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DEVELOPMENT OF ELECTRONIC [illegible] RESPIRATORY FOR DETECTING ASTHMA

CHEOW SHEK HONG

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for the award of the degree of
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ABSTRAK

Dalam tesis ini, prototaip peranti pengukuran karbon dioksida (CO_2) telah direka untuk mengesan dan memantau pesakit asma. Pada msa kini, capnogram telah diggunakan dengan secara luas dalam memantau asma serta perkhidmatan perubatan. Walau bagaimanapun, harga capnogram dalam pasaran amat mahal terutama begi pesakit kolongan berpendapatan rendah. Untuk menangi masalah tersebut, peranti kos rendah ini dihasilkan untuk mengesan dan memantau asma. Oleh itu, peranti ini dapa dimiliki ramai termasuk kolongan pendapatan rendah. Tambahan pula, spirometer dan peak flow meter terkenal dalam pemantau asma. Malanynya, kedua kedua peranti menpunyai had masing masing. Spirometer mempunyai prosedur yang complex, pesakit menghadapi kesukaran dalam melaksanakan kriteria yang ditetapkan serta peranti ini sesuai bagi pesakit umur 6 dan atas sahaja. Sementara itu, peak flow meter akan menyebabkan dada pesakit mengalami kesakitan kerana peranti itu memerlukan pesakit menghembus nafas pada kadar maksimum. Untuk mengatasi batasan-batasan tersebut, eleltronik kit diprototype bagi mudah digguna serta sesuai bagi semua pesakit walaupuun kecil daripada umur 6. Elektronik kit ini terdiri daripada MH-Z14A CO_2 sensor untuk mengesan kepekatan karbon dioxida yang dihembus dari pengguna, Arduino untuk menproses data dari sensor tersebut, TFT Display digguna untuk mempamerkan keputusan manakala Bluetooth modul HC-06 digguna untuk berinteraksi dengan komputer bagi analisis selanjutnya. Prototaip ini diuji dengan 3 pungguna asma serta biasa. Hasil kajian menunjuk bahawa pungguna asma mempunyai corak yang berbeza berbanding dengan pengguna biasa. Kesimpulannnya, peranti ini telah berjaya membezakan perbezaan antara pengguna biasa seta asma. Oleh itu, peranti ini sesuai untuk memantau atau mengesan asma.

ABSTRACT

In this paper, a prototype of a carbon dioxide (CO_2) measurement device has designed to detect and monitor asthma patient. Nowadays, capnogram is widely uses in monitoring asthma and medical services. However, capnogram is costly and unaffordable for patient especially those in a low class family. Therefore, this low cost device is produced to detect and monitor the severity of asthma, this device can be owned by every class of family. Furthermore, spirometer and peak flow meter is well known in monitoring asthma. Unfortunately, these two devices have their own limitations as spirometer has complex procedures as the patient face difficulties on performing multiple criteria when using it and only suitable for age range above 6 years old. Meanwhile, flow meter will caused patient to have chest pain as they needed maximum effort to blow in the device. To overcome these limitations, this prototype electronic kit is easy to use and suitable for all range of patients. This prototype electronic kit consists of MH-Z14A CO_2 sensor to detect the concentration of CO_2 from exhaled air from user, Arduino microcontroller to process the data, TFT Display shield for data presentation and HC-06 Bluetooth module to communicate with PC for further analysis. This device was tested with 3 asthmatic and 3 normal users. The results showed that asthmatic user has a different graph pattern compared with normal user. This device has successfully distinguished the difference between asthmatic and normal user; therefore it is suitable for asthma monitoring.

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LIST OF SYMBOLS

α	Alpha angle
β	Beta angle
m	Gradient
x_1	Previous time
x_2	Time
y_1	Previous concentration of carbon dioxide
y_2	Concentration of carbon dioxide

LIST OF ABBREVIATIONS

CATIA	Computer-aided three-dimensional interactive application
CO	Carbon Oxide
CO2	Carbon Dioxide
GUI	Graphical User Interface
IR	Infrared transceiver
mmHg	millimetre of mercury
MOS	Metal Oxide Semiconductor
NH3	Ammonia
NO	Amperometric nitric gas oxide sensor
PC	Personal computer
PEF	Peak expiratory flow
Ppm	Parts per million
RSACC	Adaptive Respiratory Spectrum Correlation Coefficient
UAK	User Awareness Kit
UART	Universal Asynchronous Receiver/Transmitter
UMP	Universiti Malaysia Pahang
USB	Universal Serial Bus

CHAPTER 1

INTRODUCTION

1.1 Introduction

Asthma is a chronic disease involved the airways in the lungs and it causes difficulty in breathing due to respiratory condition marked by spasms in the bronchi of the lungs. McPhee et al. (2010) review that asthma exacerbation is a reduction in expiratory flow which is caused by many asthma triggers and the main triggers which will lead to the symptoms of respiratory diseases included viral infection, air pollutions, exercise, cockroach allergen and dust mists.

Asthma, a disease which mainly in full grown adults but as time goes by, this disease has been rapidly spread in younger children based on Shikalgar et al. (2016). For the pass decades, countless of research has been carried out to solve this problem. Chatzimichail et al. (2011) review that it is still remain a challenge for the clinical doctor to diagnoses in children younger than five years old as they will often misdiagnoses as having common-cold, bronchiolitis or pneumonia. Namazova-Baranova et al. (2015) reported that it is exceptionally decisive for remote monitoring of various parameters not only for infants and preschool children but also school age patients and adolescents.

So far, asthma still cannot be cure. However, it can be controlled by monitoring regularly and it can be achieved through using appropriate pharmacological interventions to reduce the risk. Benjamin Franklin once said:" An ounce of prevention is worth a pound of cure". Therefore, a proper diagnosis and monitoring are crucial as the symptoms are different from patient to patient. In this twenty century, technology plays a curial role in helping asthmatic to manage their symptoms. For example, based on Seto et al. (2009) review that home telemonitoring is an alternative approach to asthma management. Home telemonitoring are monitoring an asthmatic by having clinical and physiologic data transmitted to healthcare provided.

At present, the method commonly used for monitoring and control this disease is using peak flow meter and spirometer. These devices are very useful in monitoring asthma; unfortunately, they have their limitations. Based on Zuleika et al. (2014) reviews that when patient using peak flow meter, they needed maximum effort to blow in the device and as a result it will cause chest pain. Also, spirometer suitable age range is above six years old, so for those below six years old are difficult to fulfill the end-test-result as they face difficulties on performing multiple criteria to meet the requirement set by the spirometer based on Richards et al. (2006) research.

A new method is introduced to monitor the severity of asthma without harming the patients and suitable for all range of patients. Non-invasive continuous analysis of the concentration of carbon dioxide in respiratory cycle is called capnography. This new method uses infrared technology to determine the concentration of the CO_2. Based on the capnogram, asthmatic patient and normal patient can be easily differentiated. Figure below shows a comparison between normal and abnormal capnogram.

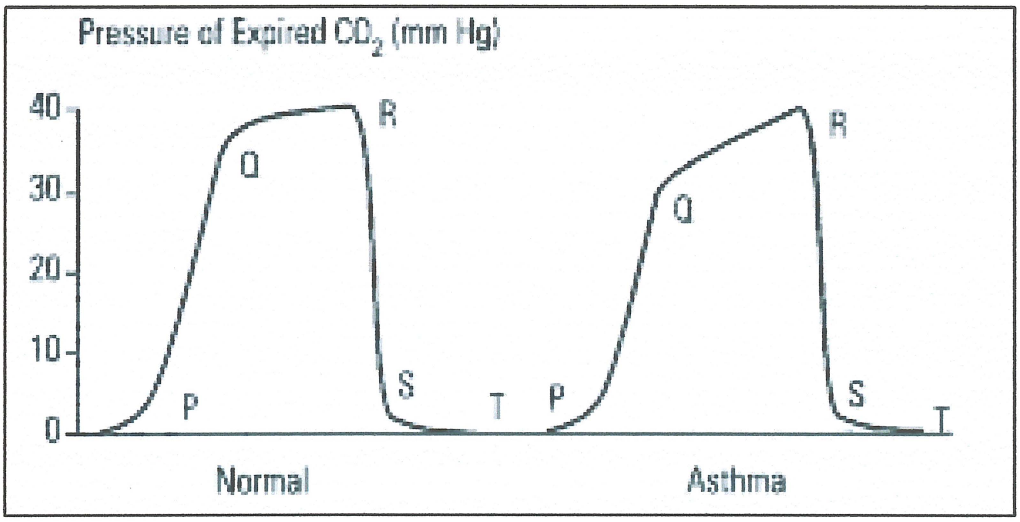

Figure 1.1 Capnogram between normal subject and Asthma subject
Source: Yaron et al (1996)

In this project, a new portable electronic kit is designed to monitor and detect asthma. The main component in this electronic kit included low cost MH-Z14A CO2 sensor, Arduino microcontroller, TFT LCD shield and HC-06 Bluetooth Module. The purpose of MH-Z14A CO2 sensor is to detect the concentration of the exhaled CO2 by the subject. Then, the information or data from this sensor will be transfer to Arduino microcontroller. Then, Arduino microcontroller will receive and process the data before sending them to data-presentation element, TFT LCD shield. Data from CO2 sensor will be display on TFT LCD shield. In order to display the data more clearly for the user, data will also sent to PC using HC-06 Bluetooth Module.

1.2 Problem Statement

As the developed country increases, asthma morbidity and mortality increases too. Our country, Malaysia is rapidly becoming industrialized, is probably similarly saddled, especially with increased morbidity. Unfortunately, asthma patient management on asthma is still poor as they believed if they took quick-relief medication three times a week, their condition was well controlled. Honestly, their thinking is totally wrong because asthma have to be managed and controlled. Therefore, this portable electronic kit is developed to detect and control this disease. By having this device, patient can always monitor this disease. This portable electronic kit is small and portable, so it is easy to carry and move from place to place. Next, this portable electronic kit is also easy to operate and it does not need to follow any difficult procedures. Thus, it is easy to work by anyone at anywhere.

Secondly, this portable electronic kit has overcome some limitation of the asthma devices such as spirometer and peak flow meter. By comparing with spirometer, this electronic kit comprised any age range of patients instead of suitable for only age range six years old and above. Likewise, this device needs not to blow in with maximum effort which cost chest pain at the end by comparing to the peak flow meter. The main reason is that this device used MH-Z14A CO_2 sensor for exhaled of concentration CO_2 detection, which is suitable for every patient either below six years old or above six years old.

Last but not least, capnogram are used in this portable electronic kit to detect and monitor the severity of asthma. Unfortunately, capnogram in market are costly and it is not unaffordable for patients. To overcome this problem, this portable electronic kit used low cost CO_2 sensor to produce a continuous monitoring based on the CO_2 concentration of the patient which is same concept as the capnogram that can found in market. Furthermore, to lower the cost for this electronic kit, electric component and material which used to build this electronic kit are low in cost but yet good in quality.

1.3 Objectives

The goals for this project are as follow:

i. To develop an electronic kit which is capable to detect and monitor asthma.

ii. To develop low-cost electronic kit which affordable for every class of asthma patient.

iii. To build an electronic kit which is suitable for every range of asthmatic patient.

iv. To test and analyse the result obtained from the device.

1.4 Significant Of Project

The project is important by develop an electronic kit which is suitable for every range of asthmatic patient to detect and monitor asthma. Asthma is a disease which cannot be cure but through monitoring, it will reduce the risk of asthma attack.

This electronic kit is developed using low-cost materials and sensor thus it will reduce the cost and affordable for everyone. Thus, everyone can monitor in house instead of paying expensive hospital bill to check on their condition.

1.5 Project Scope

First of all, the age range for this project result will be set and it will be focusing on subject age range within 20-24 years old instead subject of all range of age. On top of everything, only University Malaysia Pahang (UMP) student will be tested instead of citizen from Kuala Pahang.

Furthermore, the graph produced from the data of CO_2 sensor will be slightly difference from the capnogram as capnogram is plotted with unit of millimeter of mercury (mmHg) versus time whereas the graph for this project will be in unit of parts per million (ppm) versus time.

Next, this project is limited in low cost sensor and data presentation element thus the result expected might be different from the device available in market

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, journals were study in order to come out the best way in producing an electronic kit to detect asthma. To develop this electronic kit, a few elements are required included transducer, signal conditioning, and data-presentation element. First, sensor and transducer are crucial to build this project. Based on Harikrishnan et al. (2013) sensor is a transducer that converts a physical, biological, or chemical parameter into an electrical signal. When the electric signal is converted, then it will be processed by signal conditioning element. Signal conditioning will process the output of transducer in a suitable form. Signal conditioning element included amplifier and comparator.

Lastly, the electric signal will then process by the data-presentation element to display the data in a quantitative form for the user. Thus, in this chapter review will be focus on these elements. Nowadays, capnography has been used as a new method for detecting asthma. Monitoring the concentration of partial pressure or concentration of CO_2 is called capnography. Meanwhile, capnogram is the continuous plots of the level of exhaled CO_2 over time. Capnometers were used experimentally measure exhaled CO_2 during anesthesia during the 1950s. But then, Smallhout (1975) reviews that capnometry is widely used mainly in the anesthetic practice in the early 1980's.

Today, capnogram is widely used during anesthesia in monitoring metabolic and respiratory functions. So some literature have been analyzed and studied by using capnogram to detect and monitor the condition of the asthma patient

As mention earlier, capnogram is the continuous plots of the level of exhaled CO_2 against time. Thus, a CO2 sensor will be used to measure the concentration exhaled CO_2 from asthma and non-asthma person. Then, the reading will be used to plot the time graph to have an overview on the condition of them.

2.2 Asthma Detection & Monitoring Tools

2.2.1 Spirometer

Here and now, Spirometer is widely used in clinic or hospital. One of the main purposes of spirometer is to monitor or diagnose severe asthma. Whereas, spirometry is a common pulmonary function test which measures the lung function by using spirometer. Richards J A et al. (2006) indicates that air flow and volume are measure by spirometry as a function of time and volume against time are graphically expressed by using the value obtained.

Unfortunately, spirometer has its own limitations too. Based on Dundas et al. (2006), the spirometer is suitable for patient range six years old or above. Spirometer needs a high cooperation requirement. So, patient who has a range from six years old and below is hard to carry out test as they might have difficulties to understand the instruction during the test. Moreover, patients who are unconscious or heavily sedated are not suitable for this test.

Meanwhile, Richards et al. (2006) states that the test result from the spirometer evaluated for abnormalities against predicted values of age, height, and gender. At the same time, the test requires a lot of criteria before the test are acceptable.

At least 3 acceptable tests

- Full inhalation before start of test
- Satisfactory start of exhalation
  - Evidence of maximal effort
  - No hesitation
- No cough or glottal closure during the first second
- Satisfactory duration of test
  - At least 6 seconds
  - Up to 15 seconds in patients with airflow obstruction
- No evidence of leak
- No evidence of obstruction of the mouthpiece

Reproducible results

- For FVC and FEV_1, the two largest values should be within five percent (5%) or 0.1 liter (whichever is larger) of each other
  - If these criteria are not met, continue testing
  - If these criteria are not met after 8 trials, stop testing and proceed with the interpretation, using the three best acceptable tests.

Selection of test values for interpretation

- Select from tests of acceptable quality
- Select the largest values for FVC and FEV1, regardless of the test used
- For indexes of average or instantaneous flow, use values from the test with the largest value for FVC and FEV_1 combined

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Figure 2.1 Acceptability and reproducibility criteria
Source: Richards et al (2006)

2.2.2 Flow Peak Meter

Adeniyi et al. (2011) introduced that peak flow meter is a small hand-held device. This device purposes to measure the maximum ability of the patient to exhale and recorded as peak expiratory flow (PEF).

Peak flow meter has its own advantage and also disadvantages. A Tan et al. (2010) review that peak flow meter is very depending on their patients. Maximum efforts are needed by the patients to blow into the device. Before the actual condition of the patient is recorded, practices are much needed.

On top of everything, the result from the peak flow meter sometimes is not reproducible over a long period of time based on the review from Adeniyi et al. (2011).

The reading values may be obtained be inter-model variation. As a result, it will increase the discomfort of patient who having breath difficulties in asthma attack.

2.2.3 Capnograhy

Capnography is a new method in monitoring asthma and based on Dr. Mello et al. (2002) state that capnography is a machine which generates waveform and the waveform generated are called capnogram. Next, Tan et al. (2010) review that capnography is a non-invasive continuous analysis of the concentration of CO2 in the respiratory cycle. D. Bridgeman et al. (2010) reported in order for patient to exhale a maximum of amount air, capnography can be monitoring through the CO2 waveforms through a relax breathing.

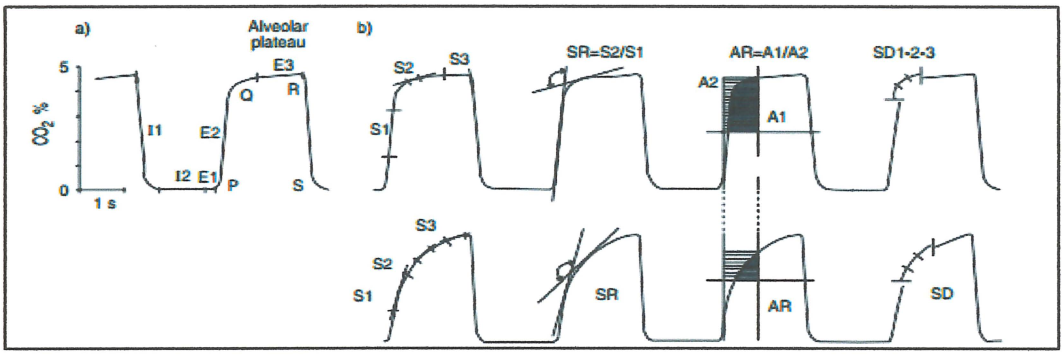


Figure 2.2 Capnogram
Source: Bridgeman (2010)

Based on Figure 2.2, Bridgeman et al. (2010) review that patient between asthmatic and non-asthmatic can be categorized based on the capnogram index. For the non-asthmatic patient, the capnogram they produce will be the square wave pattern whereas for an asthmatic patient, they will produce a shark-fin wave pattern. Although this device is convenient and easy to operate, unfortunately, it is bulky and expensive. Thus, it is unaffordable for most of the user.

