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# Novel Architecture for Real-Time Air Pollution Detection and Monitoring for Industrial Applications

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**Abstract:** A novel architecture is proposed in the present paper for detection and monitoring of air pollution at real-time condition following industrial standard, embedded with gas sensors which are able to identify both organic as well as inorganic hazardous contents. A vis-à-vis comparative analysis is carried out with existing literature highlighting cons of most referred circuits, both in component, system and power consumption levels, and a generalized drawback is reported citing their inefficacy for real-time data collection and accuracy level. Detailed review is reported based on qualitative assessments also, and henceforth, justifies the significance of the proposed design; where not only higher ranges of detection are possible, however is also associated with lower power consumption (26.41% and 10.71% respectively compared to the two latest circuits) and finer detection of dust particles even at extremely low concentration. The architecture will help to implicate precautionary steps at real-time condition for controlling the harmful effect in Society.

**Keywords:** Accuracy level, Air pollution detection, Industrial standard, Organic pollutants, Real-time monitoring

## 1 Introduction

OWING to faster rate of urbanization and consequent rapid increase of both industrial waste and vehicle pollutants, air contamination now-a-days has evolved into a critical worldwide concern, causes serious respiratory illnesses to life-threatening diseases, leading premature mortality. Causes of the diseases are well-known, however, can't be stopped at the cost of slowing down the pace of civilization, and growth of industry. Consequently, real-time monitoring [1] and detection of hazardous contents [2] becomes extremely critical, which essentially follows the minimization of fatal outcome. Here lies the role of circuit design engineers for making the novel architecture with a prime requirement of achieving higher accuracy.

The best results will be obtained if your computer word-processor has several font sizes. IoT based systems have been proposed by several group of researchers for monitoring air quality embedded with various sensors, where each article has its own merits and demerits. Shinde [3] proposed wireless sensor network-based system that captures real-time data for vehicular emissions on air, and claimed the design as cost-effective. The work was further upgraded for detection of CO, $CO_2$, temperature, humidity, and also measuring air pressure [4]. Information is sent to IBM Bluemix Cloud for analysis, which can be remotely accessed by server. Different architecture was later proposed by other groups [5] with the advantage of measuring ppm as well as Wi-Fi connectivity. At the same time, other groups exhibited efficient mechanism for detection of organic contaminants [6] e.g., alcohol, benzene, and $NH_3$; and data will be generated in web server in real-time basis.

AI model is later invoked by Sajjan and Sharma [7] tackling the challenge of controlling toxic pollutants, facilitates practical monitoring of air contamination in specific areas. Mobile phone-based prompt alert system are also proposed in recent past [8] by analyzing air

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conditions in industrial areas. GSM based systems are also implemented for the same purpose [9], as reported elsewhere with similar architecture. Further works reported from other researchers emphasized need of detecting inorganic contaminants [10]. Barot [11] claimed for cost-efficient system, whereas Saini and his co-workers [12] pointed out the biomass fuel and inadequate ventilation as prime causes for health degradation.

It has been noted that in order to reduce complexity of the circuit and also for ease of implementation, less no of contaminants are detected [13] as proposed in a few years back, where in most cases, MQTT protocol is used [14]. Filtration is proposed very recently up to 0.3 µm [15], however, enhances cost of the composite system as it needs additional power supply. However, all the architectures, as proposed, are not fully in the industrial standard, and therefore, needs modification along with cost optimization for implementing robust, efficient system. The present work has substantiated the need and justifies with the novel design, which not only able to fetch data in real-time, but also can determine both inorganic and organic contaminants. Analysis is duly characterized by predictive accuracy, and therefore, validated the industrial standard.

## 2 Methodology of Detection

Generalized flow diagram for air quality monitoring is depicted in Fig 1, where sensor, controller and server connections are shown for successful data display. At first, sensors and controller will be initialized, and thereafter data are read from sensors, and displayed. Furthermore, once server is connected with controllers, and then data are sent to servers, and displayed for external world.

