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The Development of Air Quality Monitoring System

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Abstract: This paper presents about the development of automated monitoring device for environmental air pollutant detection. The main part of the device consists of a detector, microcontroller and timer circuit. The gas sensor TGS2600 were used to detect air contaminant level, in which the detection through the sensor measures in unit of part per million (ppm). A PIC Microcontroller 16F876A was utilized to convert the analogue signal from the sensor into digital signal which finally displays the result through the liquid crystal display (LCD). The timer circuit has been designed to help the main detector unit to operate automatically at a specific programmed interval of 30 minutes. This gives an advantage to the system where the developed device does not require manual operating from the user. In addition, a light emitting diode (LED) will be utilized to indicate the user whenever the level of air quality exceeds 100ppm. Alternatively a buzzer system was also fitted to furthermore alerting the user. In all, this air pollution device has been constructed in small size to be used as a portable unit to be employed as in-situ air quality measuring devices. It could be used in various places such as the teaching and learning laboratory, clean room facility, and also open area where monitoring of air quality are at great concern.

Keywords: air pollution, air quality, gas sensor

1.0 INTRODUCTION

Air pollution is when the introduction of chemicals, particulate matter or biological materials starts to contaminate the air where it may cause harm and discomfort to human being and other living organisms. It also damages the natural environment and the atmosphere. The World Health Organization (W.H.O) stated that 2.4 million people died each year directly attributed by air pollution, with 1.5 million of these deaths was attributable by indoor air pollution. The Air Quality Index (AQI) which also known as the Air Pollution Index (API) or Pollutant Standard Index (PSI) is a number used by many government agencies to characterize the quality of the air at a given location. As the AQI increases, an increasingly large percentage of the population is likely to experience the increases of severe adverse health effects.

In life, humans needs clean air to breathe. This is essential for all chemical reaction within the human body as well as all living creatures in order to continue the heredity of life. Without air, human and other creatures on earth will find that it is almost impossible to live on. This fact shows the importance of air which consists of 78% nitrogen, 21% oxygen while the balances were from the mixture of other gases. When the gas or the contents in the air are classified as polluted, humans will start encountering difficulties in terms of breathing. This will eventually lead to an immense type of problems such as diseases that rarely exist as a result of breathing from the polluted air. Seeing that this is happening, the awareness of having clean air has radically changed the perspective of having clean air where this invaluable gift has been taken for granted by humans before.

Modern sensing technologies to detect air pollution are based on remote sensing and Geographical Information System (GIS) technologies [1]. This technology has been used by environmental managers and local authorities to continually monitoring air quality in urban areas. Web based monitoring system had also been implemented for monitoring air pollution level within the environment [2,3]. This system is able to display the current air quality measurements to be monitored by the user at their home. Alternatively, air pollution level could also be monitored remotely based on wireless communication [4-6]. The data's were sent wirelessly to the remote central computer and stored in the central computer for further analysis. All these technologies are very complicated and require a workstation for monitoring air pollution level. This technology however, is not suitable to be applied in the designing of a small size, portable air quality monitoring device.

Recent trend in fabrication of smart gas sensing is based on single chip technologies [7-8], electronic noses [9-11] multi array sensor [6, 12] and many more. All these sensors show a good response with high selectivity of different gases. Although this technology provides completely remarkable gas sensor, the cost and the technology to produce the sensor is quite substantial and need to be considered. A reliable and cost effective sensor is always preferable to be used as a gadget in monitoring air pollution in environment.

In this project, Taguchi gas sensor, TGS2600 has been chosen as a gas detector due to the small size, high sensitivity and lower price compared to other gas sensor. This sensor is widely used in many applications such as in robotic machinery [13-14], smart extinguisher [15], aromatherapy sensing [16] and many more. The characteristic of this sensor has been compared with the newly developed sensor for benchmarking purposes [17]. This shows that the TGS2600 is a very reliable sensor for detecting air contaminant level in the environment. Thus, in this study the following sensor will be used as a sensing unit incorporated in the developed air pollution monitoring device. The practicability of this air pollution monitoring device will then be tested around the main campus of the Universiti Tun Hussein Onn Malaysia (UTHM), Johor, Malaysia.

