DEVELOPING A CONTINUOUS RESPIRATORY RATE MONITORING SYSTEM

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical and Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Sep 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

There are numerous conventional methods used to determine or monitor one's respiratory rate. The methods available are by using the measurement technologies of induction, resistivity, Piezo, thermistor, impedance, pressure, magnetic, optical and capacitivity. There is a need for utilizing one of these methods or technologies and implement it in such a way that it is portable, minimum discomfort and easy to use.

Numerous studies were conducted on the methods to measure one's respiratory rate. However, even with these researches done, there is a lack of a simple and cheap device in the market to be able to determine one's respiratory rate.

The respiratory rate monitoring system proposed by the author is using the concept of piezo resistivity coupled with microcontroller (Arduino-UNO) and wireless transmission through the use of Zigbee module. Piezo-resistivity is being used in many fields nowadays due to its flexibility in term of usage and its relatively low cost coupled with its simplicity. Through this proposed system, patient's respiratory rate could be monitored through easier and cheaper means.

ACKNOWLEDGEMENTS

First and foremost I would like to show my appreciation for both my parents for supporting me through thick and thin. Without them I would have lost all hope in completing this project. Through their moral supports throughout the 11 weeks I have been doing the project they would always check on me and give me encouragement. Many times I nearly given up but their words keep me going.

Furthermore, I sincerely appreciate the supports my supervisor, Dr. Hanita has given me throughout this project. Without her I would have lost my ways in the completion of the project. She gave me advices and stern telling off when I lost my ways. She always made time in her busy schedule to have private meetings with me. For that I am eternally grateful.

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INTRODUCTION

1.1 Background

For various reasoning, respiration rate of a patient has to be monitored and measured. There are various parameters obtainable from the interpretation of respiratory rate of the patient. Some of the parameters obtainable through this are apnea measurement, pulmonary volume measurement, pulmonary function indication and etc. The minimum period in which a patient stopped breathing is a condition called apnea. Different purpose of measurement requires different requirements in term of bandwidth, accuracy, resolution and processing of algorithm. [1]

Some of the examples of medical examinations measuring the rate of respiration are sleep analysis, polygraph, pulmonary function, pulmonary screening, stress test, pediatric screening and many more. These measurements require different technologies which are feasible for each task required.

Nowadays, there are numerous technologies available in the market which could be used for the measurement of respiratory rate. The technologies used widely in this matter are Inductive, Piezo-Resistive, Thermistor, Impedance, Magnetic, Capacitive, Pressure and Optical [1].

The author aims to design a relatively cheaper and easier to use respiratory rate measuring system and combines it with a wireless transmission to the workstation for higher efficiency in monitoring of a patient. The device should be able to record the patient's respiratory rate and chart it on the computer after data is transmitted and received.

1.2 Problem Statement

There are a number of issues with most of the current respiratory rate measuring system in the market right now. One of the issues is the high prices of the respiratory measuring systems in the market. Another issue with most of the monitoring systems available in the market is the inconvenience in their usage. Furthermore, there is not many standalone respiratory rates measuring system in the market.

The author hopes to design a low cost respiratory rate monitoring system which is very convenient in usage due to the fact that it allows wireless transmission to be done with computer for better monitoring system.

1.3 Objectives

1. Able to lower the cost needed for fabricating respiratory measuring system.
2. Able to transmit the respiratory rate reading (data) wirelessly to consoles.

1.4 Scope of Study

1. Understanding the mechanism in human respiration system.
2. Understanding the principle of piezo resistivity
3. The integration of piezo resistivity sensor for respiration rate measurement.
4. Understanding the mechanism and properties of X-bee (Zigbee wireless system).

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

It is decided by the author to have a generalized overview of respiration rate in the literature review. The general overview would include how respiration rate is measured, the implications of the signs obtained from the respiration rate, pieszo-electric transducer and the Zigbee wireless transmission system.

2.1 Why is the respiration rate being measured?

Definition wise, respiration rate is one vital or important physiological parameter that helps in providing the status of the wellbeing of an individual or patient, particularly the human respiratory system. The abnormalities in one's respiratory rate could be an indication of a host of diseases relating to the respiratory system as well as abnormalities in the human system which includes acidosis and cardiovascular abnormalities. Respiratory rate is also normally used as parameters to determine patient's deterioration in clinical conditions and early sign of diseases during patient monitoring done by medical practitioners.

The parameters are very important in measuring vulnerable patients such as the critically ill, infants, the elderly and neonates [2]. Severe asthma can be detected by the indication shown by measuring the respiratory rate. Important roles are played by the dynamic monitoring of the respiration rate during sleep in diagnosing and treatment of various sleep disorder, sudden death syndrome and sleep apnea.

Carefully being controlled by actions of the peripheral and central chemoreceptors and lung receptors is the ventilation of the alveolar, which is the product of tidal volume with respiratory rate [3]. The partial pressure of the arterial carbon dioxide (PaCO2) and partial pressure of oxygen (PaO2) drive the ventilation, whereby the most important driver being PACO2 [3]. Respiratory rate and tidal volume are increased in an attempt by the body to correct hypercarbia and hypoxaemia. Hence, through measurement of respiratory rate, these conditions can be found.

In the event whereby concentration of hydrogen ions increases, leading to an increase in production of CO2 are signs showing that the respiratory rate and tidal volume increase, which in turns means that the patient's is having any conditions relating to metabolic acidosis [3]. Additionally, an increase of alveolar ventilation could also be caused by other conditions which cause hypoxia or hypercabia [3].

In essence, respiration rate is a key predictor of detrimental conditions as it is an invaluable indicator indicating anomalies in various body systems, not just that of respiratory system. Note that not all sources of hypercarbia and hypoxia mean there is an increment in respiratory rate and tidal volume. Depression in the respiratory response and respiratory drive towards hypercarbia and hypoxia is caused by a commonly used medication in hospitals called opiates. In association with consciousness being of reduced level, respiratory rate could be seen to be lowered which implies that respiration rate is useful in this situation as well.

Wearable sensors are currently piquing interest of researchers worldwide which in turns lead to their rapid development, especially those related to medical parameters wearable measuring devices [4]. Respiratory and heart failure can happen with few signs and are difficult to predict. Hence, the need of continuous monitoring system of these vital signs is of significant importance.

However, despite the importance of respiratory rate, there is a lack of simple measurement tools or instruments for measuring the respiratory rate. Nowadays, manual respiratory rate measurement is commonly still being used and this results in time consuming and labor-ridden method. One of the major functions of human respiratory system is in supplying adequate amount of oxygen to the rest of the body, which in turn producing energy and maintaining the acid-base balance through removal of carbon dioxide from it. Hence, respiratory rate is very significant in medical practices as it plays a vital role in diagnosing a host of illnesses [5, 6].

Through the discovery done by Lavoisier between 1774 and 1785 which is the theory on closed breathing system, respiration is identified as the inhalation of oxygen and exhalation of carbon dioxide which then formed the basis in general physiology. Throughout history, with development in medical science and technology, there are multiple methods being utilized and proposed based on researches on physiological parameters which includes respiratory rate [7].

Low frequency biomedical parameters such as respiration rate and heart rate are measured by measuring the instantaneous frequency in which these parameters occur. Necessary inverting function is performed through the inclusion of a circuit which is capable to do so in any rate measuring system which is basing its results on the time intervals. Numerous researches had been done in the past and researches which are still in process are being done on respiratory rate monitoring system.

However, despite the numerous past and undergoing researches, there still exist the usage of physiological instruments which are not only expensive, they are inconvenient and impractical in extended monitoring of a patient. Hence, a more practical and user-friendly method of measurement is needed for the continuous respiratory rate monitoring system. With this in mind, the author attempted to design a low cost respiratory measuring system using piezo-electric sensor and a simple digital electronics circuitry [8].