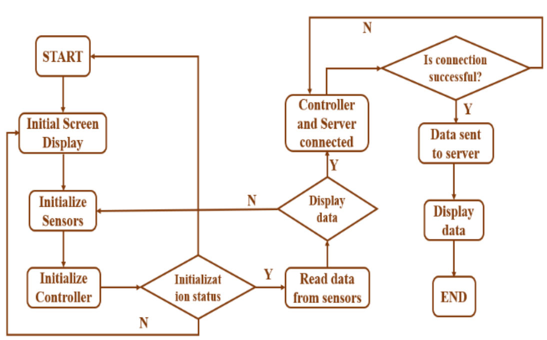


**Fig. 1** Generalized flow diagram for air quality monitoring

## 3 Limitations of Existing Circuits

Core of the fundamental circuit as described by earlier researchers [3-5] are shown in Fig 2, which consists of MQ135 sensor, and only two data pins $A_0$ and $D_0$. We nomenclature this method as method 1, for sake of identifying the output as obtained from this circuit. $A_0$ pin provides the concentration of the gases all at once e.g., Ammonia, Methane, $CO_2$, Benzene, Sulphide etc., but users cannot distinguish between gases. Moreover, MQ135 sensors can provide readings with a certain degree of accuracy, and data may vary based on factors like temperature and humidity, leading to potential inaccuracies. It often requires calibration to detect $CO_2$. Inaccuracy is also reported while detecting for higher concentration of gases.

As the sensor detects multiple gases at the same time the sensor's response to one gas may be influenced by the presence of other gases. This cross-sensitivity can lead to false readings or difficulties in accurately identifying specific gases in complex environments.

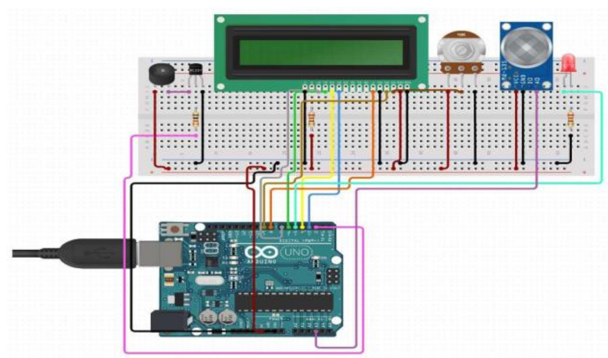

**Fig. 2** Fundamental circuit for organic and inorganic components detection in air, as described in method 1

Fig 2 and corresponding workflow as depicted in Fig 2A together exhibit operation of the circuit. After turning on the system, MQ135 sensor starts sending the data through a single analog wire to the Arduino. After processing with ADC, data is displayed in the 16x2 LCD display. Apart from that, obtained result is also compared with a trigger level for setting the threshold of the buzzer.

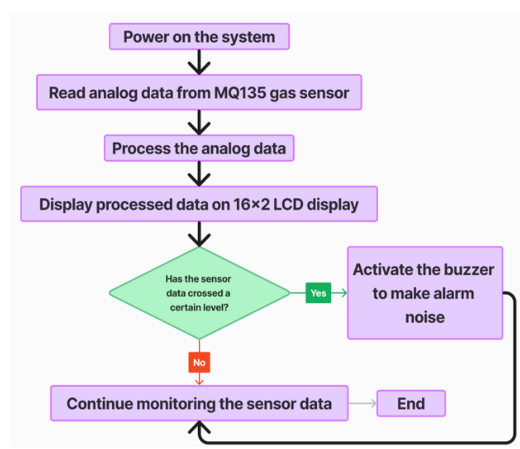


**Fig. 2A** Algorithm of Fig 2, obtained from method 1

Fig. 2 is modernized [6-8] by incorporation of additional components like PMS5003 for suspended dust particle measurement and BME280 for single point measurement of pressure, humidity and temperature. Circuit is represented in Fig 3, and nomenclature as method 2. However, despite PMS5003 being a well-built device, the entire device and the dust sensor lacks environmental protection and can get damaged in harsh conditions. Also, robustness of ESP8266 is comparatively less in severe atmospheric conditions, and therefore, reliability and accuracy suffer.

