PHYSIOLOGY MONITOR FOR FIREMAN ON DUTY

By

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14245

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
In Partial Fulfilment of the Requirements
For the Degree
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CERTIFICATION OF APPROVAL

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Approved:

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

SEPTEMBER 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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Nur Izmira Binti Mohamad Radzi

ABSTRACT

Fire-fighters or commonly called as fireman are people who have been specially trained in fighting fires and rescuing people from hazardous and dangerous situations in order to prevent loss of lives and properties. Working as a fireman is known to be very dangerous and challenging. In foreign countries, countless number of firemen died on the scene while performing their job. These on-duty deaths can be overcome by providing all firemen with better equipments, tools and gears to perform their job without sacrificing their own lives. Prolonged suffering or experiencing extremely high temperatures, cardiac emergency, fluid loss, and stress are the major contributing factors to fireman fatality. The purpose of this project is to develop a new physiology monitoring prototype where a fireman's vital signs like body temperature, heart pulse and body position can be remotely monitored and detected over a safe distance reliably using XBee wireless tool. Three major sensors which are temperature sensor, pulse sensor and accelerometer with gyroscope sensor will be integrated together in one printed circuit board (PCB). This printed circuit board (PCB) is kept inside a specially customized casing that will be strapped onto the upper body of the fireman. All inputs received from all three sensors will be sent wirelessly to an online system to monitor the health condition of every on-duty fireman in an emergency incident in real time.

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INTRODUCTION

1.1 Background Study

Fireman on duty has major responsibilities in being a life rescuer, fighting fires, saving animals in danger and many more. Nonetheless, having a job as a fireman is not easy at all. There are many threats and risks especially to a person's life and health. Long-term exposures to raging hot fire, thick smoke, carcinogenic chemicals without proper protection are the main causes to the deterioration of the fireman's wellbeing. This project focuses on constructing a development of wise digital control system with a sole purpose in monitoring fireman's body temperature, heart rate pulse and physical movement or position while on duty.

Monitoring of these firemen had to be on real time basis to ensure their safety and rescue can be sent immediately if needed. All software modules, hardware sensors and data communication built within this project will be integrated through XBee radio frequency (RF) network. The microcontroller used in this project will interpret data received by pulse sensor, temperature sensor, and accelerometer with gyroscope sensors and be sent to a computer showing their current health status through a XBee module transreceiver. A transreceiver is a device where it has a transmitter and a receiver integrated as one.

The data and results produced from this system must be reliable, accurate and valid. This is very crucial because this system deals with humans' lives. Unexpected one second delay may cause major accidents or death to those unknown heroes. With the availability of a physiology monitor device, these firemen can easily be monitored on real time basis from fire engines that are located near to the place of incident. Backup support can be given effectively and efficiently to those who are detected to have poor reading by the system. Casualties of firemen can be reduced greatly in the upcoming future by implementing and fully utilising this device.

1.2 Problem Statements

The existing manual monitoring used by firemen in whole Malaysia have great tendency in creating harm to the rescuers while performing their duty. Fireman’s vision will be at the state of total blindness once they enter or surrounded with blazing hot fire and thick smoke. Due to this hazardous condition, they cannot even protect themselves and face difficulty in detecting dangers. Therefore, it is necessary to monitor these firemen while they are conducting their duty.

Current system is seen to be lack in the following:

I. Unavailable of computerized monitoring system used to monitor rescuer’s temperature, heart rate status, and body movements while performing their operation.
II. Inefficient of manual real-time physiology monitoring will lead to delay in sending rescue and leads to fatality of rescuer on-site.
III. Ineffective way of monitoring every rescuer who are on-duty all at once.

The lack of features present in the current available system can be overcome with the prototype being built. Lives of the firemen are at risk due to the stress experienced while handling emergencies and avoiding obstacles. Exposure to smoke and excess inhalation of carbon monoxide may cause exhaustion, dehydration and heart attack [5]. With the project’s physiological monitoring system, firemen’ lives would be saved. The state of the physiology health can also be preserved. This project’s prototype will be able to record and report the heart rate, body temperature and body posture values all at once using wireless communication. Multiple firemen can be monitored at the same time.

1.3 Objectives

The project is to build a device which can monitor and measure the vital signs from the physiological state of the human body. The following objectives of the project are:

1) To develop a monitoring system of firemen physiological monitoring of temperature and heart rate and physical position during rescue mission.
2) To integrate temperature and heart rate monitoring system with firemen physical position to become one complete system.
3) To test this integrated system in the lab and on site (if time permits).

1.4 Scope of Study

The scope of this project is to build a prototype for firemen with age around 20 to 40 years old. The project focuses on integrating three different sensor types while monitoring multiple firemen all at once within a great distance of 1 mile. Actions like lying down and standing up are the only actions to be validated in this project. These actions are basic human behaviour in daily life. The scope is limited to these particular areas in order to ensure that this project is successful and a prototype will be completed at the end of Final Year. The author will focus on the applications in terms of hardware for pulse sensor, temperature sensor, accelerometer sensor and XBee radio frequency (RF) networking for wireless data transfer. There are also a few limitations found in this project. The three sensors, wireless XBee module, microcontroller and all electronic components used in this project are bulky and big. However, the prototype is still portable and easy to be worn. The limitation is ignored for the time being in order to suit the basic objectives listed above.

CHAPTER 2

LITERATURE REVIEW

2.0 Chapter Overview

Fire-fighting is well-known to be physically and mentally demanding profession which is well prone to high risks in terms of physiological and physical stress while carrying out their duties [6]. Moreover, firemen are always in a race against time to save all survivors yet avoiding obstacles throughout the operation.

An average time taken to conduct rescue mission in any type of incidents would be hours depending on the severity of the incident. If the incident is an earthquake disaster, it would take days to save surviving victims and finding the deceased. Meanwhile, for a common incident in battling fires, the time to conduct the mission will take a minimum of a few minutes or up to many days to control depending on the level of difficulty and the area where the fire outbursts occurred. Figure 1 below shows the statistics of fire breakouts occurred by state in Malaysia.

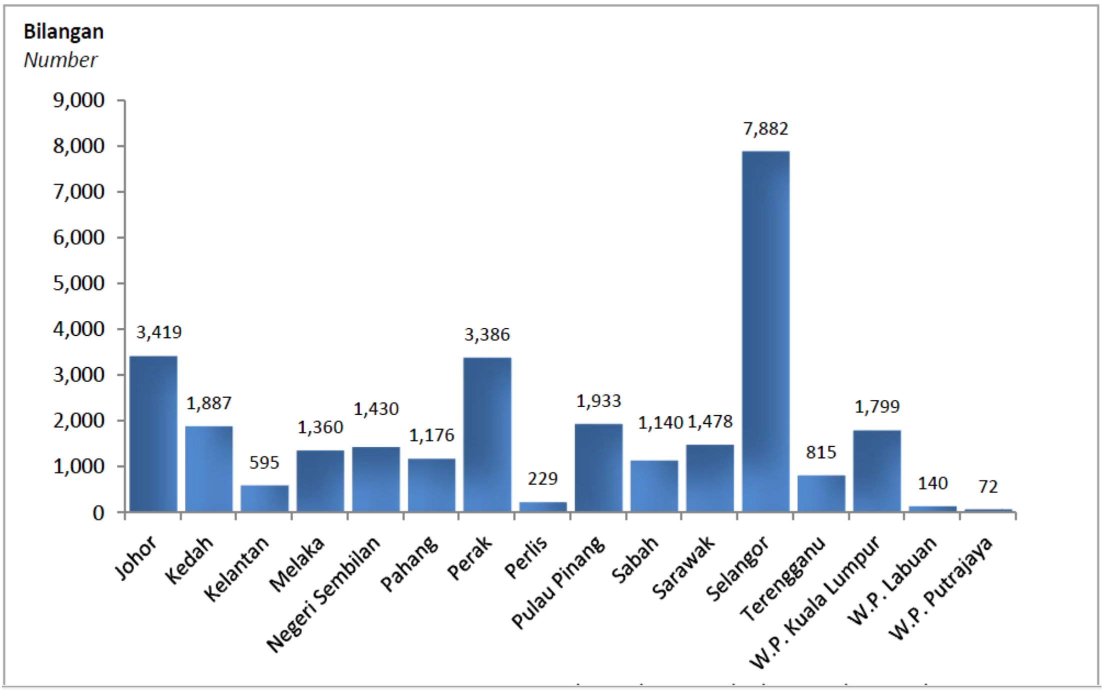

Figure 1: Statistics on Fire Breakouts by State, Malaysia, 2011 [6]

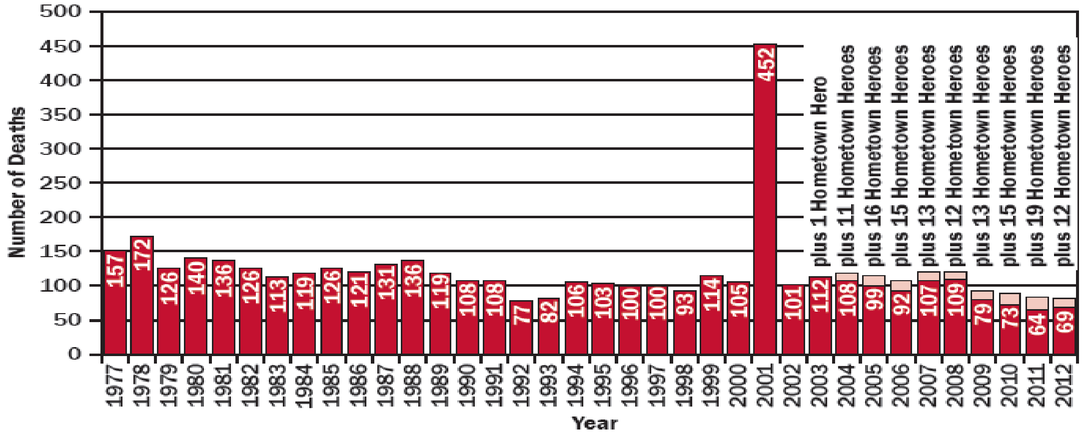

Figure 2: On-Duty Firefighter Fatalities (1977 - 2012) [7]

Figure 2 displays the statistics from year 1977 up to year 2012 of on-duty firefighter deaths in country of United States (U.S.). National Fire Protection Association (NFPA) in United States records all injured firefighters or fatalities every year. U.S Fire Administration (USFA) conducts annual analysis to find solution in reducing firefighter fatalities in the future [7]. Firefighters who died while performing their duty are the victims of sudden cardiac death, heatstroke, fallen or trapped due to unstable buildings. Figure 3 below categorises all causes. Unfortunately, the statistics of firefighters fatality in Malaysia could not be found due to lack of available resources in Malaysia's fireman association official website.

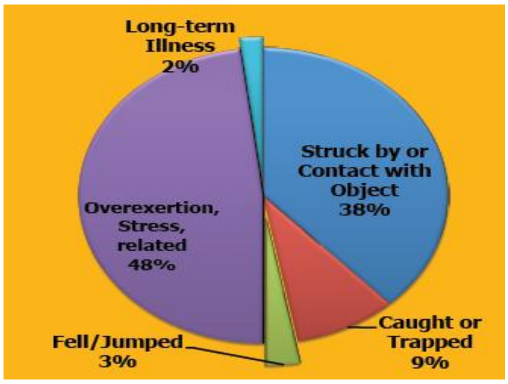

Figure 3: US Firefighting Deaths by Cause of Injury, 2012 [7]

Firefighters lives can be preserved if their actions and position are monitored closely in real time from a safe distance. Monitoring firefighters can be done through a device. The device must be able to detect the firefighter's physiological health status in terms of heart rate, temperature and body position as well as display these results into an online database system for monitoring purposes. Furthermore, the device must be up to date with current technology, reasonable cost and easy to use.

2.1 Heart Rate

Every human being on Earth has a heart which pumps blood throughout the body in order to transfer oxygen and nutrients for every living cell besides releasing dangerous toxins and carbon dioxide away from the human body [3]. A heart is an essential organ to keep a human being alive and well. Every time the heart pumps blood, a heartbeat can be heard and felt. The total frequency of this heartbeat cycle in each minute is called heart rate [8]. Thus, the unit term used to measure the heart rate is known as beats per minute (bpm). The range from 40 to 100 bpm is considered as a normal resting heart rate [9].

Heart rate of a person varies from person to person depending on the amount of oxygen and nutrients needed in the whole body in that particular minute. Furthermore, this oxygen and nutrients demand depends on an individual's fitness level and age [9]. While exercising, the heart rate increases because it needs to pump more oxygenated blood throughout the body effectively. During resting time, the heart rate will then return slowly to normal pulse value in a shorter period of time. The time taken to reach normal pulse value indicates one's fitness level [10]. Hence, athlete or sportsperson whom included exercises in their daily routine will absolutely have lower heart rates. Table 1 and Table 2 below show the ranges of resting heart rate for both men and women respectively.

Table 1: Resting Heart Rate for Men [9]

Resting Heart Rate for Men						
Age	**18 - 25**	**26 - 35**	**36 - 45**	**46 - 55**	**56 - 65**	**65+**
Athlete	49 - 55	49 - 54	50 - 56	50 - 57	51 - 56	50 - 55
Excellent	56 - 61	55 - 61	57 - 62	58 - 63	57 - 61	56 – 61
Good	62 - 65	62 - 65	63 - 66	64 - 67	62 - 67	62 – 65
Above Average	66 - 69	66 - 70	67 - 70	68 - 71	68 - 71	66 - 69
Average	70 - 73	71 - 74	71 - 75	72 - 76	72 - 75	70 -73
Below Average	74 - 81	75 - 81	76 - 82	77 - 83	76 - 81	74 - 79
Poor	82+	82+	83+	84+	82+	80+

Table 2: Resting Heart Rate for Women [9]

Resting Heart Rate for Women						
Age	**18 - 25**	**26 - 35**	**36 - 45**	**46 - 55**	**56 - 65**	**65+**
Athlete	54 - 60	54 - 59	54 - 59	54 - 60	54 - 59	54 - 59
Excellent	61- 65	60 - 64	60 - 64	61- 65	60 - 64	60 - 64
Good	66 - 69	65 - 68	65 - 69	66 - 69	65 - 68	65 - 68
Above Average	70 - 73	69 - 72	70 - 73	70 - 73	69 - 73	69 - 72
Average	74 - 78	73 - 76	74 - 78	74 - 77	74 - 77	73 - 76
Below Average	79 - 84	77 - 82	79 - 84	78 - 83	78 - 83	77 - 84
Poor	85+	83+	85+	84+	84+	84+

Heart rate is a vital physiological factor of human body due to the fact that it reflects the overall body health [10]. Fire fighting demands strong cardiovascular health and body strength for a prolonged period. In terms of determining the cardiovascular health of a person, heart rate must be measured. Firefighters who constantly must endure and suppress fire will certainly face a high risk of coronary heart disease which then leads to long-term sickness or worse, on-duty loss [11].

