UNIVERSITI TEKNIKAL MALAYSIA MELAKA

RESEARCH AND DEVELOPMENT OF LOW-COST VIBRATION MONITORING SYSTEM WITH INTERNET OF THINGS (IOT)

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BACHELOR OF TECHNOLOGY MECHANICAL ENGINEERING (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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Nik Muhammad Faris Bin Nik Ebrhiam

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NIK MUHAMMAD FARIS BIN NIK EBRHIAM

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of mechanical Engineering Technology (Automotive Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this Choose an item. entitled "Research And Development Of Low-Cost Vibration Monitoring System with Internet Of Things (IoT)" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	Nik Muhammad Faris Bin Nik Ebrhiam
Date	:	9 January 2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature	:	
Supervisor Name	:	Ts. Dr. Ahmad Fuad Bin Ab Ghani
Date	:	9 January 2023

DEDICATION

In Honor of My Father.

To provide an honest livelihood for us, to be a pillar of support, to provide the finest example possible for always doing one's best in one's life, and to inspire and motivate me to go much farther and to always put out maximum effort in everything I do.

The Mother of Me,

A courageous and sincere spirit that constantly encourages me in all I do, is there for me through the highs and lows of life, and never stops showing love and support for me.

My Treasured Brothers and Sisters,

For the Love, Support, and Encouragement They Gave Us While We Grew Up Together Successfully.

To Myself,

I want to thank you for having the confidence to know that you can prevail no matter how challenging the circumstances are and that there will always be a purpose and rewards for the things you do.

ABSTRACT

Vibration analysis in industry is a technique for detecting, predicting, and preventing mechanical failures. The presence of a number of prominent frequencies associated with the motion of various machine components is to be expected when analysing machine frequency vibrations (frequency analysis). Mechanics systems and structures can be damaged, stopped abnormally, or fail catastrophically if they are exposed to high levels of vibrations. To avoid these issues, vibration assessment is an essential countermeasure. A vibration monitoring system is a full system capable of gathering vibration signals according to pre-determined parameters, such as sampling frequency, vibration intensity and recording duration and intervals and frequency breadth. The method that using is component selection for the first step. Then circuit build up to program the microcontroller with coding make. Then setting the OBD interfaces such as blynk application. Then train the data and evaluate data for the project prototype with aid of coding software for microcontroller and sensors. Then, intergrate the system setting toward online monitoring applications to run and get the actual result and data. From this results it can be analysis from the data runing for system test. The main system using in this project are 5 components that is, Hibiscus Sense v1.0 ESP32, Ultrasonic Sensor HC-SR04, MPU6050 Vibration Sensor, Supply voltage and software platform monitoring system. There are 3 system have been created. The single vibration system is using only Hibiscus Sense v1.0 ESP32. This system stand alone to measure and carry out the acceleration 3 axis by MPU6050 inside the ESP32 microcontrollers and the temperature when vibrations occurs during system test. The single vibration with Ultrasonic sensor system includes Hibiscus sense ESP32 with Ultrasonic sensor. This system is to carry out the acceleration of 3 axis with temperature and distance. This double vibration system is to known the sustainability of both 3 axis accelerometer and to make comparison the diffenrence value of this vibration system. This system also can compare the temperature for ESP32 and MPU6050 sensor. The result was taken by using the Blynk applications with supporting guidance of coding motion detection to detection of vibration in several minutes to get the result shown in below figure. the interpreted data show of accelerometer gyroscope with aid of x, y, z axis of both ESP32 or MPU6050 sensor This data show to measure the sensitivity of vibration temperature and distance of some objects. It can be explained how IoT can help the condition monitoring and fault diagnosis of rotating machinery using vibration analysis. Further, vibration sensing has been investigated and the new generation of MEMS accelerometers has been introduced. This way the machine will be able to send its vibration status to the server and the maintenance engineers will be able to monitor it anytime, anywhere. The developed hardware has been evaluated by comparing the results of online and local data measurements at the same time. The results of the evaluation have been proved to be very precise. This paper will prove the concept of using IoT enabled sensors in predictive maintenance to overcome some gaps in the commonly used methods of condition monitoring of rotating machinery. The results can be extended to a larger scope of equipment, faults, and parameters.

ABSTRAK

Analisis getaran dalam industri ialah teknik untuk mengesan, meramal dan mencegah kegagalan mekanikal. Kehadiran beberapa frekuensi menonjol yang dikaitkan dengan gerakan pelbagai komponen mesin adalah dijangka apabila menganalisis getaran frekuensi mesin (analisis frekuensi). Sistem dan struktur mekanik boleh rosak, dihentikan secara tidak normal, atau gagal secara besar-besaran jika terdedah kepada tahap getaran yang tinggi. Untuk mengelakkan isu ini, penilaian getaran adalah langkah balas yang penting. Sistem pemantauan getaran ialah sistem penuh yang mampu mengumpul isyarat getaran mengikut parameter yang telah ditetapkan, seperti kekerapan pensampelan, keamatan getaran dan tempoh rakaman dan selang serta keluasan frekuensi. Kaedah yang digunakan ialah pemilihan komponen untuk langkah pertama. Kemudian bina litar untuk memprogramkan mikropengawal dengan pembuatan pengekodan. Kemudian tetapkan antara muka OBD seperti aplikasi blynk. Kemudian melatih data dan menilai data untuk prototaip projek dengan bantuan perisian pengekodan untuk mikropengawal dan penderia. Kemudian, integrasikan tetapan sistem ke arah aplikasi pemantauan dalam talian untuk dijalankan dan mendapatkan hasil dan data sebenar. Daripada keputusan ini bolehlah analisis daripada data yang dijalankan untuk ujian sistem. Sistem utama yang digunakan dalam projek ini ialah 5 komponen iaitu Hibiscus Sense v1.0 ESP32, Ultrasonic Sensor HC-SR04, MPU6050 Vibration Sensor, Voltan bekalan dan sistem pemantauan platform perisian. Terdapat 3 sistem telah dibuat. Sistem getaran tunggal hanya menggunakan Hibiscus Sense v1.0 ESP32. Sistem ini berdiri sendiri untuk mengukur dan menjalankan pecutan 3 paksi oleh MPU6050 di dalam mikropengawal ESP32 dan suhu apabila getaran berlaku semasa ujian sistem. Getaran tunggal dengan sistem penderia Ultrasonik termasuk deria Hibiscus ESP32 dengan penderia Ultrasonik. Sistem ini adalah untuk menjalankan pecutan 3 paksi dengan suhu dan jarak. Sistem getaran berganda ini adalah untuk mengetahui kemampanan kedua-dua pecutan 3 paksi dan untuk membuat perbandingan nilai perbezaan sistem getaran ini. Sistem ini juga boleh membandingkan suhu untuk penderia ESP32 dan MPU6050. Hasilnya diambil dengan menggunakan aplikasi Blynk dengan panduan sokongan pengesanan gerakan pengekodan untuk pengesanan getaran dalam beberapa minit untuk mendapatkan hasil yang ditunjukkan dalam rajah di bawah. data yang ditafsirkan menunjukkan giroskop pecutan dengan bantuan paksi x, y, z kedua-dua penderia ESP32 atau MPU6050 Data ini menunjukkan untuk mengukur kepekaan suhu getaran dan jarak beberapa objek. Ia boleh dijelaskan bagaimana IoT boleh membantu pemantauan keadaan dan diagnosis kerosakan jentera berputar menggunakan analisis getaran. Selanjutnya, penderiaan getaran telah disiasat dan generasi baharu pecutan MEMS telah diperkenalkan. Dengan cara ini mesin akan dapat menghantar status getarannya kepada pelayan dan jurutera penyelenggaraan akan dapat memantaunya pada bila-bila masa, di mana sahaja. Perkakasan yang dibangunkan telah dinilai dengan membandingkan hasil pengukuran data dalam talian dan tempatan pada masa yang sama. Keputusan penilaian telah terbukti sangat tepat. Makalah ini akan membuktikan konsep penggunaan penderia didayakan IoT dalam penyelenggaraan ramalan untuk mengatasi beberapa jurang dalam kaedah pemantauan keadaan yang biasa digunakan bagi jentera berputar. Hasilnya boleh diperluaskan kepada skop peralatan, kerosakan dan parameter yang lebih besar.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
f	-	frequency
RMS	-	Root Mean Square
CPM	-	Cycle Per Minute
Hz	-	Hertz
IDE	-	integrated development environment
	-	
	-	

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of study

Vibration analysis in industry is a technique for detecting, predicting, and preventing mechanical failures. The presence of a number of prominent frequencies associated with the motion of various machine components is to be expected when analysing machine frequency vibrations (frequency analysis). Mechanics systems and structures can be damaged, stopped abnormally, or fail catastrophically if they are exposed to high levels of vibrations. To avoid these issues, vibration assessment is an essential countermeasure.

Displacement, velocity, and acceleration are the three major metrics used to characterise the vibration characteristics of any dynamic piece of equipment. Mechanical looseness, gear drive problems, defective roller bearings or sleeve bearings are only some of the common causes of vibration in rotating machinery that may be detected by vibration analysis.

When the frequency of data collection does not correspond to the maintenance strategy, the ultimate goal of vibration analysis is to find flaws in rotating equipment and alert employees to the need for corrective action. In order to minimise downtime and improve plant dependability, vibration analysis can be used to detect these faults before they occur.

1.2 Problem Statement

There are several technical applications where vibration is an issue. Mechanical, civil, and aeronautical engineers often deal with a wide range of vibration issues. Vibration is the periodic movement or movement of a component or structure. Occasionally, structural deformation or failure can occur as a result of significant stresses or resonances in a component. The study of vibrations in mechanical, structural, and acoustic systems has therefore become standard practise.

This system works a combination with programming software by microcontroller and vibration sensor with aid of IoT (Internet of Things) to show the data of an object through the computer screen. Due to low cost specific we are able to swiftly screen and take action because of the low cost specificity. Adding condition monitoring technologies to your maintenance programme will provide you with deeper insights and more actionable data, allowing you to make data-driven choices.Other than that, to identify the potential early failure and the most important to reduce cost maintenance

1.3 Objective

When creating a prototype, it is a good idea to set some goals
and objectives.The purposes of this project are:

i. To program, monitors the levels and patterns of vibration signals within a component, machinery or structure show data with aid of IoT (Internet of Things).

ii. To test the vibration monitoring system on machine with low cost system method

1.4 Project Scope

The project's scope is as follows:

i. Monitoring the vibration from the laptop screen for the machine
ii. The frequency range that can be detected is 1kHz to 8kHz
iii. Arduino IDE software and Blynk application will be use to program and interprete the data or graph

1.5 Report Outline

The vibration monitoring system final report is divided into five chapters, each of which contains and elaborateson a different topic, such as the Introduction, Literature Review, Results and Analysis, and Conclusion. The following is a full description of the thesis outline for each chapter:

Chapter 1: The project's introduction. The project's clarification will be given in generalterms. The project objectives will be described in detail. It is supported by an explanation of the project's scope.

