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# Design of an IoT based indoor air quality monitoring system

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## Abstract

Indoor air pollution is receiving widespread attention as it can endanger people's health. The advantage of ending indoor environmental monitoring is the detection and improvement of indoor air quality. However, many obstacles, such as high costs, must be overcome before implementing real-time monitoring systems. The proposed IoT system can sense the indoor air sense harmful gases present in the air such as $NH_3$ (Ammonia), NOx (Nitrogen Oxides), alcohol, Benzene, smoke, and $CO_2$ (Carbon Dioxide). The gas sensor detects the presence of the mentioned gases and its ppm will be uploading to an IoT platform through Wi-Fi. Collected sensor data were pre-processed and analysed using MATLAB. The result of the design is presented.

*Keywords: Internet of Things, Smart sensors, Air quality*

## 1. Introduction

Air pollution, both indoors and outdoors, is a major environmental health problem affecting people around the world. The level of air pollution is increasing rapidly due to factors such as industries, urbanization, increasing population, vehicle use, etc. As the world's population becomes more urban, cities are under pressure to maintain a liveable life. The harmful effects of contamination include mild allergic reactions such as inflammation of the throat, eyes and nose, as well as serious problems such as bronchitis, heart disease, pneumonia, lung disease and exacerbation of asthma. Indoor air pollution results in substantially harmful effects on human health. When the level of the containments increases beyond the permissible levels in the environment can affect various organs of the human body. People spend most of the day indoor and in an air-conditioned environment which has limited scope of fresh air circulation. Poor air quality in the workplace can affect the productivity of employees. Therefore it is important to know the quality of air-breathing. This can help to avoid polluted air as much as possible and take measures to clean the polluted air [1].

## 2. Indoor air quality quantification

There are many pollutants in the indoor air. For years, there has been debate over which indoor air quality index is most appropriate. Carbon dioxide ($CO_2$) is probably the most commonly used indicator for measuring carbon dioxide produced by human breathing and carbon dioxide emitted by devices such as gas stoves and boilers [2]. Other indicators are humidity and volatile organic compounds (VOCs), both of which are indicators of indoor air quality.

Carbon dioxide is a good indicator of indoor air quality in the workplace, where residents and their activities are the main source of pollution. Outdoor air contains about 400 ppm and breathing produces $CO_2$, so indoor $CO_2$ concentrations are always at least 400 ppm,

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usually higher. An indoor $CO_2$ concentration of 1150 ppm can provide adequate air quality; 1400 ppm can maintain good indoor air quality in most cases and 1600 ppm indicates poor air quality. $CO_2$ is the most appropriate indicator in a room where ventilation requirements are related to the presence of a person, e.g. work place [2].

Exposure to carbon dioxide can have a variety of health effects. Moderate to high levels of carbon dioxide can cause headaches and fatigue, and high levels of carbon dioxide can cause nausea, dizziness, and vomiting. Very high concentrations can cause loss of consciousness. These may include headaches, dizziness, restlessness, tingling or tingling, dyspnea, sweating, tiredness, and rapid heart rhythms [2].

## 3. Related Works

Pallavi Asthana and Sumita Mishra contributed to the design of an IoT-based real-time bolt-based indoor air quality monitoring system. In their job, they design a bolt-based Internet of Things (IoT) system to monitor basic pollutants such as carbon dioxide, carbon monoxide, and particulate matter in the indoor environment of a university campus in real time. IoT systems provide pollution level information directly to smart devices in real time. In this work, the author also proposed measures to improve air quality to improve student health. This can have a positive impact on their academic performance. The project monitors the air quality of Android's basic mobile system and sounds an alarm to alert you when the value is out of tolerance [3].

Srijana Chowdhury, Isha Das, Parisosh Bhuria and Balika J. Chelliah participated in the design of an IoT air pollution meter with a digital dashboard. In this project, we will explain and implement an air pollution meter. The innovations learned here are practical implementations of the IoT concept. This special task is exploring the possibilities of using this kind of innovation in a world where natural well-being is becoming a real risk. This task is implemented using a microcontroller board for Android, iOS, and Arduino. Two sensors, such as a temperature and humidity sensor and two gas sensors, are also used to filter changes [4].