2.3 Sensor and Method Consideration for Electric Kit

2.3.1 Sensor Comparisons

According to the work of Marani et al. (2010), the proposed device prevents damages caused by mechanical ventilation which can induce serious damage due to the natural pulmonary elastance. This device able to detect and analyze the widest number of data for the monitoring respiratory system by using a new pressure sensor- based electronic medical device. By recording and evaluation of lung sounds, monitoring and analysis of respiratory health can be done.

Yu et al. (2013) develop a wheeze detection system for use in home. The respiratory sounds of asthmatic children in the emergency room can be collected and identified by using this system. In this article, soft stethoscope sensor was used. Soft stethoscope is acted as sound collector. Stethoscope is replaced by a soft chamber made of polymer to intensify the respiratory sound. This soft stethoscope replaced the traditional stethoscope as a traditional stethoscope is too large and rigid to use. This soft stethoscope can be easily used on young children and the effectiveness does not effect by loud noise.

Zuleika et al. (2014) present a preliminary design using CO_2 sensor named MG-811 with capnogram. This design has a low cost and portable. In this study, this design is suitable for all range of patient including children which is below 6 years old and it avoid all type of complicated test which cause chest pain.

Kaushal et al. (2015) proposed a technique using metal oxide semiconductors (MOS) gas sensors for analysis exhaled breath. MOS sensor basically made up from tin oxide doped with zinc oxide which is sensitive to exhaled breath. This technique eliminates the disadvantages of other technique by its low cost and easy operation features. This is because when metal oxide crystals like SnO_2 exhibit sensitivity towards oxidizing and reducing gases by a variation of their electrical properties when they are heated at a certain high temperature.

Liu et al. (2015) proposed a system which used a ultrasonic transducer sensor to extract respiratory signals from an ultrasonic videos. In this system, it overcomes the limitation of implementing ultrasound images of diaphragm movement.

Gatthy et al. (2015) designed a miniaturized electrochemical nitiric oxide (NO) sensor with a detection limit and sensitivity that is potentially detecting asthma which can overcome the limit of the chemoresistive metal oxide such as SNO_2 which has the detecting limit in the range of few ppm. For this sensor, it is suitable to detect asthma because it has a detection limit and sensitivity to changes in relative humidity, response time, flow sensitivity and stability.

Author	Title of Paper	Sensor	Contribution
Marani et al. (2010)	A new pressure sensor-based Electric Medical Device for The Analysis of Lung Sounds	Pressure Sensor	Prevents damages caused by mechanical ventilation which can induce serious damage due to the natural pulmonary elastance.
Yu et al. (2013)	Soft Stethoscope for detecting asthma wheeze in young children	Soft Stethoscope	Can be easily used on young children. The effectiveness does not effect by loud noise.
Zuleika et al. (2014)	Designing a Respiratory CO2 Measurement for Home Monitoring of Asthma	Carbon Dioxide (MG-811)	Suitable for all range patient including children below 6 years old. Avoid all type of complicated test which cause chest pain.
Kaushal et al. (2015)	Pellet Sensor Based Asthma Detection System using Exhaled Breath Analysis	Metal Oxide Semiconductor (MOS)	Sensitive to exhaled breath. Eliminates the disadvantages of other technique by its low cost and easy operation features.
Liu et al. (2015)	Asthma Pattern Identification via Continuous Diaphragm Motion Monitoring	Ultrasonic Transducer	Overcome the limitation of implementing the ultrasound images of diaphragm movement.
Gatthy et al. (2015)	An amperometric nitric oxide sensor with fast response and ppb-level concentration detection relevant to asthma monitoring.	Amperometric Nitiric Oxide	Has a detecting limit and sensitivity to changes in relative humidity, response time, flow sensitivity and stability.

2.3.2 Method Review

According to Marani et al. (2010), the device proposed is a sensor-based electronic medical device. It able to monitor the respiratory system by detects and analyzes the widest number of data. This sensor is an analog device. So the data from the sensor will be sent to Analog-Digital convertor to convert into digital form so that it can be processed by the microcontroller. Microcontroller which used in this project is the ADuC812 microcontroller. Meanwhile Universal asynchronous receiver/transmitter (UART) is used to communicate with the PC to display data.

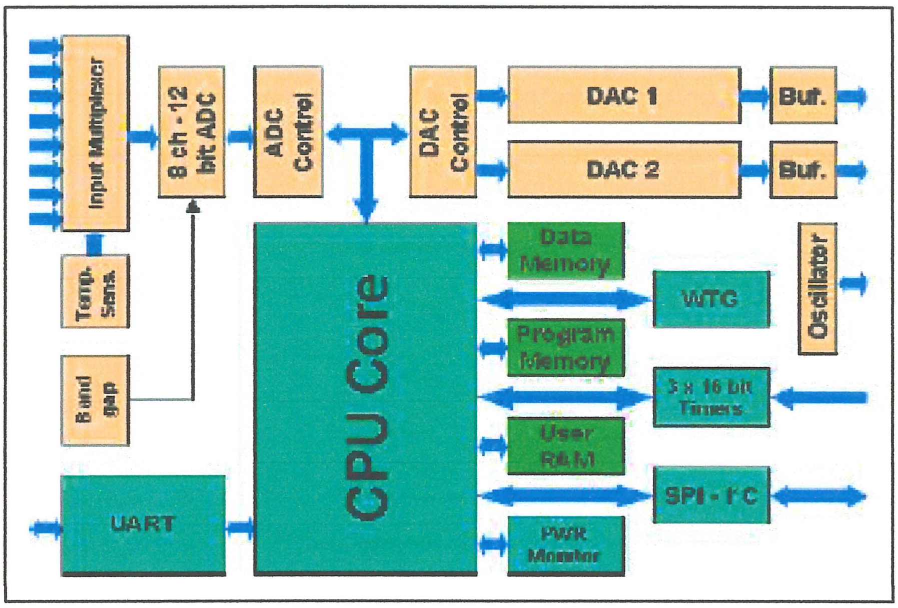


Figure 2.3 Block diagram of ADuC812 microcontroller
Source: Marani et al. (2010)

Based on Yu et al. (2013) project, a wheeze detection system by using small and soft stethoscope was developed. The main purpose of this sensor was used to collect respiratory sound. Meanwhile, wheeze detection algorithm named Adaptive Respiratory Spectrum Correlation Coefficient (RSACC) are developed to process the data from the sensor. The advantages of this algorithm are high sensitivity/specificity and a low computational requirement. To test this sensor and algorithm, fifty-nine sound files from eight young children which range from one to seven years old are collected in an emergency room and analyzed. As a result, this small soft stethoscope can be easily used on children as the system proved 88% sensitivity and 94% specificity in wheeze detection.

In Zuileika et al. (2014) design, a CO_2 measurement device is used for monitoring application. In this project, MG-811 CO_2 sensor is used to measure the pressure of exhaled CO_2 in parts per million (ppm) units. However, the output of the sensor is low so signal conditioning and comparator is used to amplifier the output before sending to microcontroller. In this project, Arduino microcontroller is used for Analog-Digital Convertor application and data analysis. In order to communicate with PC and display the data, Universal Serial Bus (USB) port is used to connect to PC.

Meanwhile, Matlab software is used as a real-time plotter to display the CO_2 measurement against time.

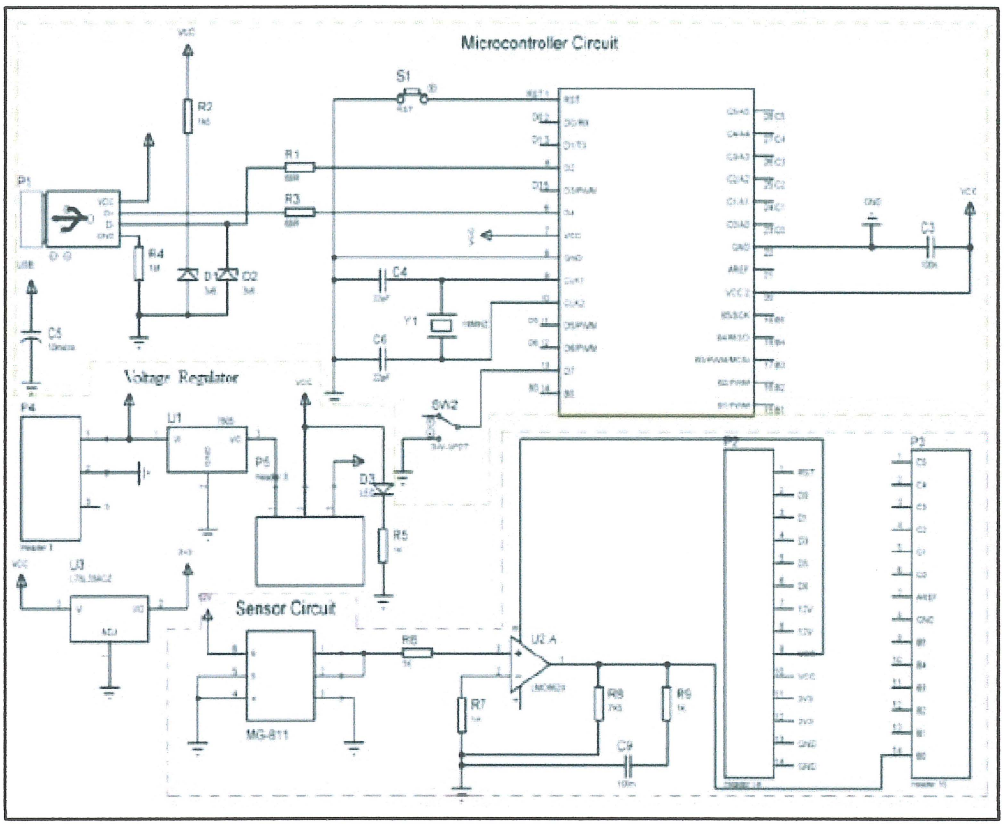


Figure 2.4 Overall electric circuit for the develop hardware
Source: *Zuileika et al. (2014)*

In Kaushal et al. (2015) review, pellet sensor is used for exhaled based analysis. This sensor is built up using MOS and it has a low cost and easy to operate. In this project, two subjects are used for the analysis. One of them is asthmatic patient and one is not. To make sure the patient is asthmatic; spirometer is used to test the patient and the result is recorded. Then, the analysis from the pellet sensor is used to compare with the result from the spirometer. The pellet analysis graph is drawn according to resistance (ohm) against time. To differentiate the patient from asthmatic and non-asthmatic, the analysis graph from the pellet sensor has lower amplitude of resistance for asthmatic patient compared to normal patient.

Based on Liu et al. (2015) paper, ultrasonic imaging sensor is used for this work. This sensor is to locate the location of the liver and diaphragm. Next, by using USB port, the information is transfer to the computer for analysis. The information included the respiratory signal from the movement of the diaphragm in the image sequence. Then, 1-D time-series signal is computed the original 1-D waveform included respiratory signal and many noises such as cardiac signal. Thus, a low-pass filter is used to filter the unwanted noise. After that, the 1-D time series signal is compared with normal breath, fast breath, apnoea and coughing; lastly the data is display on a Matlab Graphical User Interface (GUI).

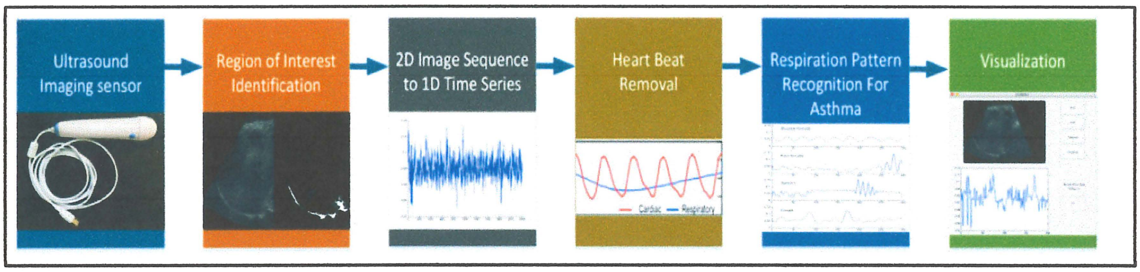


Figure 2.5 Overview of the Ultrasonicgraphy processing procedure
Source: Liu et al. (2015)

For Gatthy et al. (2015) review, MEMS based NO is used to detect asthma. Based on this review, asthma is detected by the sensitivity of the sensor and graphs are plot accordingly to the sensitivity against the changes of humidity, response time, flow sensitivity and stability. The data from the sensor are used in LabView to plot those graphs. From the results, the sensor is suitable to detect asthma as it is relatively fast response and high sensitivity to carbon oxide (CO) and ammonia (NH_3)

2.4 Signal Transmitter

A signal transmitter is an electronic device which is capable of generates electromagnetic wave carrying information and signal which lastly receive by a receiver. According to Buechley et al. (2006), in order to let the device kit communicate with another device, Infrared (IR) transceiver is installed inside the device kit. After receiving the data from IR transceiver, data will be processed by PC or smartphone and then displayed.

Next, based on Bjelica et al. (2010) User Awareness Kit (UAK) project, UART serial communication device is used to interface with the binary intra-processor protocol. In order to facilitate the device, a library in C code is written for integration to the target device. Next, the data receive will be process by Sky TV or GUI.

Based on Ramli et al. (2016) project, Bluetooth module HC-06 has been used as a signal transmitter device and Android platform are built as a receiver to receive and collect the information which sent out from the device. Android platform will process the data, and then GUI will display the data to the user.

Author	Title of Paper	Signal Transmitter	Data Processing
Buechley et al. (2006)	Multi-purpose user awareness kit for consumer electronic devices	Infrared (IR) sensor	Received and process by devices such as PC or smart phone.
Bjelica et al. (2010)	A Construction Kit for Electronic Textiles	UART Communication Device	User Awareness Kit interface binary intra-processor protocol and data are present by Sky TV application GUI.
Ramli et al. (2016)	Development of Heartbeat Detection Kit for Biometric Authentication System	Bluetooth Module	Received and process by Android platform developed. Data will be present on android application GUI.

2.5 Data Processing

Data processing mean by the data collected is turned into information which is useful in a suitable manner for the understanding of user. There are many types of data processing, such as GUI, LCD, and oscilloscope.

2.5.1 Android Operating System

Based on Yu et al. (2013) review, android is used as a platform to present data. Android operating system is so convenience as this system can be open in any electronic device such as the smartphone, PC or even pads at anywhere. Next, Ramli et al. (2016) reported that android platform is used as a function of login in the system. GUI is also built inside the android platform where the result of the detection kit will be sent to.

2.5.2 Graphical User Interface (GUI)

Buechley et al. (2006) proposed Skype TV application GUI is used to present the result and data for the user. GUI is also used by Ramli et al. (2016) to present the data from the detection kit. However, this GUI is built inside the android operating system which user can easily observe using smartphone.

2.5.3 Matlab Software

Matlab software is used by Zuileka et al. (2014) as a real time data plotter. A real-time data logger was developed by sorting the data into an array using the basics of Serial Communication in Matlab by updating the output or data plot according to the real-time.

2.5.4 Capnogram

As shown from the Figure 2.6, the normal capnogram has a square wave whereas the abnormal canagram has a 'shark-fin' appearance. The abnormal capnogram show a low level of concentration of exhaled CO_2 compared to normal capnogram. Based on Yaron et al. (1996) the angle at point Q for the capnogram, of two different subjects is caused by the asynchronous emptying of the alveolar. For airway obstruction, alveoli supplied with oxygen by regular low-resistance airways are comparably hyperventilate and have lower concentrations of CO_2 compared to the region of the lungs that are poorly ventilated. During expiration, gasses from poorly ventilated area mixed with gases in the normal region result in a delayed rise of concentrations of CO_2. Thus, causes the widen angle at point Q for the capnogram of asthmatic patient.

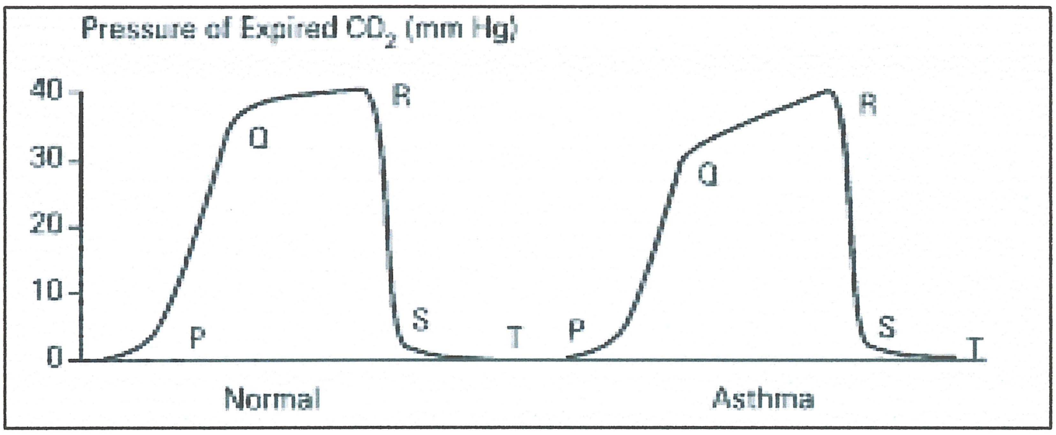
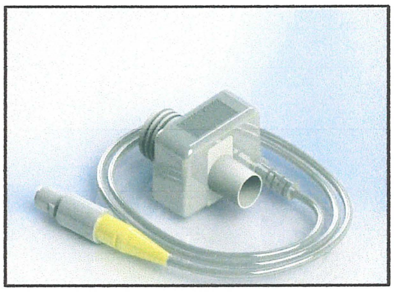


Figure 2.6 Capnogram between normal and Asthmatic subject
Source: Yaron et al. (1996)

2.6 Asthma Device Price Comparisons

Product	Device	Price	Sources

	Capnography	$1,799.00	Tuner Medical, 2016. Retrieved from: http://www.turnermedical.com/BCI_8400_CAPNOCHECK_II_CAPNOGRAPH_OXIMETER_p/bci_8400.htm
	Capnography	$1,180.88	Aliexpress, 2016. Retrieved from: https://www.aliexpress.com/item/FREE-SHIPPING-INTEGRATED-MAINSTREAM-CO2-SENSOR-NDIR-EtCO2-SENSOR/32531506295.html?spm=2114.40010208.4.6.NfrlpH ;
	Spirometer	$131.99	Aliexpress 2016. Retrieved from: https://www.aliexpress.com/item/Lung-Breath-Tester-Electronic-Spirometer/32513794729.html?spm=2114.40010508.4.7.lfS25t
	Peak flow meter	$89.00	Cardiologyforless, 2016. Retrieved from: http://cardiologyforless.com/Spirometers/Microlife-Digital-Peak-Flow-Meter.html

2.7 Conclusion

After some comparisons and review, CO_2 sensor has been decided to use in this project due to it can measure the concentration of exhaled CO_2 in a relaxing way and it is suitable for every user without limiting the range of user age. Next, Arduino microcontroller is used to collect and process the data from the sensor and it is low in cost and easy to operate. Meanwhile, to transmit data Arduino microcontroller to PC, HC-06 Bluetooth module is suitable in this project as it easy to operate and communicate with PC. A TFT LCD shield will be built on the electric kit as a data-presentation element; the data will be display in the form of the graph which is similar to capnogram. Meantime, GUI application will be built inside PC as a data analysis platform to display the graph in a more interest and clearer way for the user

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, a lot of research methodology was review and applied in order to obtain the objective for this project. Basically, this chapter is categorized into two main parts which are hardware and software. The hardware part includes the development of the electronic kit whereas software parts are the coding development for the Arduino microprocessor in order to read the data from the sensor and interface with data presentation element. In this section, MH-Z14A CO_2 sensor was chose instead of others. On top of everything, Arduino microcontroller is proposed to use in this project whereas Bluetooth module HC-06 will be used as a signal transmitter to communicate with PC while TFT LCD Shield will be used as data-presentation element in this project.

