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sbRIO Lab-On-Chip Gas Sensing and Monitoring for Multisensory Array

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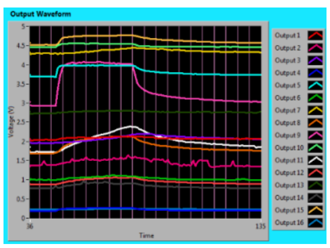
Graphical abstract



Abstract

It is utmost to create a system at which can monitor and indicate the gas level exist in certain area, especially for hazardous gas, as early preparation and protection before something worst happen. The gas sensing and monitoring system composes of hardware and software elements. A spiral chamber which is simplified on chip, known as Lab-On-Chip (LOC), plays an important role in this system. The examined gases will be analysed by 16 sensors during the flow through the spiral chamber. The responses of these sensors are obtained via analogue input channels from single board RIO (sbRIO) and are displayed on a computer using LabVIEW virtual instrument software. The system offers portable, real-time monitoring and fast response time even in room temperature.

Keywords: Spiral chamber; Lab-On-Chip; single board RIO; LabVIEW

Abstrak

Adalah penting untuk mewujudkan satu sistem yang boleh memantau kewujudan gas tertentu di kawasan tertentu sebagai persediaan awal sebelum sesuatu yang buruk berlaku, terutama bagi gas yang berbahaya kepada alam sekitar. Sistem pengesanan dan pemantauan gas terdiri daripada unsur-unsur perkakasan dan perisian. Sebuah kebuk lingkaran yang dipermudahkan dalam cip, yang dikenali sebagai makmal dalam cip (LOC), memainkan peranan penting dalam sistem pengesanan gas ini. Gas yang diuji yang mengalir di dalam kebuk lingkaran akan dianalisis oleh 16 pengesan. Tindak balas dari pengesan tersebut diperolehi melalui 16 saluran masukan input dari papan RIO dan tindak balas tersebut dipaparkan menggunakan perisian instrument maya LabVIEW. Sistem ini menawarkan kelebihan mudah aih, pemantauan masa sebenar dan masa tindak balsyang cepat walaupun di dalam suhu bilik.

Kata kunci: Kebuk lingkaran; Lab-On-Chip; single board RIO; LabVIEW

■1.0 INTRODUCTION

A gas sensing system plays an important role in sensing and monitoring the presence of the gas and it reaction to the sensors especially in this dramatic growth of industrial development and pollution.[1-3] Gas monitoring and sensing system is developed to control and measure the gas concentration in some flowable medium which is fast and give accurate result for the determination points.[4,5] Since the system is operating as a stand-alone and autonomous system, it has ability to detect and measure the gas concentration for different gases in the air. This system has important role on detecting and monitoring the gases because of the need to protect and prevent the environment from danger.[3]

There are many applications for a gas monitoring and sensing system that have been applied in the industries field. For example in an agriculture and food processing industries to determine the foodstuff acceptability, medicals for gas respiratory, the combustion control, the air quality control and military applications by using inexpensive measurement equipment, automobiles, safety and indoor air.[1,5-8]

Moreover, the modern mode of test system, Virtual Instrument of LabVIEW (LabVIEW 2011, National Instruments) has been widely used in various industry fields, and commonly the usage is due to its convenience and an existence of advance tools.[9] By using this software, the real-time sensing and monitoring system can be created and the data can be collected and analyzed whether in a short distance or in a long distance since the LAbVIEW can be connected to the internet.[10]

This paper particularly builds a sensing and monitoring system for gas which can detect the presence of gas inside the spiral chamber and simultaneously can monitor and analyze the sensor responses through the sbRIO (NI sbRIO-9632XT, National Instruments) and LabVIEW software.

The current era of high technology and advanced industry has produced an incredible rise in living standards. However, the quality of air becomes worse and uncontrollable that resulting in an air pollution which can affect the general environment quality and have significantly can effect on the population health.[1-3] In particular, atmospheric pollution especially, along with water pollution, becomes a major disaster within a short period of time, since this type of pollution can diffuse rapidly over large areas.

For example the release of various chemical pollutants, volatile organic compounds (VOCs) and fluorocarbon, from industry, automobiles, and homes, into the atmosphere, resulting in global environmental issues, such as acid rain, the greenhouse effect, sick house syndrome, and ozone depletion.[6,7,11]

Since these kinds and quantities of pollution sources have also increased dramatically, the development of the method for monitoring and controlling these sources has become very important. It is necessary to monitor and control the gas emissions and analyze the gas concentration that existed in surrounding.[5] Furthermore, the existing gas monitoring system that has been introduced by other researcher is in large scale and sometimes need a bigger space and cost to set up the overall system.