2.2 Piezo-Resistivity Sensor Overview

Piezo-resistivity is an expression used for the sensing principle in which is commonly used for micro-machined sensors. Among all known materials which exhibit piezo-resistivity, doped silicon exhibits excellent response in its piezo-resistivity characteristics [9, 10].

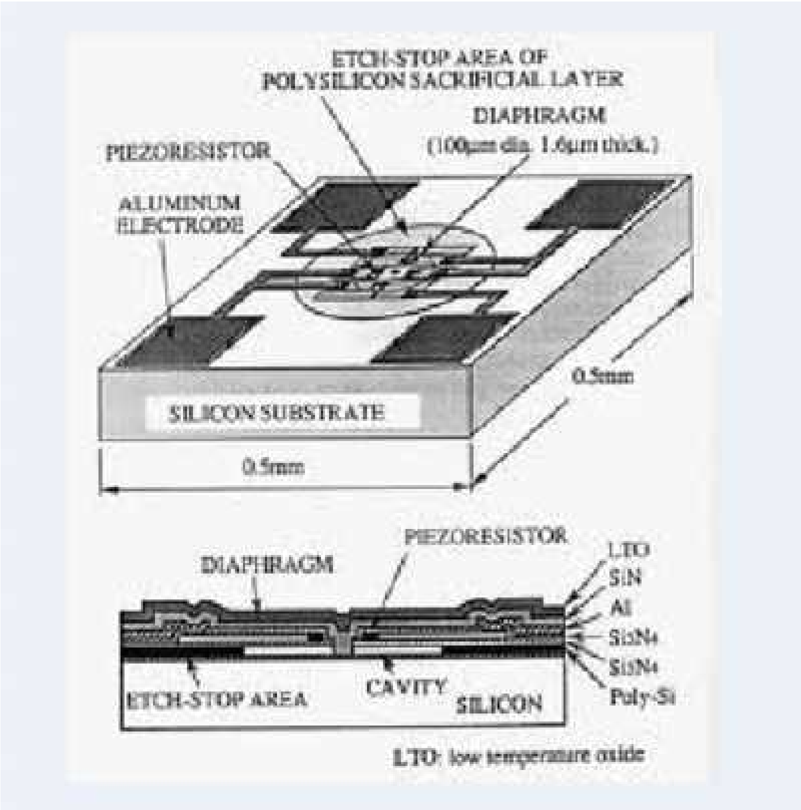

Figure 1 : The cross-section of a piezo sensor

This sensing principle was discovered firstly by Lord Kevin in the 1856 and piezo-resistive effects are now commonly practiced. This principles are based on the fact that electrical resistor may change in its resistance when being subjected by external forces (strain and deformation). It is now commonly used in chemical/biological sensors, flow sensors, sensors for measuring tactiles, sensors for gyro rotation rate, monitoring structural integrity of mechanical elements sensors, pressure sensors and etc.

Resistance is based on this formula:

$$R = \rho \frac{l}{A} \qquad (1)$$

R = resistance

ρ = resistivity

l = length of the resistor material

A = cross-sectional area of the resistor material

From the formula, resistance is affected by the dimension of the resistor material and/or its resistivity. When the length of the resistor material increases, under the finite Poisson's ratios, it is likely that the cross section would decrease. Furthermore, the resistivity of a resistor material may change due to strain. The change in resistivity affects the resistance more than the change in dimension itself.

By definition, piezo-resistors are resistors which resistivity changes due to applied strain. Silicon is a true piezo-resistor as its resistivity changes with a function of strain. Strain resistivity dependence is due to the formula for mobility of charge carriers which is:

$$\mu = \frac{q\bar{t}}{m^*} \qquad (2)$$

Which q is the charge of one charge carrier, mean of free time between carrier collision, $\bar{t}$ and m^* which the effective mass of carrier in crystal lattice is. Mean free time and effective mass are related to the average spacing of atoms in semiconductor lattice. The atomic spacing is subjected to fluctuation in physical strain is applied and contortion occurs [11]. The expression for change in resistance is expressed as:

$$\frac{\Delta R}{R} = G.\frac{\Delta L}{L} \qquad (3)$$

Change of resistance is shown to be linear to applied strain whereby G is the gauge factor of the piezo-resistor. Rearrange the expressions:

$$G = \frac{\frac{\Delta R}{R}}{\frac{\Delta l}{l}} = \frac{\Delta R}{\varepsilon R} \qquad (4)$$

Applying strain externally may contain three vectors of components which are; one along the longitudinal axis and two transverse components. The transverse strain components and the longitudinal strain are acted upon differently by the piezo-resistive element.

Changes in resistance against stress of the longitudinal component are called as longitudinal piezo-resistivity. Change of resistance relatively to the longitudinal strain is named longitudinal gauge factor. Transverse piezo-resistivity is used to call change in resistance subjected to transverse strain. Whereas, the relative change in measured resistance up against transverse strain is identified as transverse gauge factor.

The transverse and longitudinal, gauge factors are different for any given piezo-resistive material which is determined through its doping concentrations and dopant type [12].

Transverse strains and longitudinal strains are often present simultaneously; though one of them is the dominant one, which differs in different cases. The summation of changes under transverse and longitudinal stress components is the change in total resistance.

Wheatstone bridge circuit configuration is often used to read changes in the resistance. Four resistors in a loop is the basic Wheatstone bridge model. Two junctions which are separated by two resistors are applied with input voltage. The output is formed from the drop in voltage across the other two junctions. Sensing resistor is a resistor with change in its resistance due to some intended variables. At least one of the resistors in the loop is/are sensing resistor and the other resistors were made to be insensitive to strains through locating them in regions whereby there is no mechanical strain, for example, rigid substrates.

Commonly, piezo-resistors are temperature sensitive. The Wheatstone bridge is particularly effective in dealing with changing of surrounding temperature through the means of changing the resistance of the other resistors with the same percentage. Therefore, temperature effect is nullified.

2.3 Zigbee Wireless Technology Overview

There was an explosion of technology, particularly wireless technology recently. The boom in wireless technology causes an emergence of many standards, especially those used in the industry, science and medical fields [13]. Through this technological boom, a host of proprietary protocols for controls are invented worldwide in which saturating the interfacing side. Hence, the need of a standardized form of communication between sensors, especially in the low data rate wireless network. Due to this, a multitude of companies form alliances to create the accepted standard form for communication between sensors. One such alliance, the Zigbee Alliance created Zigbee. Zigbee is not considered to be both the Bluetooth and Wi-Fi technology as these aforementioned technologies were developed for files or software with complex structure and large amount of data. On the other hand, Zigbee technology was developed for simple structure like data obtained from sensors [13].

Figure 2 : Zigbee Module

Zigbee is simply a low power descendant of the Wi-fi technology. Zigbee is essentially specified as an array of high-level communication protocols for creating personal area networks out of small, low power radio basing on the IEEE 802.15.4-2003 'Wireless Personal Area Networks' standard. This specification was approved and validated by the aforementioned Zigbee Alliance, which consists of over 300 groups such as Mitsubishi Electric, Texas Instrument and etc. The alliance is committed towards developing this standard further and promoting it to the users. Eventhough, due to its low power consumption, the Zigbee devices is limited to transmission of only a 10-100 meters line of sight. Subjected to the power output and surrounding environment, Zigbee devices could be able to transmit data over longer distance. This longer distance of data transmission is able to be achieved by passing these data through a net of network of intermediate devices to reach out to the distant ones. These intermediate devices act as 'middle-man' of the whole data transmission [13].