2.0 METHODOLOGY

This section will exhibit the details of the circuit connections and the programming flow chart for the system development. Fig. 1 shows the block diagram of air quality monitoring system.

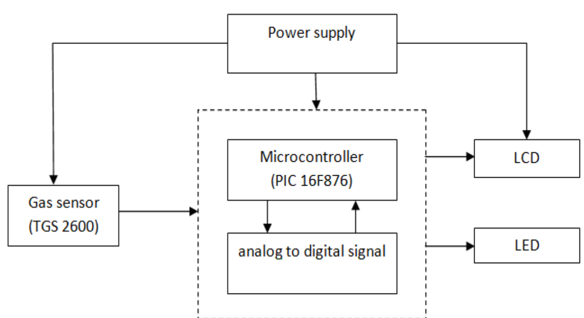

Fig. 1 Block diagram for the developed device

Power supply circuitry is an important circuit which supplies the required power for the developed entire system. In this study, the supplied voltage for the entire system is only 5V. Next, the gas sensor (TGS 2600) was employed to detect the air pollution level in ppm unit. The output from the sensor is displayed as analogue-voltage where this signal will first need to be converted to digital signal via PIC 16F876 microcontroller where the results will finally be displayed by the LCD. The LED was set to be lighted (ON) if the air contaminant level exceeds 100ppm to indicate the air in the area has been polluted. The timer circuit was designed to emit signal to the controller system to acquire the signal from the gas sensor for every 30 minutes interval. The system will be automatically reset and ready to collect a new set of data after every 30 minutes. Fig. 2 and Fig. 3 shows the operational block diagram for the timer circuit and detector circuit respectively.

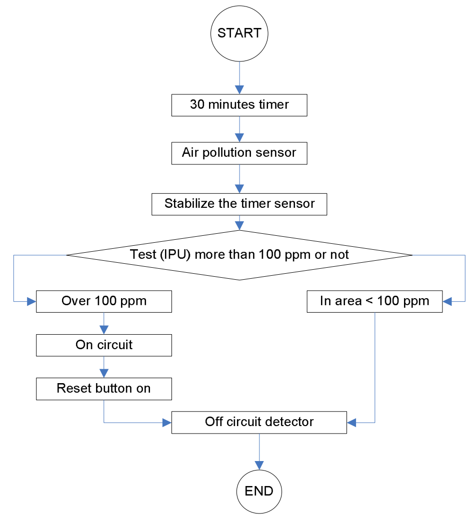

Fig. 2 Flow chart of the timer circuit

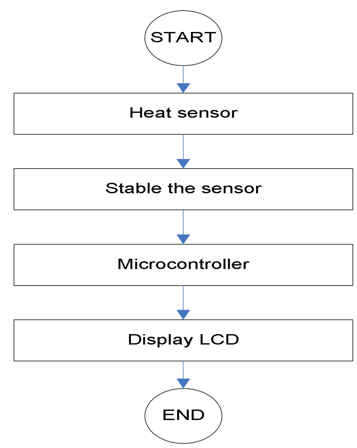

Fig. 3 Flow chart for the detector circuit

Fig. 4 shows the controller circuit for gas sensor detection and the circuit were designed and simulated using Proteus software.

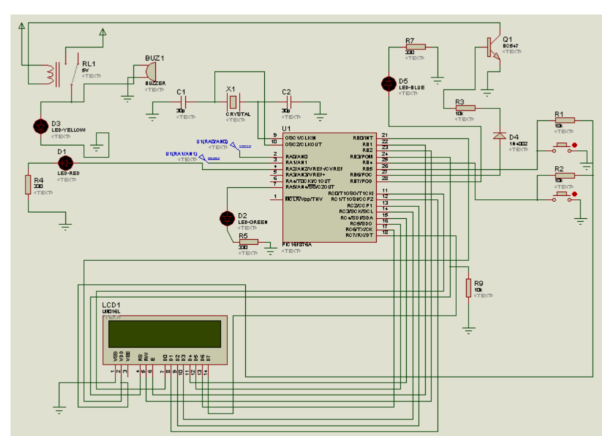

Fig. 4 The overall circuit diagram for air quality monitoring device

The Proteus software also contained the features to convert the schematic diagram to a PCB layout. Fig. 5 shows the PCB layout after the designed circuit has been successfully simulated.