Therefore, there is a need to rescale and reduce the size of gas sensing and monitoring system in order to measure the gas concentration and reaction accurately. Besides, the system should be monitored online and real-time especially in hazardous or harsh environment.

2.0 EXPERIMENTAL

The experimental schematic for gas sensing operation as shown in Figure 1 illustrates the hardware interconnection of the sensing system part. A voltage supply of 5 V is supplied to the sensor circuit in order to obtain the response of sensors towards the gas.

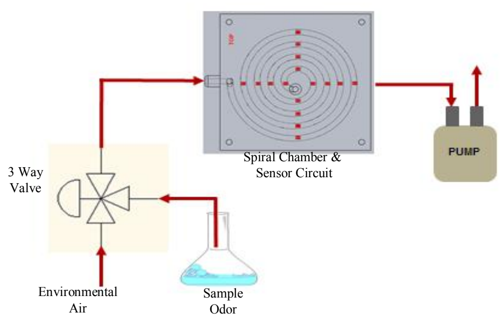


Figure 1 Experimental schematic for gas sensing operation

As an initial condition, the air is first flow through the spiral chamber to monitor the offset value of each sensor. When the valve is switched to the odor sample, the small vacuum pump will suck the odor through the multisensor array inside the spiral chamber and simultaneously react to the sensors inside the chamber. For experimental analysis, the valve is opened to odor sample only for ten seconds in order to monitor the patent of the response of sensors. While Figure 2 shows the diagram representation of gas monitoring system for multisensor array using single board RIO.

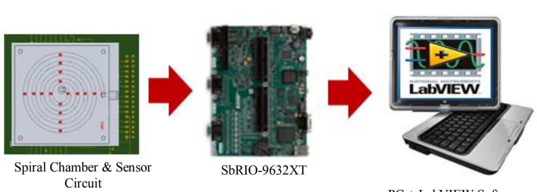


Figure 2 Diagram representation of gas monitoring system

The single board RIO is used to interface the sensor outputs to a computer. The LabVIEW software is programmed to monitor the sensors response. Since there are 16 sensors inside the spiral chamber, the output displayed 16 responses. The multisensor array circuit is designed by using Altium Designer software with the specification and dimension for each sensor is shown in Figure 3.

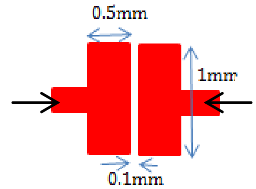


Figure 3 Sensor Specifications and dimensions

In the sensor design, 16 sensors are placed inside the spiral chamber. It is important to ensure that the arrangement of all sensors is aligned and fitted along the spiral chamber, so that the sensors can be fully utilized to detect the presence of gas. Four different composite films of carbon black polymer are deposited on the sensors, with the arrangement of four by four materials (Figure 4).

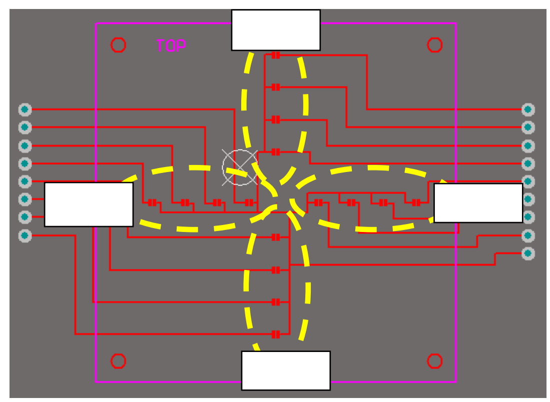


Figure 4 Polymer composition arrangement

Doleman *et al.* and Harun had studied on the advantage of using polymers material as the sensor deposition, which is able to provide the conduction of electricity in carbon black composites.[12,13] Therefore, the list of four polymers composite film that has been used in this project were Poly (Methyl Methacrylate) (PMMA), Poly (Vinyl Chloride) (PVC), Polysulfobetaines (PSB), and Polyethylene Glycol (PEG). All these four polymer composites film were mixed with 20% from carbon black.[13]

During the process of deposition of the polymers on the sensor, the resistance of sensor is monitored using multimeter. Since the simple method, which is drop-cast method has been applied to deposit the carbon black polymer, the variation of the resistance for 16 sensors is obtained within 30%, which is in the range of 20 kΩ to 60 kΩ. The sensor circuit is structured and mounted on the printed circuit board (PCB).