Firefighters heart rate can reach dangerous maximum level of beats while wearing heavy clothing with equipments at the same time putting out the blazing hot fire or saving victims' lives on an emergency site. Besides, the firefighters will experience a drastic increase in heart rate in response to the alarm ringing in the fire station [12]. The increase in heart rate will increase even more upon reaching at the fire emergency scene. While suppressing the fire outbreak, the effect of the high temperature, heat stress, oxygen deprivation, carbon dioxide suffocation will give a huge impact on the heart rate. Depending on firefighter's physical health, the prolonged high heart rate will lead to heart attack or sudden cardiac death [12].

Firefighters also handle other types of emergency situation like rescuing trapped victims due to natural disasters and nonemergency duties. Nonemergency duties are defined as maintenance, inspection, administration, fire-station tasks, fire prevention and physical training exercise. Unfortunately, it was found that the number of coronary heart disease deaths associated with suppressing fire is the highest than other types of emergency or nonemergency duties carried out [13].

2.1.1 Pulse Sensor

To sense and measure the heart rate, a sensor called Pulse Sensor is used. Heart rate can be measured at any spot of the body where pulse or heartbeat can be felt, for example, the neck or wrist [3]. This pulse sensor detects pulse from the fingertip. Figure 4 below shows the image of pulse sensor used. It uses the theory of absorption and reflection of light. Embedded inside are a bright LED, photodiode, an amplifier circuit and active low pass filter [14].

When the infrared shines through the fingertips, some light is absorbed by the skins and tissues but some will pass through easily if the skin or tissues are thin enough. Heart will pump the blood throughout the body including the fingertip. In the fingertip the blood is squeezed into the capillary and the volume of the tissues increased very slightly. In between the heartbeats, the tissues' volume then decreases [14]. This sequence will repeat on and on while the person is still alive. The change of blood volume will influence the intensity of light transmitted through and reflected by the skin [3]. The light differences will be detected by the photodiode and then calculated to find the accurate heart rate value [14].

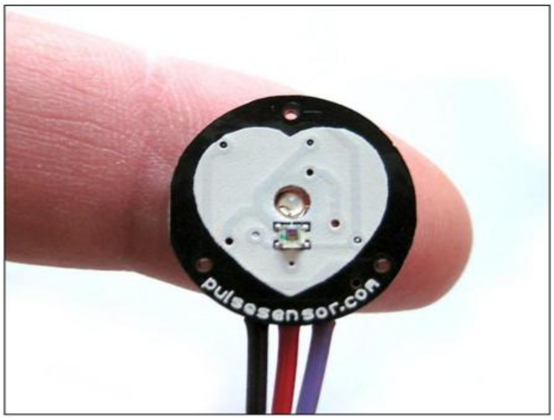

Figure 4: Pulse Sensor

This pulse sensor will produce an analogue signal. This signal will be filtered by a low pass filter and amplified into correct voltage [14]. The result will then be fed into the microcontroller used in this project. A program code is written to measure and calculate the pulse sensor output. A readable and understandable beats per minute (BPM) heart rate values can be displayed continuously [3].

2.1.2 Electrocardiography (ECG)

Another way of measuring the heart rate is using electrocardiography, ECG method. The rate of atria and ventricular contractions is called heart rate. The heart rate or pulse is actually the frequency of heart cycle, or the number of heart cycles occurred every minute. Electrocardiography can measure the electrical activity or signals produced by the pumping of the heart [15]. Based on the Figure 5 the wave labelled R is usually preceded by a P labelled wave. Measuring the time intervals between P – P waves are called atria rate. Meanwhile, ventricular rate is determined between R- R waves time interval [15]. With proper calculations, the value of heart rate pulse can be measured in beats per minute (BPM) unit. The heart frequency is produced when the Sino-atrial (SA) node starts the heart [15]. This activation propagates into the right and left atria heart muscles and tissues. Blood will flow and fill the Atrio-ventricular (AV) node during every delay occurred in between the ventricles and atria muscles contractions in the heart [15]. The depolarization signal will propagate into the heart ventricles through the Bundle of His and spreads along the Purkinje fibres of the heart according to Figure 6.

Heart ventricles then contract and pumps blood into the aorta and out towards the whole body. Finally, heart repolarisation occurs and the whole cycle will be repeated. Throughout the above cycle, the voltage difference between the internal and external spaces of the cell membrane, changes at every stage of the heart cycle [15]. The voltage differences can be measured using surface electrodes attached to certain parts of the body near where the heart is located [15]. The different peaks P, Q, R, S, T and U are measurable at these stages, as observed in the general electrocardiography waveform shown in Figure 5.

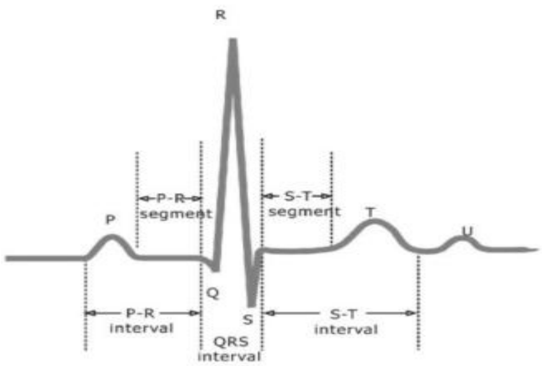

Figure 5: Electrocardiogram Waveform [15]

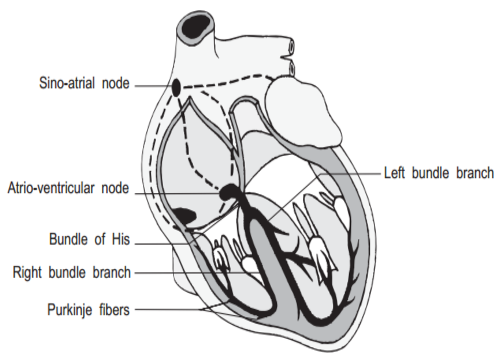

Figure 6: Heart Anatomy [15]

2.2 Body Temperature

The real definition of temperature is the measuring the amount of thermal energy stored in particles in any types of matter [1]. Nevertheless, in this project, it is specifically meant to measure only humans' body temperatures. Body heat production and body heat loss is constantly balanced out to maintain the core body temperature for body cells to survive [16].

Human body releases heat to maintain a constant body temperature and equalize with surrounding temperature. Blood circulation also aids the body in releasing heat. While the heart is pumping the blood, an increase in surrounding temperature will initiate the blood vessel to expand allowing faster blood flow towards the skin surface. The heat escapes through the skin and may trigger sweat. Through sweating, the human body cools down slowly and gradually on its own [17].

Thermometer is a very common tool used to measure average heat stored in a body. The result displayed on the thermometer shows the comparison of inner body temperature and environmental temperature [8]. Each person executes different types of activities on a daily basis. Body releases less heat while performing slow, relaxing activities during night time, meanwhile, more heat including sweating will be discharged due to rigorously, heavy activities at the peak of the day [8] [15]. Depending on how active a person is at certain of the day, body temperature changes according to those two factors. Normal value of human body temperature value is measured from 36.1˚C up to 37.3 ˚C while normal surrounding temperature changes around 0.6˚C in a day depending on country's current climate [15]. Furthermore, other factors that body temperature are sensitive to can be referred to Table 3 below.

Table 3: Factors Affecting Body Temperature [16]

Factors	**Effect**
Ovulation	High Body Temperature
Circadian Rhythm	High In Evening Low In the Early Hours of Morning
Age	Young and older inability to maintain equilibrium
Exercise	High Body Temperature
Thyroid Hormones	High Metabolic Rate High Body Temperature

Degrees Celsius (˚C) and degrees Fahrenheit (˚F) are two common temperature measurement scales [15]. Depending on the custom of region around the world, different region uses different scales to measure. Different parts of the body have different accuracy in measuring the body temperature. Thus, it can be measured in many locations on a human body where mouth (oral), ear (tympanic), armpit (axillary), and rectum are the most common measurement places [16]. Table 4 classifies the ranges of normal body temperature values for both men and women.

Table 4: Normal Body Temperature Range for Men and Women [8]

Place	**Normal Range** (˚C)	**Men** (˚C)	**Women** (˚C)
Oral	33.2 – 38.2	35.7 – 37.7	33.2 – 38.1
Rectal	34.4 – 37.8	36.7 – 37.5	36.8 – 37.1
Tympanic	35.4 – 37.8	35.5 – 37.5	35.7 – 37.5
Axillary	35.5 – 37.0	-	-

High degree of heat emitted by fire will affect the fireman’s heart to pump so much blood towards the skin causing emotional stress, heatstroke and losing concentration while on emergency site [17]. Heatstroke or hyperthermia is a life-threatening condition where the core body temperature ascends above 40˚C due to failure of the body in regulating body temperature causing it to rise continuously which leads to severe dehydration and non-functional body organs [18]. The indicators of heatstroke are confusion state of mind, coma, and reddish, dry, hot armpit skin [18]. There are two types of heatstroke available.

Table 5: Types of Heatstroke [18]

Types of Heatstroke	**Definition**
Classic Heatstroke	Exposure to a hot environment and body is unable to cool down effectively. Rate of sweating and heat transfer is to the environment is reduced. Sweating ability stopped abruptly. Last for several days.
Exertional Heatstroke	Working or exercising around a hot environment. Body sweats profusely and produces more heat than it can lose. Body temperature will rise to dangerously high levels.

2.2.1 Negative Temperature Coefficient (NTC) Thermistor

Detecting and measuring the temperature can be done by a sensor called a thermistor. Thermistor is a special kind of ceramic sensor where its' resistance changes according to the ambient temperature or heat. When it detects the heat near to it its resistance value will change. Besides, this thermistor is very suitable because it is low in cost, has fast response time and high in accuracy. There are two types of thermistors available known as positive temperature coefficient (PTC) and negative temperature coefficient (NTC). PTC has a positive temperature coefficient where the resistance will increase when the temperature increases. Meanwhile, NTC has a negative temperature coefficient where the resistance will decrease when temperature increases.

Currently, in this project, the NTC thermistor is choosen to measure the body temperature. This thermistor can read temperature values between – 40˚C and + 125˚C [4]. Beta-Factor method is used to calculate and convert the values of resistance measured in the 10K thermistor into temperature value [4]. The formula is shown below where T_o is the initial temperature vale, B is the Beta-Factor coefficient, R is the current resistance value and R_o is the initial resistance value. The coefficient Beta, B value used in the project is 3977.

$$\frac{1}{T} = \frac{1}{T_o} + \frac{1}{B} \ln\left(\frac{R}{R_o}\right) \quad \text{——} \quad (1)$$

Figure 7: Thermistor Sensor [4]

2.3 Triple Axis Accelerometer and Gyroscope

Accelerometer, an electromechanical device is specifically built to measure acceleration forces or speed of movement of the object it is attached to by moving, vibrating and tilting the device. The rate of change of velocity with respect to time defines acceleration, a vector quantity that have magnitude and direction values [19].

The basic concept of accelerometer in detecting motion is by measuring gravitational pull upon static acceleration on an object. Based on Figure 8 below, the mass (m) can be seen as attached to spring, k and a damper, c respectively. When the device is experiencing some form of acceleration, this formula; Force (F) = Mass (m) * Acceleration (a) explains that the force created will act on the mass and causes it to deflect in a certain angle or motion acted on it [19]. When the device is moved in respect to x-axis, acceleration, a calculated as:

$$m\,a + F\,d + F\,s = 0 \qquad (2)$$

$$m\,a = -\,F\,d - F\,s \qquad (3)$$

$$m\,a = -\,c\,\dot{x} - k\,x \qquad (4)$$

$$a = -\,\frac{c}{m}\,\dot{x} - \left(\frac{k}{m}\right)x \qquad (5)$$

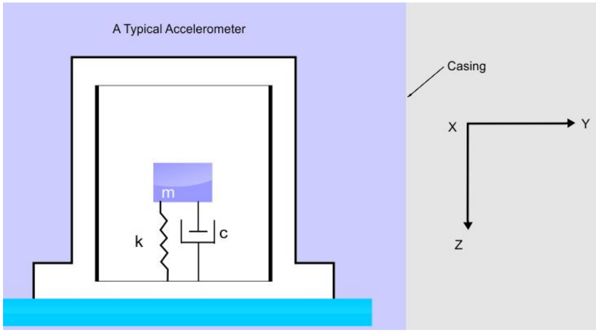

Figure 8: Schematic of a 3-Axis Accelerometer [19]

Figure 9 shows a detailed explanation in how tilt angles are measured and labelled. The ρ, ϕ and θ symbolises the tilt with respect to X, Y, Z axis respectively. Specifically θ is the angle of tilt around the Z axis with respect to Earth's gravity. The ρ is defined as pitch while ϕ is roll with respect to the ground; however, θ is not defined as yaw. Accelerometer does not have the ability to compute yaw direction. This is the obvious limitation present in an accelerometer.

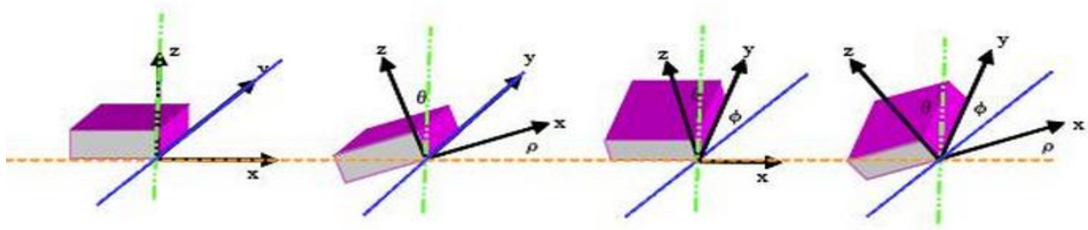

Figure 9: Tri-Axis Tilt Measurement [20]

The limitation present in an accelerometer is that it depends fully on the force of gravity acting on it. Without gravitational force, the accelerometer measurements will be inaccurate and unreliable. The second limitation is when the accelerometer is moved and rotate manually by hand, unnecessary forces are created which causes the results to fluctuate. Hence, noise and perturbations are produced unwillingly. Equations below are used to calculate angle orientations.

$$\rho = arctan\left[\frac{A_X}{\sqrt{A_Y^2 + A_Z^2}}\right] \quad \phi = arctan\left[\frac{A_Y}{\sqrt{A_X^2 + A_Z^2}}\right] \quad \theta = arctan\left[\frac{\sqrt{A_Y^2 + A_Z^2}}{A_Z}\right] \text{ ——— } (6)$$

Gyroscope is normally used to measure or sensed angular velocity for fall detection or tracking motion [21]. Gyroscope has an effect which accelerometer does not have, called precession. This effect defies gravity, thus making it as a suitable sensor to detect motion. A bicycle wheel is a great example of showing how a gyroscope functions as seen in Figure 10. A force is acted on its axle, the two red points on top and bottom of the wheel will tend to move according to the blue arrow directions as seen in Figure 10 [22]. The big advantage stored within a gyroscope is that it can differentiate restricted movement in any directions by measuring the object’s angular velocities. Unfortunately, it tends to drift and tends accumulate errors, until the direction of the object will be illogical and inaccurate [20].