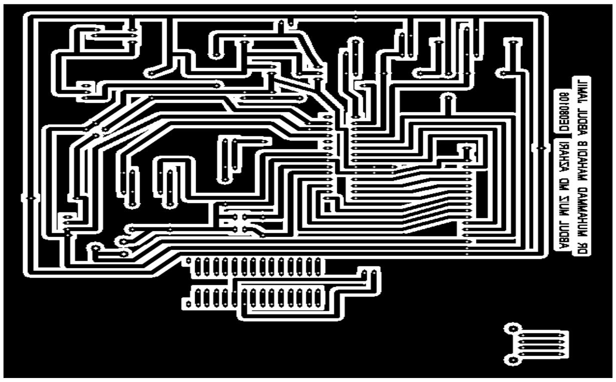

Fig. 5 PCB circuitry layout

The next step is to conduct the testing of the device performances at different location. Five different locations were selected which are the UTHM main entrance gate, Clean Room Laboratory, Medical Electronic Laboratory, Printed Circuit Board (PCB) Laboratory and Advance PCB Laboratory.

3.0 RESULT AND ANALYSIS

This section discusses the result gained from the stability gas sensor testing and the data of air quality level measured at the selected location.

3.1 The Stability of gas sensors test

In this project, TGS2600 gas sensor was utilized to measure the air pollution index. The gas sensor requires two input voltage, named as V_h and V_c. The V_h voltage is used for stabilizing the heating element at a specific temperature which is optimal for sensing while the V_c voltage is applied to allow measurement of voltage (V_{out}) across a load resistor (RL) which is connected in series with the sensor. The testing was conducted in order to determine sensor response time against Index Pollution Unit (IPU) level. Fig. 6 shows the experimental result.

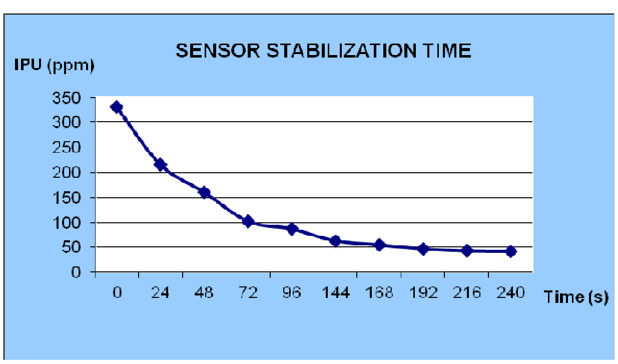

Fig. 6 Graph showing heating element stabilization time

The graph in Fig. 6 shows that the IPU values have decreased gradually until it reaches a stable level. At this point, the air pollution index can be acquired by the data logger as a valid data. From Fig. 6, it shows that the heating element was stable when the time is greater than 180 seconds.

3.2 Result on air quality level at several locations

The performance of the device was tested at different location to investigate the air quality level in the different area. The first location chosen was at the UTHM main entrance gate. The test was carried out on the 24th March 2011 starting from 7.30 am until 10.30 pm. 6 samples of the data's were collected during this experiment. The duration for each data samples collected was set for half an hour with the interval of 5 minutes.