The sensor operates as a potentiometer. When the sensing layer composes of the carbon black and polymer reacts with the certain substance of gas, it will response by producing greater output voltage. The changes of the sensor resistance vary for a different gases type and also for different level of gas concentration. The advantage of this sensor is the responses can be obtained even at room temperature. Compared to other system, for instance a research done by Harun, required a heater in the system to increase the temperature up to 50°C to make the sensor react to the gas.[13] The spiral chamber as illustrated in Figure 5 is designed by using SolidWorks (SolidWorks 2010 SP0, Dassault Systemes) software.

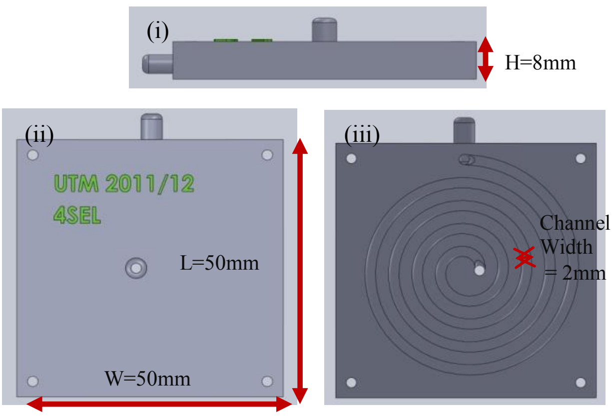


Figure 5 Structure of LOC spiral chamber: (i) front view (ii) top view (iii) bottom view

The design is innovative and creative since it is simplified on chip, known as Lab-on-chip (LOC). The concept of the Lab-on-chip is to understand clearly the bio-laboratory functions in a single chip with ever-smaller scales creation. Moreover, many applications and functions can be formed on the same substrate of this greatest small scale of bio-laboratories, such as circuits, valves, chambers, and microchannels. In order to develop all these applications, the bio-laboratories need to be fabricated by process of photolithographic. The main benefits of this technology applications are low cost and less space needed since all the components for sensing and analyzing are placed on the same LOC.[14] It is also portable to be moved and carried around anywhere.

Figure 6 shows the simulation of the gas flow inside the spiral chamber using SolidWorks Analysis. The spiral shape is chosen because it allows the gas flowing smoothly since there have less sharp edge on spiral shape. The color along the spiral chamber indicates the velocity of gas flowing through it. It was found that the velocity of gas dropped when entering the sharp edge corner and remains constant along the spiral chamber channel.

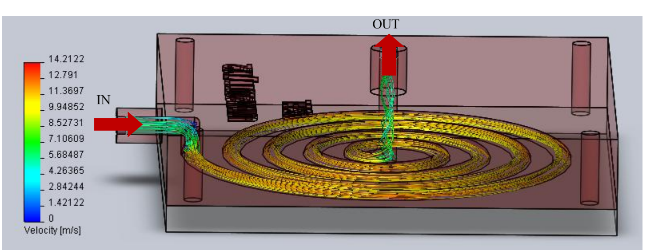


Figure 6 Simulation flow of spiral gas chamber

The system is using real-time implementation from single board RIO. The advantages of sbRIO-9632XT are it contain of 110 digital input output (DIO) lines of 3.3V (TTL/5V tolerant), 32 channels of 16-bit analog inputs and four channels of 16-bit analog outputs. Since this project used 16 sensors, 16 channels of analog inputs are connected to the sensor circuit to get an analog data. In addition, the interfacing of sbRIO and LabVIEW software is using 10/100 Mbits Ethernet cables. Therefore, the response of the sensors can be transferred much faster and lead to the real-time monitoring. Furthermore, it can be connected to the internet to analyze the data.[15]

In this project, the sbRIO is used to interface the hardware and the software part, which is to enable the communication between the sensors and the LabVIEW software. Since the data get from the sensor is in analog form, the shared variable input of Virtual Instrument of LabVIEW is chosen as the input of the system, refer to Figure 7.