3.2 Flow Chart of Methodology

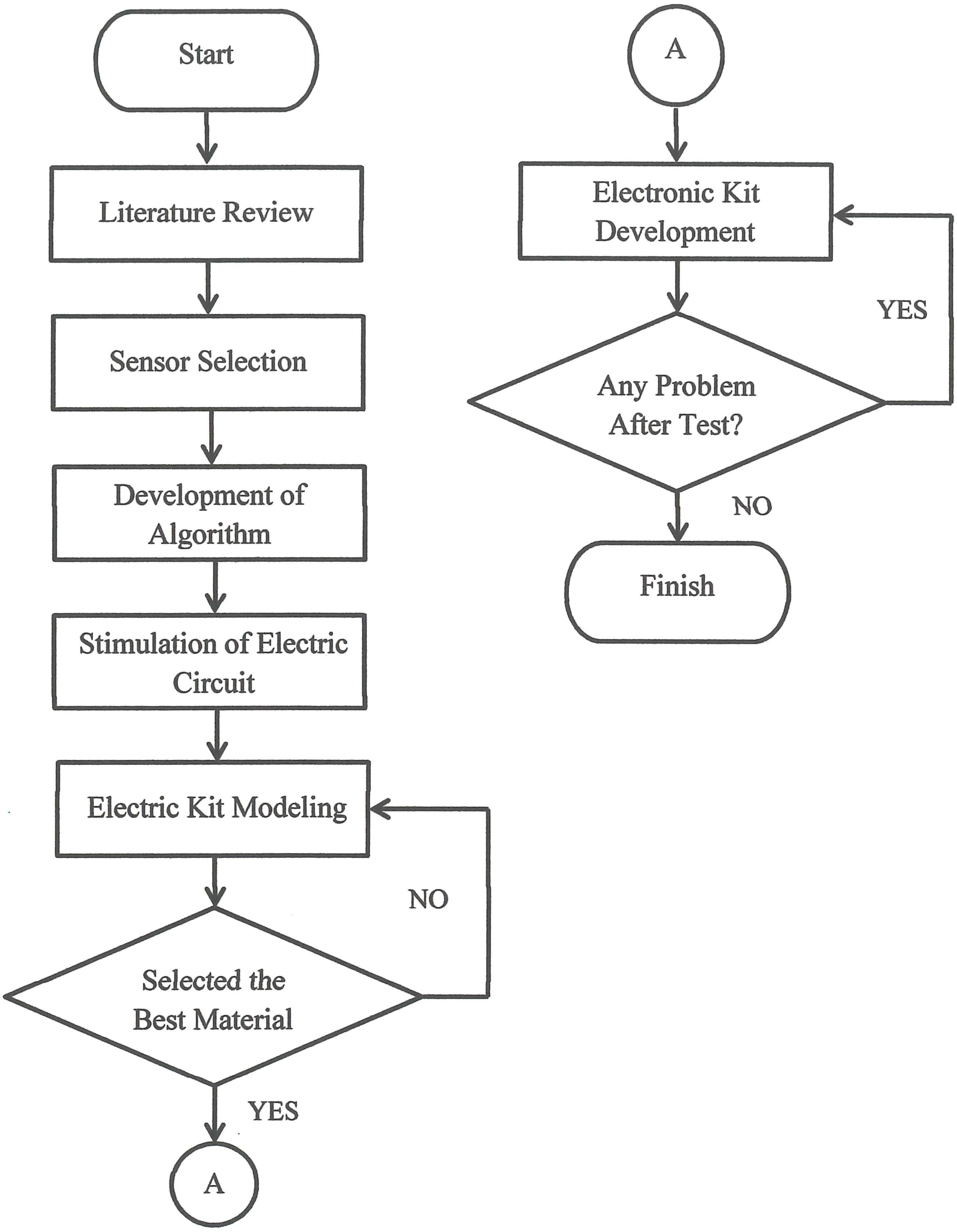


Figure 3.1 Flowchart of Methodology

3.3 MH-Z14A NDIR Carbon Dioxide Sensor

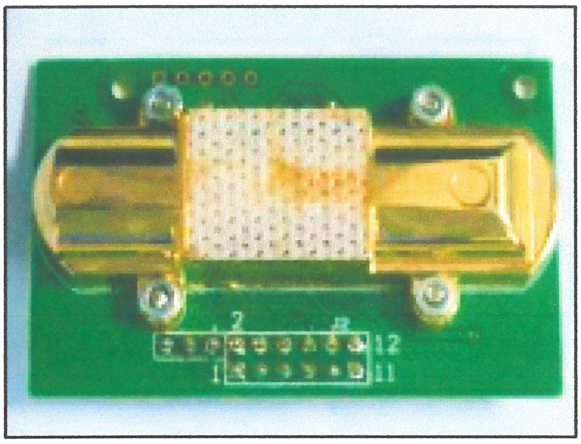


Figure 3.2 NDIR Carbon Dioxide sensor
Source: Futurlec.com (2000)

Figure 3.2 above shows a MH-Z14A sensor, which is basically a CO_2 sensor. The detection of this sensor is in the range 400-5000ppm CO_2. Based on Futurlec.com (2000), this sensor has three type of output including analog, PWM and also UART communication protocol. For this prototype, UART communication protocol will be used. Below shows the data obtain procedure and hardware serial communication.

Below order would be sent when host send concentration value of the sensor:

0	1	2	3	4	5	6	7	8
Start bit 0XFF	Detector No.	order 0x86	00	00	00	00	00	Check value

Format of data returned by subsidiary detector:

0	1	2	3	4	5	6	7	8
Start bit 0XFF	Detector No.	High channel	Low channel	Tem. channel				Check value

Figure 3.3 Data obtain procedure and hardware serial communication
Source: Futurlec.com (2000)

Based on the Figure above, for the hardware serial communication it needed 9 byte for each frame data, starting with 0xff. The serial communication consists of transceiver and receiver; therefore it consists of host and subsidiary detector. From the data obtain procedure and hardware serial communication an equation is generated as Equation 3.1 to calculate the concentration of CO_2.

$$Concentration\,of\,CO_2 = Highchannel * 256 + Lowchannel \tag{3.1}$$

Based on some experiment using this sensor, when the concentration of CO_2 is high, high channel will maintain its value however the low channel value for this sensor will increases. Low channel value is directly proportional to the concentration of gas. For example using Equation 3.1:

$$\begin{aligned} \mathit{Concentration\,of\;Carbon\,Dioxide} &= \mathit{High\,channel} * 250 + \mathit{Low\,Channel} \\ &= 8 * 256 - 176 \\ &= 1872\,ppm \end{aligned}$$

When the concentration of the CO_2 detected is high, therefore the low channel will increases from negative value to positive value as below:

$$\begin{aligned} \mathit{Concentration\,of\;Carbon\,Dioxide} &= \mathit{High\,channel} * 250 + \mathit{Low\,Channel} \\ &= 8 * 256 + 500 \\ &= 2548\,ppm \end{aligned}$$

3.4 Mechanical Design

The three-dimensional design drawing of Electronic kit is drawn by using CATIA P3 V5R21. Computer-aided three-dimensional interactive application (CATIA) is a multi-platform of product development including conceptualization, design, engineering, and manufacturing. Suitable materials will be selected and a prototype will build based on the CATIA model. The material selected to build this electric kit included electronic 3D printing model, TFT LCD shield, ON/OFF switch, inhaler, and hose. To build the inhaler, 3D printer will used to build it whereas the body will built using electric junction box. This three-dimensional design in Figure below is drawn based on the real dimension of those materials.

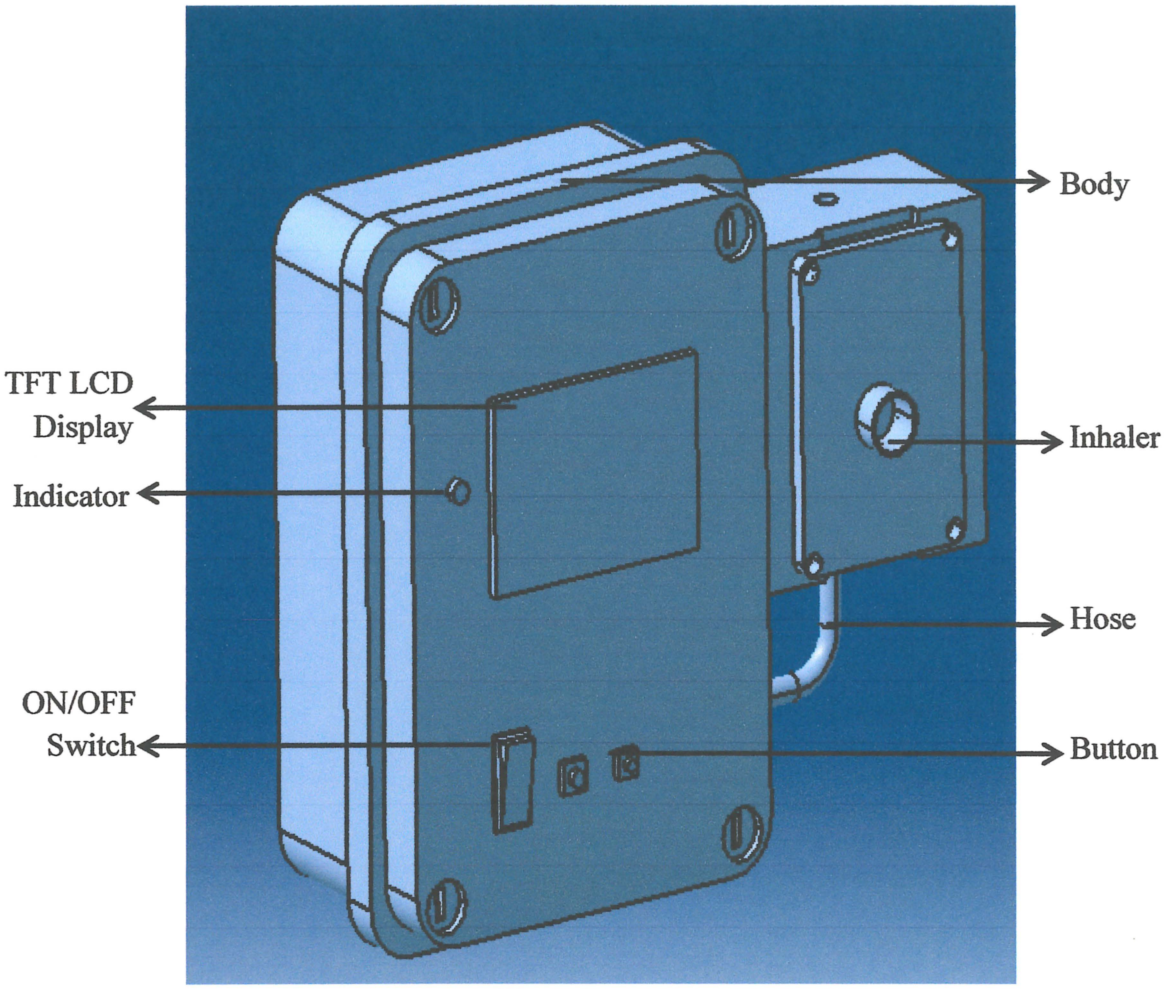


Figure 3.4 Isometric view of electronic kit

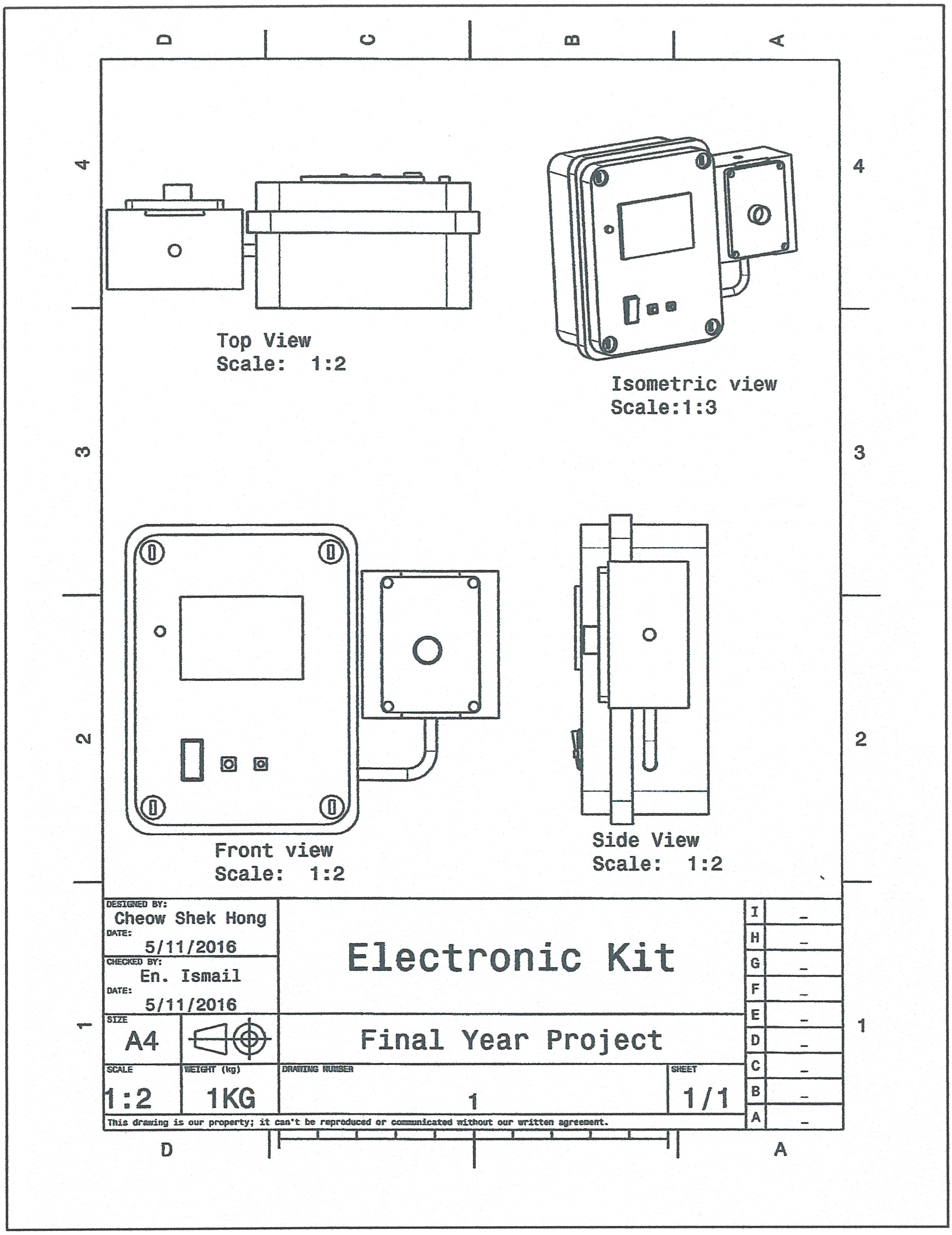


Figure 3.5 Design draft

3.5 Schematic Diagram of Electric Circuit

To build this electric circuit, Frtizing software is used. Fritzing software is basically an open source initiative to develop amateur or CAD software for the design of electrics hardware.

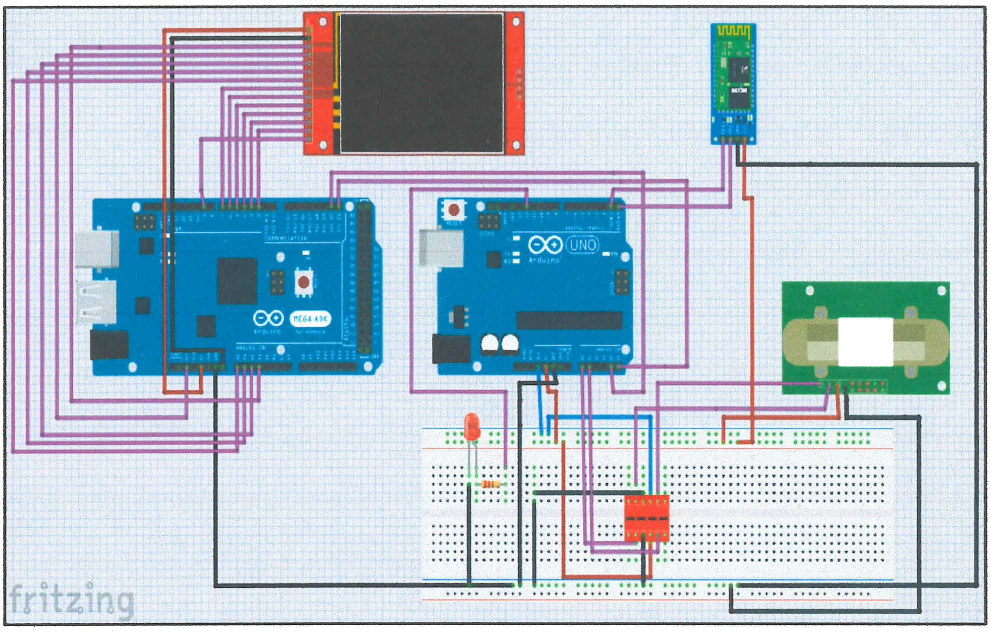


Figure 3.6 Schematic diagram of electronic kit

Based on Figure 3.6, it consists of two Arduino, TFT LCD display, HC-06 Bluetooth module, MH-Z14a CO_2 sensor, logic level converter, LED and resistor.

