IoT Based Air Quality Monitoring system-using ESP32

In this project, we are going to build an ESP32 Air Quality Monitoring System using Nova PM SDS011 sensor, MQ-7 sensor, and DHT11 sensor. We will also be using an OLED Display module to display Air Quality Values. The Air Quality Index (AQI) in India is based on eight pollutants, PM10, PM2.5, SO2 and NO2, CO, Ozone, NH3, and Pb. However, it is not necessary to measure all of the pollutants. So we are going to measure the concentration of PM2.5, PM10, and Carbon Monoxide to calculate the Air Quality Index. The AQI values will be published on Adafruit IO so that we can monitor it from anywhere. Previously we have also measured the concentration of LPG, Smoke, and Ammonia gas using Arduino.

Components Required

- ESP32
- Nova PM Sensor SDS011
- 0.96' SPI OLED Display Module
- DHT11 Sensor
- MQ-7 Sensor
- Jumper Wires

Nova PM Sensor SDS011 for Measuring PM2.5 and PM10

The SDS011 Sensor is a very recent Air Quality Sensor developed by Nova Fitness. It works on the principle of laser scattering and can get the particle concentration between 0.3 to 10µm in the air. This sensor consists of a small fan, air inlet valve, Laser diode, and photodiode. The air enters through the air inlet where a light source (Laser) illuminates the particles and the scattered light is transformed into a signal by a photodetector. These signals are then amplified and processed to get the particle concentration of PM2.5 and PM10. We previously used Nova PM Sensor with Arduino to calculate the concentration of PM10 & PM2.5.

SDS011 Sensor Specifications:

•Output: PM2.5, PM10

•Measuring Range: 0.0-999.9μg/m3

•Input Voltage: 4.7V to 5.3V

•Maximum Current: 100mA

•Sleep Current: 2mA

•Response Time: 1 second

•Serial Data Output Frequency: 1 time/second

•Particle Diameter Resolution:≤0.3μm

•Relative Error: 10%

•Temperature Range: -20~50°C

Basics of 0.96’ OLED Display Module:

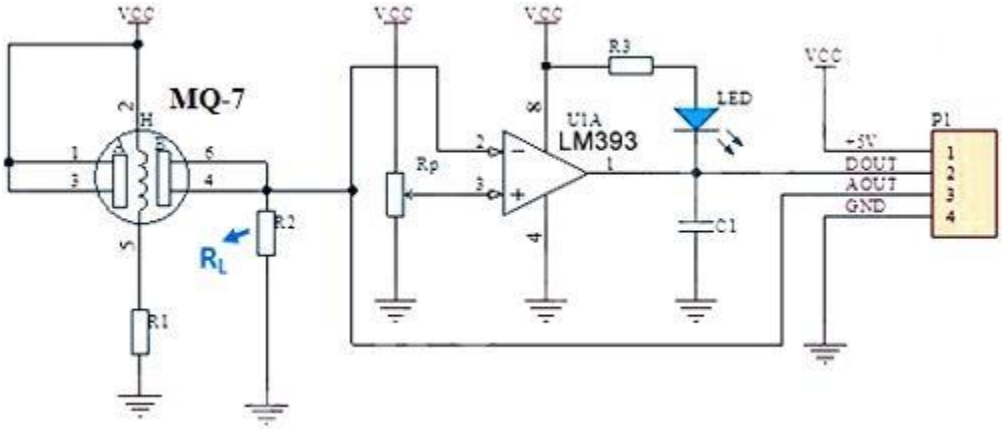
OLED (Organic Light Emitting Diode) is a kind of Light Emitting Diode that is made using organic compounds that excites when the electric current is allowed to flow through them. These organic compounds have their own light hence they don’t require any backlight circuitry like normal LCDs. Because of this reason, OLED display technology is power efficient and widely used in Televisions and other display products.

Various types of OLEDs are available in the market based on the color of the display, the number of pins, size, and controller IC. In this tutorial, we will use the Monochrome Blue 7-pin SSD1306 0.96” OLED module which is 128 pixels wide and 64 pixels long. This 7-pin OLED supports SPI protocol and controller IC SSD1306 helps the OLED to display the received characters.

