STUDY, DESIGN, AND DEVELOPMENT OF A SMART SAFETY HELMET

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This report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DECLARATION

I declare that this report entitled "Study, Design, and Development of a Smart Safety Helmet" is the result of my own work except for quotes as cited in the references.

Signature :

Author : THINESH A/L VIJAYAKUMARAN

Date : 19 AUGUST 2020

APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : ....

Supervisor Name : Mazran Esro

Date : 21/08/2020

DEDICATION

This work is dedicated to University Technical Malaysia Melaka (UTeM) whose without their requirement these Bachelor Degree Project would not be possibly conducted. Besides that this work is dedicated to my parents who have passed on the love of reading and respect on education that has demanded me to become a responsible and educated person. Never forget my project supervisor Mr. Mazran Esro and co-supervisor Dr. Siva Kumar Subramaniam from the Faculty of Electronic Engineering and Computer Engineering who has given me courage, support, and guidance along with my Bachelor's Degree Project. By all the above who has contributed support and courage to my project and without this courage dedicating me over and over, I would have doubtfully a lot of confidence and would not to be brave enough to finish the project perfectly.

ABSTRACT

The underground mining industry is pivotal to the world's economy. However, it is not one of the safest industries to work in. The life of miners is always at stake. This project attempts to help the miners in distress so that they receive immediate help. The helmet used by the miner can be improved by adding necessary sensors, which will help in monitoring the health condition of the miner wirelessly using the LoRa (Long Range) communication network. Whenever the load felt on the helmet or the helmet hits hard on any rough surface and the threshold value exceeded, a distress alarm will be sent to the Control Room through the wireless network. When a distress alarm received at the Control Room, officials from the room can send in a medical team. The miner's supervisor and miners in neighboring rooms can be informed so that they can help voluntarily. However, a reset button can be used by the miner if there are no major injuries and the miner in the safe condition. On the other hand, a panic button also placed in the helmet so that the miner can alert the Control Room if there are any serious injuries to them, neighboring miners, or any abnormal condition in the working environment. Thus, the proposed product ensures the safety and reliable wireless communication inside the underground mines.

ABSTRAK

Industri perlombongan bawah tanah penting bagi ekonomi dunia. Namun, ini bukan salah satu industri paling selamat untuk dikendalikan. Kehidupan pelombong selalu dipertaruhkan. Projek ini berusaha menolong para penambang yang berada dalam kesusahan sehingga mereka mendapat pertolongan segera. Helmet yang digunakan oleh pelombong dapat diperbaiki dengan menambahkan sensor yang diperlukan, yang akan membantu dalam memantau keadaan kesihatan pelombong tanpa wayar menggunakan rangkaian komunikasi LoRa (Long Range). Setiap kali beban yang dirasakan di helmet atau helmet memukul keras di permukaan kasar dan nilai ambang melebihi, penggera bahaya akan dihantar ke Bilik Kawalan melalui rangkaian tanpa wayar. Ketika penggera bahaya diterima di Bilik Kawalan, pegawai dari bilik boleh menghantar pasukan perubatan. Penyelia pelombong dan pelombong di bilik berdekatan boleh dimaklumkan supaya mereka dapat membantu secara sukarela. Walau bagaimanapun, butang reset boleh digunakan oleh pelombong jika tidak ada kecederaan besar dan pelombong dalam keadaan selamat. Sebaliknya, butang panik juga diletakkan di topi keledar sehingga pelombong dapat memberi amaran kepada Bilik Kawalan sekiranya terdapat kecederaan serius pada mereka, pelombong tetangga, atau keadaan tidak normal di persekitaran kerja. Oleh itu,

produk yang dicadangkan memastikan keselamatan dan komunikasi tanpa wayar yang boleh dipercayai di dalam lombong bawah tanah.

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I finally managed to complete my Bachelor's Degree Project report. I would like to express my deep appreciation to the following persons for their support and guidance during the whole semester.

First and foremost I would like to send our deep appreciation to Mr. Mazran Esro, my supervisor and Dr. Siva Kumar Subramaniam, my co-supervisor for my Bachelor's Degree Project. I appreciated the times they spent in guiding me into the work. With their help, I able to fit myself in the working environment smoothly and adapted to it.

Now I send my apologies to Mr. Mazran Esro and Dr. Siva Kumar Subramaniam for the mistake and inconvenience I had to create. The friendly working environment had greatly helped me through my Bachelor's Degree Project smoothly. Once again I would like to thanks everyone for giving me such a wonderful learning experience and wish everyone all the best in the future.

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CHAPTER 1

INTRODUCTION

In 2018, two construction workers were dead due to a couple of concrete slabs crushed on them. This accident occurred at Jalan Dewan Sultan Sulaiman, Kuala Lumpur, around 2 am in the morning. The workers were working on the formwork structure with four other workers on the 15th floor[1], [2]. One worker was dead immediately after the fall of the concrete slabs while the other died at Kuala Lumpur Hospital.

A similar case, in July 2019 was happed in a quarry at Perak. The victim, Loi Thiam Fatt, 56, was buried under debris at a quarry in Sungai Raia Mukim, Bukit Raja for 45 minutes before the firefighters locate him[2], [3].

Alternatively, the victim in these cases could be saved if the incident gets noticed by the rescue team immediately. The main reason for death is the lack of proper communication with the rescue team and the time taken to pass the alert message to the responsible team. If a worker working at an open place could face this kind of accident, how about the miners who work underground? They could face some worst cases to pass the alert message to the responsible team. It makes it more difficult for the miners who work at radiation hazard places such as petroleum mining where they cannot communicate using mobile phones.

This project attempts to help the miners in distress so that they receive immediate help. The helmet used by the miner can be improved by adding necessary sensors, which will help in monitoring the health condition of the miner wirelessly. Whenever an impact hits on the helmet or the helmet hits hard on any rough surface, a distress message will be sent to the Control Room through the wireless network. When a distress message received at the Control Room, the responsible team from the room can take immediate action. A reset button will be added to alert the control room if there is no danger. On the other hand, an emergency button will help the miner to alert the Control Room if there are any serious injuries to them. Thus, the proposed project ensures the safety and reliable wireless communication inside the underground mines.

1.1 Problem Statement

Figure 1.1 shows the widely used safety helmet and its function of each part. People are still involved in accidents at the workplace that leads to head injuries even though wearing a safety helmet. These injuries lead to paralyzing or death sometimes. The big problem nowadays is that people are working hidden places such as underground where only a few people will be in the surrounding. Moreover, the base of the workplace will be far away from the working area. This will be difficult for the other workers to pass the emergency message during an accident. The time is taken for the medical team to arrive at the working area also will be late once they received the emergency call. Sometimes the delayed medical attention to the victim may cause some serious health issues in the future.

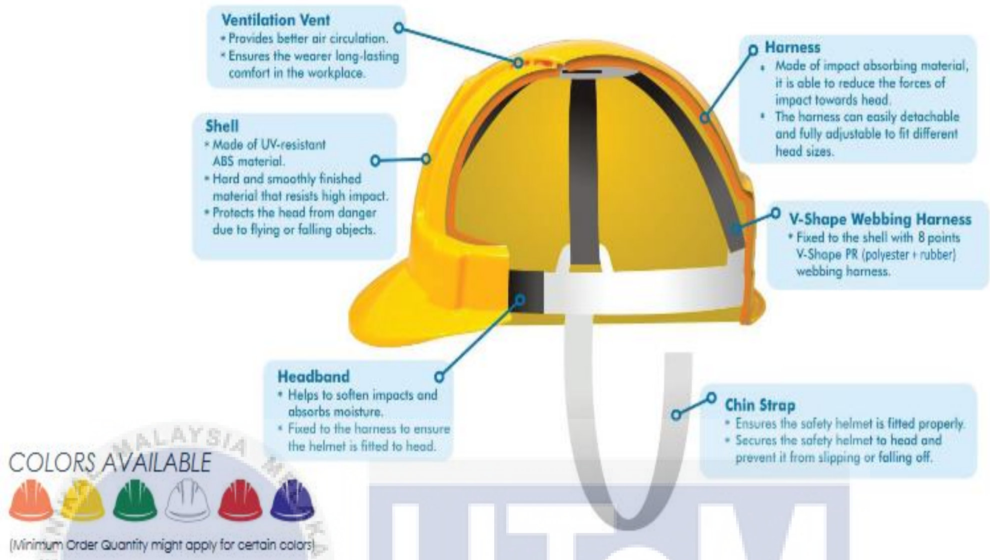


Figure 1.1: Safety Helmet parts and its function

Figure 1.2 shows the radiation hazard sign where some mining industries such as the petroleum mining area are highly prohibited to radiation. Thus communication devices such as hand-phones cannot be used. Alternatively, people used walkie-talkie in those areas as the main communication device. The problem with a walkie-talkie is a half-duplex communication device where only one person can use the network at a time as shown in Figure 8. If there is an emergency at two different places, then only one of the incidents can be informed at a time while the others need to wait for its turn.

Thus, there is a need to have an alternative solution which could overcome the issues as reported earlier. Therefore this project intends to offer a viable solution to improve the safety precautions and safety standard for a safe workplace.

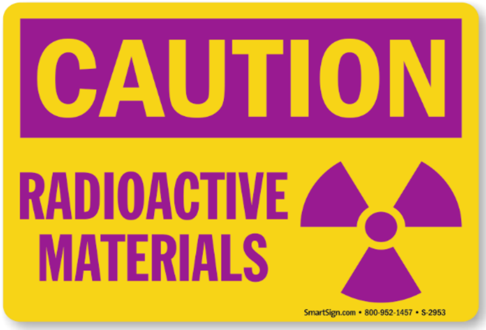


Figure 1.2: Radiation hazard

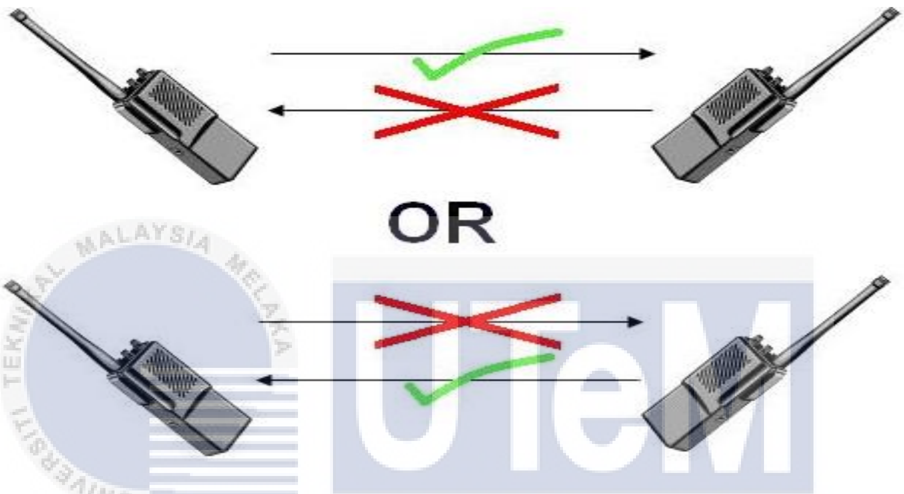


Figure 1.3: Half-duplex communication system

1.2 Objective

The objectives of this project are:-

i. Design and develop a Smart Safety Helmet to monitor the impact on the safety helmet wirelessly using Long Range, LoRa communication technology.

ii. Design and develop a Smart Safety Helmet to store data about the amount of pressure act on the helmet due to falling objects using a suitable Internet of Things (IoT) platform.

1.3 Scope of Project

The scope of this project consists of four stages:

i) Monitor impact, pressure and movement only.

ii) Live monitoring through IoT platform using ThingsBoard.

iii) Store the data for future medical references.

iv) Developed with Arduino Nano microcontroller integrates with the RFM 95 module.

1.3.1 Analysis

To carry out this project there are some information need to be gathered initially. First, an observation made by reading and looking at some projects that are similar to this title. Some information and knowledge was gain from the research. Besides, a set of data was collected based on the accident rate in the underground mining industry. A set of data on the consequences due to the accident also collected. Furthermore, a study was conducted to identify the minimum and maximum pressure that can be withstood by a safety helmet. The available wireless communication system has also been studied to identify a suitable system that can be used in the underground and a wide range of areas. Research on suitable sensors and microcontrollers to be used in this project also has been made.

1.3.2 Evaluation

In this section, the data collected from the analyses section was evaluated and filtered. The accident rate at the underground mining industry was then filtered to identify the number of head injuries specifically. Then, the data was divided into fatal injuries and non-fatal injuries to identify the number of death caused by head injuries. Besides, the pressure range that is used to develop this project was identified. Three wireless communication system was identified to be suitable for this project which is Bluetooth, Wi-Fi, and Long Range (LoRa). However, the wireless communication system needs to be tested in a different area to find out the best system that can be used in a wider area. The suitable sensor and microcontroller to be used are as shown below:

- ✓ Arduino Nano (ATmega328P) as the microcontroller
- ✓ FSR 402 as the pressure sensor
- ✓ KY-031 as the impact sensor
- ✓ Tilt sensor as the motion sensor

1.3.3 Design

The design part is divided into software and hardware. In the first phase of the software part, the coding for each of the sensors must be developed and tested to connect with the microcontroller. As for the second phase of the software part, the coding to connect microcontroller with the wireless communication system must be developed and tested. A PCB layout needs to be designed which is suitable to place inside the helmet.

In the hardware part, the sensors must be placed in a suitable position on the helmet. Besides, a rechargeable battery that is suitable to power up the microcontroller needs to be identified and placed on the helmet.

1.3.4 Development

In this part, the hardware and software will be gathered and integrated. The design will be tested to achieve the desired objective.

1.4 Expected Outcome

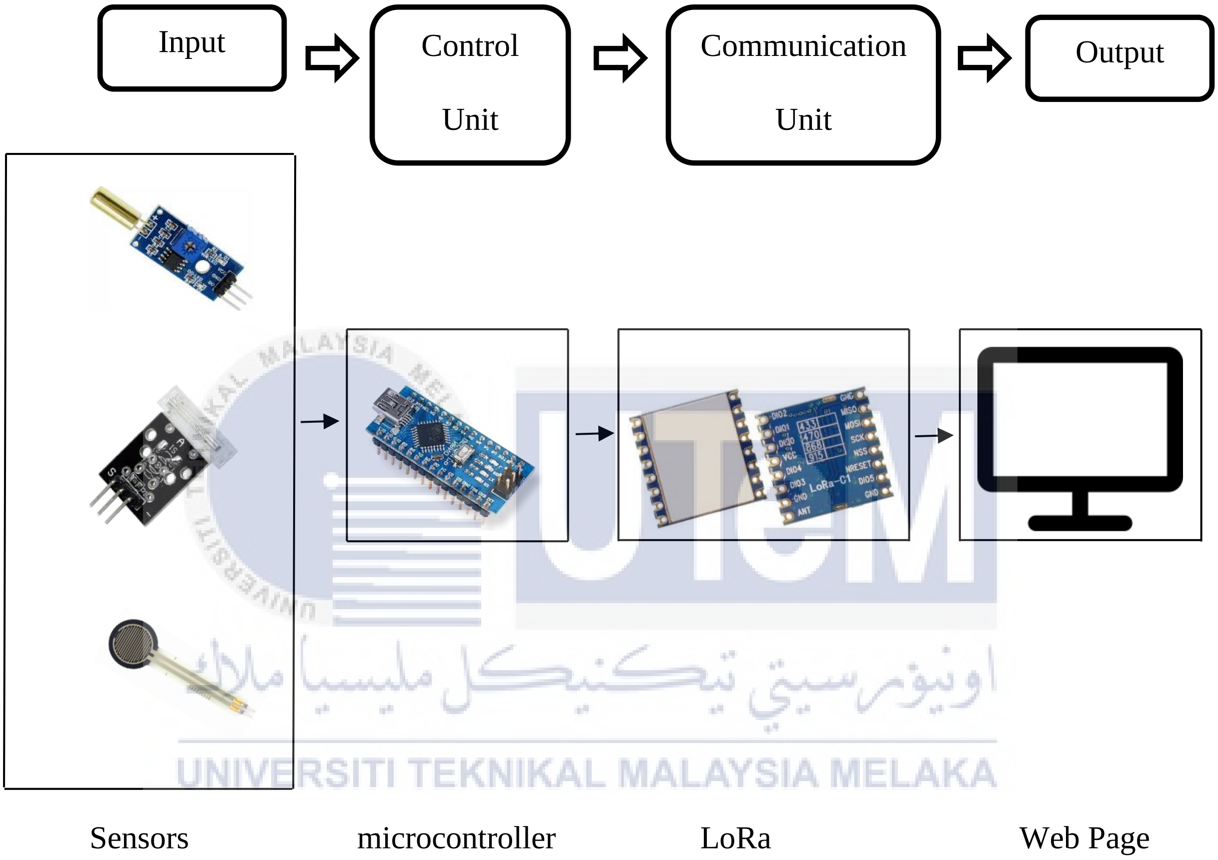


Figure 1.4: Expected Outcome

At the end of this project, I expect to produce a prototype of a Smart Safety Helmet. The Smart Safety Helmet will have 3 sensors as input which measure the parameters of pressure, impact, and vibration. The all 3 sensors will be fabricated with a microcontroller. The microcontroller will act as the control unit which processes the data from the sensor and produce an output message. The microcontroller also will be connected to a Wireless Sensor Network using LoRa Module, where the output message will be transmitted through the wireless network to a computer.

1.5 Conclusion

This chapter discussed the current issues in the construction and mining industries. Besides, the reason for late medical attention for injured workers and the problem faced in communicating with each other in those fields also has been explained. An alternative solution for these problems has been proposed with suitable objectives. The planning of the project execution is divided into four phases which are analysis, evaluation, design, and development. The responsibilities in each phase are explained. The next chapter will discuss the background study of projects such as personal protective equipment (PPE), accident rate at the workplace, fatal and non-fatal injuries, and others.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

In this chapter, a detailed background study about workplace accidents involving safety helmets will be discussed. Besides, the rate of injuries from accidents is analyzed. The evolution of the safety helmet from the beginning to the latest model was analyzed. Furthermore, an overview of the sensors to be used in this project also has been discussed in this chapter.

2.2 Safety

According to the oxford dictionary, safety is the state of being safe and the measure of how far a person from danger or harm. The level of risk also can be related to safety. The lowest level of risk is considered to be safe. Safety always points to the condition of a person or the place where a person is. As comparing both conditions of a person and the place where the person is, the condition always depends on where the person is[4]. Thus, safety is majorly connected to the place rather than the condition of a person.

2.2.1 Importance of Workplace Safety

Workplace safety refers to the condition of the working environment which is free from danger. The different workplace has a different level of safety depends on the place and the work a person does. The importance of workplace safety can be measured in terms of individual and business.

An individual should be aware of the surroundings where they work with other people. Any action taken by an individual can affect the safety of the surrounding. Thus, an employee should understand the hazards that may occur in the workplace. This may help in reducing the risk and allow the co-workers to take precautionary steps during danger.

Besides, a safe working environment will reduce the stress of employees. A safe workplace will encourage employees to work without any hesitation. Moreover, using or wearing much safety equipment during worktime will make the employee feel uneasy during carrying out the task.

From a business point of view, a safe workplace could increase the quality of the work and quantity of production. The safest workplace will create a peaceful environment for the employee to work which can lead to an increase in the quality of the work.