Chapter 2: A literature review was conducted in preparation as the vital element during the implementation of a vibration sensor device. This chapter goes into the project's literature review in detail. This entire part will be based on theory and conceptual ideas that will focus on the previous model of sensor that hasbeen studied.

Chapter 3: The methodology for the project. This chapter discusses the overall planning to this project, as well as the component and circuitry development.

Chapter 4: The outcome and the analysis. This chapter discusses the vibrating monitoring system's performance and the results received.

Chapter 5: Conclusion and Discussion. Costing and commercialization, as well as potential recommendations, were addressed in this chapter. Lastly, the project's conclusion also is being discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Throughout the project, a literature review was conducted to acquire information and develop skills required to complete the project. This project's primary sources include previous related efforts, research theses, books, journals, and articles. This chapter will focus on the vital concepts and theories that are essential to this project scope.

2.2 Vibrations

Some vibrations are beyond our comprehension. As a result, several novel technologies for monitoring and analyzing it have emerged. So, what precisely is vibration? It refers to the movement of a machine or its components from one location to another. This vibration may be created for a specific purpose in some circumstances, while in others, it may cause damage to the machine. As a result of the vibrations, money and time are lost. Here, we're largely concerned with unintentional machine vibrations. Machine lifespan is inversely related to vibration. Low vibratory forces indicate low vibration levels, which leads to extended machine life. Machine vibration increases when the dynamic forces created by the machine get more intense or the physical integrity of the machine is damaged, depending on the state of a machine's performance at the time. Exciting force, mass of vibrating system, rigidity of vibrating system, and damping qualities are all factors in determining vibration characteristics. The first component causes vibration, whereas the other three factors are designed to lessen or avoid it.(Kv 2015)

2.2.1 Causes of vibrations

A. Repeating forces

It's the frequency with which a pattern is repeated that determines its intensity. When a machine is subjected to a constant force, it will vibrate. Recurring strains are caused by malfunctioning, damaged, or misplaced machine components. 30 percent of the problem is due to imbalance; 20 percent is due to misalignment; ten percent is due to resonance; and the remaining 40 percent is due to other problems. Errors in machining, material density variations, and other factors may all contribute to unevenness. As a result of mismatched pieces and bending moments, repetitive stresses are formed. Misalignment may be caused by a variety of factors, including faulty assembly, thermal expansion, and more.. (Kv 2015)

B. Looseness

Vibration may result from loose machine components. Because of loose components, there may be a lot of vibration. Non-rotating and rotating equipment may produce vibrations. The looseness is caused by loose bolts, uneven components, and other issues.. (Kv 2015)

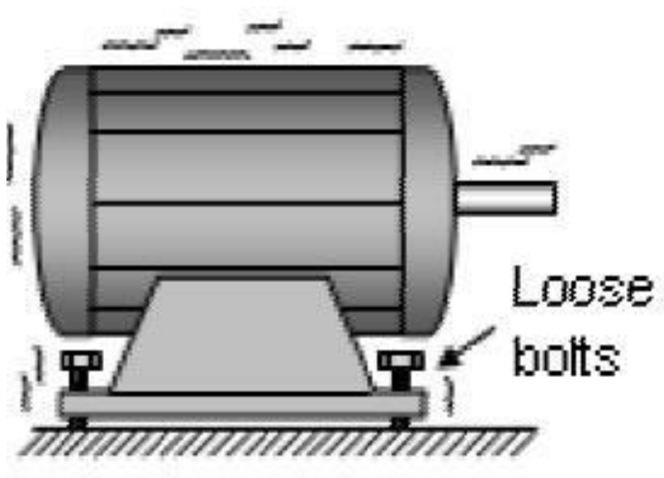


Figure 2.1 looseness of bolt when vibration occur

C. Resonance

When an external force is added to a machine's inherent oscillation rate, extra vibrations are generated. Adding these alien vibrations together creates the resonance. The frequency of natural oscillations increases as the complexity of the machine increases. Avoid the resonance at all costs since it has the potential to be quite harmful. Soldiers marching in lockstep over a bridge have caused it to collapse on many occasions.(Kv 2015)

2.2.2 Describing and observation of vibrations

Amplitude and frequency are two crucial numerical qualities. Machines with bigger amplitudes are more vulnerable to vibrations since amplitude defines the intensity of the vibration. Representation of overall vibration data in rms is a common practice. It is possible to quantify the vibration's energy using the root mean square amplitude (rms amplitude). The root mean square amplitude of the vibrational energy is inversely proportional to this energy. RMS value should never be larger than maximum peak intensity. To gauge the entire noise level, the above-mentioned function comes in handy.

It provides a good sense of the system's imbalance. The rate at which a machine component oscillates is known as its vibration frequency or oscillation. The frequency of vibration is used to characterize the pace at which it oscillates. The quicker the machine oscillates, the greater the vibration frequency. Cycles per second (cps), cycles per minute (cpm), and Hertz (Hz) are all ways to represent frequency (Hz).

1 Hz equals 1 cps equals 60 cpm.

A waveform is a graphic representation of how the quantity of vibration changes over time. The amount of data included in a waveform is determined by its length and resolution. The duration of a waveform's data is the total length of time it took for the waveform's data to be gathered. Resolution is used to measure the level of detail in an image.(Kv 2015)

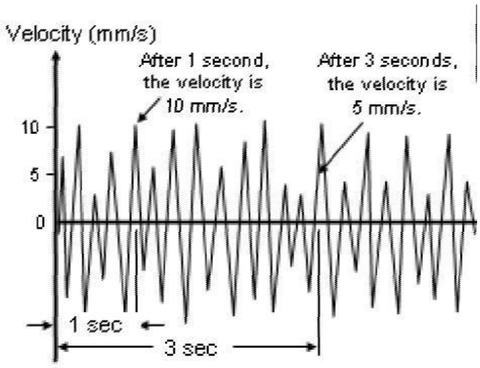


Figure 2.2 waveform

Vibration analysis makes use of a spectrum or waveform. The term "spectrum" describes a visual representation of the frequencies of vibration. It's an excellent research tool. The spectrum is most often used in vibration analysis. Data-richness of a spectrum is determined by its highest frequency and resolution. The machine's speed affects Fmax. Because of the link between spectral line density and spectral resolution, more lines in a spectrum means greater information.(Kv 2015)

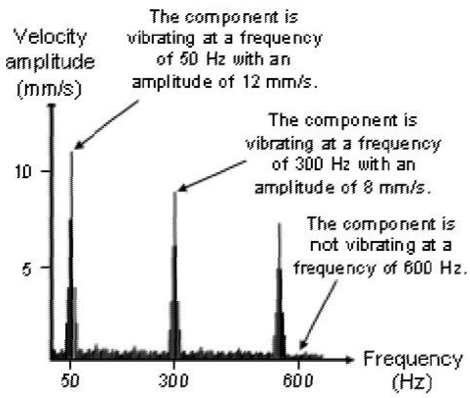


Figure 2.3 spectrum

The machine whose vibration is being monitored should have a sensor installed. When a moving part accelerates, an accelerometer measures the change in electrical potential and outputs a corresponding signal. Using this data, the user may see a waveform or spectrum of the velocity signal that has been gathered.(Kv 2015)

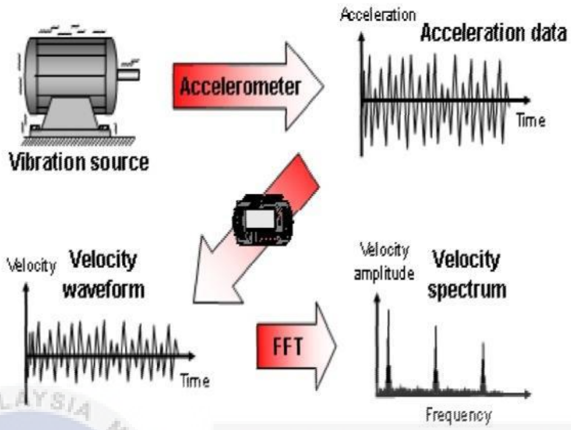


Figure 2.4 working of instrument

2.2.3 Vibration Sensing for Machine Health Monitoring

MHM (Machine Health Monitoring) offers effective methods for safeguarding equipment and reducing downtime. Vibration monitoring allows for preventive maintenance on almost any type of machine in industries such as aerospace, civil engineering, oil and gas, rail, robotics, and unmanned vehicles. Sensors are mounted to mechanical components of machines during condition monitoring to track failures and malfunctions. Sensors can be put on machinery and Line-Replaceable Units in industry and aeroengine (LRU). A modular component of an aero plane or spacecraft that is meant to be easily replaced in the field is known as an LRU. LRU are components that are not directly connected to the main engine but are necessary for it to function. (Marcocchio 2018)

2.3 Sensors

A sensor, also known as a transducer, translates mechanical signals to electrical signals. The frequency range, sensitivity, design, and operating limits frequently dictate the type of sensor used. The larger the frequency range and reading accuracy, independent of sensor type, the firmer the sensor mounting. In vibration analysis, three types of sensors are usually used to collect the vibration signal. An accelerometer, a velocity sensor, and a displacement sensor are among the sensors. This section also includes information on the noncontact LDV sensor. (Mohd Ghazali and Rahiman 2021)

2.3.1 Sensor Mounting Method.

Vibration measurements need careful consideration of the mounting mechanism used and the way it is applied. For continuous or real-time monitoring of machine status, vibration sensors are often put in a specific region of the machine. Stuck-on, adhesive, magnet, and non-mounting techniques are the four forms of mounting available. Permanent installation often involves the use of stud mounting. The sensor is attached to the machine by screwing it into a stud. In addition to being very durable and safe, this way of mounting has the widest frequency response of any other approach. Clean and paint-free surfaces are necessary for the sensor to work properly since any irregularities in the mounting surface might cause inaccurate readings or even sensor breakdown. Adhesive installation does not need much machining due to the application of epoxy, glue, or wax. Installing using adhesive is generally the best solution when drilling holes for stud attachment is not possible on the machine. Due to the damping in the glue, this method of attachment is less precise than other options. Furthermore, it is more difficult to remove the sensor when compared to other mounting techniques. (Mohd Ghazali and Rahiman 2021)

2.3.2 Accelerometer.

The acceleration of a structure is measured with an accelerometer, which uses the SI unit of g (m/s2). When a force is applied to the accelerometer's piezoelectric material, a charge is generated in direct proportion to that force. Acceleration is inversely proportional to force; therefore, any change in this parameter alters the charge generated and is magnified as a result. Unlike a uniaxial accelerometer, a triaxial accelerometer can measure movement in all three dimensions simultaneously. The memory capacity of the triaxial accelerometer is more than that of the uniaxial accelerometer, but it is much more costly. The accelerometer is an extensively used sensor due to its reliability, simplicity, and resilience. It may be separated into a piezoelectric and a microelectromechanical system accelerometer (MEMS).(Mohd Ghazali and Rahiman 2021)