Preparing the MQ-7 Sensor to Measure Carbon Monoxide (CO)

MQ-7 CO Carbon Monoxide Gas Sensor Module detects the concentrations of CO in the air. The sensor can measure concentrations of 10 to 10,000 ppm. MQ-7 sensor can either purchased as a module or just as a sensor alone. Previously we have used many different types of Gas sensors to detect and measure various gas, you can also check them out if you are interested. In this

project, we are using the MQ-7 sensor module to measure Carbon Monoxide concentration in PPM. The circuit diagram for the MQ-7 board is given below:



The load resistor RL plays a very Important role in making the sensor work. This resistor changes its resistance value according to the concentration of gas. The MQ-7 sensor board comes with a Load resistance of 1KΩ that is useless and affects the sensor readings. So to measure the appropriate CO concentration values, you have to replace the 1KΩ resistor with a 10KΩ resistor.

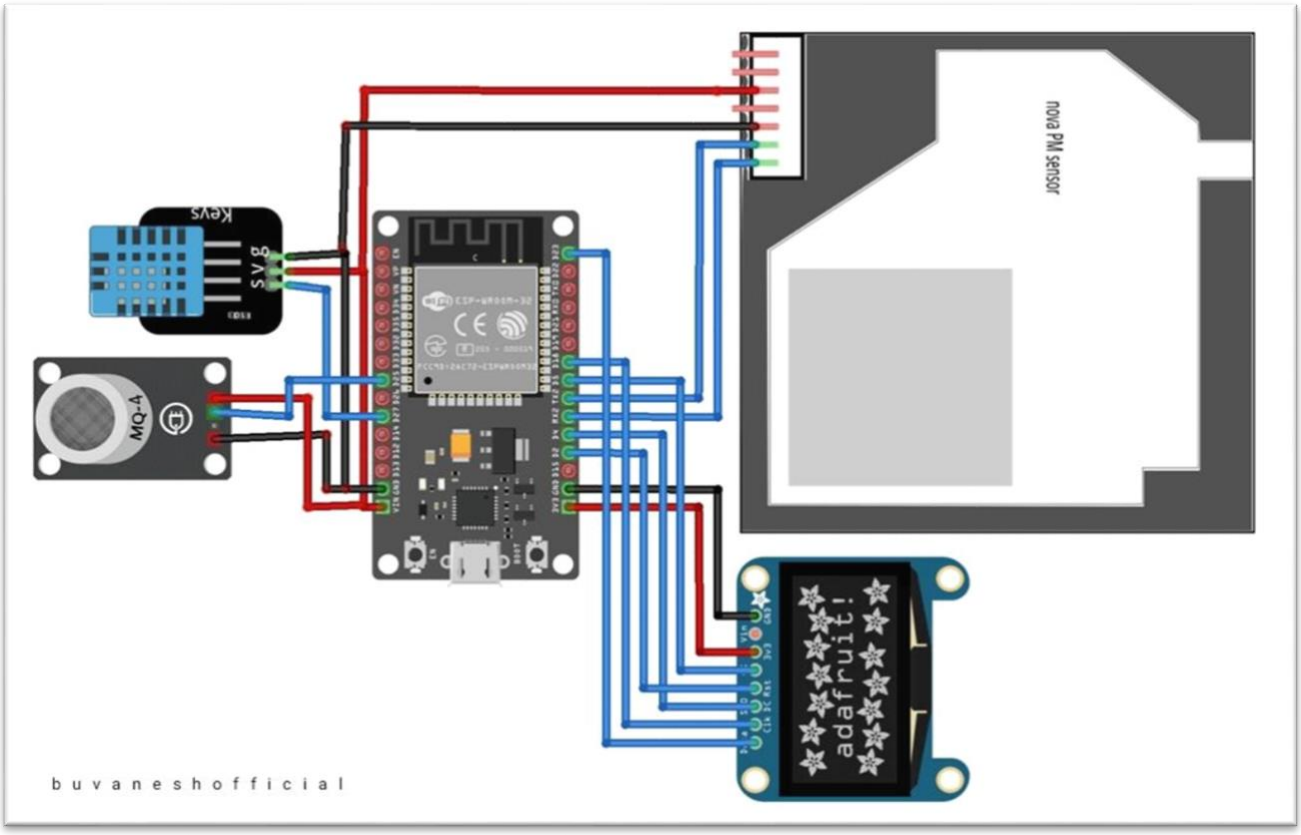
Air Quality Index Calculation

The AQI in India is calculated based on the average concentration of a particular pollutant measured over a standard time interval (24 hours for most pollutants, 8 hours for carbon monoxide and ozone). For example, the AQI for PM2.5 and PM10 is based on 24-hour average concentration and AQI for Carbon Monoxide is based on 8-hour average concentration). The AQI calculations include the eight pollutants that are PM10, PM2.5, Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2), Carbon Monoxide (CO), ground-level ozone (O3), Ammonia (NH3), and Lead (Pb). However, all of the pollutants are not measured at every location.

