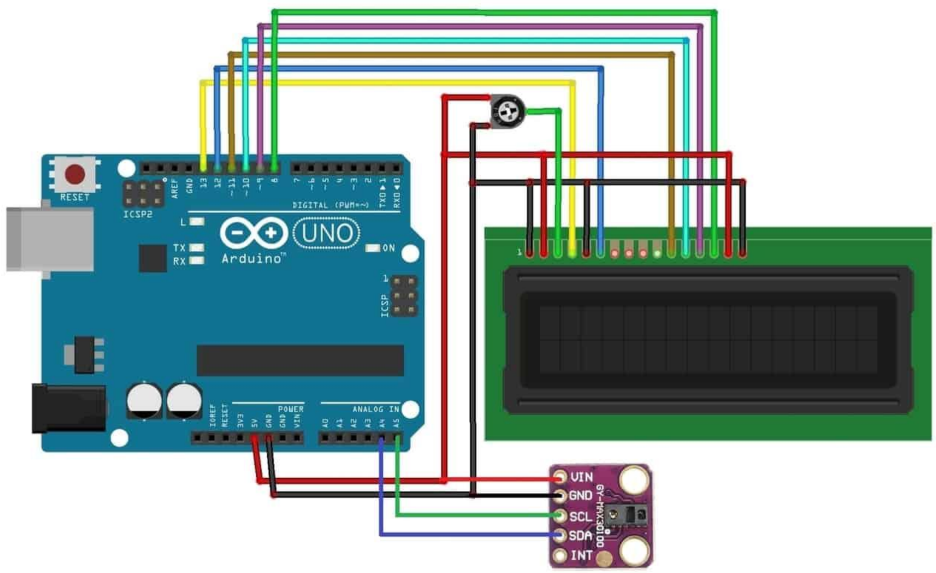

Figure 17: LCD interface with Arduino

3. MG996R servo Motor interface

The MG996R servo is used to move the arm to press on pump. Servo interface with Arduino is shown in the circuit diagram below in Figure 18. [13]

- The Servo VCC is connected to 5V power supply separated from Arduino as the current needed by the servo higher than that served by the Arduino that may cause damage to the Arduino or affect its performance.
- The Servo GND is connected to the common GND of the whole circuit
- The Servo control pin is connected to PWM pin of the Arduino

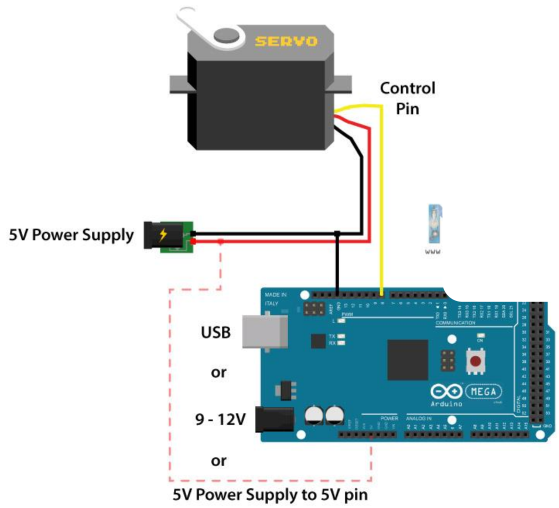

Figure 18: servo motor interface with Arduino

4. Circuit power

Arduino input power from 12V power source by using the same power source and voltage regulator 7805 to get 5V for the Servo motor using the below circuit shown in Figure 19. [14]

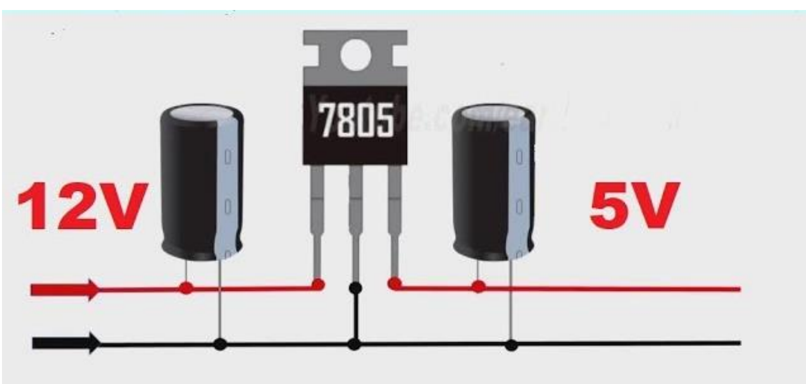

Figure 19: regulating circuit

Testing and Results:

After implementing of all setup and successful run of Arduino code operated several times to obtain result. Here is a video one of our team uploaded it on his account of Facebook on June 3, 2021 https://www.facebook.com/100001792488395/videos/3928632473873130/

And will be attached with the report.