Both of the Arduino board will communicate with each other using inter-integrated circuit or I2C. Arduino Mega acts as the slave whereas Arduino Uno acts as the master. At first, Arduino Uno will receive data from MH-Z14A CO_2 sensor then it will send the data to Arduino Mega so that TFT LCD shield can display the result in a graph form.

The purpose of using Bluetooth module HC-06 is to communicate with PC instead of using cable. Data collected from the sensor will send to PC through this module. Meanwhile, logic level converter is used because the UART output for the sensor maximum is 3.3V; unfortunately the input for the Arduino pin required a high voltage which is 5V. Therefore, this logic level converter is to collect the signal from low voltage side and send to a higher voltage side

3.6 Process Flowchart

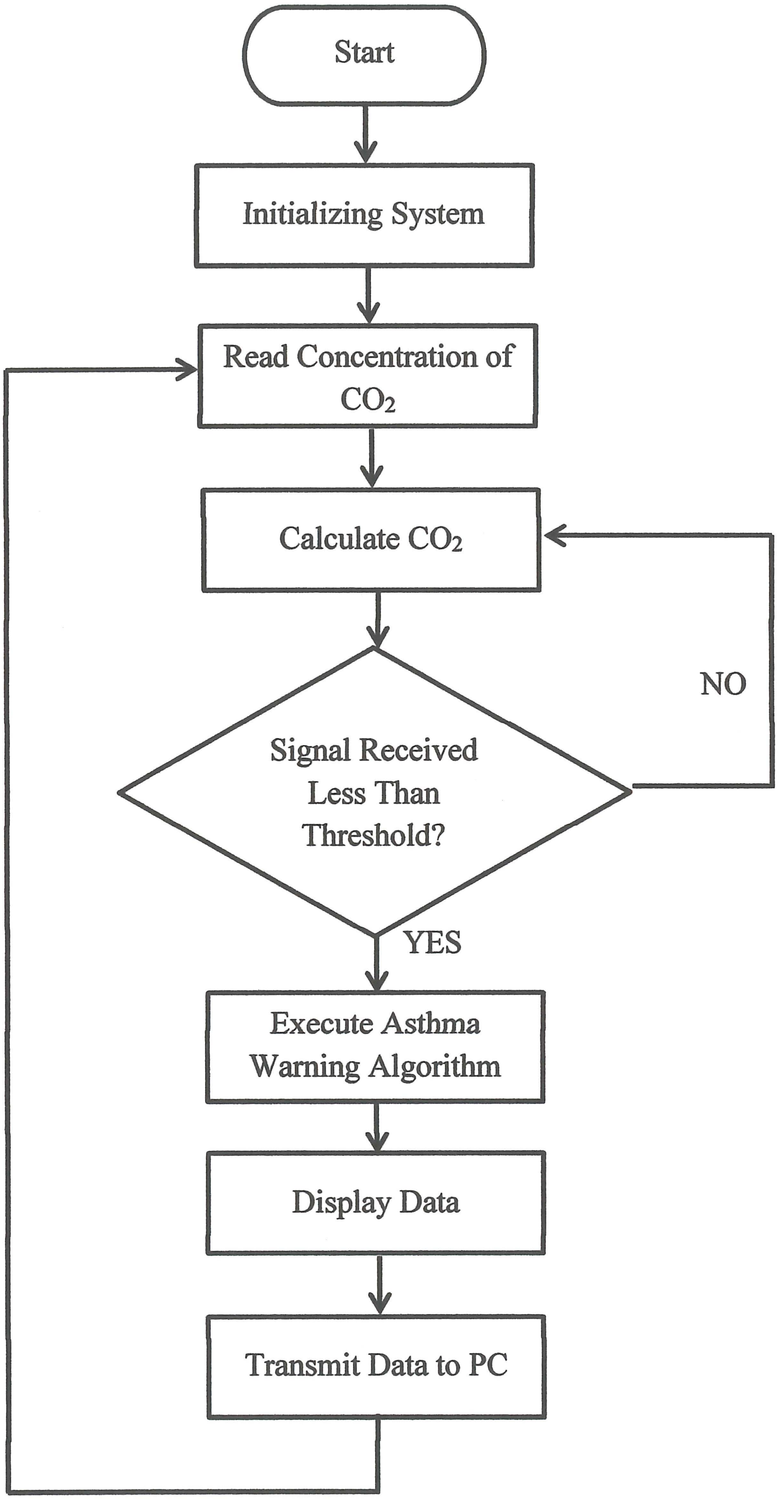


Figure 3.7 Process flowchart

Based on the Figure above, it shows the process flow chart for the device. When the ON/OFF button is on, then system will initialized and the sensor will started to warm up. When the sensor sensed concentration of CO_2, it will start to read and calculated the concentration. When the concentration of CO_2 is less than the threshold then it will execute the asthma warning algorithm. This is to give warning for the user for further diagnosis or treatment. However, if the concentration does not reach the threshold, then the warning algorithm will not be executed and it will back to the previous stage by calculating the concentration again. Next, the raw data will be displayed on the TFT LCD shield. Meanwhile, the data will also send to the PC for a better view.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This section describes the results of this prototype that were carried out based on the methods as described in Chapter 3. It elaborates more on the results gathered from these researches and comparisons between researches and prototype are done. The raw data and results were labeled and tabulated orderly. At the same time, the results are obtained throughout the serial monitor from Arduino for analyzed and interpreted. The results will be presented using Microsoft Excel for better and clearer view. Next, comparisons and analysis are done between the raw data and the research data.

4.2 Arduino Serial Monitor

Serial connection is used for communication between the Arduino board and a computer or other devices. UART or USART is one of the serial ports for Arduino board. It communicates on digital pins 0 (RX) and 1 (TX) meanwhile it also can communicates with the computer via USB.

In our case, UART is used to communicate with the computer. The raw data from the sensor will generate through the serial monitor and user can monitor through it.

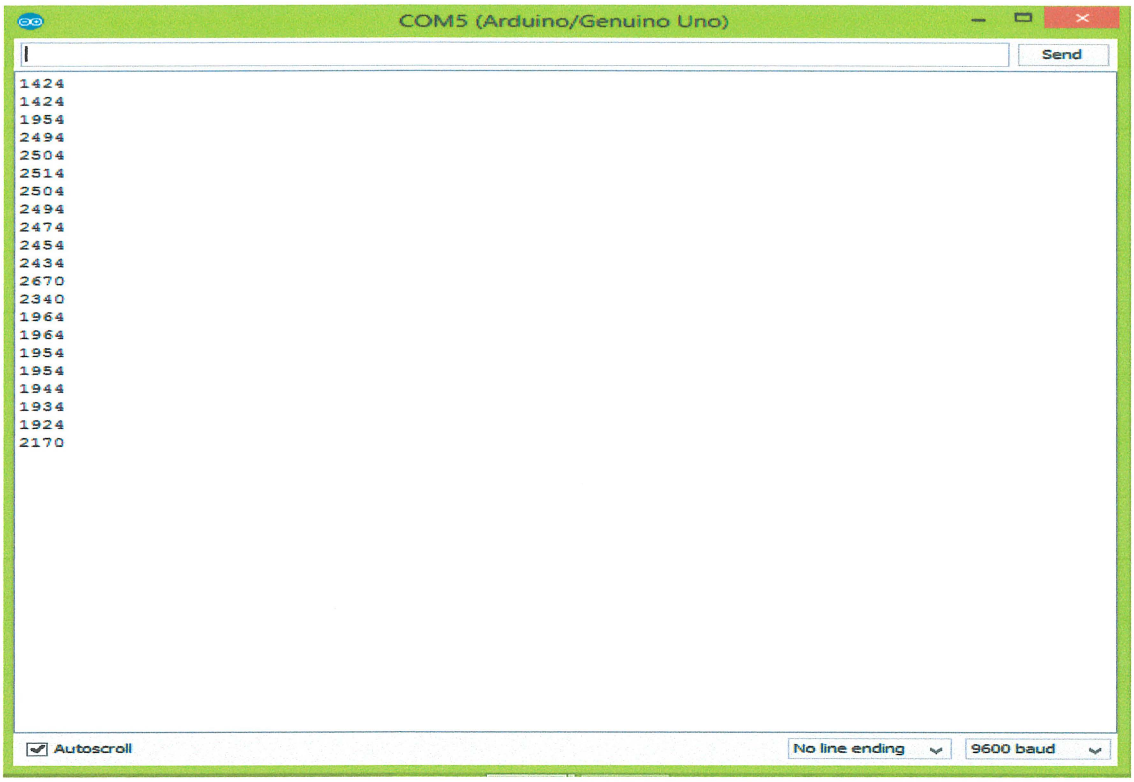


Figure 4.1 Arduino Serial Monitor

Based on Figure 4.1, the data was starting from 1424ppm then it rose to 2514ppm. This is due to the MH-Z14A CO_2 sensor sensed the concentration of CO_2 from the exhaled breath of the user. Then it generated data to Arduino Serial Monitor based on the concentration of CO_2 sensed. Then, the concentration of CO_2 started to decreases and thus the reading on the serial monitor started to decline. Next, the data is copied to Microsoft Excel to generate the pattern of CO_2 concentration for further analysis.

4.3 Microsoft Excel

Microsoft excel is a spreadsheet features calculation, graphing tools, pivot tables, and a macro programming language called Visual Basic for Applications. In this project, Microsoft Excel is used as a graphing tool. Based on the data collected graph is generated for further analysis.

4.3.1 Raw Data and Graph from Normal User

Table 4.1 Raw data collected from normal user 1

Time (s)	Concentration of CO2 (ppm)		
	Test 1	Test 2	Test 3
10	1764	1724	1754
20	1765	1934	1744
30	2984	2754	3064
40	3004	2774	3400
50	3004	2784	3400
60	3004	2784	3380
70	2984	2774	3150
80	2954	2754	2544
90	2444	2734	2534
100	2640	2714	2524
110	2640	2264	2514

Table 4.2 Raw data collected from normal user 2

Time (s)	Concentration of CO_2 (ppm)		
	Test 1	Test 2	Test 3
10	1534	1534	1504
20	1534	1524	1734
30	2764	1754	2224
40	3100	2820	2244
50	3110	2820	2254
60	3110	2830	2254
70	3090	2820	2264
80	2814	2554	2244
90	2784	2534	2234
100	2840	2514	2224
110	2254	2494	2214

Table 4.3 Raw data collected from normal user 3

Time (s)	Concentration of CO_2 (ppm)		
	Test 1	Test 2	Test 3
10	1244	1250	1214
20	1254	1534	1560
30	3940	3650	2880
40	4294	3650	2880
50	4294	3630	2880
60	4284	3600	2870
70	4254	2714	2840
80	3484	2694	2264
90	3464	2940	2360
100	3620	2920	2350
110	1244	1250	1214

From the Table 4.1, 4.2 and 4.3, it showed the raw data collected from three different normal users. 3 tests were carried out from the each of the user to improve the accuracy of the result. From the Table above, it clearly showed that the raw data starting from the range of 30 second to 60 second shows the concentration of carbon dioxide maintain at the same level before dropping. To have a better view on the raw data, graph was generated as below:

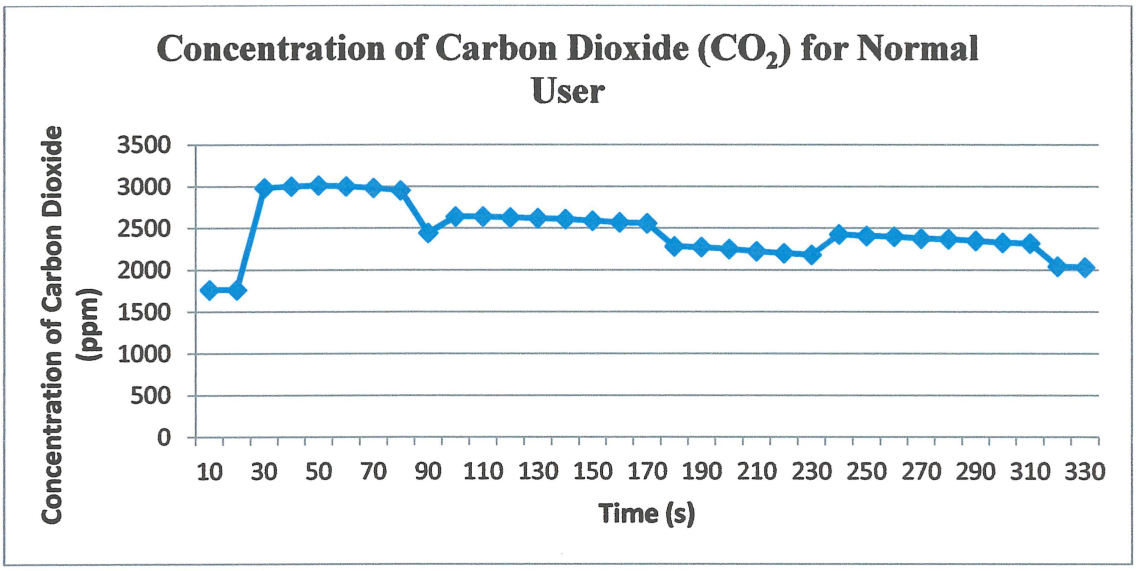


Figure 4.2 Graph generated from raw data of normal user

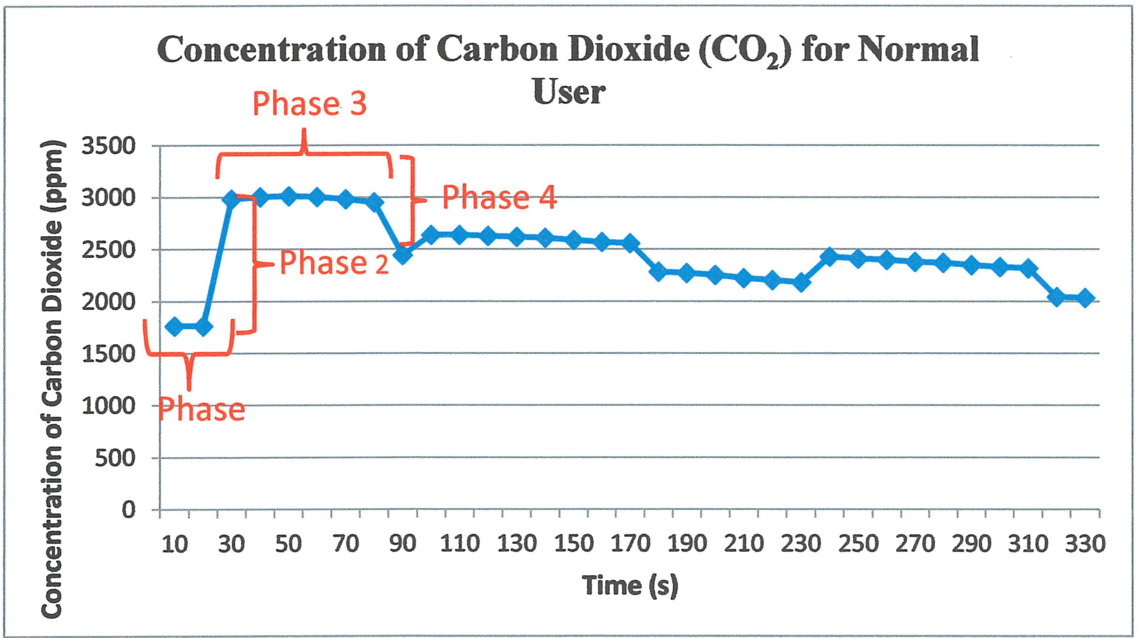


Figure 4.3 Phase 1-4 of the graph generated by normal user

Based on Figure 4.2, raw data for test 1 of the normal user 1 is used to generate the graph. From the graph above, the concentration of CO_2 started to rocket up to 3004 ppm then it maintained at the level for 30 seconds before dropped to 2984 ppm then it slowly return to its initial value.

Based on Dr. Mello et al. (2002), capnogram consists of 4 phase. Phase 1 also known as Baseline. Baseline is the beginning of exhalation where no CO_2 presented. As shown in Figure 4.3, baseline started around 1764ppm due to this sensor measured the concentration of CO_2 of the surrounding instead of the human exhalation. When the user exhalation was sensed thus it caused phase 2 to begin.

Phase 2 also known as ascending phase, caused by the CO_2 from the alveoli begins to reach the upper airway and caused the amount of CO_2 to rise rapidly. From Figure 4.3, the concentration rise from baseline to the peak was phase 2.

Next will be phase 3, also known as alveolar plateau. The concentration of CO_2 in this phase is stable as shown from the Figure above. This is because the CO_2 rich alveolar gas constitutes the majority exhaled air. Meanwhile the concentration of CO_2 is uniform from alveoli to mouth or nose.

Lastly, phase 4 (descending phase) where the CO_2 level drops quickly to its initial value. This phase can be seen from the graph above when the concentration started to drop after the peak level.