Based on the measured 24-hour ambient concentrations of a pollutant, a sub-index is calculated, which is a linear function of concentration (e.g. the sub-index for PM2.5 will be 51 at concentration 31 µg/m3, 100 at concentration 60 µg/m3, and 75 at a concentration of 45 µg/m3). The worst sub-index (or maximum of all parameters) determines the overall AQI.

Circuit Diagram

The circuit diagram for **IoT Based Air Quality Monitoring System** is very simple and given below:



SDS011 Sensor, DHT11, and MQ-7 sensor are powered with +5V while the OLED Display module is powered with 3.3V. The transmitter and Receiver pins of SDS011 are connected to GPIO16 & 17 of ESP32. The Analog Out pin of the MQ-7 sensor is connected to GPIO 25 and the data pin of the DHT11 sensor is connected to the GPIO27 sensor. Since the OLED Display module uses SPI

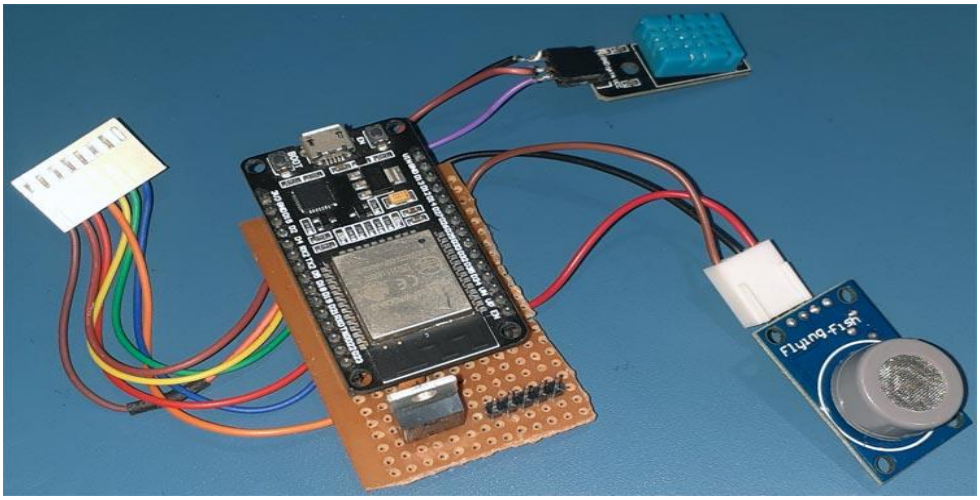
communication, we have established an SPI communication between the OLED module and ESP32. The connections are shown in the below table:

S.No	OLED Module Pin	ESP32 Pin
1	GND	Ground
2	VCC	5V
3	D0	18
4	D1	23
5	RES	2
6	DC	4
7	CS	5
S.No	SDS011 Pin	ESP32 Pin
1	5V	5V
2	GND	GND
3	RX	17
4	TX	16

S.No	DHT Pin	ESP32 Pin
1	Vcc	5V
2	GND	GND
3	Data	27
S.No	MQ-7 Pin	ESP32 Pin
1	Vcc	5V
2	GND	GND
3	A0	25