Typically, Zigbee is used for low data transmission applications that require secure networking (networks secured by 128 bit encryption keys of symmetric values) and longer battery life. The defined rate of 250kbit/s of Zigbee is very suitable for transmissions of data of periodic proportion from a sensor or input device. The Zigbee technology is intended for the purpose of lower costing and simpler in design compared to other wireless personal area networks (WPANs) namely Wi-Fi and Bluetooth.

Figure 3 : Working Principle of Zigbee topology

CHAPTER 3

METHODOLOGY AND PROJECT WORK

3.1 Methodology

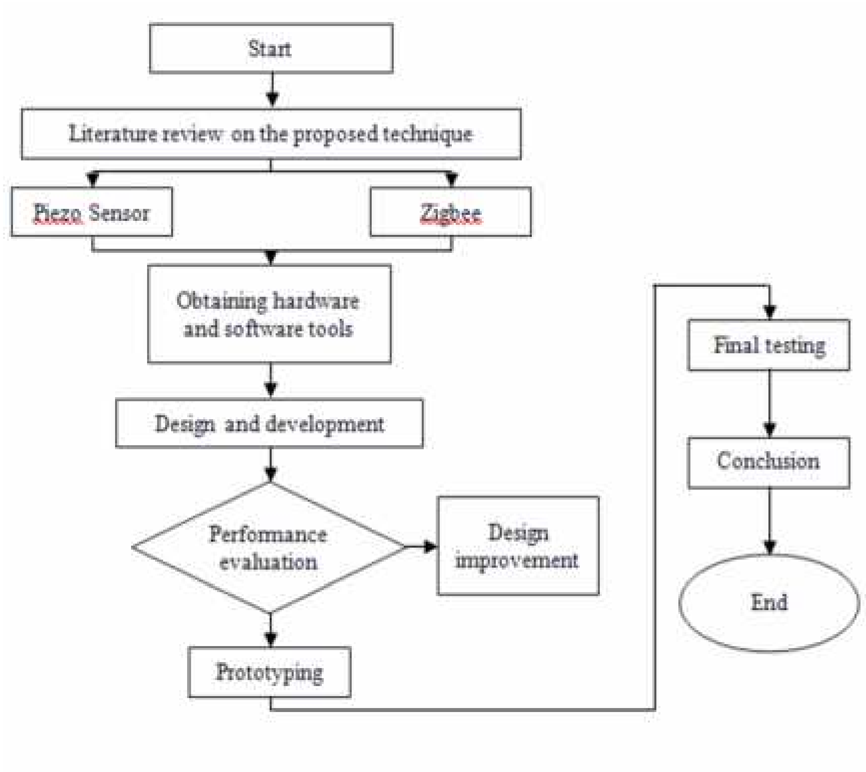

Figure 4 : Flow Diagram of Methodology

3.2 Project Work

Essentially there are three components in the project namely the piezo sensor, wireless communication and the interface.

Exhalation and inhalation movement of the chest is detected by the piezo belt. Signal is amplified by amplifier and smoothens by low pass filter. Then, it is interpreted by the microcontroller (Arduino) before communicating with the computer through Zigbee Network Topology.

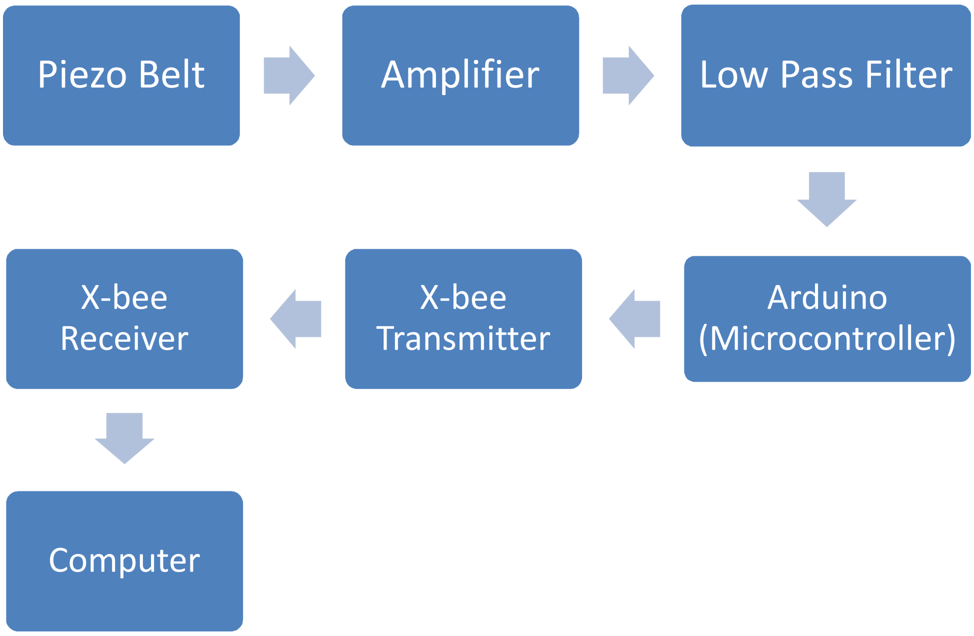

FIGURE 5 The diagram shows the process flow of the concept design.

3.3 Support Tools

There are a couple of tools being utilized during the development of the project. These tools are divided into software and hardware.

TABLE 1 : List of the main hardware tools and the description.

No.	Tools	Description
1.	Pasco Respiratory Belt	Calibration of the designed respiratory belt.
2.	9 V Battery	To supply power.
3.	Digital Multimeter	To measure electrical parameters.

Figure 6 : Pasco Respiration Belt

TABLE 2 : List of the main software tools and the description.

No.	Tools	Description
1.	Open Source Arduino Software	Use to write and compile programming codes for uploading into Arduino board.
2.	Microsoft Excel	To analyse the respiration rates obtained.
3.	Multisim	To simulate the circuit design before fabrication of circuit.

3.4 Hardware Components

3.4.1 Piezo Belt

The author constructed a piezo-resistive transducer belt. The materials that were purchased for such belt are the piezo sensor, Velcro strap of 60 cm long and 2.5 cm wide, latex strip of 25 cm long and 2cm wide, copper wire of 2 mm thick and fast curing epoxy compound.

The copper is bent and cut to make two brackets. The brackets are then soldered to both sides of the metal surface of the sensor. A small quantity of the resin base and hardener of the epoxy compound were mixed thoroughly. Fix it to the metal surface of the sensor in a way in which a small protruding knob is formed. 30 minutes is used to wait for epoxy to set. The latex strip is folded and passed through copper brackets in such a way that the latex strip went over the epoxy knob. Then, staple the ends of the latex strip to the Velcro strap. The wires of the sensor are connected to the data acquisition system.

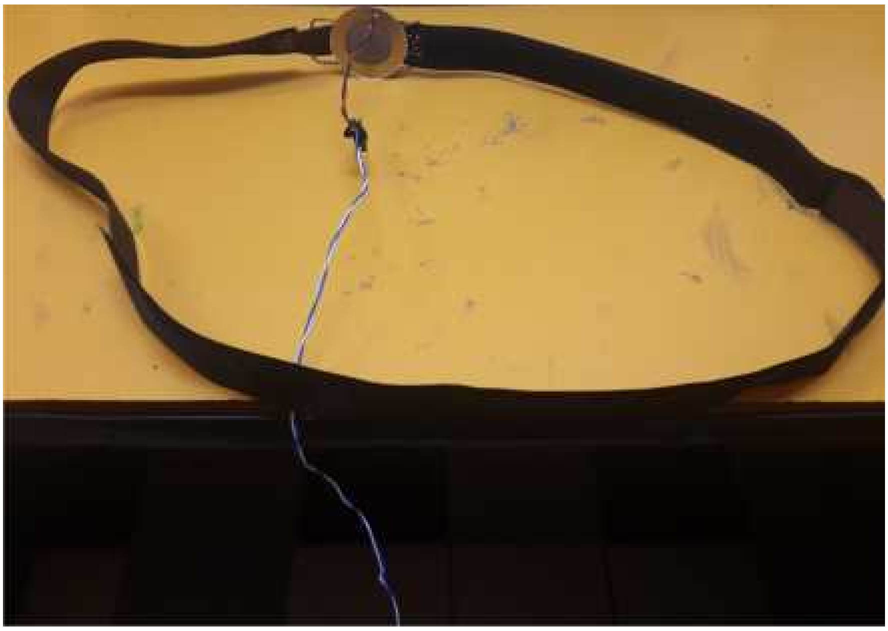

Figure 7 : Self-Made Piezo Belt

3.4.2 Arduino UNO Rev. 3 (Microcontroller)

In this project, Arduino Uno Rev. 3 is used as controller. The Arduino Duemilanove is a microcontroller board based on Atmega328. It has 14 digital input/output pins, 6 analogue inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Notes that out of 14 digital input/outputs pins, there are 6 of them can be used as PWM outputs. The analogue inputs are connected with built-in ADC where capable to convert or quantize 0 V to 5 V analogue input into 1024 level digital input (0 to 1023, 9 bits).