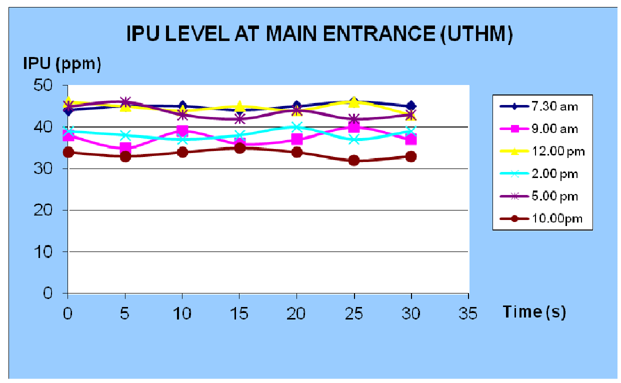

Fig. 7 Graph showing IPU level at the main entrance gate

As shown in Fig. 7, the air pollution index was unstable due to the unbalanced condition of the testing area. The air contamination at this area was mainly contributed from the smoke and dust from the vehicle that past through the main gate. The peak hours for traffic are in the early morning at 7.30a.m, afternoon break hours 12.00pm and in the late evening at 5.00pm. During this time, the pollution index was found to be around 45 ppm compared to lower traffic hour which is at 9.00am and 10 pm whereas the pollution index was found to be around 33 ppm. Other than that, reasonably high at 2.00pm where this could due to people returning from their afternoon break. These results show that the higher number of vehicles that passes through the main gate has greatly resulted to higher level of air pollution.

The second location to evaluate the device performance is by placing it at Microelectronic Clean Room laboratory. The experiments were conducted to ensure that the device is able to give response in the clean room area. The experiment was carried out on the 25th March 2011 at 3.00 pm. In this experiment, data's were collected at the interval of 3 minutes. Fig. 8 show the acquired data of air pollution index in Microelectronic Clean Room laboratory.

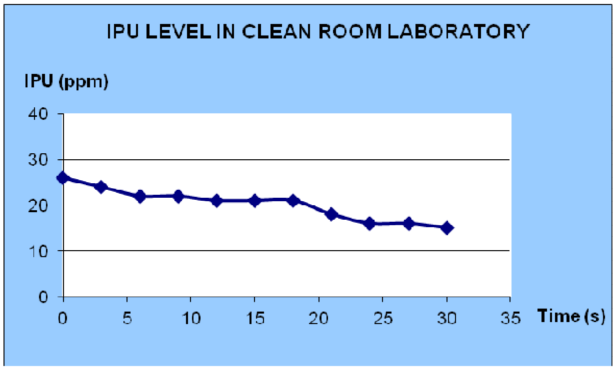

Fig. 8 IPU level for Clean Room Laboratory

As shown in Fig. 8, the IPU index was found slightly decreased against time. The data can be plotted as a linear equation, $y = 0.342x + 25.31$ with the variance value is 0.938. The unstable condition shows that the gas sensor could potentially senses some evaporation of chemical which have been used in the clean room area. This particular lab was used by students performing experimental work using chemical inside the clean room area resulting chemical evaporation thus, the unstable readings or condition of the IPU, the average data was calculated as follow:

$$\text{Average: } \frac{26+24+22+22+21+21+21+18+16+16+15}{11}$$

$$: 20.18 \text{ ppm}$$

Nevertheless, the average value of air pollution index in a clean room is 20.18 ppm. This was as expected since the clean room should maintain its dust free clean area for the kind of experimental work performed within this lab that requires cleanliness or dust-free environment.

After that, the device performance has been tested inside the Medical Electronic Laboratory on the 24th March 2011. The experiment starts at 3.40 pm. Again, data were collected with time interval of 3 minutes. Fig. 9 shows the result of the experiment.

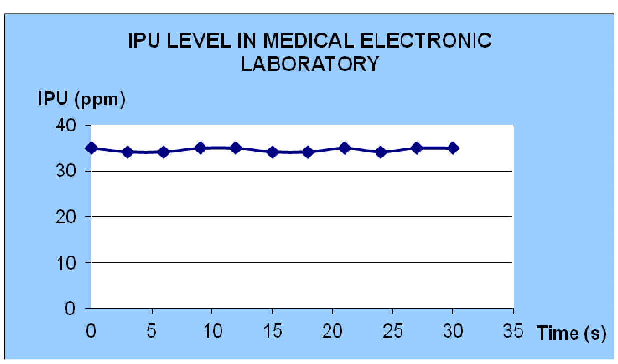

Fig. 9 IPU level recorded for Medical Electronic Laboratory

The result shows that the IPU index within Medical Electronic laboratory is in stable condition with the average readings of 34.5 ppm. This shows that there are no other conditions or resources which could potentially contribute to the increment of air pollution index level within this room.