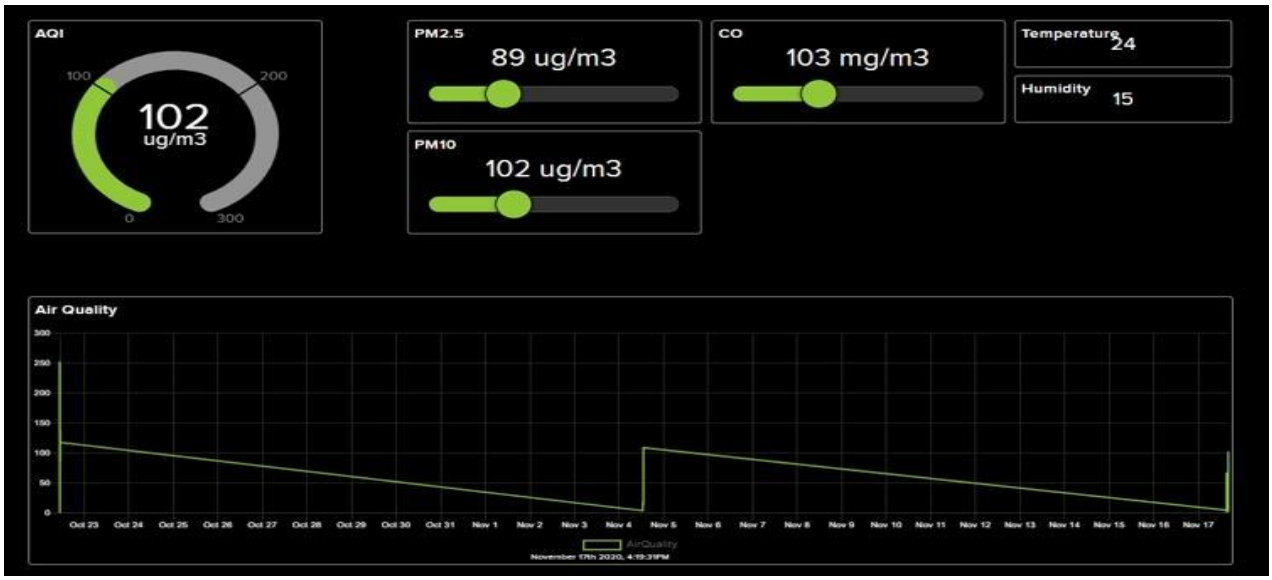
Building the Air Quality Monitoring System Circuit on Perf Board

As you can see from the main image, the idea was to use this circuit inside a 3D Printed Casing. So the complete circuit shown above is soldered onto a perf board. Make sure to use wires to leave enough distance to mount the OLED and Sensors. My perf board soldered to OLED and the sensor module is shown below.



Code Explanation for IoT Based Air Quality Index Monitoring System

The code uses the SDS011, Adafruit_GFX, Adafruit_SSD1306, Adafruit_MQTT, and DHT.h libraries. The SDS011, Adafruit_GFX, and Adafruit_SSD1306 libraries can be downloaded from the Library Manager in the Arduino IDE and install from there. For that, open the Arduino IDE and go to Sketch < Include Library < Manage Libraries. Now search for SDS011 and install the SDS Sensor library by R. Zschiegner.



Install the Adafruit GFX and Adafruit SSD1306 libraries by Adafruit. The Adafruit_MQTT.h and DHT11.h should be downloaded

After installing the libraries to Arduino IDE, start the code by including the needed libraries files.

```
#include <SDS011.h>
#include <SPI.h>
#include <WiFi.h>
#include “Adafruit_MQTT.h”
#include “Adafruit_MQTT_Client.h”
#include “DHT.h”
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
```

In the next lines, define the OLED display width and height. In this project, I have used a 128×64 SPI OLED display. You can change the SCREEN_WIDTH, and SCREEN_HEIGHT variables according to your display.

```
#define SCREEN_WIDTH 128
#define SCREEN_HEIGHT 64
```

Then define the SPI communication pins where OLED Display is connected.

```
#define OLED_MOSI 23
#define OLED_CLK 18
#define OLED_DC 4
#define OLED_CS 5
#define OLED_RESET 2
```

Then, create an instance for the Adafruit display with the width and height and SPI communication protocol that is defined earlier.

```
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, OLED_MOSI, OLED_CLK, OLED_DC, OLED_RESET, OLED_CS);
```

Then include the WiFi and Adafruit IO credentials that you copied from the Adafruit IO server. These will include the MQTT server, Port No, User Name, and AIO Key.

*Const char *ssid = “Galaxy-M20”;*

*const char *pass = “ac312124”;*

#define MQTT_SERV “io.adafruit.com”

#define MQTT_PORT 1883

#define MQTT_NAME “choudharyas”

#define MQTT_PASS “988c4e045ef64c1b9bc8b5bb7ef5f2d9”

Then set up the Adafruit IO feeds for storing the sensor data. In my case, I have defined six feeds to store different sensor data, namely: AirQuality, Temperature, Humidity, PM10, PM25, and CO.