A) **Piezoelectric**

At its basis, a piezoelectric accelerometer employs the piezoelectric effect. The output of preloaded quartz or ceramic crystals is proportional to their acceleration. The charge generated is affected by this acceleration. One of the advantages of a piezoelectric accelerometer is that it has a wide dynamic range and is quite sensitive. It is, nonetheless, vulnerable to external influences. In order to acquire AC-linked velocity and displacement data, electrical integration is also required. (Mohd Ghazali and Rahiman 2021)

B) **MEMS accelerometer**

An MEMS accelerometer consists of moveable proof masses with plates attached to the frame through a mechanical suspension mechanism. Because of its intrinsic inertia, the proof mass tends to impede forward motion when accelerated. As a consequence, the applied acceleration generates a force equal to the applied acceleration. This makes MEMS accelerometers perfect for detecting low-frequency vibration and acceleration. In addition to being more efficient, it is also more sensitive. Modern MEMS accelerometers give good data quality up to several tens of kHz. It has a poor signal-to-noise ratio, which is a major downside.(Mohd Ghazali and Rahiman 2021)

A microelectromechanical system (MEMS) is a method of combining mechanical and electrical components to build microscopic structures. Miniaturization lowers costs by lowering material usage. Furthermore, because MEMS are small and light, they can be used in places where a regular system would not fit. MEMS accelerometers are utilised in a variety of applications, including shock detection, tilt control, and vibration monitoring. MEMS accelerometers stand out due to their small size, light weight, and inherent signal filtering. (Kok et al.) integrated, for example, a complete wireless data gathering system that includes a MEMS accelerometer, a CPU, and an RF transceiver. They determined that its total weight is little.(Marcocchio 2018)

2.3.3 Velocity Transducer.

A velocity transducer measures the voltage generated by an object's relative movement in millimetres per second or centimetres per second, depending on the specific application. It's powered by electromagnetic induction and doesn't need an additional device to work. When the surface on which the sensor is positioned vibrates, the movement of the magnet in the coil generates a voltage that is proportional to the speed of the vibration. This voltage signal is delivered into a meter or analyzer and indicates the vibrations that have been generated. It is not recommended to utilize velocity sensors for diagnosing high-speed equipment since their functioning frequency range is restricted to 10 Hz-2 kHz. For rotating machinery, velocity transducers are more cost-effective than other sensors, especially when paired with their simplicity of installation. Despite its size and weight, most velocity transducers fail at temperatures more than 121°C, and this device is no exception.(Mohd Ghazali and Rahiman 2021)

2.3.4 Displacement Sensor.

The displacement sensor, often known as an eddy current or proximity sensor, senses both relative vibration and shaft position. The displacement unit can be measured in meters, centimeters, or millimeters. It is most used to monitor low-frequency vibrations less than 10 Hz, but it can also measure vibrations of up to 300 Hz. However, excel at analyzing a shaft bending away from the probe position. The displacement probe can detect problems such as unbalance and misalignment. The amplitude of observed vibration frequencies exceeding 1 kHz is frequently lost in the noise level. It has a good dynamic range within a defined frequency range, as well as reasonable sensitivity. with a low-maintenance postprocessing circuit It is, however, difficult to install, prone to shocks, and certain classic displacement sensors are not calibrated for unknown metal alloys. (Mohd Ghazali and Rahiman 2021)

Sensors	Advantages	Disadvantages
Piezoelectric accelerometer	Lightweight, high sensitivity, good frequency, dynamic range	Needs electronic integration to acquire velocity and displacement data, vulnerable to interference from the external environment
MEMS accelerometer	Cheaper than piezoelectric sensor, requires low processing power, high sensitivity	Suffers from poor signal-to-noise ratio
Velocity transducer	Can operate without any external device, generally costs less than other sensors	Limited operational frequency range, most velocity transducers are prone to reliability problems at operational frequency of more than 121°C
Displacement sensor	Good sensitivity, simple postprocessing circuit with negligible maintenance	Succeptible to shock, difficult to install
LDV	Ease of changing the measurement points, ability to provide long-range measurements without compromising the signal quality	Extremely high cost, limited portability

Figure 2.5 sensor benefits and drawbacks for vibration analysis in machine monitoring and diagnostics

2.4 The general for Arduino and Microcontrollers

The Arduino microcontroller is open source and free to use. It may be programmed, wiped, and reprogrammed at any time. The Arduino platform, which debuted in 2005, was created to give a low-cost and simple means for amateurs, students, and professionals to construct devices that interact with their surroundings by sensors and actuators. It is a free and open-source computing platform used to develop and programmed electronic devices based on low-cost microcontroller boards. It can also function as a minicomputer, much like other microcontrollers, by accepting inputs and regulating the outputs of various electronic devices. (Louis 2016)

Arduino shields, some of which are detailed in this paper, may be used to receive and deliver data over the internet. The Arduino IDE and Arduino development board are the tools used by Arduino to create software (Integrated Development Environment). Using the Arduino IDE and the C or C++ programming languages, these 8- or 32-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors may be readily programmed.(Louis 2016)

As opposed to other in Indian microcontroller boards, Arduino boards were first introduced to the electrical industry just a few years ago and were first restricted to small-scale purposes. Arduino's effectiveness in electronic projects is progressively being recognized and acknowledged by those in the field. This development board may also be used to upload fresh code to the board by connecting it to a computer through a USB cable. Users may write Arduino programme in C or C++ using the Arduino IDE, a simpler integrated platform that runs on standard PCs.(Louis 2016)

Popularity of the Arduino is based on its simplicity of use, easy programming, and inexpensive cost, making it a great tool for rapidly constructing and testing electrical prototypes. A USB port on a computer or an external power source may be used to power it. Using Arduino as a data gathering system is the goal of this research. Mechanical vibration phenomena may be studied using sensors like accelerometers, gyroscopes, and ultrasonography by undergraduate physics and engineering students. To make things even more affordable, these sensors have become commonplace in smartphones and other electronics because of their ubiquitous usage. The Arduino port takes data from sensors through analogue and digital ports, and is connected to the computer via USB to establish the connection..(Varanis et al. 2016)

2.4.1 Using the ESP32 for data processing

Wi-Fi 802.11 b/g/n, dual mode Bluetooth 4.2, and a number of other peripherals are all included into the SoC (System on Chip) microprocessor known as the ESP32. It's a superior replacement for the 8266 processor since it has two cores running at different speeds of up to 240 MHz. Increased GPIO pin count, 16 PWM channels per 16, and 4MB flash memory are also included in the new version. When it comes to the ESP32 processor, Espressif Systems developed it. This SoC is now available in multiple ESP32 versions, including the ESP32 Dev Kit, the ESP32 Wrover Kit, which includes an SD card and a 3.25-inch LCD display, and the ESP32 Azure IoT Kit, which includes a USB Bridge and other built-in sensors. In addition to Espressif Systems, there are a number of other companies that specialise in these chips, including SparkFun, WeMoS, and Adafruit, as well as DF Robot, which makes the ESP32 FireBeeatle. (Babiuch, Foltynek, and Smutny 2019)

ESP32 has two parts (Xtensa LX6 processor made with 40 nm technology). Separate cores may be governed. On-chip SRAM stores data and instructions. ESP32-Wrover has 4 MB of external SPI flash and 8 MB of SPI PSRAM (Pseudo static RAM). Depending on the board, we employ SPI, I2S, I2C, CAN, UART, Ethernet MAC, and IR. Azure IoT and Developer kit has built-in Hall Effect, temperature, and touch sensors. SoC supports AES, SHA-2, RSA, ECC, and a random number generator (RNG).(Babiuch, Foltynek, and Smutny 2019)

Prototype ESP32 boards are produced for use in smart home applications, automation, wearables, audio applications, cloud based IoT applications, and other applications. A development kit can be chosen, or a custom embedded system based on the ESP32 microcontroller can be created. The ESP32 microcontroller versions with which we collaborate at the Control System and Instrumentation Department are depicted in Figure 1. (Babiuch, Foltynek, and Smutny 2019)

Figure 2.6 various ESP32 boards

A popular framework for developing for the ESP32 is the Espressif Systems Internet of Things Development Framework (ESPIDF), which is open-source and available on GitHub. To execute bash files on the ESP-IDF, you will need a Linux terminal. MSYS2 may, on the other hand, be used in Windows development. Thanks to this free software, a Linux terminal may be used on Windows computers. You'll also need the ESP-IDF-Template to get started with an ESP32 project. In this collection, you'll find files required for a successful compilation but not included in the IDF.(Maier, Sharp, and Vagapov 2017)

2.4.2 Developing application of ESP32

The development of the ESP32 platform provides us with a diverse set of applications. This section explains how to set up the ESP32 platform environment. Any Windows, Linux, or MacOS operating system can be used to build the ESP32 device. Most of this lesson will focus on installing and configuring the Windows development environment. The Espressif IoT Development Framework native platform, the ESP32 Arduino add-on environment, and the Python environment powered by the Micropython engine are all available. (Babiuch, Foltynek, and Smutny 2019)

2.4.3 ESP32 Application system

The actual implementation of numerous applications in the field of collecting and processing of measured data from IoT sensors on the ESP32 microcontroller has benefited from the knowledge acquired from the use of unique development environments on the Windows platform. Figure 2.10 depicts the embedded system's block diagram. (Babiuch, Foltynek, and Smutny 2019)

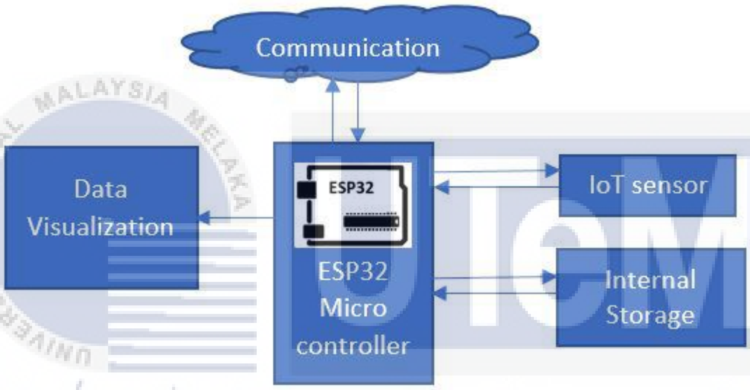


Figure 2.7 Block scheme of the embedded system

We focused on the depiction of measured data on a display that is part of our embedded system in this post. The communication buses vary based on the type and size of the display, and the size of the display is determined by the type of information to be displayed. We chose to present only the status information on lower resolution displays and transferred the measured data to the superior system for evaluation. We provide several bits of information on the display, such as whether the microcontroller is connected to the network, which task is now being handled, and how far along the measurement cycle is. In addition to status information, we display the measured data as a graphical flow on larger, higher-resolution monitors. Only one graph was provided, with the option to pick among the graphs of the measured amounts, because numerous variables were assessed concurrently. For our embedded system, we used a variety of screens.(Babiuch, Foltynek, and Smutny 2019)

