DEVELOPMENT OF LOW-COST VIBRATION MONITORING MACHINE LEARNING SYSTEM ON MACHINERY USING IOT

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2024

Faculty of Mechanical Technology and Engineering

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Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

2024

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**A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours**

Faculty of Mechanical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: DEVELOPMENT OF LOW-COST VIBRATION MONITORING MACHINE LEARNING SYSTEM ON MACHINERY USING IOT

SESI PENGAJIAN: **2023-2024 Semester 1**

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DEDICATION

Dedicated, grateful and thankful appreciation for support, encouragement, and understanding to my beloved father, mother, brothers, and sisters.

Whose support, encouragement, and prayers throughout the day and night enable me to achieve such accomplishment and honour.

Project supervisor, Ts. Dr. Mohd Irman Bin Ramli

Project Co- supervisor, Ts. Dr. Ahmad Fuad bin Ab Ghani

Along with everyone who is related and most well

Lectures and friends

ABSTRACT

Vibration analysis is crucial to this project. The goal of this project is to demonstrate growing interest of Blynk IoT applications by creating a low-cost vibration monitoring system with which to monitor the vibration of the target machinery. The Hibiscus Sense, an accelerometer (model number: GY-521 MPU6050), and a 5000mAh battery pack make up this cheap vibration monitoring system. The Hibiscus Sense is an ESP32 development board that incorporates a microcontroller, accelerometer MPU6050, and temperature sensor BME280. It was a piece of equipment that connected to the Internet of Things and exchanged data using radio frequency networks like Wi-Fi and Bluetooth Low Energy (BLE). The CPU within the Hibiscus Sense manages the MPU6050 and GY-521 accelerometers and sends the data they collect over Wi-Fi to the Blynk app. Three MPU6050s are used to monitor the motor's vibrations. This cheap vibration monitor is controlled using the Arduino Software Development Kit (IDE) and Blynk. For vibration analysis, the Arduino IDE is used to build the code, while Blynk is utilized to display the received data in gauge form and trend form.

ABSTRAK

Analisis getaran adalah penting untuk projek ini. Matlamat projek ini adalah untuk menunjukkan minat yang semakin meningkat terhadap aplikasi Blynk IoT dengan mencipta sistem pemantauan getaran kos rendah untuk memantau getaran jentera sasaran. Hibiscus Sense, pecutan (nombor model: GY-521 MPU6050), dan pek bateri 5000mAh membentuk sistem pemantauan getaran murah ini. Hibiscus Sense ialah papan pembangunan ESP32 yang menggabungkan mikropengawal, pecutan MPU6050 dan sensor suhu BME280. Ia adalah peralatan yang disambungkan ke Internet Perkara dan bertukar-tukar data menggunakan rangkaian frekuensi radio seperti Wi-Fi dan Bluetooth Tenaga Rendah (BLE). CPU dalam Hibiscus Sense mengurus pecutan MPU6050 dan GY-521 dan menghantar data yang mereka kumpul melalui Wi-Fi ke apl Blynk. Tiga MPU6050 digunakan untuk memantau getaran motor. Pemantau getaran murah ini dikawal menggunakan Arduino Software Development Kit (IDE) dan Blynk. Untuk analisis getaran, Arduino IDE digunakan untuk membina kod, manakala Blynk digunakan untuk memaparkan data yang diterima dalam bentuk tolok dan bentuk trend.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise my God, my Creator, for everything I received since the beginning of my life. I would like to express my sincere appreciation to Universiti Teknikal Malaysia Melaka (UTeM) on providing all necessary platform for me tocomplete this project.

My utmost appreciation goes to my main supervisor, Ts. Dr. Mohd Irman Bin Ramli, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice, and inspiration. His continuous patience in instructing and imparting significant insight will be remembered for the rest of the time. Also, to my co-supervisor, Tr. Dr. Ahmad Fuad Bin Ab Ghani, Faculty of MechanicalEngineering, Universiti Teknikal Malaysia Melaka (UTeM) who constantly supported my journey. My special thanks go to Tc. Mohd Khairul Bin Hassan for all the help and assistanceI received from you.

Last but not least, I would also like to thank my beloved parents for their endless support, love and prayers. Finally, thank you to all the individual(s) who had provided me the assistance, support, and inspiration to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
a	-	Acceleration
FFT	-	Fast Fourier Transform
MEMS	-	Micro-Electro-Mechanical System
kHz	-	Kilohertz
IC	-	Intergrated Circuit
SoC	-	System-On-Chip
IDE	-	Intergrated Developement Environment
t	-	Time
temp	-	Temperature

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CHAPTER 1

INTRODUCTION

1.1 Background

The phrase "vibration" refers to a succession of separate vibrations, each of which has its own frequency, direction, and typically short duration. (Tricker & Tricker, 1999). Vibration is the short-distance, mass-constrained motion toward equilibrium. Since the force pulling on the oscillator always points toward the equilibrium point, the mass will eventually settle back to that point regardless of how it oscillates. The only way for the vibration to stay close to the equilibrium point is if the force (the elastic force in a solid) acts in the opposite direction as the motion. Since the operating force and displacement are in opposite directions, vibration can be defined as a sort of mass motion (Yang, 2014).

Vibration analysis is the process of monitoring the levels and patterns of vibration signals within a component, machinery, or building to detect aberrant vibration events and assess the overall condition of the test object. Usually Fourier-based analysis has been used to convert vibration data from the time domain to the frequency domain for use in condition monitoring of dynamic systems. However, signals that were tightly constrained in time were not effectively represented by Fourier analysis. It is challenging to detect and identify the signal pattern from the expansion coefficients in this scenario since the information is spread thin throughout the entire basis. We present the wavelet packet transform (WPT) as an alternate approach to time-frequency information extraction from vibration signals. Using the generated WPT coefficients, one can obtain signal time-frequency resolution of their choosing. Many of the feature components with minimal discriminant information could be removed with the use of statistically-based feature selection rules, leading to a feature subset with fewer parameters without impacting the classification performance. The derived lower dimensional feature vector is sent into a neural network classifier. This greatly shortens the normally lengthy training time required by the neural network classifier and boosts its capacity to generalize. (G.G. Yen, 2000)

The wavelet transform is a relatively recent and strong tool in the field of structural health monitoring utilising vibration analysis. Common signal analysis methods based on spectral approaches, like the rapid Fourier transform, can effectively diagnose a wide range of vibration-related issues in rotating machinery. Despite their usefulness as diagnostic tools under steady-state conditions, these methods fall short when dealing with non-stationary data, which may be produced by fast operational conditions like the rapid start-up of an electrical motor, or by the presence of a fault that causes a discontinuity in the vibration signal being monitored. (F. Al-Badour, 2011)

In order to accurately measure vibrations with very large amplitudes and very high frequencies, most commercially available vibration sensors employ piezo-electric crystal technology. Strain sensors can be used in these situations as well. In cases when non-contact measurement of very weak vibrations is necessary, proximity probes can be used. Proximity probes may utilize either eddy currents, capacitive, or inductive technology. It is also possible to utilize laser and ultrasonic sensors to detect vibration and movement

1.2 Problem Statement

Nowadays, the high price of a vibration monitoring system makes it difficult for startups to deploy industrial vibration monitoring systems, which in turn prevents thorough inspection of machines' health. As a result, there is an urgent requirement for a cheap vibration monitoring system that can be readily adopted by small enterprises for health checks on machinery. There are many low-cost vibration sensors on the market, and Arduino is a widely used programming language for controlling them. Arduino IDE commands will be used to capture vibration data from machines utilizing the hibiscus sense ESP32 and the MPU6050 vibration sensor. The Blynk IoT app will be used to display the gathered data for the purpose of vibration analysis.

As an added complication, people may question the authenticity and accuracy of data collected by inexpensive vibration sensors. To solve this problem, we'll do a data validation procedure by comparing the readings from our inexpensive vibration monitoring sensors to those from a commercially available vibration monitoring system. Through this study, we will be able to evaluate the sensors' precision and responsiveness.

Checking the condition of machinery used in industry is crucial to avoiding production line slowdowns and other indirect effects of sudden machine failures. A low-cost vibration monitoring system is necessary to prevent the unexpected breakdown of machine parts, in accordance with the adage "Prevention is better than cure," as such a system can aid the industry in identifying which parts may be out of balance, misaligned, worn, or loose. When compared to the cost of maintaining an industrial vibration monitoring system, its periodic inspections are more affordable.

1.3 Research Objective

The objectives of this project are:

a) To produce and verify a low-cost vibration monitoring system for axis x, y and z.

b) To conduct Blynk software develepmont for low-cost vibration monitoring system

1.4 Scope of Research

The following are the project's scopes:

a. Monitoring the vibration for the machine

b. The frequency range that can be detected is 1kHz to 8kHz

c. Arduino IDE software and Blynk iot software will use.

1.5 Summary

In this low-cost vibration monitoring system report, there are five chapters, each covering a different type of topic. Each topic will describe and contain different titles which are the Introduction, Literature Review, Methodology, Results and Analysis, and Discussion and Conclusion. The following is a detailed overview of each chapter's thesis outline:

Chapter 1: Introduction. This part of the report will describe the categories of project in general terms. This section will list the objectives of the project. The project's scopes will also be given in this part of the report.

Chapter 2: Literature Review. This section will explain the preparation of vibration monitoring system in detail. This chapter will provide a more in-depth description of the project title which is supported by previous research. This section will build on the theoretical and conceptual ideas of vibration monitoring systems that have been studied before.

Chapter 3: The methodology of the project is about the overall flow of the entire project. This part will discuss development of a low-cost vibration monitoring system.

Chapter 4: The result and the analysis. This part of the report will explain about the outcome Obtained, as well as the performance of the system.

Chapter 5: Discussion and Conclusion. This chapter will highlight accomplishments, practicalities, and future recommendations. Lastly, the project's conclusion will also be present in this section.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This report's section will assess the theoretical and conceptual frameworks relevant to the project's title. The theoretical and conceptual ideas presented in this chapter will be backed up by a variety of sources, including but not limited to books, journals, articles, and periodicals.

2.2 Vibration

In terms of the 12 Universal Laws, the law of vibration comes in second. Everything in the universe is always moving and vibrating at a specific frequency, according to this law. Even our ideas, feelings, and beliefs have a specific frequency at which they resonate (DailyDish, 2023). The act of vibrating, the condition of vibrating, or the motion of vibrating; moving quickly from one place to another; swinging, as in a pendulum or string. Physics defines vibration as a constrained continuous rotation of a molecule within an elastic object or substance in the opposite direction of its equilibrium point. When the balance is upset, as happens when an extended cord or other body makes tones or air molecules bring melodies to the ear, the route of the particle can be straight, spherical, or have another curve. (Biology Online, 2021).

In mechanics, vibration and oscillation are often used interchangeably to represent the same type of motion, that of a wobbling or up-and-down movement of a hanging or stable body. Both phrases mean the same thing, although their applications are slightly different. A vibration is a brief, quick motion in one direction or the other, or to and from a fixed point. Various variables, including as disruptions, forces of attraction among atoms within a body, and external forces operating on the system, can all contribute to this phenomenon. Vibration is typically associated with high frequencies and rapid oscillations of the body. Oscillation is more broadly used to describe any repetitive motion of a body around a stable equilibrium point. It's not limited to either slow or rapid motion, and is typically connected with periodic back and forth motion. Depending on the system or forces at play, oscillation can take place over a wide range of frequencies and amplitudes (Biology Online, 2021).

An object's amplitude of vibration is the greatest angle by which it can rotate relative to its original position during a period of oscillation. Part of the motion of a particle or body that can be characterized by a whole vibration, as opposed to, say, moving from one end to the other, or resting on one edge of a surface rather than the other. Two substances are said to be "in phase" if they are moving in the same direction and at the same speed, or if their paths of motion cross. (Biology Online, 2021).

When a rigid or elastic body is displaced from its equilibrium position, it creates a motion known as vibration. This vibration can take the form of oscillating, reciprocating, or periodic motion. Harmonic vibration occurs when both the frequency and magnitude of the vibration remain constant. On the other hand, random vibration refers to a situation where the frequency and magnitude of the vibration change over time (Steffan Kasula, 2018). Excessive vibrations in rotating shafts, such as those seen in pumps, gearboxes, turbines, and compressors, are a warning sign of a potentially dangerous situation. Such tremors are an indicator that the machinery won't survive as long as it should, which could lead to breakdowns and other problems down the line. Alignment issues, unbalance, resonance, loose parts, damaged bearings, and damaged or worn gears are the most prevalent six causes of machine vibration (istec, 2018).