Figure 8 : Arduino Uno Rev. 3

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Piezo Sensor Test

A test was conducted to determine whether the piezo-resistor sensor is working as expected.

The author experimented with the piezo-resistive sensor through a simple programming whereby, when a threshold of 1000 (pressing force) is exceeded, the LED would light for 5 seconds before switching off. Below is the programming for the testing ;

Test_1 §

```
const int sensorPin=0;
const int ledPin= 13;
const int threshold= 1000;
void setup() {
  // put your setup code here, to run once:
pinMode(ledPin, OUTPUT);
}

void loop() {
  // put your main code here, to run repeatedly:
int val= analogRead(sensorPin);
if (val >= threshold)
{
digitalWrite(ledPin, HIGH);
delay(5000);
digitalWrite(ledPin, LOW);
}
else
digitalWrite(ledPin, LOW);
}
```

Figure 9 : Programming for piezo-resistive sensor testing

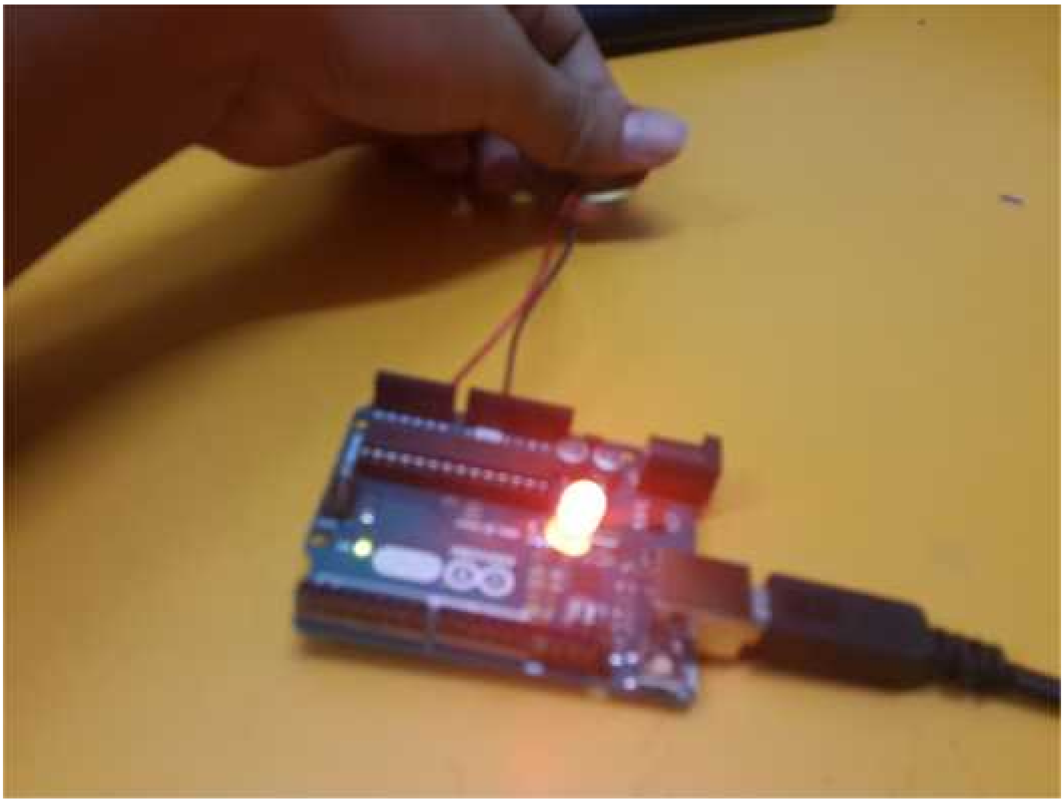

Figure 10 : LED lights up

4.1.2 The Prototype

The piezo sensor is fabricated in such a way that it is wearable as a chest belt. The chest belt is then worn by the patient around the chest area. The piezo belt would detect a spike in reading whenever inhalation occurs due to the expansion of the chest area. The spike signal is amplified by the amplifier and filtered by the low pass filter. The spike is then read by the Arduino-UNO Rev 3 and through some programming the value is sent and recorded on the computer through the Zigbee wireless communication sytem and breath per minute is obtained.

The amplification of 200 times is obtained through the use of LM 358 and combination of two resistors of 2000 Ω and 100 Ω respectively. The amplified signal is then low pass filtered using 10 μF capacitor and 16 kΩ resistors to obtain 1 Hz filtering.