2.3 Head Injuries

Head injuries can be much entangled. The consequences after the accident are very clear within hours. However, some we might ignore for small injuries, which may lead to death later. Those injuries can be categorized as internal injuries, where we can't see the wound or bleeding directly. Besides, head injury includes damage to the skull and its contents. Since most of the nerves from the neck have direct contact with the brain, neck injuries also included in head injury classification.

The "head injury tolerance" is a difference for all individuals. Thus, the amount of force that can cause head injuries is different. However, the range for the amount of force that can lead to serious head injuries and death is 600 N to 20 000 N[5]. The force more than 3000 N can lead to moderate or more serve concussion.

2.4 Importance of Head Protection

The head is the main organ of the human body that is completely encased in bone. This by the pronouncement of nature expresses the significance of securing an indispensable working part of our body, the mind[6]. Head is one of the sensitive parts of the human body. Head injuries can lead to lifetime injuries such as paralyze and death. The human brain is fragile and the skull around the brain is not good enough to protect it from all shocks or impacts[5].

Head protection in Personal Protective Equipment (PPE) is the protection against impact injury and some burn injuries. It commonly shields the scalp area but not the face area. This is because eye and face protection, noise protection, and respiratory protection are different types of PPE[7].

The general objective of head protection is to diminish the amount of force or acceleration on the head to an acceptable level. The head protection is designed to absorb some of the energy from an impact which reduces the amount of force or acceleration assisted by the head.

Besides, head protection also prevents objects from penetrating the head using the impulse force principle[5]. The maximum force or acceleration on the head can be reduced by increasing the duration of the impact.

2.5 Types of Head Protection

Head protection is usually considered as the sheild that covers the skull area from any kind of damage due to impact. There are few types of head protection available on the market nowadays with each of them have their unique functions as well.

2.5.1 The Safety Helmet

The industrial safety market promotes many different designs of safety helmets, but significantly all have the same purpose which is to protect the user from head injury arising from a falling object or the head mistakenly hitting hard objects. It is essential to choose a helmet that fulfills the nationally or internationally recognized standards to ensure the proper protection of the user[8]. In Malaysia, Proguard Technologies Sdn. Bhd. designs the head protection that conforms to the Malaysia SIRIM standard.

Polycarbonate is the main element in designing a safety helmet because it meets the requirements for use at low or high temperatures, electrical insulation, and molten metal splash. An adjustable headband is a must to ensure good fit and comfort for the user. The maximum shelf life of a safety helmet is usually from 2 to 3 years[8]. Helmets beyond its expected life span must be replaced. Besides, helmets that have received an impact, even from dropping, must be withdrawn from use. Marking or labeling from the approved marker must be done to prevent the effect from the solvent to the integrity of helmets.

2.5.2 The Bump Cap

The bump cap is not suitable to use as a high impact resistance because it only provides lightweight head protection but there is a risk of minor bumps or scrapes to the head[8]. Bump caps cannot be used as a safety helmet in areas where protection against high-level impact is required. The comfort of the bump caps due to its lightweight is an advantage that causes the user to wear it for a long period compared to a conventional safety helmet. The fashionable design is another reason to use it regularly.

2.6 History of Safety Helmet

Most head injuries can be avoided by selecting, using, and maintaining proper head protection. Safety helmets are one of the most frequently used forms of personal protective equipment (PPE) nowadays. PPE defines as all equipment which is meant to be worn or used by people at work and which protects them against one or more risk to their health and safety, and any addition or accessory designed to meet those goals[7]. Safety helmets act as the first line of barrier against head damage but are only effective when it is worn correctly. Safety helmet will protect the user's head against impact from objects falling from above and hitting fixed dangerous objects at the workplace, by resisting and deflecting blows to the head[7]. A suspended band inside the helmet spread the helmet's weight and the force of any impact over the top of the head. The suspension also provides space of approximately 30mm (1.2 inches) between the helmet's shell and the wearer's head, so that if an object hits the shell, the impact is less likely to be transmitted directly to the skull[7].

Figure 2.1 shows the Boar's Tusk Helmet, which was created in the 17th century BCE by using slivers of ivory attached to a leather cap and padded with felt[9]. The reason to create this helmet was to be used at the battlefield even it provided less protection than a metal helmet[9].

Figure 2.1: Boar's Tusk helmet

The first mining helmet was created by Edward Dickinson Bullard in 1919 as picturized in Figure 2.2. During the same time, the United States Navy had commissioned Bullard to create a protective cap for their shipyard workers. However, this helmet was used by the workers of Six Companies Inc. in 1931[9], [10].

Figure 2.2: First mining helmet

Figure 2.3 shows the first aluminum hard hat was designed in 1938, which was manufactured by Bullard. This helmet was considered very durable and reasonably lightweight for that time. However, the biggest disadvantage of the helmet was, aluminum is a great conductor of electricity. Thus, Bullard developed a three-rib, heat resistant fiberglass hard hat in the 1940s. As the material technology developed, the fiberglass was replaced by thermoplastic[11].

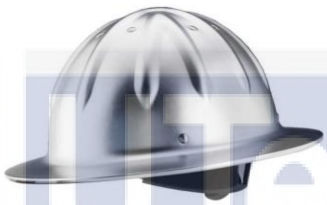


Figure 2.3: The first aluminum hard hat

The Bullard's hat now became known as the "3000 R". The 3000 R is lightweight, which was made up of polyethylene plastic. Polyethylene plastic also makes the helmet durable, easy to mold, and non-conductive to electricity[10]. The 3000 R then was redesigned by Bullard as C30 for easy lock snap, easy height adjustment, and an enhanced brow pad, which is known as today's standard yellow hard hat (the famous safety helmet) as shown in Figure 2.4[11].

Figure 2.4: C30, Yellow hard hat

2.7 Head Injuries in Industries

Table 2.1: Fatal Occupational injuries for all sectors in Malaysia from 2013 to 2016[12]**.**

Occupational Sectors	2013	2014	2015	2016
Manufacturing	58	45	46	72
Mining and quarrying	5	15	4	4
Construction	69	72	88	99
Agriculture, forestry, logging, and fishery	33	42	31	25
Utility	7	1	6	2
Transport, storage and communication	8	15	22	13
Wholesale and retail trade	5	6	3	0
Hotel and restaurant	2	1	0	3
Financial, insurance, real estate, and business services	2	4	14	16
Public service and statutory bodies	2	5	0	6
Total	**191**	**206**	**214**	**240**

Table 2.1 shows 851 fatal occupational injuries that occurred in all sectors in Malaysia from 2013 to 2016. All the data were collected from The Department of Occupational Safety and Health (DOSH) reports. According to A. Ayob, the majority

of fatalities are due to falling from heights[12]. Falling from height contributes 46.28% of the total fatalities.

According to Hui-Nee's survey in 2014, 37% of the fatal injuries in Malaysia were accounted for by Construction and mining industries[12]. The statistic also shows that more than half of the fatal injuries are caused by an accident that leads to head injuries initially. The reason behind this situation is the late medical attention to the injured labors due to the delay in receiving emergency calls.

In another survey, Heap Yih Chong and Thuan Siang Low state that the working environment and the complexity of working practices was the main reason for the safety and health issues remain critical in the construction industries[13]. They also discussed those head injuries had the highest possibility of death or permanent disabilities.

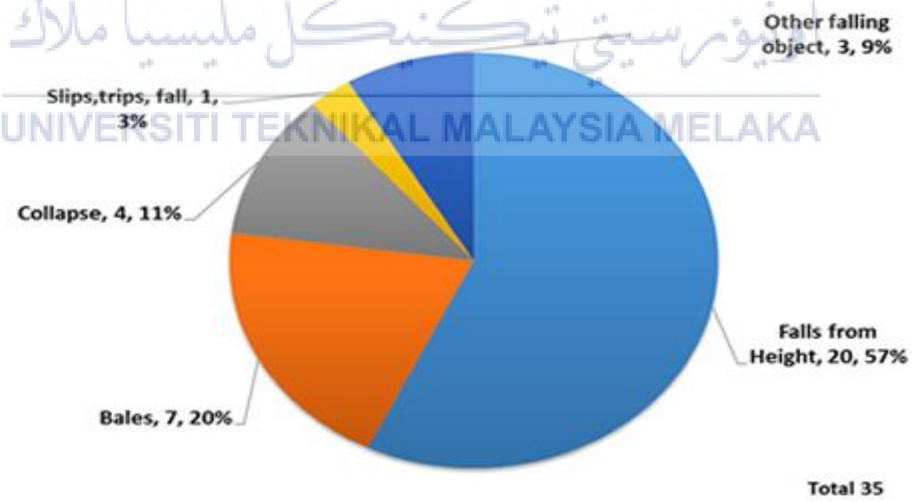


Figure 2.5: Chart of death due to falls and collapses in Construction Industries from 2009 to 2018[14]**.**

Figure 2.5, above shows the number of death due to falls and collapses in the last 10 years in Malaysia[14]. From the information, it can be proven that the construction industry contributes to the high number of fatal injuries in Malaysia due to falls and collapses. Another statistic from the Health and Safety Authority shows that the mining industry is a top 3 position of contributing fatal injuries in the last 10 years[15].

2.8 Wireless Communication System

The lack of communication between labor, supervisor, and medical team during an accident is one of the biggest threats that lead to fatal injuries nowadays[16]. So in this project, I used a wireless network to inform the medical team about the accident. Few wireless communication systems can be used in this project such a Bluetooth, WiFi, and LoRa.

Table 2.2: Comparison of three possible wireless network system to be used

	Wireless Communication System	**Characteristics**
1)	Bluetooth / Bluetooth Low Energy (Bluetooth 4.0 and above)[17]	• IEEE 802.15.1 standard • 2.400GHz to 2.485GHz • 10 meter to 100 meters • 60 meters (Bluetooth 4.0 & Bluetooth 5.0) • 7 devices connected at a time
2)	WiFi[18]	• IEEE 802.11 standard • Frequency Band ✓ 802.11a (5GHz) ✓ 802.11b (2.4GHz) ✓ 802.11g (2.4GHz) ✓ 802.11n (2.4 & 5GHz) ✓ 802.11ac (Below 6GHz) ✓ 802.11af (Up to 60GHz) • 100 meters to 1000 meters

		• 255 devices connected at a time
3)	LoRa[19]	• IEEE 802.15.4 • 433MHz, 868MHz (Europe) and 915MHz (North America) • Up to 3km and more than 10km in rural areas • Up to 62000 nodes can be handled by the gateway

2.8.1 Bluetooth

The Bluetooth technology was invented by a Swedish company, Ericsson in 1994. In 1998, a group of companies formed the Bluetooth Special Interest Group (SIG) to collaborate using Bluetooth technology as a way to connect their products[20]. SIG is an organization devoted to maintaining the technology which means the Bluetooth technology no longer owned by a single company. Bluetooth SIG developed Bluetooth specifications before it became a part of the IEEE 802.15 standard[20].

The main reason to invent Bluetooth technology is to replace cables and wires between things like phone and headset or computers, keyboards, and mice[17]. These devices still using Bluetooth technology due to its reliability. The technology has developed widely like connecting the mobile phone to the car stereo and even can print a picture directly from the camera phone.

Bluetooth technology utilizes radio waves, but the distance is the major difference between Bluetooth technology and devices such as FM radio and television[20]. Bluetooth technology uses Personal Area Network (PAN) to send information within a distance of 10 to 100 meters. 2.4GHz to 2.485GHz of the unlicensed industrial, scientific, and medical (ISM) band is the operating frequency of Bluetooth technology[20]. The 2.4GHz ISM band is mostly available and unlicensed in most of the countries.

Recently, Bluetooth 4.0 is introduced which is a low energy technology to the Bluetooth Core Specification. This latest technology enables new Bluetooth Smart devices to operate for months or even years on tiny, coin cell batteries. Health care, sports and fitness, security, and home entertainment are the biggest user of this low energy technology.

Figure 2.6: Bluetooth Logo

2.8.2 WiFi

Initially, the way of getting broadband internet to a device with the help of wireless transmitters and radio signals is called WiFi. The transmitter receives data from the internet, then it converts the data into a radio signal which, can be received and read by WiFi enable devices[18].

In 1997, WiFi was invented and released with the name of 802. 11. The creation of IEEE802. 11 was guided by the WiFi's initial name which is the set of standards that defines communication for wireless local area networks (WLANs)[18]. Later on, a basic specification for WiFi was fixed. The specification allows two megabytes per second of data transfer wirelessly between devices[18]. This triggered an upgrade in prototype equipment (router) to comply with IEEE802. 11[21]. The introduction of WiFi for home usage was made in 1999.

2.4GHz (802.11b) and 5GHz (802.11a) are the two main frequencies that utilize by WiFi to communicate data using electromagnetic waves[21]. 2.4GHz has been the popular choice for WiFi users, as it worked with most mainstream devices and was cheaper compared to 802.11a. The factor of speed and distance coverage of the earlier WiFi encourage to make the 802.11g standard[21]. The routers of 802.11g were better with high power and further coverage than previous standards. In 2009, the final version of 802.11n was introduced, which was even faster and more reliable than its predecessor[21]. The reason for the increase in efficiency is the utilization of 'Multiple input multiple output' (MIMO) concept, where multiple antennas used to enhance communication of both the transmitter and receiver[18]. This allows us to transfer more data with minimum bandwidth and transmit power. The popularity of 2.4GHz causing it to become slower and overcrowded. Thus, 5GHz become an alternative option. The simultaneous dual-band router was created to solve the overcrowded problem. The router can support both 2.4GHz and 5GHz frequency. The device will connect to the faster and more efficient 5GHz automatically while the 2.4GHz frequency is used as a backup if the device was further away[18], [21]. In 2012, 801. 11ac aimed to transfer data more quickly by increasing the speed by four times than 801. 11n. It also can support more antennas and has greater bandwidth[18], [21].

Figure 2.7: WiFi Logo

Figure 2.8: Typical WiFi modem

2.8.3 LoRa Technology

In June 2015, a company called Semtech from California developed and introduced extensive utilization of advanced spread spectrum with LoRa Technology[22]. LoRa is a ‘Long Range’ communication network designed to provide a cellular style low data rate using low power wireless standard. The central target of LoRa is the machine-to-machine (M2M) communication and Internet of Things (IoT) network applications which allow the user to connect several applications running on the same network[23], [24]. LoRa was developed to overcome the transmission distance problem of other wireless communication systems, where it can provide intermittent low data rate connectivity over a large distance. By utilizing LoRa, low power transmission can be achieved at a significant range because it was developed to enable extremely small signal levels to be received[25].

Although LoRa was developed by Semtech, LoRa Alliance is an industry body that is set up, develop, and promote the LoRa wireless system across the industry[22]. The body was launched in March 2015, at Mobile World Congress. The main goal of the Alliance is to provide an open global standard for secure, carrier-grade IoT Low Power Wide Area Network (LPWAN) connectivity[22]. The popularity of LoRa started to increase since the number of the company started to adopt the technology.

Up to millions of nodes can be handled by LoRa gateway. The signals can cover a significant distance of 15km to 20km, so less infrastructure is needed. Thus, the base set up of the network is less expensive and easy to implement[19], [25]. LoRa also includes an adaptive data rate to help boost the hub's battery life and system limit. The protocol of LoRa incorporates several different layers including encryption at the network, application, and device-level for secure communication[19].

The physical layer of LoRa controls the aspects of the Radio Frequency (RF) signal that is transmitted between the sensors and the LoRa gateway where signals are received. Besides, the open protocol stack allowed the concept of LoRa to grow because of the involvement of the different companies in LoRa development, use and deployment have been able to combine to create a user-friendly and cheaper solution for connectivity all type of connected IoT devices[24].

Figure 2.9: LoRa gateway

The IEEE set 802. 15. 4g as the standard for the LoRa wireless network. The unlicensed frequencies that are available around the world are the frequencies used by the LoRa wireless system[19]. The most widely used frequencies are:

- Europe: 868 MHz
- North America: 915MHz
- Asia: 433MHz

According to the Malaysian Communication and Multimedia Commission (MCMC), 915Mz is the standard frequency that can be utilized in Malaysia for IoT applications[26]. LoRa wireless modules and devices can achieve much better coverage by using lower frequencies than 2.4GHz or 5.8GHz of ISM bands specifically when the nodes are within the same buildings.

LoRa uses the spread spectrum modulation technique to transmit data[27]. The fluctuation level of frequency over time is used to encode the data to be transmitted. The major advantage of this spread spectrum communication technique is that it can avoid interference. The signals with this modulation technique are hard to interfere with and jammed[26]. Thus, LoRa can overcome the security problem in IoT applications.

Figure 2.10: LoRa Logo

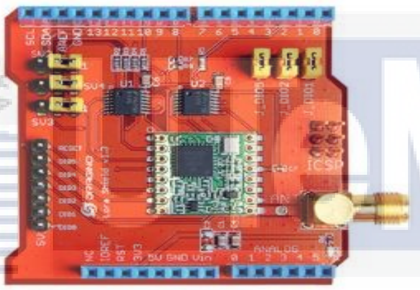


Figure 2.11: LoRa Arduino Uno Sheild

2.9 Microprocessor

A microprocessor is a computer processor that incorporates the functions of a computer's central processing unit (CPU) on a single integrated circuit (IC), or at most a few integrated circuits. The microprocessor is a multipurpose, programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and provides results as output[28].

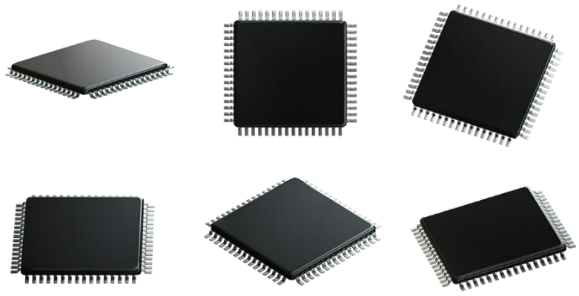


Figure 2.12: Microprocessor

2.9.1 History of Microprocessor

Microprocessors are part of embedded systems, providing digital control over myriad objects from appliances to automobiles to cellular phones and industrial process control. The first use of the term "microprocessor" is attributed to Viatron Computer Systems describing the custom integrated circuit used in their System 21 small computer system announced in 1968[28]. During the 1960s, computer processors were constructed out of small and medium-scale IC each containing tens of transistors to a few hundred. A large number of discrete logic gates were used. The distance that signals had to travel between IC on the boards limited a computer's operating speed. The first microprocessors emerged in the early 1970s and were used for electronic calculators, using binary-coded decimal (BCD) arithmetic on 4-bit words.

2.9.2 Application of Microprocessor

The application of the microprocessor are[28]:

A) Instrumentation

B) Communication

C) Office Automation and publication

2.9.3 The microprocessor in Smart Safety Helmet

The microprocessor was used in the main circuit that controlling the Arduino NANO circuit. It measures and keeps the pressure reading and count of impact for some time. The microprocessor also receives input from two push buttons to either reset the data or request for emergency attention and transfer all data to the wireless communication device.

2.10 Force Sensing Resistor (FSR)

The force-sensitive resistor is a component, which is similar to a variable resistor that can detect physical pressure, squeezing, and weight in terms of resistance[29].