Adafruit_MQTT_Client mqtt(&client, MQTT_SERV, MQTT_PORT, MQTT_NAME, MQTT_PASS);

Adafruit_MQTT_Publish AirQuality = Adafruit_MQTT_Publish(&mqtt,MQTT_NAME “/f/AirQuality”);

Adafruit_MQTT_Publish Temperature = Adafruit_MQTT_Publish(&mqtt,MQTT_NAME “/f/Temperature”);

Adafruit_MQTT_Publish Humidity = Adafruit_MQTT_Publish(&mqtt,MQTT_NAME “/f/Humidity”);

Adafruit_MQTT_Publish PM10 = Adafruit_MQTT_Publish(&mqtt,MQTT_NAME “/f/PM10”); Adafruit_MQTT_Publish PM25 = Adafruit_MQTT_Publish(&mqtt,MQTT_NAME “/f/PM25”); Adafruit_MQTT_Publish CO = Adafruit_MQTT_Publish(&mqtt,MQTT_NAME “/f/CO”);

Now inside the setup() function, initialize the Serial Monitor at a baud rate of 9600 for debugging purposes. Also Initialize the OLED display, DHT sensor, and SDS011 sensor with the begin() function.

Void setup()

{

my_sds.begin(16,17);

Serial.begin(9600);

dht.begin();

display.begin(SSD1306_SWITCHCAPVCC);

The for loop inside the setup function is used to collect the values up to a defined number and then set the counter to zero.

For (int thisReading1 = 0; thisReading1 < numReadingsPM10; thisReading1++) { readingsPM10[thisReading1] = 0;

}

Reading the Sensor Values:

Now inside the loop function, use the millis() method to read the sensor values in every one hour. Each of the gas sensors outputs an analog value from 0 to 4095. To convert this value into voltage, use the following equation: RvRo = MQ7Raw * (3.3 / 4095); where MQ7Raw is the analog value from the analog pin of the sensor. Also, read the PM2.5 and PM10 readings from the SDS011 sensor.

```
If ((unsigned long)(currentMillis – previousMillis) >= interval) {
 MQ7Raw = analogRead( iMQ7 );
RvRo = MQ7Raw * (3.3 / 4095);
MQ7ppm = 3.027*exp(1.0698*( RvRo ));
Serial.println(MQ7ppm);
error = my_sds.read(&p25,&p10);
        if (! Error) {
        Serial.println("P2.5: "+String(p25));
        Serial.println("P10: "+String(p10)); } }
```

Converting the Values:

The PM2.5 and PM10 values are already in µg/m3 but we need to convert the Carbon Monoxide values from PPM to mg/m3. The conversion formula is given below:

Concentration (mg/m3) = Concentration (PPM) × (Molecular Mass (g/mol) / Molar Volume (L))

Where: Molecular Mass of CO is 28.06 g/mol and Molar Volume is 24.45L at 25°C

```
ConcentrationINmgm3 = MQ7ppm* (28.06/24.45); Serial.println(ConcentrationINmgm3);
```

Calculating 24-Hour Average:

Then in the next lines, calculate the 24 hour average for PM10, PM2.5 reading, and 8 hour average for Carbon Monoxide readings. In the first line of code, take the current total and

subtract the first element in the array, now save this as the new total. Initially, it will be Zero. Then get the sensor values and add the current reading to the total and increase the number index. If the value of the index is equal to or greater than numReadings, then set the index back to zero.

```
totalPM10 = totalPM10 – readingsPM10[readIndexPM10];

readingsPM10[readIndexPM10] = p10;

totalPM10 = totalPM10 + readingsPM10[readIndexPM10];

readIndexPM10 = readIndexPM10 + 1;

if (readIndexPM10 >= numReadingsPM10) { readIndexPM10 = 0;

 }
```

Streaming online:

We should create a web platform to display the real time air quality data to the public. Steps to create a website. First we need to choose a hosting ,Choose the framework ,Create an architecture ,Buying a domain name, Adapting the product to devices and systems, Ensuring the security of the web platform, Choosing CMS And by using codes we can design a online platform for the air quality Monitoring. IoT devices share the sensor data they collect by connecting to an IoT gateway, which acts as a central hub where IoT devices can send data. Before the data is shared, it can also be sent to an edge device where that data is analyzed locally. Fir sharing transferring the data we need cellular or wifi and it takes more Gigabytes.