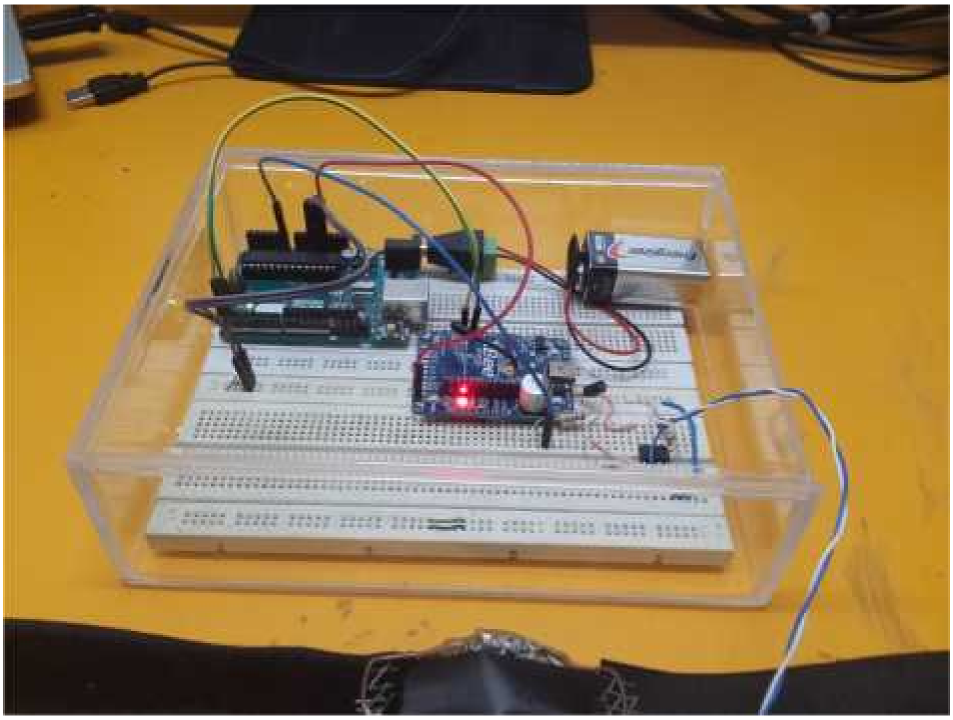

Figure 11 : The Prototype and Transmitting X-Bee

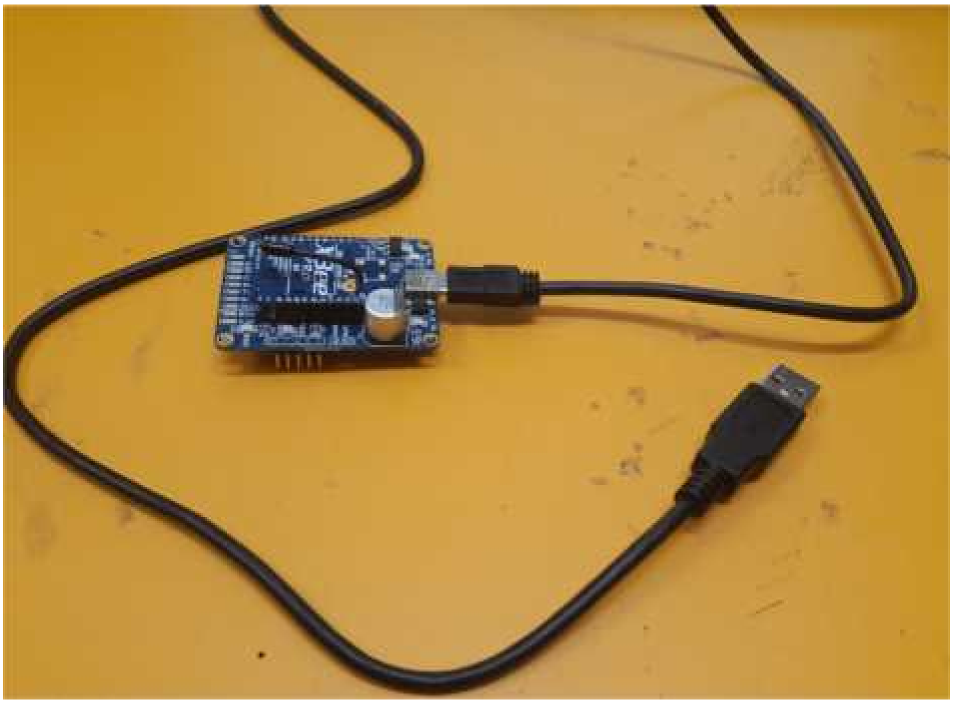

Figure 12 : The Receiving X-Bee

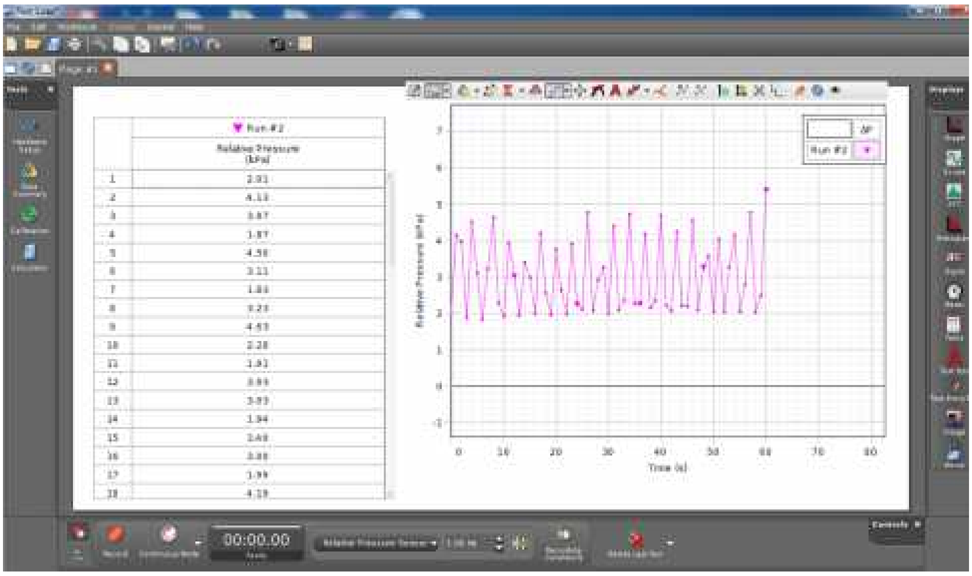

Figure 13 : The Benchmark shown 20.5 Breaths

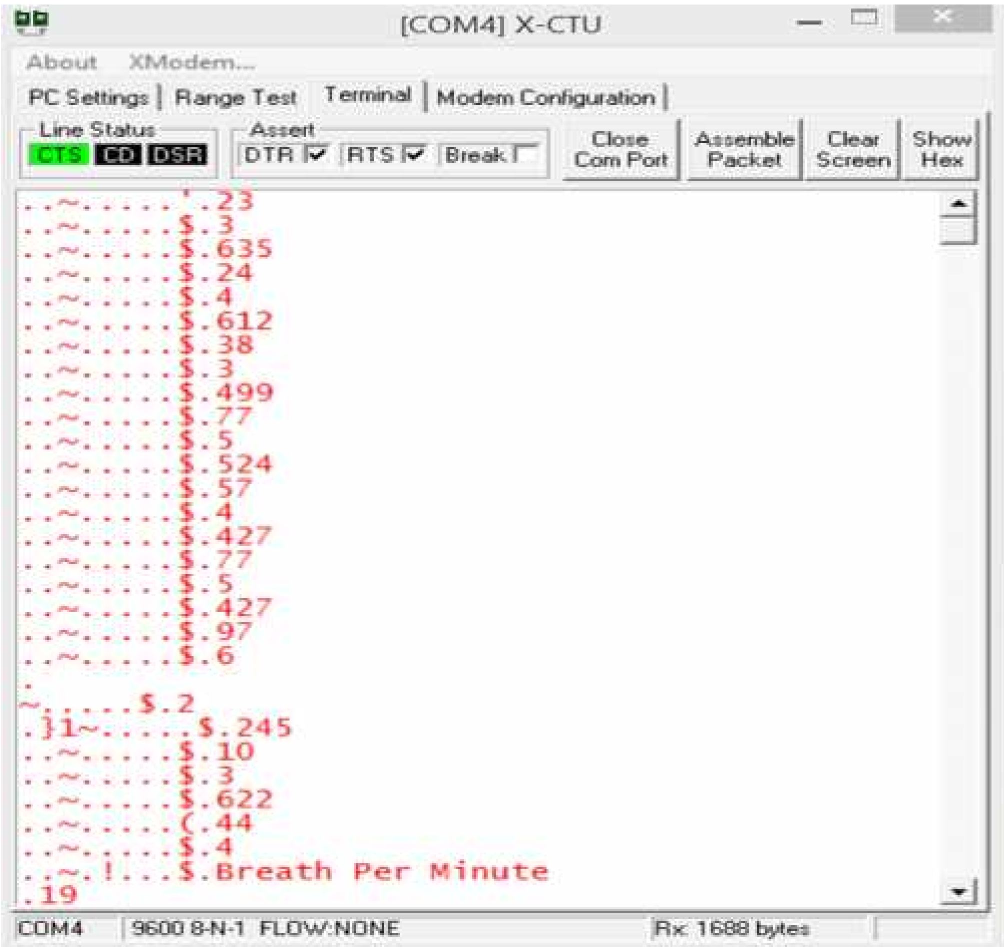

Figure 14 : Prototype Run 1 through wireless transmission

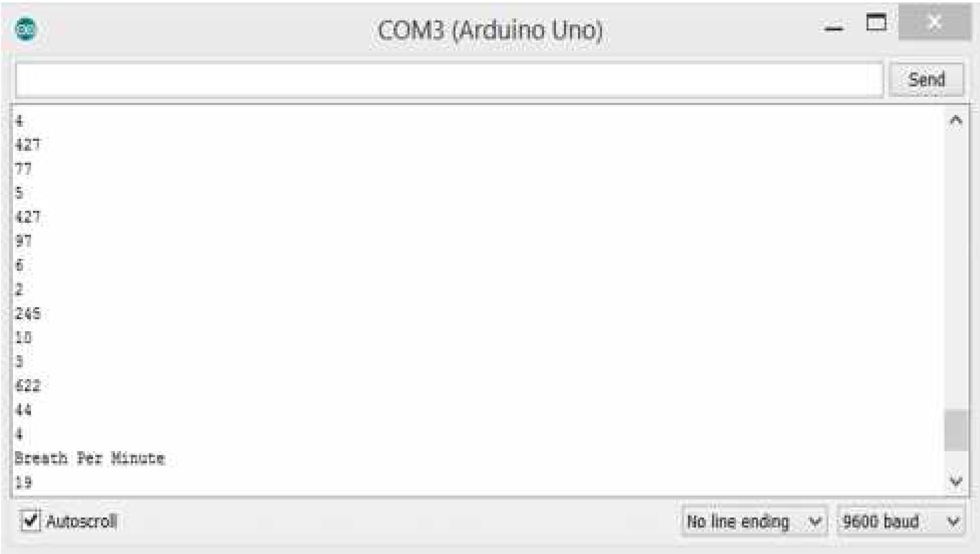

Figure 15 : Prototype Run 1 through direct connection

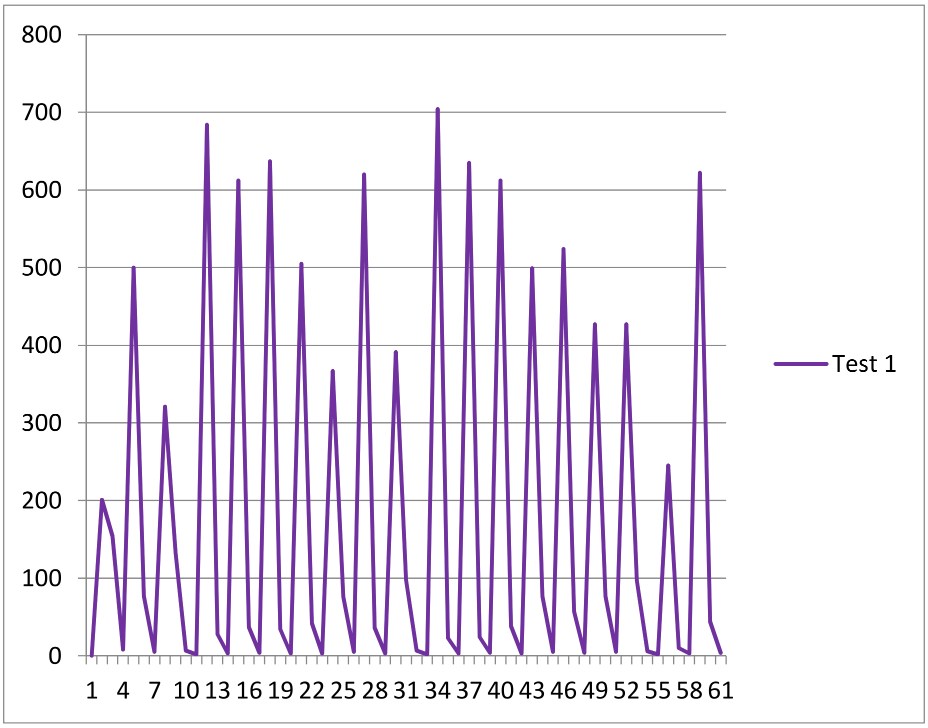

Figure 16 : Prototype Run 1 showing 19 breaths per minute

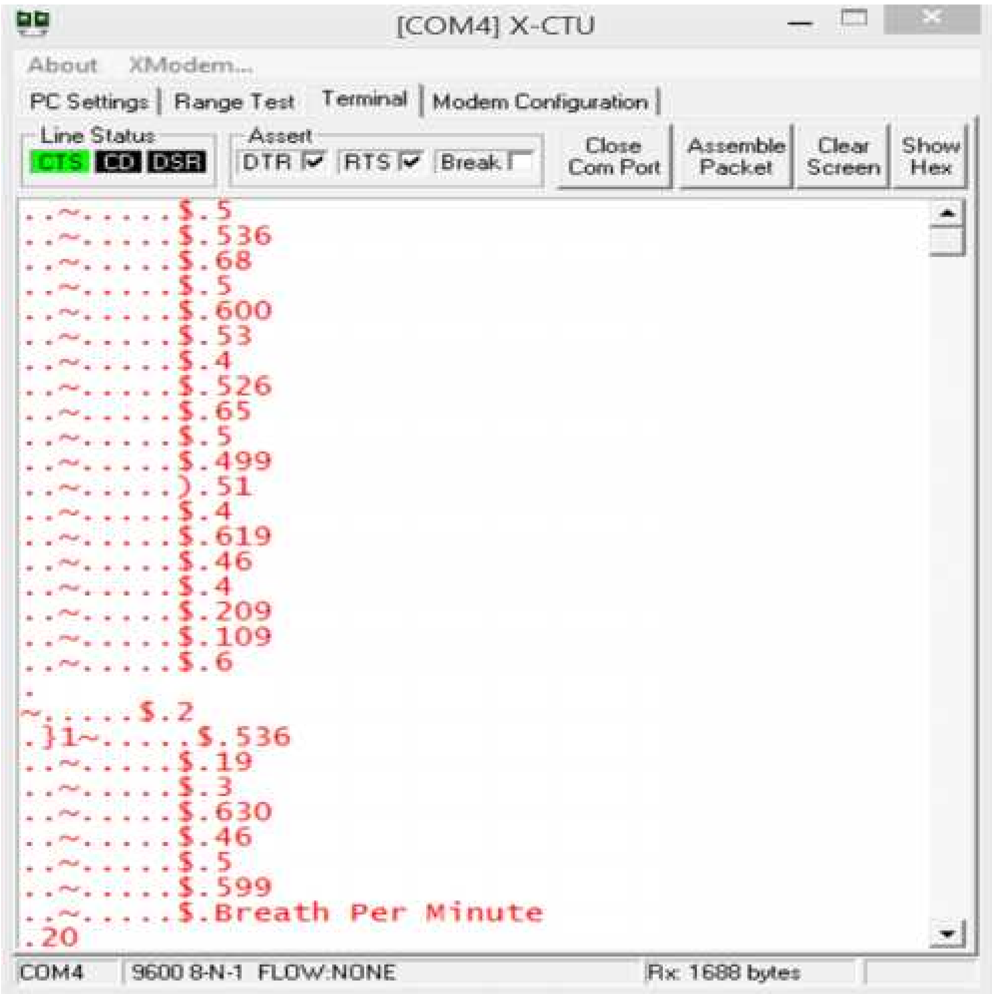

Figure 17 : Prototype Run 2 through wireless transmission

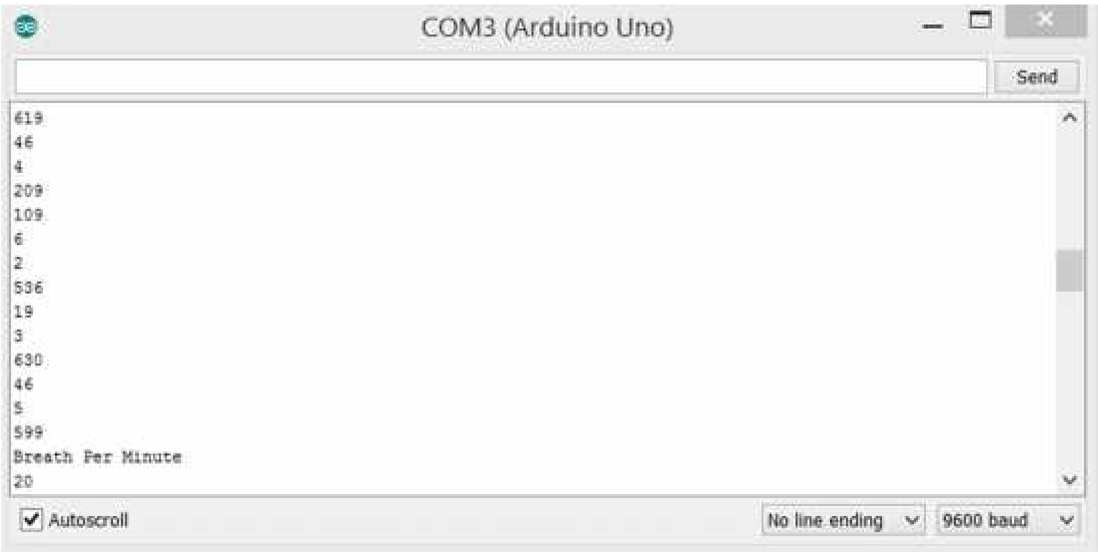

Figure 18 : Prototype Run 2 through direct connection

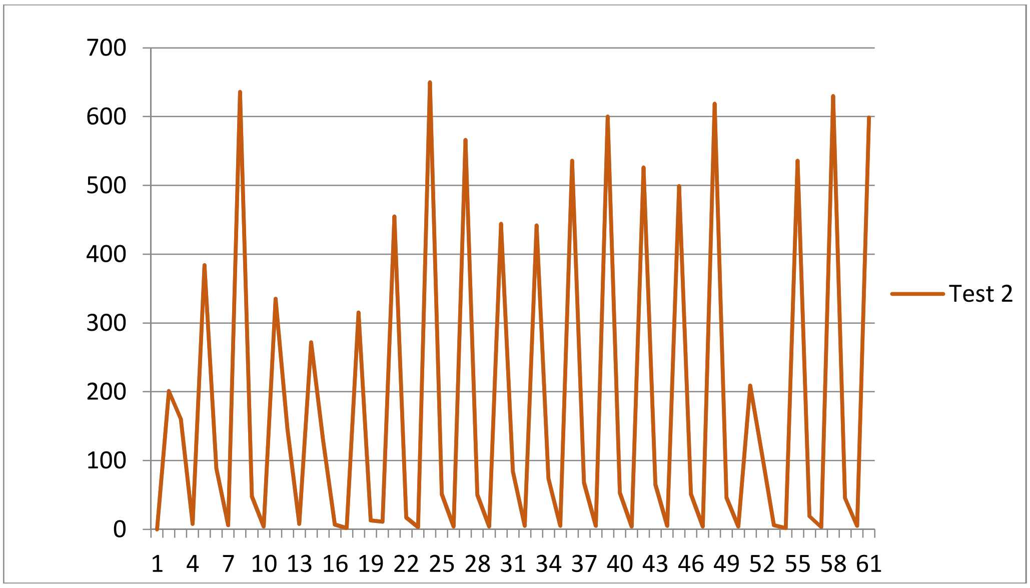

Figure 19 : Prototype Run 2 showing 19.5 breaths per minute

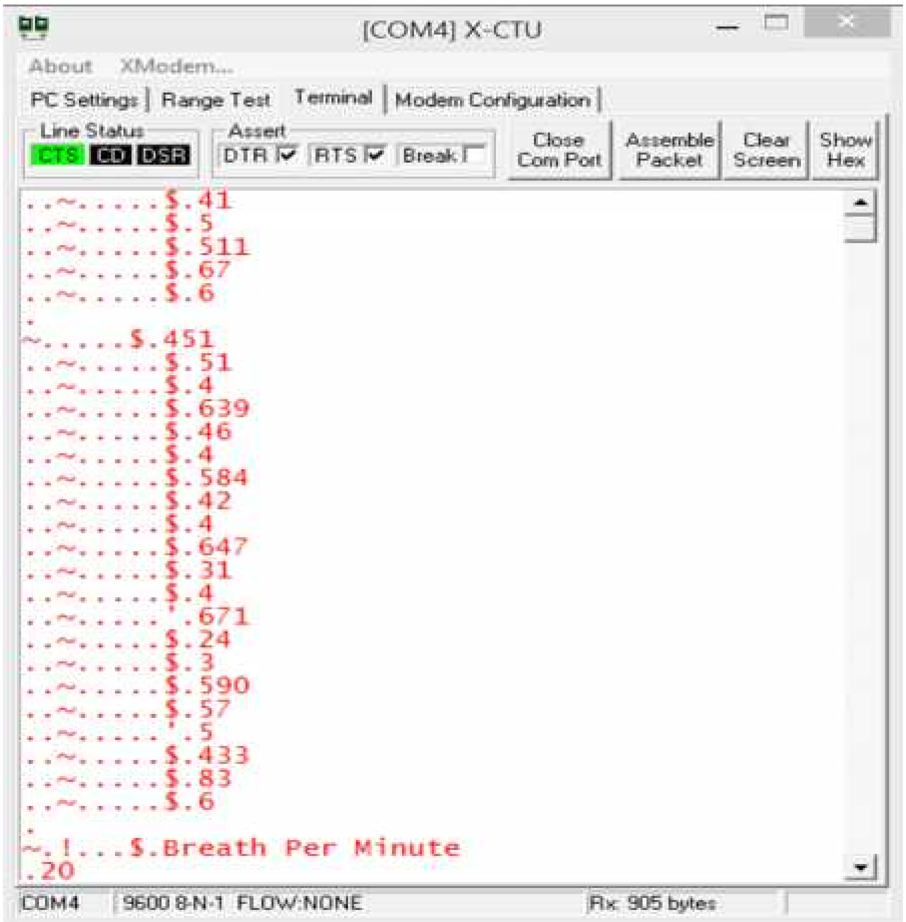

Figure 20 : Prototype Run 3 through wireless transmission

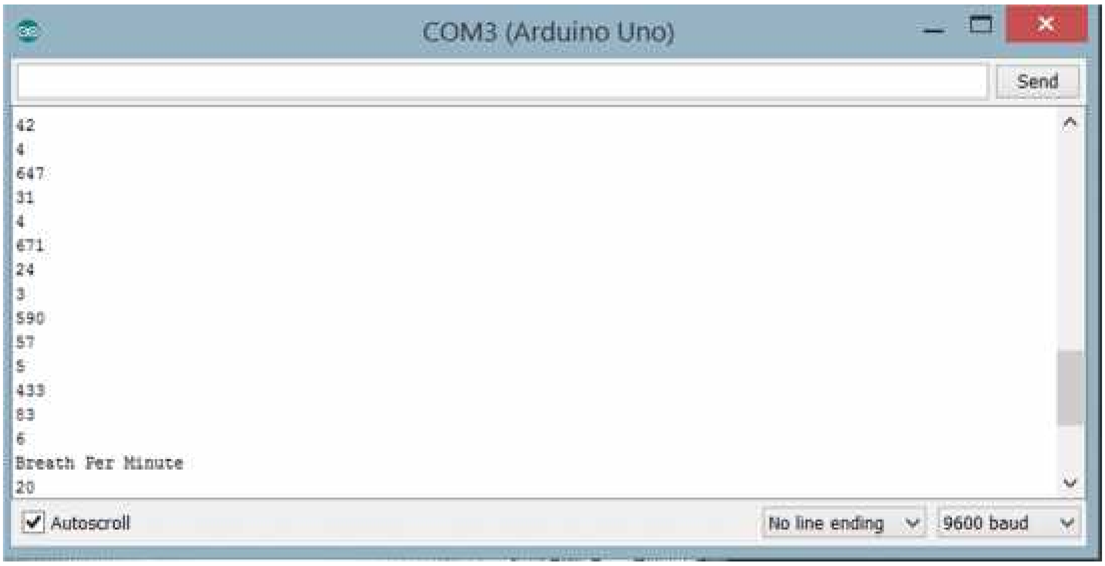

Figure 21 : Prototype Run 3 through direct connection

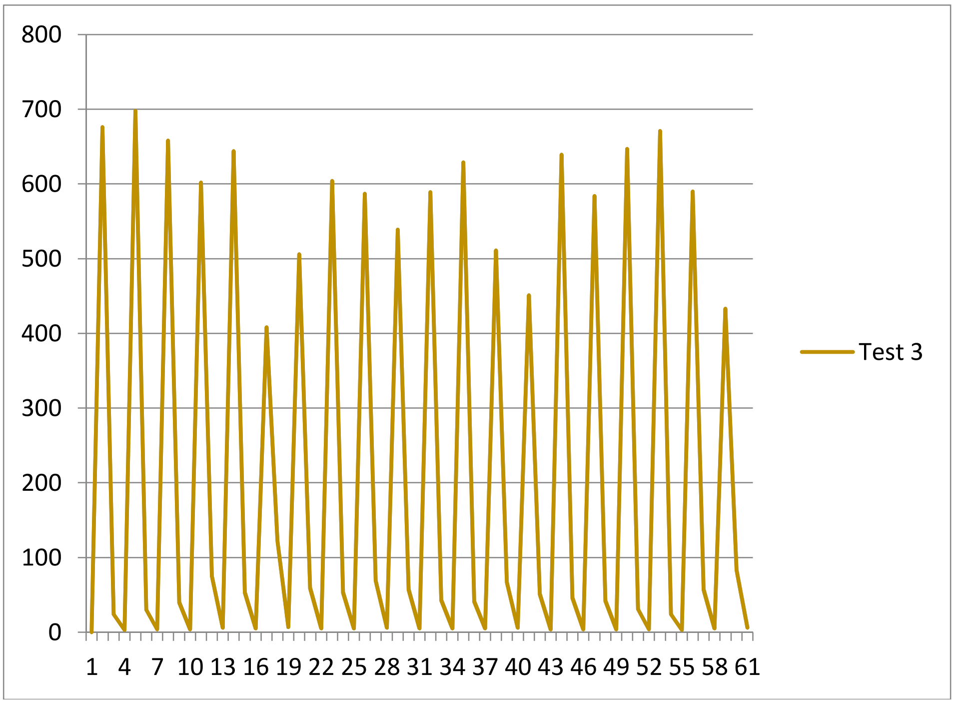

Figure 22 : Prototype Run 3 showing 20 breaths per minute

4.2 Conclusion

Based on the results in the 3 runs, the breaths per minute obtained are quite accurate when compared with the benchmark respiration system (PASCO Respiration Belt).

However, the belt sometimes is showing irregular result due to it being worn loosely.

Hence, consideration must be placed when the belt is being put on a patient.

Chapter 5

CONCLUSION & RECOMMENDATION

5.0 Conclusion