Figure 2.13: Force Sensing Resistor

2.10.1 Physical Construction of Force Sensing Resistor

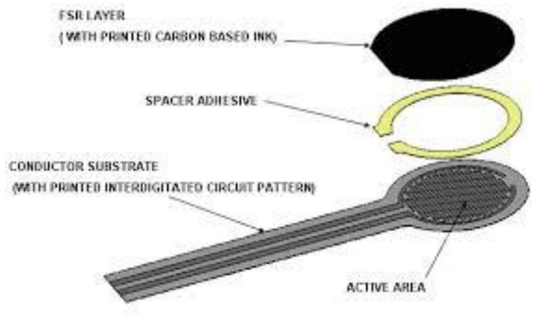


Figure 2.14: FSR layers

The FSR is made of 2 layers that are isolated by a spacer as shown in Figure 2.14. The FSR layer with printed carbon is to make contact with the active area. The conductor substrate was designed using semiconductor with printed interdigitating electrodes that can carry the resistance value to the reading device[29]. The more the pressure applied on the printed carbon makes it touch the conductor substrate and it reduces the resistance.

2.10.2 Working Principles of Force Sensing Resistor

The force-sensing resistor is a variable resistor that changes its value based on the pressure act on it. The FSR act as an infinite resistor (open circuit), when there is no pressure applied to it[30]. As the pressure applied on the FSR surface increase, the resistance between the two terminals will decrease, but the resistance value will return to its original value (open circuit value) immediately after the pressure act on it is removed[30]. Figure 2.15 below shows the graphical format of the approximate resistance value of the sensor at different force measurements for the FSR 402 model.

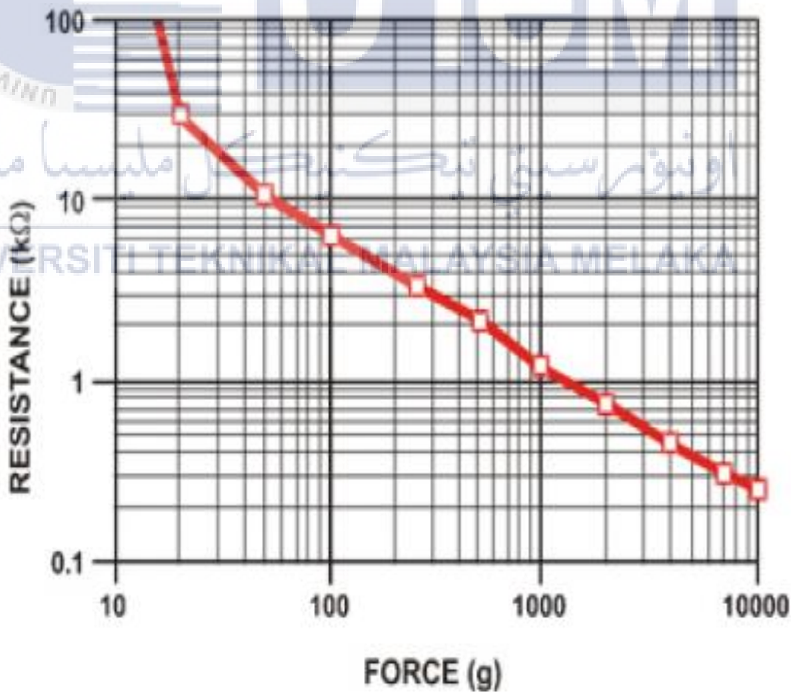


Figure 2.15: Approximate resistance value at different force measurements for FSR 402[30]**.**

2.10.3 Force Sensing Resistor in Smart Safety Helmet

The FSR was connected with the Arduino NANO to measure the pressure act on the user's head when an impact act on the helmet. There is a coding written to differentiate the pressure value as 'low risk' and 'high risk' to indicate the probability of injury occurrence to the user.

2.11 Tilt Sensor

The tilt sensor is an instrument that measures the tilting position concerning gravity. They empower the simple identification of direction or tendency[31].

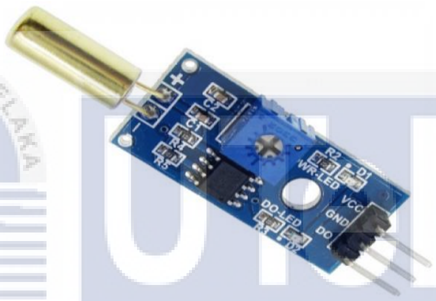


Figure 2.16: Tilt Sensor Module

2.11.1 The physical construction of the Tilt Sensor

The tilt sensor consists of a mass metal rolling ball that can move freely inside the shield as the sensor move[32]. A pair of conductive plates placed at the bottom of the shield as shown in Figure 2.17. The conductive plate also directly connected to the anode and cathode terminals of the sensor.

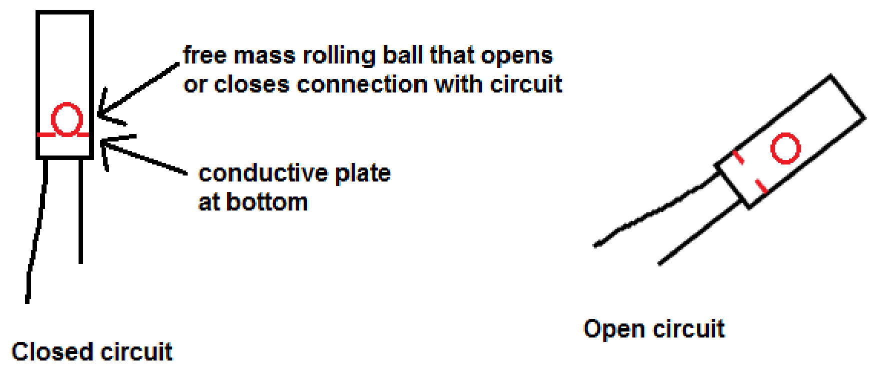


Figure 2.17: Tilt construction[32]

2.11.2 Working Principles of Tilt Sensor

As mentioned before the mass metal rolling ball moves freely. A pair of the metal plate makes an open circuit connection. When the sensor powered up, the metal rolling ball falls to the bottom of the sensor to form a closed circuit connection[33]. Once, the sensor is tilled, the rolling ball won't fall to the bottom so that the current cannot flow the two end terminals of the sensor[33].

2.11.3 Tilt Sensor in Smart Safety Helmet

The role of the tilt sensor in a smart safety helmet is to indicate the movement of the user. Besides, they also detect the position of the user. If the user is lying down for a time interval, then the microprocessor will indicate an emergency message.

2.12 Knock Sensor

The knock sensor detects the knock and vibrations. It works as a switch where there will be a signal from the sensor for a very short period when external force hit on the sensor[34].

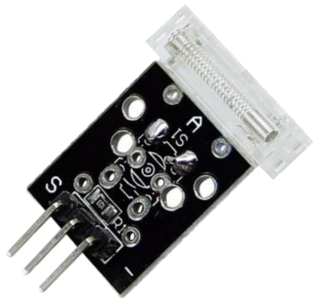


Figure 2.18: Knock Sensor

2.12.1 Physical Construction of Knock Sensor

As shown in figure 2.19, knock sensors consist of a conductive vibrating spring which is the main sensing element. It also consists of a resistor and three pins. The three pins of the knock sensor module are ground, power (+5V), and output (signal)[34].

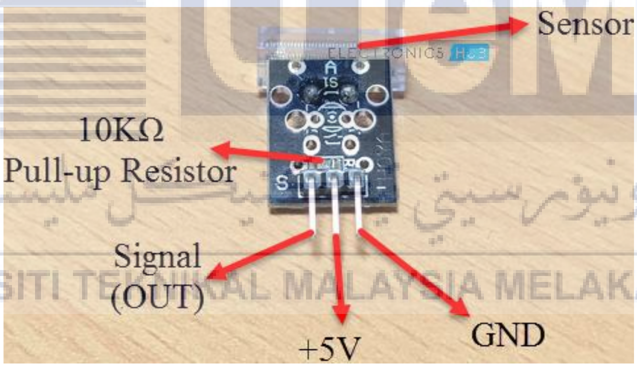


Figure 2.19: Knock Sensor Module components explanation

2.12.2 Working Principle of Knock Sensor

Based on Figure 2.20, knock sensors consist of a switch and a resistor where the vibrating spring is represented as the switch. The output pin always stays as HIGH with the help of the 10kΩ Pull-up resistor[34]. Thus, under normal conditions the output of the sensor is HIGH. The vibrating spring (switch) closes when the sensor detects any vibration or shocks. Hence, the output of the sensor will become LOW for a very short interval and get back to its normal condition[34].

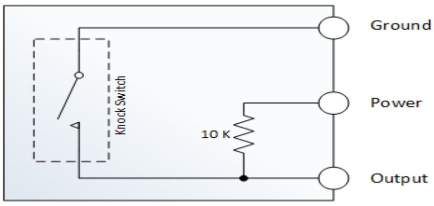


Figure 2.20: Schematic diagram of Knock Sensor

2.12.3 Knock Sensor in Smart Safety Helmet

The knock sensor used in this project is KY-031. The sensor is selected for its low sensitivity characteristic which can avoid small impact to be detected. Once, the microprocessor detects the output signal from the knock sensor, it will verify the pressure value whether the pressure is above the threshold value. Another important characteristic in this sensor is that it won't produce any output signal if there is no impact but the shell of helmet been pressed for a long time. Hence, this can avoid frequent dummy emergency messages.

2.13 Operation of the Project

The flow chart below shows the operation of the project:

1. The microcontroller verifies the FSR output value.
2. The microcontroller sends an FSR based emergency message.
3. The knock sensor will detect any high impact on the helmet.
4. The microcontroller sends an Impact based emergency message.
5. Microcontroller check "RESET" pushbutton input.
6. Microcontroller checks the tilt sensor reading.
7. The microcontroller sends Tilt based emergency message.

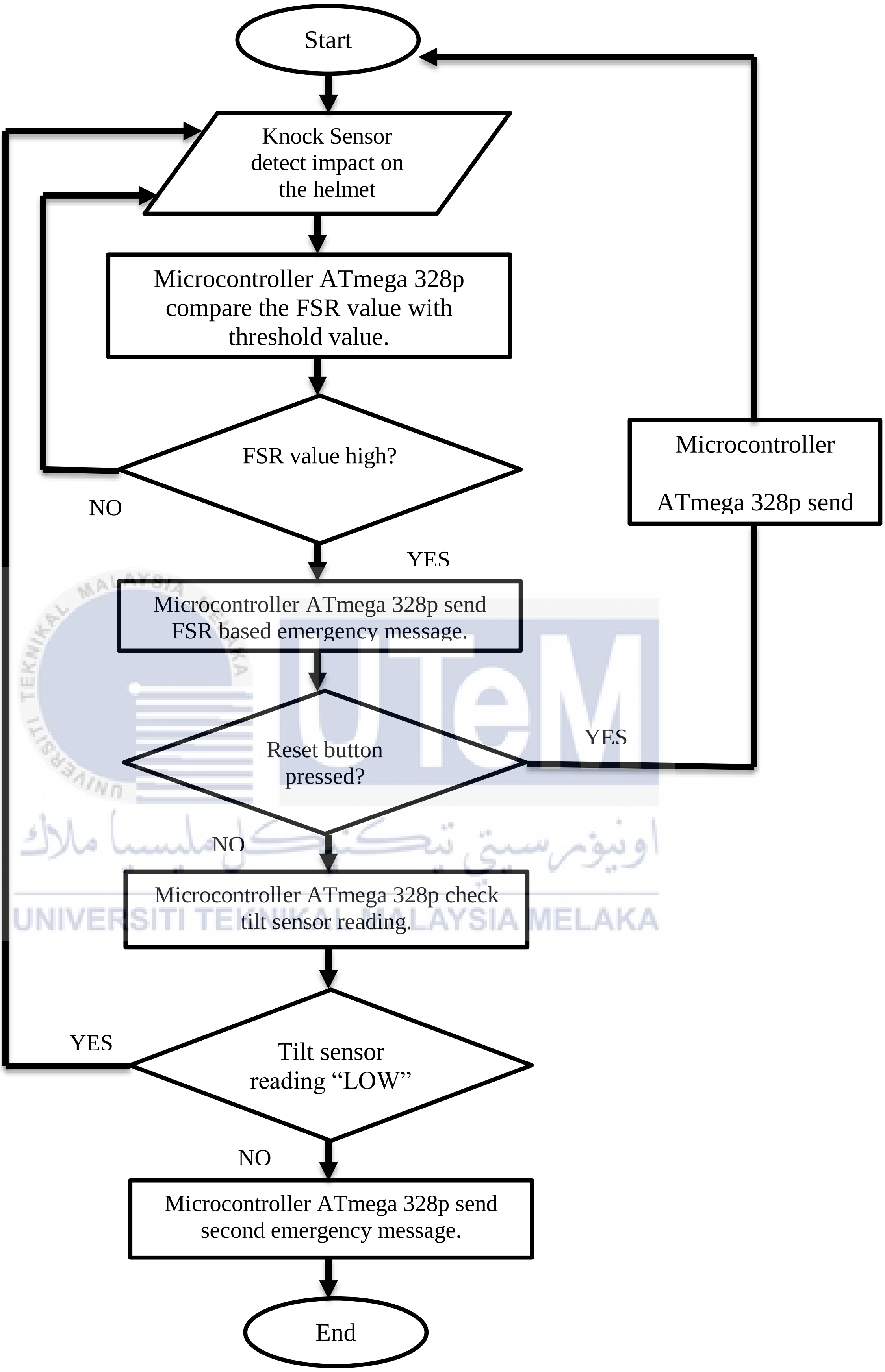


Figure 2.21: Project Operation Flow Chart

2.14 Introduction to the Components

In this project, several types of circuits are used to move the output of this project. In the circuit, there are various types of components used. The overall literature review covers a wide scope of the study as a basic component in the circuit and applies all learning in the university.

Overall this study based on reference materials taken through books and the internet. Through this study, it can increase the general knowledge of the project as well as tools and components to be used in the project.

2.14.1 Resistor

A linear resistor is a linear, passive two-terminal component that implements electrical resistance a circuit element[35]. The current through a resistor is in direct proportion to the voltage across the resistor's terminals. Thus, the ratio of the voltage applied across a resistor's terminals to the intensity of current through the circuit is called resistance. This relation is represented by Ohm's law:

Figure 2.22: Resistor

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high – resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybrid and printed circuits[35].

The electrical functionality of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders. When specifying that resistance in electronic design, the required precision of the resistance may require attention to the manufacturing tolerance of the chosen resistor, according to its specific application[36]. The temperature coefficient of the resistance may also be of concern in some precision applications[35]. Practical resistors are also specified as having a maximum power rating which must exceed the anticipated power dissipation of that resistor in a particular circuit: this is mainly of concern in a power electronics application. Resistors with higher power ratings are physically larger and may require heat sinks. In a high – voltage circuit, attention must sometimes be paid to the rated maximum working voltage of the resistor.

Practical resistors have a series and a small parallel capacitance; these specifications can be important in high-frequency applications. In a low-noise amplifier or pre-amp, the noise characteristics of a resistor may be an issue. The unwanted inductance, excess noise, and temperature coefficient are mainly dependent on the technology used in manufacturing the resistor[36]. They are not normally specified individually for a particular family of resistors manufactured using a particular technology. A family of discrete resistors is also characterized according to its form factor, that is, the size of the device and the position of its leads (or terminals) which is relevant in the practical manufacturing of circuits using them.

Most of the resistor has 4 bands:

- The first band gives the first digit.
- The second band gives the second digit.
- The third band indicates the number of zeros
- The fourth band is used to shows the tolerance (precision) of the resistor, this may be ignored for almost all circuits but further details are given below.

A special color code is used for the fourth band tolerance:

Silver ±10%, gold ± 5%, red ±2%, and brown ±1%. If no fourth band is shown the tolerance is ±20%.

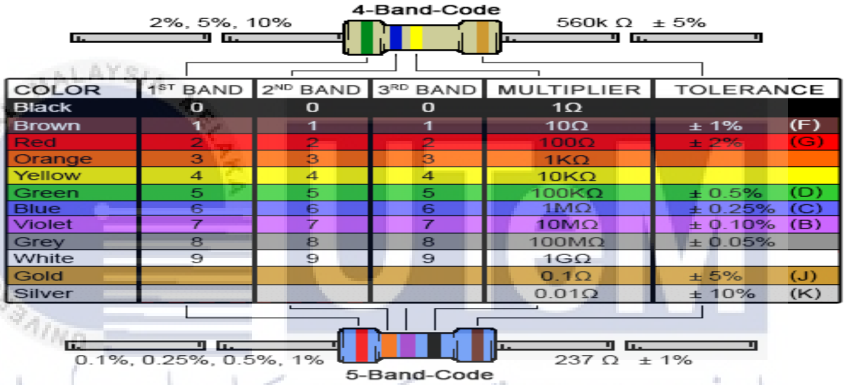


Figure 2.23: Resistor Color Code

2.14.2 Push Button

Push-button is a basic type of switch that controls the action in a mechanical process. Most of the pushbuttons are made from plastic or metal. There is no specific shape for push-button as it can be any size depends on the place it is used. Normally open and normally closed are the two basic states of push-button. The push-button has three main parts which are actuator, stationary, and groves. The actuator will move over the switch and into a thin cylinder at the bottom and there will be a movable contact and spring. When an external force presses the button, it touches with stationary contacts. This action makes the normally open switch to become close and vice-versa. In some situations, the button needs to be pressed continuously or repeatedly to make changes. Some push button comes with a latch connection which makes the state stay until the button pressed again.

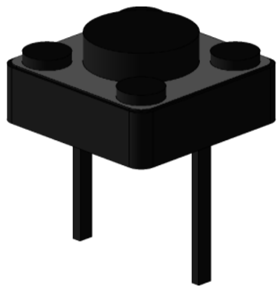


Figure 2.24: Push Button

2.14.3 Arduino NANO

The Arduino NANO is a widely used open-source microcontroller board based on the ATmega328P (similar to Arduino UNO) microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced with various expansion boards (shields) and other circuits. The board features 14 Digital pins and 8 Analog pins[37]. It is programmable with the Arduino IDE (Integrated Development Environment) via a type USB mini type cable[37]. It can be powered by a USB cable and by an external unregulated 6-12Volt through V_{in} pin where the onboard voltage regulator regulates it to +5V. Arduino NANO also accepts regulated +5V directly through the +5V pin[37].

2.15 Conclusion

This chapter discussed the importance of safety at the workplace, type of head injuries and its consequences, importance of head protection, type of head protection, initial purposes that lead to safety helmet design, and evolution of safety helmet. Besides, in this chapter three types of wireless communication system that are possible to be used in this project was discussed based on various characteristics. The next chapter will discuss the details about how the project is completed. The discussion will include both hardware and software.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Detailed project methodology explains rules or procedures used to undertake such projects trace, soldering, and testing. Besides that, the methodology also highlighted the aspects related to the project design, materials used, methods, or procedures of work carried out for the production of the "SMART SAFETY HELMET". To ensure the project is successful, the measures must be planned and systematic procedure properly causes the project is carried out or performed according to a satisfactorily established plan.