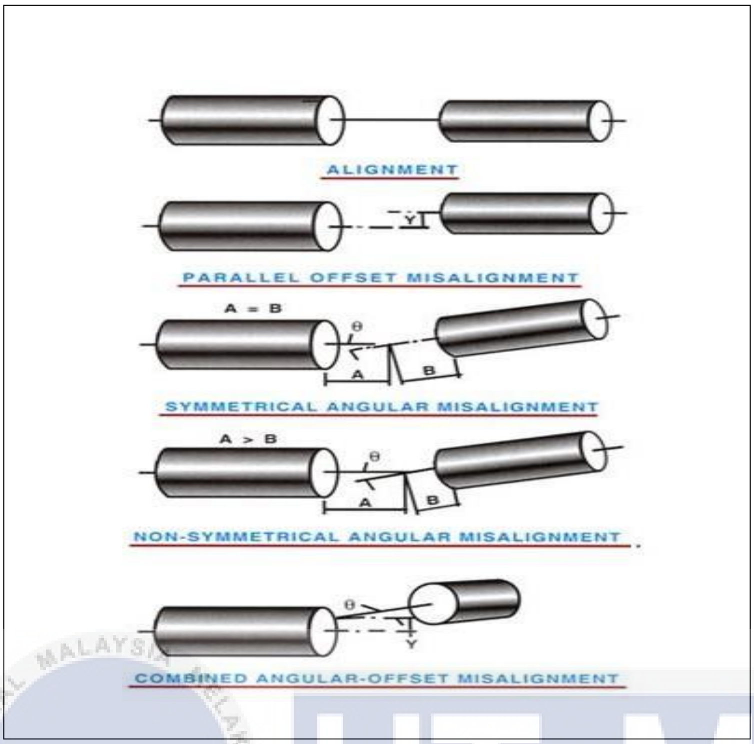

Figure 2.1 Types of the alignment problem

Figure 2.2 Types of the unbalance

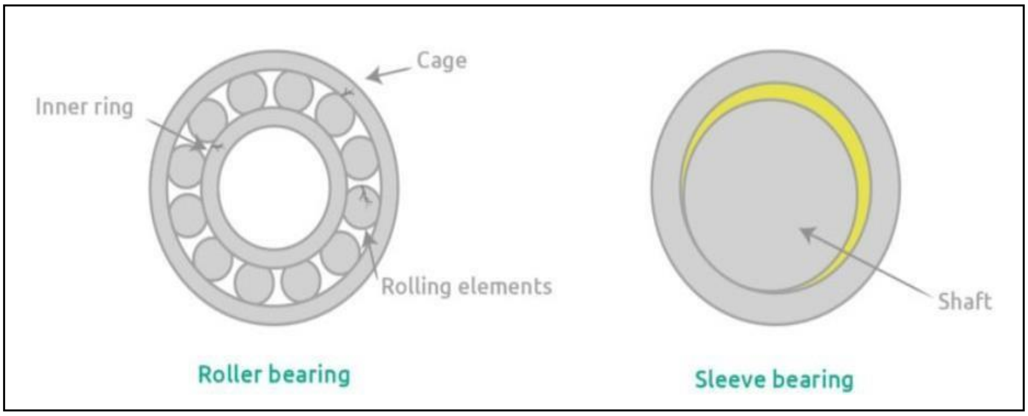

Figure 2.3 Types of the bearing damage

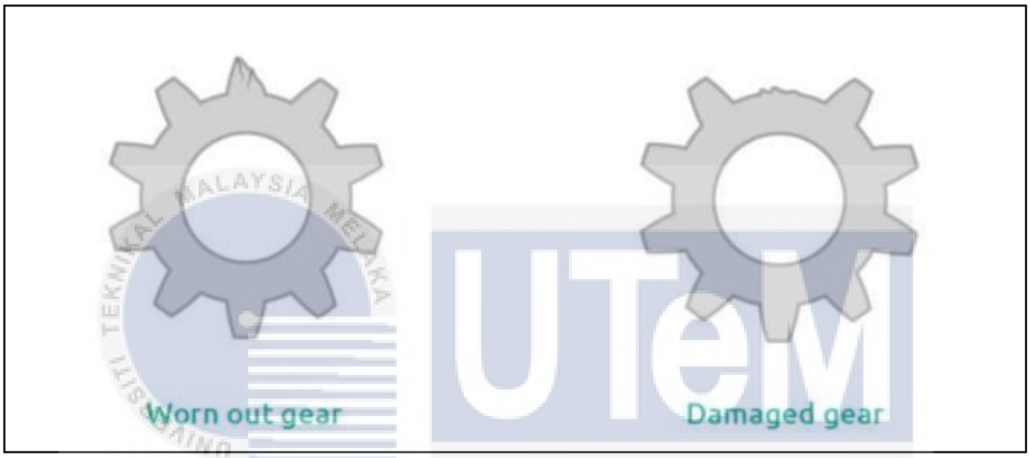

Figure 2.4 Types of the damaged or worn-out gear

2.3 Sensor

A sensor is a device that sends out some kind of signal in response to some kind of input. The phrase "input device" implies that the sensor is a subsystem that feeds information into a more central system, like a processor or microcontroller. According to yet another definition, a sensor is a detection device that "transmits electrical impulses from one domain to another." (Ravi Teja, 2021)

2.3.1 Vibration Sensor

To detect mechanical vibrations, needs a vibration sensor. It monitors the vibration levels of your machinery and notifies you of any impending dangers, such as the need to repair broken or old parts.

By anticipatorily detecting these issues, vibration sensors can assist boost productivity and reduce maintenance costs. In order to detect vibrations, shocks, and sounds, we have vibration sensors. They can be installed in machines to foresee potential breakdowns. Vibration sensors are able to detect the movement of a substance or an item by picking up on the frequency of the vibrations. A vibration sensor will pick up a higher frequency reading the faster the motion is.

In the industrial industry, for instance, abnormal vibrations can indicate a problem with the bearings. Flexible motion is made possible, and vital parts like gears and motors are supported and stabilized, thanks to bearings. These components are susceptible to wear and breakdown from abnormal vibrations. (FlixSoftware, 2016)

2.3.1.1 Piezoelectric Vibration Sensor

Piezoelectric vibration sensors, commonly known as piezo vibration sensors, detect and record variations in physical properties and forces. The applied force creates an electrical charge, which is then read as electrical signals. Highly accurate and dependable data can be collected with piezo vibration sensors, which can also withstand harsh conditions. They're not phased by a large temperature swing. However, these vibration sensors consume more power than any others (PRUFTECHNIK, 2021).

2.3.1.2 Eddy-Current Vibration Sensor

Eddy-current sensors are non-contact detectors that use eddy current principles to measure movement. Eddy currents are loops of electrical current that occur inside a conductor when that conductor is subjected to a fluctuating magnetic field. Eddy-current vibration sensors are commonly used for measuring shaft displacement. Misalignment like this is one example of a mechanical issue that might be uncovered through vibration monitoring. Eddy-current sensors excel in measuring vibrations with a high frequency and high resolution. If you're using a lot of eddy-current vibration sensors, be sure they aren't too close to one another. Having them too near together can cause their electric fields to interfere with one another, resulting in less accurate readings (PRUFTECHNIK, 2021).

2.3.1.3 Accelerometer Vibration Sensor

Vibrations are commonly measured with ceramic piezoelectric sensors or accelerometers. Accelerometers rely primarily on the piezoelectric phenomenon, in which a voltage is formed across particular crystals when they are subjected to a load. The acceleration of the structure under test is transmitted to a seismic mass inside the accelerometer, resulting in a proportionate force on the piezoelectric crystal. This force causes the crystal to generate an electrical charge that has a high impedance and is proportional to the applied force and acceleration.

There are two primary types of accelerometers: Piezoelectric accelerometers (charge mode) and integrated electronic piezoelectric accelerometers (IEPE). These accelerometers are generally linked directly to high-frequency components such as rolling bearings, gears, or revolving blades. They are adaptable sensors used for a range of applications, including shock measurements (e.g., explosions, fault testing) and slower, low-frequency vibration measurements. Accelerometers offer advantages such as linearity over a wide frequency range and a big dynamic range.(National Instrument, 2020)

Accelerometers in charge mode require an external amplifier or inline charge converter to amplify the generated charge, lower output impedance for compatibility with measuring equipment, and minimize susceptibility to external noise sources and crosstalk. Piezoresistive accelerometers (PR) are much less sensitive than piezoelectric accelerometers and are ideal for load and transport collision testing. The resistance of a piezoresistive accelerometer increases in proportion to the pressure applied to it. Because of their limited sensitivity, they are often little used for vibration analysis. PR Accelerometers have a large capacitance and a sampling rate that drops to 0 Hz, so they can monitor long duration vibration. The capacitive accelerometer is the third type of accelerometer. In capacitive accelerometers, the acceleration of an object is determined by changes in electrical capacitance. These accelerometers are characterized by high sensitivity, low bandwidth, and excellent temperature stability. These sensors can be used to measure low-frequency vibrations, movements and steady-state accelerations (ets solutions, 2021).

2.4 Micro-electro-mechanical System (MEMS)

On April 1, 1954, what is today known as MEMS technology had its debut in an essay by Smith (1954) published in Physical Review at the Bell Telephone Lab. Piezo resistors, a phenomenon in silicon and germanium that is responsive to stress, have never before been described. Due to the vast scope and variety of devices and systems that are being shrunk, MEMS is not the most appropriate acronym to describe the field (i.e., the field is not just micro, electrical, and mechanical systems) (Algamili et al., 2021).

However, in the United States, the acronym MEMS (sometimes spelt micro-electro-mechanical, Microelectromechanical, or micro- electronic and MEMS) is most commonly used to refer to the entire field (i.e., all devices arising from micromachining other than integrated circuit (IC)). This fundamental subfield of miniaturization goes by a variety of names in different parts of the world, including the more well-known Microsystems Technology (MST) in Europe and the more obscure Micromechanics in Asia. The data collection and signal processing processes of MEMS devices span many different disciplines. (Algamili, A., A. A., & A. 2021).

The acronym "MEMS" stands for "Micro Electro Mechanical Systems," as defined by the Administrator Electronics Hub in 2019. Microscale devices that employ this technology include sensors, transducers, actuators, gears, pumps, and switches. In other terms, microelectromechanical systems (MEMS) are tiny integrated electronics made up of electronics, electricity, and mechanics that work together to meet a single need using a technology called MST.

When compared to the conventional method of manufacturing ICs, MEMS is seen as a significant improvement. When compared to traditional IC Manufacturing technology (VLSI), MEMS has the distinct advantage of being able to construct both mechanical and electrical components, such as gears, springs, and beams. Standard IC technology only allows for the creation of conductors, insulators, diodes, and transistors (Administrator Electronics Hub, 2019).

2.4.1 MEMS Sensor

All processing and calculation now takes place digitally, so a connection between the digital and analogue realms is essential. Sensors assist close this chasm by monitoring the impacts of time on analogue physical features and providing actionable information to the computer. Detecting and transforming physical qualities like temperature and humidity into electrical impulses are the primary functions of sensors (Administrator Electronics Hub, 2019).

Microelectromechanical systems (MEMS) are a subset of electronic devices that are notable for their miniature size and fabrication technique. These consist of parts that are anywhere from 1 micrometer to 100 micrometers in size. Complex MEMS devices can have many moving parts and be controlled by integrated microelectronics, yet they can also have a simple construction. Microelectromechanical systems (MEMS) encompass mechanical microstructures, micro actuators, microsensors, and microelectronics (electronicsforu.com, 2018).

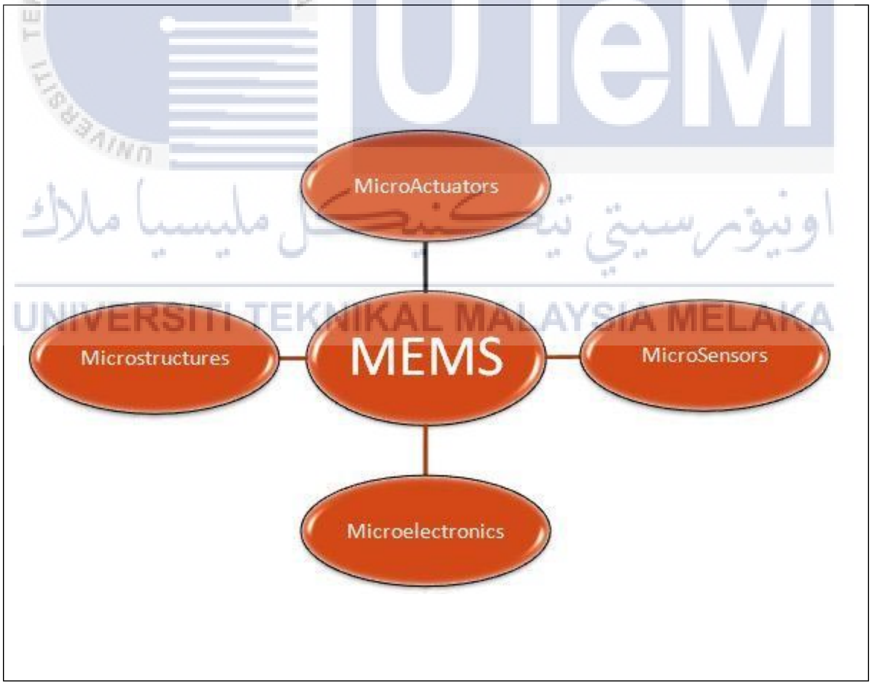

Figure 2.5 General block diagram of MEMS device

An amplifier, filter, analog-to-digital converter, or some combination thereof is only some of the data acquisition components that can be found inside a sensor. A microfabricated microsensor is a MEMS sensor that has been created and produced utilizing microelectromechanical system (MEMS) technology. Some of the sensors and processors found on the MPU6050 chip are a 3-axis accelerometer, 3-axis gyroscope, and a digital mobility processor. It is manufactured via MEMS technology (Administrator Electronics Hub, 2019).

MEMS sensors are rapidly becoming an essential component in the creation of smart sensing systems due to its many advantages, including reduced size, low cost, and low power consumption. The study of developing small-scale systems is known as microsystems engineering. To this end, it explores the materials and methods for creating incredibly little devices and systems with features and behaviors similar to those of existing macrosystems. The development of sensors like accelerometers and pressure gauges is not the focus. In addition, microfabrication methods should be considered as manufacturing capabilities that may be integrated into standard industrial processes to produce enhanced or novel end products (Quero et al., 2018).

MEMS sensors are a promising new area with applications spanning from consumer electronics to the aerospace and aviation sectors. By fusing electronic and mechanical capabilities, MEMS technology has revolutionized the sensor market. MEMS' most notable quality is its capacity to interact with electrical components in microchips. Small form factor typically means low power dissipation and high sensitivity in MEMS. Many different kinds of applications can benefit from MEMS-based sensor devices because of their many useful properties (Algamili et al., 2021).

Advantages include low power consumption, small size, and low cost due to array production capability. Other advantages of MEMS include its lightweight design, high resolution, consistent performance, and simple integration with external hardware and software. Inertial sensors, chemical sensors, inkjet printers, gyroscopes, satellites, RF communications, cellphones, pressure sensors, accelerometers, biomedical instruments, and military applications have all benefited from increased micromechanical-to-micromechanical device efficiency. Commercial production relies heavily on factors like cheap cost and simple forming (Algamili et al., 2021).

2.4.2 MEMS Accelerometer

These sensors are used in smartphones for a number of purposes, such as detecting when the device is in a pocket and automatically switching to a portrait or landscape orientation. MEMS accelerometers can be divided into two categories: variable capacitive and piezoresistive. In order to record continuous accelerations and keep an eye on structures, engineers use variable capacitive (VC) MEMS accelerometers due to their small size and great sensitivity. High-precision, low-sensitivity piezoresistive (PR) MEMS accelerometers are used in stress and blast application.

While large rotors are often operated at speeds below their critical speed, the maximum sampling rate of a MEMS accelerometer is typically a few kilohertz. MEMS accelerometers are sensitive enough to pick up rotor vibrations at low operating frequencies as a result. Additionally, MEMS sensors are tiny and have a low power consumption. Because IoT sensors are typically quite small and run off of battery power, these characteristics are especially helpful in IoT applications. Traditional piezo- based accelerometers see widespread application in industry, although cutting-edge MEMS alternatives are available. Comparisons between MEMS and IEPE accelerometers have been made for condition monitoring (Koene et al., 2019).

Microelectromechanical systems (MEMS) are a type of technology that combine mechanical and electrical micro-elements created by micro-fabrication techniques. Although the microfabrication process is more labor-intensive and costly, the resulting pieces are so tiny that they may be mounted in incredibly tight quarters and utilized in systems with minimal footprints. The hollow nature of many MEMS designs allows them to be extremely portable without sacrificing durability (Andrejasic, 2008). Acceleration variations along all three axes of the Cartesian coordinate system may be recorded using MEMS accelerometers. The compact and lightweight nature of MEMS-based accelerometers makes them useful in many contexts.

The performance of a MEMS accelerometer was studied and compared to that of an IEPE accelerometer, with special attention paid to sinusoidal, random, and impulsive excitations, by Albarbar et al. In comparison to an IEPE accelerometer, a capacitive MEMS accelerometer performed well under a wide range of excitations in their tests. However, phase shift was seen when the MEMS accelerometer was subjected to sinusoidal or random excitations (Koene et al., 2019).