In this project, authors used an IoT-based air pollution monitoring system to monitor air quality through a web server that uses the Internet. An alarm is triggered when the air quality drops to a certain level. This means that there are plenty of harmful gases in the air such as $CO_2$, smoke, alcohol, benzene, $NH_3$ and $NO_x$. PPM displays air quality on LCD and web pages for easy monitoring of air pollution. The system uses MQ135 and MQ6 sensors to monitor air quality. This is because it can detect the most harmful gases and accurately measure their amounts [5].

In this work, authors propose a model where a gadget will be joined to silencer of vehicles. Since vehicles discharge unsafe gases such as Carbon Monoxide (CO), carbon dioxide ($CO_2$) and so on which are the significant purposes behind contamination. In the event that contamination produced by that vehicle is more than edge esteem proprietor will be given an implication through a sensor. On the off chance that vehicle driver doesn't make any move even after two insinuations vehicle will be bolted by the gadget after 10 km and send points of interest of vehicles to RTO office [6].

Yamunathangam, K. Pritheka, P. Varuna contributed to design an IOT Enabled Air Pollution Monitoring and Awareness Creation System. The proposed system includes a design to monitor air pollution and raise public awareness. It aims to combine the use of the Internet of Things with cloud technology to drive services in real time and quickly. The proposed system is installed in certain areas with severe air pollution. Regularly monitor the level of each toxic pollutant. Raise public awareness through an Android application that determines the air quality index (AQI) of observed pollutants and displays the level of each pollutant observed and the air quality index for that particular location. Therefore, the general public can understand the air quality of the area by displaying the gas concentration in digital and graph formats. In addition, the system is extended by allowing the general public to register with the app. This pushes weekly or monthly air quality reports through messages that reach users in a more comfortable way. In this system it has used Arduino Uno board, Ethernet Shield, gas sensors and Thing Speak platform [7].

## 4. Design and Implementation

### *4.1 Design*

Figure 1 shows the system overview of proposed system. It used NodeMCU platform as the main microcontroller. It has an inbuilt ESP8266 Wi-Fi module. This is very easy to interface with sensors and also cost effective. MQ135 sensor was interfaced with NodeMCU and sensor data were uploaded in to the IoT server through a WiFi router. We used the power supply design proposed in [8]. Figure 2 shows the image of MQ135 sensor.

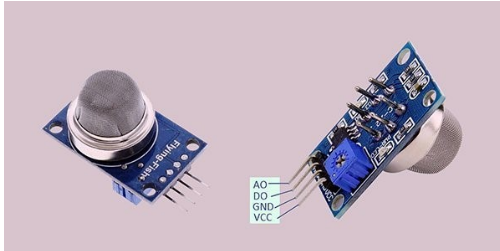


Figure 2: MQ135 Gas Sensor

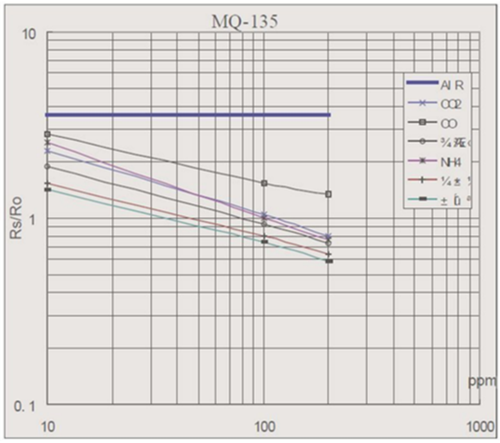


Figure 3: MQ135 Characteristics

### *4.2 Sensor Calbration*

Characteristics of MQ135 sensor is shown in figure 3. Typical sensitivity characteristics of the MQ135 gas sensor for several gases. The graph given shows the gas concentration in parts per million (ppm) based on the resistivity of the sensor. (Rs/Ro). Here, Rs is the resistance of the sensor that changes depending on the concentration of gas, whereas Ro is the resistance of the sensor at a known concentration without the presence of other gases, or in fresh air.

