Design and Development of a Salbutamol Intake Detector for Low Respiratory Treatment

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Abstract - This paper proposed a new salbutamol intake detector design using asthma spacer and gas sensor. The device enable real time monitoring of propellant level inhaled by the infant which will decrease the recovery time of the asthma attack. Microcontroller Arduino UNO is program to control the input and output of the system. MQ6 gas sensor detecting the propellant Hydrofluoroalkane from the metered dose inhaler (MDI) canister and demonstrated the level of propellant inhaled on the LCD in real time. MQ6 gas sensor suitable used to detect concentration of propellant inside the asthma spacer due to it is low sensitive to natural gas where include the carbon dioxide exhaled by the infant. Besides this, MQ6 gas sensor also highly sensitive to propane and the preview aerosol inventor mentioned propane as propellant which used for MDI to push the salbutamol out from MDI canister. Therefore, MQ6 gas sensor is suitable to detect propellant inside asthma spacer. The output voltage of MQ6 in initial state where no propellant inside asthma spacer is between 0.55V and 0.65V. Furthermore, when the MDI canister is been pressed, the concentration of propellant is increased and the output voltage of MQ6 gas sensor also increased in ranged between 1.1V and 1.2V.

1. Introduction
Today, the biggest challenge in healthcare industry is the diagnosis of disease with accuracy and at affordable price [1]. Around 334 million people in the world is estimated of having asthma disease [2, 3]. Asthma is a complex condition characterized by the presence of chronic inflammation in the lower airways which results in variable airflow obstruction, causing recurrent episodes of coughing, wheezing, breathlessness, and chest tightness [4, 5]. Infant without asthma have the normal bronchioles which access air to pass through easily [6, 7]. The smooth muscles of the bronchioles are relaxed, in normal airway. Infant with asthma, normally have bronchioles which are smaller than the normal bronchioles. The main reason of asthma is the wall inflamed and thickened [8]. When the infant is under asthma attack, the bronchioles becomes narrow and the smooth muscles of the bronchioles is tightened. This may lead to trap air in the alveoli which causes difficulty in breathing. Since infant bronchioles are smaller than older children and adults, infant need the fastest treatment to recover from asthma attack [9]. If asthma attack is severe the person need to take an emergency treatment to restore the normal breathing. The fastest treatment is through the use of salbutamol.
Studies show asthma disease is the most frequently occurs in town or city than rural community [10-12]. Asthma can be categories into two groups which is allergic asthma and non-allergic asthma. In Malaysia, around 80 percent to 90 percent people experience allergies [13, 14]. Adult patients normally use metered dose inhaler (MDI) to take inhalation of salbutamol through the mouth to recover from the asthma attack because the MDI only require to shake for 10 seconds before use it [15]. MDI was the most widely used treatment for controlling symptoms of asthma and chronic obstructive pulmonary disease (COPD) [16, 17]. The canister containing two components which are propellant and salbutamol. Salbutamol is a short-acting β2-adrenergic receptor agonist used for the relief of bronchospasm in conditions such as asthma and chronic obstructive pulmonary disease [18, 19]. It helps relax the smooth muscles in the air passages in the lungs allowing the airways to open up [20, 21]. For MDI, salbutamol is found in dry powder type, so it requires propellant to propel the salbutamol for inhalation [16]. For infant or child, when experiencing the asthma attack they are also in need of salbutamol to recover. However, they are unable to use the inhaler to take salbutamol directly because of their inability to inhale properly. In this case, doctor or medical staff will use asthma spacer (aero chamber) together with the salbutamol [22]. It has a mask which is positioned on the child nose and mouth as depicted in Figure 1 [23].

![Figure 1. A child using an asthma spacer (aero chamber) to inhale the salbutamol](image)

When using the asthma spacer to inhale the salbutamol, some infants are frightened by the mask and fight the treatment [24]. This sometimes results in insufficient amount of salbutamol inhaled by the infant. Current asthma spacer only indicate manually the inhalation of salbutamol by using Flow-Vu® Inspiratory Flow Indicator (IFI) which count the breaths for 5 to 6 flips after the MDI is pressed. Current devices are incapable of monitoring and displaying reading of salbutamol level in real time. It is essential to ensure the salbutamol is sufficiently inhaled by the infant when using the asthma spacer to decrease the recovery time of the asthma attack.