All three capacitive MEMS accelerometers were utilized to perform the same tests. A CNC machine was used to test how well they would fare in practical applications. Similarly to the IEPE accelerometer, two of the three MEMS accelerometers tested in the lab showed similar performance. Unfortunately, one of the MEMS accelerometers had subpar performance for no apparent reason. These two high-performance accelerometers proved that microelectromechanical system accelerometers might be utilised to keep tabs on machinery. The fundamental speed, the line frequencies, and their multipliers were all recorded. (Koene et al., 2019)

2.4.3 MEMS Gyroscope

A gyroscope is a type of inertial sensor that calculates an object's rotational velocity with regard to a fixed frame of reference. Coriolis effect theory is used by MEMS gyroscopes to calculate the angular velocity of a moving object in respect to a rotating reference frame. Imagine a weight hanging on a set of springs to help visualize this. This mass is driven by an x-axis force, causing it to rapidly oscillate along that axis. A constant angular velocity about the z-axis, , is applied during motion. Because of the Coriolis force, the mass is displaced in the y-direction, and this motion is detected by a capacitive sensing mechanism. (Vectornav, 2023)

When mounted on a rotating frame, gyroscopes measure the rotation's angular velocity. Depending on the underlying physical concept and technology employed, gyroscopes fall into one of several broad types. A gyrocompass, inertial measurement unit, inertial navigation system, or attitude heading reference system are all examples of more advanced systems that make use of gyroscopes (Passaro et al., 2017).

2.4.4 Wireless MEMS Sensor

MEMS technology sensors are inexpensive, high-precision inertial sensors with several industrial uses. Micro electro-mechanical systems (MEMS) are sensors made up of a mass hung between a pair of capacitive plates, and they are a type of chip-based technology. When the sensor is tilted, this free weight causes a change in electrical potential. Capacitance is used to quantify the resulting disparity. (Althen, 2023)

Numerous uses incorporate MEMS sensors, which are small and use little power, with wireless communication. This allows for deployment in areas where running cables would be too costly or cumbersome, such as more rural areas or more hostile environments. Wireless sensors can be set up in a fraction of the time it takes to set up wired sensors, saving you money in the long run. Rapid problem resolution is made possible by better installation practices (Koene et al., 2020).

2.5 Arduino

The Arduino platform is an open-source software environment for creating electrical artifacts. A physical programmable circuit board (sometimes called a microcontroller) and accompanying computer software, known as an IDE (Integrated Development Environment), are required to utilize an Arduino board. (B_E_N, 2011)

The Arduino platform has quickly gained favor among electronics newcomers, and with good reason. The Arduino can have fresh code loaded onto it through a USB cable, unlike most earlier programmable circuit boards that required a separate piece of hardware (called a programmer) to do so. Furthermore, the Arduino IDE employs a tamed version of C++ that facilitates learning. Arduino, with its standardized form factor, simplifies access to the micro-controller's features. (B_E_N, 2011)

Figure 2.6 Typical Arduino development board

The Arduino is widely used because of its low price, ease of programming, and ease of usage, all of which make it ideal for swiftly building and testing electrical prototypes. You can plug it into a computer's USB port or an external power source to run it. The focus of this study is on the feasibility of using Arduino as a data collection system. Undergraduates in physics and engineering can investigate mechanical vibration phenomena with the help of sensors like accelerometers, gyroscopes, and ultrasonography. Due to their widespread application, these sensors have been widely available at low prices, making smartphones and other gadgets more accessible to the general public. The Arduino port is connected to the computer by USB, and it receives data from the sensors via analogue and digital interfaces. (Varanis et al., 2016)

2.5.1 ESP32 for Data Processing

The ESP32 is an inexpensive System on Chip (SoC) Microcontroller designed by Espressif Systems, the same company responsible for the widely used ESP8266. The Tensilica Xtensa LX6 Microprocessor is a 32-bit successor to the ESP8266 SoC that features built-in Wi-Fi and Bluetooth and is available in single-core and dual-core configurations. (ElectronicsHub, 2021)

The ESP32, like the ESP8266, has a Power Amplifier, Low-Noise Receive Amplifier, Antenna Switch, Filters, and an RF Balun built right in. Because of this, hardware development for the ESP32 may begin with very few extra parts.TSMC's ultra-low-power 40 nm technology is used throughout production, which is another noteworthy characteristic regarding the ESP32. Therefore, employing ESP32 should make it simple to create battery-operated applications like as wearables, audio equipment, baby monitors, smart watches, etc. (ElectronicsHub, 2021)

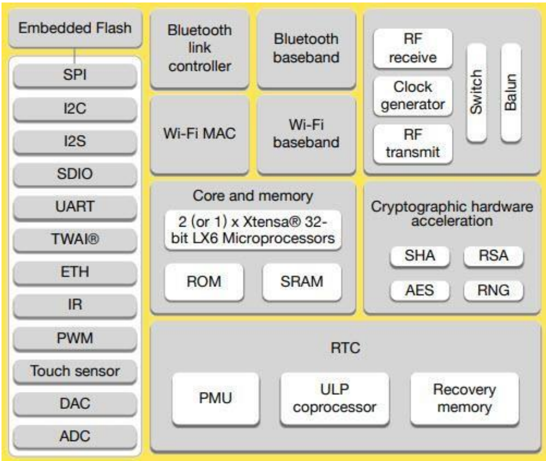

Figure 2.7 ESP32 Function block diagram

The Espressif Systems Internet of Things Development Framework (ESPIDF), which is open-source and hosted on GitHub, is a widely used framework for ESP32 development. A Linux terminal is required for running bash files on the ESP-IDF. Alternatively, MSYS2 can be utilized for Windows development. This free program allows Linux terminals to be used on Windows machines. To get started with an ESP32 project, you'll also need the ESP-IDFTemplate. There are several files that are necessary for compilation but aren't included in the IDF that can be found in this archive. (Maier, Sharp, and Vagapov, 2017)

2.5.2 Developing application of ESP32

The ESP32 is a multipurpose microcontroller that has both Wi-Fi and Bluetooth connectivity already built in. It can be used to rapidly prototype and develop solutions for the Internet of Things, home automation, environmental monitoring, wearables, data recording and analytics, robotics and automation, mobile apps, and more. Developers that want to create cutting-edge networked solutions frequently opt for it because of its portability, low power consumption, and flexibility in integration.

In this section, you will learn the basics of configuring the ESP32 platform. The ESP32 can be built on Windows, Linux, or MacOS. In this session, you'll learn how to set up a Windows environment for programming. Available options include the native Espressif IoT Development Framework platform, the ESP32 Arduino add-on environment, and a Python environment driven by the Micropython engine. . (Babiuch, Foltynek, and Smutny 2019)

2.5.3 Developing application of ESP32

The ESP32 application system includes the ESP32 microcontroller's software and firmware stack, which makes possible a broad variety of uses and features. It has the ESP-IDF framework for development, Wi-Fi and Bluetooth stacks for wireless connectivity, libraries for connecting with peripheral devices, communication and file system support, power management, and security. This all-inclusive platform gives programmers access to the resources they need to design and implement unique firmware and software for Internet of Things gadgets, home automation systems, sensor networks, robotics, and more.

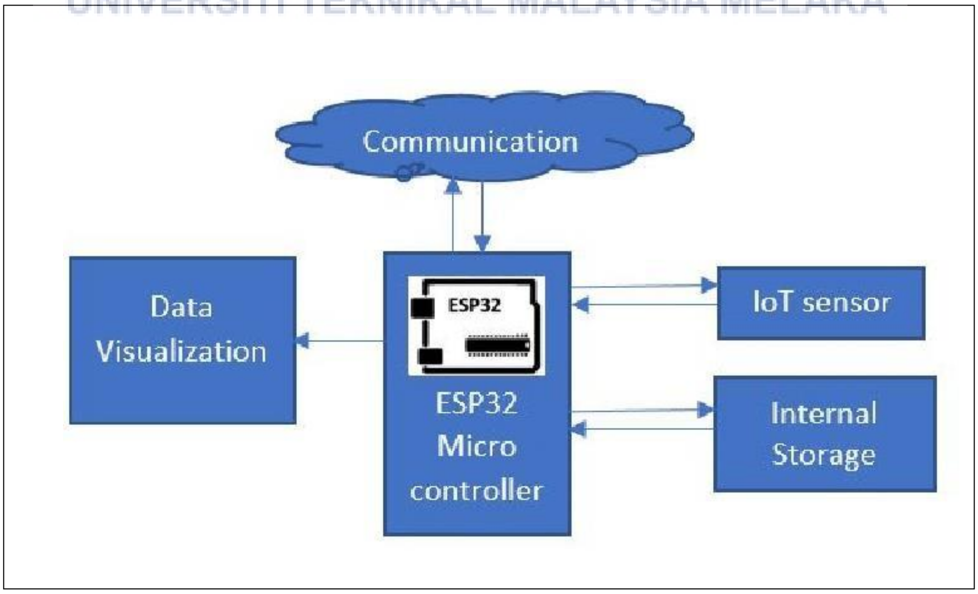

Figure 2.8 Block scheme of the embedded system

In this post, we'll be discussing how to see data from your measurements on a screen that's built into our embedded system. Different types of information require different sized displays, which in turn affects the required bandwidth of the associated communication buses. To save bandwidth, we just showed the status information on lower resolution displays while sending all the data we collected to the more powerful system for analysis. Our display shows a number of different pieces of data, like whether or not the microcontroller is online, what task is now being processed, and how far along the measurement cycle we currently are. We show the measured data as a graphical flow on larger, higher-resolution monitors, in addition to status information. Due to the high number of variables being measured simultaneously, only one graph was produced, with the option to select from among 28 graphs of the measured amounts. We used multiple displays in our embedded system. (Babiuch, Foltynek, and Smutny 2019)

2.5.4 MPU6050

The MPU6050 is a Micro-Electro-Mechanical System (MEMS) that contains an Accelerometer and Gyroscope with the same number of axes. This allows us to assess many different properties of a system or object in motion, including acceleration, velocity, direction, and displacement. This module also includes a Digital Motion Processor (DMP) that can free up the Microcontroller by doing difficult calculations on its own.There are additionally two auxiliary pins on the module that can be used to connect to external IIC modules like a magnetometer. As the module's IIC address is programmable, more than one MPU6050 sensor can be connected to an ADC or ADC/ADC converter through the AD0 pin. This module is incredibly user-friendly because of the extensive documentation and updated libraries that make it compatible with popular development boards like the Arduino. (Jobit Joseph, 2022)

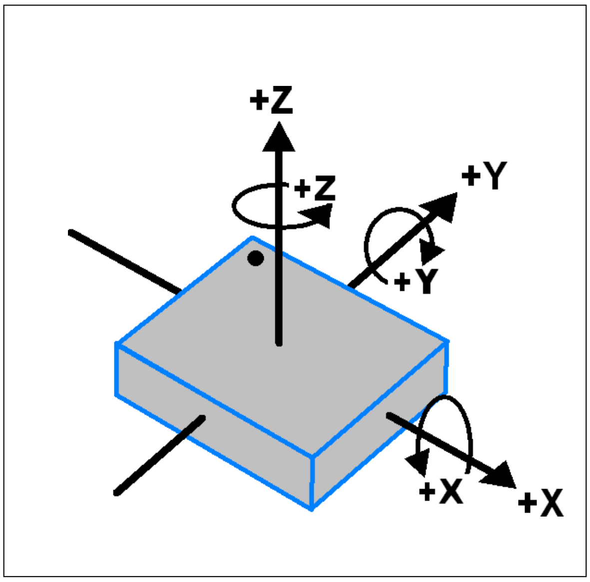

Figure 2.9 MPU-6050 Orientation and Polarity of Rotation

The module's various output pins allow for the interconnection of additional, non-required IIC modules, such as a magnetometer. Since the IIC address of this module is programmable, the AD0 pin may be required when connecting several MPU6050 sensors to a microcontroller. This module comes with modern, well-documented libraries that make it simple to use with popular platforms like Arduino. This sensor may be useful if you're building an RC vehicle, drone, personality robot, humanoid, biped, or something similar and need an accelerometer (COMPONENTS101, 2021).

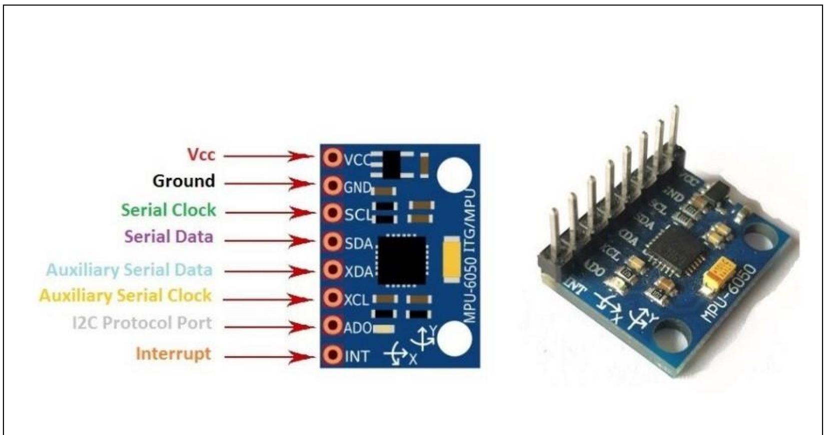

Figure 2.10 MPU6050 Detail

2.6 Vibration Monitoring System / Vibration Analysis

A vibration monitoring system is a device used to detect problems with a machine by keeping track of the vibrations it experiences. The facilities, the procedure, and the employees are all safer as a result. This device may detect imbalance, misalignment, and a loose part, all of which contribute to machine downtime. One of the best ways to anticipate a potential machine problem and provide early warning of machine failure is using a vibration monitoring system, even for a single channel. Important in numerous fields for both worker protection and smooth operations. (METRIX, 2023)

Monitoring and diagnostics also enable early detection of developing problems in machine configuration, upgrades, and replacement parts. In this way, predictive upkeep moves from reactive to proactive. An open PC-based continuous vibration monitoring system was developed to easily meet the evolving needs of the manufacturing facility over time. Predictive upkeep takes a more proactive approach in this way. A continuous vibration monitoring system 35 was developed on an adaptable PC platform to meet the evolving requirements of a manufacturing facility.Reference: (Klempnow, La Bruna, & Saporiti, 2009)

2.6.1 Low-Cost Vibration Monitoring System

A low-cost vibration monitoring system is a cost-effective method of monitoring and analyzing vibration levels. Vibration sensors, data collecting hardware, and analysis and visualization software are the usual components. Accelerometers and piezoelectric sensors are two examples of vibration sensors that can be put in optimal positions to record vibrations. In order to process and evaluate the analog signals from the sensors, the data acquisition devices must first digitize them. Filtering, signal processing, and the ability to spot unusual or unexpected vibration patterns might all be included in this program. Data can be stored locally or sent to a remote server or the cloud, depending on the configuration of the system.