From the graph above, the concentration of CO_2 has some increment before dropping to the initial value. This is due to the sensor might has sensed the concentration of the surrounding environment

4.3.2 Comparison between Three Normal User

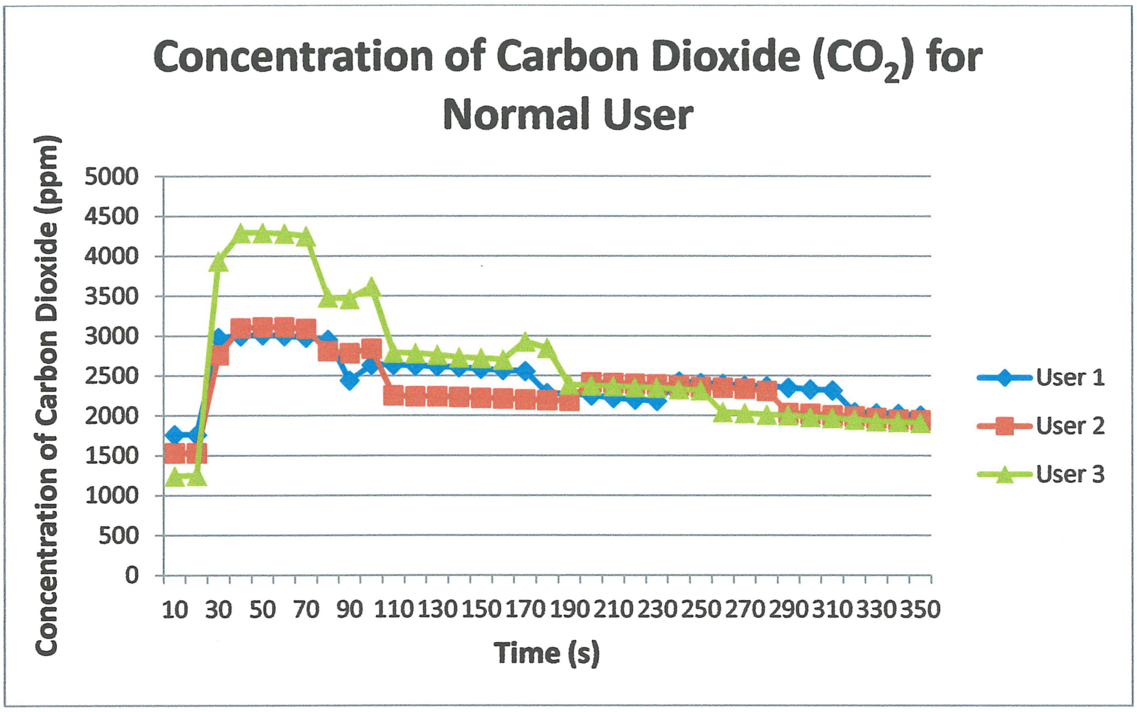


Figure 4.4 Comparison between three normal user

Based on Figure 4.4, three of the graphs show the same pattern for the previous 110 second of the user. As shown above, the peak concentration range is between 2700 to 3100 ppm. Each of the graph show that when they reached the peak level of concentration, they tend to maintain at the same level for some time before starting to decrease. The peak level of concentration is different from various users due to the way of user exhale on the sensor is different. This can be explained when the user exhaled on the sensor, some might take a shorter time or longer time so when the exhaled period is different so the concentration sensed by the sensor might be slightly different. Besides, this happened because the distance between the user and the sensor is different when exhaled. Although the concentration peak level is different but it did not influenced the pattern of the graph.

4.3.3 Raw Data and Graph from Asthmatic User

Table 4.4 Raw data collected from Asthmatic user 1

Time (s)	Concentration of CO2 (ppm)		
	Test 1	Test 2	Test 3
10	1454	1494	1580
20	1454	1484	1580
30	3450	1484	1580
40	4910	3890	2814
50	4900	4410	4094
60	4870	4400	4360
70	4130	4140	4094
80	4110	3690	3850
90	3630	3670	3620
100	3400	3314	3400
110	1454	1494	1580

Table 4.5 Raw data collected from Asthmatic user 2

Time (s)	Concentration of CO2 (ppm)		
	Test 1	Test 2	Test 3
10	1560	1184	1164
20	1570	1184	1164
30	1764	2274	2004
40	4744	4484	3724
50	4744	4730	3724
60	4594	4630	3960
70	4314	3950	3710
80	4284	3930	3004
90	3484	3330	2984
100	3474	2984	2964
110	1560	1184	1164

Table 4.6 Raw data collected from Asthmatic user 3

Time (s)	Concentration of CO_2 (ppm)		
	Test 1	Test 2	Test 3
10	1484	1580	1560
20	1484	1580	1570
30	3890	2814	1764
40	4410	4094	4744
50	4400	4360	4744
60	4140	4094	4594
70	3690	3850	4314
80	3670	3620	4284
90	3314	3400	3484
100	2734	2784	3474
110	2724	2714	3710

Based on Table 4.4, 4.5 and 4.6, it shown the raw data of three asthmatic users. To make sure the accuracy of the result, the results are taken three times from each of them and each time there is 35 raw data collected to generate the graph for analysis. However, the table above will only have the first 11 data only. All the raw data inside the Microsoft Excel is collected from the Arduino Serial Monitor.

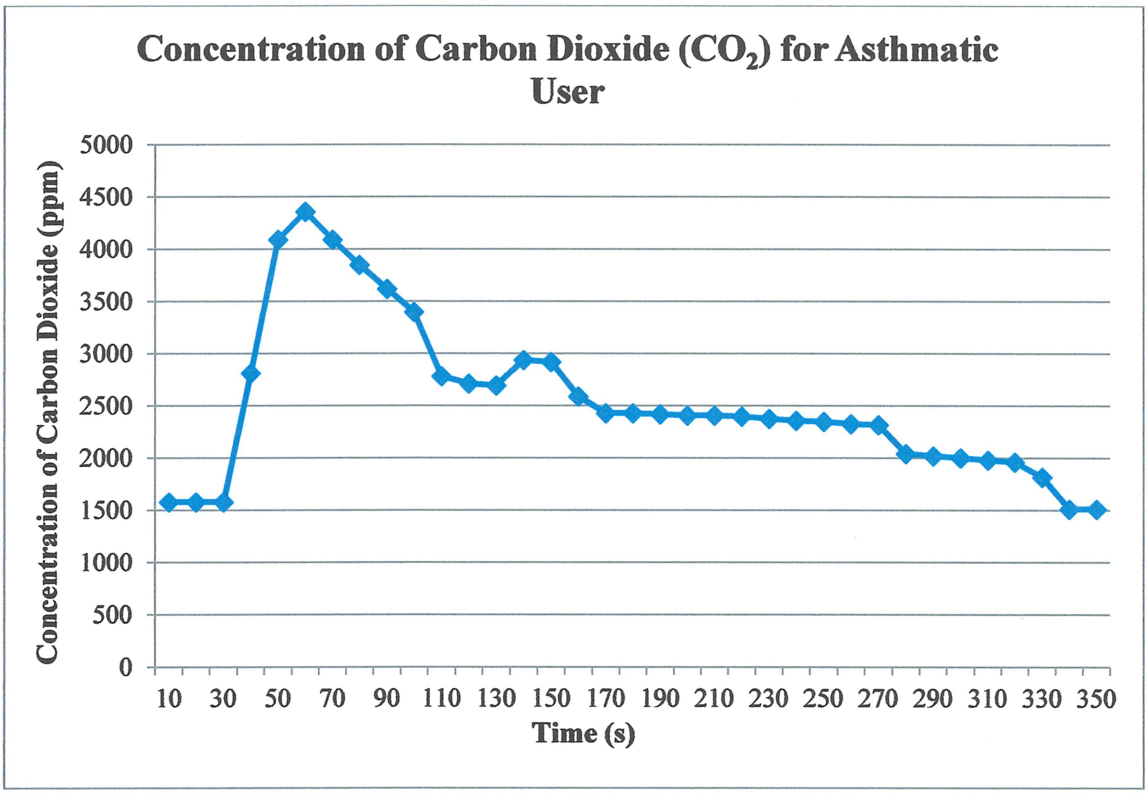


Figure 4.5 Graph generated from raw data of Asthmatic user

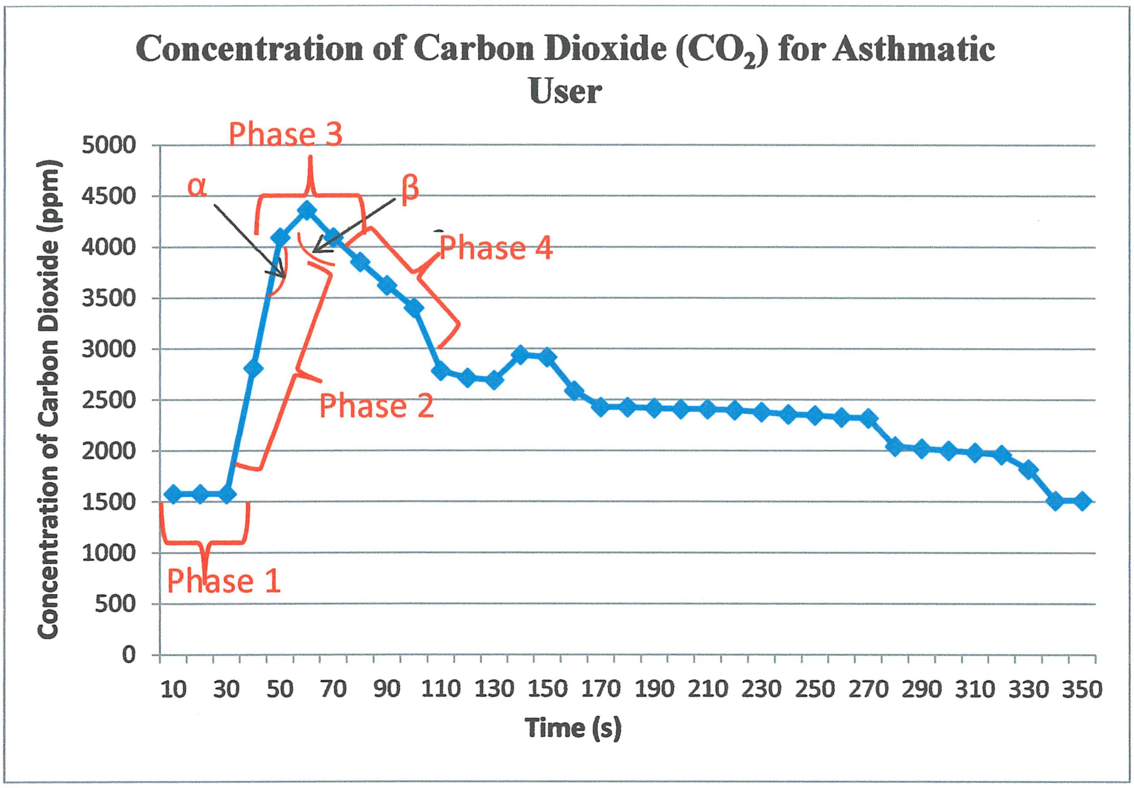


Figure 4.6 Phases 1-4 of the graph generated by Asthmatic user

Based on Figure 4.5, the raw data started to rocket up when the sensor sense the concentration of CO_2 from the asthmatic user. Then it started to decrease as the concentration of the CO_2 started to decrease until it reached the initial value.

For asthmatic user, smaller airway is narrow by the half mark of asthma and caused obstruction to flow within the airways especially during expiration. In asthma, airway obstruction causes regional decreases in airflow and causes "alveolar ventilation". Therefore it causes the deformation of the normal curve as shown in Figure 4.6. From the graph, we can observe the deformation cause the opening angle in phase 2 (α) and 3 (β).

4.3.4 Comparison between Three Asthmatic User

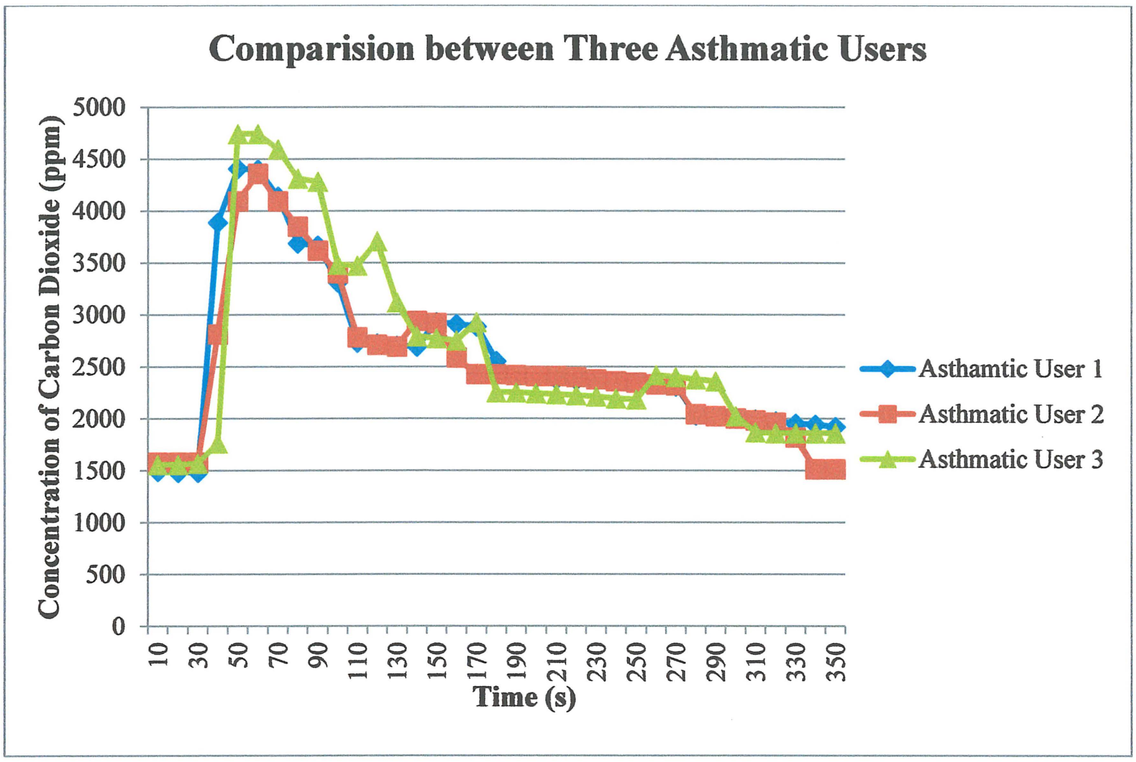


Figure 4.7 Comparison between Asthmatic user

Based on Figure 4.7 above, it showed the graph comparing three asthmatic users' CO_2 concentration level. From the graph above, it showed that the highest concentrations of CO_2 for three of the asthmatic patient are in the range of 4400 to 4800 ppm. When the concentration of the CO_2 reaches the highest level, they started to drop until they reached the original level

4.3.5 Comparison between Asthmatic and Normal User

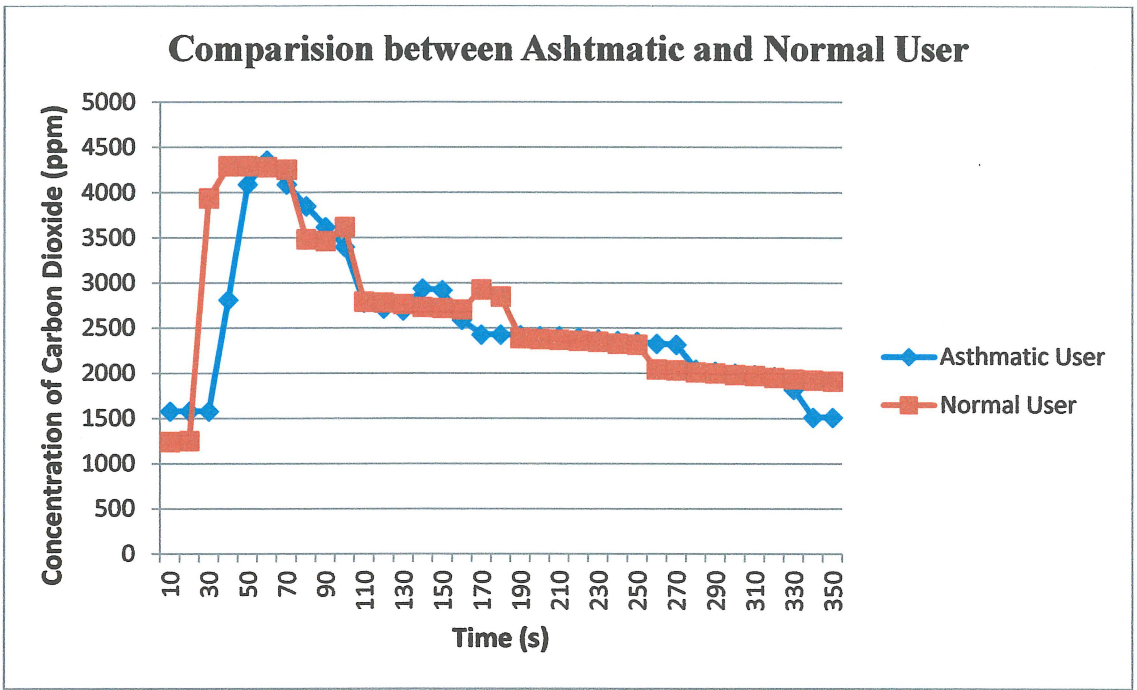


Figure 4.8 Comparison between Asthmatic and normal user

Based on Figure 4.8, it shows the comparison between the concentration of CO_2 between asthmatic and normal user. As shown above, the pattern between the two graphs are slightly difference. At first, the starting point and the peak concentration of CO_2 is almost the same. However, when they reach the peak level, for the CO_2 concentration of the normal user stabilize and maintain for quite some time before it started to decline. Meanwhile, for the CO_2 concentration of the asthmatic user, it started to decline just after reaching the peak. Then, both of the CO_2 concentration stated to fall until they reached a level below 2000ppm.

From the graphs above, the angle in phase 2 and 3 are slightly different. For asthmatic user, the graph in phase 2 and 3 is wider than the normal user graph. This is due to "alveoli ventilation". Therefore, from the comparison above, the category of the user can be easily categorized either normal or asthmatic.

By using the Equation 4.1, the gradient of the graph for normal user and asthmatic user is calculated from 70 second to 90 second to differentiate the difference between them.

$$m = \frac{y_2 - y_1}{x_2 - x_1} \quad 4.1$$

For normal user:

$$m = \frac{4294 - 4254}{90 - 70}$$
$$= 2$$

For asthmatic user:

$$m = \frac{3852 - 3400}{90 - 70}$$
$$= 22.5$$

From the calculation above, it shows that the gradient for the normal user is steeper than asthmatic user.

4.4 Actual Result from Electronic Kit

4.4.1 Comparison between Asthmatic and Normal User

Based on Figure 4.9, it shows the graph of concentration CO_2 versus time for normal user. As shown above, the graph started from 1800ppm, then it started to rocket to 3400ppm and then it maintain for a moment before decreased. By comparing with Figure 4.10, the peak values for both graphs are totally different.

Based on the Figure 4.10, the CO_2 concentration started from around 1800 ppm then it rocket to its peak level which around 4400ppm. Then it started to decrease and return to its initial value slowly.