3.2 Schematic Searches

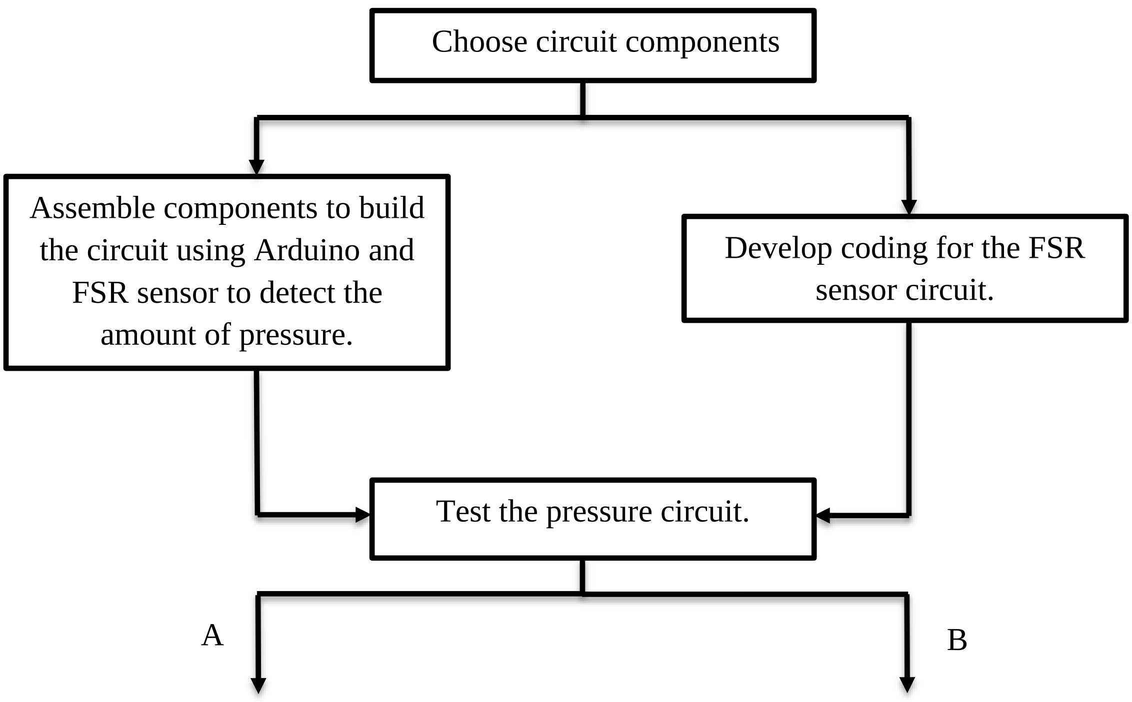
Before carrying out this project, the available problems should be shorted out and study it to find a suitable title for the project. After identifying the project which is to be implemented, the circuit for the project must be identified. The circuit to be used was searched and identified in the electronic project book, electronic stores, websites, advice, and knowledge of supervisors, and lastly from my view.

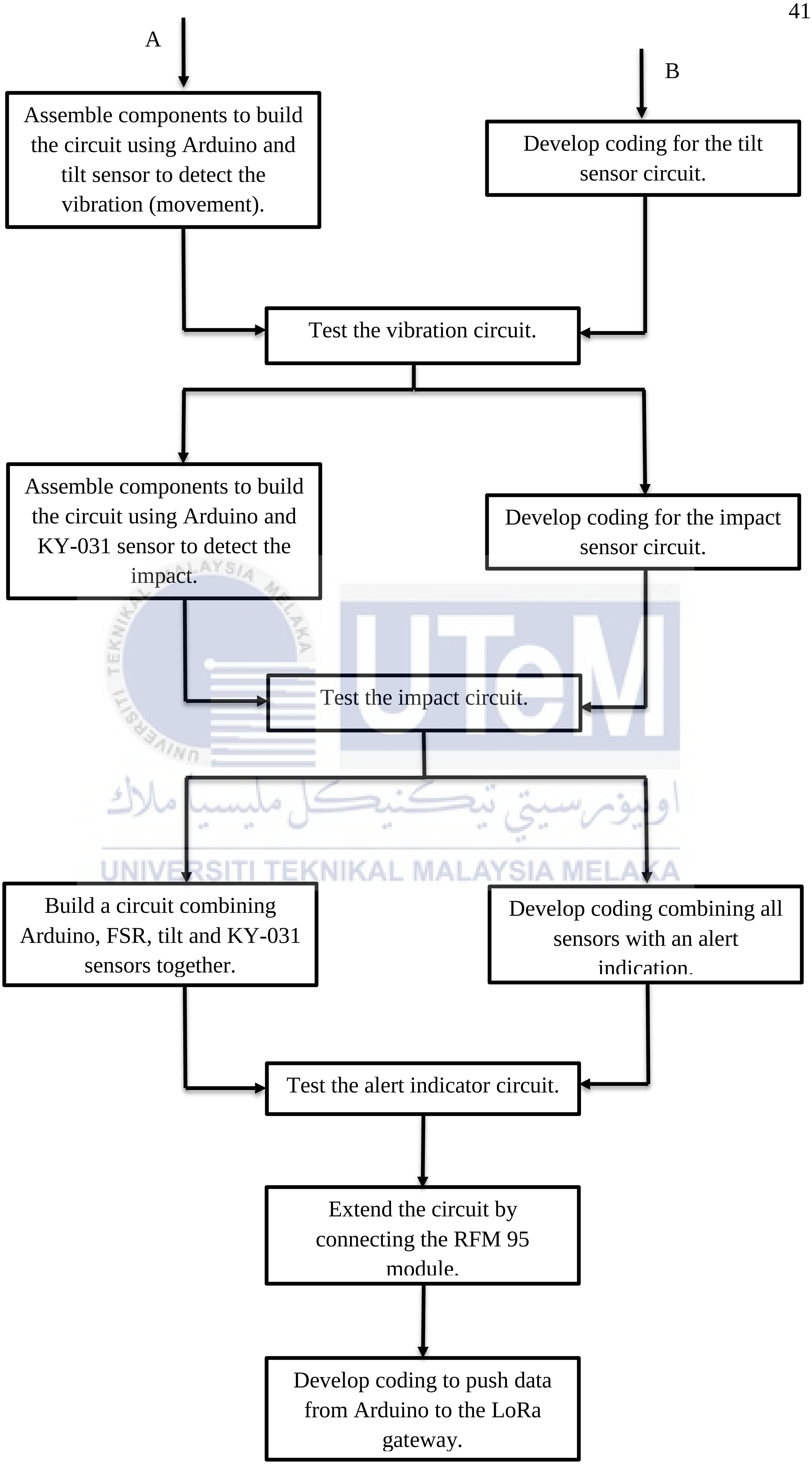
In search of the schematic, it is very important to understand the operation of the project correctly. By understanding the operation of the project, it is easy to find and design the schematic circuit. By taking this to mind, I have made some studies and surveys on the schematic, and finally found a suitable schematic for this project.

3.2.1 Components Searches

After circuits and components are identified, the necessary components were sought. Hence, observation has been made in components, which will be used to ensure that no mistake took place during the purchasing of the components. The purchased components are also tested and checked to ensure it is in good condition and accordance. The component is mainly searched online. After searching the component online, a manual survey also conducted to ensure the component to be purchased is correct.

3.3 Project Implementation Method




A
B
Assemble components to build the circuit using Arduino and tilt sensor to detect the vibration (movement).
Develop coding for the tilt sensor circuit.
Test the vibration circuit.
Assemble components to build the circuit using Arduino and KY-031 sensor to detect the impact.
Develop coding for the impact sensor circuit.
Test the impact circuit.
Build a circuit combining Arduino, FSR, tilt and KY-031 sensors together.
Develop coding combining all sensors with an alert indication.
Test the alert indicator circuit.
Extend the circuit by connecting the RFM 95 module.
Develop coding to push data from Arduino to the LoRa gateway.

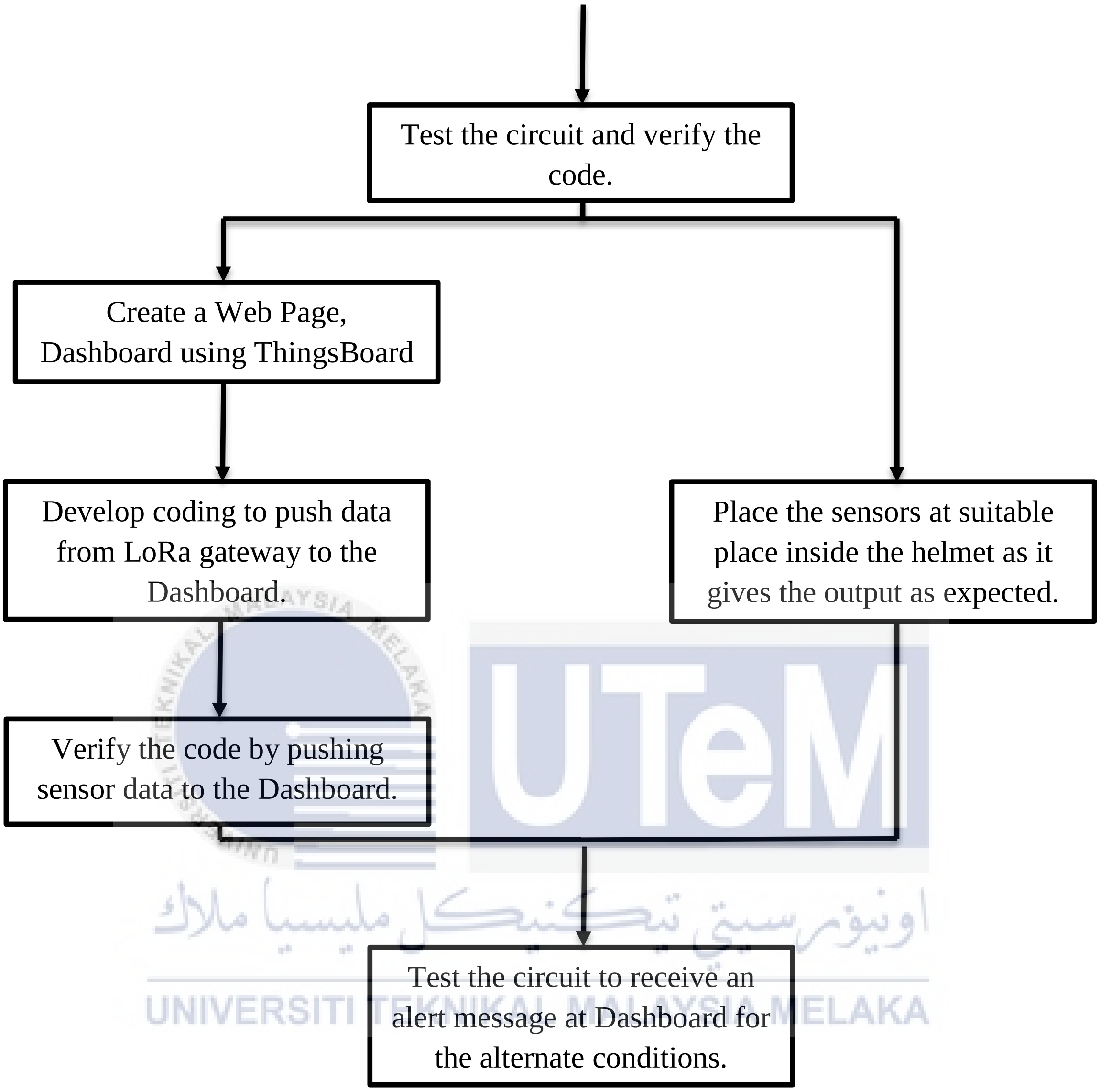


Figure 3.1: Flow Chart of Project Implementation

3.3.1 Designing and Developing Pressure Detection Circuit

Initially, a survey was conducted to identify the type of pressure sensor to be used in this project. The size and measurement parameter was considered while choosing the sensor. The interface of the sensor with Arduino was another important aspect of choosing the sensor.

The force-sensitive resistor (FSR) was chosen to use as the pressure detecting sensor[38]. After choosing the suitable sensor, the pinout diagram and the sample circuit were studied to understand the working principle. Besides, a sample coding to connect the sensor with Arduino also been searched and studied.

A circuit connecting the pressure sensor (FSR) with Arduino was developed as shown in figure 3.2 below. The circuit also included with a resistor to control the amount current passing through the sensor and a light-emitting diode (LED) to monitor the functionality of the FSR sensor. The output of the sensor was connected to the pin A0 of the Arduino as the output is an analog signal. The digital pin D9 from Arduino connected to the LED as an output to monitor the performance of the sensor.

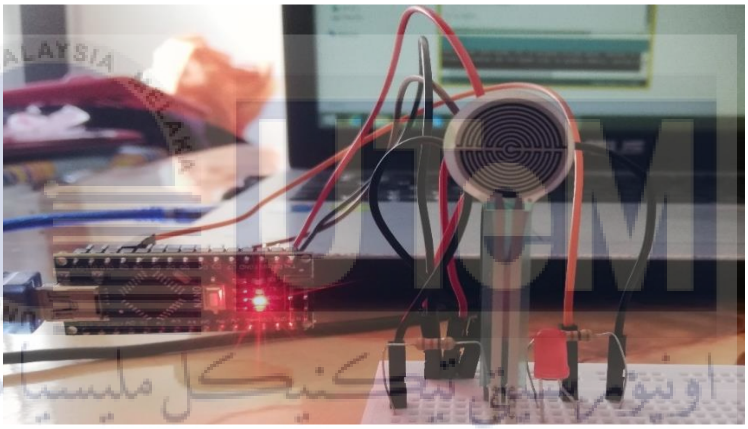


Figure 3.2: Circuit connecting FSR sensor with Arduino Nano.

A coding was developed to interface the sensor with Arduino and monitor the performance of the sensor. The FSR sensor has a range of 0-400Ω as the output. Thus, the coding was developed to indicate when the range exceeds the value 100Ω.

As shown in figure 3.3 an alert message is displayed in the serial monitor of the IDE software when the value from the FSR sensor exceeds 100Ω. A LED also used to indicate the alert message as shown in figure 3.4.

```
Analog reading = (Alert)247
Analog reading = (Alert)247
Analog reading = (Alert)245
Analog reading = (Alert)241
Analog reading = (Alert)249
Analog reading = (Alert)250
Analog reading = (Alert)253
Analog reading = (Alert)254
Analog reading = (Alert)246
Analog reading = 1
Analog reading = 0
```

Figure 3.3: Alert message on the IDE serial monitor.

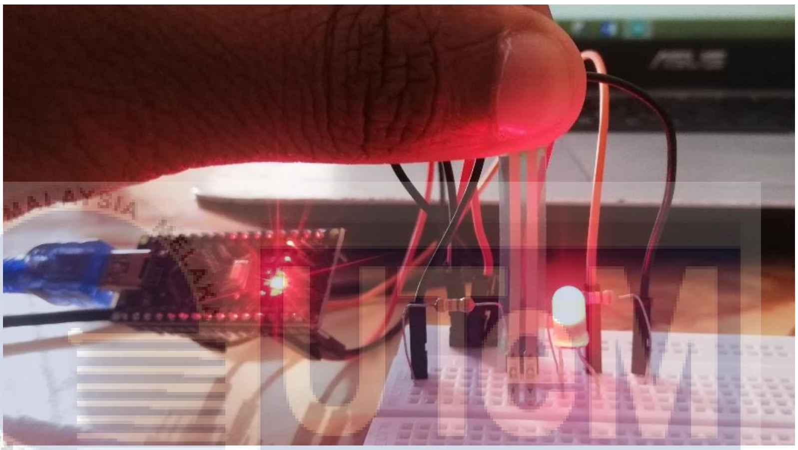


Figure 3.4: LED as the indicator for alert message.

3.3.2 Designing and Developing Vibration Detecting Circuit

A survey about the available vibration detecting sensors in industries was conducted. The specifications and the functionality of the sensors were found using their respective datasheets from the production company. After, reviewing the specification with the project requirement, the tilt sensor was chosen to use for vibration detection. One of the main reasons to choose a tilt sensor is a sensitivity in detecting vibration and it also responsible for the angle of its placement. This specification can help to identify the user's state either standing, sitting, or laying down.

The pinout diagram and sample codes were obtained from the internet to understand the working principle and technique to use the tilt sensor[33]. A circuit connecting the tilt sensor with Arduino was developed as shown in figure 3.5 below. Besides, the circuit also added with a resistor and LED to indicate whenever vibration is detected. The function of the resistor is to control the amount of current passing through the LED. The tilt sensor supplied with 5V from the Arduino board to switch on. The digital output of the tilt sensor was connected to the digital pin D3 of the Arduino to receive input signals whenever the vibration detected. The digital pin D4 of the Arduino connected to the LED to indicate the performance of the sensor.

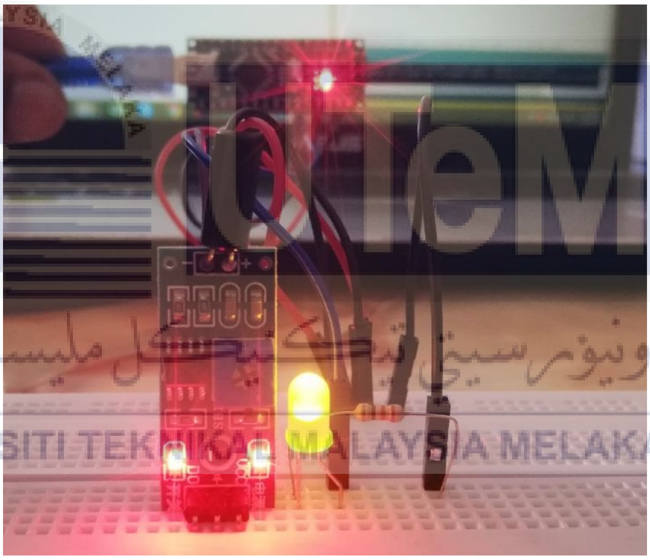


Figure 3.5: Circuit connecting the tilt sensor with Arduino Nano

A coding was developed coding to interface the tilt sensor with Arduino and monitor the performance using LED. The tilt sensor is always high condition, so the LED will light up when connected as shown in figure 3.5.

As shown in figure 3.6 below, the LED will goes off when the tilt sensor moved to 90° from its initial position. The LED also will start to blink whenever the vibration detected. The state of the sensor was monitored using the IDE serial monitor to ensure the LED function is correspondent to the state of the sensor as shown in figure 3.7.