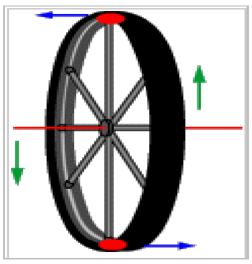

Figure 10: Bicycle Wheel acting as a Gyroscope [22]

Gyroscope and accelerometer are very common to be integrated together in one motion tracking device. This is because, each sensor are prone to systematic errors and noises. Some methods used in a motion detection sensor only utilized either accelerometers or gyroscopes in a separate manner. These separated sensors can only produce results for restricted movements within specific directions [21]. Hence, it is not accurate because accelerometers produce noise in a short term, but precise in long term [20]. Meanwhile, gyroscope measures changing orientation accurately but tends to drift after a certain period of time [20]. To overcome these errors, combining multiple sensors in one device can obtain best results in recognizing a vast amount of activities performed by the wearer of the device [21].

Sampling rate = Δt

Change in gyroscope angle = $\omega \times \Delta t$ [20]

Gyroscope angle = $\theta + (\omega \times \Delta t)$ [20]

Time constant = T

Gyroscope angle = θ

Equation below is the combination of accelerometer and gyroscope angle formula.

$$\left(\frac{T}{(T + \Delta t)} \times \left(\theta + (\omega \times \Delta t)\right) + (1 - \alpha) \times \left(\begin{matrix} Accelerometer \\ Angle \end{matrix}\right)\right) \text{——} \quad (7)$$

Both gyroscopes and accelerometers have two working principles which are one-axial and three-axial. One-axial only can detect acceleration forces and angular velocity in one axis, on the other hand, three-axial detects both on three axis system. Three-axial accelerometers and gyroscopes have the high sensitivity and accuracy in registering or storing movements and actions act upon it. With the data obtained from both devices, the electrical signal output can be measured manually to distinguish the differences in terms of the wearer's activity and actions [21].

In terms of a human body as the object, there are many parts of the body that can be used to measure movements and position. The head is the most uncomfortable place, thus this part of the body is excluded immediately. Wrist and feet also falls under the same category as they will restrict the person's daily activities. Places like, waist, chest, and thigh are actually the best places for devices attachment. Besides, these suitable places will not interfere with wireless connection in real time.

2.3.1 MPU6050 (MEMS Gyroscope and MEMS accelerometer)

MPU6050 is a low power, low cost and high performance 6-axis motion tracking device. Inside is a combination of one MEMS 3-axis gyroscope sensor and one MEMS 3-axis accelerometer sensor embedded on one silicon die. MEMS abbreviation stands for Micro-Electro-Mechanical Systems. It is a technology in a form of miniaturized mechanical and electromechanical elements that are made using the technique of micro fabrication. The combination of accelerometer and gyroscope is referred as Inertial Measurement Unit (IMU) to increase the accuracy of motion tracking sensor. MPU6050 has a characteristic of 6-DOF (Degrees of Freedom). The term DOF is referring to the number of inputs available on the MPU6050 chip, therefore 6-DOF means that MPU6050 has 6 inputs. The 6 inputs are from the 3-axis gyroscope combined with 3-axis accelerometer and using standard I2C bus will transmit the data as the output.

By using Arduino Uno microcontroller the output data from MPU6050 chip can be easily retrieved. With some programming code written, the data can be calculated and obtain the person’s movement or body posture. In this project, GY-521 sensor module is used to detect the body posture.

Figure 11: GY-521 Breakout Board Module [20]

2.4 ZigBee

It is built as a wireless personal area network (WPAN) standard with low data rate based on IEEE 802.15.4 protocol [8]. It provides compatibility between many process control equipments placed anywhere to communicate with other systems at the same time via a short-range radio signal or commonly known as Radio Frequency (RF) [23]. An open standard technology like ZigBee involves low data rate, long battery span, and a secured networking found in radio frequency (RF) applications [24].

Star, mesh and cluster tree are the three well-known ZigBee network layer topologies which at the same time provides network, security including application framework profile layers based on IEEE 802.15.4 system. Long battery lifespan is one of the benefits found in star networks. Mesh network has the ability to provide multiple paths throughout the network placed in a close distance at the same time enabling high levels of reliability and scalability. Lastly, cluster tree network is a combination of star and mesh topologies including their benefits.

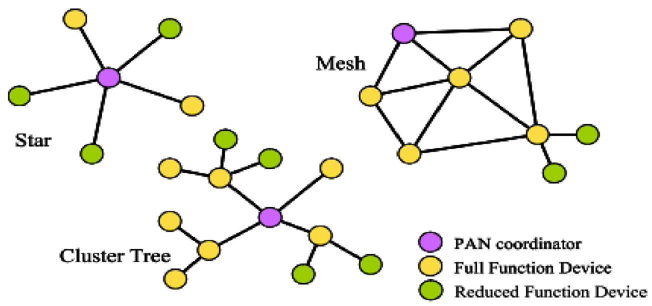

Figure 12: ZigBee Network Topologies [25]

ZigBee was made by ZigBee Alliance who is a rapid-growing and non profit organization founded in August 2001. This organization is truly committed in providing flexible and simple electronic products for their consumers worldwide. Frequency bands of 2.4GHz and 900MHz are used by current ZigBee with a transmission rate around 20kbps up to 250kbps for easy application in all fields.

ZigBee wireless network is very suitable to be integrated in any hardware, devices or systems that require portability, real-time capability, easy deployment and reconfiguration [26]. There are many types of transmission technologies used to communicate with sensors or applications which are known as Wi-Fi, ZigBee, Bluetooth, Radio Frequency (RF) and Radio Frequency IDentification (RFID). These transmission technologies have been readily integrated into a more significant technology called Wireless Sensor Network (WSN) [2]. Ultra-wideband (UWB) is a network mainly utilised for data communications, radar, sensing and safety applications [27].

Table 6: Characteristics of Widely-Used Networks [28]

Technology	**Standard**	**Frequency Band**	**Data Rate**	**Network Topology**	**Range**	**Battery Life**	**Cost**
Wi-Fi	IEEE 802.11b,g	2.4 GHz	Up to 22 Mb/s	32 active nodes	100 m	Hours	Relatively high
Bluetooth	IEEE 802.15.1	2.4 GHz	1 Mb/s	8 active nodes	10 /100 m	Days	Relatively low
UWB	IEEE 802.15.3a	3.1 GHz-10.6 GHz	40-600 Mb/s	N/A	30 m	Hours	Highest
ZigBee	IEEE 802.15.4	868/915 MHz, 2.4 GHz	20/40/250 kb/s	255 active nodes	10/100 m	Years	Lowest

Based on Table 6, these existing technologies have certain limitations which ZigBee can overcome. Most of them are costly, not power efficient, unable to comply with large number of devices connected to its network and limited number of nodes [26]. Meanwhile, ZigBee is designed to provide higher network flexibility, low-data rate, has low power consumption which makes it highly power efficient and also offers larger range of transmission enabling it to communicate with other ZigBee nodes at the same time [2]. Nodes used in ZigBee Protocol are known as Coordinators, Routers and End Device where each of them plays specific roles in sending and receiving data.

2.4.1 XBee Pro Series 1 Module Transreceiver

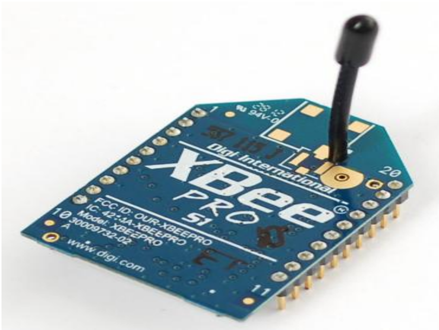

Figure 13: XBee Pro Series 1 [29]

XBee is the brand name of a product which utilises partially the ZigBee standard protocol. It is produced by Digi International as a form of compatible radio modules. Digi International has produce four well-known product series called XBee Series 1, XBee Series 2, XBee Pro and XBee-Wifi. However, they are not fully ZigBee standard compliance thus making it unable to communicate with other types of ZigBee communication or ZigBee radio frequency devices except for Xbee Series 2. XBee still uses the IEEE 802.15.4 protocol and the same Medium Access Control (MAC) as its lower layer. Both can also be found in lower layer of ZigBee. Nevertheless, the manufacturer has made the XBee's upper layer different with ZigBee. In simpler words, XBee uses different language than ZigBee hence making both incompatible with each other. Due to this, XBee Series 2 is created by Digi International to be compatible and able to communicate with all ZigBee devices.

This project is using XBee Pro Series 1 module. It provides a wide range of communication with low data rate and 250kbps speed. XBee Pro Series 1 can communicate within 100m indoors, meanwhile 750m in outdoor communication range. This range is limited to line-of-sight range of communication. Line-of-sight is defined as an open space with nothing in between the object and XBee Pro module. The presence of Wi-Fi, Bluetooth and other Radio Frequency (RF) devices will certainly interfere with the XBee module communication. The module also acts as a transreceiver which can transmit and receive data simultaneously. Therefore, it is used as a cable replacement in sending data between from one host to another host.

2.4.2 X-CTU Software

X-CTU software can be use to display the data received by the Xbee transreceiver. X-CTU can read the type, configuration settings, and firmware of any transreceiver through the computer’s universal serial bus (USB) communication port. X-CTU is a free, open-source configuration platform application. It is designed to enable developers to interact with variety Digi Radio Frequency (RF) modules using a simple-to-use graphical interface. New tools are included to make the interface easy to set-up, configure and test XBee Radio Frequency (RF) modules. X-CTU includes so many tools especially to quickly start up and run devices with XBee transreceivers. Furthermore, X-CTU is also able to manage, configure and control multiple connected XBee modules remotely from a safe distance. Each modules need to have the same baud rate, network ID, channel, and addresses settings to be able to communicate simultaneously. Besides, to avoid lost communication, XBee receiver’s identification number, input output setting and many more can be changed easily by the developer with the help of the easy-to-use interface. The terminal section which is the large area in X-CTU can continuously display received data of the XBee transceiver module. Arduino board can send wireless data and results into the XBee interface like in Figure 32 in result section of this report.

2.5 Microcontroller

Arduino Uno is a microcontroller board which is an open-source electronic platform specifically for the makings of interactive and innovative projects. The hardware is based on a high performance, low power 8-bit ATmega328 microcontroller chip that has 23 programmable input output (I/O) pins, 32k bytes of flash memory, 1k byte of EEPROM and 2k bytes of SRAM. In addition, 6 analogue input pins, 14 digital input output (I/O) pins inclusive with 6 pulse width modulation (PWM) output pins, power jack, reset button and an USB port are all provided. More specifications about Arduino Uno are listed in Table 7 below.

Table 7: Arduino Uno Specifications [30]

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7 - 12V
Input Voltage (limits)	6 - 20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analogue Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

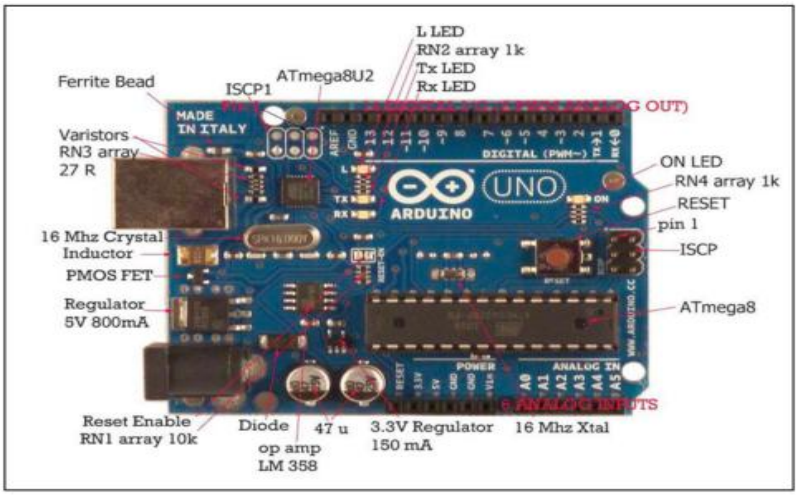

Figure 14: Arduino Uno Board [30]

2.5.1 Arduino Environment (Arduino IDE)

Arduino environment or IDE refers to the programming software which is widely used by Arduino users in order to programme its microcontroller board only. Mostly everything related to Arduino is open-source and is easily accessible. With this programming software, writing codes and uploading into the microcontroller board is easy and simple to do. Figure 15 below show that arduino environment has many features embedded and ready to use. It contains text editor, error message area, text console, toolbar and a series of menus. Toolbar provided will allow verification, uploading, create, open and save programme codes. The environment is developed in Java language and Processing, with many other open-source software types [30].

Programming codes written in the text editor are known as sketches. In addition, the sketch written also has copy/paste and find/replace text functionalities. When saved, it will be in a file extension called .ino file. Similar to other programming languages' compilers, arduino environment is also able to verify codes to check for syntax errors before uploading into the microcontroller. Errors will be displayed in the black coloured message area. The serial monitor feature in Arduino is able to read the serial port of the computer that it is connected to. The data and results produced will be able to be viewed in the serial monitor on the computer screen [30]. Arduino environment is user-friendly, convenient to use and is always up-to-date.

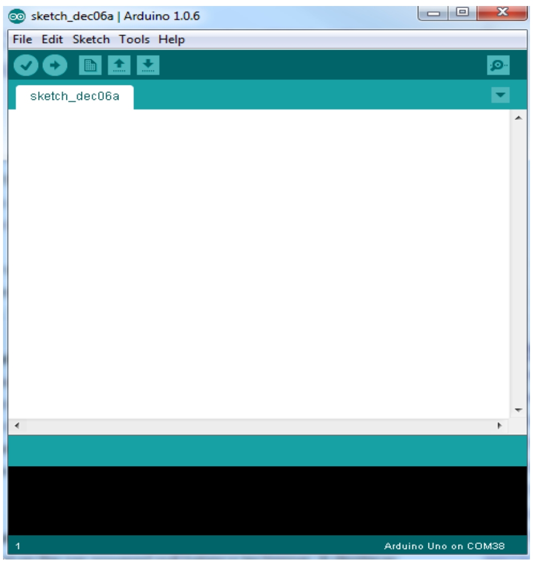

Figure 15: Arduino Environment (Arduino IDE) **[30]**

2.6 Nokia BL - 4U Battery

It is a rechargeable Li-ion battery used in Nokia branded hand phones only. It is used as the power input of this project. The features of the battery are listed below:

Type: Lithium-ion (Li-Ion)

Capacity: 1200 mAh

Voltage: 3.7V

GND – BSI Resistance: 82kΩ

Regarding GND – BSI resistance, it is actually a circuit connector used when the battery is suddenly removed while the hand phone is still turned on. This connector will create an interrupt to inform the processor inside in order to immediately shut down the phone. This will prevent from any damage on the hand phone.