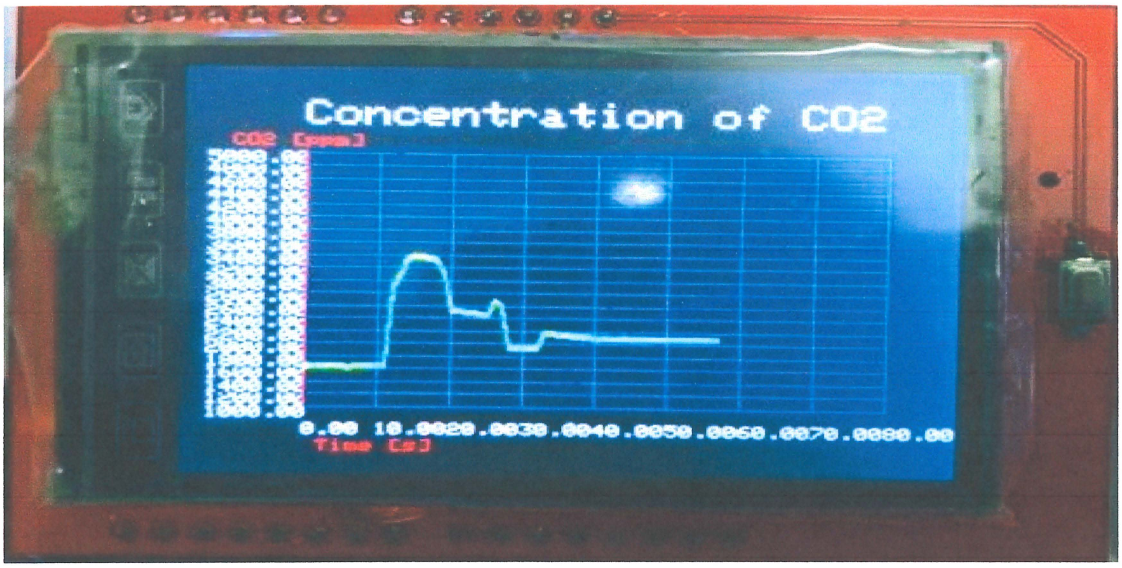


Figure 4.9 Graph of concentration carbon dioxide versus time for normal user

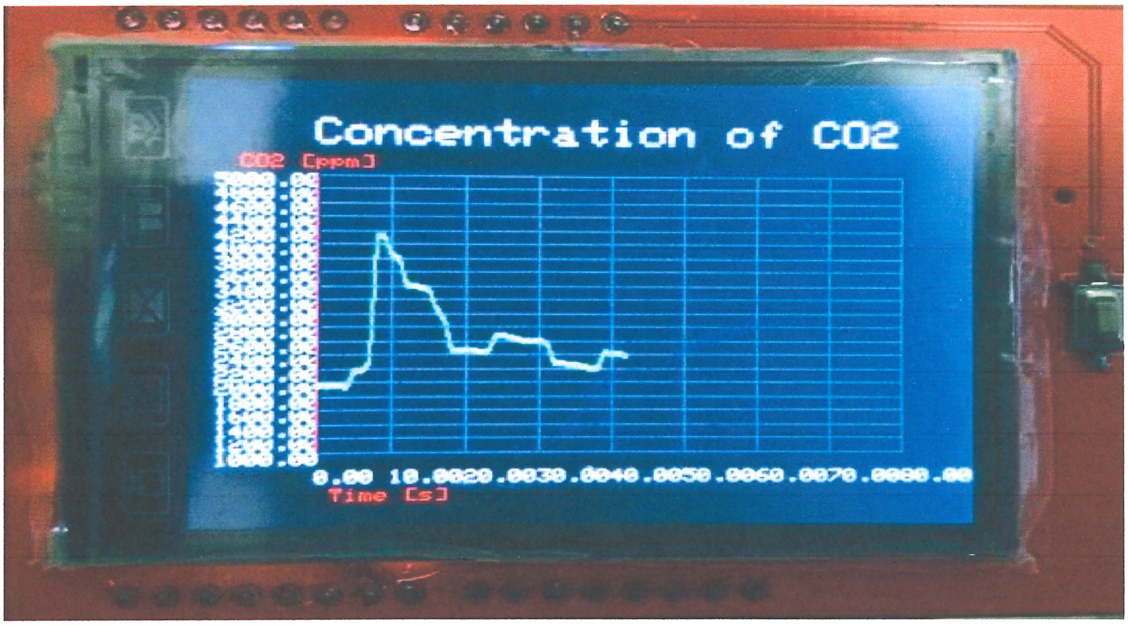


Figure 4.10 Graph of concentration carbon dioxide versus time for Asthmatic user

4.4.2 Comparison between Asthmatic and Normal User

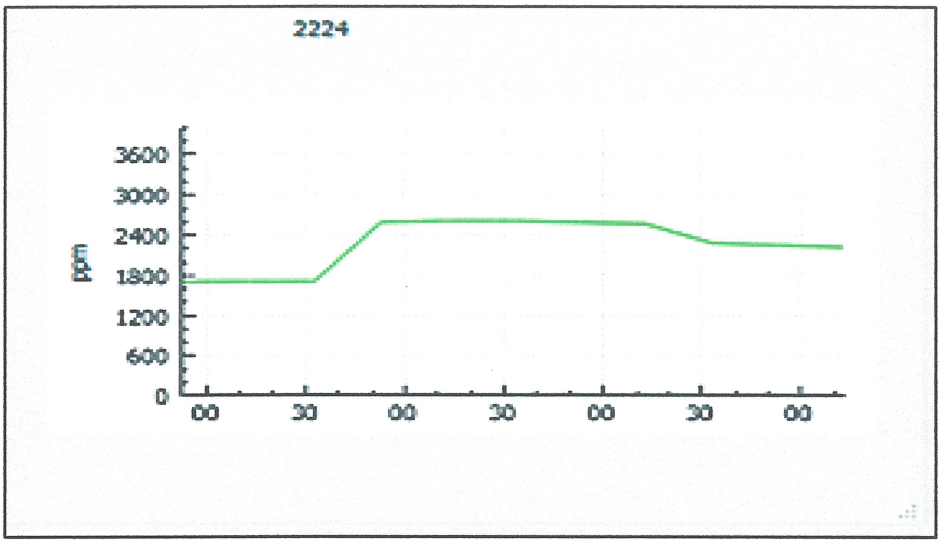


Figure 4.11 Graph of concentration of carbon dioxide versus time for normal user in GUI Application

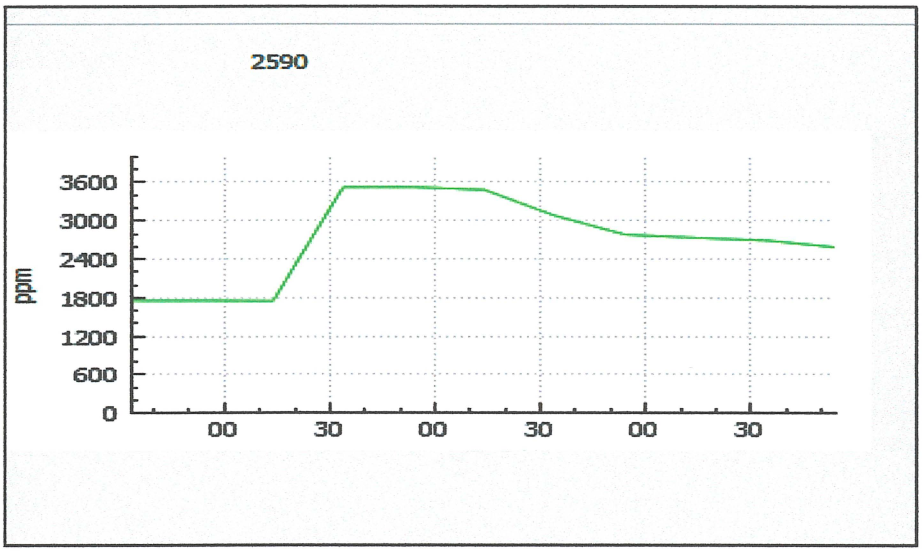


Figure 4.12 Graph of concentration of carbon dioxide versus time for asthmatic user in GUI Application

Figure 4.11 and 4.12 shows the graph plotted inside the GUI application. Based on the figures above, both graph look alike but actually they are slightly difference. Figure 4.10 shows the real time graph for the normal user. As shown above, the peak level is maintaining its level. At the same time, Figure 4.11 shows the real time graph for the asthmatic user. When the concentration reached the maximum level, then it started to decrease instead of staying at the same level. The difference is same is due to the distance between the value is far from each other so it will cause them hard to be differentiate.

4.4.3 Indicator

Based on the difference gradient between normal and asthmatic user, indicator is built inside the electronic kit. Based on Eq. (4.1), calculation showed that the gradient for normal user is steeper than asthmatic user therefore algorithm was programed to calculate the gradient and lastly to differentiate the user's state. When asthmatic user is indicated, the red LED will light up as a warning for the asthmatic user for further treatment. On the other hand, red LED will not lights up if the user is normal.

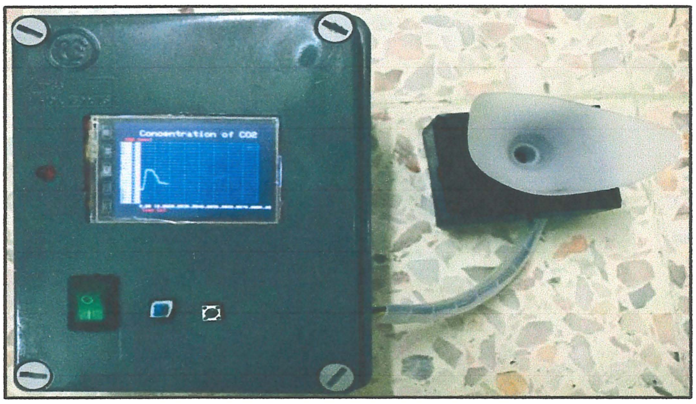


Figure 4.13 Indicator result for normal user

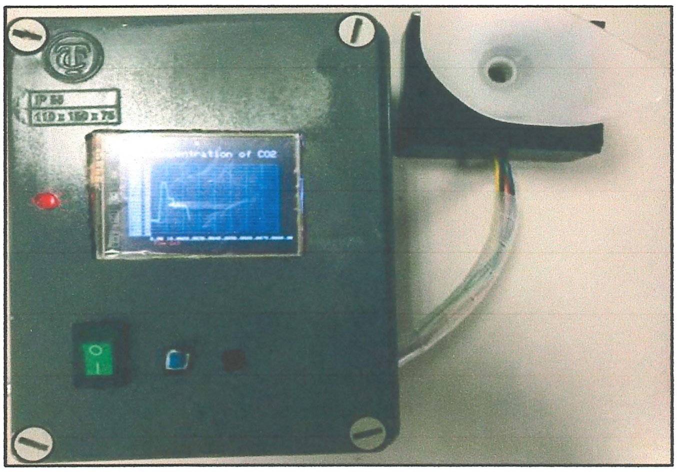


Figure 4.14 Indicator result for Asthmatic user

Based on Figure 4.13, the indicator did not activate as the user is a normal user. This is due to the concentration of CO_2 does not meet the threshold set inside the algorithm therefore the LED will not lights up.

Based on Figure 4.14, the indicator activator as the device detected asthmatic user. Because the gradient for concentration of CO_2 has a gradual slope compared with normal user therefore it triggers the threshold for the algorithm and thus the LED lights up.

4.4.4 Prototype of Electronic Kit

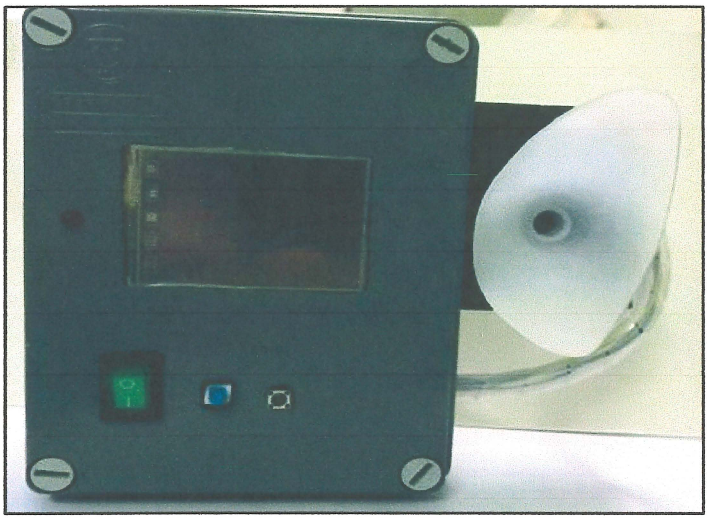


Figure 4.15 Prototype of electronic kit

Based on Figure 4.15, shows the prototype of electronic kit. Based on the figure above, this device's body is built from electric junction box, the inhaler is built from Perspex, and the inhaler cover is made from 3D printing. Meanwhile, TFT LCD Shield, ON/OFF button, switches and hose were included inside this device

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The use of capnography in monitoring asthma and other medical treatment is increasing for the purpose of diseases monitoring application. Nevertheless, capnography is still expensive and unaffordable for patient especially those from low income family. Therefore, in this research a low cost and portable CO_2 monitoring device is proposed to address this problem. For this device, the main component is carbon dioxide sensor, TFT LCD display and also Bluetooth module. The result from the user can be display using TFT LCD display and also PC; meanwhile the result display in a type of graph which can categorize the user either asthmatic or normal. In this research, three asthmatic and normal users are gather to test this device and the result for each of them are gather for analysis. The pattern of the graph for asthmatic user show a significant different compared with normal user. The results show that asthmatic capnography has “shark fin” shape whereas normal user has “square wave” shape. In future, prototype of this device can be tested and validate to be used as a home monitoring device instead of others device such as peak flow meter and spirometer as this prototype device outperforms the complex procedure for both of the devices.

5.2 Recommendations

Although the result in this research has shown that this prototype can differentiate between asthmatic and normal user. However, further development for this prototype can also differentiate others such as hyperventilation, hypoventilation and also bronchospasm. Meanwhile, it was suggested to replace the better carbon dioxide sensor as this sensor has included the carbon dioxide concentration for the surrounding environment into the final calculated value. This might affect the result from the user and mislead the user for further treatment. Last but not least, the result of this prototype might be able to store in a database for further analysis or as a record for the doctor to review and diagnose in a correct way

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APPENDIX A
ARDUINO CODE

MH-Z14A CO_2 Sensor Coding

```
#include <SoftwareSerial.h>
#include<Wire.h>
SoftwareSerial mySerial(A0,A1);
byte cmd[9] = {0xFF,0x01,0x86,0x00,0x00,0x00,0x00,0x00,0x79};
char response[9];
String ppmString = " ";
float n[ 100 ] ; // n is an array of 10 integers
float T1 = 0;
float PP = 0;
float PK = 0 ;
float T4=0;
float T5=0;
float n_PK=0;
float n_PP=0;
float n_T4=0;
const int led = 12;
void setup () {
 Serial.begin(9600);
 mySerial.begin(9600);
 Wire.begin();
 pinMode(led,OUTPUT);
}

void loop () {
  mySerial.write(cmd,9);
 mySerial.readBytes(response, 9);
 int responseHigh = (int) response[2];
 int responseLow = (int) response[3];
 int ppm = (256*responseHigh)+responseLow;

 ppmString = String(ppm);
  Serial.println(ppm);
 delay(10000);
 Wire.beginTransmission(8);
 Wire.write(ppm/20);


 Wire.endTransmission();
    for ( int i = 0; i < 3; i++ )
  {
      n[ i ] = ppm;
    //peak
    if(n[i+1]== n[i+2] && n[i+1] > n[i]){
    PP=n[i];
    PK=n[i+1];
```

```
      T4=n[i+2];
      T5=n_PK-n_PP;
      if(PK>n_PK){
        n_PK=PK;
      }
      if (PP>n_PP)
      {
        n_PP=PP;
      }
      if (T4>n_T4){
        n_T4=T4;
      }
      Serial.print("Peak");
      Serial.print(",");
     Serial.println(n_T4);
      Serial.print(",");
      Serial.println(n_PK);
      Serial.print(",");
       Serial.println(n_PP);
      }


   }
   if (T5>300)
   {
    digitalWrite(led, HIGH);
  }
  else if((n+2)<(n+1)&&(n+1)>n){
   digitalWrite(led, HIGH);
  }
 }
```