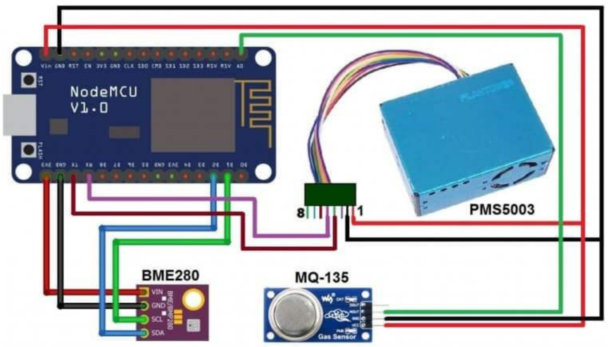


**Fig. 3** Modified architecture of Fig 2 for detection of gases and atmospheric parameters, described in method 2

Fig 3A describes that at the beginning, Node MCU is initialized takes place where the simple Wi-Fi web server is adjusted to establish the communication with sensor network. Here UART communication is made with PMS5003, I2C communication is set up with BME280 and analog communication is established with MQ135.

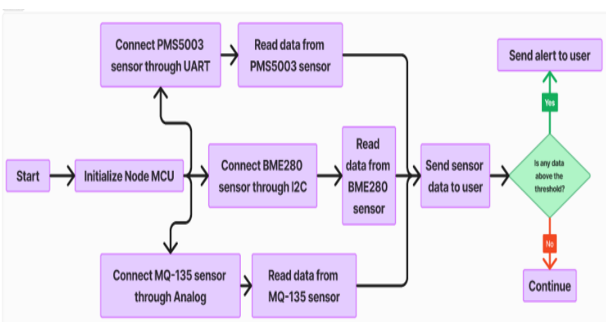


**Fig. 3A** Algorithm of Fig 3, as obtained using method 2

For further improvement, multiple gas sensors are introduced in the form of DH22, MH-Z19 and BME280, as shown in Fig 4. This is designated as method 3. DH22 measures temperature and humidity, MH-Z19 detects carbon dioxide, and BME280 measures air pressure, humidity etc. Though the later has better accuracy, but robustness of all the associated components are in question.

It is noteworthy to mention that the PMS7003 is the seventh generation of the PMSx003 series [16], while the PMS5003 is the fifth generation [17]. The PMS7003 is a late design (2016), 53% smaller, and uses less power than PMS5003.

After receiving all the data, these are compared with respect to certain threshold. If the data crosses the threshold, the sensor will alert the user. Finally, all the sensor data along with the alert if any is going to be send to user through Wi-Fi.

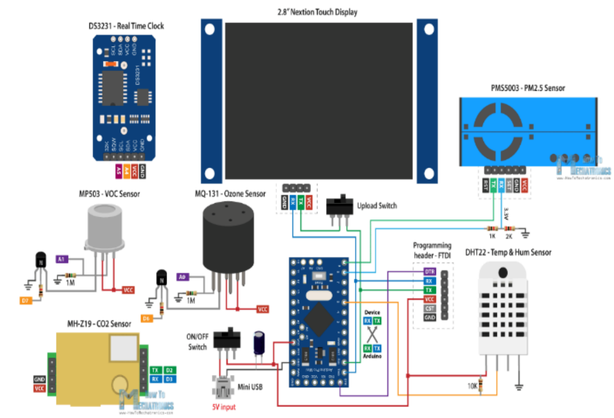


**Fig. 4** Air pollution monitoring with multiple gas sensors, described as method 3

Processing is initialized with Node MCU, and thereafter, display begins. The sensor communication needs to be established as all the 4 sensors have different communication method where the MH-Z19 and MP503 both uses UART communication, DHT22 uses one-Wire communication and MQ131 uses analog communication.

Again, after data is received, the pre-described methodology is adopted, and corresponding buzzer is activated. Finally, all the sensor data along with the alert if any and time from the RTC (Real time Clock) are send to the display.