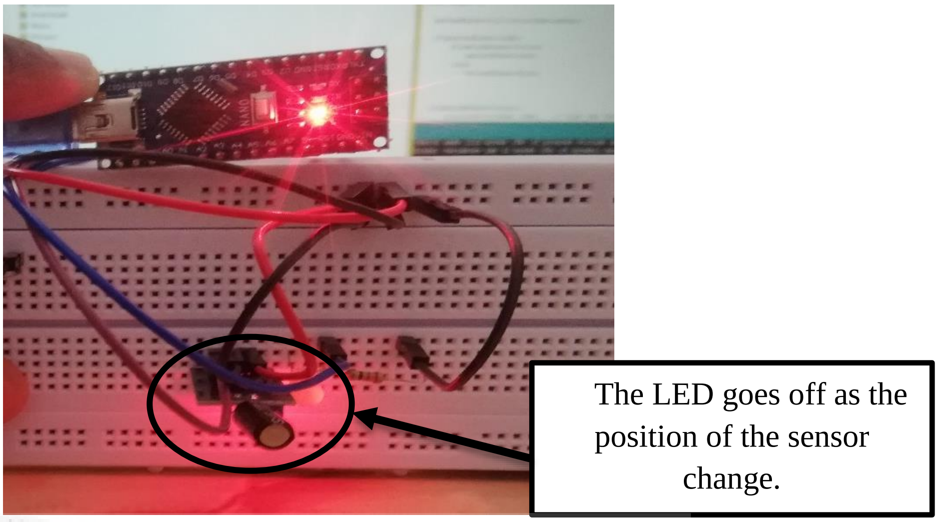


Figure 3.6: LED as an indicator for the state of the tilt sensor

```
Analog reading = Vibration1
Analog reading = Vibration1
Analog reading = Vibration1
Analog reading = Vibration1
Analog reading = Vibration0
Analog reading = Vibration0
Analog reading = Vibration0
```


Figure 3.7: Tilt sensor state transition on IDE serial monitor

3.3.3 Designing and Developing Impact Detecting Circuit

A survey for the available impact sensor in the market was made. The survey includes the size of the sensor and the sensitivity of the sensor mainly. The impact sensor should able to ignore small impact to avoid frequent distress messages sent to the control room. Besides, the sensor should be able to interface with Arduino.

KY-031 sensor was chosen after the survey. The pinout diagram and a sample circuit were studied to interface it with Arduino according to its working principles. Then, a sample coding of Arduino to control the sensor was searched and studied.

As shown in figure 3.8 below, a circuit connecting the impact sensor (KY-031) with Arduino was developed. The circuit also added with a resistor and LED to indicate when there is an impact applied on the sensor. The KY-031 sensor was supplied with a 5V supply from the Arduino board to switch on. Since the output of the sensor is digital, the pin was connected to the digital pin, D6 of the Arduino. The digital pin D8 from Arduino connected to the LED as an output to monitor the performance of the sensor.

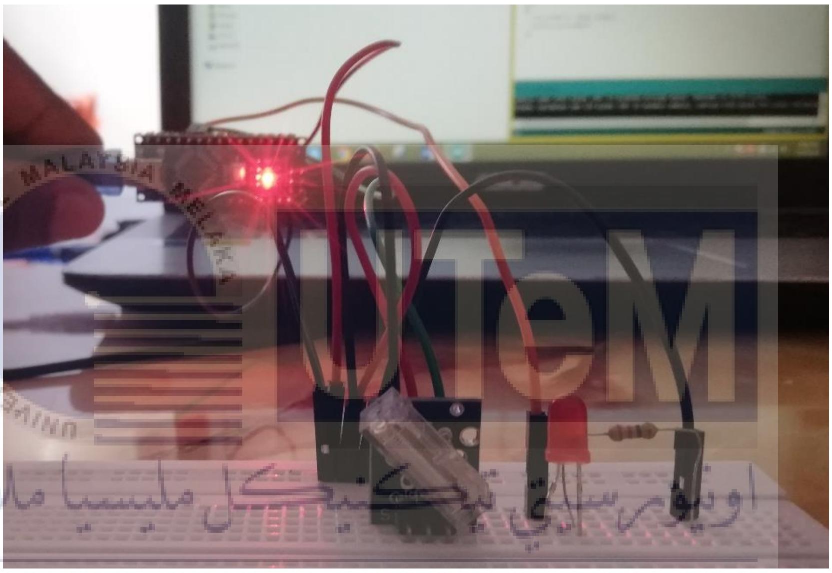


Figure 3.8: Circuit connecting KY-031 sensor with Arduino Nano.

A coding was developed to interface the KY-031 impact sensor with Arduino and monitor the performance of the sensor. The digital pin, D6 was declared as input, and the digital pin, D8 was declared as output which was connected to the LED. Since the sensor state is always low, it will light up the LED whenever the impact is detected. Besides, coding to monitor the state of the sensor through the IDE serial monitor also developed.

The LED will light up for a few milliseconds when the sensor detects any impact. The state of the sensor was monitored using the IDE serial monitor to ensure the LED function synchronously to the state of the sensor as shown in figure 3.9 and figure 3.10.

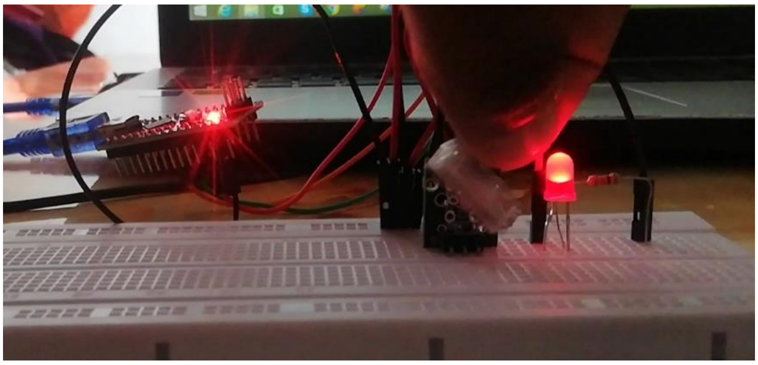


Figure 3.9: LED as an indicator for the state of the impact sensor

```
Digital reading = Impact0
Digital reading = Impact0
Digital reading = Impact0
Digital reading = Impact1
Digital reading = Impact1
Digital reading = Impact1
Digital reading = Impact1
Digital reading = Impact1
```


Figure 3.10: Impact sensor state transition on IDE serial monitor

3.3.4 Developing The Alert Indication using FSR, Tilt and KY-031 sensors

The alert system is a combination of all three sensors. Practically, the alert system will send a distress message to the dashboard when there is an emergency. Initially, the alert system was developed simply with an LED indication.

First, the three sensors interfaced with the Arduino. Then, the coding for each sensor was combined to form a complex coding that controls all the sensors. The digital output pin, D12 was connected to external LED to indicate the working principle of the alert system as shown in figure 3.11 below.

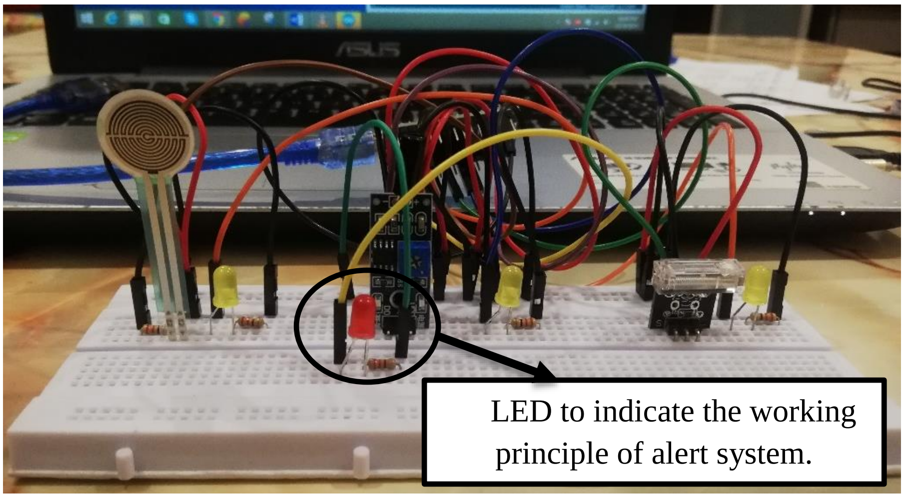


Figure 3.11: Circuit combining all three sensors to indicate the alert system

A coding was developed for the alert system. There are 2 conditions for the alert system to send a distress message to the dashboard. Those conditions are:-

- The FSR sensor reading must be more than 100Ω.
- The KY-031 sensor must detect an impact.

Or

- The tilt sensor must be at 90° from its original position.

All this condition will trigger the LED to lights up (sending distress message).

Figure 3.12 below shows the IDE serial monitor for the distress message. The word "EMERGENCY" shows when all the requirement is met. Besides, the LED also lights up to indicate the emergency as shown in figure 3.13.

```
Analog reading = (Alert)152
Digital reading = Impact0
Digital reading = Vibration1
EMERGENCY
Analog reading = (Alert)147
Digital reading = Impact0
Digital reading = Vibration1
EMERGENCY
Analog reading = 81
Digital reading = Impact0
Digital reading = Vibration1
Analog reading = 1
Digital reading = Impact1
Digital reading = Vibration1
```

Figure 3.12: “EMERGENCY” message on IDE serial monitor

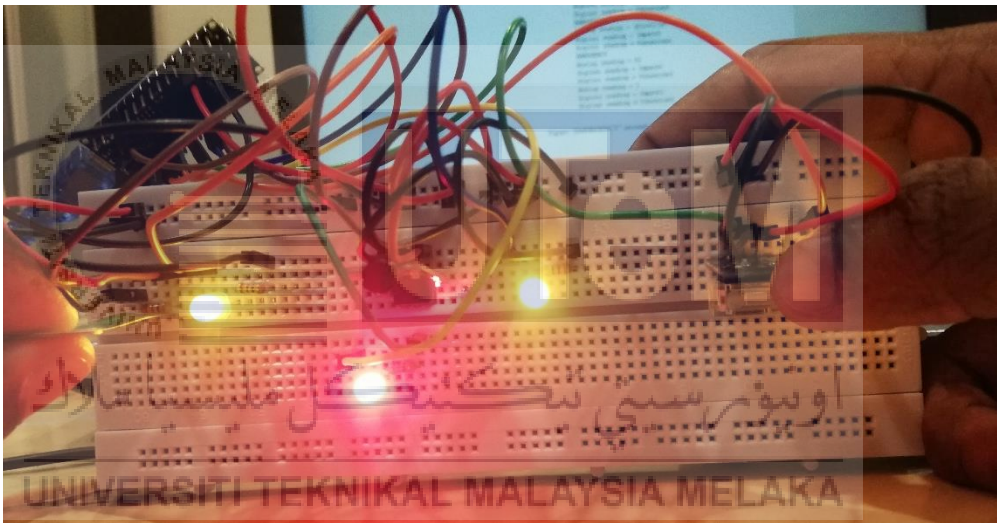


Figure 3.13: LED as an indicator for the “EMERGENCY” message

3.3.5 Installing Dragino Board Package in Arduino IDE

To be able to program the LoRa gateway, the third party board needs to be added to the Arduino IDE software first[39]. A URL which is “http://www.dragino.com/downloads/downloads/YunShield/package_dragino_yun_test_index.json” is added to the Additional Boards Manager URLs field that can be found in File > Preferences option as shown in Figure 3.14. Next, install the board by clicking Tools > Boards > Board Manager and search Dragino Yun in search bar to proceed with the installation process as shown in Figure 3.15. Once succeed, the board is available to be program.

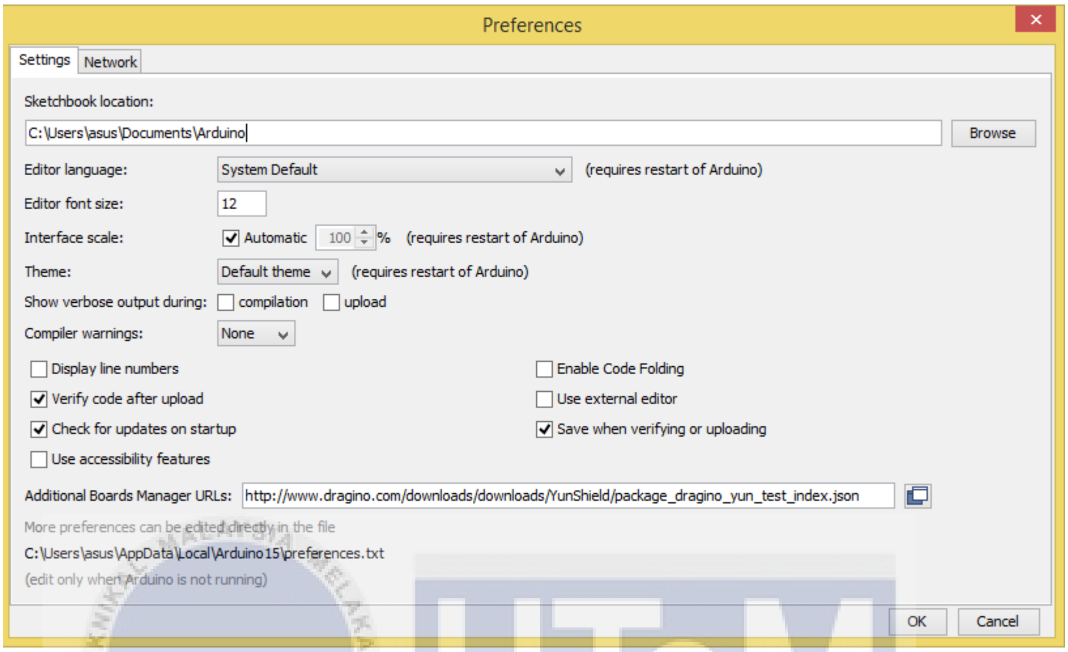


Figure 3.14: Adding Dragino Yun Board into Arduino IDE software using URL

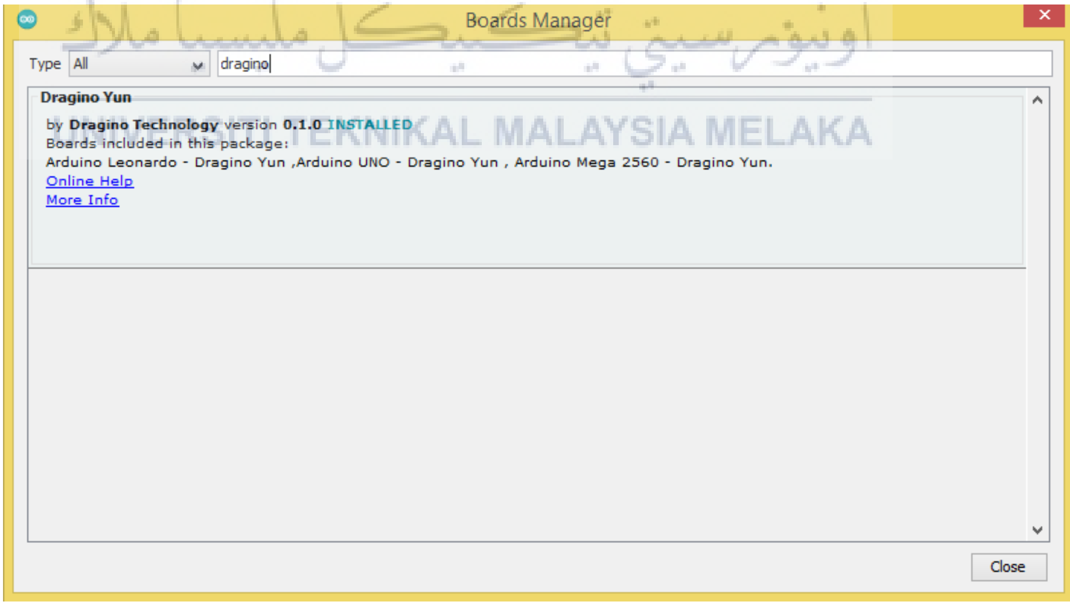


Figure 3.15: Download Dragino Yun Board to Arduino IDE software

3.3.6 Designing and Integrating RFM 95 with Arduino Nano

RFM 95 is a transceivers module that features the LoRa long range modem that provides ultra-long range spread spectrum communication. Since the LoRa Arduino Uno module is very big, and not suitable to place inside the helmet, the RFM 95 module as shown in figure 3.16 can be integrated with Arduino Nano to perform the same function as the LoRa Arduino Uno module. A survey was conducted to find the circuit diagram and sample code to integrate the RFM 95 module with Arduino Nano[40]. Figure 3.17 shows the schematic circuit of the RFM 95 module integrates with Arduino Nano. The circuit was powered up using a 7.4V rechargeable lithium polymer (lipo) battery which able to support up to 5 days.

Figure 3.16: RFM 95 LoRa module

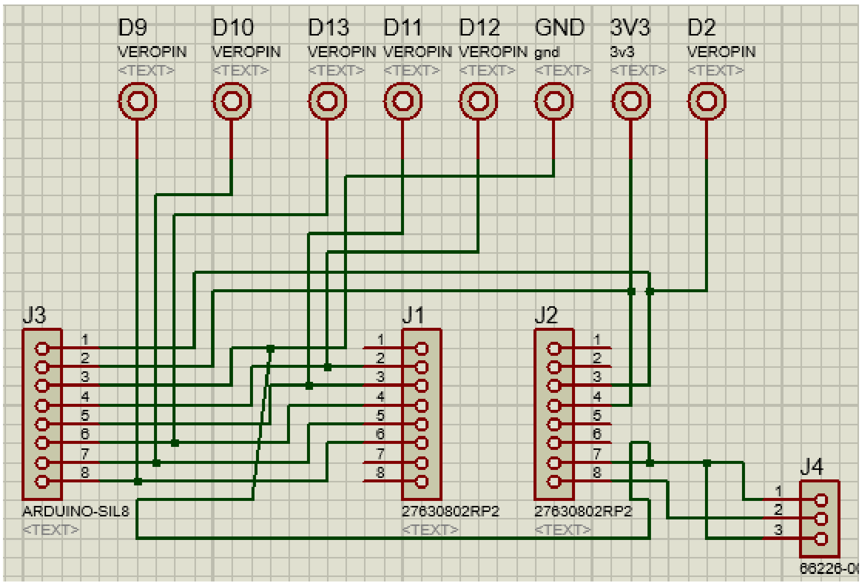


Figure 3.17: Schematic diagram of RFM 95 integrates with Arduino Nano

Based on the schematic diagram, a circuit connecting the RFM 95 module with Arduino Nano and all the sensors was developed as shown in figure 3.18. Besides, a complex code to push sensor data to the LoRa gateway was developed using the sample code. Figure 3.19, shows the IDE serial monitor that displays the sensor data from Arduino Nano. Another code was developed and uploaded to display the received data at the LoRa gateway. Figure 3.20, shows the IDE serial monitor that displays the sensor data at LoRa gateway. The comparison of data between figure 3.19 and figure 3.20 shows the data received at the gateway is similar which verifies the developed codes.