TFT LCD Shield Coding

```
#include <Adafruit_GFX.h>    // Core graphics library
#include "SWTFT.h" // Hardware-specific library
#include <Wire.h>

#defineBLACK   0x0000
#defineBLUE    0x001F
#defineRED     0xF800
#defineGREEN   0x07E0
#define CYAN    0x07FF
#define MAGENTA 0xF81F
#define YELLOW  0xFFE0
#define WHITE   0xFFFF
#define GREY    0xC618
SWTFT tft;

double x;
double y;
```

```
double ox;
double oy;
//double a1, b1, c1, d1, r2, r1, vo, tempC, tempF, tempK;
int dat;

boolean display9 = true;

void setup(void) {
//  pinMode(ledPin,OUTPUT);
  tft.reset();
  Wire.begin(8);
  Wire.onReceive(receiveEvent);
  Serial.begin(9600);

  uint16_t identifier = tft.readID();


 tft.begin(identifier);
 tft.begin(0x9341);
  tft.setRotation(1);

  tft.fillScreen(BLACK);
}
void loop()
  {
  testText();
  delay(3500);
  tft.fillScreen(BLACK);
  graphing();
  //delay(10000);
tft.fillScreen(BLACK);
testText1();
 delay(20000);
tft.reset();
}


void Graph(SWTFT &d, double x, double y, double gx, double gy, double w, double h,
double xlo, double xhi, double xinc, double ylo, double yhi, double yinc, String title,
String xlabel, String ylabel, unsigned int gcolor, unsigned int acolor, unsigned int
pcolor, unsigned int tcolor, unsigned int bcolor, boolean &redraw) {

  double ydiv, xdiv;
  double i;
  double temp;
  int rot, newrot;

  if (redraw == true) {

    redraw = false;
```

```
ox = (x - xlo) * ( w) / (xhi - xlo) + gx;
oy = (y - ylo) * (gy - h - gy) / (yhi - ylo) + gy;
// draw y scale
for ( i = ylo; i <= yhi; i += yinc) {
  // compute the transform
  temp =  (i - ylo) * (gy - h - gy) / (yhi - ylo) + gy;

  if (i == 0) {
    d.drawLine(gx, temp, gx + w, temp, acolor);
  }
  else {
    d.drawLine(gx, temp, gx + w, temp, gcolor);
  }

  d.setTextSize(1);
  d.setTextColor(tcolor, bcolor);
  d.setCursor(gx - 40, temp);
  // precision is default Arduino--this could really use some format control
  d.println(i);
}
// draw x scale
for (i = xlo; i <= xhi; i += xinc) {

  // compute the transform

  temp =  (i - xlo) * ( w) / (xhi - xlo) + gx;
  if (i == 0) {
    d.drawLine(temp, gy, temp, gy - h, acolor);
  }
  else {
    d.drawLine(temp, gy, temp, gy - h, gcolor);
  }

  d.setTextSize(1);
  d.setTextColor(tcolor, bcolor);
  d.setCursor(temp, gy + 10);
  // precision is default Arduino--this could really use some format control
  d.println(i);
}

//now draw the labels
d.setTextSize(2);
d.setTextColor(tcolor, bcolor);
d.setCursor(gx , gy - h - 30);
d.println(title);

d.setTextSize(1);
d.setTextColor(acolor, bcolor);
d.setCursor(gx , gy + 20);
d.println(xlabel);
```

```
   d.setTextSize(1);
   d.setTextColor(acolor, bcolor);
   d.setCursor(gx - 30, gy - h - 10);
   d.println(ylabel);


  }

  //graph drawn now plot the data
  // the entire plotting code are these few lines...
  // recall that ox and oy are initialized as static above
  x =  (x - xlo) * ( w) / (xhi - xlo) + gx;
  y =  (y - ylo) * (gy - h - gy) / (yhi - ylo) + gy;
  d.drawLine(ox, oy, x, y, pcolor);
  d.drawLine(ox, oy + 1, x, y + 1, pcolor);
  d.drawLine(ox, oy - 1, x, y - 1, pcolor);
  ox = x;
  oy = y;

}

unsigned long testText() {
  tft.fillScreen(BLACK);
  tft.setRotation(3);
  unsigned long start = micros();
  tft.setCursor(70, 50);
  tft.setTextColor(WHITE);  tft.setTextSize(3);
  tft.println("Welcome =)");
  tft.println();
  tft.setTextColor(GREY);  tft.setTextSize(3);
  tft.println("Good Day Everyone");
  tft.println();
  tft.setTextColor(MAGENTA);
  tft.setTextSize(3);
  tft.println("Initializing...");
  // tft.println();
  tft.setTextColor(RED);
  tft.setTextSize(3);
  tft.println("Warming up...");
  return micros() - start;
}
unsigned long testText1() {
  tft.fillScreen(BLACK);
  tft.setRotation(3);
  unsigned long start = micros();
  tft.setCursor(80, 50);
  tft.setTextColor(WHITE);  tft.setTextSize(3);
  tft.println("Thank you");
  tft.println();
```

```
  tft.setTextColor(BLUE);
  tft.setTextSize(2);
  tft.println("Please press the reset    button for next user");
  tft.setTextColor(RED);
  tft.setTextSize(3);
  tft.println("Bye Bye");
  tft.println();
  tft.setTextColor(RED);
  tft.setTextSize(3);
  tft.println("Have a nice day");
  return micros() - start;
}
void receiveEvent(int howMany) {
  while (1 < Wire.available()) { // loop through all but the last
    char c = Wire.read(); // receive byte as a character
    Serial.print(c);         // print the character
  }
  int x = Wire.read();    // receive byte as an integer
  dat=x*20;
  Serial.println(dat);

}
void graphing()
{
  for (x = 0; x <= 80; x += 1) {
    y = dat;
    Graph(tft, x, y, 50, 200, 240, 150, 0, 80, 10, 1000, 5000, 200, "Concentration of
CO2", " Time [s]", "CO2 [ppm]", BLUE, RED, GREEN, WHITE, BLACK, display9);
    delay(10000);
    //}
}
}
```

APPENDIX B
QT SOFTWARE

GUI Appkication Code

```
#include "mainwindow.h"
#include "ui_mainwindow.h"
#include <QSerialPort>
#include <QtSerialPort/QSerialPort>
#include <QTime>
#include "qcustomplot.h"
#include <QTimer>
#include<QDateTime>
#include <QKeyEvent>
#include <QApplication>
#include<QDebug>
QSerialPort *serial;
QTimer *timer;
bool Pressed;
MainWindow::MainWindow(QWidget *parent) :
   QMainWindow(parent),
   ui(new Ui::MainWindow)
{
   ui->setupUi(this);
  // myTimer.start();
   serial = new QSerialPort(this);
   serial->setPortName("com6");
   serial->setBaudRate(QSerialPort::Baud9600);
   serial->setDataBits(QSerialPort::Data8);
   serial->setParity(QSerialPort::NoParity);
   serial->setStopBits(QSerialPort::OneStop);
   serial->setFlowControl(QSerialPort::NoFlowControl);
   serial->open(QIODevice::ReadWrite);
   connect(serial,SIGNAL(readyRead()),this,SLOT(serialReceived()));
   timer=new QTimer(this);
   connect(timer,SIGNAL(timeout()),this,SLOT(serialReceived()));
   timer->start(0);
   vecCounter.push_back(0);

}

MainWindow::~MainWindow()
{
   delete ui;
   serial->close();
}

void MainWindow::serialReceived()
{
   buffersplit=serialBuffer.split("\r\n");
```

```
    if(buffersplit.length()<3)
    {
      serialData=serial->readAll();
      serialBuffer +=QString::fromStdString(serialData.toStdString());
      qDebug()<<serialData;
    }
    else
    {
      serialBuffer2=buffersplit[1];
      buffersplit2=serialBuffer2.split(",");
      qDebug()<<buffersplit2;

      QString n;
      n = buffersplit2.at(0);

      //int tend = myTimer.elapsed();
      //float sec;
     // sec =tend/1000;
      double ppm;
     ppm = n.toDouble();
      ui->label->setText(buffersplit2[0]);
      //double distance;
      //double ac;
     // ac = 0.98*ac +0.02* dis;
    //  distance = 0.5*dis*sec*sec;
     // ui->distance->setText(QString::number(distance,'f',2));
    //  ui->tim->setText(QString::number(sec,'f',2));

      time = QDateTime::currentDateTime().toMSecsSinceEpoch()/1000.0;
      temptime.push_back(time);
      tempdis.push_back(ppm);
      //acc.push_back(ac);
      vecCounter.push_back(vecCounter.back()+1);

      plotgraph();
      serialBuffer = "";
    }
}

void MainWindow::plotgraph()
{
    ui->widget->yAxis->setLabel("ppm");
    ui->widget->yAxis->setRange(0,4000);
    ui->widget->xAxis->setTickLabelType(QCPAxis::ltDateTime);
    ui->widget->xAxis->setDateTimeFormat("ss");

    ui->widget->addGraph();
    ui->widget->graph(0)->setPen(QPen(Qt::green));
    ui->widget->graph(0)->setData(temptime,tempdis);
    //ui->widget->graph(1)->setPen(QPen(Qt::red));
```

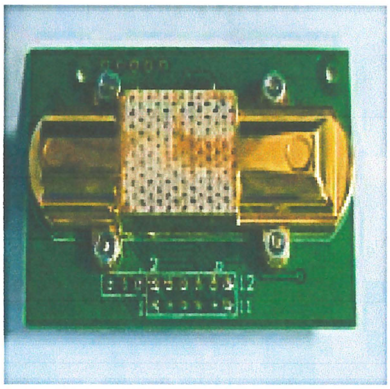
```
    //ui->widget->graph(1)->setData(temptime,acc);

    if(tempdis.length()>10)
    {
        tempdis.pop_front();
        temptime.pop_front();
        vecCounter.pop_front();

    }
    ui->widget->xAxis->rescale();
    ui->widget->replot();
}
```

APPENDIX C
MH-Z14A CO_2 DATASHEET

MH-Z14 CO2 Module



MH-Z14 NDIR Infrared gas module is a common type, small size sensor, using non-dispersive infrared (NDIR) principle to detect the existence of CO_2 in the air, with good selectivity, non-oxygen dependant, long life. Built-in temperature sensor can do temperature compensation; and it has digital output and analog voltage output. MH-Z14 NDIR Infrared gas module is applied in the HVAC, indoor air quality monitoring, industrial process, safety and protection monitoring, agricultrue and animal husbandry production process monitoring.

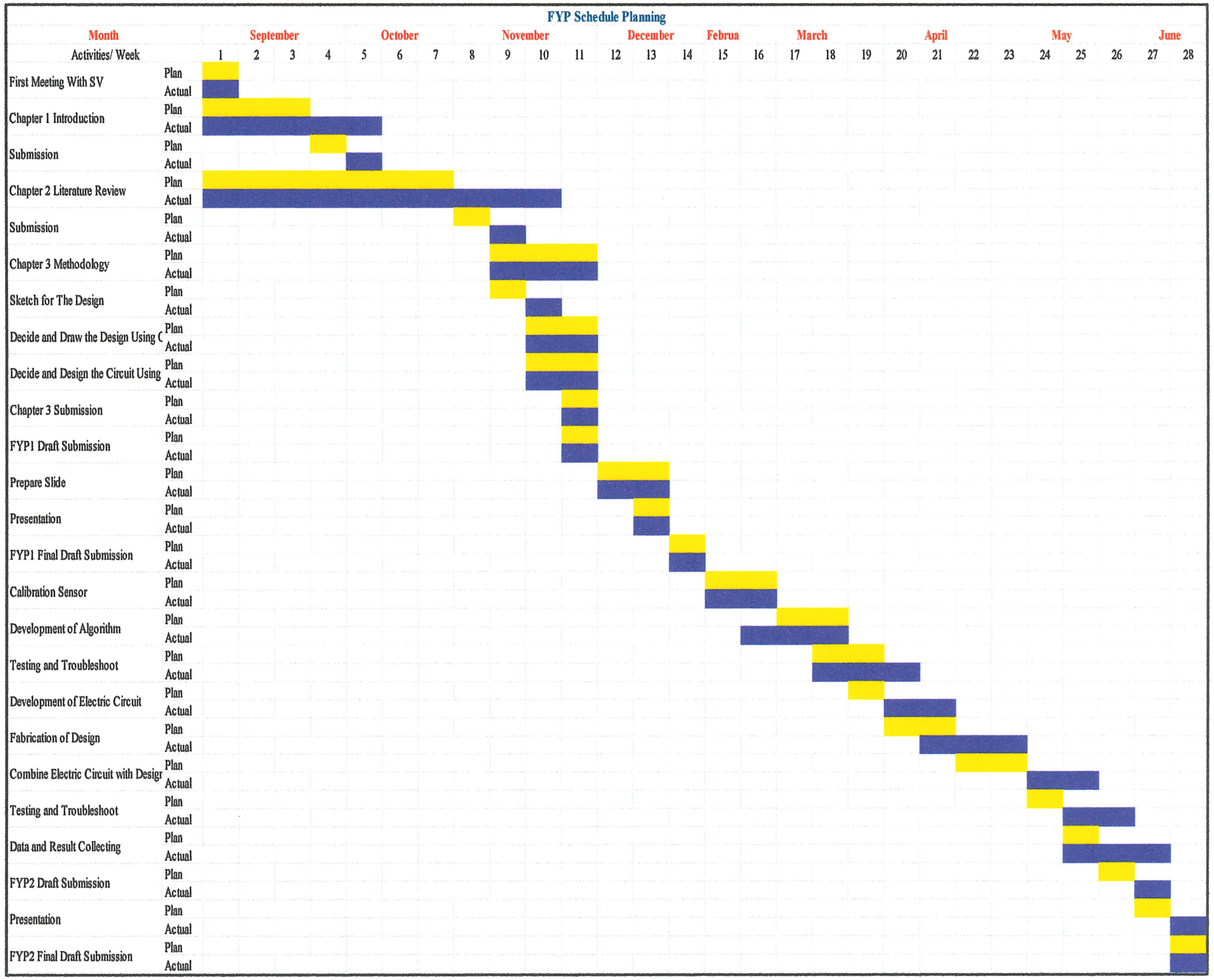
1. Technical specification:

Detection range	0~10000ppm（optional）
Resolution ratio	5ppm（0~2000ppm）
	10ppm（2000~5000ppm）
	20ppm（5000~10000ppm）
Accuracy	±50ppm±5%
Repeatability	±30ppm
Responsible time	<30S
Warm-up time	3min
Working temprature	0~50℃
Working humidity	0%~90%RH（No condensation）
Storage temprature	-20~60℃
Working voltage	4~6V
Working current	Max current <100mA, Average current <50mA
Usingage	>5year

APPENDIX D
BILL OF MATERIALS (BOM)

No	Item	Quantity	Price (RM)	Total (RM)
1	Arduino Mega	1	50.00	50.00
2	Arduino Uno	1	30.00	30.00
3	Electric Junction Box	1	12.00	12.00
4	Hose	1	1.00	1.00
5	Inhaler 3D Model Part	1	20.00	20.00
6	MH-Z14A CO2 Sensor	1	120.00	120.00
7	Miscellaneous	1	20.00	20.00
8	Mouth piece	30	0.20	6.00
9	ON/OFF Switch	1	10.00	10.00
10	TFT LCD Display	1	16.00	30.00
			Total	299.00

APPENDIX E
PROJECT SCHEDULE



APPENDIX F
CONFERENCE PAPER

Development of Electronic Kit for Respiratory System for Detecting Asthma

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***Abstract*— In this paper, a prototype of a carbon dioxide (CO2) measurement device has designed to detect and monitor every class of asthma patient. Nowadays, capnogram are widely uses in monitoring asthma and medical services. However, capnogram in market are costly and unaffordable for patient especially those in a low class family. Therefore, this low cost device is produced to detect and monitor the severity of asthma, this device can be owned by every class of family. Furthermore, spirometer and peak flow meter is well known in monitoring asthma. Unfortunately, these two devices have their own limitations which spirometer has complex procedures as the patient face difficulties on performing multiple criteria when using it and only suitable for age range above 6 years old. Meanwhile, flow meter will caused patient to have chest pain as they needed maximum effort to blow in the device. To overcome these limitations, this prototype electronic kit is easy to use and suitable for all range patients. This prototype electronic kit consists of MH-Z14A carbon dioxide (CO2) sensor to detect the concentration of carbon dioxide from exhaled air from user, Arduino microcontroller to process the data, TFT Display shield for data presentation and HC-06 Bluetooth module to communicate with PC for further analysis. This device was tested with 3 asthmatic and 3 normal users. The results showed that asthmatic user has a different graph pattern compared with normal user. Asthmatic user has a pattern like "shark fin" whereas normal user has a pattern like "square wave". This device has successfully distinguished the difference between asthmatic and normal user; therefore it is suitable for asthma monitoring.**

***Keywords*— Respiratory system, Asthma, MH-Z14A Carbon dioxide sensor, Arduino microcontroller.**

I. Introduction

Asthma is a chronic disease involved the airways in the lungs and it causes difficulty in breathing due to respiratory condition marked by the spasms in the bronchi of the lungs. Mc Phee et al. (2000) review that asthma exacerbation is a reduction in expiratory flow which is caused by many asthma triggers and the main triggers which will lead to the symptoms of respiratory diseases included viral infection, air pollutions, exercise, cockroach allergen and dust mists.

At present, peak flow meter and spirometer are commonly used for monitoring asthma. However, they have their limitations. Based on Zuileka et al. (2014) reviews patient using peak flow meter will experience chest pain as they need maximum effort to blow in the device. Meanwhile, spirometer is only suitable for patient age 6 and above. It also required multiple criteria to fulfill the requirement set by the device. To overcome these problems, capnography is introduced to monitor the severity of asthma without harming patient and suitable for all age patient. Non-invasive continuous analysis of the concentration of carbon dioxide in respiratory cycle is called capnograhy. Infrared technology is used to determine the concentration of carbon dioxide (CO2). Therefore, it can easily to differentiate normal and asthmatic patient. Figure 1 below shows the difference concentration carbon dioxide between normal and asthmatic patient.

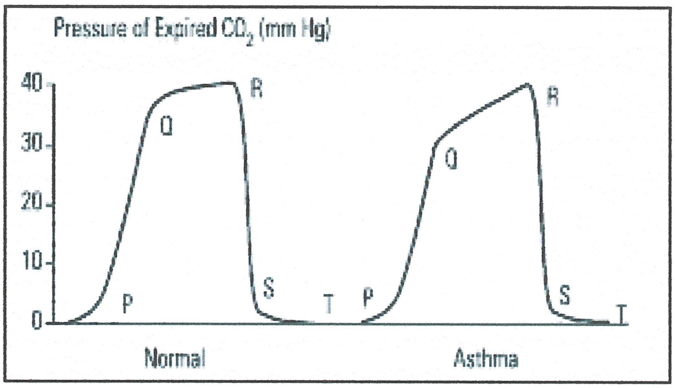

Figure 1. Capnogram between Normal and Asthmatic Patient

There are few sensors considerations in producing this electronic kit. Sensor comparisons were done to select the best sensor. Based on Marani et al. (2010), pressure sensor is used for lung sound analysis. It can prevent damages caused by mechanical ventilation which can induce serious damage due to the natural pulmonary elastance. Yu et al. (2013) used soft stethoscope for detecting asthma wheeze in young children. Soft stethoscope has been modified and it can be easily used on young children. This sensor can easily use on young children. Normally soft stethoscope easily effect by loud sound but this modify soft stethoscope totally opposite, will not effect by loud sound. Next, Zuleika et al. (2014) design a respiratory carbon dioxide measurement for home monitoring asthma using carbon dioxide (CO2) sensor. This sensor is suitable for all range patient including children below 6 years old. It can also avoid all type of complicated test which cause chest pain. Kaushal et. Al (2015) using a pellet sensor based asthma detection system for exhaled breath analysis. This pellet sensor consists of metal oxide semiconductor (MOS) and it is sensitive to exhaled breath. It eliminates the disadvantages of other technique by its low cost and easy operation features. On the other hand, Liu et al. (2015) using ultrasonic transducer for asthma pattern identification via continuous diaphragm motion monitoring. It can overcome the limitations of implementing the ultrasound images of diaphragm movement to identify the asthma pattern. Last but not least, Gathy et al. (2015) used amperometric nitric oxide for asthma detection. It has a detecting limit and sensitivity to changes in relative humidity, response time, flow sensitivity and stability.