2.6.1 Voltage Booster MAX757

Using a voltage divider and a reference voltage of 1.25V, voltage booster circuit can be created and the output voltage can be set easily by playing around with the resistor values. The circuit can be found in a chip called MAX757. The MAX757 can boost input voltage of minimum 0.7V value. It can also generate adjustable output voltage from range of 2.7V to 5.5V in value [31]. The adjustable output voltage will be set by voltage divider in between the ground (GND) and the feedback input located at pin 2 of the 8 pin MAX757 chip.

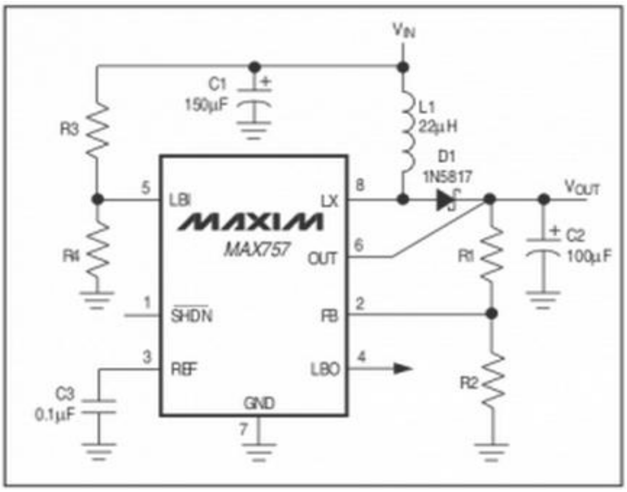

Figure 16: Circuit schematic of DC-DC Boost Converter

MAX757 is a complementary metal-oxide-semiconductor (CMOS) step-up DC-DC switching regulators for small, low input voltage [31]. Resistor 1 (R1) and Resistor 2 (R2) values can be chosen according to the designed circuit to obtain certain amount of voltages required. The MPU6050 module requires 5V input voltage; meanwhile XBee transreceiver can handle ± 3.1V. Therefore, this project must include two different booster circuits to boost up the Nokia BL - 4U and supply separately the correct amount of voltage to each MPU6050 and XBee modules. The formula in calculating the resistor values is:

$$V_{OUT} = (1.25) \left[\frac{(R2+R1)}{R2}\right] \quad (8)$$

Based on the formula, to obtain output 5V, Resistor 1 (R1) must be value of 30kΩ, while Resistor 2 (R2) must be 10kΩ. Meanwhile, for the 3.1V output, Resistor 1 (R1) must be value of 18kΩ, while Resistor 2 (R2) must be 12kΩ. The schematic of the booster MAX757 is drawn using Eagle Cad software.

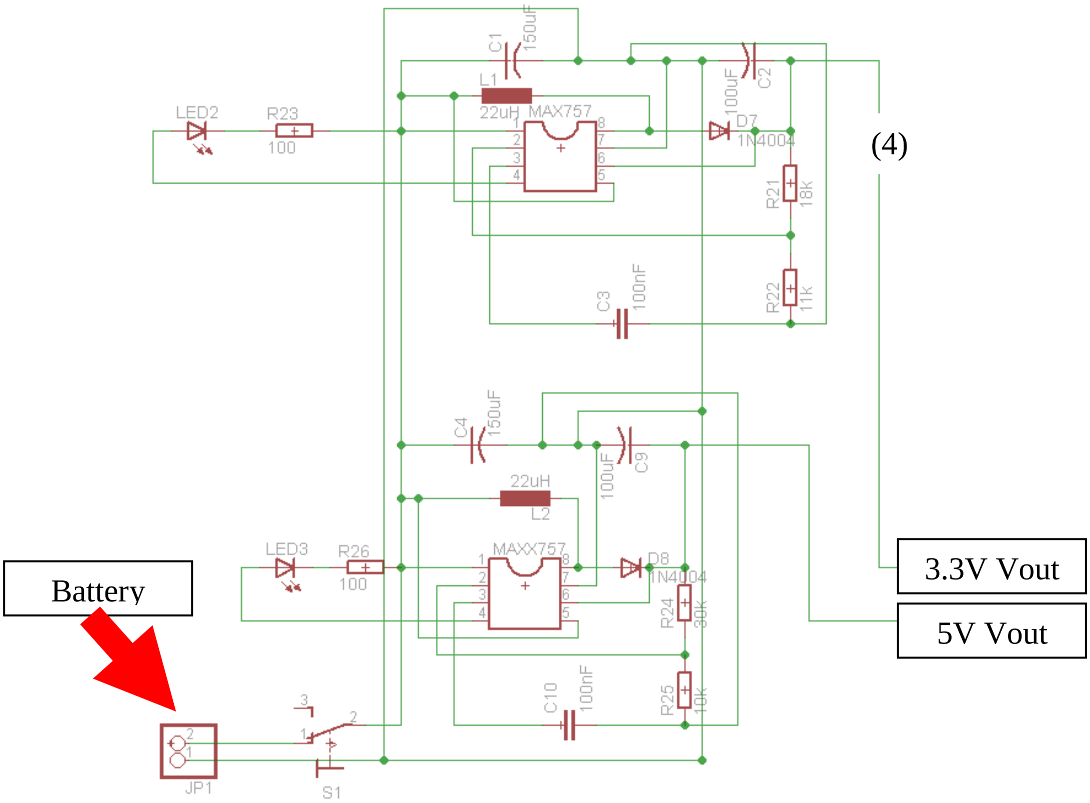

Figure 17: Eagle Cad Schematic of Booster Circuit

2.7 EAGLE Cad

EAGLE stands for Easily Graphical Layout Editor, which is open-source software for schematic or circuit design. It is created by CadSoft Computer and it is a well-known as powerful and flexible PCB design software. The author utilise this software for creating and drawing schematic diagrams. Many applications or features like Printed Circuit Board (PCB) Layout Editor, Schematic Editor, and Auto router. Electrical components libraries can be easily updated from time to time. Electronic parts can be placed on design sheets and be connected to each other through ports. The most interesting part is that PCB layout editor allows back annotation in the schematic. Auto-routing feature can automatically connect all design traces based on the connections drawn in schematic sheet. Moreover, Eagle Cad is very easy to learn and user-friendly. Designing printed circuit boards (PCB) have never been easier thanks to EAGLE.

2.8 Microsoft Office

Microsoft Office softwares used are listed in Table 8 below. Mainly these softwares are fully utilized to help the author in completing through the Final Year Project documentation purposes.

Table 8: Microsoft Office Software

Software Type	Description
Microsoft Power Point 2007	To create presentation slide shows
Microsoft Excel 2007	Organize, recording data and converting into graph charts
Microsoft Word 2007	Writing and documenting report

2.9 Currently Available Rescue System

Firefighters casualties keep on increasing year by year in every countries around the world. Nevertheless, these unsung heroes are not forgotten because scientists, inventors, technologists are developing and improving physiology monitoring systems to save firefighters lives. The most current updated system available used by the firefighters is in Worcester, Massachusetts which is known as Physiology Status Monitoring (PSM) [32].

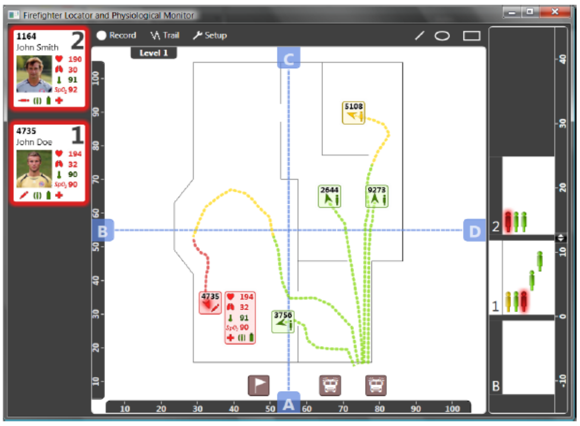

Figure 18: PSM Interface [32]

In this system, it is capable in locating each user relative with any reference point chosen. The location is displayed in 3-dimensional (3-D) form together with all information of the related path in a building at the incident command center computer. Furthermore, the command center computer will update the location of every firefighter on-duty at every 2 seconds with an accuracy of ± 1m of 20m in range. PSM will also show the data collected from Heart Rate, Respiration Rate, Skin Temperature with Posture and Activity Level, all in one device. The device is developed in a form of T-shirt stretchable according to the firefighters' body size including extreme flexibility [32].

Figure 19: PSM T-Shirt [32]

The second existing monitoring device can record and report via radio the status of temperature and carbon monoxide concentration of the surrounding emergency area. This device also includes in monitoring heart rate and breathing rate as well as position and information on the firefighter's movement. Besides monitoring, this lightweight and portable device also provides the channel for firefighter and command center to communicate with each other. The channel is not using the conventional communication type, but it is using digital communication.

Based on Figure 20, the device has GPS Receiver and Antenna which display continuous global view of the emergency ground. Meanwhile the 3 LED indicators with input switches are used by the firefighter to communicate with the command center manually. The main box is integrated with a microprocessor for automatic programme functions, an alarm for alert purposes, wireless modem to communicate and 'AA' alkaline cells for power supply.

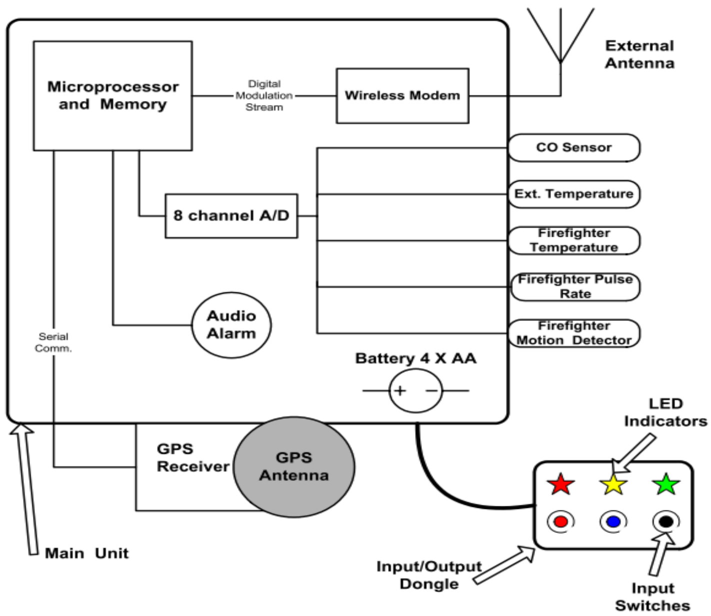

Figure 20: Draft Picture of the Device [5]

Improvements are being made on this device. The software is being improved for better command end receiving and to be built in on PDA devices. This device is still under experiment and simulation before being deployed to public usage.

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.1 Research Methodology

Figure 21 below shows the overall progress of the methodology flow while conducting Final Year Project (FYP) 2 smoothly and efficiently continuing from Final Year Project (FYP) 1 progress of last semester.

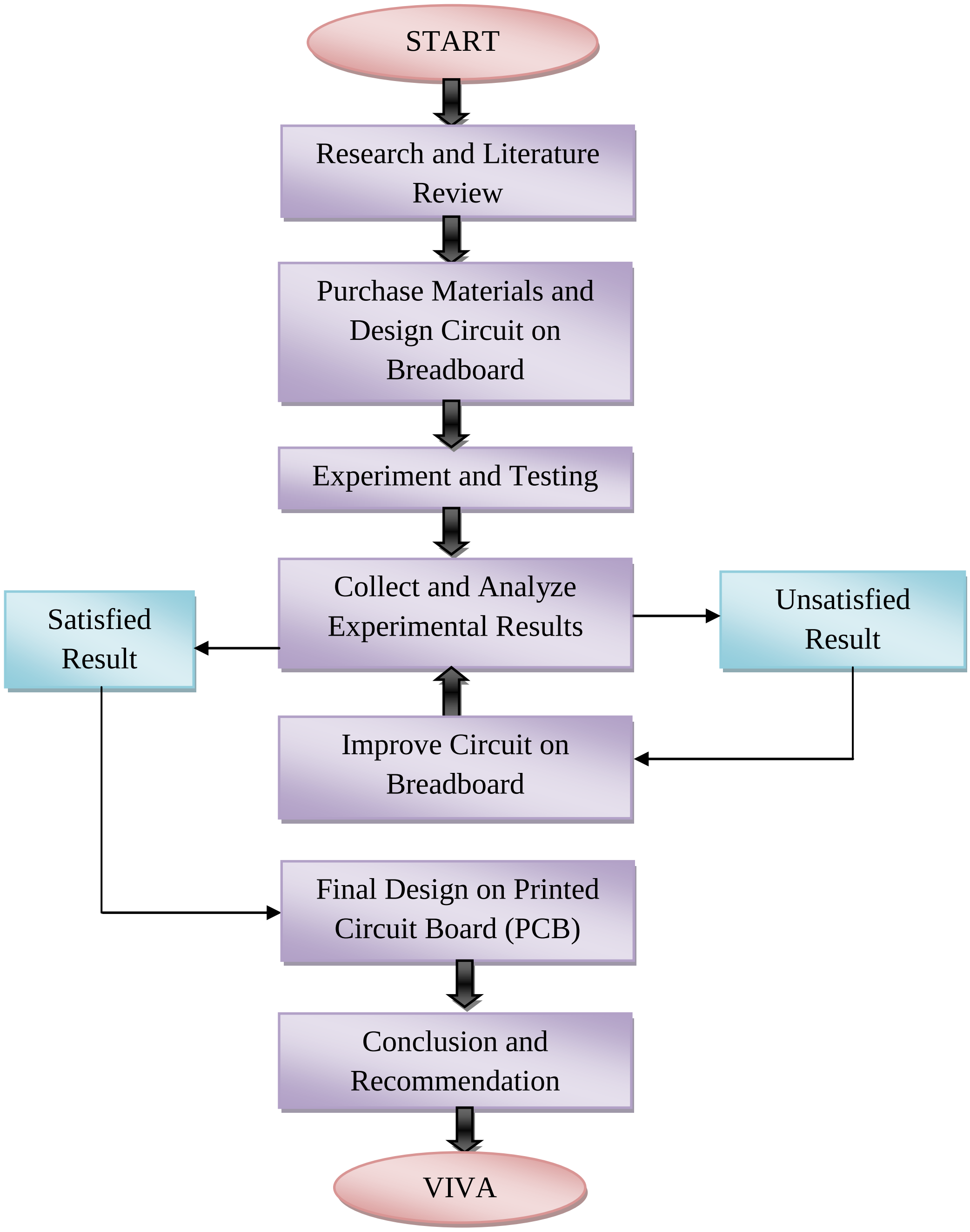

Figure 21: Methodology Flow

3.2 Detailed Research Methodology

Descriptions and explanations of Research Methodology for Final Year Project (FYP) 2 in Figure 22 are listed below.

