Compensation of Inherent Errors in Arduino and ESP System for various sensor reading

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Abstract:

The MQ-135 sensor has to be calibrated before taking any further measurements. Without the process, it will only give meaningless results. Two sources at known carbon dioxide (CO_2) concentration levels are required to achieve an accurate calibration result. In the data sheet it is suggested to calibrate the MQ-135 sensor for 10 ppm and 200 ppm. However, it is not easy for most users to get access to a reliable 200 ppm source, therefore; this study included the exhaled air as an alternative source which gives a second calibration point at 200 ppm. The value of the sensor resistance in clean air was practically calculated by connecting several different loads on the sensor, and the resistance of the sensor in clean air was calculated. The value of the sensor resistance we obtained was adopted in the PPM equation.

Keywords: MQ-135, sensor, calibration, resistance in clean air

Introduction:

The occurrence of diseases associated with poor ventilation has led to an increased interest in monitoring air quality. Indoor carbon dioxide (CO_2) concentration above 1,000 ppm is generally considered an indicator of an unacceptable ventilation rate. Various national guidelines give specifications for CO_2 concentration standards. It is classified into four categories:

Category	CO_2-level above level of outdoor air in ppm	
	Typical range	Default value
Special indoor air quality	≤400	350
High indoor air quality	400-600	500
Medium indoor air quality	600-1000	800
Low indoor air quality	>1000	1200

Carbon dioxide (CO_2) concentration should not exceed 1000 ppm and levels less than 800 ppm indicate adequate fresh air supply [1]. An increase in carbon dioxide (CO_2) in the air negatively affects brain activity and causes a number of vascular changes in the brain [2]. Inhalation of CO_2 also causes pneumonia, as carbon dioxide is an inflammatory substance [3]. When the CO_2 level reaches 7-10%, a person loses consciousness within a few minutes and may be at risk of death. It also causes dizziness and drowsiness, which leads to poor work performance [4]. In 2019, Goncalo Marques and others, divided indoor air quality, by measuring the proportion of CO_2 gas in the air, as CO_2 is an indicator of air quality, because of its ease of measurement, scalability, low cost, and ease of installation. The ESP8266 microcontroller with built-in Wi-Fi communication technology is used as a communication and processing unit and includes a CO_2 sensor as a sensing unit [5].

MQ-135 Sensor:

The MQ-135, air quality sensor, is part of the MQ gas sensors series, it is sensitive to multiple gases including Carbon dioxide (CO_2), Benzene, Acetone, Alcohol and Ammonium [6]. MQ-135 is shown in figure (1), It has four pins as output, VCC, DOUT, AOUT and GND as shown in figure (2).

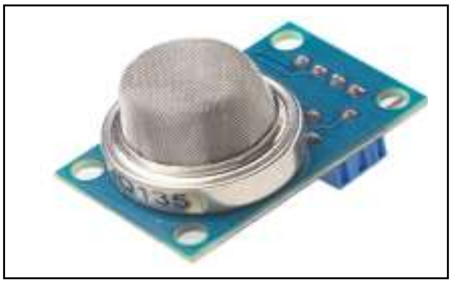


Figure (1) MQ-135 Sensor

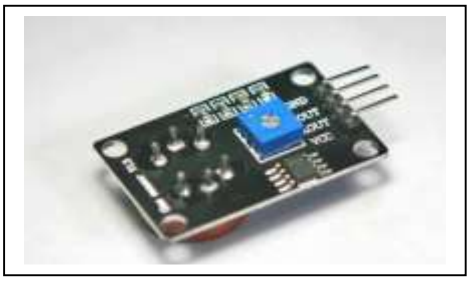


Figure (2) Pins Output

Equations (1,2,3,4) are describe the relation between RS, Ro and PPM derived from sensor's log-log curve shown in figure (3)

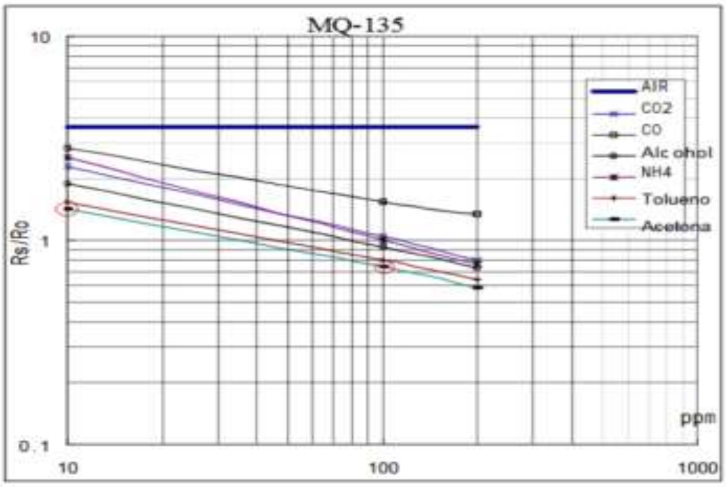


Figure (3) MQ-135 Sensor log-log curve

$$K = \frac{\log y2 - \log y1}{\log x2 - \log x1} \quad \text{………………………….. } (1)$$