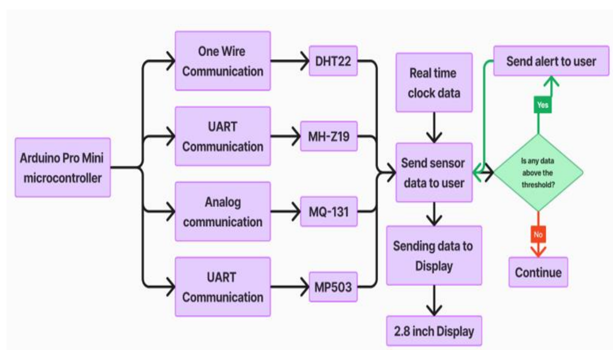


**Fig. 4A** Algorithm of Fig 4, obtained using method 3

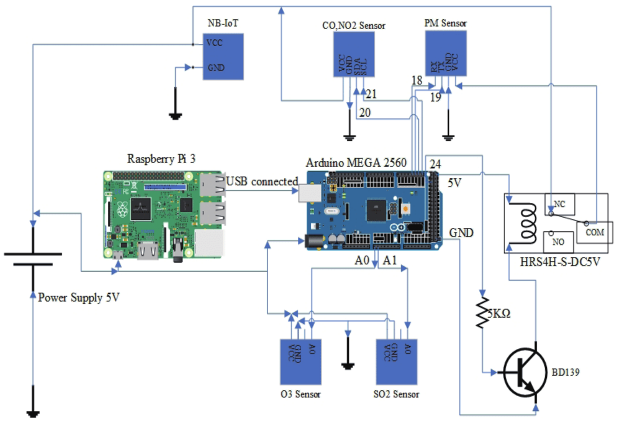


**Fig. 5** Modernized architecture for air pollution detection with raspberry pi

Design represented in Fig 4 is further modified in Fig 5, where Raspberry pi is invoked with array of sensors for detecting as many as gases and smoke [13-14]. This procedure is nomenclature as method 4. However, significant increase in power consumption and enlarged size speaks against portability. Moreover, it can't be embedded with drone owing to higher power requirement, and therefore, provides unnecessary complications. Added complexity arises due to the factor that all the transmitted data to the raspberry pi through USB is made serially, henceforth, serial terminals must be implemented to read the data and for long range applications. This is not reliable compared to other communication technologies such as RS485, CAN, RS232 etc.

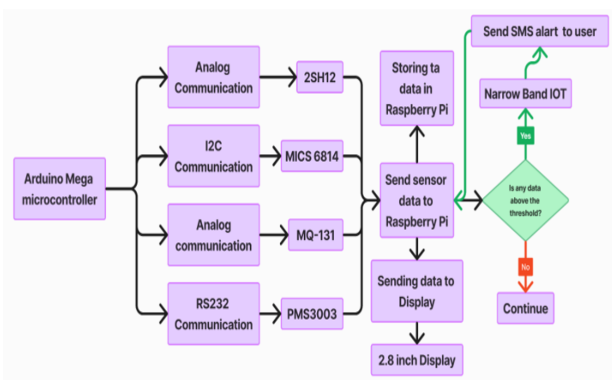


**Fig. 5A** Algorithm of Fig 5, obtained using method 4

In this case, sensor communication modes are different. 2SH12 and MQ-131 both uses Analog communication, MICS6814 uses I2C communication and PMS3003 uses RS232 communication. Rest of the things are quite similar, excluding the initialization of Raspberry Pi. Finally, all the sensor data along with the alert if any are sent to the Raspberry Pi through USB to get stored.

In general, major common part proposed in various literature [3-14] are the inaccuracy of gas sensors, and therefore, reliability also. This speaks against possible industrial implementations. A major alternative may include [i] electrochemical gas sensors (precisely for toxic gases), [ii] MOS gas sensor (higher stability and lower power consumption), [iii] photoionization detectors (PID) type gas sensor (able to detect volatile organic compounds over wider range), [iv] MEMS based Gas sensors (small size, low power consumption, high sensitivity, robustness).

In the next section, proposed architecture is discussed with its major pros compared with existing literature.