The designed belt prototype is quite accurate if being compared with the Pasco Respiration Belt monitoring system, with an error of +/- 1. However, it is not as precise as it could be as the piezo belt which is designed by the author is sometimes exhibiting unstable characteristics which is why many trials is required for the reading obtained to be of higher accuracy.

5.1 Future Works & Recommendations

It can be recommended that the belt requires some fine tuning to be able to work reliably in the future. The interface of the prototype could be improved further with it being able to be plotted into graph form automatically. With this in mind, the prototype would have a large market to enter due to the high prices of peer devices and the very low price of this prototype. The total price of the Pasco Respiration meter is RM 1500 for the belt, RM 500 for the data acquisition system and a further RM 700 for individual license on the software (used is 60 days free trial version). On the other hand, the prototype made by the author cost lower than RM 500 and on top of that could provide wireless capabilities. Without the wireless capability, it would only cost half as much. Rule of thumb for commercialized product is that it would be 3 times as costly in the market than in manufacturing it. In which case, the author’s prototype could be sold as much as RM 1500 as most of the profit being used for copyrighting purposes. This is still RM 500 cheaper (or RM 1200 cheaper with lifetime licensing program) than the Pasco Respiration Belt as in the case of the prototype, the programming used in Arduino is of open source which requires no payment for the software.