$$K = \frac{\log 0.8 - \log 2.4}{\log 200 - \log 10} \quad \text{………………………….. } (2)$$

$$Y = \frac{y1}{(X1)^K} * (X)^K \quad \text{………………………….. } (3)$$

The equation now for getting the concentration in PPM for CO_2 is:

$$PPM = 109.56 * \left(\frac{RS}{R0}\right)^{-2.74} \quad \text{……… } (4)$$

Where, R_0 is the resistance of sensor in clean air, RS is the resistance of the MQ-135 when CO_2 is present.

Experimental and Results:

The system consists of an MQ-135 sensor, an ESP-32 microcontroller, and an Arduino Uno. The output of sensor is connected to the ESP and Arduino at the same moment, Then ESP and Arduino microcontroller were connected to the computer using the USB. The connection of MQ-135 sensor to Arduino Uno and ESP-32 microcontroller is shown in figure (4)

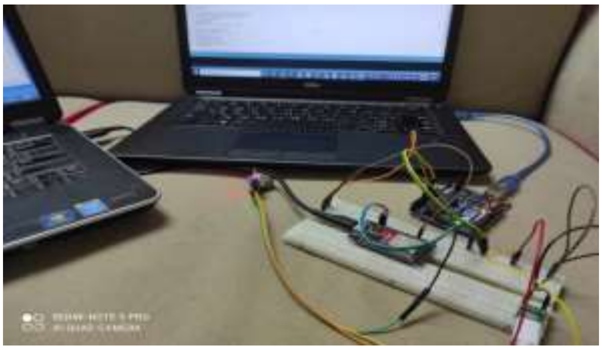


Figure (4) MQ-135 Sensor connects with Arduino Uno and ESP-32

The value of (R_0) was practically calculated, by connecting different loads on the sensor, as shown in figure (5). Then, the resistance of the sensor in clean air was calculated using equations (4) and (5).

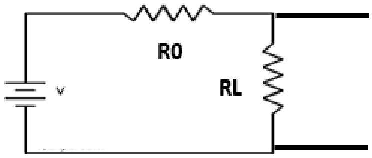
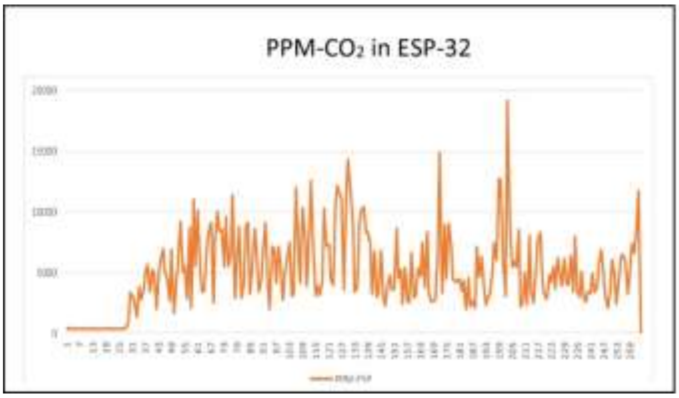


Figure (5) electrical circuit to calculate R_0

$$V0 = Vcc * \frac{RL}{RL+R0} \quad \text{……………} \ equation\ (4)$$

$$R0 = \frac{Vcc}{Vo}\ RL - RL \quad \text{……………} \ equation\ (5)$$

The average value of the sensor resistance in clean air obtained was 40 KΩ. The program was written in the Arduino IDE. Once the sensor is connected to power; it starts heating to aid the chemical reaction, when the surface temperature is high enough; the sensor will generate a potential difference which is equivalent to the concentration of carbon dioxide in the air. This lower voltage then needs to be amplified by applying relative equations so that it can be read. Carbon dioxide (CO_2) levels were recorded inside the mask as well as in clean air every two seconds. Figure (6) and (7) show the CO_2 level inside the mask in ESP-32 microcontroller and Arduino Uno respectively.