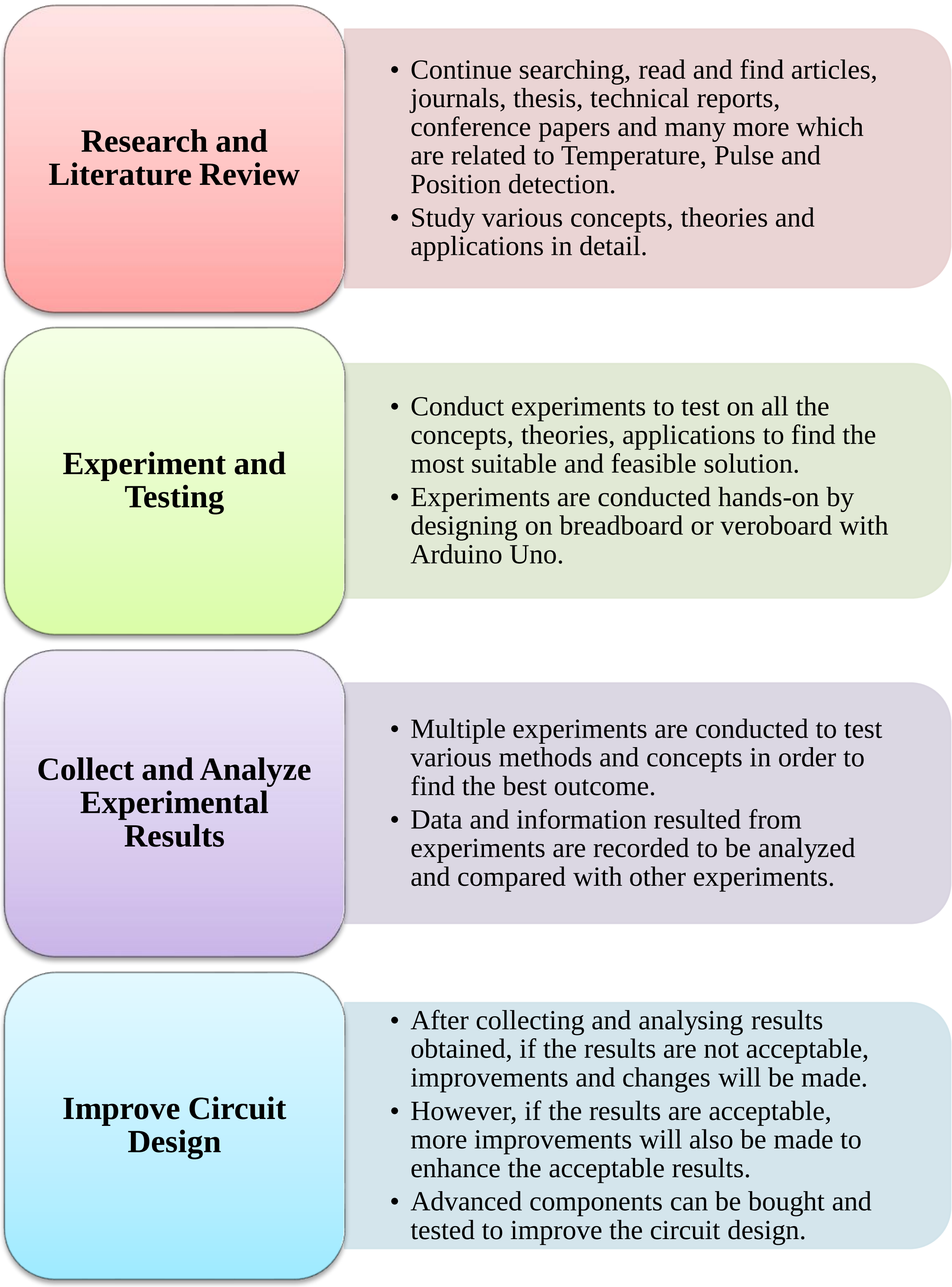

Figure 22: Detailed Descriptions of Methodology Flow

3.3 Final Year Project (FYP) 1 Gantt Chart

Table 9: Final Year Project (FYP) 1 Gantt Chart

Activities	Week													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Title Selection and Confirmation		◆												
Literature Review and Research			■	■	■	■	■	■	■	■	■	■		
Extended Proposal Submission							◆							
Preparation for Proposal Defence							■	■						
Proposal Defence and Progress Evaluation									◆					
Experimentation and Testing Hardware			■	■	■	■	■	■	■	■	■	■		
Preparation of Interim Report										■	■	■		
Draft Interim Report Submission													◆	
Completed Interim Report Submission														◆

Legends:

◆ Key Milestone ■ Timeline

3.4 Final Year Project (FYP) 2 Gantt Chart

Table 10: Final Year Project (FYP) 2 Gantt Chart

Activities	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Improve and Enhance Circuit Design Schematic	■	■	■	■	■	■	■							
Writing Progress Report						■	■							
Progress Report Submission								◆						
Printed Circuit Board (PCB) Design			■	■	■	■	■							
Gather and Analyze (PCB) Prototype Results								■	■	■				
ELECTREX											◆			
Writing Final Report and Technical Paper											■	■		
Draft Final Report Submission													◆	
Final Report and Technical Paper Submission														◆

Legends:

◆ Key Milestone   ■ Timeline

3.5 Tools and Software Required

Hardware

1) Basic Soldering Kit
2) Breadboard
3) Electronic Components
4) Negative Temperature Coefficient (NTC) Thermistor
5) Pulse Sensor
6) Electrocardiography (ECG) Surface Electrodes
7) MPU6050 (MEMS Gyroscope and MEMS Accelerometer)
8) XBee Pro Series 1 Module Transreceiver

Software

1) EAGLE Cad
2) Arduino Environment
3) Microsoft Office
4) XCTU Software

3.6 System Architecture

The project is successful due to the system architecture below. Each fireman wearing all sensors integrated together with XBee module will take position in many locations. When the prototype device is turned on, data readings will be calculated and collected by microcontroller and transmit towards XBee receiver placed in command centre. Next, the readings will go into the Ethernet system route created personally, then through the Wide Area Network (WAN). Online database will store previous and current data readings of the firemen for future reference. Using internet, an online website called Fireman Monitoring System can be use to access and monitor the readings continuously in real-time. Mobile phones, laptop or other devices using the internet are also suitable.

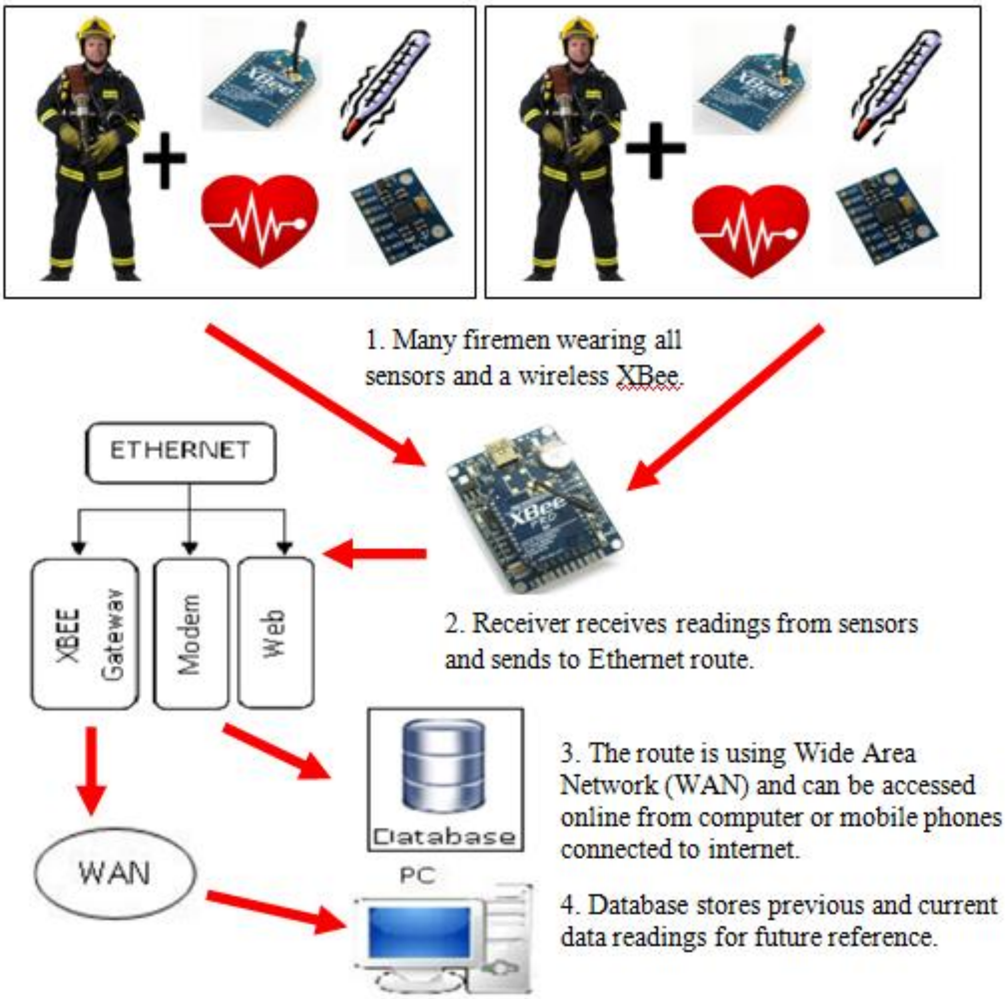

Figure 23: Entire System Architecture [1-3]

3.7 Experimentation and Testing Prototype

Firstly, the author builds a circuit for temperature sensing phase. Next, the accelerometer and gyroscope module is combined with the temperature circuit. The last sensor which is the Pulse Sensor is finally combined with both existing circuits. Figure 24 is the circuit first prototype in finding the perfect sensors.

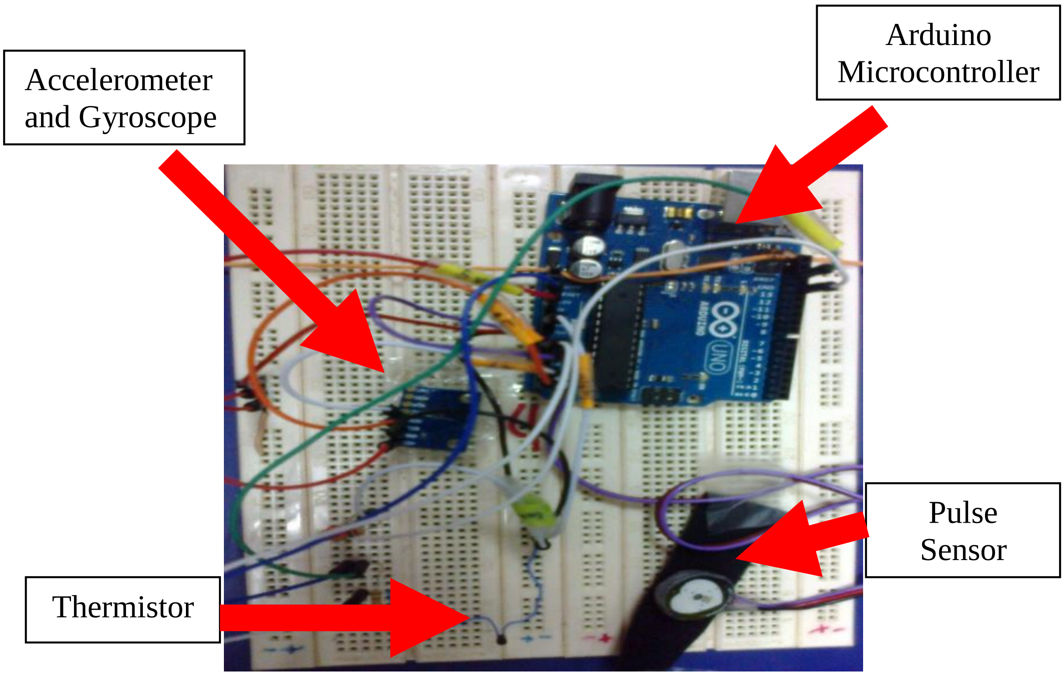

Figure 24: Prototype on Breadboard

After completing the prototype circuit, the author tested the circuit to monitor and analyze the results using Arduino microcontroller. The upcoming phase is to integrate the ZigBee wireless networking utilising fully the XBee Pro Series 1 module. Integrating all elements into one electrical circuit is complicated and complex. Many factors have to be taken into consideration to ensure that the sensors and XBee are fully functional without any short circuit. Improving the electrical design was time-consuming. Programming the codes onto the integrated circuit has to be trial and error until no error occurred. Fortunately the design was completed according to the Final Year Project (FYP) 2 Gantt Chart planning.

As soon as the results produced from the final circuit design are validated, a printed circuit board (PCB) is drawn using the EagleCad software. This software provides the capability to construct and design many types of PCBs according to the user’s own will. Figure 25 displays the electrical schematic, while Figure 26 shows the expected PCB board design.