Next, PCB laboratory is the last location to verify the device performance. The experiment was carried out at two different location of PCB laboratory. The first location was in PCB laboratory while the second location was in the Advanced PCB laboratory. The differences between these two locations are the amount of the laboratory usage. Higher number of users was found at the Advanced PCB laboratory compared to the PCB laboratory. Indirectly, this will increase the amount of experimental work performed within this labs thus, increasing the amount of chemicals that being used for each PCB development operations. The duration of the measurement was set at half an hour with readings taken at regular intervals of every 3 minutes. Fig. 10 and Fig. 11 show the result of IPU index in PCB laboratory and Advanced PCB laboratory respectively.

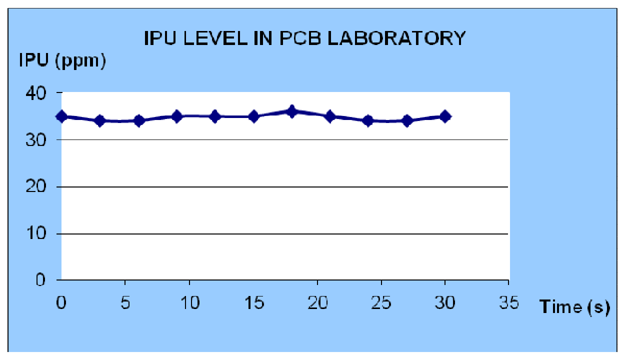

Fig. 10 IPU level for PCB Laboratory

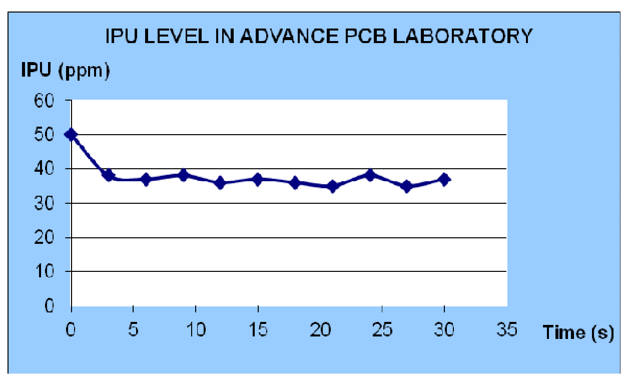

Fig. 11 IPU level for Advance PCB laboratory

The result demonstrates that the IPU level inside the Advanced PCB laboratory was found higher than the IPU level inside the PCB laboratory. The average values for the IPU index obtained for the Advanced PCB laboratory is 37.91 ppm while 34.73 ppm for the PCB laboratory. These result shows that higher amount of users have affected on the environmental condition inside the PCB laboratory. As the user increases, the amount of chemical used also increases. Potentially, the pollution level that can be detected by the sensor has also increased. These were in line with the previous tests conducted in other labs and also the specific chosen location in this study.

4.0 CONCLUSION

Although his device has been designed in compact scale to be used as portable device, it exhibits extraordinary capabilities. In this study we have chosen five different locations to demonstrate the effectiveness of this developed system. For example, the main entrance location was selected because it has its own peak and off-peak hours during traffic inwards and outwards movements to the university area. The Clean Room Lab was selected due to its controlled clean area. Then, followed by the PCB Lab due to its involvement with chemicals and Medical Electronic Lab for comparisons purposes.

Based on the experimental results gained, it shows that the device is capable to operate in various locations and has the ability to sense the air pollution index within different environment. The result shows that the average value for each testing location was found below than 40 ppm. These results indicate that all the testing areas are safe from air pollutant and exhibits excellent condition for living and studying. As a conclusion, this device has been found to be very useful for monitoring air pollution index and could be considered as an important gadget as one of household appliance to detect the air pollution around ones living area.

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