Likewise, MEMS gyroscopes and accelerometers have made their way into a wide variety of industrial systems as a result of ongoing improvements in functional integration and performance. Although some of these make the first-ever use of inertial sensing, others offer cheaper replacements for market leaders. Both inexperienced and experienced technicians might benefit from vibration monitoring. Piezoelectric technology is widely employed in conventional devices for performing preventative maintenance and safety inspections on mechanical systems. High-speed automation equipment can use vibrations to initiate feedback control of lubrication and speed, or to shut down entirely so that maintenance can attend to the problem immediately. (Maluf, 2004)

2.6.2 Wireless Vibration Monitoring System

Wireless sensor networks (WSNs) are a viable replacement for hardwired systems in the monitoring of industrial rotating machinery. The report describes the problems with wired solutions, such as the requirement for new wiring or repairs to existing lines, as well as the high costs of installation and maintenance. The authors highlight the risks of accidents caused by wires, as well as the limitations of wired solutions in specific industrial settings. The research evaluates the relative merits of various wireless sensor network technologies with regards to the monitoring of revolving machinery. It sheds light on the merits, difficulties, and possible uses of WSNs in manufacturing environments. (Bengherbia et al., 2017)

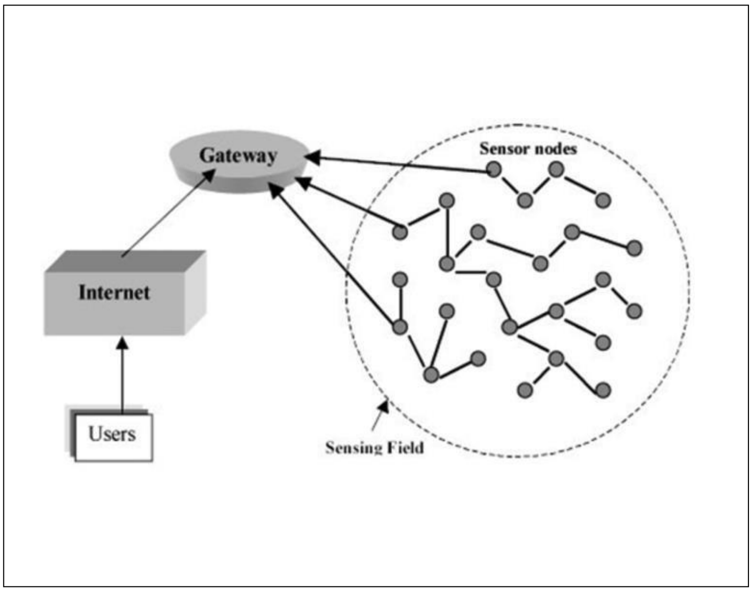

Figure 2.11 Wireless Sensor Netwrok

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter covers the solution proposed in this project, ensuring the achievement of the project's objectives. It begins with an explanation of the overall workflow, followed by the development of hardware and software for the vibration monitoring system. The chapter also explores the integration of the vibration monitoring system's hardware and software. The research methodology employed in this project adopts a methodical approach, focusing on specific procedures and examining their fundamental principles. It utilizes various methods, including surveys, experiments, focus groups, and in-depth interviews, to gather knowledge and understand the outcomes of the event under investigation. Each research method has its own advantages and disadvantages, contributing to the comprehensive analysis and understanding of the project's objectives.

3.2 Project Workflow

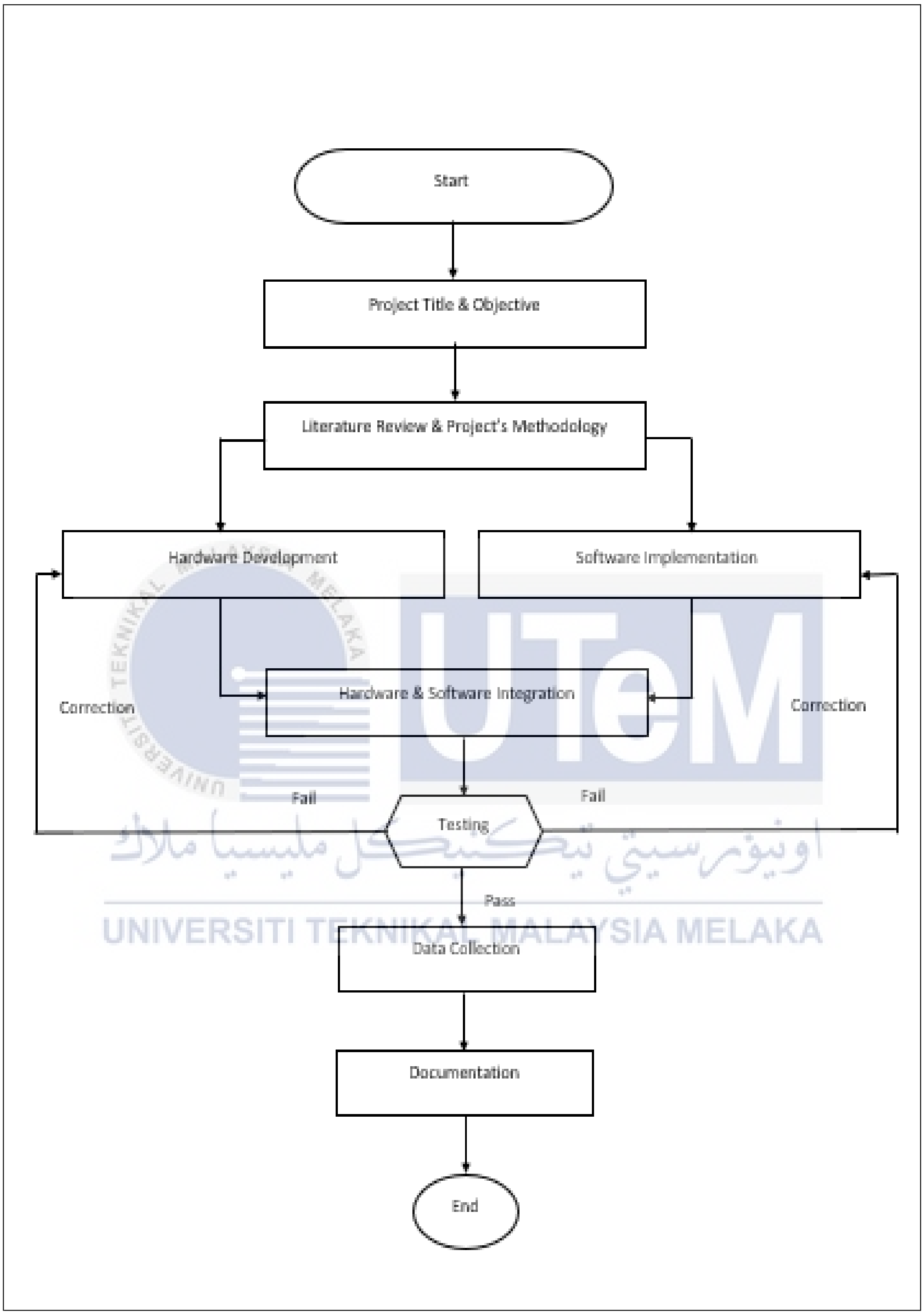

Figure 3.1 Project Workflow Flowchart

3.3 Vibration Monitoring System

The hardware and software development of the vibration monitoring system are two crucial components. The hardware section emphasizes the component choice and the actual appearance of the component, whereas the software section emphasizes the programming selection that was utilized to programmed the vibration monitoring system. If you're continuing a project from last semester, you probably already have the necessary hardware. MPU6050, a vibration sensor, is used.

3.4 Hardware Development

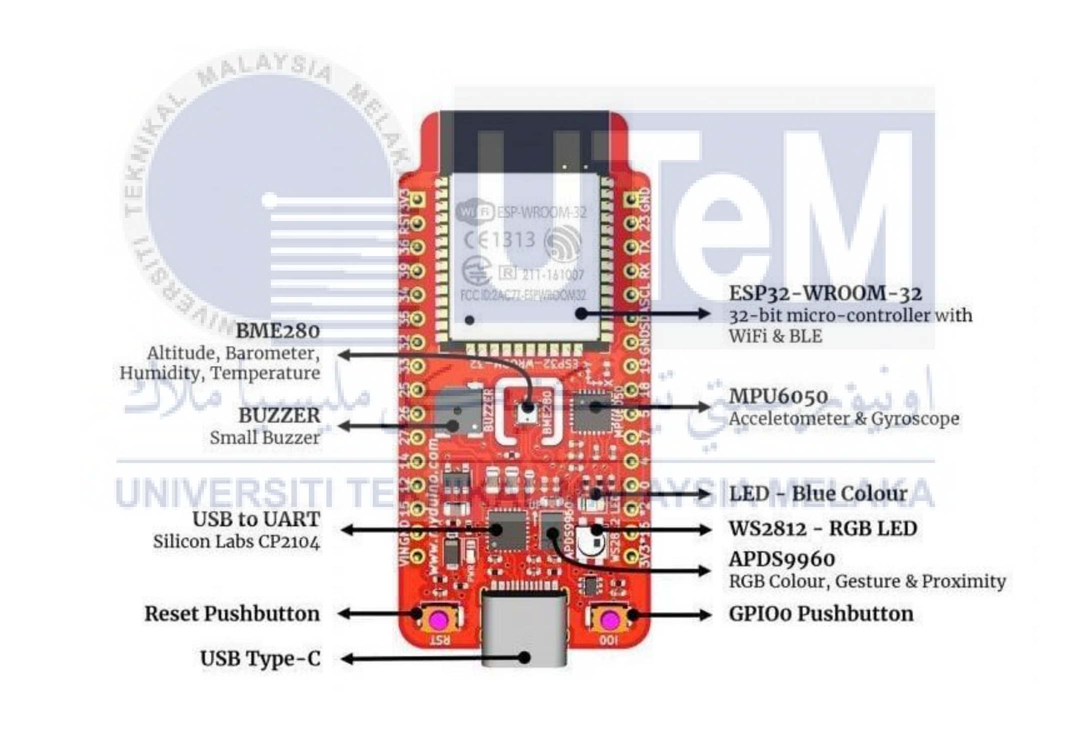

Figure 3.2 Overview of Hibiscus Sense

Working Voltage	3.3V
Working Frequency	240MHz
MPU6050’s Sampling Range (Max)	8kHz

MPU6050’s Sampling Range (Min)	1kHz
Dimension	58.7mm X 27mm X 20.4mm (Length X Width X Height)

Table 3.1 Hibiscus Sense required specification.

The Hibiscus Sense is a development board that supports Wi-Fi and Bluetooth wireless connections to personal computers and mobile devices. So, a portable battery pack is needed to charge the Hibiscus Sense. This development board only requires a USB connection to the hibiscus sense's Type-C port in order to be powered by any standard external battery bank.

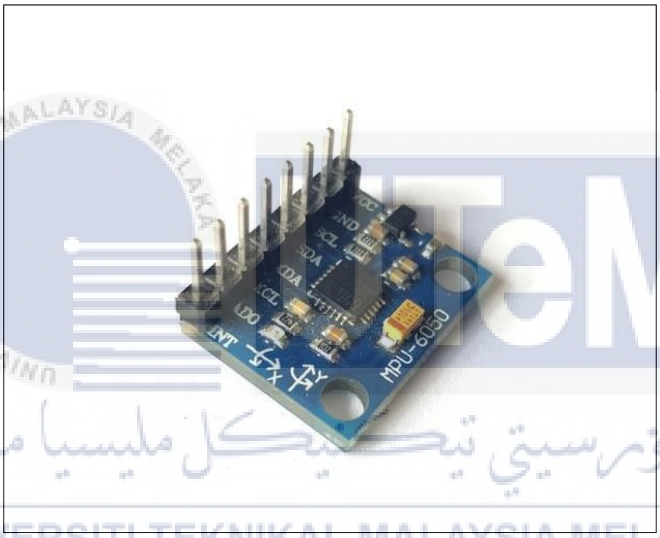

Figure 3.3 GY-521 MPU6050 Accelerometer Sense

Operating Voltage & Current	3.3V to 5V, 500µA
Operating Frequency	29MHz
Sampling Range	1kHz to 8 kHz
Temperature Sampling Range	-40°C to 85°C
Dimension (Excluding Pins)	21.2 x 16.4 x 3.3mm

Table 3.2 GY-521 MPU6050 Accelerometer Specification

The GY-521 MPU6050 sensor module is used to track and analyze vibration levels in operational machinery. It can detect linear acceleration and rotational motion thanks to its three-axis accelerometer and gyroscope. Insights into the machinery's health and condition can be gleaned by recording and analyzing vibration signals. The information gathered by the MPU6050 sensor module can be cross-referenced with other sources or compared to known vibration patterns to spot abnormalities. Reduced downtime and better machine performance are the results of preventative maintenance practices made possible by this. Preventative maintenance techniques rely heavily on the MPU6050 module, as it is important in performing accurate vibration analysis and maintaining the smooth functioning of industrial machinery.

Figure 3.4 Power Bank with 5000mAh

In this project, we decided to use a 5000mAh power bank to charge both the Hibiscus Sense and the GY-521 MPU6050. When comparing to other available options, this power bank stands out due to its small size and light weight construction. The GY-521 MPU6050 and the hibiscus system both benefit from the battery's generous 5000mAh capacity. The GY-521

MPU6050 and Hibiscus Sense can share a single power supply provided by the external battery pack via a Type-C connection connected to the USB port on the device.

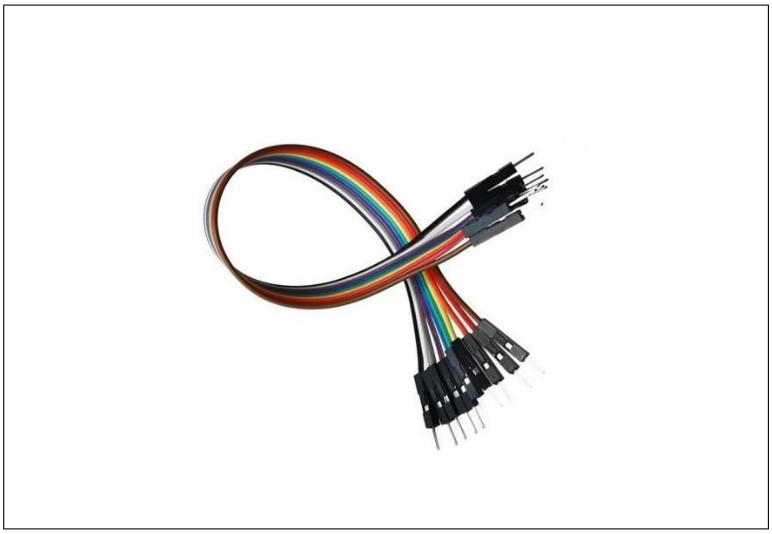

Figure 3.5 Jumper wire

Jumper wires are commonly used with breadboards and other prototyping tools to perform circuit modifications quickly and easily. Male-to-male, female-to-female, and female-to-male jumper wires are the three most common types. The terminal of each wire is where the two types diverge. Male ends feature a protruding pin for use in plugging into other devices, while female ends feature no such pin and are instead used to receive plugs. The male-to-male jumper wires are the most widely available and practical. There is a 2.54mm Pitch.

Figure 3.6 Type c extension cable

Usb Type	Usb 3.1 gen 2 male to female
Base Adapter	Data cable station Nintendo
Power	100w support
Voltage	20V/5A
Speed rate	10Gbps

Table 3.3 Type c extension cable specification

The hibiscus sense ESP32 is powered by a 5000mAh power bank, which is connected by a USB type C extension cord.