2.4.4 Development of Falling Notification System for Elderly Using MPU6050 Sensor

This article describes the creation of a falling detection and notification system for the elderly in the form of short messages sent to mobile phones and recorded in the system database. The proposed prototype uses the MPU6050 sensor to detect falling movements and a continuous alerting system composed of three separate messages received shortly after falling. To put the research findings to the test, the confusion matrix approach was used. The experimental results of this study indicate that the recall value is 90%, the precision is around 82 percent, the specificity is approximately 94 percent, and the accuracy is approximately 93 percent. (Najmurrokhman, Udin, and Aditya 2021)

2.5 IoT (Internet of Things)

One of the most powerful technologies for creating, changing, and sharing data is the Internet of Things (IoT). While the growth of connected devices has the potential to improve every aspect of our lives, security concerns are increasing. The Internet of Things is widely regarded to be a threat to user privacy first and foremost. In addition, numerous strategies, and solutions for dealing with IoT security challenges are discussed. We provide an in-depth assessment of IoT security in this Systematic Literature Review (SLR), considering the most generic architecture with the many levels and their security concerns, as well as the solutions presented to address them. This SLR also provides information on current developments in IoT security as well as future research directions.(El et al. 2021)

2.5.1 Background information and concept of IOT gateways

Popular terms in the information technology area include "Internet of Things" (IoT). In the future, real-world things will be transformed into intelligent virtual ones thanks to the Internet of Things. The goal of the Internet of Things is to bring all of our world's systems together under a single infrastructure, allowing us to control and monitor everything around us. A comprehensive review of scholarly literature, business white papers, expert interviews, and internet databases is used to analyse IoT ideas in the current study. In addition, Internet of Things definitions, genes, fundamental criteria, features, and aliases are the subject of this study. Most of this paper's focus has been on introducing the Internet of Things, its designs, and the most important technologies that make it possible. As a novice researcher in the subject of Internet of Things (Technological GOD), you will find this article to be useful in obtaining knowledge in an effective manner..(Madakam, Ramaswamy, and Tripathi 2015)

It is well-known that a great deal has been done in the areas of Internet of Things (IoT) research (Gubbi et al., 2013), cloud computing research (Ray, 2016), fog computing research (Yousefpour et al., 2019), and even edge computing research (Yousefpour, 2019). Ai While investigating gateways, it was discovered that there is no systematic literature research that can explain the general workings and features of IoT gateways. However, (Yan et al., 2020) attempt to design a smart gateway for smart homes. The objective of this systematic study is to give a detailed analysis and comprehensive summary of earlier work connected to this field inquiry.(Beniwal and Singhrova 2021)

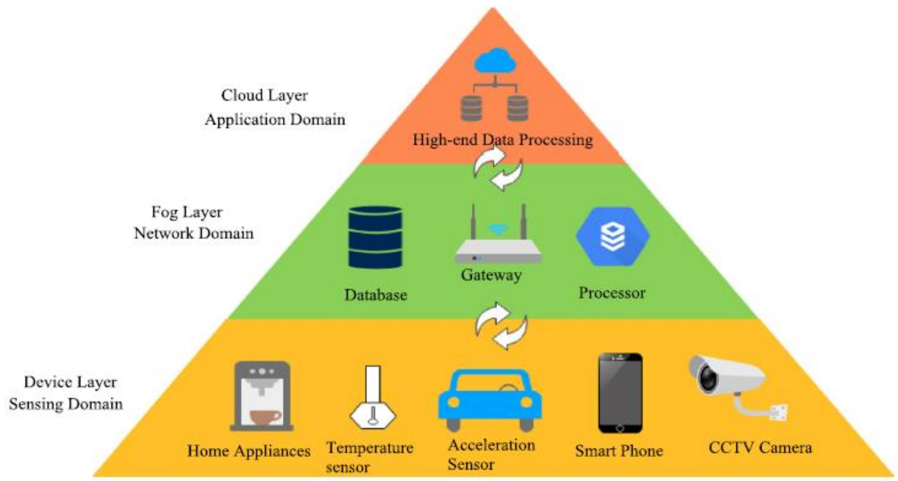


Figure 2.8 Placement of Gateway in IoT architecture

2.5.2 Basic Gateway and Smart Gateway

There are two sorts of gateways: basic gateways and smart gateways. By transmitting incoming data, Basic Gateway works as a proxy between low-end IoT devices and data centers. A smart gateway, on the other hand, processes data effectively by preprocessing, filtering, and analyzing it before transferring just the relevant or essential data to the cloud platform. These cutting-edge gadgets are designed to survive harsh weather conditions and to quickly reestablish contact in the event of a malfunction. As a hardware and software device, the Gateway is the primary focus of our investigation. Essentially, it's a little operating system that assists in the preparation and storage of the nodes (Bansal and Kumar, 2020). Aside from that, the gateway should be able to record the current system state, run in nested mode to recover, and operate from the same failure point without losing any data (Zhu et al., 2010; Kang, 2018). Message Queuing Telemetry Transport (MQTT), Constrained Application Protocol (CoAP), Advanced Message Queueing Protocol (AMQP), Extensible

Messaging and Presence Protocol (XMPP), Representational State Transfer (REST), and others can be used by gateways to communicate using various communication technologies such as Wi-Fi, Bluetooth, Zigbee, and Ethernet. (Beniwal and Singhrova 2021)

As shown in Fig.2.12 a smart gateway can be classified into three types based on its functionalities.

- Passive Gateway
- Semi-automated Gateway
- Fully automated Gateway

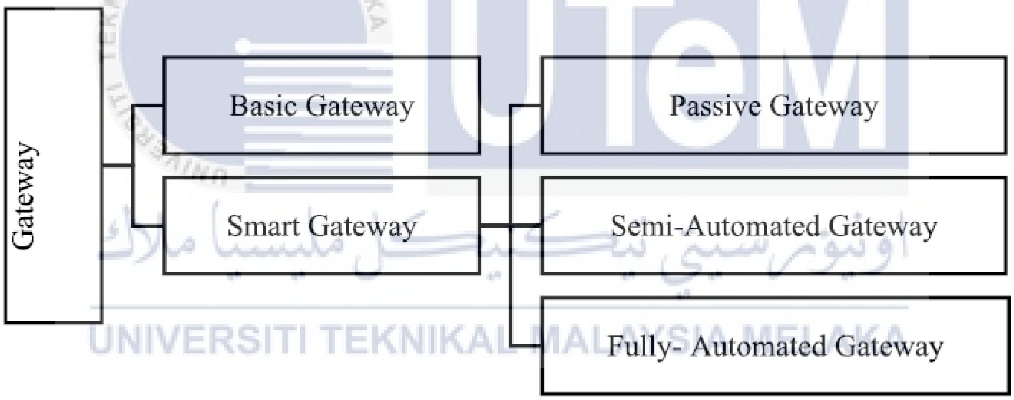


Figure 2.9 Types of the gateway in IoT.

a) Passive Gateway

For increased speed, gateways in some applications are built to respond intelligently by recognizing IoT devices, registering them on the network, or removing them. When these activities are carried out manually, the device is known as a passive gateway. Users grant permission to add new devices or remove old ones. However, these gateways are not adaptive or customizable (Zhu et al., 2010; Mueller et al., 2007; Emara et al., 2009; Yoon et al., 2009; Bimschas et al., 2010). (Beniwal and Singhrova 2021)

b) Semi-automated Gateway

A semi-automated gateway maintains and connects newly additional devices via an interface. These gateways have pluggable configuration architecture, which means they can be plugged in dependent on the network device's demands. These gateways are more adaptable and perform better in real-time applications than passive gates (Min et al., 2012; Guoqiang et al., 2013; Wu et al., 2013; Xu et al., 2015; Chang et al., 2015). (Beniwal and Singhrova 2021)

c) Fully automated Gateway

There are self-configuring and self-managing smart gateways (Kang et al., 2017; Ramirez et al., 2020; González Ramirez et al., 2021). The gadget may be added or deleted from the network without any human interaction. These gateways are capable of operating in a wide variety of networks. They may now connect to many protocols and interfaces, such as Wi-Fi, MQTT, and CoAP (Carpio et al., 2019), including Bluetooth, ZigBee, Ethernet, and others. Quality and performance can only be achieved with a fully automated gateway for every IoT application. Even though some progress has been made in this area, researchers can improve gateways so they can deliver better performance and security to customers. Customers' Satisfaction (QoS).(Beniwal and Singhrova 2021)

2.5.3 Iot Based Vibration Measurement And Monitoring System Using An Accelerometer Sensor

An accelerometer sensor on a Real-Time Vibration measuring system was used to construct a Thing Speak IoT. A number of systems have already been put in place however it has been discovered that there are certain gaps where the recording of data obtained does not give adaptive connections and notifications to web sites. Prior system model knowledge will help determine how important new construction parameters are in constructing the new system. Before constructing a new architecture, it is critical to assess the present model, hardware, and software. Experimentally, an experimental system was built for remotely monitoring and measuring the vibration of a system and customising alert levels. An internet connection was used to aid in the construction of the machine vibration monitoring system. Hardware development and software development are two separate research approaches. C-language programming is used to write code that connects an accelerometer sensor to the software. In order to see the acceleration of the system, the code is then built and uploaded to a Node MCU. (Kumari, Raj, and Komati 2021)

2.5.4 Developing an Internet of Things Sensing System to Monitor and Assess Construction-Induced Vibration

Sensors that detect the influence of vibration on the surrounding environment are used often during construction. Aside from the expense of expensive sensors and the difficulty of installation, traditional vibration monitoring systems have several drawbacks. The integration of in-person data processing with remote data transfer and access is rare among these monitoring systems. The classic vibration monitoring system has been replaced with an Internet of Things (IoT) sensor system that takes use of current breakthroughs in information technology. Using a Raspberry Pi microprocessor and a MEMS accelerometer, we were able to cut both the price and the size of our system. USB internet dongles are used to connect to the cloud through 4G.(Meng and Zhu 2020)

2.6 Vibration monitoring system

Mechanical vibration monitoring focuses on early detection of abnormal operating conditions. Follow these steps and you may avoid unexpected plant shutdowns as well as significant repair costs, extensive damage, and the loss of other equipment pieces that can be saved by identifying and addressing concerns early. Additionally, monitoring and diagnostics allow the detection of potential or incipient flaws within the machine set up, modifications and spare component assemblies. Predictive maintenance becomes proactive in this manner. In order to quickly adapt to the changing requirements of the industrial plant over time, a continuous vibration monitoring system was designed on an open PC platform. prospective or incipient gatherings. In this way, predictive maintenance becomes proactive. On a PC platform with an open design, a continuous vibration monitoring system was built that could be easily modified to the changing needs of the industrial plant over time.(Klempnow, La Bruna, and Saporiti 2009)

2.6.1 Low-Cost Vibration Monitoring system

MEMS accelerometers and gyroscopes have also found their way into a wide range of industrial systems thanks to the constant progress in functional integration and performance. Some of these applications use inertial sensing for the first time, while others provide lower-cost alternatives to current products and services. Vibration monitoring is a tool that may be used by both novices and experts alike. Piezoelectric technology is commonly used in traditional devices that check on the health of machines for reasons of maintenance and safety. In the case of high-speed automation equipment, vibrations can be used to trigger feedback control of lubrication and speed, or to shut down equipment for immediate attention from maintenance personnel. Since piezoelectric devices have a well-established customer base, MEMS accelerometers may be easily integrated and cost less to a new group of consumers.(Maluf 2004)

2.6.2 A Low-Cost MEMS Based Vibration Monitoring System For A Stressribbon Footbridge

An as-built stress-ribbon footbridge in Valladolid, Spain, was fitted with a remote-controlled continuous vibration monitoring system (Spain). Low-cost MEMS-based accelerometers were inserted (with cabling) inside a handrail because of the structure's uniqueness, the requirement of not changing it, and the financial constraints. The MEMS accelerometers were compared to traditional piezoelectric accelerometers in order to validate the monitoring system. In these tests, it was found that these sensors are a viable replacement to traditional ones and that the system is ready to be utilised for dynamic analysis of the structure and to incorporate a continuous structural health evaluation.