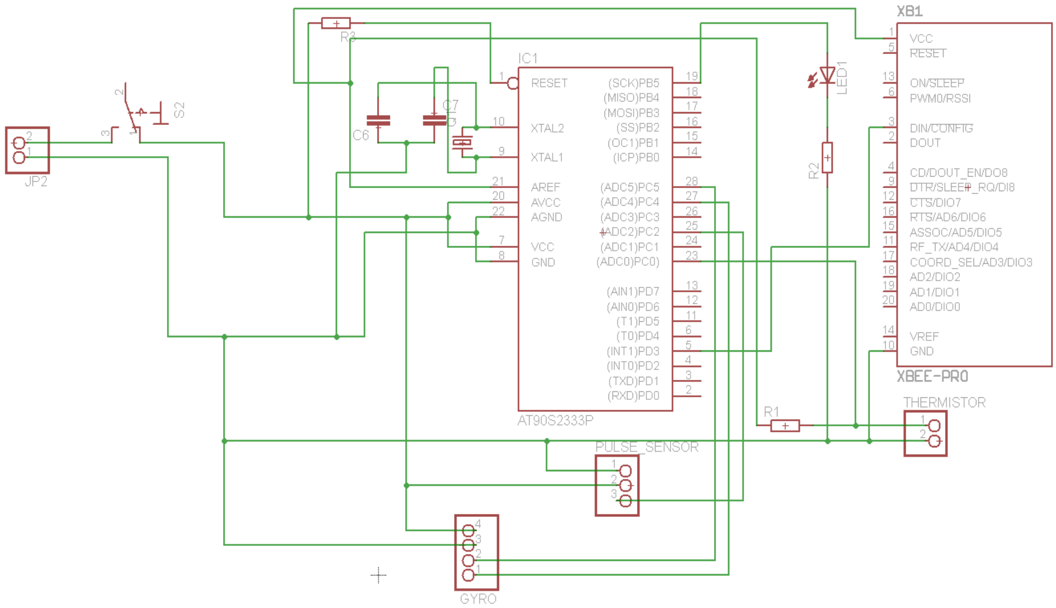

Figure 25: Schematic of First Prototype in EagleCad

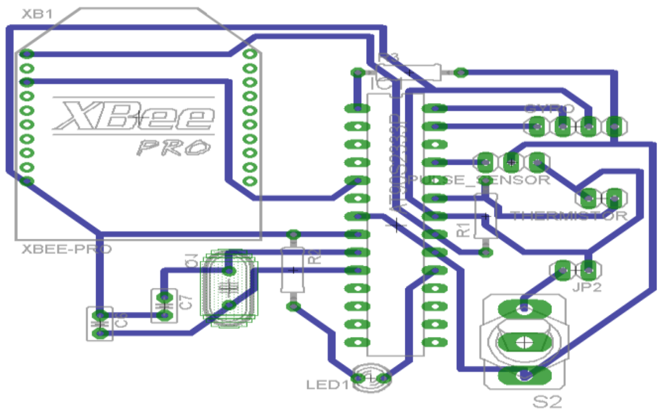

Figure 26: EagleCad Board of First Prototype

Both the schematic and board drawing are sent to the Universiti Teknologi PETRONAS laboratory to be printed out. While waiting for the printing and fabrication process to complete, more electrical components were bought and delivered to be soldered onto the Printed Circuit Board (PCB) later on. It took 3 days to complete just one set of Printed Circuit Board (PCB) as the process is not easy. As soon as the PCB was ready and materials such as electrical components, soldering kit, wires were bought and prepared. Figure 27 shows the first soldered prototype.

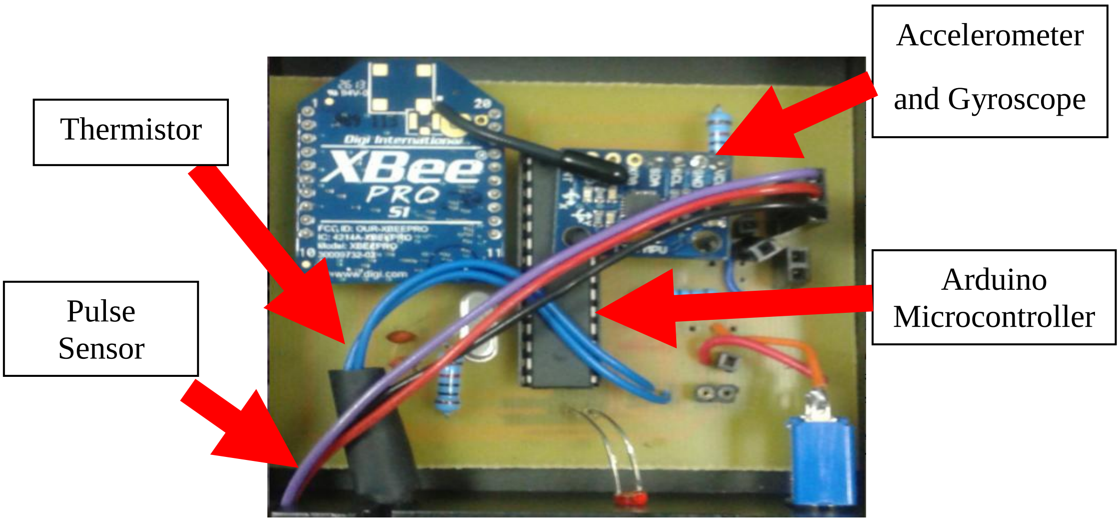

Figure 27: Printed Board of Circuit of First Prototype

Once the Printed Circuit Board (PCB) circuit has finished being soldered and tested, a casing to cover the whole circuit is designed. The dimension of the Printed Circuit Board (PCB) is measured to be 8cm x 8cm in length and width. In addition, the casing is made of Perspex, a lightweight and shatter-resistant material painted in black. Velcro is added so that the test subject can wear it easily around the body.

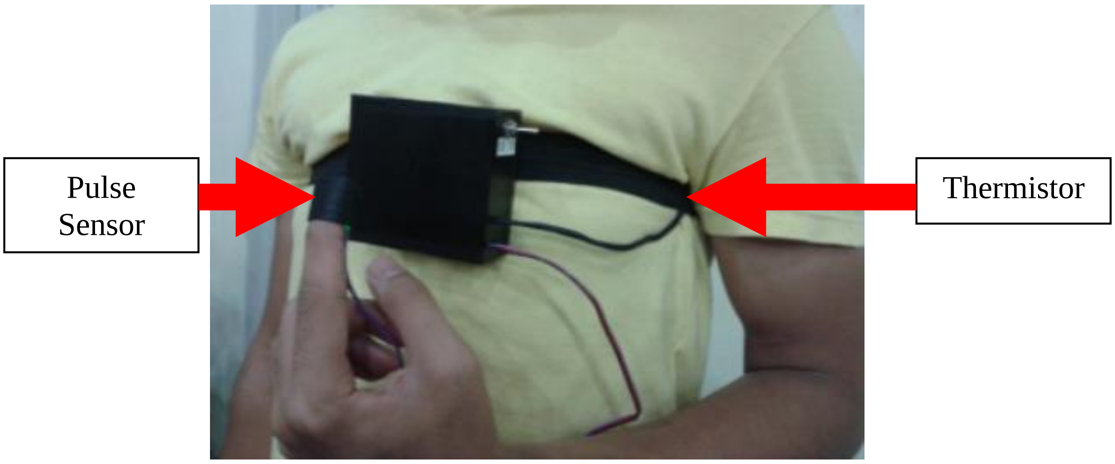

Figure 28: First Prototype Strapped onto a Person's Chest

However, while carrying out experimentation using this prototype, the author found out that the Pulse Sensor attached to the fingertip will surely hinder the fireman from performing handy activities. The Pulse Sensor has a long 3-wire which sends heart rate signals into the microcontroller. This wire has length limitation and is also breakable. From this realisation, the author has decided to improve the prototype before the upcoming Final Year Project (FYP) viva in the end of the year.

In the literature review, the basic concept of Electrocardiography (ECG) has been explained thoroughly. Pulse Sensor will be replaced and ECG will be integrated into the existing circuit. Unfortunately, ECG has no ready-made sensor available. But there are many ways to create a replica circuit of ECG. Usually this replica is called as Do-It-Yourself (DIY) ECG Machine. ECG machines used by the hospitals are bulky and not portable. The circuit schematic below basically can replace the ECG machine, but this DIY ECG still has existing unavoidable limitations.

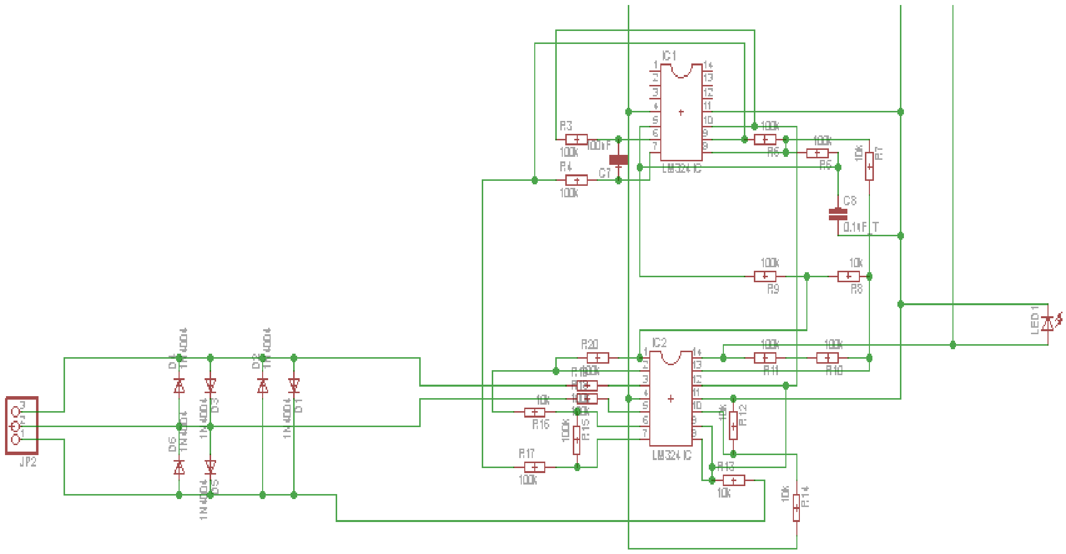

Figure 29: Electrocardiography (ECG) Circuit Schematic Design

The limitation is regarding the method of obtaining heart rate signals directly from the heart. Electrode acts a medium for the electrical signals to travel from the heart into the circuit by going through the human skin. Human skin is a good conductor of electricity. The electrodes must stick strongly to the skin for accurate results. However, it has to be replaced with every usage, and this can become a hassle in a long term. Referring to the schematic in Figure 29, 6 operational amplifiers (op-amp) are fully utilised to greatly amplify the heart electrical signals and at the same time eliminate noise effects. This is because electrical heart signals are very weak and are very difficult to detect and measure. Total of 6 diodes are used to prevent electrical backflow thus protecting the wearer from electrical shock. Light Emitting Diode (LED) will flash according to detected heart beat. Appendix A displays the whole final schematic drawing of this project.

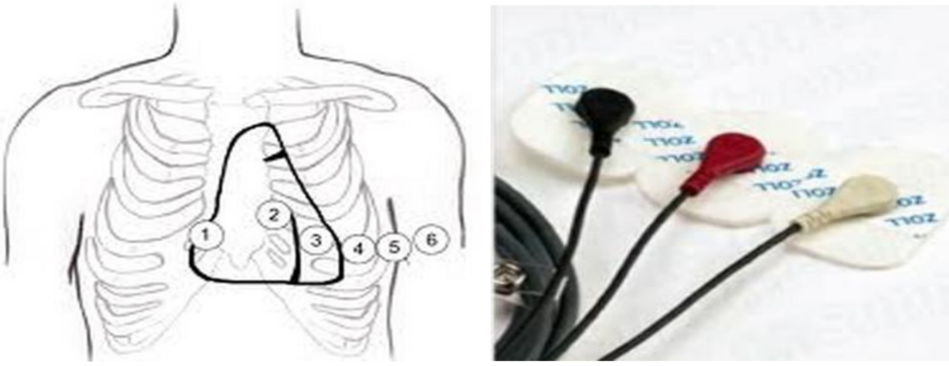

Figure 30: Electrodes Placement on the Body

There are many suitable places to place the electrodes in order to detect the electrical heart signals. After conducting many experiments, author has found out that the places labelled 2, 3, 4 and 5 are suitable for electrodes placement. In this project, only three electrodes are used for each experiment. Two electrodes are positioned either at 2, 3, 4 and 5 while one electrode grounding is placed on the base of the stomach. The grounding is required to get a clean signal and avoid electrical shock. Another limitation involving electrocardiograph is that, it is not meant to be worn during active actions. A fireman is a highly energetic job which requires a lot of movements. These movements will make the electrodes loosen from time to time. Thus, heart rate readings will be affected.

After going through multiple trials and tests, the author is finally able to come out with the final design of electrical circuit. This circuit integrates the Electrocardiography (ECG) circuit, Temperature sensor, Accelerometer with Gyroscope sensor and XBee module all into one. Next, the circuit is sent again to be printed into a Printed Circuit Board (PCB) for finalization.

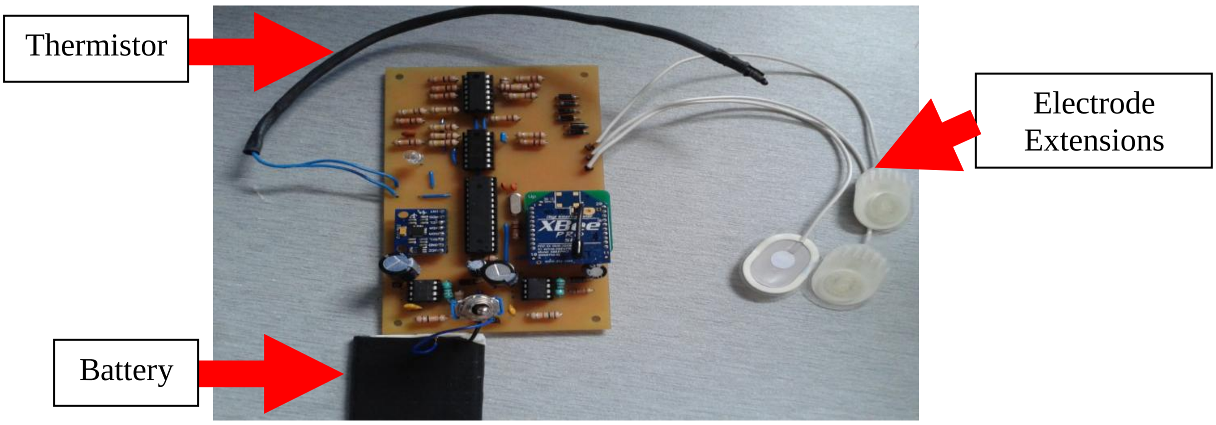

Figure 31: Final Design of Second Prototype

CHAPTER 4

RESULTS & DISCUSSION

Both prototypes from Figure 27 and Figure 31 produce the same results format, even though using different sensors which are Pulse sensor or ECG electrodes. Figure 32 below shows the results produced with XBee tag identification of number 0005. Heart Rate, Temperature, X-axis and Y-axis Accelerometer readings are listed out consecutively with 10 seconds interval for each reading.