Signal transmitter is an electronic device which is capable of generates electromagnetic wave carrying information and signal which lastly receive by a receiver. Buechley et al. (2006) in multi-purpose user awareness kit for consumer electroninc devices used infrared sensor (IR) to receive and process by devices such as personal computer (PC) and smart phone. Meanwhile, Bjelice et al. (2010) used UART communication device in construction kit for electronic textiles. This kit interface binary intra-processor protocol and data are present by Sky TV application GUI. Next, Ramli et al. (2016) in development heartbeat detection kit for biometric authentication system, Bluetooth Module is used as signal transmitter. It received and processed by Android platform developed. Data will be present on Android application GUI.

Data processing mean by the data collected is turned into information which is useful in a suitable manner for the understanding of user. There are many types of data processing such as GUI, LCD and oscilloscope. Based on Yu et al. (2013) review, android is used as a platform to present data. Android operating system is so convenience as this system can be open in any electronic device such as smartphone, PC or even pads at everywhere. Whereas. Rasmli et al. (2016) reported that android platform is used as a function of login in the system. Graphical User Interface (GUI) is used to present the result and data for the user by Buechley et al. (2006) in Skype TV application. Matlab software is used by Zuileka et al. (2014) as a real time data plotter. A real time data logger was developed by sorting the data into the array using the basics of Serial Communication in Matlab by updating the output or data pot according to the real-time.

After comparisons and review, carbon dioxide (CO2) sensor has been decided to use as it can measure the concentration of carbon dioxide (CO2) in a relaxing way and it is suitable for every range of user age. Arduino microcontroller is used to collect and process the data from the sensor. Meanwhile, Bluetooth Module is used as a signal transmitter to communicate with personal computer. TFT LCD shield will used a data presentation element. The data will be generated into a graph and based on the graph analysis will be carried out. Meanwhile Graphical User Interface (GUI) will be build inside the computer for better view of result. GUI is also used as a platform to analysis the result from the user.

II. METHODOLOGY

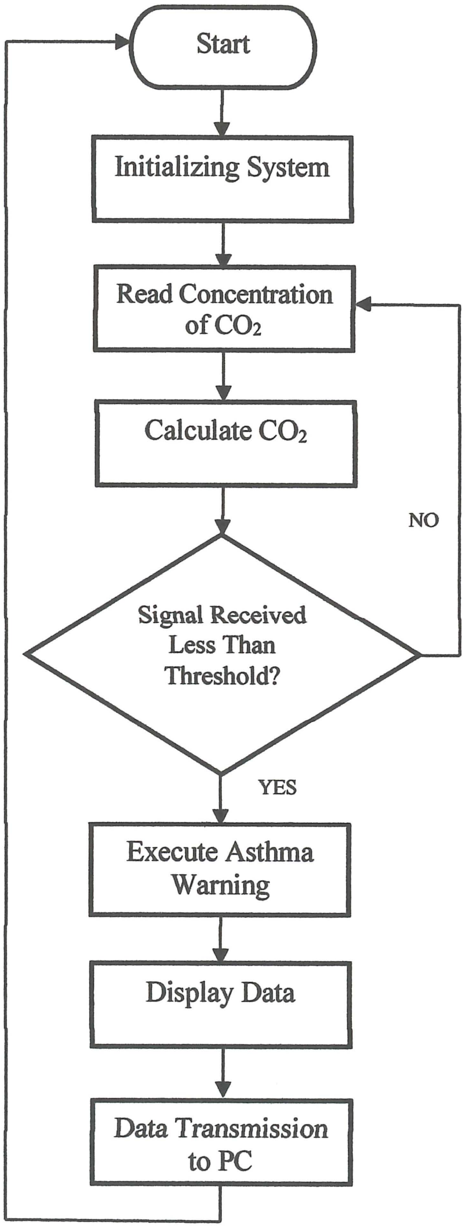

Figure 2 System Flowchart

Figure 2 shows the process flowchart for the electronic kit. Basically, this electronic kit consists of three main parts including electronic, hardware and software parts. The process flowchart will be controlled by the software part. Code is programmed in Arduino microcontroller to process the data collected from the carbon dioxide (CO_2) sensor by calculating the concentration. Next, it will send the data to the TFT LCD shield to display the result in a graph form. When asthmatic user is detected, threshold will be activated then warning will be given to the user. Meanwhile, Bluetooth module is used to communicate with personal computer (PC) for a better view of the result.

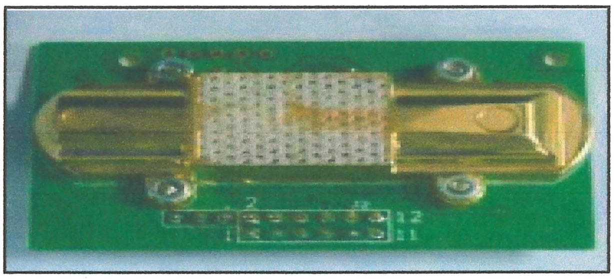

Figure 3 MH-Z14A Carbon Dioxide Sensor

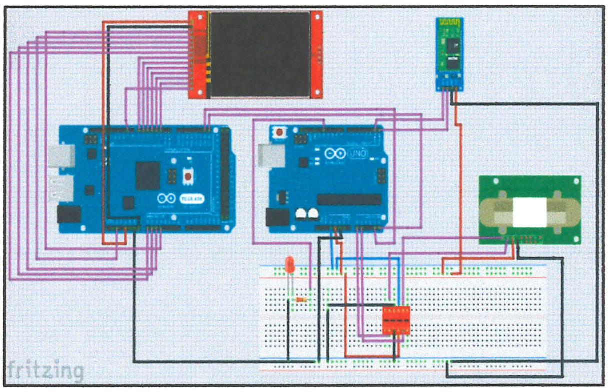

Figure 4. Schematic Diagram for Electric Circuit

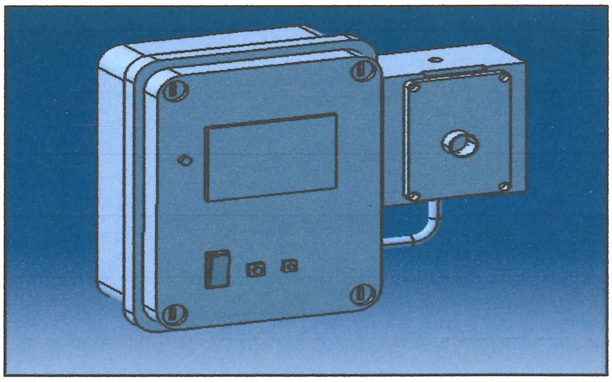

Figure 5. Mechanical Design for Electronic Kit

Figure 3 shows the MH- Z14A carbon dioxide (CO_2) sensor which will be used in this project. This sensor has three types of output including analog, PWM and UART communication. However, in this project UART communication will be used and it consists of host and subsidiary detector. Concentration of carbon dioxide (CO_2) is calculated based on the Eq. 1 below:

$$Concentration\,of\; CO2 = HC * 255 + LC \qquad (1)$$

where
CO_2 = Carbon Dioxide
HC = High channel
LC = Low channel

Figure 4 shows the schematic diagram of the electric circuit. This circuit included MH-Z14A carbon dioxide (CO_2) sensor, Arduino microcontroller, level logic converter, TFT LCD shield, HC-06 Bluetooth module and LED. The purpose of the level logic converter is to collect the low voltage signal from the sensor and convert to a high voltage signal. TFT LCD shield is used as a tool for data presentation whereas Bluetooth module is for the communication with PC. Last but not least, LED is an indicator to differentiate between asthmatic and normal user.

Figure 5 shows the mechanical design for electronic kit. Basically this design is drawn using CATIA software. Dimension of this drawing is same as the dimension of the electronic kit. In this design, the electronic kit included electric junction box, TFT LCD shield, ON/OFF switch, LED, buttons, hose and breather

III. RESULTS AND DISCUSSIONS

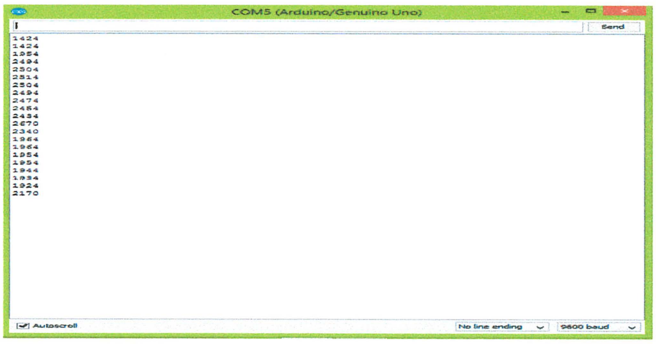

Figure 6. Serial Communication between Computer and Arduino

Table 1 shows the raw data collected fro the normal user. From the table below, there will be at least two same peak value for each test within the range of 40 to 60 sesconds. After maintaining the value, it will started to decrese.

Table 2 shows the raw data from asthmatic user. From the table blow, there will be only a peak value before the concentration of carbon dioxide dropped. The peak value happened at 60 seconds then it dropped at least 100ppm Therefore from the both table, normal and asthmatic user can be differentiated.

Table 1 Raw Data from Normal User

Time (s)	Concentration of CO2 (ppm)		
	Test 1	Test 2	Test 3
10	1764	1724	1754
20	1765	1934	1744
30	2984	2754	3064
40	3004	2774	3400
50	3004	2784	3400
60	3004	2784	3380
70	2984	2774	3150
80	2954	2754	2544
90	2444	2734	2534
100	2640	2714	2524
110	2640	2264	2514

Table 2 Raw Data from Asthmatic User

Time (s)	Concentration of CO2 (ppm)		
	Test 1	Test 2	Test 3
10	1484	1580	1560
20	1484	1580	1570
30	3890	2814	1764
40	4410	4094	4744
50	4400	4360	4744
60	4140	4094	4594
70	3690	3850	4314
80	3670	3620	4284
90	3314	3400	3484
100	2734	2784	3474
110	2724	2714	3710

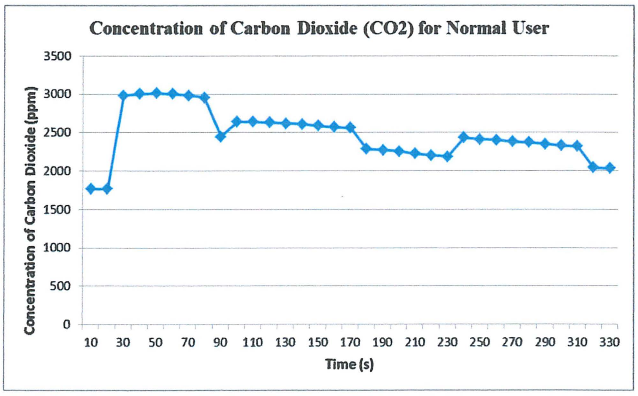

Figure 7. Graph of Concentration Carbon Dioxide for Normal User

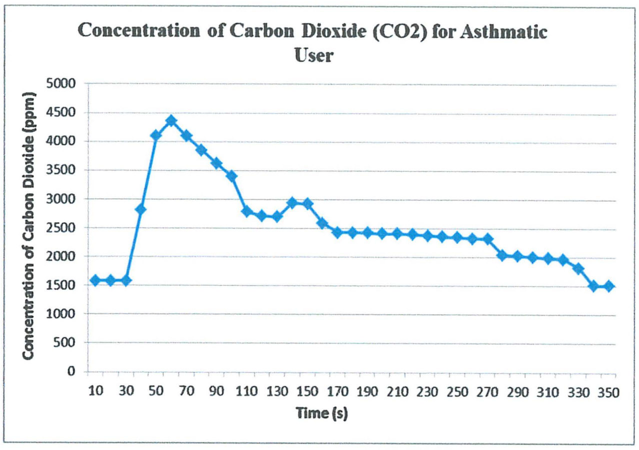

Figure 8. Graph of Concentration Carbon Dioxide for Asthmatic User

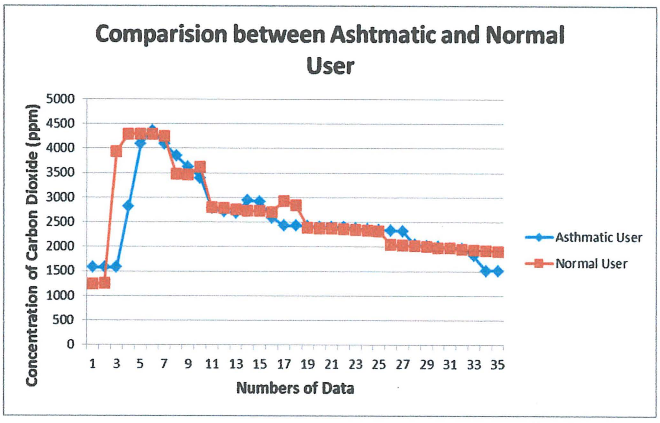

Figure 9. Comparision between Normal and Asthmatic User

Figure 6 shows the Arduino serial monitor, the raw data is the concentration of carbon dioxide (CO2) collected form the sensor. These values are used to generate graph by using Microsoft Excel for further analysis.

Figure 7 is the graph generated using the concentration of carbon dioxide (CO2) from a normal user. From the graph above, the concentration of carbon dioxide (CO2) started to rocket up to reach 2880 parts per million (ppm) then it became stable before it decreases to 2264 ppm then back to its original value. Meanwhile, the graph has a "square wave" pattern from data 1 to data 10. However, the data after that shows some inconsistent value. This might due to the concentration of carbon dioxide from the surrounding environment.

Based on Dr. Mello et al. (2002), capnogram consists of 4 phase. Phase 1 also known as Baseline. Baseline is the beginning of exhalation where no carbon dioxide presented. As shown in Figure 7, baseline started around 1800ppm due to this sensor measured the concentration of carbon dioxide of the surrounding instead of the human exhalation. When the user exhalation was sensed thus it caused phase 2 to begin. Phase 2 also known as ascending phase, caused by the carbon dioxide from the alveoli begins to reach the upper airway and caused the amount of carbon dioxide to rise rapidly. From

Figure 7, the concentration rise from baseline to the peak was phase 2.

Next will be phase 3, also known as alveolar plateau. The concentration of carbon dioxide in this phase is stable as shown from the graph above. This is because the carbon dioxide rich alveolar gas constitutes the majority exhaled air. Meanwhile the concentration of carbon dioxide is uniform from alveoli to mouth or nose.

Lastly, phase 4 (descending phase) where the carbon dioxide level drops quickly to its initial value. This phase can be seen from the graph above when the concentration started to drop after the peak level.

Figure 8 shows the graph generated from the asthmatic user. The raw data started to rocket up when the sensor sense the concentration of Carbon Dioxide (CO2) from the asthmatic user. Then it started to decrease as the concentration of the Carbon Dioxide (CO2) started to decrease until it reached the beginning value.

For asthmatic user, smaller airway is narrow by the half mark of asthma and caused obstruction to flow within the airways especially during expiration. In asthma, airway obstruction causes regional decreases in airflow and causes "alveolar ventilation". Therefore it causes the deformation of the normal curve as shown in Figure 4.5. From the graph, we can observe the deformation cause the opening angle in phase 2 and 3.

Figure 8 shows the comparison between the asthmatic and normal user. As shown above, the pattern between the two graphs are slightly difference. At first, the starting point and the peak concentration of carbon dioxide is almost the same. However, when they reach the peak level, for the concentration of the normal user stabilize and maintain for quite some time and formed a "square wave" before it started to decline. Meanwhile, for the concentration of the asthmatic user, it started to decline just after reaching the peak. Then, both of the CO2 concentration stated to fall until they reached a level below 2000ppm.

From Figure 8 above, the angle in phase 2 and 3 are slightly different. For asthmatic user, the graph in phase 2 and 3 is wider than the normal user graph. This is due to "alveoli ventilation". Therefore, from the comparison above, the category of the user can be easily categorized either normal or asthmatic.

Based on Figure 10, it shows the prototype of electric kit. The body of the lit was built using electric junction box. Whereas Perspex was used to build the body of the inhaler and the cover was made by 3D printing model. Based on the figure above, TFT LCD Shield, ON/OFF button, switches and hose have been included in this prototype.

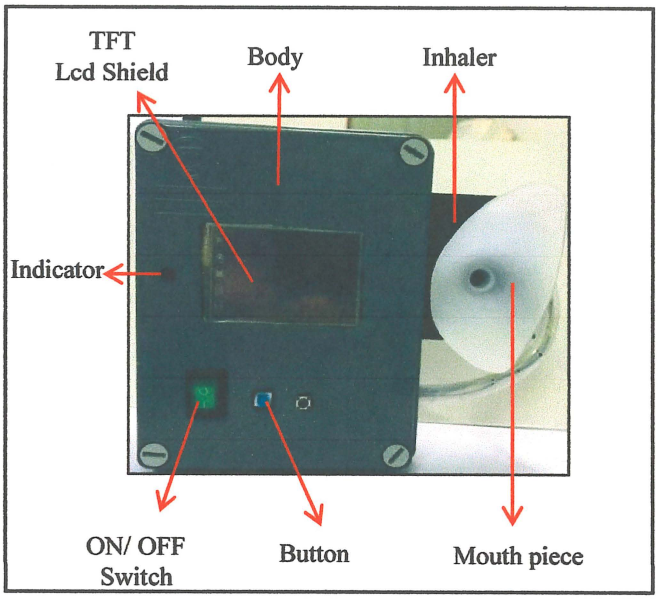

Figure 10 Actual Protoype

IV. CONCLUSION

Use of capnography in monitoring asthma and medical services is increasing; however capnography is still expensive and unaffordable for patient especially those from low class family for monitoring application. Therefore, in this research a low cost and portable carbon dioxide monitoring devices is proposed. For this device, the main component is carbon dioxide sensor, TFT LCD display and also Bluetooth module. The result from the user can be display using TFT LCD display and also PC; meanwhile the result display in a type of graph which can categorize the user either asthmatic or normal. In this research, three asthmatic and normal users are gather to test this device and the result for each of them are gather for analysis. The pattern of the graph for asthmatic user show a significant different compared with normal user. In future, prototype of this device can be tested and validate to use as a home monitoring device instead of others device such as peak flow meter and spirometer as this prototype device cancelled out the complex procedure for both of the devices.

Fig. 1. Example of a figure caption. *(figure caption)*

ACKNOWLEDGMENT

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