REFERENCES

1. TMSi- Measuring Respiration version 2.0

2. K.S. Tan, R. Saatchii, H. Elphick, and D. Burke: Real-Time Vision Based Respiration Monitoring System, 7th International Symmposium on Comunication Systems Networks and Digital Signal Processing (2010), p. 771-774.

3. West JB. Respiratory physiology: the esssentials. 4th ed. Balltimore: Williams and Willkins, 1990.

4. Bonato, P., Wearable sensors or systems and their impacts on biomedical engineering. *Enginering in Medicine and Biology Magazine, IEEE* **2003**, *22*, 19-20.

5. FQ AL-Khalidi, R. Saatchi, D. Burke and H. Elphick: Facial Tracking Method for Noncontact Respiration Rate Monitoring, 7th International Symposium on Communication Systems Networks and Digital Signal Processing (2010), p. 751-754.

6. B. Mazzanti et al.: Validation of an ECG-derive respiration monitoring methods, Computers in Cardiology, Vol.30 (2003), pp.613-616.

7. D.C. White: The History and Development of Low Flow Breathing Systems. IEE Seminar, Low Flow
Anaesthesia Breathing Systems - Technology, Safety and Economic (1999), p.1.

8. S. Das ,Health Informatics - An International Journal (HIIJ) Vol.2, No.2, May 2013

9. Kanda, Y., *Piezoresisstance Effect of Silicon*, Sensors and Actuators A: Physical, 1991. **28**: p. 85–91.

10. Smith, C.S., *Piezoresisstance Effect in Germanium and Silicon*, Physics Review, 1954. **94**: p. 42–49.

11. Geyyling, F.T., and J. Forst, Semiconductor Strain Transducer, The Bell Systems Technical Journall, 1960. 39: p. 715–731.