2. Method

2.1 Development of salbutamol intake detector

The proposed device consists of a gas sensor (MQ6) as an input to detect the propellant while to push the salbutamol in the MDI canister. This proposed device employed a rechargeable battery, that is Li-
ion battery 7.4V to supply power source for the whole electronic components such as the gas sensor, microcontroller and the liquid crystal display (LCD). The microcontroller will receive analogue signal from the gas sensor when the MDI canister is been pressed and then the microcontroller process the analogue to produce an output. The output of this device is to demonstrate the percentage of the level of propellant inside the asthma spacer. MDI canister uses propellant which is the hydrofluoroalkane (HFA) to propel the salbutamol in dry powder form. The LCD demonstrate the percentage of propellant inside the asthma spacer and during inhalation. This is implemented using microcontroller Arduino UNO (ATmega328P) to program the source code into chip ATmega328P. The block diagram of the proposed device is depicted in Figure 2.

![Block diagram of the proposed device](image)

**Figure 2.** Block diagram of the proposed device

### 2.2 System Operation of the proposed device

When the power source is turned on, the MQ6 gas sensor will detect the propellant inside the asthma spacer. When the user presses the MDI canister, the propellant will push the salbutamol. The sensor detects the level of the propellant inside the asthma spacer. The LCD will demonstrate “Gas (%): xxx%”. While the infant or child is inhaling the salbutamol together with propellant, the reading percentage of propellant on the LCD decreases and demonstrated the percentage of the inhaled salbutamol in real time which is “Inhaled: xxx%”. The child will keep on inhaling until the LCD show “Gas (%): 0%”. The flow chart of the system is shown in Figure 3.
To obtain the real time percentage of the gas and percentage of inhaled were given by:

\[
\text{Percentage of gas} = \left[ \frac{\text{val} - x}{y} \right] \times 100 \tag{1}
\]

\[
\text{Percentage of inhaled} = 100 - \left[ \frac{\text{val} - x}{y} \right] \times 100 \tag{2}
\]

Where, \(\text{val}\) is the reading of analogue signal value obtain from the MQ6 gas sensor. \(x\) is the minimum value of analogue signal inside the asthma spacer without propellant which is 180. \(y\) is the comparison value of analogue signal between the maximum and minimum value of analogue signal. The maximum value of analogue signal inside the asthma spacer is 220 with propellant when MDI canister is been pressed by one.

### 2.3 Experimental setup

The experiment has carried out two kind of gas sensors which are the MQ5 and MQ6 gas sensor. Based on the theoretical The Table 1 below demonstrated the advantage and disadvantage of the MQ5 and MQ6 gas sensor. The MQ5 gas sensor is highly sensitive to liquid petroleum gas (LPG), natural gas and town gas but less sensitivity to alcohol and smoke. For MQ6 gas sensor, it highly sensitive to LPG, iso-butane and propane but less sensitivity to natural gas, alcohol and smoke. Preview aerosol inventor mentioned propane as propellant [25] which used for MDI to push the salbutamol out from MDI canister.
Table 1. Advantage and disadvantage of MQ5 and MQ6 gas sensor

| Gas Sensor | Advantage                                                                 | Disadvantage                                             |
|------------|---------------------------------------------------------------------------|-----------------------------------------------------------|
| MQ5        | High sensitivity to LPG, natural gas, town gas                            | Small sensitivity to alcohol and smoke.                   |
| MQ6        | High sensitivity to LPG, isobutane, propane                               | Could not detect natural gas, small sensitivity to alcohol and smoke. |

The gas sensor is employed analogue signal as an inputs for microcontroller to process the signal and produce an output. The Arduino UNO board will connect to personal laptop by using universal serial bus (USB) cable where the obtained analogue signal will simultaneously send to personal laptop by using serial communication. Hence, by using Matlab to analyse the obtained analogue signal in real time.

The components for the analytical is depicted in Figure 4 which included laptop (A), multi-meter (B) and proposed device (C). The probe of multi-meter probed at analogue pin of Arduino UNO for acquisition analogue signal of sensor. The analogue pin for gas sensor is connected to pin “A2” in Arduino UNO and the positive probe of multi-meter will be probed at this pin. Hence, by using the USB cable connect the Arduino UNO to personal laptop and by using the Matlab to obtain the result of initial state and peak of propellant after the MDI canister is pressed and during inhalation salbutamol.