Conclusion:

The COVID-19 pandemic has crippled healthcare infrastructures across the globe due to insufficient supplies of protective, diagnostic, and therapeutic equipment. Most notably, clinically-approved ventilator shortages have led to many preventable deaths. This shortage has motivated engineering communities to quickly mobilize and develop alternative solutions that could provide a last resort for patients who face triage. As part of this effort, the Vanderbilt Open-Source Ventilator was developed by a team of engineers, In our project we have designed and developed a ventilator to support COVID-19 patients. It is low cost, portable, light weight. Power requirement is very low.

Code:

```
#include<Servo.h>
#include <LiquidCrystal.h>
#include <Wire.h>
#include "MAX30100_PulseOximeter.h"

LiquidCrystallcd(13, 12, 11, 10, 9, 8);

#define REPORTING_PERIOD_MS     1000

PulseOximeter pox;
uint32_t tsLastReport = 0;

// Servo Initializtaion
int pos1 = 0;
Servo Servo1;

// LEDs & Buzzer Init
int LED7 = 7;
int LED4 = 4;
int Buzz = 3;

void onBeatDetected()
{
Serial.println("Beat!");
}

void setup()
{
Serial.begin(115200);
Serial.print("Initializing pulse oximeter..");
lcd.begin(16,2);
lcd.print("Initializing...");
```

```
delay(3000);
lcd.clear();

    // LEDs & Buzz
pinMode(LED7, OUTPUT);
pinMode(LED4, OUTPUT);
pinMode(Buzz, OUTPUT);

    // Servo
    Servo1.attach(5);
    Servo1.write(0);

    // Initialize the PulseOximeter instance
    // Failures are generally due to an improper I2C wiring, missing power supply
    // or wrong target chip
    if (!pox.begin()) {
Serial.println("FAILED");
for(;;);
    } else {
Serial.println("SUCCESS");
    }
pox.setIRLedCurrent(MAX30100_LED_CURR_7_6MA);

    // Register a callback for the beat detection
pox.setOnBeatDetectedCallback(onBeatDetected);
}

void loop()
{
while(1)
  {
    // Make sure to call update as fast as possible
pox.update();
    if (millis() - tsLastReport> REPORTING_PERIOD_MS) {
```

```
Serial.print("Heart rate:");
Serial.print(pox.getHeartRate());
Serial.print("bpm / SpO2:");
Serial.print(pox.getSpO2());
Serial.println("%");

lcd.clear();
lcd.setCursor(0,0);
lcd.print("BPM : ");
lcd.print(pox.getHeartRate());

    int o = pox.getSpO2();

lcd.setCursor(0,1);
lcd.print("SpO2: ");
lcd.print(o);

    if ( o<= 94)
    {
lcd.print("%  ----");

      if (pos1 == 0)
      {
        pos1 += 95;
        Servo1.write(pos1);
      }
      else
      {
        pos1 = 0;
        Servo1.write(pos1);
      }

digitalWrite(LED7, HIGH);
digitalWrite(LED4, LOW);
```

```
digitalWrite(Buzz,HIGH);


       }
       else
      {
        if (pos1 != 95)
        {
            pos1 = 95;
            Servo1.write(pos1);
         }
lcd.print("%  ~^~^");

digitalWrite(LED7, LOW);
digitalWrite(LED4, HIGH);

digitalWrite(Buzz,HIGH);
delay(60);
digitalWrite(Buzz,LOW);


      }
tsLastReport = millis();
    }
  }
} [6]
```

References

[1] [Online]. Available: https://www.webmd.com/lung/coronavirus-ventilators.

[2] [Online]. Available: https://www.bbc.com/news/health-52036948.

[3] [Online].Available:https://www.idsmed.com/news/how-does-a-ventilator-work_398.html.

[4] [Online].Available:https://www.medicinenet.com/what_is_bag_valve_mask_ventilation_bvm_used_for/article.htm.

[5] [Online]. Available: https://www.aedsuperstore.com/resources/ultimate-ambu-bag-faq/.

[6] [Online]. Available: https://www.youtube.com/watch?v=ZHcU50w9N8I&t=315s.

[7] [Online]. Available: https://how2electronics.com/interfacing-max30100-pulse-oximeter-sensor-arduino/.

[8] [Online]. Available: [Online]. Available: https://www.circuitstoday.com/interfacing-lcd-to-arduino..

[9] [Online]. Available: https://components101.com/motors/mg996r-servo-motor-datasheet.

[10] [Online]. Available: https://how2electronics.com/interfacing-max30100-pulse-oximeter-sensor-arduino/.

[11] [Online].Available:https://www.teachmemicro.com/max30100-arduino-heart-rate-sensor/.

[12] [Online].Available:https://how2electronics.com/interfacing-max30100-pulse-oximeter-sensor-arduino/.

[13] [Online].Available:https://www.instructables.com/Arduino-How-to-Control-Servo-Motor-With-Arduino/.

[14] [Online]. Available: https://www.youtube.com/watch?v=_fvhivDASAs.

[15] [Online]. Available: https://www.circuitstoday.com/interfacing-lcd-to-arduino.