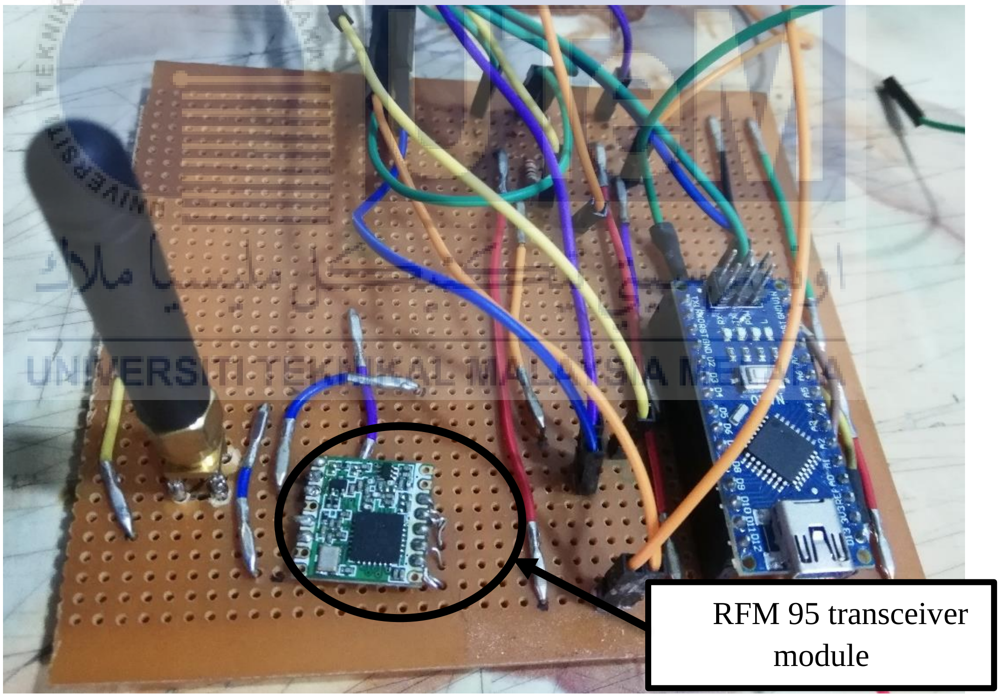


Figure 3.18: RFM 95 integrated with Arduino Nano

```
Sending to LoRa Server
FSR:100
Impact:2
Tilt:1
Reset:2
Panic:2
Sending to LoRa Server
FSR:36
Impact:2
Tilt:1
Reset:2
Panic:2
```

Figure 3.19: IDE display of sensor data from Arduino Nano

```
Hai
FSR:100
Impact:2
Tilt:1
Reset:2
Panic:2
Sent a reply
Hai
FSR:36
Impact:2
Tilt:1
Reset:2
Panic:2
Sent a reply
```


Figure 3.20: IDE display of sensor data from the LoRa gateway

3.3.7 Sensor Placements

There are three sensors used in this project which are FSR, Tilt, and KY-031. Each sensor brings a specific output to generate the alert message. Thus, the placements of each sensor inside the helmet are very important.

The FSR sensor must detect the highest possible amount of pressure as an object hits the helmet. So, the sensor will be placed in the middle of the helmet as shown in figure 3.21. A partially elastic rode was attached at the top of the V-shape webbing harness as shown in figure 3.22. Besides, the tilt sensor must detect the movement and the head's position all the time. Since the position of the head is important, the tilt sensor must be in a normal condition (output as LOW) when the user is in a standing or walking position. However, as soon as the user in the laydown position (90° from the original position) the sensor must change its state to "HIGH". So, the sensor must place at the side of the helmet as shown in figure 3.21 where it can detect the changes in degrees of the head's position. As the KY-031 sensor is only sensitive to the high impacts, it is a must to place it in a position where it can detect the maximum amount of vibration during the impact. So, the KY-031 sensor will be placed hanging beside the FSR sensor as shown in figure 3.21.

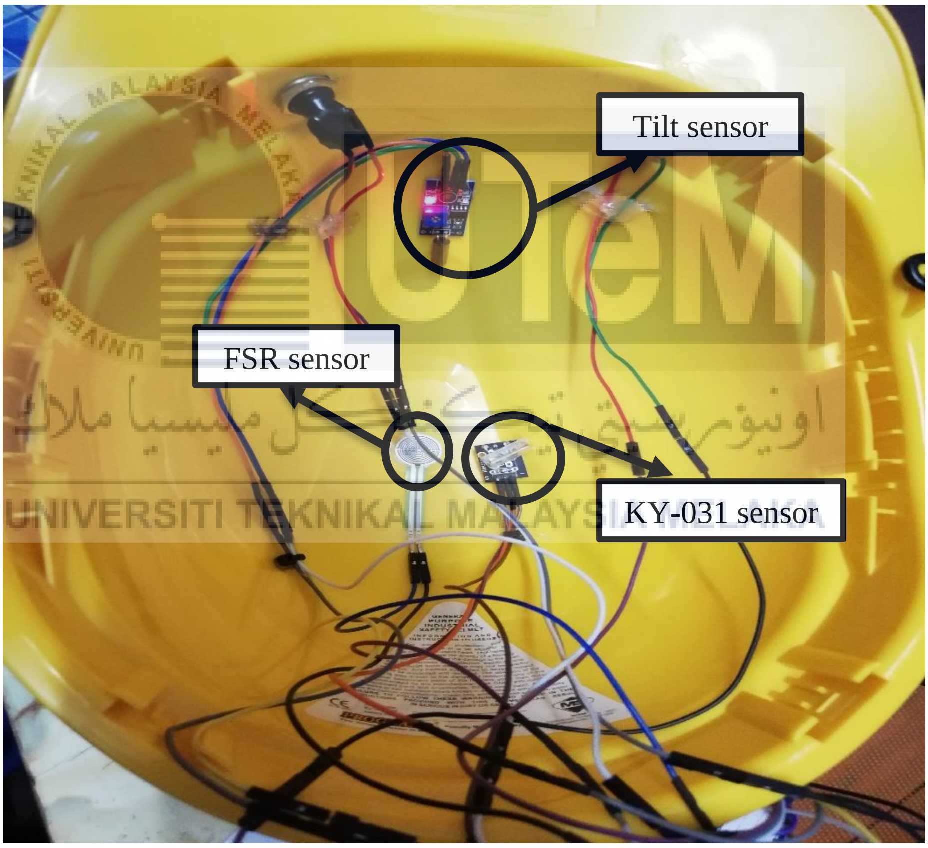


Figure 3.21: Sensor placements inside the helmet

Figure 3.22: Partially elastic rod on V-shape webbing harness

There are two pushbuttons used in the helmet to Reset the alert message and indicate a special Panic message. Both pushbuttons must be visible and easy to be used by users. Thus, the pushbuttons are placed at the front of the helmet as shown in figure 3.23.

Figure 3.23: Pushbutton placements

3.3.8 Development of Dashboard

The dashboard can be created using many applications to store data using the Internet of Things (IoT). ThingsBoard is one of the applications to create a dashboard to manage data wirelessly. By using the tutorial and examples a suitable dashboard was created to view the alert message[41]. The dashboard is also able to display the history of the sensor state in a day time which can be used for medical purposes. Figure 3.24 shows the dashboard that displays the FSR details.

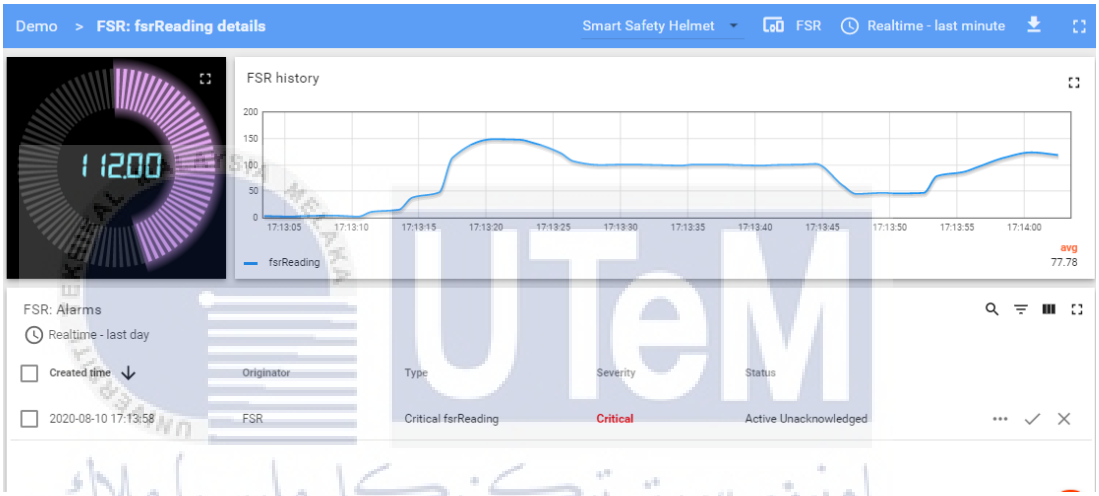


Figure 3.24: Dashboard displaying FSR details

3.4 Planning of Project Execution

The planning of project execution is very important before the real project was created or produced. The aim of the project will give the early pictures on project appearance and the circuit to be used. There are various methods and procedures used for the process of creating and make the project deliverable.

i. Initial planning and search for the schematic circuit.

ii. The components used for the design were searched and found.

iii. The schematic of the circuit was drawn and tested in PCB test software.

iv. The preliminary design of the project model was done before it was made in real. The suitability of the project was considered to ensure no error for the project.

v. The process of etching, drilling, continuity testing, soldering, and components connection circuit was done. (The etching process is not carried out due to coronavirus pandemic and replaced with a stripboard).

vi. The model's frame for the project was made according to measurement as prescribed.

vii. The accessory for the framework was installed.

viii. The project model was done and the testing of the project was carried out.

3.5 The Design of the Project

The method of designing is a very important aspect of doing a project. The objective of the project will describe the early appearance of the project. Some various methods and procedures were used for the designing process of the project.

i. The circuit was selected and the suitability of the circuit was tested.

ii. The 'test run' for the project circuit board and the circuit was done to ensure the component purchased corresponds with the project planning.

iii. The preliminary sketches for the design of the project model are made before the actual project is made.

iv. The etching, drilling, circuit continuity test, and circuit soldering was done depending on the schedule and Gantt chart planning.

v. The project was outlined depend on the planning size of the project. The project item was recycled items.

vi. The circuit was installed on the project frame as planned.

vii. The project model was done depending on the schedule.

3.6 Review Process

The circuit that was successfully soldered was tested many times to prevent failure during the assembling of the project frame. If there is any failure during the project installation, the whole project must be dismantled to do the troubleshooting process. The circuit that is used in the project

i. Arduino Nano
ii. Force Sensing Resistor (FSR)
iii. Tilt Sensor
iv. KY-031
v. RFM 95 module

A double-sided PCB circuit was successfully designed for etching as shown in figure 3.25. Unfortunately, the design unable to etched due to the Coronavirus Outbreak. As an alternative, the stripboard was used to complete the project. However, this report includes all the processes that should be carried out for a PCB design.

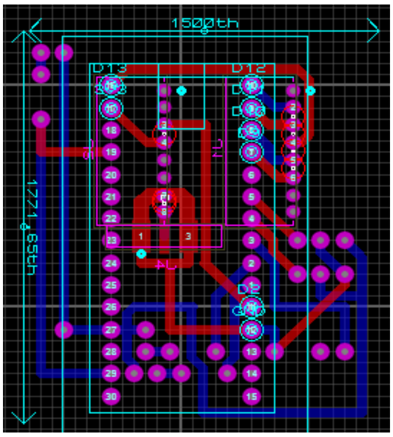


Figure 3.25: Double-sided PCB design of Smart Safety Helmet

3.7 Lettering Process

This process is intending to be the closing for the circuit on the PCB that has been traced. This condition is intending to ensure that during the process of etching, the traces that have been drawn not fade. Before tracing the circuit, hands must be washed first with detergent to avoid manufacturing fingerprints and other dirt. Tracing should be evaluated repeatedly for the designed circuit to ensure the capacity of the traces is not lost during the etching process later. This is an important process to ensure the circuit can operate properly as required.

3.8 Etching Process

The etching is the process of dissolving unwanted copper with acid Ferric chloride solution conditions. The material that required for the etching process is:

i. Acid ferric chloride
ii. Plastic Tupperware
iii. Hot water
iv. Hand gloves
v. Flux
vi. Thinner

3.8.1 Method of etching

i. Use gloves preferably, as ferric chloride acid can erode the skin and it is very dangerous.
ii. This acid is also able to cause water pollution because it is easily soluble.
iii. Heat the water and add the acid into the hot water.
iv. After the circuit is drawn on the circuit board (PCB board), parts that are not needed are removed after the acid-soluble with the water together, the circuit

board was inserted to the solution and have to wait for few minutes. During that time, the acid will remove all the unwanted copper.

v. After the unwanted copper was eroded from the circuit board then the circuit was removed from the acid solution.

vi. After wash, the PCB checking process was taking place to ensure the circuit was printed correctly on the PCB board.

vii. The incorrect printing will cause an error in the project.

3.9 PCB Cleaning

After the completion of the etching process, the unused copper in the PCB is removed fully. After that, the PCB is washed and rinsed with the water from the reservoir. Thinner was used to remove the black lettering attached to the circuit.

3.10 Drilling Process

This process seeks to introduce a component before soldering. This process uses a drill to drills the appropriate point used for component insertion. .The size of the hole was chosen depending on the component to be used. The bigger size sometimes will damage the copper pattern.

3.11 Order and Installing Components on Circuit

i. After completion of the PCB drilling, the PCB pattern was checked to ensure the pattern was not damaged during the drilling process.

ii. The component that is installed on the PCB board was tested using the multimeter.

iii. The component failed in the test was rejected and replaced with the new component.

iv. The component was inserted into the PCB board by referring to the schematic drawing.

v. The polarity for each of the components was tested.

vi. Lastly, the PCB was prepared for the soldering process.

3.12 Soldering Process

Soldering is a process in which two or more metals items are joined together by melting and flowing a filtered metal (Solder) into the joint, the filter metal having a lower melting point than the workpiece. Soldering differs from welding in that soldering does not involve melting the workpieces. In brazing, the filter metal melts at a higher temperature, but the workpiece metal does not melt. Formerly nearly all solders contained lead, but environmental concerns have increasingly dictated the use of lead-free alloys for electronics and plumbing processes.

Cleanliness is essential for efficient, effective soldering. Solder will not adhere to dirty, greasy, or oxidized surfaces. Heated metals tend to oxidize rapidly. This is the reason the oxides, scale, and dirt must be removed by chemical or mechanical means. Grease or oil films can be removed with a suitable solvent. Connections to be soldered should be cleaned just before the actual soldering operation.

Items to be soldered should normally be “tinned” before making a mechanical connection. Tinning is the coating of the material to be soldered with a light coat of solder. When the surface has been properly cleaned, a thin, even coating of flux should be placed over the surface to be tinned. This will prevent oxidation while the part is being heated to soldering temperature. Rosin-core solder is usually preferred in electrical work. However, a separate rosin flux may be used instead. Separate rosin flux is frequently used when wires in cable fabrication are tinned.

3.12.1 Technique of Soldering

Materials that are needed for this soldering process are:

i. Soldering iron
ii. Solder
iii. Solder sucker
iv. Cutter
v. Flux

3.12.2 The Procedure of the Process Soldering

i. The soldering iron with good condition was selected for the soldering process. The tip of the soldering iron was cleaned. The shape of the tip may vary from one soldering iron to the next but generally, they should look clean and not burnt.

ii. A PCB eraser is used to remove any film from the tracks. This must be done carefully because the film will make an error during the soldering process. The track was checked using a magnifying glass. If there are gaps in the tracks, sometimes they can be repaired using wire but usually, a new PCB has to be etched to ensure the PCB works properly after soldering.

iii. All the component was inserted to its position and the PCB was clipped to bull clip. The bull clip will give mechanical strength for the PCB.

iv. The heated soldering iron was placed in contact with the track and the component was allowed to heat them. Once they are heated the solder is applied. The solder should flow through and around the component and to the track.

v. After the soldering process was done, the extended leg was trimmed to avoid touching with the other component. The circuit is now ready for testing.

3.12.3 Cleaning of PCB after Soldering

i. After the soldering process was done, the excessive solder was removed from the PCB to ensure no shorting.

ii. The excessive solder was cleaned by the disorder process.

iii. Then, the PCB was tested using the multimeter to ensure no shorting and all the connection was correct.

3.13 Conclusion

This chapter discusses the project methodology. The rules or procedures used were explained in detail. The next chapter will analyze the output of the project.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, all the outcomes of the project will be discussed. The obtained outcome will be compared to the expected outcome. The output of the Smart Safety Helmet mainly focuses on the emergency message that created when the requirements are met. Thus, the result will be based on the alert signal on the helmet itself and the emergency message at the dashboard. All the result was obtained from a demonstration using a watermelon as the dummy head.

4.2 Alarm Based on Impact Detection

The FSR is one of the sensors used in the helmet which provides the data about the amount of pressure act on the user's head when an object hits the helmet. As mentioned in the previous chapter, a threshold value of 100Ω was set to indicate the high pressure. However, the impact of detection does not only depend on the FSR value. The impact detection also concerns the value from KY-031 sensor.

A bottle partially filled with water was dropped from a height of 0.5 meters to indicate the low impact output as shown in figure 4.1. The weight of the bottle is 0.07kg. The helmet was assumed to be moved 0.1m downward as the bottle hits the helmet. The average impact act on the helmet is calculated as 3.43 Newton[42]. As shown in figure 4.2, the KY-031 sensor's output state is "HIGH" at the time of 1:26:08 and there is no alarm created on the dashboard, even the FSR value exceeds its threshold value at the time 1:26:08. However, the FSR dashboard will create an alarm that can be view anytime as shown in figure 4.3 and cleared by the user using the "RESET" pushbutton as shown in figure 4.4 and figure 4.5. The value of the KY-031 sensor remains unchanged for the low impact.