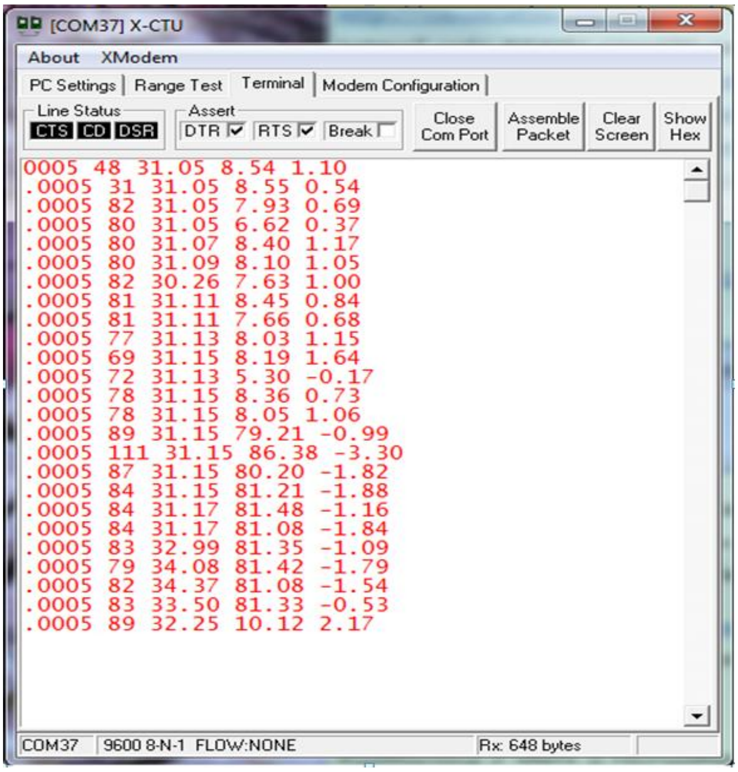

Figure 32: Results Produced in X-CTU Software

However, these results are not organized and difficult to be interpreted by a normal user. Therefore, another program is created which is interconnected with the Arduino environment to display the results in a more interesting interface. The new interface is written using website programming knowledge. The XCTU program is linked together with XBee module transreceiver and displays the results in an online website. Based on Figure 34, the new interface displays body temperature reading, heart rate reading in unit beats per minute (BPM) and the position or posture of the human body who is currently wearing the prototype. This website can be only be monitored by certain registered doctors and nurses on duty.

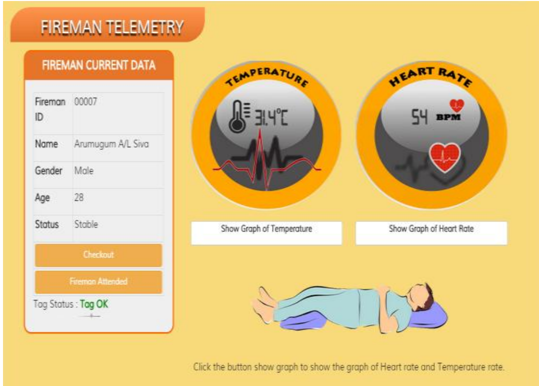

Figure 33: Login Page **Figure 34**: Home Page

With the knowledge of website programming in PHP language, the author is able to create a new webpage to show the results of the prototype in a more interactive and interesting way. Based on Figure 33, only registered doctors or nurses can login into the webpage through the login page. Then, a list of patients whom are in their care will appear. Every patient has its own data and webpage where temperature, pulse and body position are displayed and updated every 10 seconds.

Figure 35: Real-Time Status of Wearer **Figure 36**: Graph of Previous Readings

Meanwhile in Figure 35, the page shows the difference between standing position and resting position of the patient. Usually the pulse rate will increase when standing up due to vigorous pumping of the heart in distributing blood to body muscles. Therefore, the pulse will definitely be reduced while the patient is resting. Furthermore, graphs for both temperature and pulse rate are available with a click of a button. These graphs store the previous results of the patient since their first day in the ward. The tag status shows that the prototype is still active. Looking at the interface above, viewers will easily understand the real-time output of the prototype.

The prototype is able to detect when the wearer took it off, or when the wearer is in a critical condition. Figure 37 displays the image of the webpage when the prototype is removed. A large notification saying “ATTENTION REQUIRED” will flash repeatedly on the top of the page. At the same time, the tag status will change to ‘Tag Removed” as an indicator to the doctor.

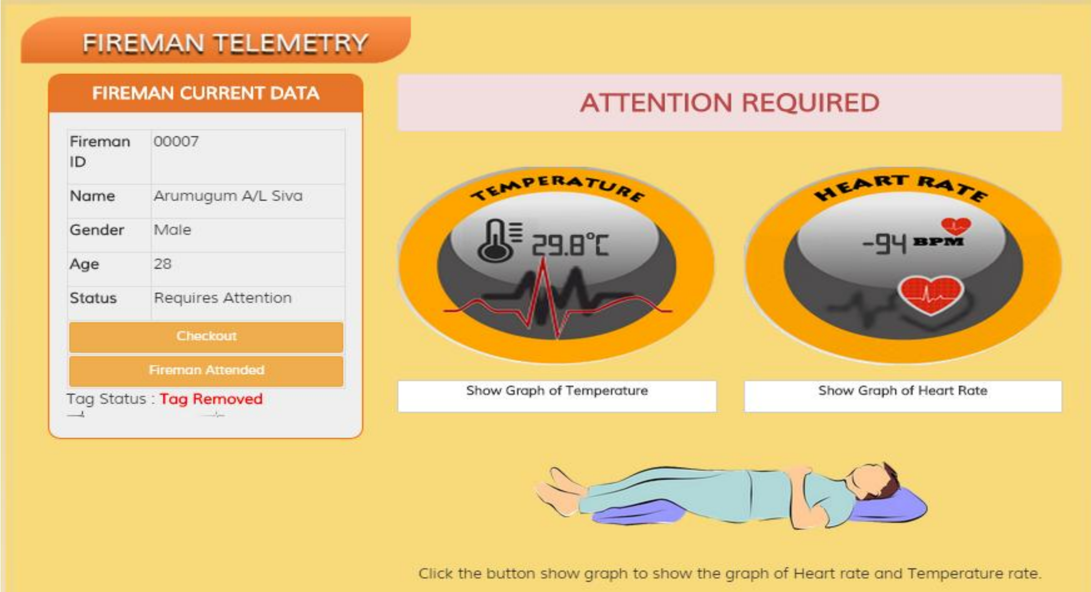

Figure 37: Alert Notification

If suddenly, the wearer fainted, his or her heartbeat will be reduced greatly and this is abnormal. Thus, an alert will pop up on the screen with an alarm sound ringing in the background. The alert will display the wearer’s name and the particular time which the emergency occurred. After the doctor attended the critical patient, the alert can be disabled by clicking the “Check” button on the top right.

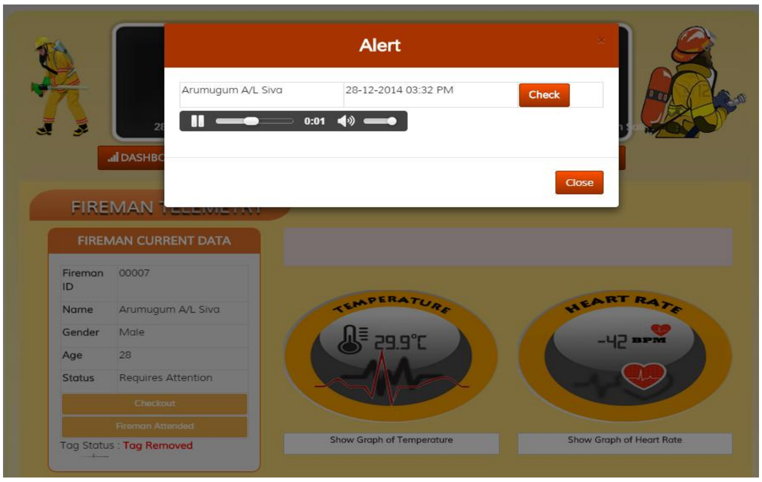

Figure 38: Alert Pop-Up with Sound

The first experiment conducted consists of three (3) male test subjects from an age group between 18 – 25 years old with different body weights. This experiment requires the subjects name A, B and C to lie down flat for accurate readings. The test subjects will be wearing the prototype onto their chest and also a clinical thermometer with clinical blood pressure devices. The thermometer and blood pressure (BPM) devices are required to be worn physically in order to create a benchmarking. This benchmark results will be compared to the results produced by the prototype device at the same time, in real-time. Figure 39 shows the graphical data obtained from subject A. Figure 40 shows the graphical data obtained from subject B. Figure 41 shows the graphical data obtained from subject C.

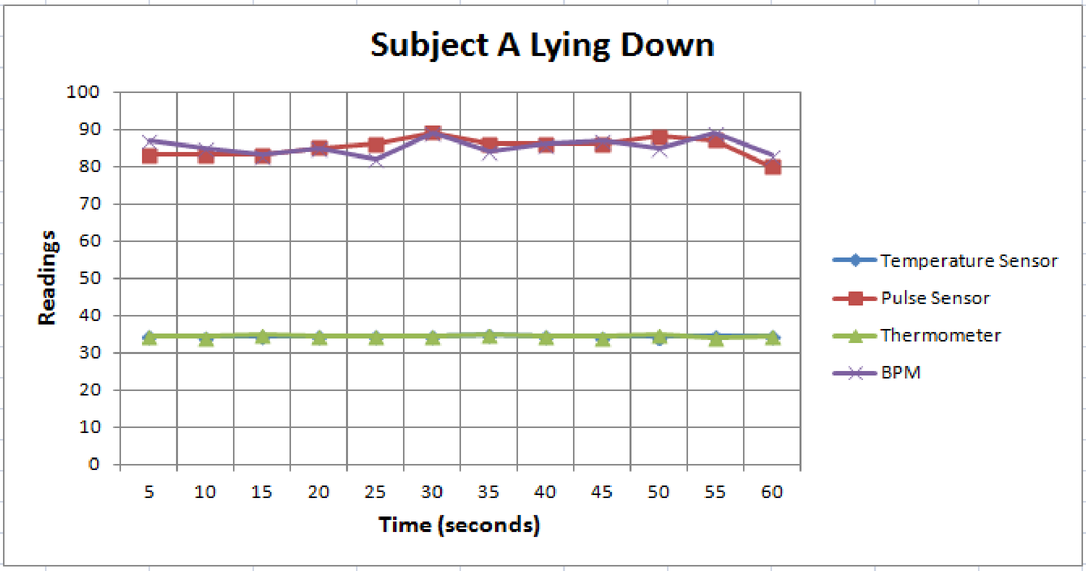

Figure 39: Experimental Results on Subject A Lying Down

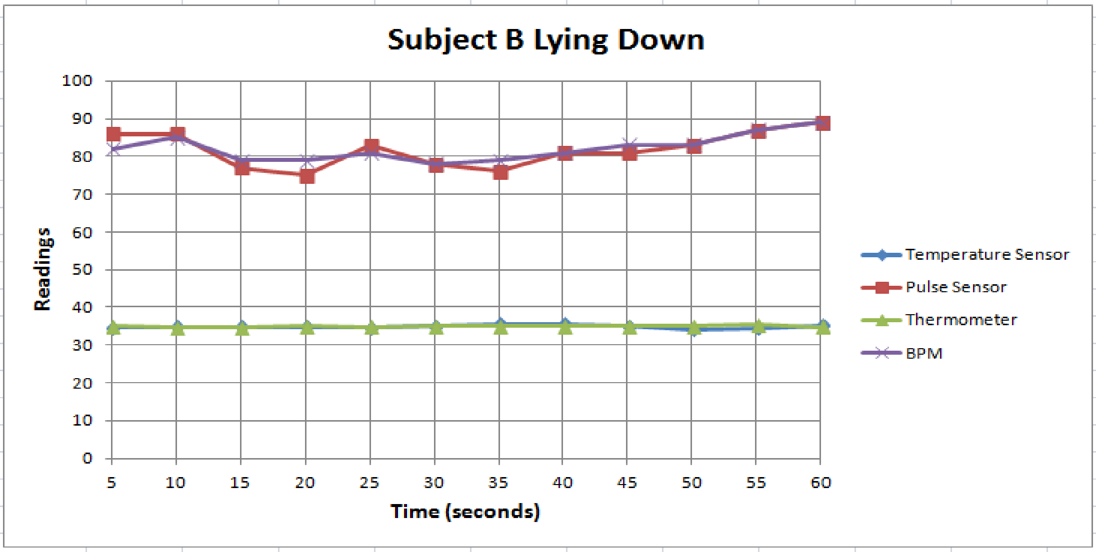

Figure 40: Experimental Results on Subject B Lying Down

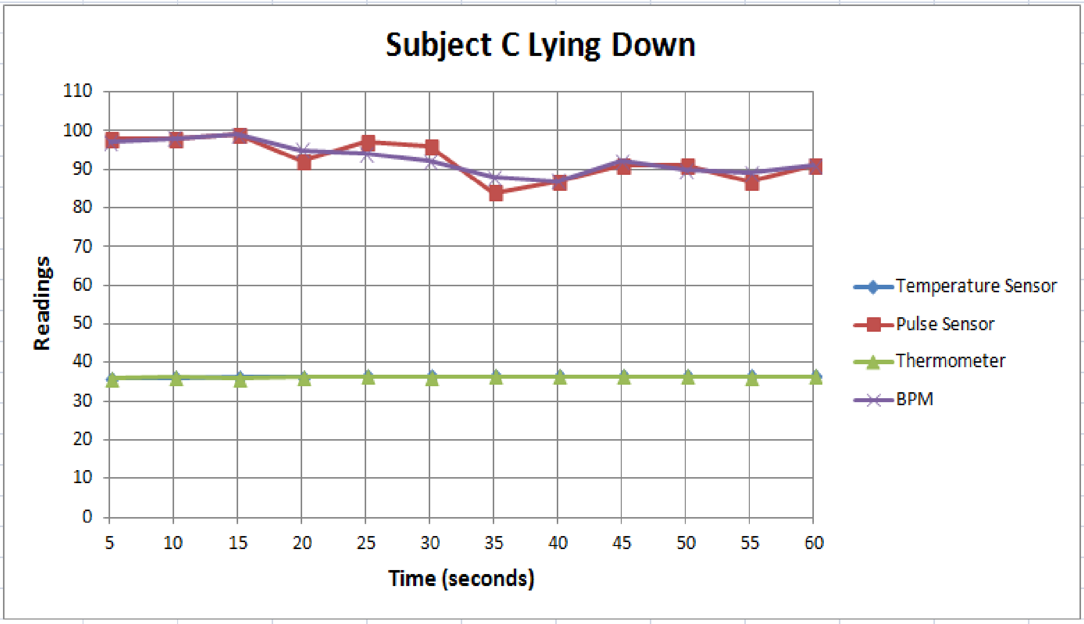

Figure 41: Experimental Results on Subject C Lying Down

Next experiment requires the same subjects A, B and C to stand up straight for accurate readings. Similar to the first experiment, all subjects must wear the prototype together with clinical thermometer and clinical blood pressure (BPM) devices at the same time in same condition. Figure 42 shows the graphical data obtained from subject A. Figure 43 shows the graphical data obtained from subject B. Figure 44 shows the graphical data obtained from subject C.