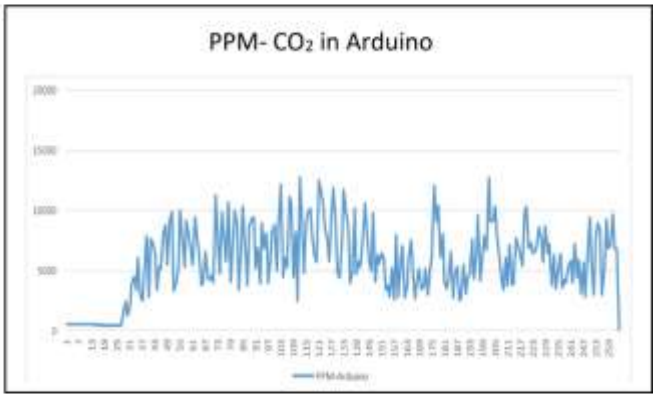
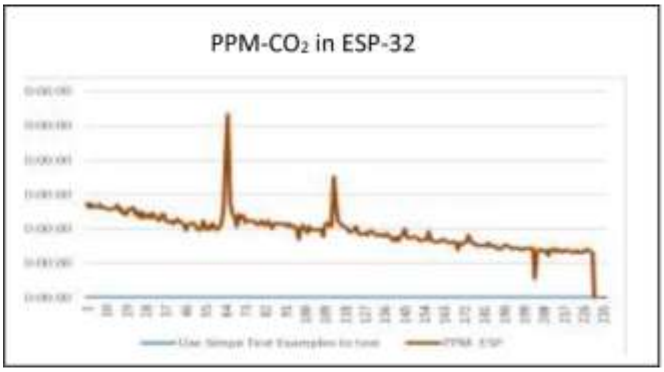


figure (6) CO_2 level inside the mask in ESP-32

figure (7) CO_2 level inside the mask in Arduino

Figure (8) and (9) show the CO_2 level in clean air in ESP-32 microcontroller and Arduino Uno respectively.



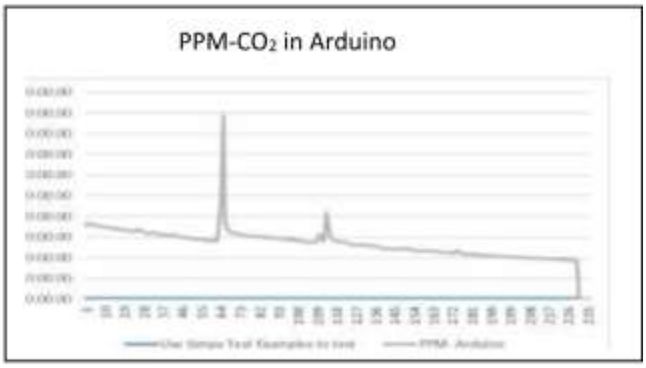


figure (8) CO_2 level in clean air in ESP-32

figure (9) CO_2 level in clean air in Arduino

Through the above results, there is an error in the value of the PPM and it needs to calibration. The drop in voltage from the source to the A/D pin in a certain amount; leads to a change in voltages, and thus a change in the PPM reading of the sensor. The voltages of the ESP and Arduino were measured with the sensor instantaneously, by dropping 6volt from a charged battery, and through a potentiometer; several different readings were obtained from the real voltages measured by voltmeter with the corresponding ESP and Arduino reading voltage. Table (1) and figure (10) shows the difference voltage between this reading.

voltemet	ESP	Arduino
0	0	0
0.16	0	0.06
0.26	0.09	0.15
0.4	0.2	0.33
0.87	0.73	0.71
0.91	0.71	0.75
1.04	0.86	0.87
1.36	1.23	1.15
1.44	1.3	1.23
1.65	1.46	1.42
1.73	1.64	1.47
2.14	2.04	1.86
2.25	2.17	1.93
2.75	2.74	2.38
3.14	3.28	2.75

Table (1) Difference voltage reading

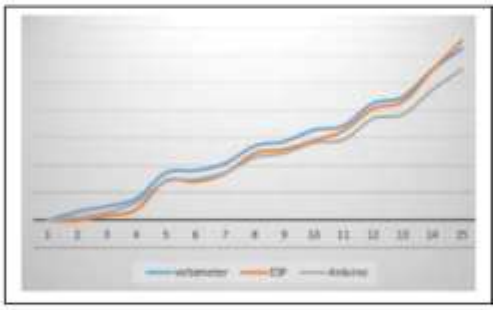


Figure (10) Difference voltage reading

The amount of voltage error between the reading of the voltmeter with the reading of the ESP and the Arduino volt is entered to curve fitting via Mat lab program. as shown in figure (11); curve fitting of ESP volt, figure (12) is a curve fitting of an Arduino volt.