Figure 4.1: Set up to trigger a low impact

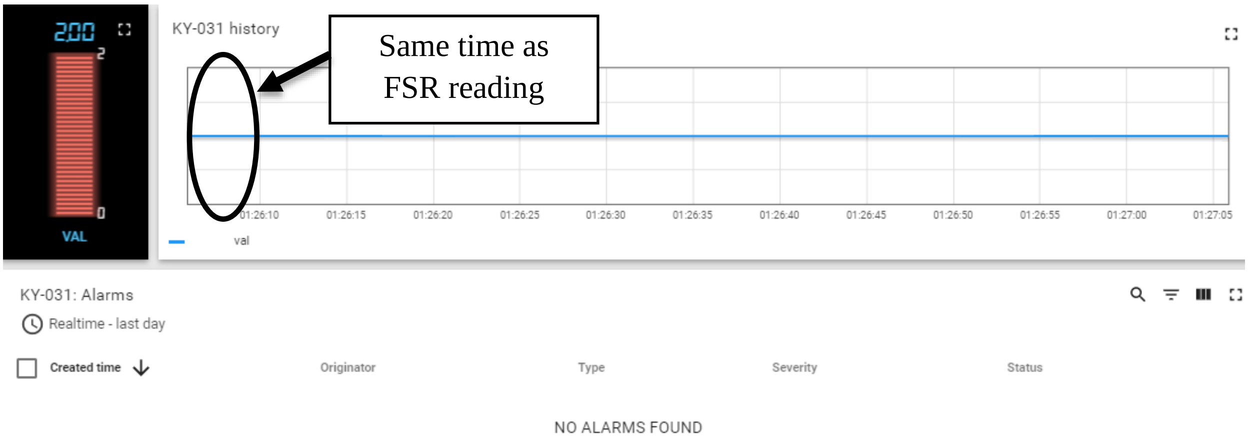


Figure 4.2: KY-031 sensor's details dashboard for low impact

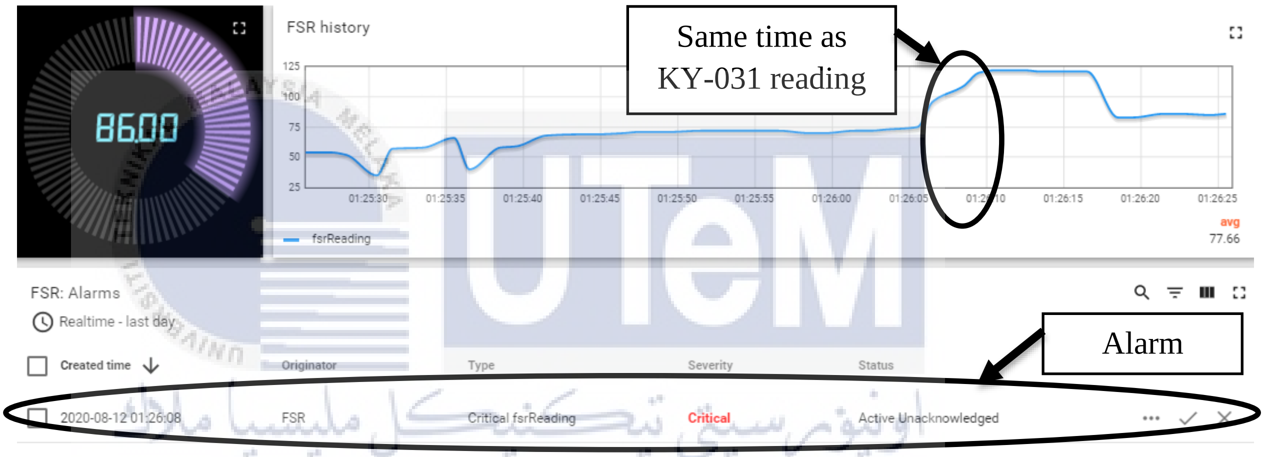


Figure 4.3: FSR sensor's details dashboard for low impact

Figure 4.4: Utilization of RESET pushbutton

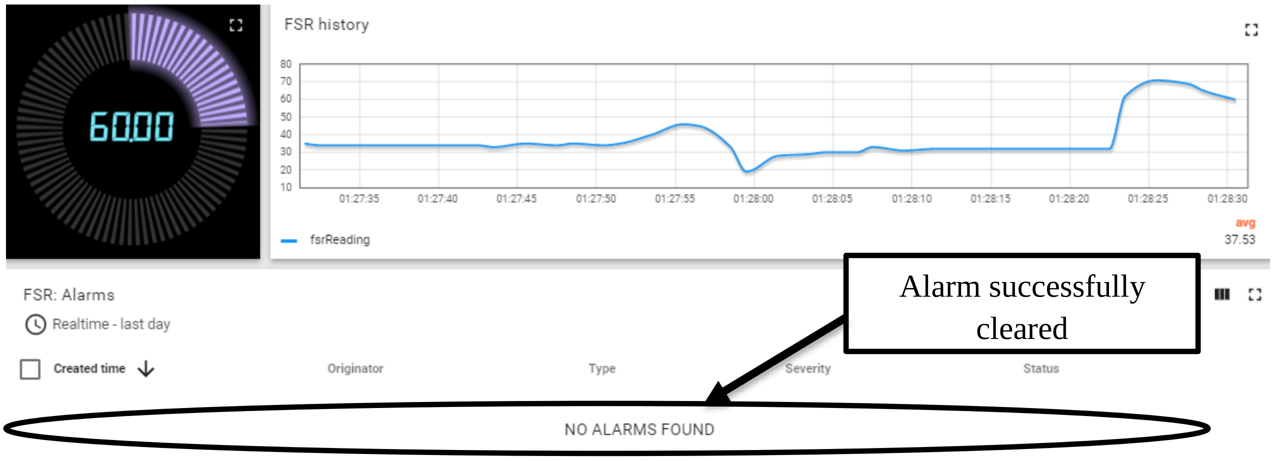


Figure 4.5: FSR sensor's dashboard of cleared alarm

A 0.5kg hammer was used to indicate a high impact. The hammer was dropped from a height of 0.5 meters. The helmet was assumed to be moved 0.1 meters downward as the bottle hits the helmet. The average impact act on the helmet is calculated as 24.5 Newton[42]. Once the hammer hits the helmet as shown in figure 4.6, the KY-031 sensor's value is "LOW" at the time 1:35:18 and the FSR value exceeds its 100Ω threshold value at the time 1:35:19. Thus, an alarm created on both FSR and KY-031 dashboards as shown in figure 4.7 and figure 4.8. The alarm on the FSR dashboard can be cleared by the user using the "RESET" pushbutton. However, the alarm on the KY-031 dashboard can be cleared via the dashboard by the authorized person only as shown in figure 4.9.

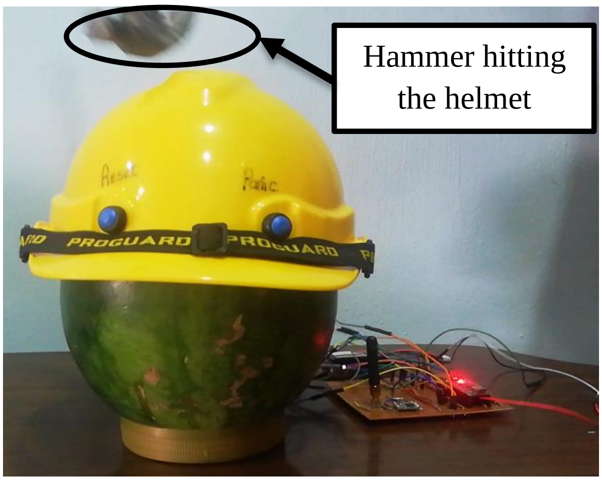


Figure 4.6: Set up to trigger a high impact

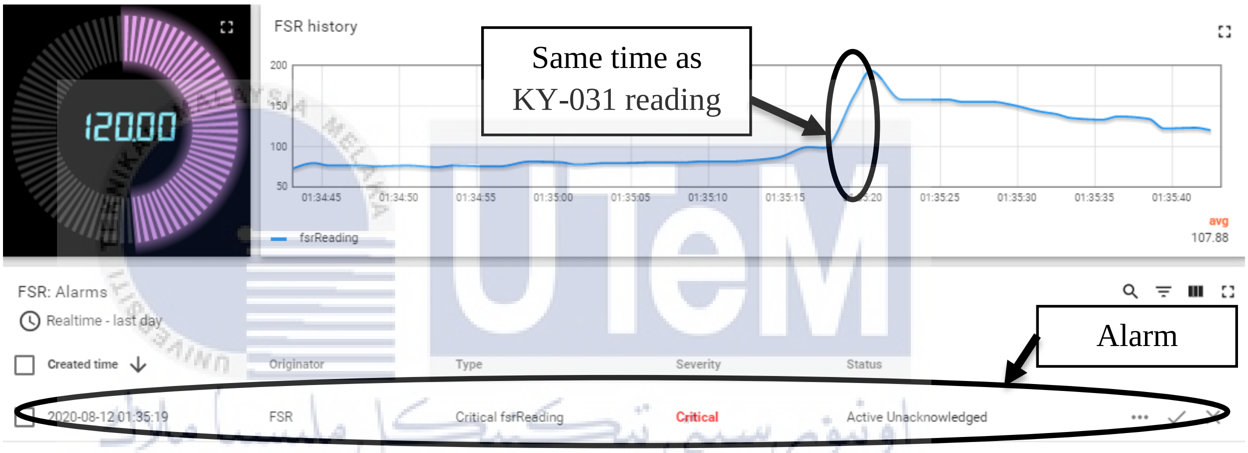


Figure 4.7: FSR sensor's details dashboard for high impact

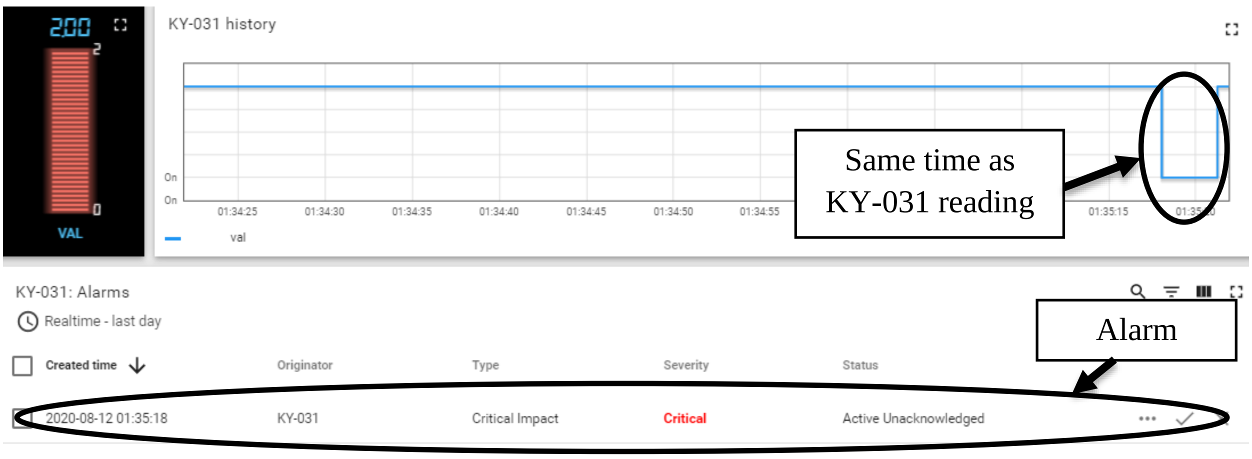


Figure 4.8: KY-031 sensor's details dashboard for high impact

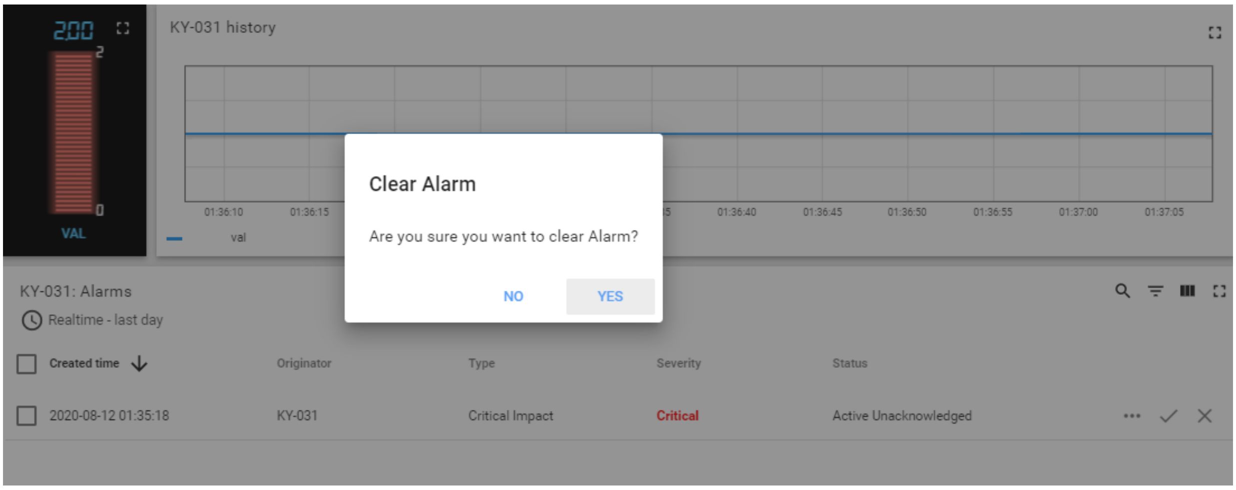


Figure 4.9: Clearing the KY-031 sensor's alarm by an authorized person

4.3 Alarm Based on Head Position

Figure 4.10 shows the helmet placed at the original or normal position on the watermelon (dummy head). The normal position is referred to as the user's head position while standing, walking, or sitting steadily. Figure 4.11 shows the tilt sensor output while the helmet is at its normal position.

Figure 4.10: Helmet in normal position

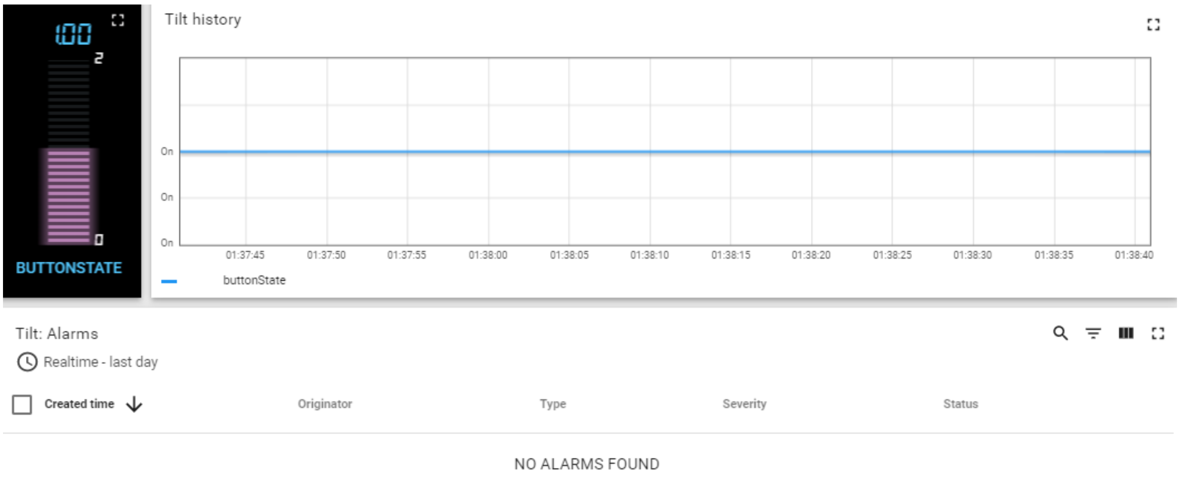


Figure 4.11: Tilt sensor's details when helmet in normal position

Once, the watermelon moves to a 90° from its original position (lay down position) as shown in figure 4.12, the state of the tilt sensor on the dashboard changes as shown in figure 4.13. Besides, the dashboard also created an alarm as soon as the state of the tilt sensor changes. The alarm will be cleared automatically when the helmet back to its normal position as shown in figure 4.14. As long as the helmet is in the laydown position, the alarm will be continuously triggered on the dashboard.

Figure 4.12: Helmet in the laydown position

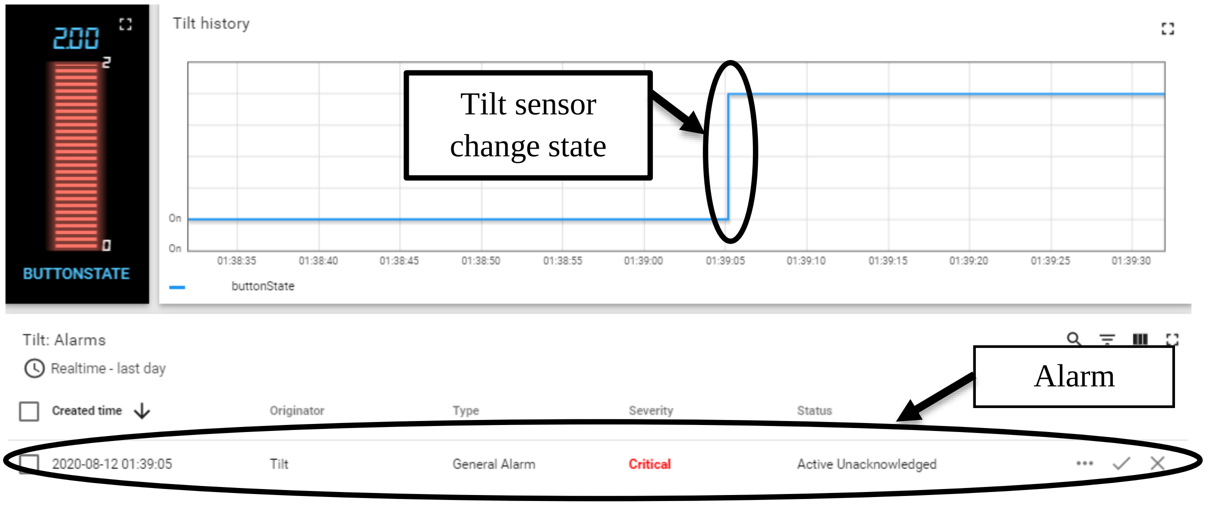


Figure 4.13: Tilt sensor's details when helmet in the laydown position

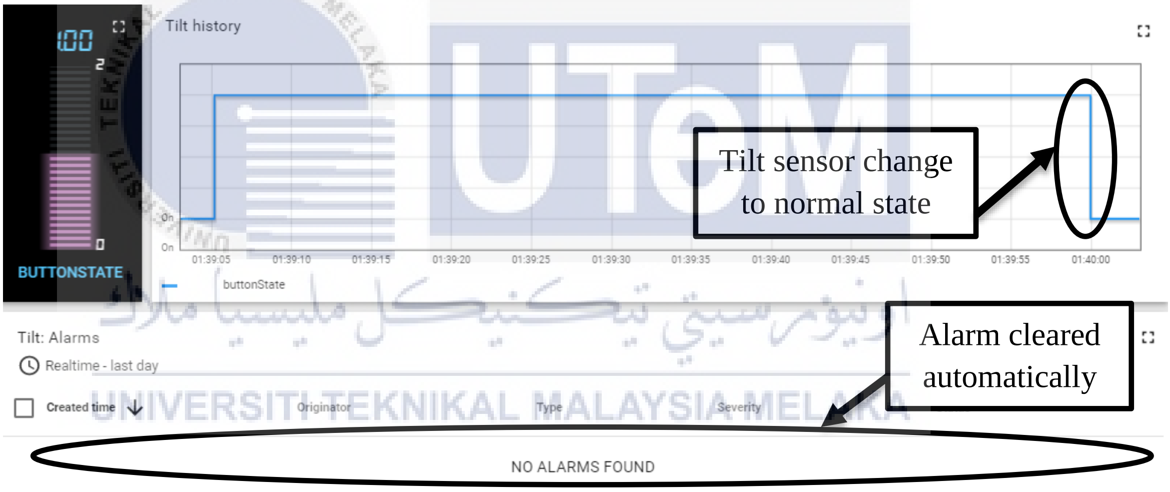


Figure 4.14: Tilt sensor's details when helmet back to normal position

4.4 Alarm Based on Pushbutton

Pushbutton is another alternative way to create an emergency alarm. The "PANIC" pushbutton needs to be pressed and hold for 2 seconds as shown in figure 4.15 to create an alarm on the dashboard as shown in figure 4.16.

Figure 4.15: Utilization of PANIC pushbutton

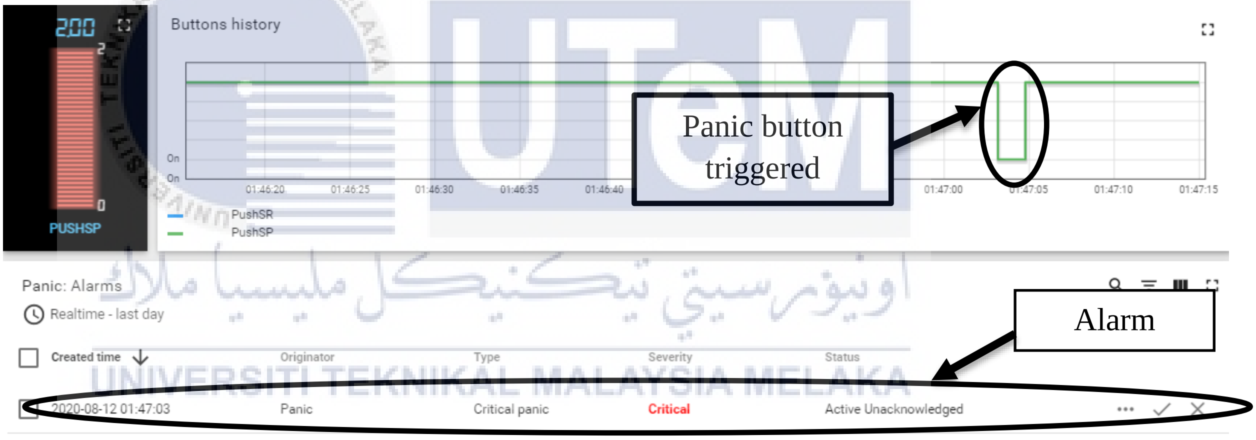


Figure 4.16: Dashboard with Panic Alarm

The “RESET” pushbutton is used to clear the created alarm wirelessly by the users themselves. The red color LED on the helmet will light up when there is an alarm as shown in figure 4.17. The created alarm can be cleared by the user using the “RESET” pushbutton.