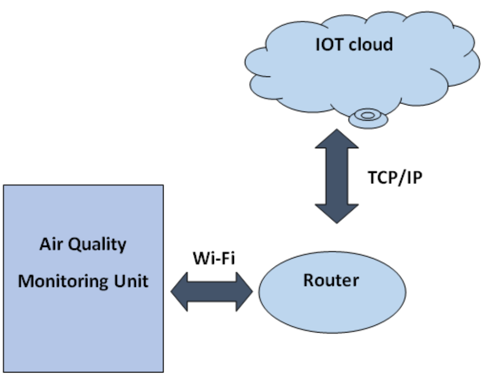


Figure 1: System Overview

The graph in figure 3 shows an exponential function for each gas. The x axis starts in 10 PPM and ends in 1000 PPM and the y axes starts in 0.1 and ends in 10 which it is basically the measured resistance from the analog output of the sensor over the resistance zero (Rs/Ro), provided by data sheet.

Resistance of the sensor can be found by using following formula where the value of Rs is calculated with reference to the value of the resistance in fresh air. Initially, sensor is calibrated to find the value for R0. This can be found by burning MQ135 for 24 hours in fresh air, approximately at 20-25 Celsius. Then check R0 value from serial monitor. When the value becomes stable it can be used as the R0 value.

$$Rs = \left(\frac{V_c}{V_{out}} - 1\right) \times RL \quad (1)$$

RL = 20 kΩ $V_c$ = Circuit voltage $V_{out}$ = Voltage corresponding to Analog Value provided by sensor.

After calculation of Rs, Rs/Ro can be determined. Ppm value can be measured by investigating the (Rs/Ro) v/s ppm graph taken from the MQ135 datasheet shown above. However after calibrating the sensor, the digitized value that is proportional to the concentration of gases in ppm can be directly obtained by correctly coding the microcontroller. Based on the graph in figure 3, The equation for a log-log graph can be written as,

$$y = a \times x^k \quad (2)$$

Where,
a = intercept of the graph
k = slope of the graph

Slope of log- log graph can be found as,

$$k = \frac{log(y2) - log(y1)}{log(x2) - log(x1)} \quad (3)$$

$$k = log\left(\frac{y2/y1}{x2/x1}\right) \quad (4)$$

X and y coordinates for each graph can be found by visually and coordinate for $CO_2$ is (10, 2.3), (200, 0.8).

Therefore using equation 3,

$$k = \frac{log(0.8) - log(2.3)}{log(200) - log(10)}$$

$$k = -0.3525$$

Equation 2 can be re-write as follows using x and y coordinates,

$$y = \left(\frac{y1}{x1^k}\right) \times x^k$$

By substituting the values in the above equation,

$$y = \left(\frac{2.3}{x1^{-0.3525}}\right) \times x^{-0.3525}$$

$$y = 5.1788 \times x^{-0.3525}$$

This equation can be re-arrange to make subject x,

$$x = 5.1788 \times y^{-2.83688}$$

Since the x axis of the graph represent ppm value and the y axis represent the Rs/Ro, above equation can be re-write as follows,

$$ppm = 106.19425 \times \left(\frac{Rs}{Ro}\right) - 2.83688$$

This method can be used for each gas in the graph and build the equation to calculate the ppm. This equation is needed to write the code for the sensor. In addition to this method power regression and correlation also can be used to get this equation

Figure 4: IoT Sensor Node

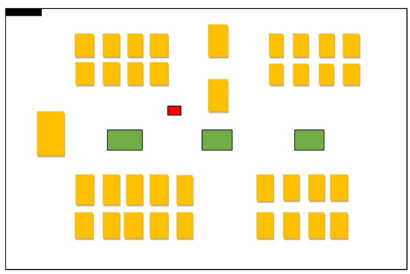

Figure 5: Floor diagram of the room

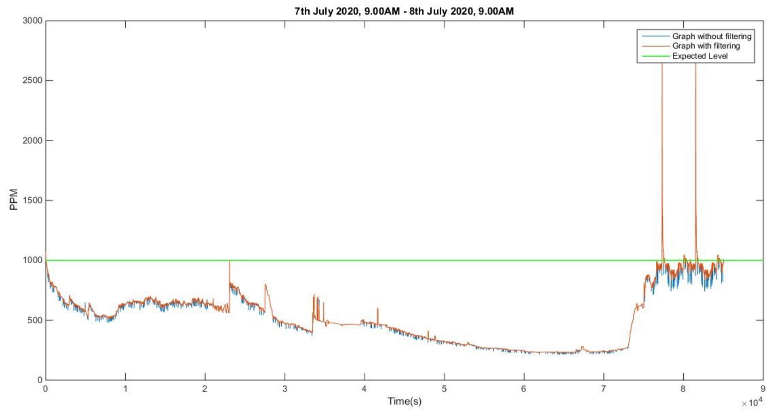


Figure 6: Time vs $CO_2$ ppm level –Day 1 (9:00am-5:00pm)