3.5 Software Implementation

This section will describe the interface software used to transform incoming vibration data into a time domain graph and a fast Fourier transform (FFT) graph. Because of its accessibility, ease of use, and compatibility with the ESP32 microcontroller development board, version 1.8.19 of the Arduino IDE software was selected for this project. The Arduino IDE can be used to write the code for this vibration monitoring system. Furthermore, Arduino code is written in Java and is derived from C++.

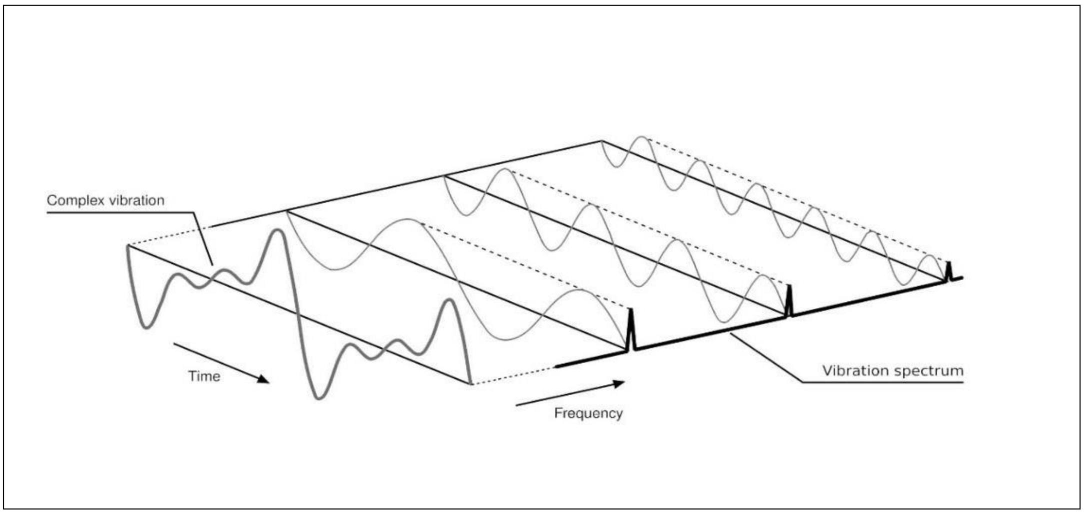

Figure 3.7 Fast Fourier Transform

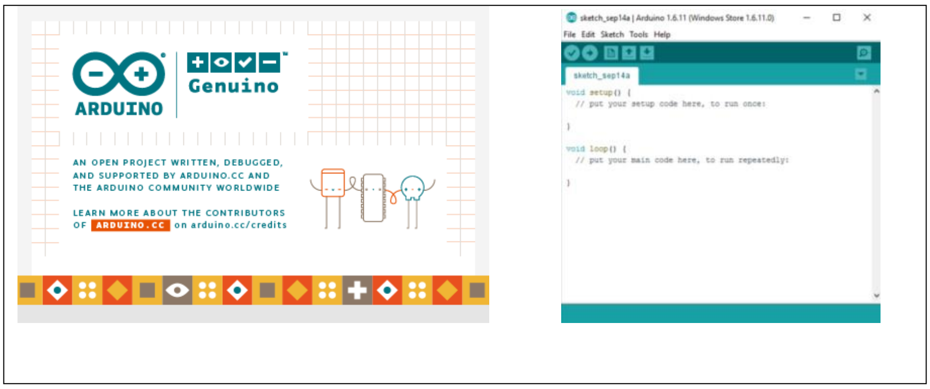

Figure 3.8 Arduino IDE software

Blynk was selected as the interface software due to its ease of use and flexibility in data presentation. You can monitor the vibration data using either the Blynk IoT website or the Blynk mobile app. After receiving vibration data over Wi-Fi from the microcontroller of the Hibiscus Sense system, the Blynk software may provide the data in the form of gauge charts and graphical representations. The vibration characteristics of the system could be tracked with relative ease. The Blynk software enhances the user experience by providing fast and comprehensive access to the vibration data.

Figure 3.9 Blynk software

3.6 Costing Component

N0	COMPONENT/ MATERIALS	QUANTITY	PRICE
1	Hibiscus sense v1.0 ESP32	1	RM 120.00
2	USB Type C to Type C	1	RM 10.00
3	Power bank	1	RM 60.00
4	MPU6050 Sensor vibration	2	RM 30.00
5	Black box project case	1	RM 5.00
6	Jumper wire (20cm and 30cm)	2	RM 5.00
	TOTAL COST		RM 200.00

Table 3.4 Costing component table

3.6.1 Intangible Cost

When a cost is intangible, it is not easy to put a price on it. Thus, intangible expenses are associated with immaterial characteristics. In this case, the cost of the arduino ide software and the Blynk iot applications is seen as an intangible investment in the success of the low-cost vibration monitoring system.

Figure 3.10 Arduino IDE and Blynk IOT applications

3.6.2 Comparison Cost

This subtopic will present the comparison of cost of equipment to build a low-cost vibration monitoring system, which enables access to the Arduino IDE software.

No.	Required Equipment	Overall Cost (RM)
1.	SW-420 vibration sensor, GY-521 MPU6050, micro USB data cable, Jumper Wires, ESP32 Devkit V1	5.00 + 12.00 + 7.50 + 3.00 + 35.00 = 62.50
2.	GY-61 ADXL335, GY-521 MPU6050, micro USB data cable, Jumper Wires, ESP32 Devkit V	18.60 + 12.00 + 7.50 + 3.00 + 35.00 = 76.10
3.	2 x GY-521 MPU6050, micro USB data cable, Jumper wires, ESP32 Devkit V1	2 x 12.00 +7.50+3.00 + 35.00 = 69.50
4.	Hibiscus Sense – ESP32 Development Board (with USB Type C cable), 2 x GY-521 MPU6050,Jumper Wires	2 x 15.00 +120.00 + 10.00= 165.00

Table 3.5 Comparison of cost of Low-cost Vibration Monitoring System

3.7 Summary

The summary for this chapter can be seen in the image below, which also displays the configuration for the Blynk IoT application as well as the settings for programming in the Arduino IDE. The final section's demonstration of hardware configuration will be the main subject. The Hibiscus sense ESP32 board controller will receive the file via a type-C cable upload. The code is meant to be used with the MPU6050 to issue commands in the Hibiscus sense, after which the data is transferred to an external MPU6050 and transmitted through the Blynk IOT application over a Wi-Fi connection.

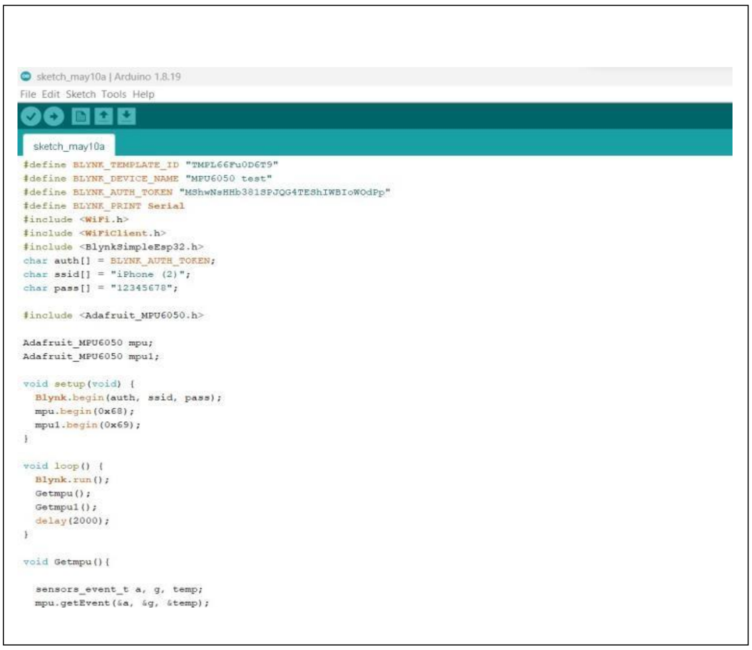

Figure 3.11 Arduino IDE programming setup and Arduino IDE coding setup to link with the Blynk application.

From the **Figure 3.11,** this is the Arduino IDE code that will issue a command to communicate with the Blynk IOT app and collect data on vibrations from the sensor

```
void loop() {
  Blynk.run();
  Getmpu();
  Getmpu1();
  delay(2000);
}

void Getmpu(){

  sensors_event_t a, g, temp;
  mpu.getEvent(&a, &g, &temp);

  Blynk.virtualWrite(V0,a.acceleration.x);
  Blynk.virtualWrite(V1,a.acceleration.y);
  Blynk.virtualWrite(V2,a.acceleration.z);
  //Blynk.virtualWrite(V6,temp.temperature);
}
```

```
void Getmpu1(){

  sensors_event_t a, g, temp;
  mpu1.getEvent(&a, &g, &temp);

  Blynk.virtualWrite(V3,a.acceleration.x);
  Blynk.virtualWrite(V4,a.acceleration.y);
  Blynk.virtualWrite(V5,a.acceleration.z);
  //Blynk.virtualWrite(V7,temp.temperature);
}
```

Figure 3.12 Arduino IDE coding setup for the MPU6050 built in the ESP32 And Arduino IDE coding setup for the external MPU6050

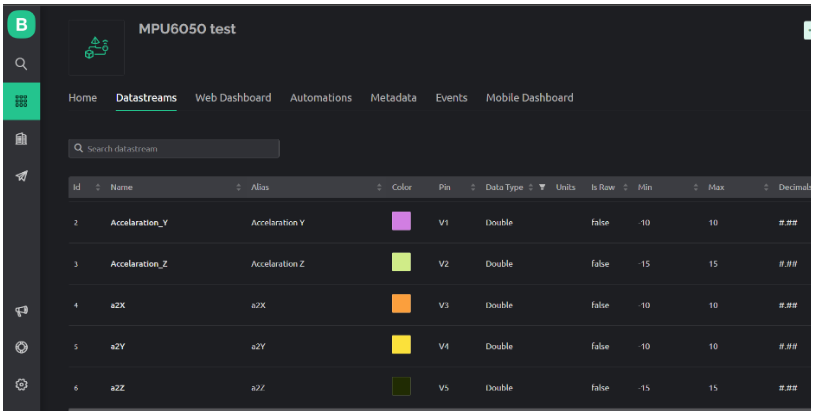

Figure 3.13 The data streams setting for the ESP32 and MPU6050 gauge in Blynk

From the **Figure 3.13,** It displays the data streams that must be configured in the Blynk IOT application for it to display the data in meter gauge in this application

Figure 3.14 The meter gauge that will show the reading of the vibration

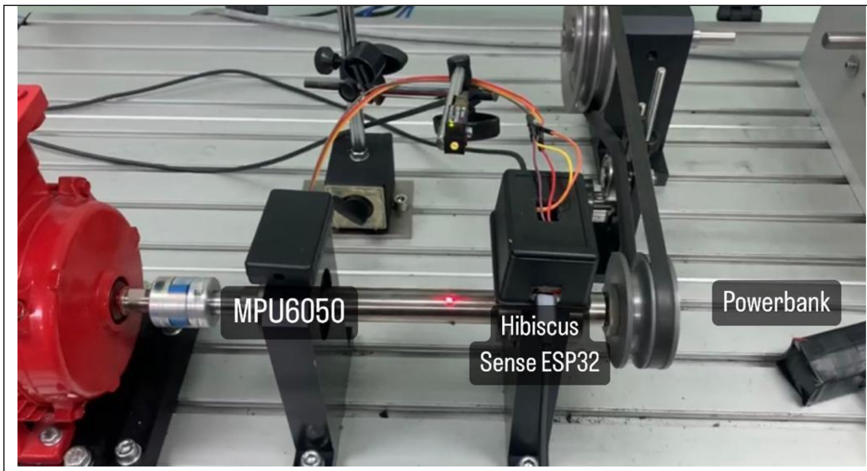

Figure 3.15 Hardware setup on the machinery fault simulator

From **Figure 3.15** shows displaying the machinery fault simulator's hardware setup. Power is provided by the power bank to the ESP32 and MPU6050 of the Hibiscus Sense. The hibiscus sense is installed in a black box with double-sided adhesive on the bottom in order for it to stick to the equipment that we will be monitoring. In order to connect the external MPU6050 to the hibiscus sense, a jumper wire is necessary. To simulate the vibration dependent on the selected bearing, the vibration of the machinery fault simulator is employed

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the analysis and validation of equipment vibration monitoring systems are presented. The results of this section will be displayed in the form of tables and graphic that we get from the test we run to clearly display the vibration data received by the low-cost vibration monitoring sensor and heavy-duty vibration accelerometer for data comparison and vibration analysis. This section presents the data comparison between the three MPU6050s and the heavy-duty vibration accelerometer on the vibration analysis of the computerized vibration trainer (unbalanced rotor) under the same vibration conditions.

4.2 Heavy duty vibration meter

Figure 4.1 Heavy Duty Vibration Meter

The Extech Instruments Model 407860 is a robust Heavy Duty Vibration Meter designed for industrial applications, featuring an accelerometer with a magnetic mount for easy attachment to machinery. This equipment will be used in this test to make the comparison of the data between the low-cost vibration monitoring system. It offers a wide frequency range, providing measurements in both velocity and acceleration. The instrument includes a convenient LCD display for real-time monitoring, data hold function, and may have built-in memory for data logging over time. Its versatility extends to applications such as predictive maintenance, quality control in manufacturing, research and development, environmental testing, and continuous monitoring of industrial machinery.

4.3 Low-cost vibration monitoring system

Figure 4.2 Hibiscus sense it connected to two other GY-521 MPU6050

This low-cost vibration monitoring system is a vibration monitoring system that have been built by using hibiscus sense that is being used as a main sensor for the coding. The hibiscus sense has been chosen because it has a built-in MPU6050 in it. Then the hibiscus sense it connected to two other GY-521 MPU6050, so that it can be used to collect data for 3 axis.

4.4 Data comparison

This section presents the data recorded on the computerized vibration trainer in tabular for data comparison and vibration analysis. The collected data of three MPU6050s are all in unit acceleration, m/s2. The temperature data will not be used for data acquisition and data comparison because this data is used to detect the ambient temperature of the vibration monitoring system to avoid overheating of Hibiscus Sense and GY-521 MPU6050 during data recording. The maximum and minimum data obtained at each run can be generated by the vibration meter itself. Thus, the maximum and minimum values that appear on the real vibration meter are the data that are being utilized for this data comparison.

Figure 4.3 Computerized vibration trainer

4.5 Procedure of Experimental

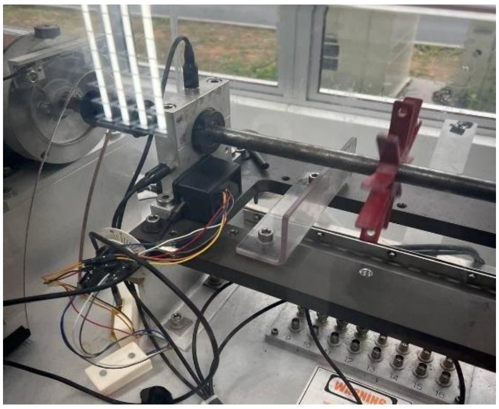

Figure 4.4 Hardware setup on the axis

The Hibiscus Sense ESP32 is set to get the data for the X axis, the MPU6050 is set to get the data from the Y axis, and another MPU6050 set for Z axis to demonstrate how the hardware is set up before the machine is operated.