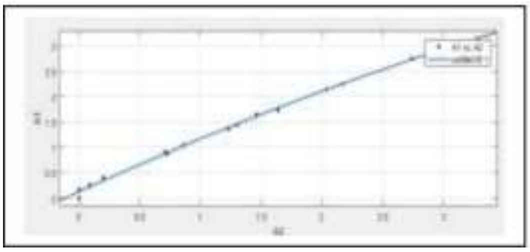


Figure (11) curve fitting for ESP

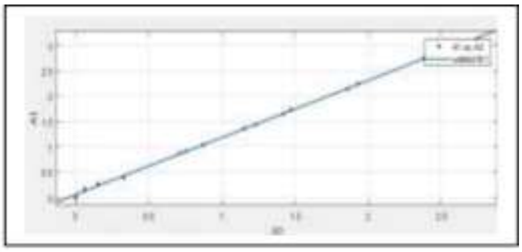


Figure (12) curve fitting for Arduino

The equation obtained from curves is:

$f(x) = P_1 * X^2 + P_2 * X + P_3$ …………….. (6)

$f(x) = P_1 * X + P_2$ …………….. (7)

Where equation (6) represents ESP-32 corrected volt, while equation (7) Arduino corrected volt. The PPM value of CO_2 inside the mask for ESP-32 and Arduino Uno according this corrected voltage is shown in figure (13), (14) respectively.

figure (13) CO_2 level inside the mask by ESP-32

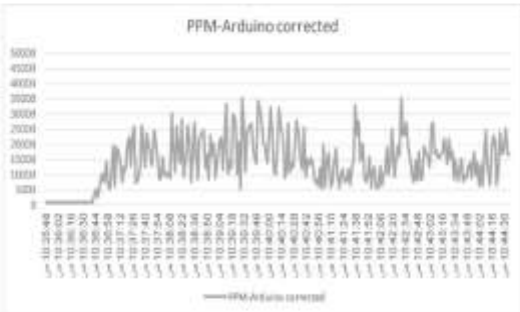


figure (14) CO_2 level inside the mask by Arduino

The PPM value of CO_2 in clean air for ESP-32 and Arduino Uno according the corrected voltage is shown in figure (15), (16) respectively.

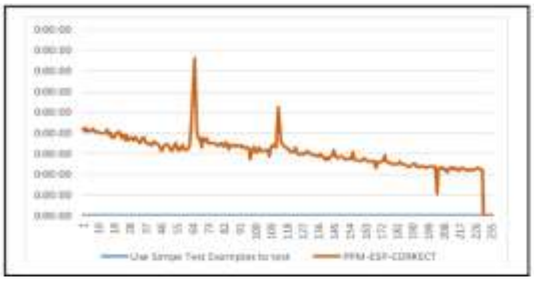


figure (15) CO_2 level in clean air by ESP-32

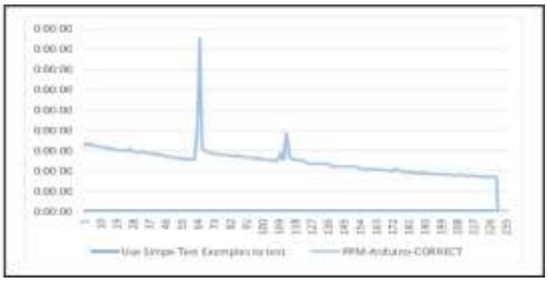


figure (16) CO_2 level in clean air by Arduino

The PPM value of CO_2 inside the mask for ESP-32 and Arduino Uno before and after corrected voltage is shown in figure (17), (18) respectively.

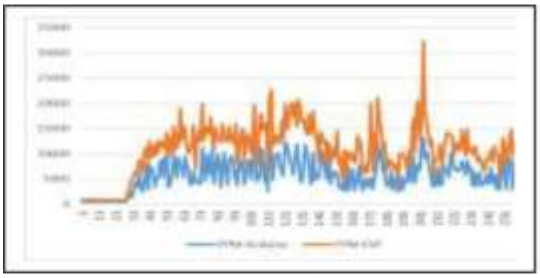


Figure (17) before correcting

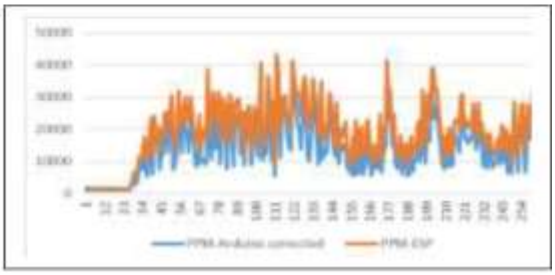


Figure (18) after correcting

Conclusions:

A prototype MQ-135 carbon dioxide air quality monitor is successfully constructed based on a proposed system design. The performance of the completed device is evaluated. Results of the operational testing show that the MQ-135 sensor is usable under room conditions and able to indicate the variation of CO2 concentration levels. Therefore, it can be concluded that the MQ-135 is a useful tool for estimating the air quality and ventilation rates. To give an overview of the project, the proposed MQ-135 carbon dioxide design has been proven to be both useful and practical. All components are affordable and easy to get while the construction is simple and can be accomplished in domestic environment. Nevertheless, sufficient efforts are expected to be put in device calibration, which is crucial to its final success and for the future of the device.

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