![Figure 4. Experiment setup of analogue signal acquisition](image)

3. Results and discussion

Results obtained by using the MQ6 gas sensor to detect the present of the propellant in the asthma spacer is shown in Figure 5 When there is no propellant detected the results show “Gas (%): 0%”. Hence, when the MDI was pressed, the gas sensor detected 100% of propellant inside the asthma spacer. While the infant inhales the salbutamol, the LCD screen demonstrated the percentage in real time, for example “Inhaled: 50%”. Once the salbutamol is fully inhaled, the LCD will demonstrated “Inhaled: 100%” and it would return to show “Gas (%): 0%”. 
The experiment is carried out using two types of gas sensors, MQ5 and MQ6. From observation made shown in Table 2, The MQ5 gas sensor is highly sensitive to natural gas which will detect the carbon dioxide that the infant exhaled. This may display false reading of propellant on the LCD. On the other hand, gas sensor MQ6 is less sensitive to natural gas including carbon dioxide that the infant exhaled and highly sensitive to propane. Hence, the propane as propellant found by the inventor [25] also used in the MDI canister. Therefore, the MQ6 gas sensor suitable to detect the level of propellant in the asthma spacer.

Table 2. Observation of experiment for MQ5 and MQ6 gas sensor

| Gas Sensor | Observation / Result                                      |
|------------|----------------------------------------------------------|
| MQ5        | It could detect the carbon dioxide while inhalation of salbutamol. |
| MQ6        | While inhalation of the salbutamol, MQ6 gas sensor was less sensitivity to carbon dioxide |

The output voltage of a gas sensor in initial state where there was no propellant in the asthma spacer is presented Figure 6 (a). The positive probe of multi-meter was probed at the analogue pin of Arduino Nano (pin A2). The range of output voltage of the gas sensor in initial state is between 0.55V and 0.65V.
Once the MDI canister is been pressed, the concentration of propellant is increased. Hence, the output voltage of the gas sensor also increased which is between 1.1V and 1.2V.

![Image of gas sensor output voltages](image1.png)

**Figure 6.** (a) Output voltage of gas sensor in initial state (No propellant), (b) Output voltage of gas sensor after pressed MDI

The graphical represents the concentration of propellant in voltage versus time is depicted in Figure 7. The graph shows the initial state condition inside asthma spacer (no propellant) which recorded 0.55V. Once the MDI canister is pressed, the output voltage of the gas sensor was increased due to the concentration of propellant is also increased where recorded at 1.18V. Therefore, concentration of propellant is decreasing during inhalation of salbutamol. When the asthma spacer is empty with propellant, the concentration of propellant is very low and the voltage is 0.65V.

![Graphical representation of gas concentration](image2.png)

**Figure 7.** Graphical represents the concentration of gas in voltage versus time

The concentration of propellant depends on the room temperature due to the MQ6 gas sensor having standard working temperature as listed in the datasheet. The standard working temperature for MQ6 gas sensor is around 20°C to 22°C [26]. MQ6 gas sensor has been designed with a heater as depicted in Figure 8. When the gas sensor is concentrated of propellant is high, the temperature of heater will decrease due to the temperature of the propellant is low when MDI canister is pressed. Hence, the heating element will increase the temperature by the heating element that is connected with 5V DC or AC (VH) to maintain the temperature at approximately 20°C to 22°C and above. Therefore, present use
of this proposed device is in room temperature below 20\(^\circ\)C to prevent the inaccurate reading of gas percentage.

The sensing element of MQ6 gas sensor is tin oxide (SnO2) and this kind of material could detect various kind of gases [27]. When the propellant is pushed from the MDI canister and it would close to the sensing element, then it would ionized and absorbed by the sensing element. Therefore, the sensing element would be heated by the heating current. Hence, the detection of propellant is the change of the sensing resistance and it produce different output voltage due to different concentration of propellant.

\[\text{Figure 8. Basic circuit for MQ6 [26]}\]

4. Conclusion
Current asthma spacer only indicate manually the inhalation of salbutamol by using Flow-Vu\textsuperscript{®} Inspiratory Flow Indicator (IFI) which is a disadvantage in ensuring the salbutamol gas is sufficiently inhaled by the infant. Current devices are also incapable of monitoring and displaying reading of salbutamol level in real time. Therefore, salbutamol intake detector was designed and developed for application with the infant asthma spacer. Through experiment conducted, the device is capable of real time monitoring of the propellant level present in the asthma spacer using the MQ6 sensor over the MQ5 sensor. This is due to the facts that MQ6 sensor does not sense natural gas, in this case carbon dioxide which may lead to false reading. It is essential to ensure the salbutamol is sufficiently inhaled by the infant when using the asthma spacer to decrease the recovery time of the asthma attack.

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