Figure 4.17: Red LED on the helmet to indicate the created alarm at the dashboard

4.5 Analyze Data from FSR Dashboard

Figure 4.18 shows the FSR dashboard with the time interval option. The time interval option is used to retrieve data from the dashboard. Figure 4.19 shows the FSR dashboard with the pressure act on the helmet for 5 hours interval. Besides, the dashboard also able to view the time-based FSR sensor value.

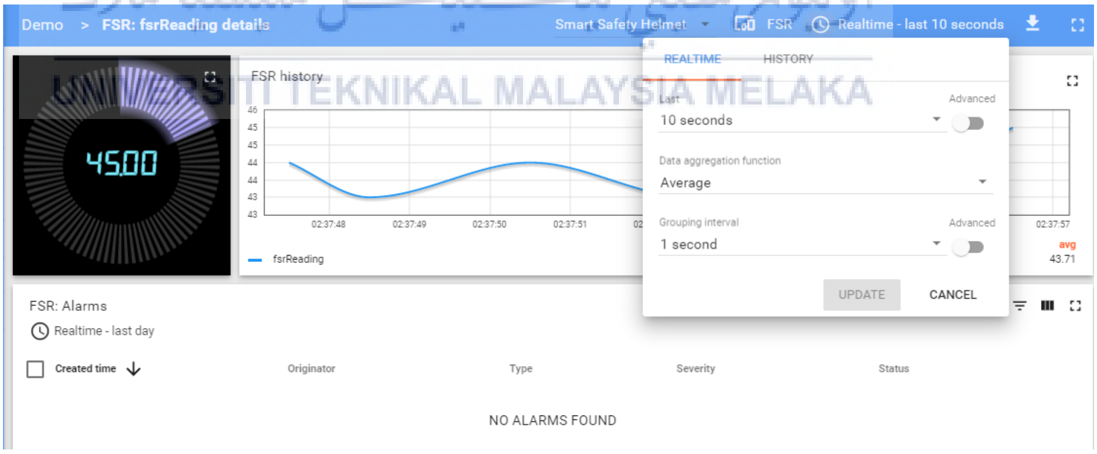


Figure 4.18: Time interval option available on the dashboard

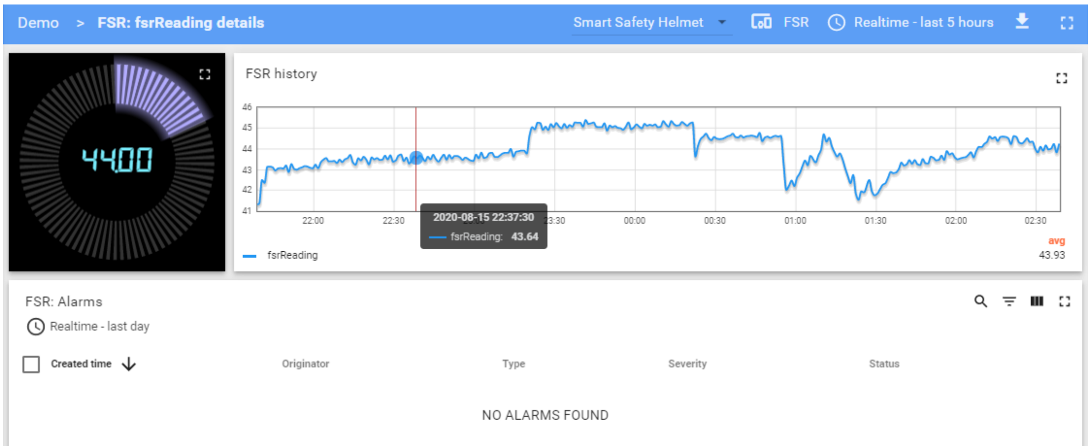


Figure 4.19: Pressure history for 5 hours interval

4.6 Coverage distance

Figure 4.20 shows, the FSR history for 10 minutes. The helmet was keep moved further to analyze the data receiving capability with distance. After 14.10 minutes the dashboard stops receiving data. The distance between the LoRa gateway and the helmet is measured to be around 420 meters. Thus, the coverage range is at a radius of 420 meters. Once the helmet moved back to the coverage range, the data is received normally.

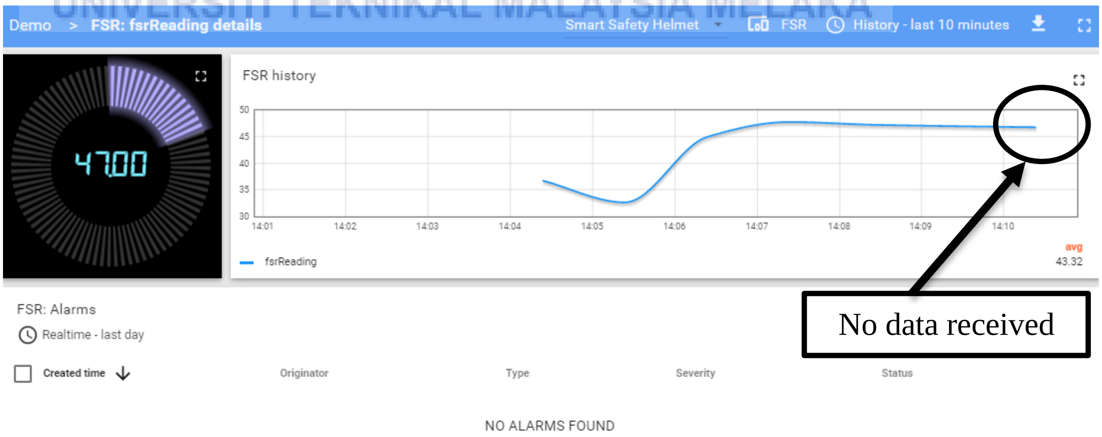


Figure 4.20: FSR history for a 10-minute interval

The reason behind the shorter coverage distance is the place where the test conducted. Theoretically, it is stated that RFM 95 can transmit data up to 3km. The test at a bare ground proves that LoRa transmission is up to 3km. However, the Smart Safety Helmet is tested at a housing area due to the coronavirus outbreak. Thus, the transmission range is shorter.

4.7 Conclusion

This chapter has explained the result obtained. The results include the changes on the helmet and the dashboard. The timeframe from the dashboard proves the changes in the state between two different sensors. The next chapter will conclude the project outcome and discuss possible future works.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

In conclusion, the objective of this project is to design and develop a safety helmet to monitor the impact on the safety helmet wirelessly using Long Range, LoRa communication technology and to store data about the amount of pressure act on the helmet due to falling objects using suitable Internet of Things (IoT) platform. A circuit connecting all the sensors with Arduino Nano was initially designed and developed. The circuit then extended by connecting an RFM 95 module to transmit data to the LoRa gateway wirelessly. A dashboard was designed using the ThingsBoard application to display the received data. The dashboard is also useful to retrieve data about the amount of pressure act on the helmet for last 7 days.

By doing this project, I can apply the knowledge that we get from the University of Technical Malaysia Melaka (UTeM) in a good manner. The project was successful because I carried out all the tests when finishing the project. Some more I have followed all the procedures given correctly. I hope that this project will give many advantages to the government and underground mining works. The objectives are achieved.

5.2 Future Work

The Smart Safety Helmet can be improved in the future for a better outcome. I suggest adding some sensors to measure the safety of the surrounding. A gas sensor can be added to measure the oxygen level, carbon dioxide level, and carbon monoxide level as the mining area is very much exposed to these gases. Thus, a reminder can be created do notify users if they are in a place that exposes to carbon dioxide and carbon monoxide gases for a long time.

Besides, artificial intelligence (AI) technology can be used to track the helmet. This can help to identify the user who works at a hidden place. As the medical team can track the user faster and efficiently.

A notification alarm to the mobile phone is another suggestion to improve this project. The notification alarm via mobile phone will help the supervisors to get know about any accidents immediately. This also can avoid any unnoticed accidents.

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APPENDICES

LoRa Client Code (Uploaded through Arduino Nano)

```
#include <SPI.h>
#include <RH_RF95.h>

RH_RF95 rf95;

int buttonPin=7;
int buttonState;
int fsrAnalogPin = A0;
int fsrReading;
int Shock = 6;
int val;
int pushR = 4;
int pushP =3;
int danger1 = 5;
int pushSP;
int pushSR;

float frequency = 915.0;
```

```
void setup() {
 Serial.begin(9600);
 while (!Serial) ; // Wait for serial port to be available
 Serial.println("Start LoRa Client");
 if (!rf95.init())
   Serial.println("init failed");
 else
   Serial.println("init OK!");
 // Setup ISM frequency
 rf95.setFrequency(frequency);
 // Setup Power,dBm
 rf95.setTxPower(13);

 // Setup Spreading Factor (6 ~ 12)
 rf95.setSpreadingFactor(7);

 // Setup BandWidth, option: 7800,10400,15600,20800,31200,41700,62500,125000,250000,500000
 //Lower BandWidth for longer distance.
 rf95.setSignalBandwidth(125000);

 // Setup Coding Rate:5(4/5),6(4/6),7(4/7),8(4/8)
 rf95.setCodingRate4(5);

}
uint16_t calcByte(uint16_t crc, uint8_t b)
```

```
{
    uint32_t i;
    crc = crc ^ (uint32_t)b << 8;

    for ( i = 0; i < 8; i++)
    {
        if ((crc & 0x8000) == 0x8000)
            crc = crc << 1 ^ 0x1021;
        else
            crc = crc << 1;
    }
    return crc & 0xffff;
}
uint16_t CRC16(uint8_t *pBuffer,uint32_t length)
{
    uint16_t wCRC16=0;
    uint32_t i;
    if (( pBuffer==0 )||( length==0 ))
    {
      return 0;
    }
    for ( i = 0; i < length; i++)
    {
      wCRC16 = calcByte(wCRC16, pBuffer[i]);
    }
```

```
  return wCRC16;
}


void loop()
{


 fsrReading = analogRead(fsrAnalogPin) + 1;
 val = digitalRead (Shock) + 1;
 pushSR = digitalRead(pushR) + 1;
 pushSP = digitalRead(pushP) + 1;
 buttonState = digitalRead (buttonPin) + 1;


  unsigned char data[50] = {0} ;
  // Use data[0], data[1],data[2] as Node ID
  data[0] = 1 ;
  data[1] = 1 ;
  data[2] = 1 ;
  data[3] = fsrReading;
  data[4] = val;
  data[5] = buttonState;
  data[6] = pushSR;
  data[7] = pushSP;

 if (fsrReading>=100 & val == 2){
 digitalWrite(danger1, HIGH);
```

```
}

if (pushSP == 1){
digitalWrite(danger1, HIGH);
}

 if (pushSR == 1){
digitalWrite(danger1, LOW);
}

  int p = data[3];
  int k = data[4];
  int t = data[5];
  int rs = data[6];
  int pn = data[7];

  Serial.print("FSR:");
  Serial.println(p);
  Serial.print("Impact:");
  Serial.println(k);
  Serial.print("Tilt:");
  Serial.println(t);
  Serial.print("Reset:");
  Serial.println(rs);
```

```
Serial.print("Panic:");
Serial.println(pn);

int dataLength = strlen(data);//CRC length for LoRa Data

uint16_t crcData = CRC16((unsigned char*)data,dataLength);//get CRC DATA

unsigned char sendBuf[50]={0};
int i;
for(i = 0;i < 8;i++)
{
  sendBuf[i] = data[i] ;
}

sendBuf[dataLength] = (unsigned char)crcData; // Add CRC to LoRa Data

sendBuf[dataLength+1] = (unsigned char)(crcData>>8); // Add CRC to LoRa Data

rf95.send(sendBuf, strlen((char*)sendBuf));//Send LoRa Data
Serial.println("Sending to LoRa Server");

uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];//Reply data array
uint8_t len = sizeof(buf);//reply data length
  if (rf95.waitAvailableTimeout(300))
{
```

```
// Should be a reply message for us now
    if (rf95.recv(buf, &len))//check if reply message is correct
    {
        if(buf[0] == 1||buf[1] == 1||buf[2] == 1) // Check if reply message has the our node ID
        {
            pinMode(4, OUTPUT);
            digitalWrite(4, HIGH);
            Serial.print("got reply: ");
            Serial.println((char*)buf);

            delay(400);
            digitalWrite(4, LOW);
        }
    }
else
    {
        Serial.println("recv failed");//
        rf95.send(sendBuf, strlen((char*)sendBuf));//resend if no reply
    }
}
else
{
    Serial.println("No reply, is LoRa server running?");//No signal reply
    rf95.send(sendBuf, strlen((char*)sendBuf));//resend data
}
```

```
  delay(500);
}
```

LoRa Server Code (Uploaded through LoRa gateway)

```
#define BAUDRATE 115200
#include <Console.h>
#include <SPI.h>
#include <RH_RF95.h>
#include <PubSubClient.h>
#include "YunClient.h"
#define NAME "FSR"
#define TOKEN "C3ssFGj9U8YSOaWlIhXS"
#define NAME1 "KY-031"
#define TOKEN1 "wZixzkjcHRAXHsRXrsJq"
#define NAME2 "TILT"
#define TOKEN2 "7JifseBJFSGr7W9ApRBJ"
#define NAME3 "RESET"
#define TOKEN3 "R2sm7TQxDxWB3ECeSayj"
#define NAME4 "PANIC"
#define TOKEN4 "UsFJwPN1WAOSnI9I1V0T"


RH_RF95 rf95;
 int a;
 int p;
 int k;
 int t;
 int rs;
 int pn;
```

```
int led = A2;
uint16_t crcdata = 0;
uint16_t recCRCData = 0;
float frequency = 915.0;
YunClient yun;
PubSubClient client("iiotsme.com", 1883, yun);
void setup() {
  pinMode(led, OUTPUT);
  Bridge.begin(BAUDRATE);
  Console.begin();
  while (!Console) ;
  Console.println("Start Sketch");
  if (!rf95.init())
    Console.println("init failed");
  rf95.setFrequency(frequency);
  rf95.setTxPower(13);

  rf95.setSpreadingFactor(7);

  // Setup BandWidth, option: 7800,10400,15600,20800,31200,41700,62500,125000,250000,500000
  rf95.setSignalBandwidth(125000);

  // Setup Coding Rate:5(4/5),6(4/6),7(4/7),8(4/8)
  rf95.setCodingRate4(5);
```

```
  Console.print("Listening on frequency: ");
  Console.println(frequency);
}
uint16_t calcByte(uint16_t crc, uint8_t b)
{
    uint32_t i;
    crc = crc ^ (uint32_t)b << 8;

    for ( i = 0; i < 8; i++)
    {
      if ((crc & 0x8000) == 0x8000)
        crc = crc << 1 ^ 0x1021;
      else
        crc = crc << 1;
    }
    return crc & 0xffff;
}

uint16_t CRC16(uint8_t *pBuffer, uint32_t length)
{
    uint16_t wCRC16 = 0;
    uint32_t i;
    if (( pBuffer == 0 ) || ( length == 0 ))
    {
        return 0;
```

```
    }
    for ( i = 0; i < length; i++)
    {
        wCRC16 = calcByte(wCRC16, pBuffer[i]);
    }
    return wCRC16;
}

uint16_t recdata( unsigned char* recbuf, int Length)
{
    crcdata = CRC16(recbuf, Length - 2); //Get CRC code
    recCRCData = recbuf[Length - 1]; //Calculate CRC Data
    recCRCData = recCRCData << 8; //
    recCRCData |= recbuf[Length - 2];
}
```



```
void loop() {
 if (rf95.waitAvailableTimeout(300))
  {
    // Should be a message for us now
    uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
    uint8_t len = sizeof(buf);
    if (rf95.recv(buf, &len))
        {
          Console.println("Hai");
```

```
recdata( buf, len);
if(crcdata == recCRCData) //Check if CRC is correct
{
  if(buf[0] == 1||buf[1] == 1||buf[2] == 1) //Check if the ID match the LoRa Node ID
  {
    int newData[6] = {0, 0, 0, 0, 0, 0}; //Store Sensor Data here
    for (int i = 0; i < 5; i++)
    {
      newData[i] = buf[i+3];
    }

    p = newData[0];
    k = newData[1];
    t = newData[2];
    rs = newData[3];
    pn = newData[4];

    Console.print("FSR:");
    Console.println(p);
    Console.print("Impact:");
    Console.println(k);
    Console.print("Tilt:");
    Console.println(t);
    Console.print("Reset:");
    Console.println(rs);
```

```
                Console.print("Panic:");

                Console.println(pn);


            }

        }

     a=1;

    uint8_t data[] = "And hello back to you";

    rf95.send(data, sizeof(data));

    rf95.waitPacketSent();

    Console.println("Sent a reply");

      }

   else

   {

    Console.println("recv failed");

    a=0;


   }

 }

if (client.connect(NAME, TOKEN, NULL))

   {

    //a=2;

    char telemetry [100];

    String data = String("{\"fsrReading\": " + String(p) + "}");

    data.toCharArray(telemetry, 100);

    client.publish("v1/devices/me/telemetry", telemetry);
```

```
    client.disconnect();
  }
if (client.connect(NAME1, TOKEN1, NULL))
  {
    //a=2;
    char telemetry [100];
    String data = String("{\"val\": " + String(k) + "}");
    data.toCharArray(telemetry, 100);
    client.publish("v1/devices/me/telemetry", telemetry);
    client.disconnect();
  }
 if (client.connect(NAME2, TOKEN2, NULL))
  {
    //a=2;
    char telemetry [100];
    String data = String("{\"buttonState\": " + String(t) + "}");
    data.toCharArray(telemetry, 100);
    client.publish("v1/devices/me/telemetry", telemetry);
    client.disconnect();
  }
     if (client.connect(NAME3, TOKEN3, NULL))
  {
    //a=2;
    char telemetry [100];
    String data = String("{\"PushSR\": " + String(rs) + "}");
```

```
    data.toCharArray(telemetry, 100);
    client.publish("v1/devices/me/telemetry", telemetry);
    client.disconnect();
  }
   if (client.connect(NAME4, TOKEN4, NULL))
  {
    //a=2;
    char telemetry [100];
    String data = String("{\"PushSP\": " + String(pn) + "}");
    data.toCharArray(telemetry, 100);
    client.publish("v1/devices/me/telemetry", telemetry);
    client.disconnect();
  }
}
```