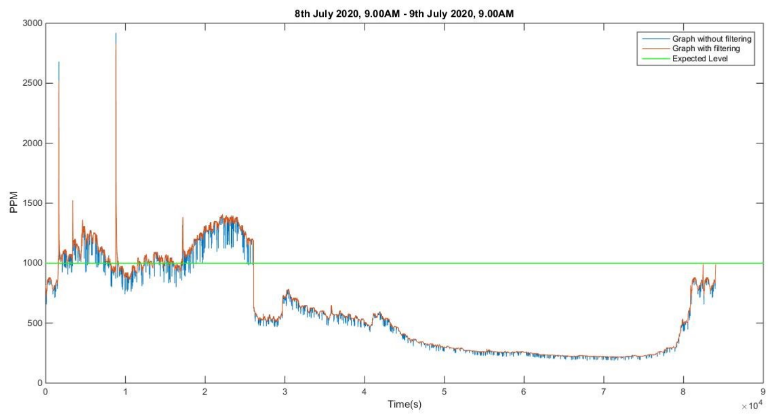


Figure 7: Time vs $CO_2$ ppm level –Day 2 (9:00am-5:00pm)

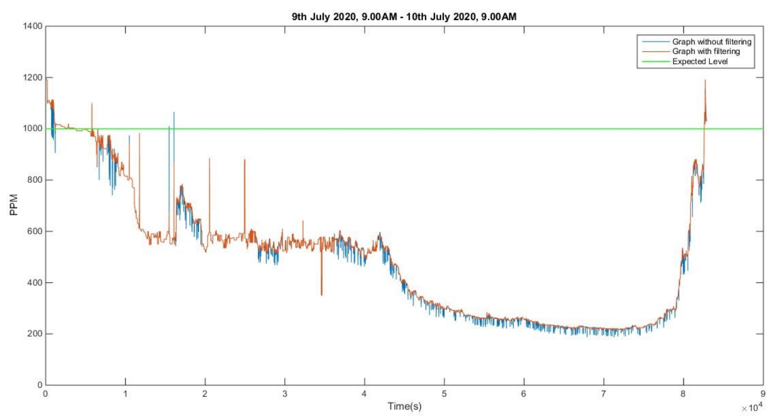


Figure 8: Time vs $CO_2$ ppm level –Day 3 (9:00am-5:00pm))

## 5. Testing and Results

According to the objectives of the project, the Indoor environment ppm of $CO_2$ level collected for 3 consecutive days. The air quality measuring unit was placed on the office floor which is 30 × 40 square feet closed room with no open windows and an average of 40-50 people working per day from 9:00am to 5:00pm in the room. The floor diagram of the room is shown below in figure 5 and where sensor node denotes in red color.

During the data pre-processing phase, data filtering techniques are used to remove periodic trends from the data for specific frequencies. A filter is a function that transforms one time series into another. By choosing the right filter, you can clarify or remove certain patterns in the original time series in the new series. For example, a low-pass filter removes high-frequency components and estimates slow-moving tendencies.

In figures 6,7 and 8, the graph in blue color is drawn with original data. Red color graph is after filtering. All the five graphs show a similar trend with variations. According to graphs ppm level is higher during the daytime when compared with the night time. Sensor takes about one hour to show true data for each day. Huge spikes were occurred due to accidently exposing the sensor to various gases such as hand sanitizer. However $CO_2$ level is within the limit of 1000 ppm which is the healthy indoor $CO_2$ level during most of time.

## 6. Conclusions

The purpose of this project is to design and develop an air quality monitoring system based on the Internet of Things. Air quality is a major issue facing people today. Factors such as industry, urbanization, population growth, and vehicle use pollute the indoor and outdoor air to a considerable extent. Inhaling polluted air affects people's health and causes many illnesses. In this project, we sensed the amount of carbon dioxide. The ppm levels of carbon dioxide were collected for 5 consecutive days and the results were presented. Daily carbon dioxide levels can change for the following reasons: the number of people in the area, the time the area is occupied by other items such as furniture, and the fresh outdoor air (ventilation) that enters the area.

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