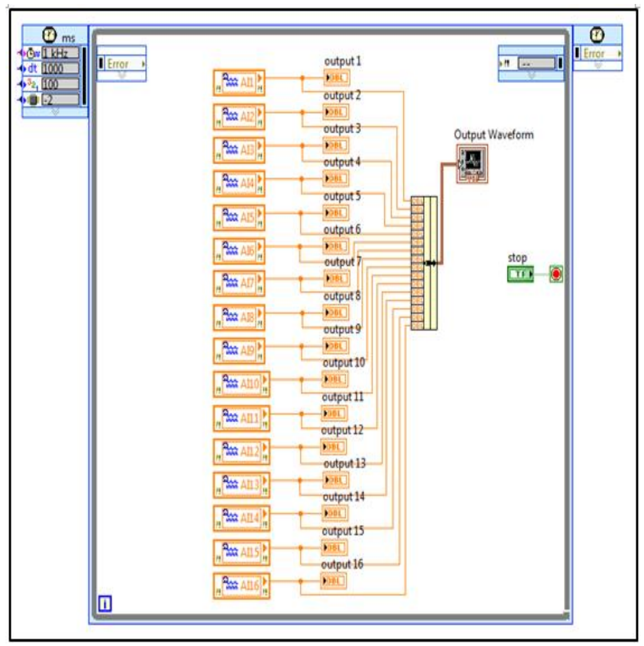


Figure 7 Data input program

The shared variable input represent the Analog Input pin on sbRIO and it is connected to the sensors output. The output data will be displayed on graph in term of voltage changed. Since there have different 16 responses of sensors, the cluster is used in the program to display all 16 output waveform in a single window. Initially valve is opened for fresh air, and once the valve is opened for tested gas, the gas will flow through inside the spiral chamber, thus make the sensors react to the gas. The output is displayed on the front panel of the LabVIEW development platform.

3.0 RESULTS AND DISCUSSION

The gas sensing and monitoring system was implemented by creating a real-time Virtual Instrument to display the sensors responses. 5 V was supplied to the sensors, as an initial state of the sensor. The initial voltage value that represented the sensors responses is becomes an offset for each sensor. Figure 8 shows the initial sensor responses, at which the valve is open to the fresh air. The position of the output sensor inside the spiral chamber that indicates the output response is illustrated in Figure 9.