Figure 4.5 Data in Blynk IOT

From **Figure 4.5,** it shows the data streams in the Blynk IOT application. The data is shown in meter gauge in this application.

Figure 4.6 Data in Heavy-duty vibration meter

As we can see, from **Figure 4.6** the Heavy-duty vibration meter produces the similar result of our low-cost vibration monitoring system that we put in the machine in the lab when it is placed on the Y axis, producing data vibration for the Y axis. The machine creates an acceleration vs. time graph. Therefore, based on the data we obtain, we may conclude that the data generated by the Heavy-duty vibration meter and the low-cost vibration monitoring system is accurate.

4.6 Results and Analysis

4.6.1 Under Balanced Condition

As illustrated in Figure 4.4, when the rotor is free of bolts and nuts, the machinery fault simulator creates balanced circumstances. Three distinct motor speeds were used for this vibration monitoring; the speeds were set at 10 RPM, 20 RPM, and 30 RPM, respectively, and data was collected. The data produced by the Blynk program is recorded for data validation and displayed on the computer's screen. It is utilized to compare the data produced by the real vibration meter that is being used in experiments in the lab.

Figure 4.7 Rotor with no bolts and nuts

Table 4.1 Acceleration of Three MPU6050s when Motor Speed is 10/min.
(Balance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	1	0	1	2	2	1	1	2	1	1	1.1	1.3
MPU1 X V3-V5	2	1	2	1	3	2	1	1	2	1	1.1	1.3
MPU2 X V6-V8	1	1	1	2	2	3	2	1	2	2	1.1	1.3
MPU Y V0-V2	2	0	1	1	1	2	3	2	2	1	1.1	1.6
MPU1 Y V3-V5	0	2	1	1	3	1	2	1	2	2	1.1	1.6

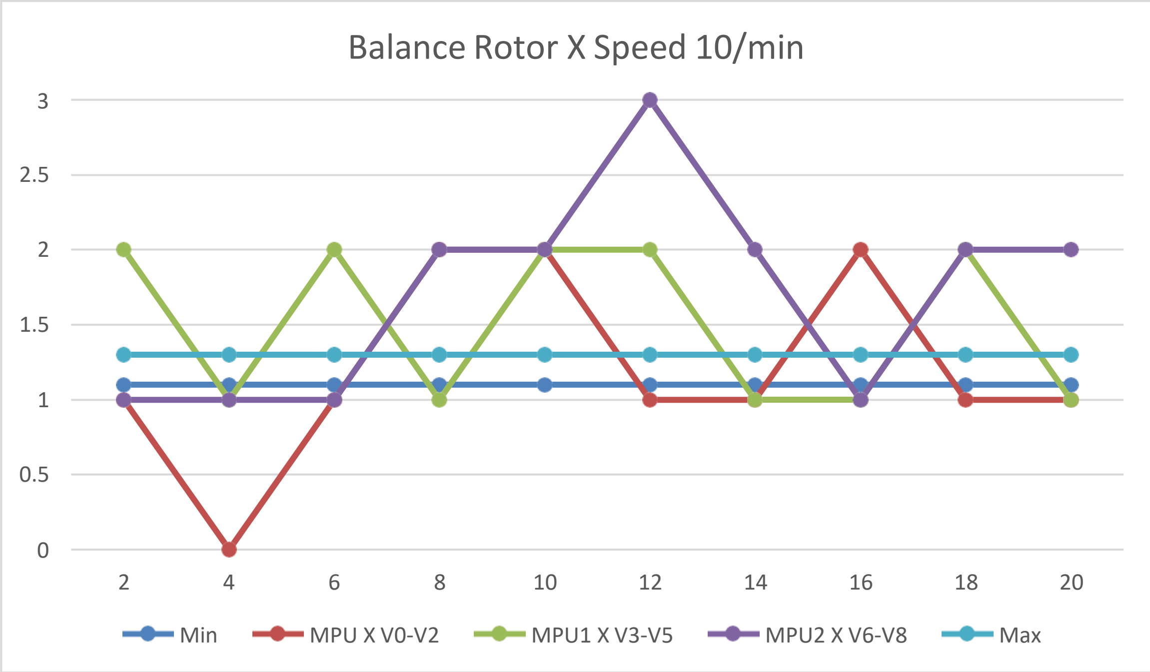

Figure 4.8 Acceleration of Three MPU6050s when Motor Speed is 10/min. (Balance Rotor)

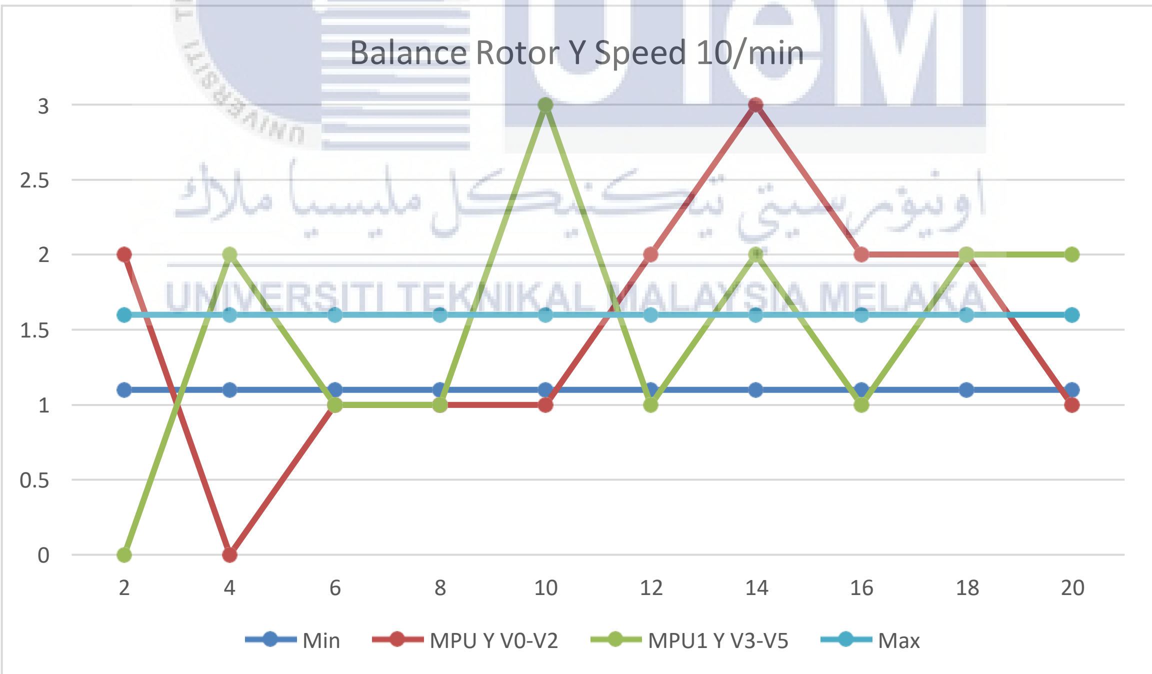

Figure 4.9 Acceleration of Three MPU6050s when Motor Speed is 10/min. (Balance Rotor)

Based on the graphs of acceleration versus time of the low-cost vibration monitoring system, which includes the Hibiscus Sense and two MPU6050 sensors, **Figures 4.8** and **4.9** show the results of the system's operation when a balanced rotor was running at 10 RPM. The red trend, designated X V0-V2, represents the Hibiscus Sense, while the green trend, designated X V3-V5, represents the first MPU6050 sensor and the purple trend, designated X V6-V8, represents the second MPU6050 sensor. On the Y axis, the first MPU6050 is represented by the green trend name, Y V3-V5, and the hibiscus sense is represented by the red trend name, Y V0-V2. as the data displayed in **Figure 4.10** for the y-axis. These two figures demonstrate that the data obtained by the low-cost vibration monitoring system is higher than that obtained from the genuine vibration meter, indicating that it is more sensitive.

Table 4.2 Acceleration of Three MPU6050s when Motor Speed is 20/min. (Balance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	0	1	2	0	2	2	1	1	0	1	1.1	1.6
MPU1 X V3-V5	1	1	0	2	2	1	2	1	2	1	1.1	1.6
MPU2 X V6-V8	1	1	0	1	1	2	1	1	2	2	1.1	1.6
MPU Y V0-V2	0	2	1	2	2	3	3	2	1	1	1.1	2.5
MPU1 Y V3-V5	1	1	2	3	3	2	1	1	0	1	1.1	2.5

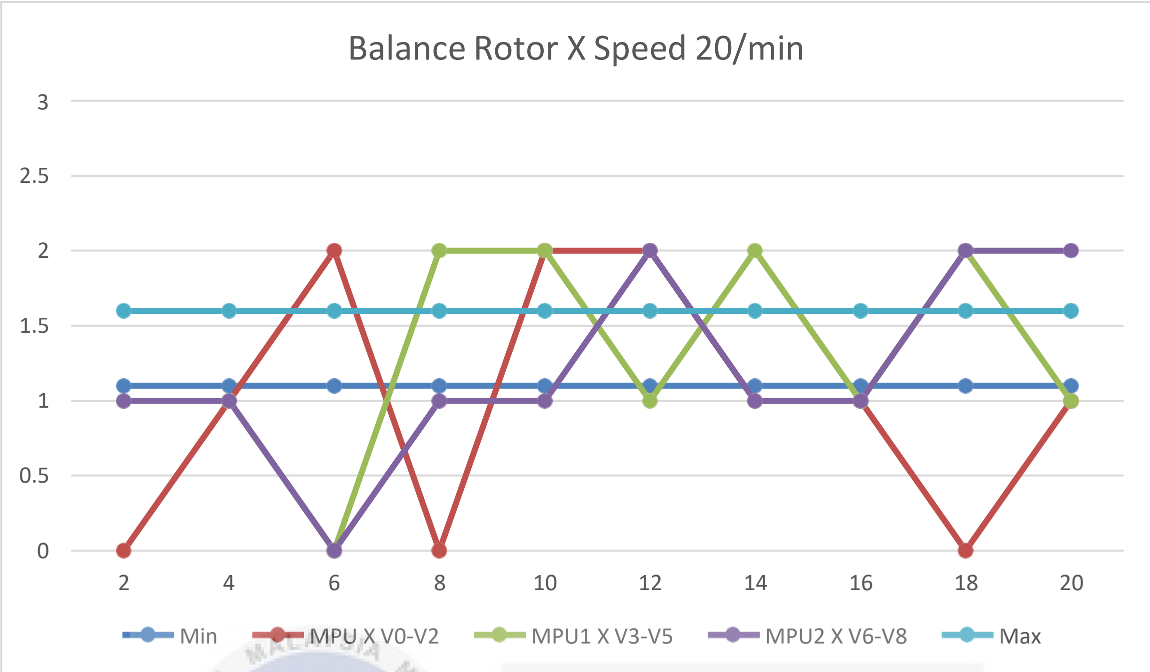

Figure 4.10 Acceleration of Three MPU6050s when Motor Speed is 20/min. (Balance Rotor)

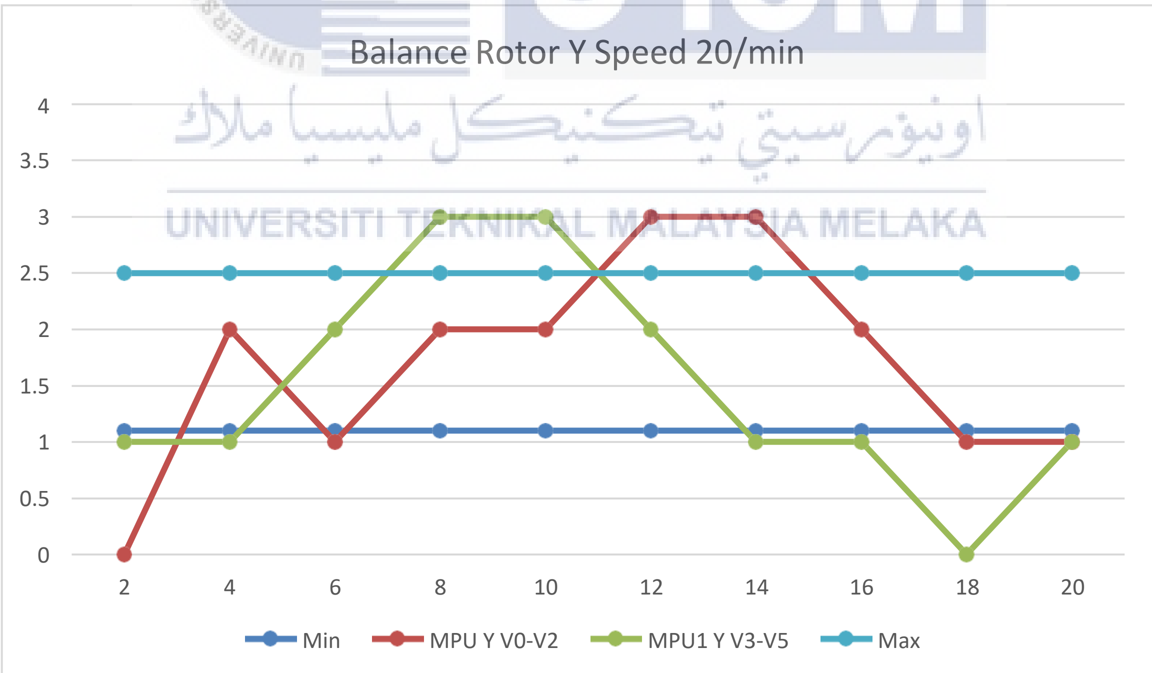

Figure 4.11 Acceleration of Three MPU6050s when Motor Speed is 20/min. (Balance Rotor)

Table 4.3 Acceleration of Three MPU6050s when Motor Speed is 30/min. (Balance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s²)	Time (s)										Heavy-duty vibration accelerometer (m/s²)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	1	2	0	1	2	1	1	2	1	2	1.1	1.7
MPU1 X V3-V5	1	1	2	1	1	2	1	0	2	1	1.1	1.7
MPU2 X V6-V8	1	2	1	2	2	1	2	0	1	2	1.1	1.7
MPU Y V0-V2	0	1	2	2	2	3	2	3	1	1	1.1	2.7
MPU1 Y V3-V5	0	2	2	1	2	0	2	1	2	1	1.1	2.7