## 4 Proposed Design

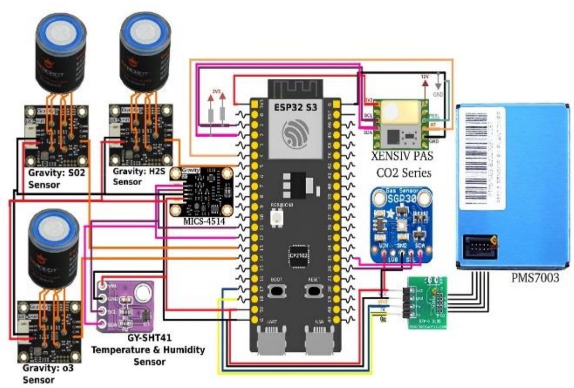


**Fig. 6** Proposed architecture for air pollution detection and monitoring with industry-standard sensors

The present architecture is exhibited in Fig 6 where non-standard gas sensors are replaced by electrochemical sensors in order to achieve higher accuracy at real-time condition, and also the added benefit of detection of toxic gases. Along with that, PIDs are used in industry for their ability to detect a wide range of volatile organic compounds (VOCs) and other hazardous gases with high sensitivity and accuracy.

In the proposed design, used sensors and their advantages are specified vis-à-vis comparative analysis with the previous circuits:

[i] Gravity $SO_2$: compared to 2SH12, which is semiconductor based $SO_2$ detector, the present one is an electrochemical gas detector which is more accurate and more sensitive.

[ii] GY-SHT41: more accurate with higher temperature range with higher response time and unlike BME280 which generates heat.

[iii] MICS 6814: used for gas detection in the system with a broader range of gases such as CO, $NO_2$, $NH_3$, $C_2H_5OH$, $CH_4$, $C_3H_8$, $C_4H_{10}$

[iv] MICS 4514: it is the same with a shorter list of detectable gases however, serves as better VOC (Volatile Organic Compounds) detector.

[v] XENSIV PAS CO2 SERIES: It has a detection range of 0 - 32000 ppm compared to lower range of 0-

5000 ppm for MH-Z19. This is used to detect $CO_2$ level.

[vi] Gravity O3: Being an electrochemical sensor, has higher accuracy than MQ131 and has detection range 0-10 ppm, therefore, can detect finer gases with very low concentration.

[vii] SGP30: SGP30 has a combined range of 0 - 60000 ppm for tVOCs, 0 - 1000 ppm for ethanol, 0 - 1000 ppm for $H_2$ and 400 - 60000 ppm for $CO_2$. It replaces MP503, having combined range of 0 - 1000 ppm.

Based on the circuit, it may be presumed that in terms of accuracy, sensitivity and even the functionally effective for lower concentration detection, the real-time detection will become more fruitful.

## 5 Results

A comparative analysis is carried out in real-time basis between performance of different circuits with our proposed one, for both organic, inorganic and dust particles.

Fig 7a shows the variation in detection of ammonia ($NH_3$), Fig 7b speaks for $CO_2$ detection and in Fig 7c, total volatile organic compound detection is represented. In each case, proposed circuit works far better than the earlier published architectures.