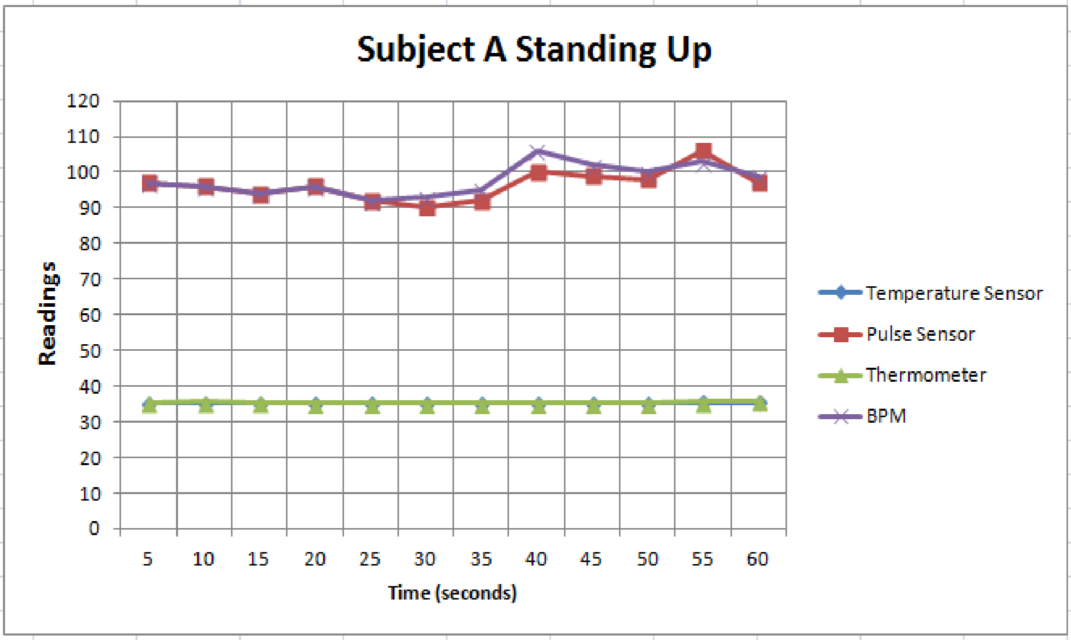

Figure 42: Experimental Results on Subject A Standing Up

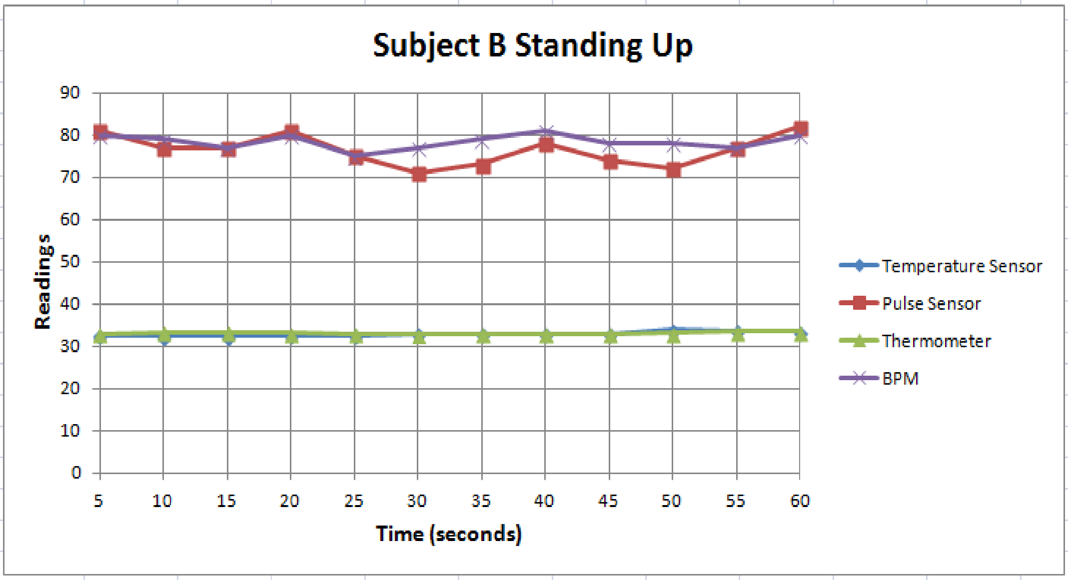

Figure 43: Experimental Results on Subject B Standing Up

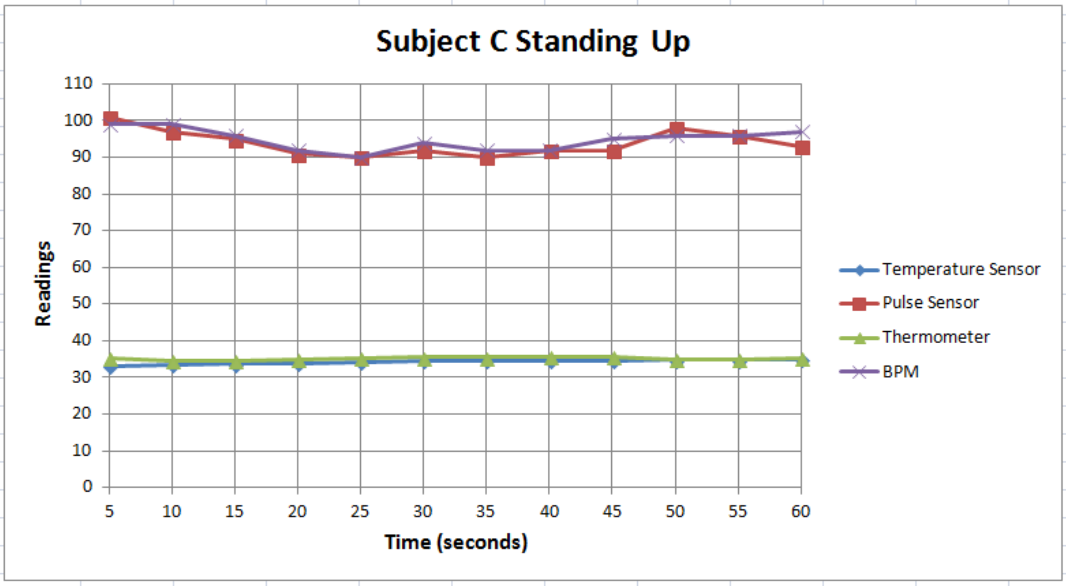

Figure 44: Experimental Results on Subject C Standing Up

From Figure 39 to Figure 44, it can be seen that the prototype provides stable and excellent reading for all test subjects in both standing and lying down postures. The difference in prototype and clinical device readings are known as measurement errors. By analysing each of the graphs, it can be clearly seen that the error readings for heart rate and temperature are very small. It is confirmed that the prototype can be used to achieve accurate and stable results in real – time data transmitting method using XBee wireless monitoring. However, more tests and experiments need to be carried out in a real fire fighting, search and rescue operations or other emergency handling constraints to include more body postures and further justify this claim.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In conclusion, by fully utilising pulse sensor, temperature sensor, accelerometer with gyroscope sensors as the hardware implementation for this project and XBee wireless networking as the software implementation, a prototype can be created that is able to monitor physiology state of the fireman on site. Physiology monitoring of fireman will certainly produce a significant improvement in terms of situational awareness on the emergency scene. The off-site rescue team will be able to monitor on-site firefighters' health condition as well as his posture on a computer screen online. The data from the prototype is sent in a reliable manner wirelessly to the computer using a well-known XBee technology. Whenever one man is down, the prototype of the wearer sends out a distress signal during the emergency handling, any nearby rescuer can quickly intervene and save his colleague's life.

The prototype may have some more spaces for potential improvements in the future. Even though accelerometer and gyroscope sensors can calculate the force acceleration and angular velocity at once, by adding a magnetometer will certainly improve and enhanced the basic motion detection sensors. Besides that, the pulse monitor is not comfortable to wear on the finger as it may obstruct handy activities. Another recommendation would be replacing the pulse sensor with an Electrocardiography (ECG) electrode which can detect electrical signals produced by the heart by placing it on the skin. However, wearing Electrocardiography (ECG) electrode is also not suitable because being a fireman is an active and vigorous job. Improvements must be made to secure the electrode firmly onto the body.

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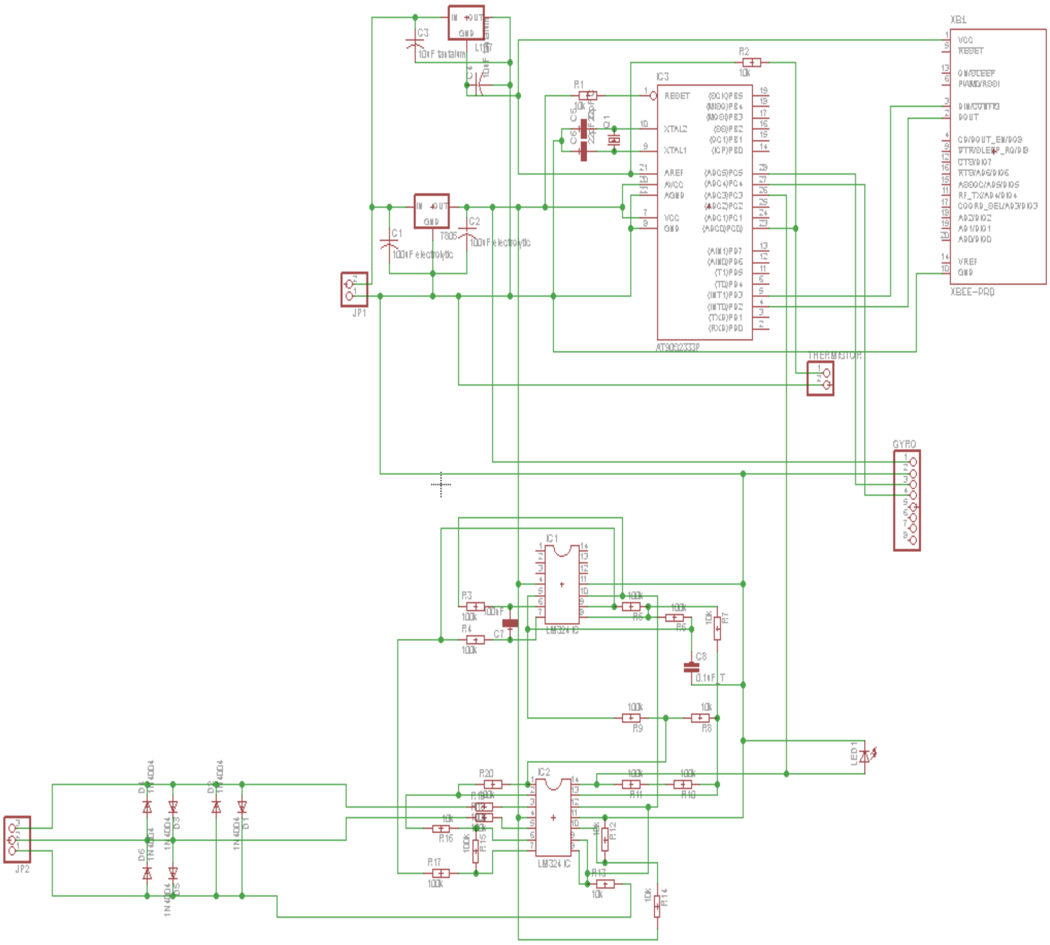
APPENDIX

Appendix A: Final Schematic Design



Appendix B: Electrocardiography (ECG) Source Code

```
unsigned long highCounter = 0;
int BPM;
unsigned long previousMillis = 0;
unsigned long interval = 3000;
void loopECG()
 {
  for(i = 0; i < 3000; i++)
  {
        int Pulse = analogRead(3);
        float voltage = Pulse * (5.0 / 1023.0);

         if(voltage > 2.00)
        {
              highCounter++;
         }
  }
  BPM = (highCounter / 30);
  xbee.print("0001 ");
  xbee.print(BPM);
  highCounter = 0;
}
```

Appendix C: MPU6050 and NTC Thermistor Source Code [20]

```
void loop()
{   loopCNC( );
    loopECG( );          }
void loopCNC( )  {
  accel_t_gyro_union accel_t_gyro;
  float gyro_x = (accel_t_gyro.value.x_gyro - base_x_gyro)/FS_SEL;
  float gyro_y = (accel_t_gyro.value.y_gyro - base_y_gyro)/FS_SEL;
  float gyro_z = (accel_t_gyro.value.z_gyro - base_z_gyro)/FS_SEL;
  float accel_x = accel_t_gyro.value.x_accel;
  float accel_y = accel_t_gyro.value.y_accel;
  float accel_z = accel_t_gyro.value.z_accel;
  float RADIANS_TO_DEGREES = 180/3.14159;
  float accel_angle_y = atan(-1*accel_x/sqrt(pow(accel_y,2) +
pow(accel_z,2)))*RADIANS_TO_DEGREES;
  float accel_angle_x = atan(accel_y/sqrt(pow(accel_x,2) +
pow(accel_z,2)))*RADIANS_TO_DEGREES;
  float accel_angle_z = 0;
  float dt =(t_now - get_last_time())/1000.0;
  float gyro_angle_x = gyro_x*dt + get_last_x_angle();
  float gyro_angle_y = gyro_y*dt + get_last_y_angle();
  float gyro_angle_z = gyro_z*dt + get_last_z_angle();
  float unfiltered_gyro_angle_x = gyro_x*dt + get_last_gyro_x_angle();
  float unfiltered_gyro_angle_y = gyro_y*dt + get_last_gyro_y_angle();
  float unfiltered_gyro_angle_z = gyro_z*dt + get_last_gyro_z_angle();
  float angle_x = alpha*gyro_angle_x + (1.0 - alpha)*accel_angle_x;
  float angle_y = alpha*gyro_angle_y + (1.0 - alpha)*accel_angle_y;
  float angle_z = gyro_angle_z;
  set_last_read_angle_data(t_now, angle_x, angle_y, angle_z,
unfiltered_gyro_angle_x, unfiltered_gyro_angle_y, unfiltered_gyro_angle_z)
```

```
  float medium;
  for (i = 0; i < num;  i++)
{
          amostra[i] = analogRead( 0 );
          delay(10);
  }
  medium = 0;
  for (i=0; i< num; i++) {
  medium += amostra[i];
  }
  medium /= num;
  medium = 1023 / medium - 1;
  medium = res / medium;
  float temperature;
  temperature = medium / nominal_T;
  temperature = log(temperature);
  temperature /= BCOEFFICIENT;
  temperature += 1.0 / (nominal_T + 273.15);
  temperature = 1.0 / temperature;
  temperature = - 273.15;


   xbee.print(temperature);
   xbee.print(accel_angle_x);
   xbee.println(accel_angle_y);
   delay(10000);
}
```