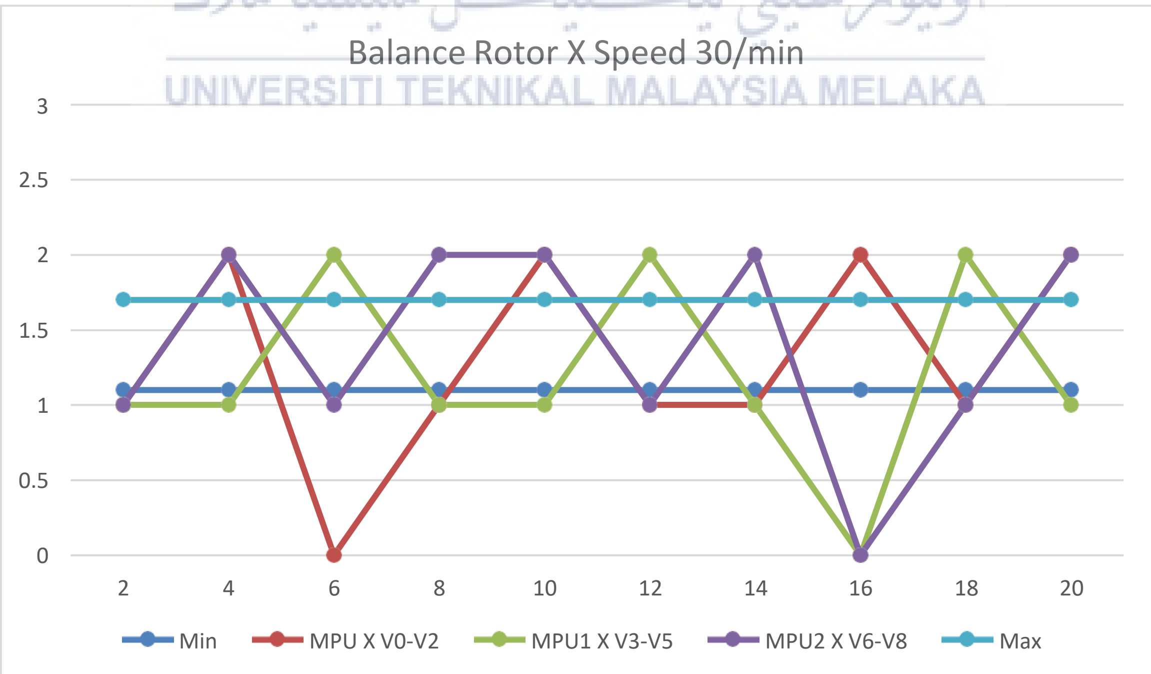

Figure 4.12 Acceleration of Three MPU6050s when Motor Speed is 30/min. (Balance Rotor)

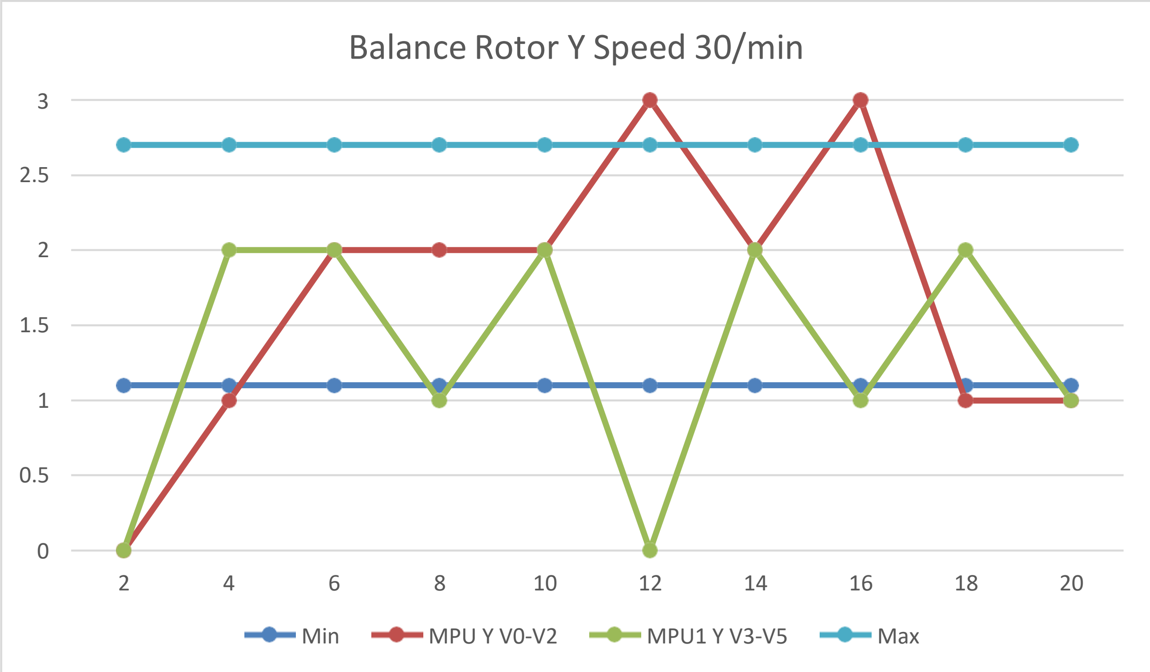

Figure 4.13 Acceleration of Three MPU6050s when Motor Speed is 30/min. (Balance Rotor)

The acceleration versus time graphs in **Figures 4.12** and **4.13** for 30RPM show that the low-cost vibration monitoring system and the actual vibration meter have a Y axis that is higher than the X axis. The vibration data has increased significantly, matching the 20 RPM speed of the balance rotor. As we can see, the MPU6050 and the hibiscus sense are equally sensitive and continuously produce data that is comparable to the vibration meter actually.

4.6.2 Under Unbalanced Condition

Regarding the unbalanced state, it is produced by the machinery fault simulator when the rotor has three more bolts and nuts added to it. Data was collected when the motor speed was changed to 10 RPM, 20 RPM, and 30 RPM, respectively. Data from the Blynk dashboard is also recorded by the computer's screen recorder.

Figure 4.14 Rotor with bolts and nuts

Table 4.4 Acceleration of Three MPU6050s when Motor Speed is 10/min. (Unbalance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	1	2	2	1	2	2	1	3	2	1	1.1	1.5
MPU1 X V3-V5	1	1	2	1	2	3	2	1	2	2	1.1	1.5
MPU2 X V6-V8	0	3	1	2	1	0	3	2	2	3	1.1	1.5
MPU Y V0-V2	1	2	1	1	2	3	3	2	2	1	1.1	2.4
MPU1 Y V3-V5	0	2	1	2	2	1	2	2	1	0	1.1	2.4

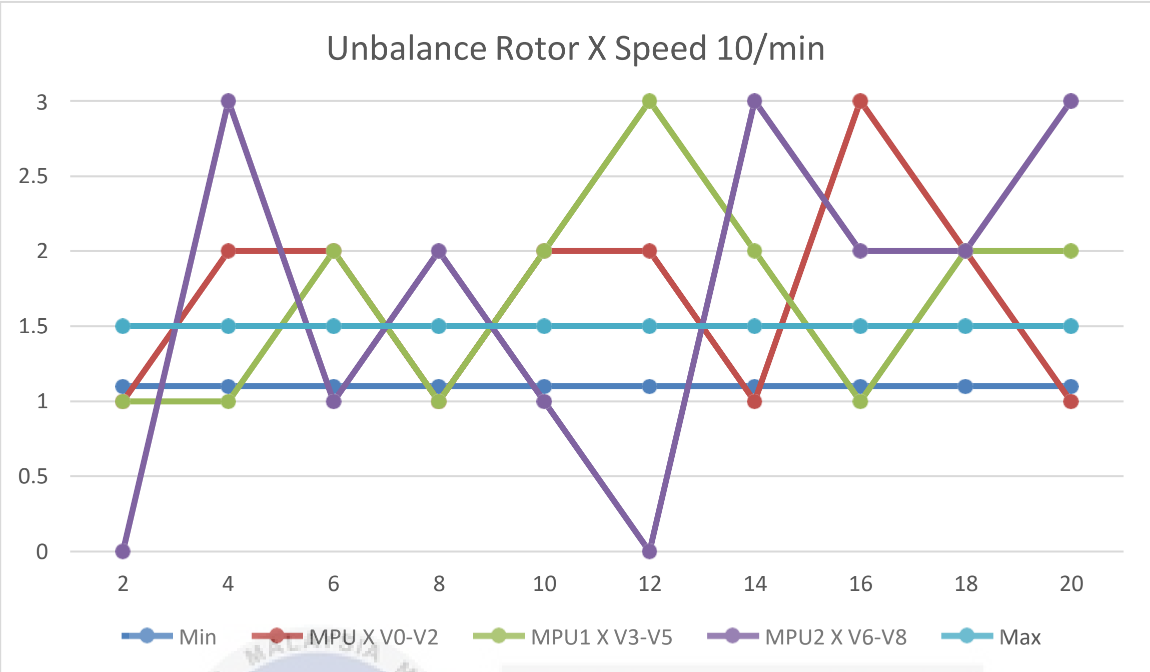

Figure 4.15 Acceleration of Three MPU6050s when Motor Speed is 10/min. (Unbalance Rotor)

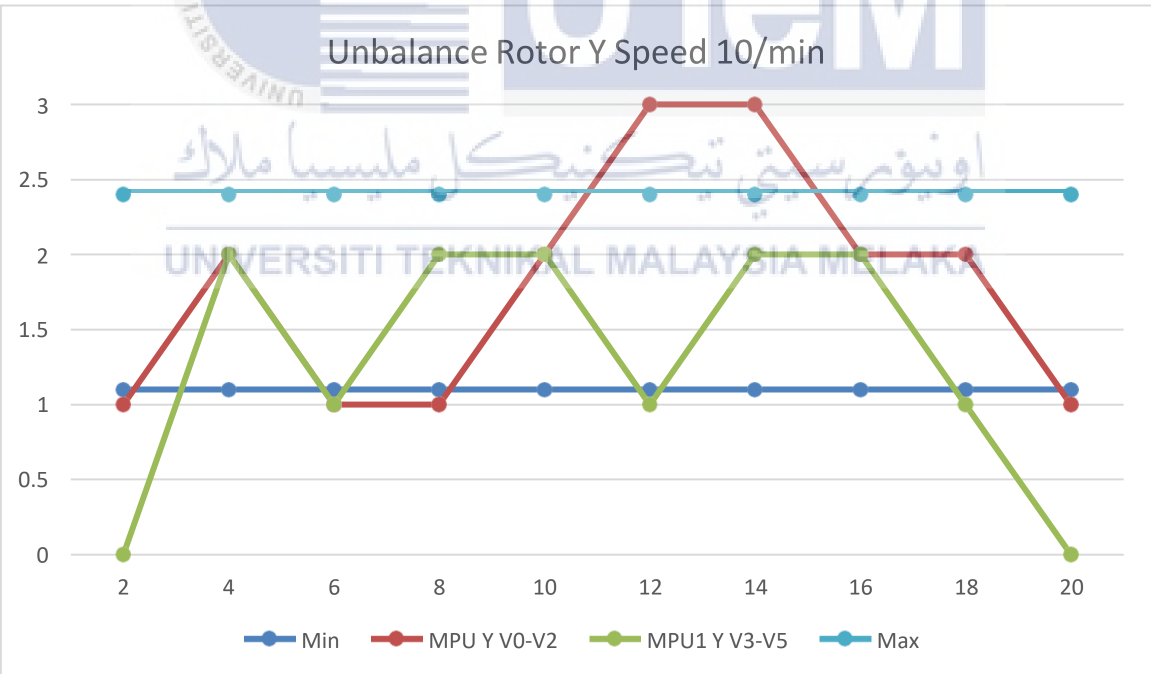

Figure 4.16 Acceleration of Three MPU6050s when Motor Speed is 10/min. (Unbalance Rotor)

The graphs of acceleration vs time for the unbalanced rotor running at 10 RPM are based on **Figures 4.15** and **4.16**. The Hibiscus Sense and two MPU6050 sensors are part of the low-cost vibration monitoring system. It operates at 10 RPM on a balanced rotor. The red trend, X V0-V2, represents the hibiscus sense. The green trend, X V3-V5, represents the first MPU6050 sensor. The purple trend, X V6-V8, represents the second MPU6050. On the Y axis, the first MPU6050 is represented by the green trend, Y V3-V5, and the hibiscus sense is represented by the red trend, Y V0-V2.

Table 4.5 Acceleration of Three MPU6050s when Motor Speed is 20/min. (Unbalance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	0	1	2	2	2	1	1	2	2	0	1.1	1.8
MPU1 X V3-V5	2	2	1	1	3	2	3	1	1	2	1.1	1.8
MPU2 X V6-V8	1	2	1	0	1	1	2	2	1	0	1.1	1.8
MPU Y V0-V2	1	2	0	2	3	3	2	2	1	1	1.1	2.7
MPU1 Y V3-V5	0	2	1	2	3	2	2	1	0	1	1.1	2.7

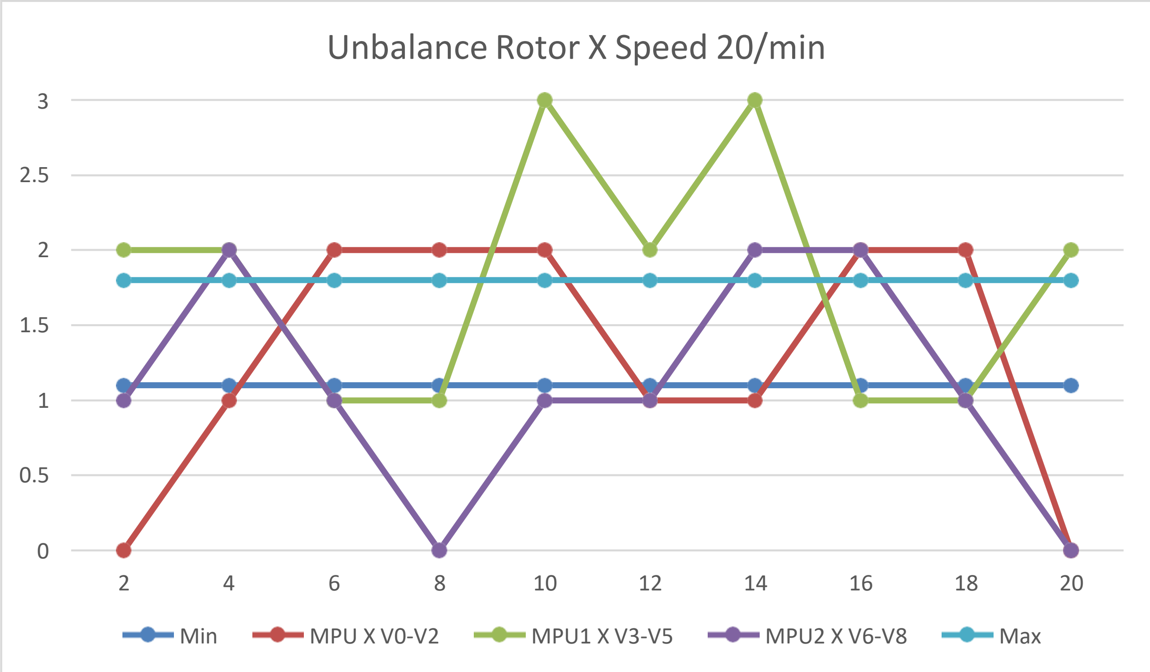

Figure 4.17 Acceleration of Three MPU6050s when Motor Speed is 20/min. (Unbalance Rotor)