As a result of this, a monitoring system for structural vibration was developed to continually estimate the structure's modal characteristics and monitor their changes as the environment changes. These factors can be compared over time to see how they change. Because of this, in addition to the accelerometers required to perform modal analysis, wind and temperature sensors were also fitted. The monitoring system has two additional limits in addition to the previously stated needs. First and foremost, it had to be as inexpensive as possible (because to a very constrained budget), and secondly, it had not in any way detract from the aesthetics of the footbridge. 18 triaxial accelerometers are located on the deck, 9 on each side. A temperature sensor and an anemometer/vane are also included in the monitoring system (see Figure 2.10). There were two accelerometers on either side of the span. The railing was wired and equipped with acceleration sensors. The installation process became more difficult because of this.(de Sebastián et al. 2013)

Figure 2.10 Structure bridge with aid of sensors distribution.

2.6.3 Vibration Monitoring of Rotating Machines Using MEMS Accelerometer

Rotating machinery in heavy industry is notoriously prone to mechanical breakdowns of many kinds. It has been shown that vibration monitoring has great potential for discovering and pinpointing problems in the machinery using analytical methodologies. A variety of vibration detecting methods are available. Despite the fact that MEMS accelerometers are becoming an alternative way for rotating machine vibration monitoring, they have yet to be extensively investigated for a broader range of applications. An accelerometer-based vibration sensor may be developed at minimal cost by merging the sensor's fundamental components with the intelligence of vibration analysis. Vibration monitoring may be readily carried out on a variety of spinning machinery with this module. Tests are conducted on a 7.5kW, 3, 440V, 4 pole squirrel-cage induction motor to determine the sensitivity of the sensor and the efficacy of the suggested intelligent signal processing. The tests are done to see if the fault frequency peaks may be detected under various fault combinations. The findings that have been given here are really encouraging.(Chaudhury, Sengupta, and Mukherjee 2014)

CHAPTER 3

METHODOLOGY

3.1 Introduction

It is possible to focus on a single procedure, a group of procedures, or an entire area as a methodological focus, examining its fundamental principles. Using a methodical approach to find out the outcome of an event is called a research methodology. There are many ways to receive knowledge, and this is one of them. There are many different ways to conduct a research study, and each method has its own advantages and disadvantages. Surveys and experiments play a significant role in the research process. As a result, interpretative approaches such as focus groups and in-depth interviews are increasingly employed in qualitative research.

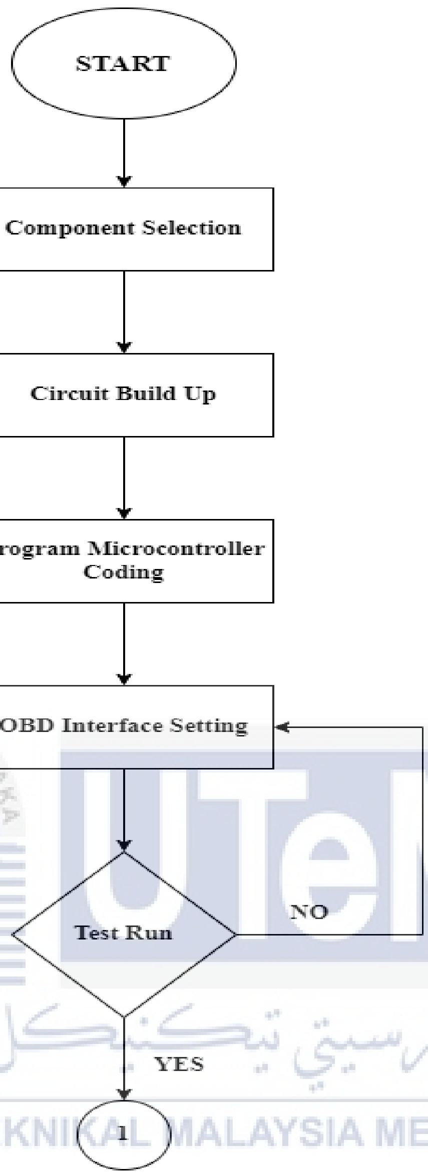


Figure 3.1 the objective and the flow chart of the methodology for project

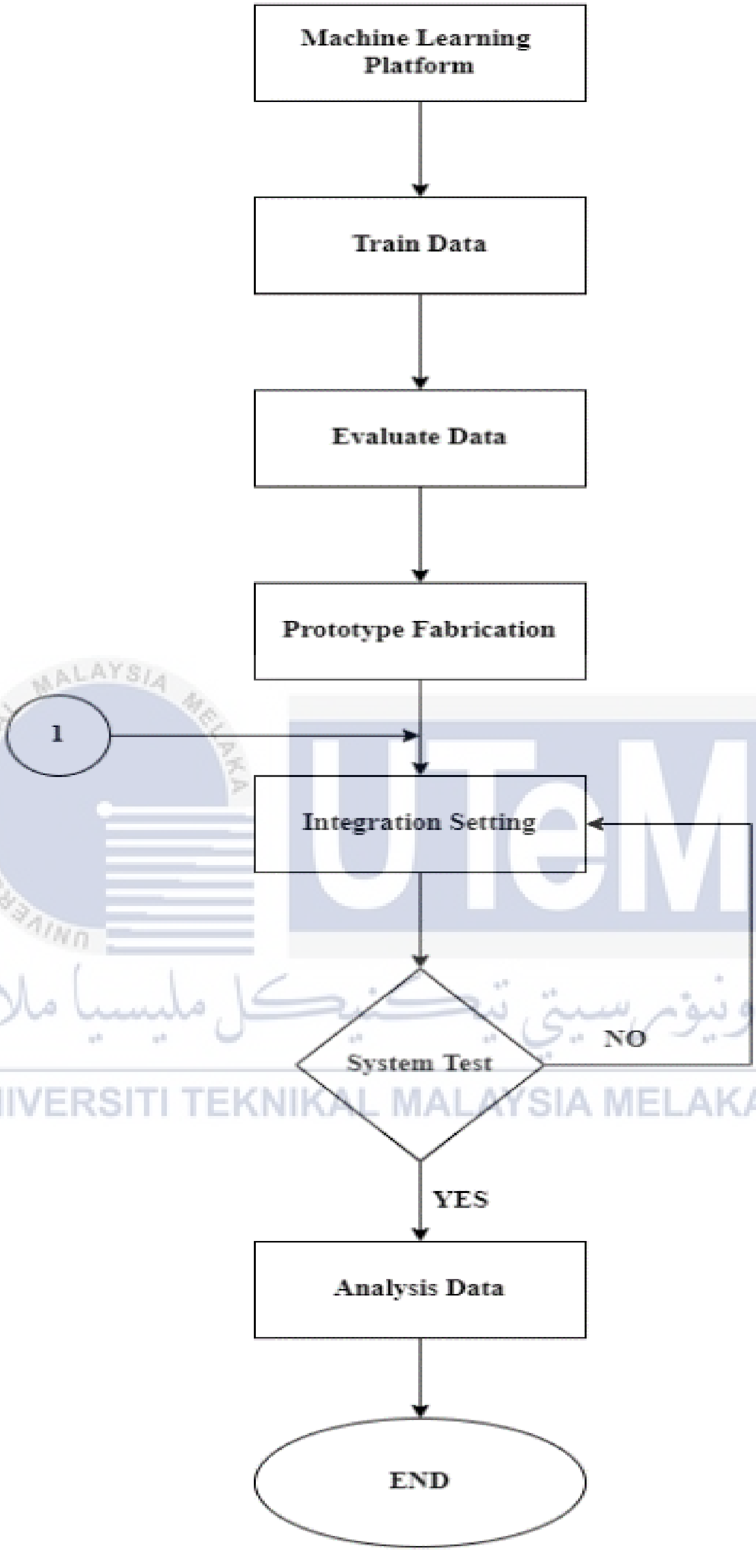


Figure 3.2 sum up of flow chart objective 1 of system test run with analysis data