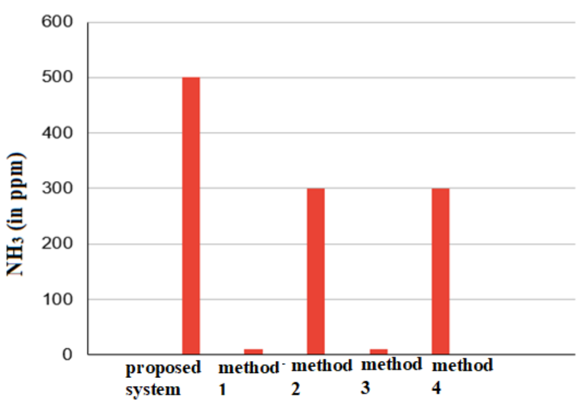


**Fig. 7a** Comparative study for ammonia ($NH_3$) detection

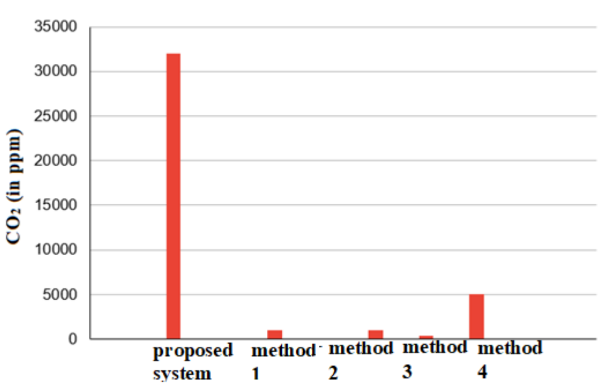


**Fig. 7b** Comparative study for carbon-di-oxide ($CO_2$) detection

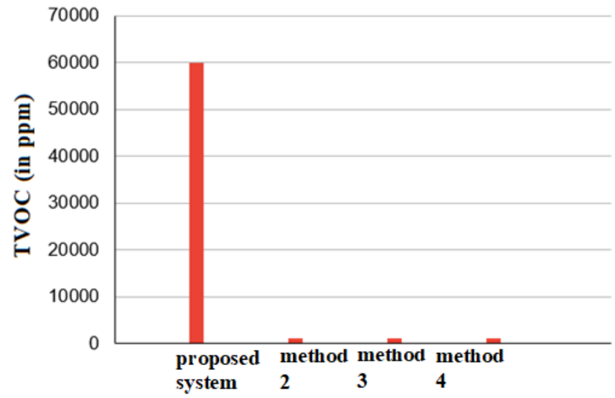


**Fig. 7c** Comparative study for TVOC (total volatile organic compound) detection

Detection of dust particles is also correlated with the power consumption. If higher power is consumed, the circuitry can't be associated with any UHV to judge the air standard where physical survey is impossible. As the major power is consumed by the dust sensor among others, therefore, it becomes essential to measure the power taken by the individual, and the need of type of microcontroller can also be determined through this analysis. Henceforth, lower range of detection of dust particles (even when the concentration is minutely small) as well as lower power consumption are simultaneously required. Data are represented in Fig 8a and Fig 8b respectively which together speaks in favor of the proposed design.

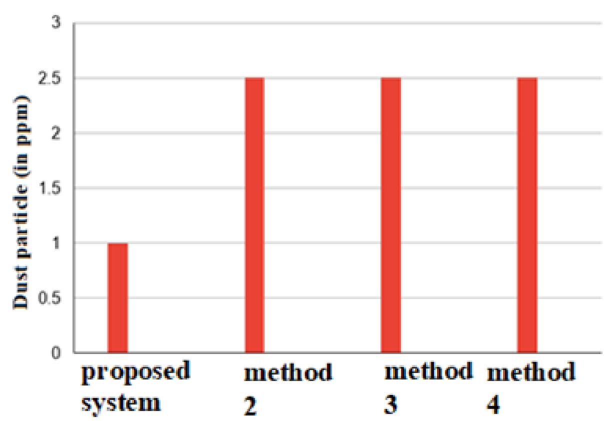


**Fig. 8a** Comparative study of lower ranges for dust particle detection

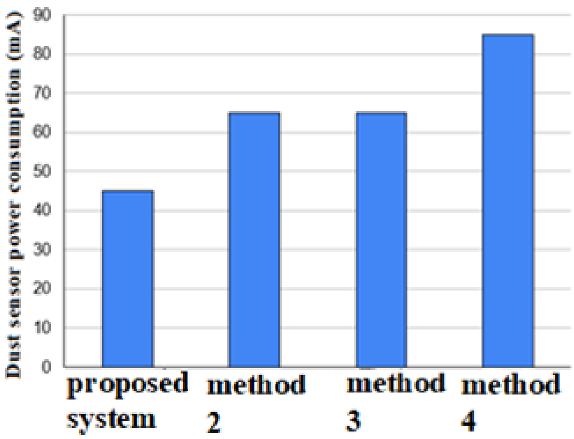


**Fig. 8b** Comparative study of power consumption by dust sensors

## 6 Discussion

Comparative study is carried out for the power consumption for all the circuits mentioned in the manuscript, and it has been found that very low power is consumed for the proposed circuit compared to those published in various literature considering the variety of features incorporated. This comparative study further substantiates our claim about superiority of the work, and henceforth, justifies the novelty of the outcome.