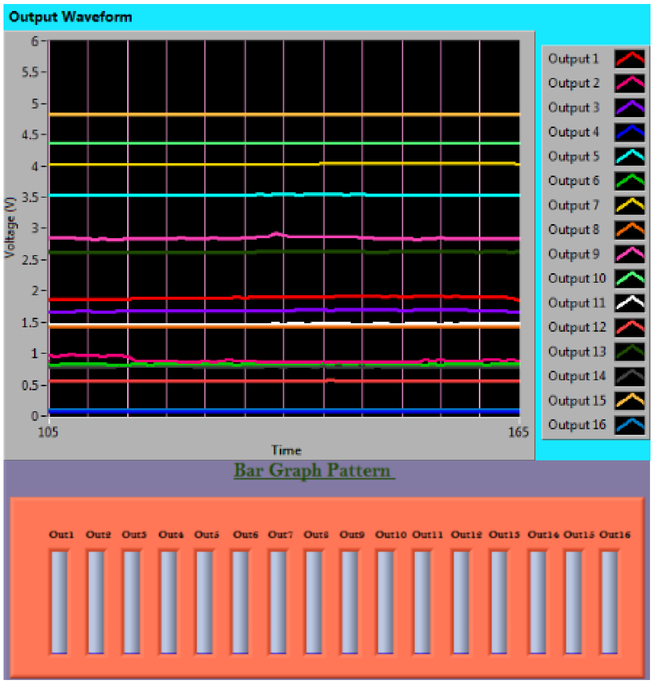


Figure 8 Initial responses without sample gas

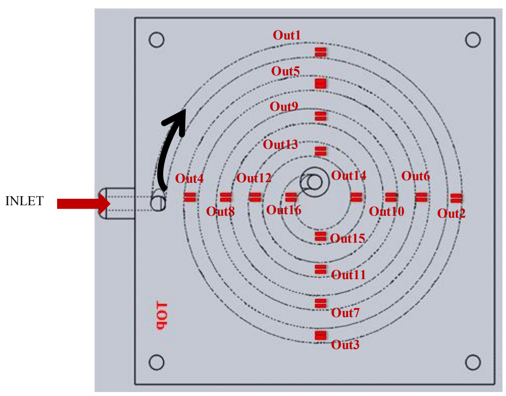
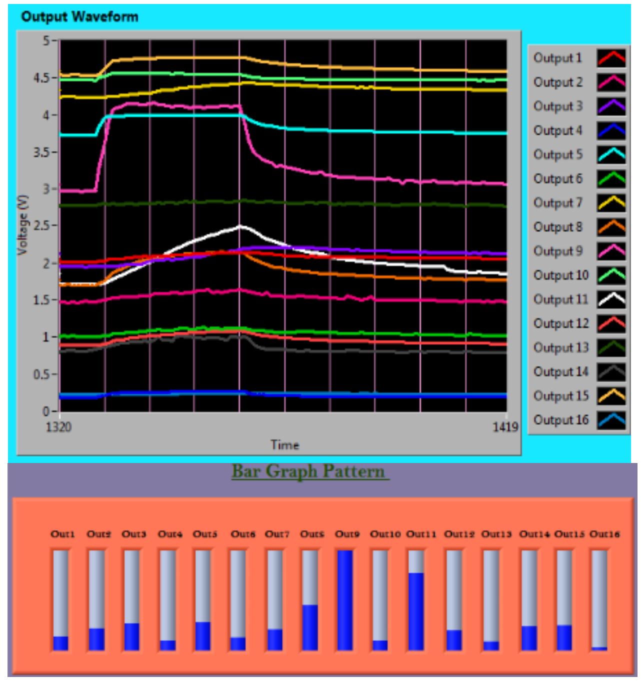
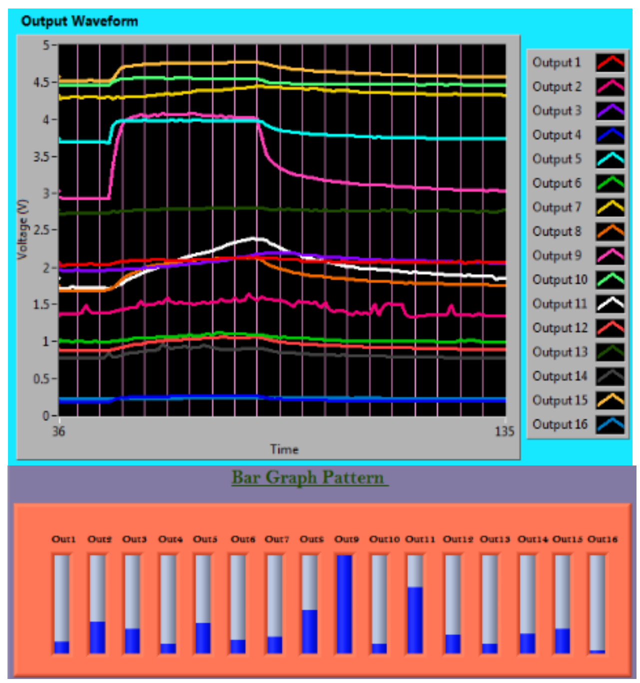


Figure 9 Output sensor arrangements

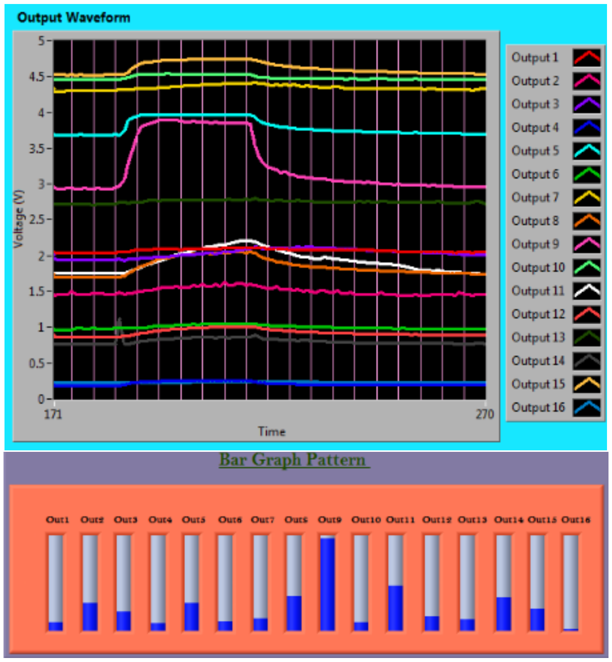
In this system experiment, heavy odor has been used as a sample to observe the response of the sensor and to evaluate the ability of LOC spiral chamber in providing path for the odor flow. Repeatability of the response must be taken into consideration in order to have an intelligent and innovative system. Thus the pattern of a sample can be obtained and recorded for the further action of recognition. Figure 10 illustrates three experimental of repeatability tests for responses of the gas sensor towards the perfume odor and its pattern.