3.2 Method Workflow

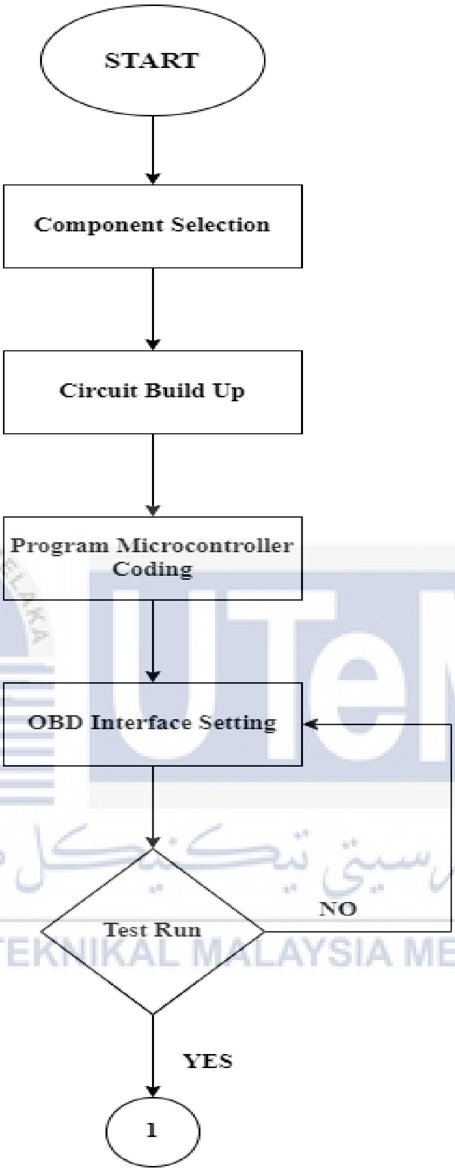


Figure 3.3 the objective and the flow chart of the methodology for project

Vibration analysis in industry is a technique for detecting, predicting, and preventing mechanical failures. The presence of a number of prominent frequencies associated with the motion of various machine components is to be expected when analysing machine frequency vibrations (frequency analysis). Mechanics systems and structures can be damaged, stopped abnormally, or fail catastrophically if they are exposed to high levels of vibrations. To avoid these issues, vibration assessment is an essential countermeasure. The method that using is component selection for the first step. Then circuit build up to program the microcontroller with coding make. Then setting the OBD interfaces such as blynk application. Then train the data and evaluate data for the project prototype with aid of coding software for microcontroller and sensors. Then, intergrate the system setting toward online monitoring applications to run and get the actual result and data. From this results it can be analysis from the data runing for system test. The main system using in this project are 5 components that is, Hibiscus Sense v1.0 ESP32, Ultrasonic Sensor HC-SR04, MPU6050 Vibration Sensor, Supply voltage and software platform monitoring system. There are 3 system have been created. The single vibration system is using only Hibiscus Sense v1.0 ESP32. This system stand alone to measure and carry out the acceleration 3 axis by MPU6050 inside the ESP32 microcontrollers and the temperature when vibrations occurs during system test. The single vibration with Ultrasonic sensor system includes Hibiscus sense ESP32 with Ultrasonic sensor. This system is to carry out the acceleration of 3 axis with temperature and distance. This double vibration system is to known the sustainability of both 3 axis accelerometer and to make comparison the diffenrence value of this vibration system. This system also can compare the temperature for ESP32 and MPU6050 sensor. This system can be measure the data and result by observe the live data on the blynk application platform. The result was taken by using the Blynk applications with supporting guidance of coding motion detection to detection of vibration in several minutes to get the result shown in below figure. the interpreted data show of accelerometer gyroscope with aid of x,y,z axis of both ESP32 or MPU6050 sensor This data show to measure the sensitivity of vibration temperature and distance of some objects. It can be explained how IoT can help the condition monitoring and fault diagnosis of rotating machinery using vibration analysis. Further, vibration sensing has been investigated and the new generation of MEMS accelerometers has been introduced. This way the machine will be able to send its vibration status to the server and the maintenance engineers will be able to monitor it anytime, anywhere. The developed hardware has been evaluated by comparing the results of online and local data measurements at the same time. The results of the evaluation have been proved to be very precise. This paper will prove the concept of using IoT enabled sensors in predictive maintenance to overcome some gaps in the commonly used methods of condition monitoring of rotating machinery. The results can be extended to a larger scope of equipment, faults, and parameters.

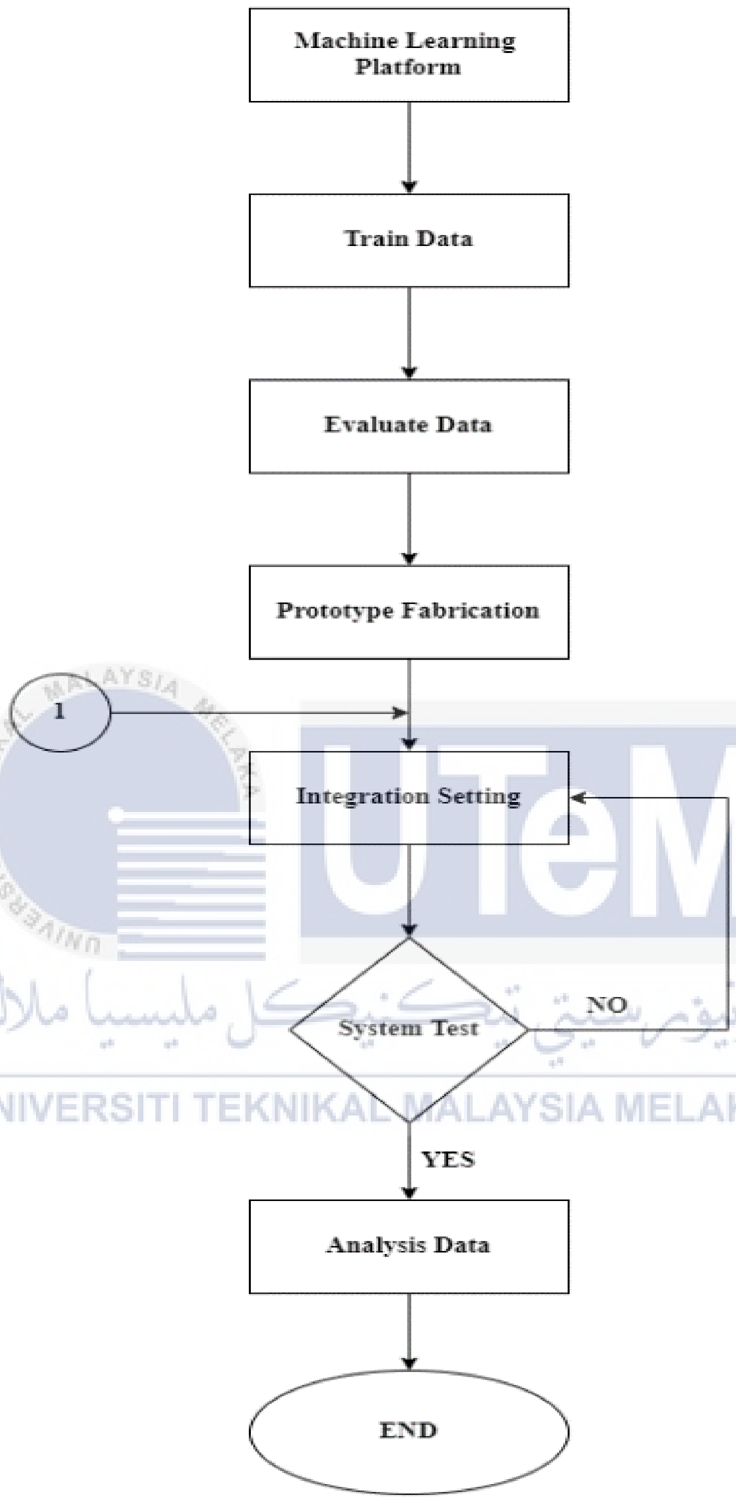


Figure 3.4 sum up of flow chart objective 1 of system test run with analysis data

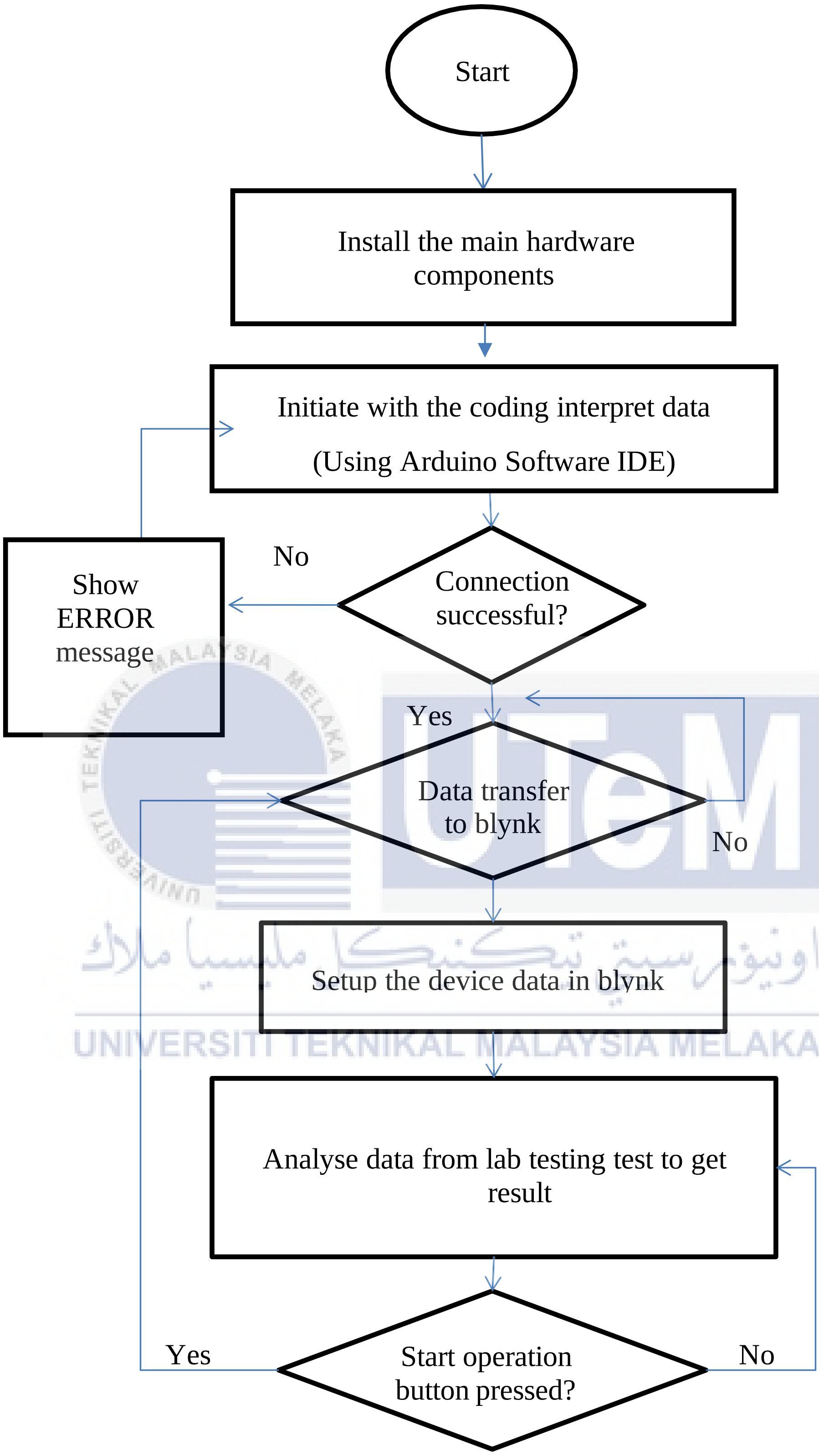


Figure 3.7 Flowchart of the desktop software

3.3 Gantt chart

Table 3.1 Gantt Chart of Project

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 with supervisor.	Plan														
		Actual														
3	Component exploration	Plan														
		Actual														
4	Component selection	Plan														
		Actual														
5	Circuit builds up	Plan														
		Actual														
6	Program Microcontroller coding	Plan														
		Actual														
7	OBD interface setting	Plan														
		Actual														
8	Machine Learning Platform, Train Data, and Evaluate Data	Plan														
		Actual														
9	Prototype Fabrication	Plan														
		Actual														
10	Integration Setting	Plan														
		Actual														
11	System Test	Plan														
		Actual														
12	Analysis Data	Plan														
		Actual														
13	Writing a report	Plan														
		Actual														
14	Preparing for presentation	Plan														
		Actual														