**Table. 1A** Power computation in Fig 2, using method 1

| Item | Voltage (Volt) | Current (mA) | Power (Watt) |
|---|---|---|---|
| Arduino Uno | 5 | 100 | 0.5 |
| 16x2 LCD display | 5 | 20 | 0.1 |
| MQ135 | 5 | 150 | 0.75 |
| Potentiometer | 5 | 5 | 0.025 |
| Total | | | 1.375 |

**Table. 1B** Power computation in Fig 3, using method 2

| Item | Voltage (Volt) | Current (mA) | Power (Watt) |
|---|---|---|---|
| ESP8266 | 5 | 80 | 0.4 |
| BME280 | 5 | 3.6×10-3 | 1.8×10-4 |
| MQ135 | 5 | 150 | 0.75 |
| PMS5003 | 5 | 100 | 0.5 |
| Total | | | 1.65 |

**Table. 1C** Power computation in Fig 4, using method 3

| Item | Voltage (Volt) | Current (mA) | Power (Watt) |
|---|---|---|---|
| Arduino pro mini | 5 | 40 | 0.2 |
| DHT22 | 5 | 1.5 | $1.8\times10^{-4}$ |
| MQ131 | 5 | 900 | 4.5 |
| PMS5003 | 5 | 100 | 0.5 |
| MP503 | 5 | 3000 | 1.5 |
| Nextion touch display | 5 | 65 | 0.325 |
| MP-Z19 | 5 | 80 | 0.4 |
| Total | | | 7.425 |

**Table. 1D** Power computation in Fig 5, using method 4

| Item | Voltage (Volt) | Current (mA) | Power (Watt) |
|---|---|---|---|
| Raspberry pi 3 | 5 | 1.5 | 7.5 |
| Arduino Mega | 5 | 250 | 1.25 |
| MQ131 | 5 | 900 | 4.5 |
| PMS5003 | 5 | 200 | 1 |
| MICS 6814 CO | 5 | 30 | 0.15 |
| MICS 6814 NO2 | 5 | 30 | 0.15 |
| 2SH12 SO2 | 5 | 750 | 3.75 |
| Total | | | 18.3 |

**Table. 1E** Power computation in Fig 6

| Item | Voltage (Volt) | Current (mA) | Power (Watt) |
|---|---|---|---|
| ESP32 -S3 | 5 | 250 | 0.8 |
| PMS7003 | 5 | 100 | 0.5 |
| XENSIN PAS $CO_2$ sensor | 5 | 50 | 0.25 |
| SGP30 | 5 | 48 | 0.24 |
| MICS 4514 | 5 | 5.92 | 0.296 |
| Gravity H2S | 5 | 5 | 0.025 |
| Gravity $SO_2$ | 5 | 5 | 0.025 |
| Gravity $O_3$ | 5 | 5 | 0.025 |
| Total | | | 1.961 |

Owing to incorporation of more features, the proposed circuit is more complex than those published in the literature. However, cost of the circuit is comparatively less due to usage of electrolyte capacitors. Therefore, a combination of the cost, power consumption and feature complexity give the edge of the present proposal.

## 7 Conclusion

The present architecture exhibits real-time detection and monitoring of air pollution by detecting both organic and inorganic contaminants, and even the dust particles; where all the detection are kept at industrial standard owing to the utilization of electrochemical sensors replacing conventional semiconductor sensors. From the comparative study of power consumption, it has been found that the proposed architecture draws 26.41% and 10.71% respectively compared with two latest literatures, and that clearly establishes novelty of this work. Higher detection value is observed for all the inorganic and organic undesired gases which are critical for survival. Even finer concentration detection becomes realizable through this circuit, which speaks in favor of its industrial utilization. All data can be accessed in real-time condition through server from remote places, and proper decision will help to survive the society, whenever desired.

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