(a) Test 1



(b) Test 2



(c) Test 3

Figure 10 Repeatability test (Test 1, test 2 and Test 3) for perfume odor, the responses and pattern

Based on the repeatability test, the system was able to produce reliable response and similar pattern. Therefore, other types of odor have also been sensed to observe the sensor response and their pattern. Two hazardous odors were sensed and the patterns were generated. As the results, Figure 11 and Figure 12 show the response and pattern of cigarette smoke and acetone respectively.

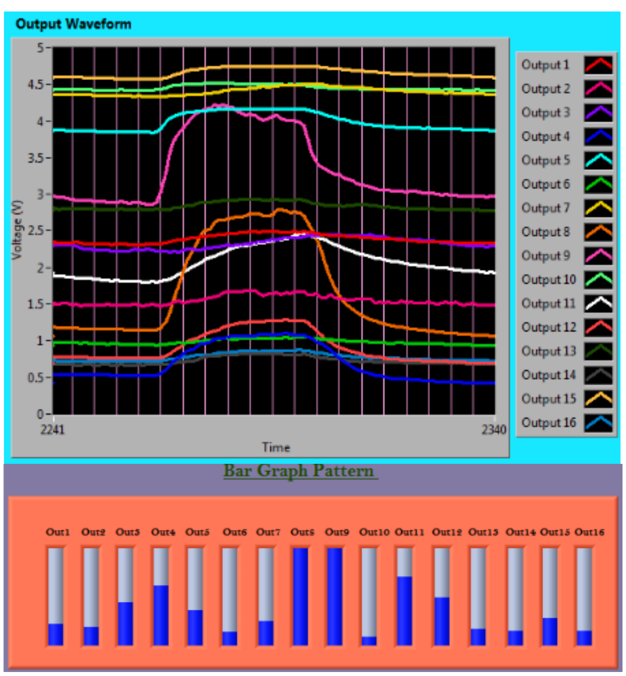


Figure 11 Responses and pattern for cigarette smoke

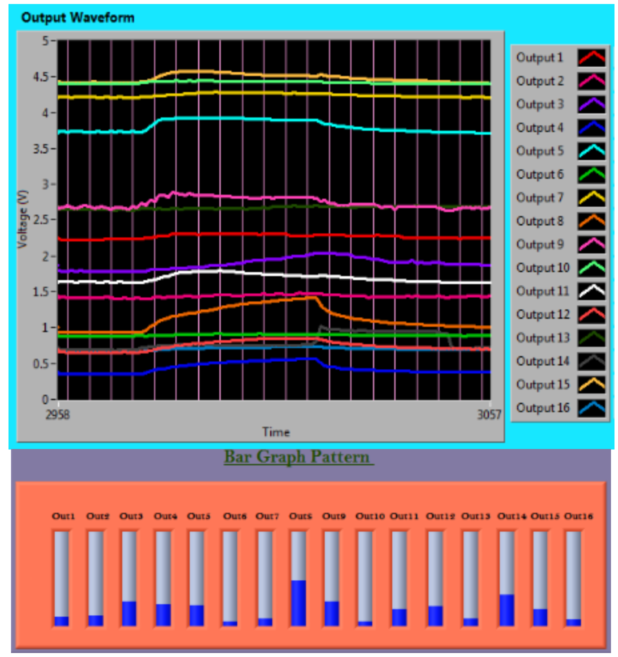


Figure 12 Responses and pattern for acetone

From the experimental analysis, each sensor produces different response towards the odor substances. Therefore, any type of odor can have a unique pattern. The pattern can be saved as the data based. Later it can be used to detect unknown hazardous odor such as cigarette smoke and acetone.

■4.0 CONCLUSION

The sbRIO lab-on-chip gas sensing and monitoring for multi-sensor array has been developed to measure and monitor the presence of gas substances in real time by the assist of single board RIO and LABVIEW program. The system is useful especially in this growing era of technology which various types of hazardous gas are released.

The system is reliable as the repeatability test has been done. Moreover, the system is simple, portable and cheaper to response to different type of gases. It has been shown that able to differentiate three types of odor namely perfume, acetone and cigarette smoke. In addition, the sensors are able to be operated at room temperature and produce quick response, thus providing a system that can be monitored online and real-time.

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