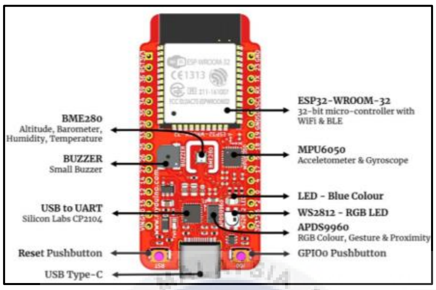
3.4 Software equipment

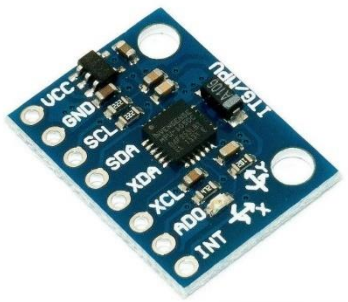
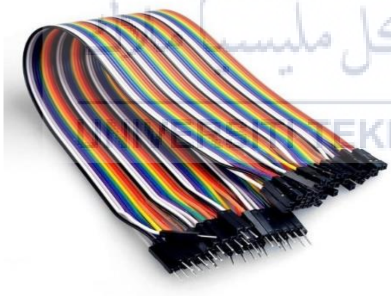
Table 3.2 The table of Software Equipment and requirement

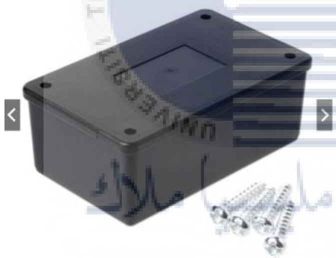
No.	Software Name	Requirement
1	Arduino and microcontrollers Software (IDE)	i. **Operating system:** Window 10, Window 8, Window 7, Window Vista SP2, Windows Server 2012, Windows Server 2008 R2 SPI. ii. **Processor:** Pentium 2 266 MHz iii. **Ram:** 128 MB. iv. **Hard Disk:** 600 Mb. v. Java 8 requires. vi. **License:** Non-academic.
2	. The Arduino IDE software version 1.8.19	i. **Operating system:** Window 10, Window 8, Window 7, Window Vista SP2, Windows Server 2012, ii. **Processor:** Pentium 2 266 MHz iii. **File size:** 111.87 MB iv. **Ram:** 35-40 MB v. **License:** Non-academic / Free 

3.5 Hardware Equipment

Table 3.3 The table of Hardware Equipment and requirement

No.	Hardware Name	Requirement
1	Hibiscus sense v1.0 ESP32  	i. **Microcontroller:** ESP- 32 ii. **Model:** Hibiscus sense iii. **Size: 58.7**mm x 27mm x 20.4mm iv. **Working frequency:** 240 MHz v. **USB to Serial:** Silicon Labs CP201402 vi. **USB Connector:** type C vii. **Operating voltage:** 3.3V viii. **Input voltage:** 4.5V – 10V ix. **Flash memory/ SRAM:** 4 MB / 520 KB x. **Wi-Fi Built-In:** Integrated WiFi, Bluetooth and ESP-NOW wireless protocols xi. **Product Link:** Espressif
	Ultrasonic sensor HC – SR04  	i. **Operating Voltage:** 5V DC ii. **Operating Current:** 15mA iii. **Operating Frequency:** 40KHz iv. **Maximum reading distance:** 400cm v. **Minimum reading distance:** 2cm vi. **Detection Angle:** 15° vii. **Trigger pulse:** >10us TTL pulse viii. **Output pulse with proportional to distance** ix. **Maximum pulse width:** 38ms if no obstacle x. **Dimension:** 45 x 20 x 15 mm

2	MPU6050 Vibratiion Sensor  	**xi.** **Operating Voltage:** 5V DC **xii.** **Operating Current:** 15mA **xiii.** **Operating Frequency:** 40KHz **xiv.** **Maximum reading distance:** 400cm **xv.** **Minimum reading distance:** 2cm **xvi.** **Detection Angle:** 15° **xvii.** **Resolution:** 0.5cm **xviii.** **Trigger pulse:** >10us TTL pulse **xix.** **Output pulse with proportional to distance** **xx.** **Maximum pulse width:** 38ms if no obstacle **xxi.** **Dimension:** 45 x 20 x 15 mm
3	Jumper wire 20 cm & 30cm 	**Jumper wire** These are jumpers terminated as Male to Male, Male to Female, and Female to Female. Use these to jump from any female header on any board. Multiple jumpers can be installed next to one another on a 2.54mm header. **[Specifications]** i. **Connector Type:** Dupont 1 way Male to Male, Male to Female, Female to Female **ii.** **Pitch:** 2.54mm **iii.** **Jumper Length:** 20cm or 30cm **iv.** **Number of ways:** 40 ways
4	Type c extension cable (male to female)	**i.** **Name:** Type-C Extension Cable

		**ii.** **Usb Type:** Usb3.1gen2 Male to Female **iii.** **Base Adapter :** Data Cable Docking Station Ns Nintendo **iv.** **Materials:** pvc+aluminium alloy Support **v.** **Power:**100w Support **vi.** **Voltage/Electricity:**20V/5A **vii.** **Speed rate:**10Gbps viii. **Application:** extending docking station,hdmi cable,charging cable etc.
5	Black box project case 	**i.** **Material :** anti-stamping ABS/PC material **ii.** **Colour code :** Black **iii.** **Operating temperature:** -20°C to 90°C. **iv.** **Size :** 70x50x40mm/2.75x1.96x1.57inch **v.** **Weight :** 63 gram
6	Round magnet with hole 	**i.** **Size:** 10mm(W) x 3mm(H) **ii.** **Hole Diameter :** 3mm
7	Capsule Mini powerbank	**Port type :** type C (male) **Battery capacity:** 5000mAh **Rated capacity:** 5000mAh **Output:** 5V/1.5A(MAX) **Input:** 5V/1.5A(MAX)

		**Product size:** 80*33*26mm **Product weight:** 78g
8	Jumper insulated cover wire 	Black PVC Tubing Introduction and Features: General PVC tubes are mainly used **to electronic insulation and wire / cable protection** etc. It has **good acid, corrosion-resistant and fire-retardant property.** **Smooth, flexible, protection tubing, insulation, light weight and tear-resistant round, stable, sustainable** and **eco-friendly** Applications: 1. Automobile / motorcycle wire harness 2. Household appliances wire harness 3. Earphone wire sleeving tube 4. Electronic products insulation tube

3.6 Analysis Cost

This analysis is making the process of calculating the potential earnings from a situation or project and subtracting the total cost associated with completing it. It predicts the profit gained from a project and compares the project's cost to its estimated financial benefits. Many finance professionals use cost analysis to show clients their potential profits from a project.

a) Real Cost

Table 3.4 the cost estimation of component and materials

No	COMPONENT/ MATERIALS	QUANTITY	PRICE
1	**Hibiscus sense v1.0 ESP32**	1	RM 120.00
2	**USB Type C to Type C (male to female)**	1	RM 3.50
3	**Mini capsule Power bank**	1	RM 27.50
4	**Ultrasonic HC-SR04**	1	RM4.50
5	**MPU6050 Sensor vibration**	1	RM15.00
6	**Soft PVC insulated tube wire (8mm)**	1	RM 2.50
7	**Black box project case**	1	RM5.50
8	**Double sided tape**	1 roll	RM4.00
9	**Jumper wire @ 20cm and 30cm**	2	RM5.00
10	**Plastic flexible water oil coolant pipe hose**	2	RM7.00
11	**Electric alligator clips**	10	RM4.00
12	**Mini G-clamp**	1	RM8.00
	TOTAL COST		**RM 206.50**

b) Direct Cost

This cost represents material or components that directly used toward project or main type project component or materials

Table 3.5 Direct cost table

No	COMPONENT/ MATERIALS	QUANTITY	PRICE
1	**Hibiscus sense v1.0 ESP32**	**1**	**RM 120.00**
2	**Ultrasonic HC-SR04**	**1**	**RM4.50**
3	**MPU6050 Sensor vibration**	**1**	**RM15.00**
	TOTAL COST		**RM139.50**

c) Indirect Cost

This cost represents the project that not directly involve with the main project but need to include in the budget. So, this cost not have any value or price because this lab need to booking for free since we are student to using the vibration lab machine that is rotary machine to take and evaluate data and results. So, this cost in not include in the real costs table.

Figure 3.5 rotary machine vibration with balancer at vibration lab

d) Tangible Cost

This cost is for supporting the project or upgrading the component or material such as, cover for components or purchasing tools etc.

Table 3.6 The tangible cost of the project

No	COMPONENT/ MATERIALS	QUANTITY	PRICE
2	**USB Type C to Type C (male to female)**	**1**	**RM 3.50**
3	**Mini capsule Power bank**	**1**	**RM 27.50**
6	**Soft PVC insulated tube wire (8mm)**	**1**	**RM 2.50**
7	**Black box project case**	**1**	**RM5.50**
8	**Double sided tape**	**1 roll**	**RM4.00**
9	**Jumper wire @ 20cm and 30cm**	**2**	**RM5.00**
10	**Plastic flexible water oil coolant pipe hose**	**6**	**RM7.00**
11	**Electric alligator clips**	**10**	**RM4.00**
12	**Mini G-clamp**	**1**	**RM8.00**
	TOTAL COST		**RM67.00**

e) Intangible Cost

This cost means how the project impact outcome occurs. A cost that can be identified but cannot be quantified or easily estimated. Arduino platform website and Blynk application is the intangible for this project but since using the student authencity account the platform can be used for free subscriptions.

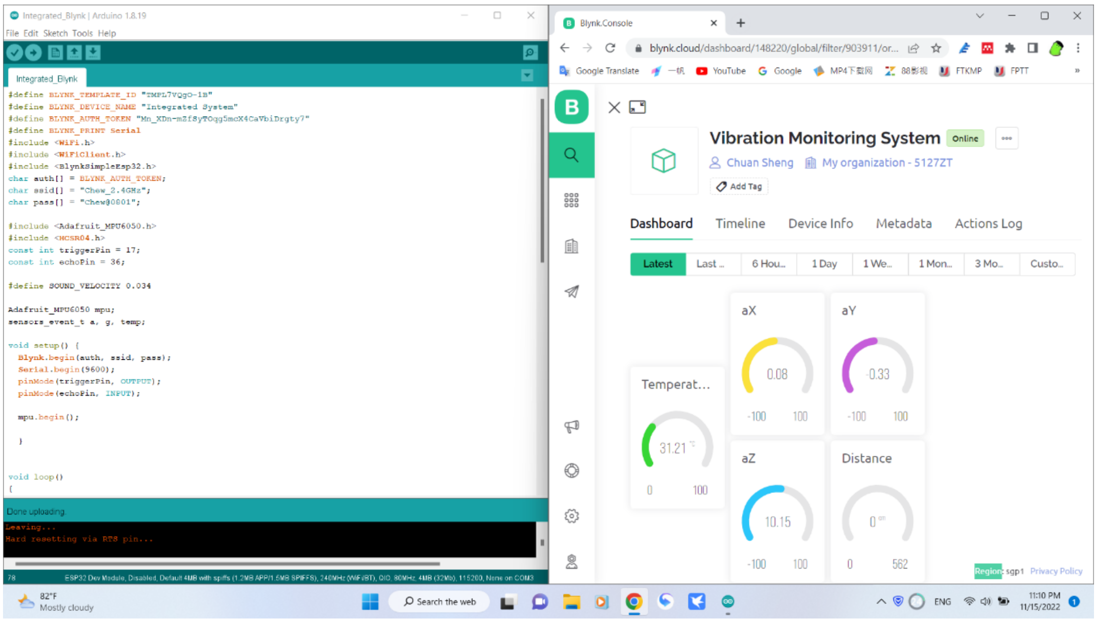


Figure 3.6 Arduino IDE and Blynk applications interfaces

3.6.1 Compare component analysis with pervious project

This project have to compared with the previous project to know what component and material are the best for this current project. From this we can identify which component is more better. From previous project its using ESP8266 NodeMcu with Ultrasonic sensor and also using LiPo battery to power up the microcontrollers. For this current project are using ESP32 Microcontroller with Ultrasonic sensor. ESP32 is the main and core system in this project. So this table below is to make comparison base on requirement and specifications :