12. French, P.F., and A.G.R. Evanns, *Piezoresistace in Polysilicon and Its Application to Strain Gauges*, Solid-State Electronics, 1989. **32**: p. 1–10.

13. A. Thakur, Engineers Garage, Zigbee Technology
Retrieved on 10 November 2014
http://www.engineersgarage.com/articles/what-is-zigbee-technology

APPENDICES

APPENDIX A

Respiration Rate Arduino Code Program

```
#include <SoftwareSerial.h>
SoftwareSerial xbee(0, 1); // RX, TX
int variableCount;
int time;
int sensorValue;
int setValue = 200;
void setup() {


  // initialize the serial communication:
  Serial.begin(9600);
  xbee.begin( 9600 );

}

void loop()
{
  variableCount=0;                          //sum of variable, initially 0
   time=0;                                  //time counter, initially 0
   sensorValue = analogRead(A0);            //read analog value

   if (sensorValue>setValue)                //if value more than set value enter loop
   {
      variableCount=1;                      //first time meet set value
      while(time<60)                        //stay in loop for 60 secs
      {  Serial.println(analogRead(A0));
         sensorValue = analogRead(A0);            //read sensor value
         if(sensorValue>setValue)                 //if meet set value...
         {
            variableCount++;                      //...increment counter
         }
         time++;                                  //increment time by 1
         delay(1000);               //after exit loop print sum to computer
                            //delay 1 sec before repeat loop
      }
      Serial.println("Breath Per Minute");
      Serial.println(variableCount);

   }
}
```