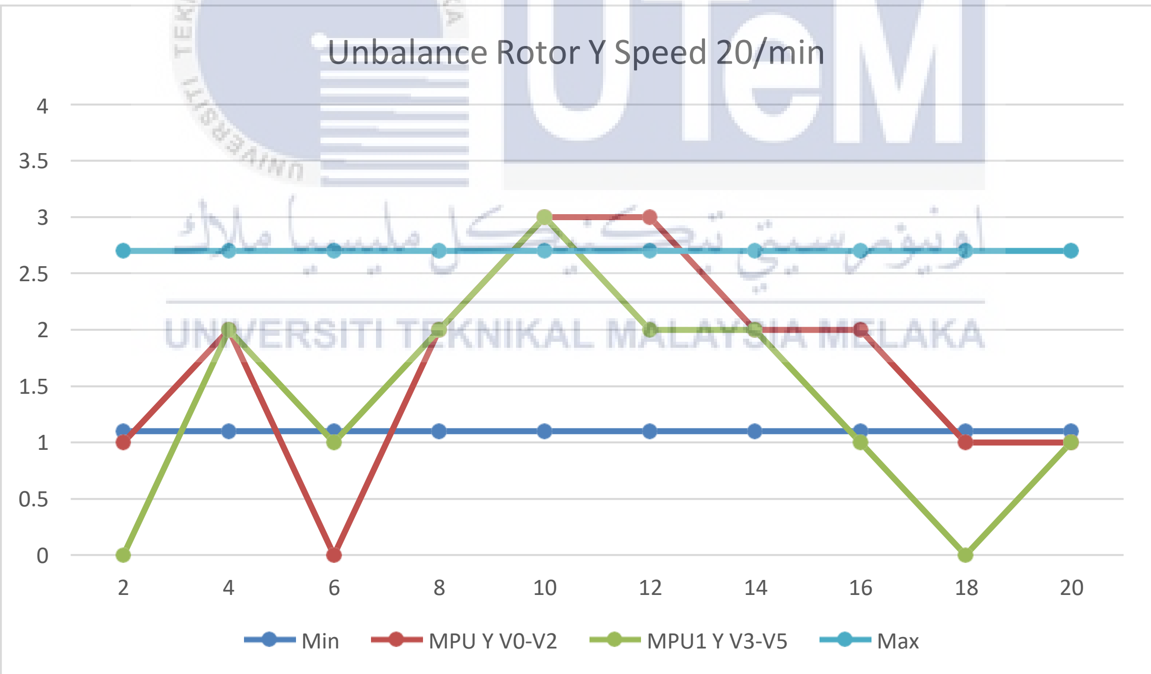

Figure 4.18 Acceleration of Three MPU6050s when Motor Speed is 20/min. (Unbalance Rotor)

Table 4.6 Acceleration of Three MPU6050s when Motor Speed is 30/min. (Unbalance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s²)	Time (s)										Heavy-duty vibration accelerometer (m/s²)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	0	1	2	2	2	1	2	1	1	0	1.1	2.2
MPU1 X V3-V5	1	2	1	2	2	1	2	2	1	2	1.1	2.2
MPU2 X V6-V8	0	2	2	1	3	2	1	2	2	1	1.1	2.2
MPU Y V0-V2	1	2	2	3	4	3	4	2	3	2	1.1	3.8
MPU1 Y V3-V5	1	2	3	2	3	3	4	3	2	1	1.1	3.8

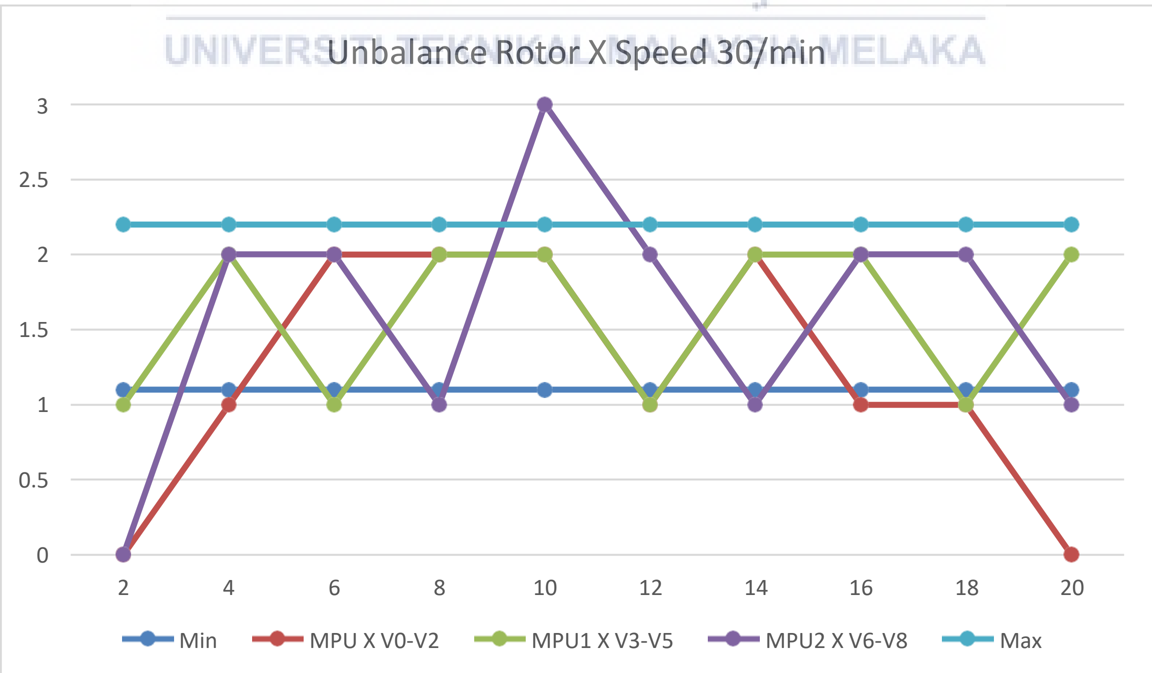

Figure 4.19 Acceleration of Three MPU6050s when Motor Speed is 30/min. (Unbalance Rotor)

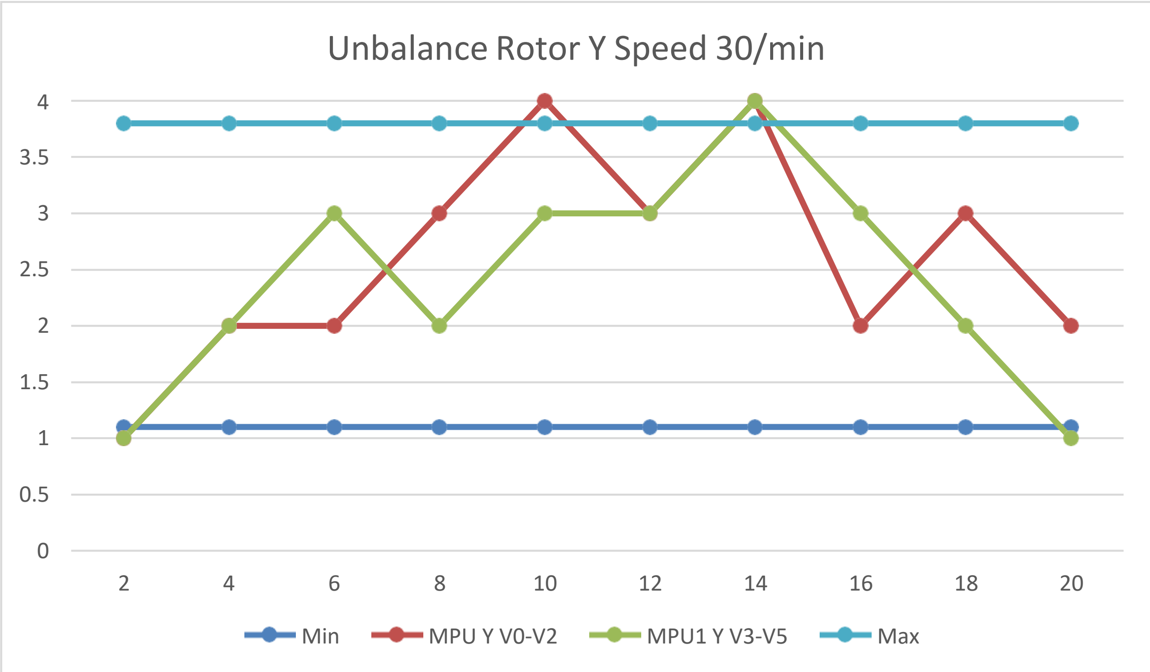

Table 4.20 Acceleration of Three MPU6050s when Motor Speed is 30/min. (Unbalance Rotor)

The acceleration versus time graphs in **Figures 4.19** and **4.20** demonstrate that, within the data range, the X and Y axis for the low-cost vibration monitoring system and the real vibration meter are identical. The amount of vibration data has increased significantly at 10 RPM, 20 RPM, and 30 RPM on the unbalanced rotor. As we can see, the MPU6050 and the hibiscus sense are equally sensitive and continuously produce data that is comparable to the vibration meter actually.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In order to create an integrated vibration monitoring system at a reasonable cost, we decided to use two free interface software options for this project: the Arduino IDE and Blynk software. The Arduino IDE was used to create the necessary code for the vibration monitoring system in an efficient manner. The two GY-521 accelerometers and the integrated MPU6050 accelerometer are controlled by the Hibiscus Sense microcontroller. Vibration detection and data collection are handled by the MPU6050 and sent to the microcontroller. Moreover, the microcontroller has the capability to transfer the obtained data to the Blynk program via the Wi-Fi connection in the laboratory.

Additionally, the project's use of gauge charts and graphs to convey data is made possible by the Blynk program. Wireless link has been established between Hibiscus Sense and the Blynk software. Thus, the successful implementation of an affordable wireless integrated vibration monitoring system is assigned to the efficient wireless communication between the hardware and software elements of the system.

The outcomes of the study confirm that both the built-in accelerometer MPU6050 and two GY-521 MPU6050 accelerometer can effectively distinguish vibration patterns along the x, y, and z axes during both balanced and unbalanced conditions. This substantiates the capability of the low-cost integrated vibration monitoring system developed in this project for conducting industrial vibration analysis.

In conclusion, the system has successfully built a wireless integrated low-cost vibration monitoring system through the verification of the findings, indicating that the project's goals have been met. The system has accomplished the project aim, which is the IoT vibration monitoring evaluation, as it can transmit data to the Blynk software via a Wi-Fi connection, and the Blynk software stores the data in the Blynk IoT cloud.

5.2 Installation Suggestion

This section will focus on suggestions for installing low-cost vibration monitoring systems in industry for machinery vibration analysis.

5.2.1 Procedures Install Low Cost Vibration Monitoring System

The Arduino IDE software (version 1.8.19) and the libraries needed for code upload must be downloaded and installed by users. Hibiscus Sense must first connect to the Wi-Fi network by the user entering his or her Wi-Fi name and password in a designated line of the code before uploading the code for the low-cost vibration monitoring system to Hibiscus Sense.

The user needs to access the Blynk IoT website, log in with the provided account, and open the specified device from the device list in order to verify the connection between Hibiscus Sense and Blynk software after uploading the code. In case Blynk is online, it indicates that Hibiscus Sense has successfully connected to Blynk and is functional. The code has to be reviewed and uploaded again if the status is offline, which indicates that the Wi-Fi name and password were given incorrectly.

The Hibiscus Sense and GY521 MPU6050 must be placed on the machine's measuring motor using the attached magnets located at the bottom of the Hibiscus Sense's case. A longer jumper wire between Hibiscus Sense and GY-521 MPU6050 allows the device to be positioned at multiple points on the machine to detect different vibration sources, such as a shaft or gear. If the motor casing 72 is composed of non-metallic material, Hibiscus Sense and GY-521 MPU6050 can be attached to the top of the motor using heavy-duty double-sided tape. Using magnets or strong double-sided tape, the power bank may be fastened to the machine casing or a flat surface surrounding the motor that is being tested. Following that, users may view the real-time vibration trend produced by the vibration monitoring system by refreshing the Blynk website.

5.2.2 Quantity of Sensor

Only two accelerometer MPU6050s may be controlled simultaneously by Hibiscus Sense or ESP32 development boards. Thus, there are just two vibration sensor accelerometers in a vibration monitoring system that uses Hibiscus Sense or another ESP32.

5.2.3 Power Supply

In this project, the vibration monitoring system is powered entirely by a 5000mAh battery bank. In actuality, the integrated low-cost vibration monitoring system in this project has been powered by power banks or Lithium Polymer (LiPo) batteries with a capacity of at least 4000mAh. For this project, a 5000mAh power bank was used since it has a longer lifespan than a 4000mAh battery.

5.3 Future Improvement

The project's integrated low-cost vibration monitoring system will look better if heat shrink tube is used to hide the jumper wire between the Hibicsus Sense and the GY-521

MPU6050. Electrical cables are wrapped in heat shrink tubes, which are shrinkable insulators. Heat causes the tubing to contract, turning the jumper into a single cable and preventing the jumper connections from coming loose. In order to decrease the size of the vibration monitoring system, it is also possible to specifically order the housing for the Hibiscus Sense and accelerometer GY-521 MPU6050 from online or physical retailers. Solar cells might eventually be used to power the vibration monitoring system instead of power banks or LiPo batteries, which would eliminate the need to constantly charge and replace the battery.

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APPENDICES

APPENDIX A Result of Turnitin

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APPENDIX B Gantt Chart PSM 1

Gantt Chart for PSM 1																
No	**Task Project**	**Plan / Actual**	**Week**													
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	PSM title registration	Plan														
		Actual														
2	Project briefing withsupervisor.	Plan														
		Actual														
3	Study and find the journal, thesis, and article for literature review	Plan														
		Actual														
4	Research about required components vibration	Plan														
		Actual														
5	Planning the project workflow	Plan														
		Actual														
6	Draw a flowchart of project workflow	Plan														
		Actual														
7	List and study the Component that will used	Plan														
		Actual														
8	Study about the software of vibration monitoring system	Plan														
		Actual														
9	Machine Learning Platform, Train Data, andEvaluate Data	Plan														
		Actual														
10	Install the coding and install the applications	Plan														
		Actual														
11	System Test	Plan														
		Actual														
12	Analysis Data	Plan														
		Actual														
13	Writing a report	Plan														
		Actual														
14	Preparing for presentation	Plan														
		Actual														

APPENDIX C Gantt Chart PSM 2

Gantt Chart for PSM 2																	
No	**Task Project**	**Plan / Actual**	**Week**														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	PSM 2 Briefing	Plan														
		Actual														
2	Doing some research about the project	Plan														
		Actual														
3	Discovering the coding information	Plan														
		Actual														
4	Setup for project	Plan														
		Actual														
5	Doing some connection on project	Plan														
		Actual														
6	Check all the setup of project	Plan														
		Actual														
7	Doing the cosmetic for the project	Plan														
		Actual														
8	Run the experiment	Plan														
		Actual														
9	Take data machine from lab	Plan														
		Actual														
10	Doing validation from the result	Plan														
		Actual														
11	Analysis data	Plan														
		Actual														
12	Doing some correction from data collection	Plan														
		Actual														
13	Writing a report	Plan														
		Actual														
14	Preparing for presentation	Plan														
		Actual														