Table 3.7 comparison of ESP8266 NodeMCU and Hibiscus Sense ESP32

specifications	**ESP8266** 	**ESP32** 
MCU	Xtensa Single core 32-bit L106	Xtensa Dual core 32-bit LX6 with 600 DMIPS
Wi-Fi type	HT20	HT40
Bluetooth	None	Bluetooth 4.2 and BLE
Frequency	80MHz	160MHz
SRAM & Flash	None	Yes
GPIO	17	34
Hardware / Software PWM	None / 8 channels	None / 16 channels
SPI/I2C/I2S/UART	2/1/2/2	4/2/2/2
ADC	10 bit	12 bit
CAN	None	Yes
Ethernet MAC	None	Yes
Touch / Temperature and Hall effect sensor	None	Yes
Working temperature	-40 to 125 degree celcius	-40 to 125 degree celcius

From the table above the Hibiscus Sense ESP32 is more feature and availability also reliability. Which consist Xtensa Dual core with bluetooth type 4.2 and BLE with frequency 160MHz. Then, it has more GPIO and hardware and software PWM. This microcontroller simply using the newest USB type-C to program it which has built-in USB to Serial converter (Silicon Labs CP2104) with auto matic bootloader, so it does not have to RESET the button when to upload the program itself. The ESP32 is consists with 4MB of SPI aand Flash running at 240MHz with Wi-Fi support and BLE connectivity. It has 2.4GHz low power at wireless connectivity. So,ti give flexibility to develop Iot project for example wireless connectivity to your smart phone by visualise data on the blynk application. Indeed the ESP32 is more powerful and better than ESP8266 on perfoemance cricteria.

3.7 Summary

In summary, after hardware and software equipment were setup. This subtitle will explain about the interfacing software that is used to generate the time domain graph and FFT (Fast Fourier Transform) graph through the received data for vibration analysis purposes. The Arduino IDE software version 1.8.19 and blynk application was chosen for this project because it is free to use, easy to access, and the most crucial factor is that the development board of ESP32 microcontroller is compatible with this programming software. The blynk is easy friendly user because can monitor thorugh the website or the application on the phone and also easy to setup and configure the data and result by using blynk application The coding of this vibration monitoring system can be programmed through the Arduino IDE software and transfer the blynk data to the Arduino IDE to activate the feature on blynk. Furthermore, the code for Arduino programming is written in Java and is based on C++ programming.

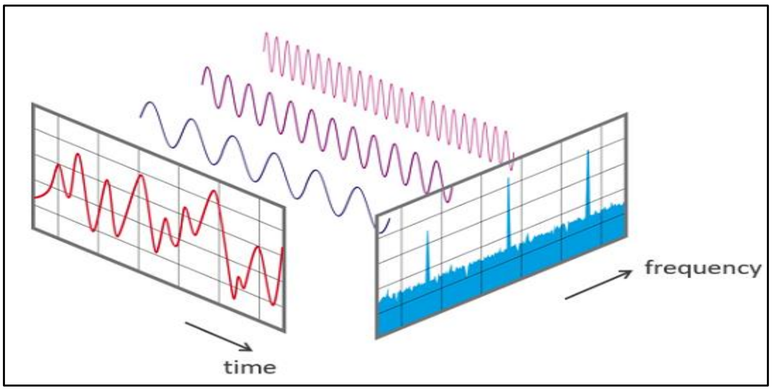


Figure 3.7 Fast Fourier Transform (Source from: https://www.nti-audio.com/en/support/know-how/fast-fourier-transform-fft)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

An ESP 32 microcontroller and an MPU6050 insert microcontroller were used to create a vibrating system. The first step is to connect the ESP32 to the laptop computer through USB type A using a type C connection, and then use software IDE to check its status.

The first step in this study is to gather data from the accelerometer MPU6050. Vibration analysis is a technique for examining the patterns in vibration data and keeping tabs on the levels of vibration. Time waveforms and the frequency spectrum obtained by applying the Fourier transform to a time waveform are frequently used in this process. Time domain analysis of historically recorded vibration waveforms reveals when and how severe aberrant vibration events occur by extracting and measuring metrics including root-mean-square (RMS), standard deviation, peak amplitude, kurtosis, crest factor, skewness, and many more. Time domain analysis can be used to gauge an object's overall health.

4.2 Main system and Working Principle development

The set of instructions that instructs the hardware to do a task is referred to as software. The operating system of a computer is the most well-known example of software, as it allows the user to communicate with the hardware. Input, processing, storage, and output are the four essential operations of software. Primary storage is heavily used in input, processing, and output processes. Input data is kept in memory, the CPU processes data in memory, and processing output is staged in memory before being transmitted to the output unit.

4.2.1 Hibiscus Sense v1.0 ESP32

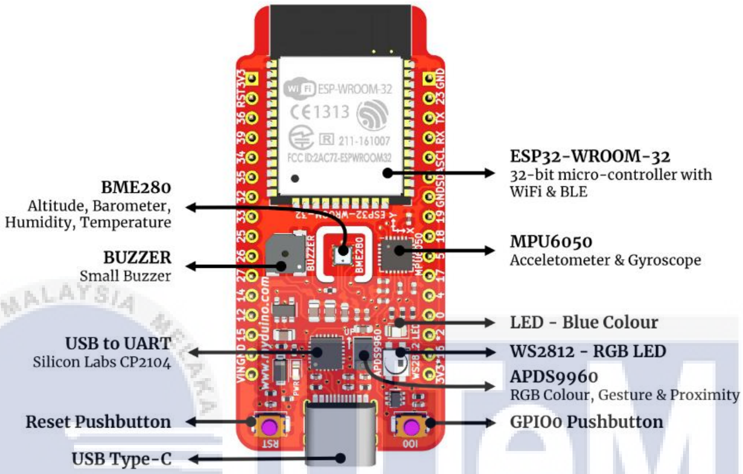


Figure 4.1 Hibiscus sense v1.0 ESP32 features diagram

Hibiscus Sense is a quick Internet of Things (IoT) development board powered by the formidable and popular dual-core ESP32 microcontroller, which is on-board equipped with a plethora of sensor data and simple actuators, as seen below.:

- 3 sensors:
  - **APDS9960**: an ambient sensor that detects proximity, RGB, and gesture
  - **BME280**: an atmospheric sensor capable of measuring *altitude, barometric pressure, humidity, and temperature*
  - **MPU6050**: 6-axis motion tracking sensor that detects *gravity acceleration, rotational velocity, and temperature* on three axes.

- 3 actuators:

- ○ **Buzzer**: short distance small buzzer.
- ○ **LED**: blue LED.
- ○ **RGB LED**: WS2812 RGB LED.

Hibiscus Sense includes a USB Type-C cable for powering up the board and programming the ESP32. We don't have to hit the RESET button every time we upload the software since the on-board USB-to-Serial converter Silicon Labs CP2104 has an automated bootloader reset circuit.

However, we may programme the ESP32 in various languages like as C, C++, Micropython, Rust, or even using the RTOS (Real Time Operating System) FreeRTOS. However, in this lesson, we will be learning and developing with Arduino.

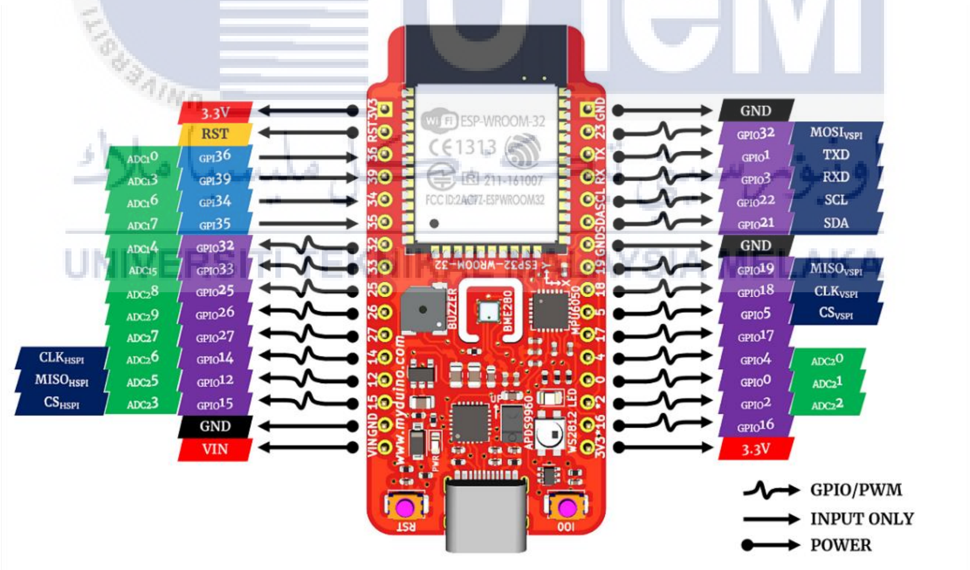


Figure 4.2 Hibiscus Sense v1.0 ESP32 Pin Out diagram

- **Blue LED** is connected to ESP32's GPIO2.
- **Small Buzzer** is connected to ESP32's GPIO13.
- **WS2812 RGB LED** is connected to ESP32's GPIO16.

- All GPIO can generate digital input/output (3.3V) and PWM signal output, except GPIO34-GPIO39 because it is an input pin only.
- ESP32 VSPI is

  complete **MISO** GPIO19, **MOSI** GPIO32, **CLK** GPIO18 and **CS** GPIO5.
- ESP32's I2C **SDA** GPIO21 and **SCL** GPIO22, without pullup resistor.
- **Sensors**: **APDS9960**, **BME280** and **MPU6050** interfaced to the ESP32's I2C, respective I2C address: 0x39, 0x77 and 0x68.
- Avoid using ADC2 channel while using WiFi.
- Each GPIO absolute maximum current drawn only 16mA.
- Board measurement including header in mm: 58.7 x 27 x 13.3 (length x width x height).
- Package measurement in mm: 71.8 x 35.5 x 20.4 (length x width x height).

4.2.2 Ultrasonic Sensor HC-SR04

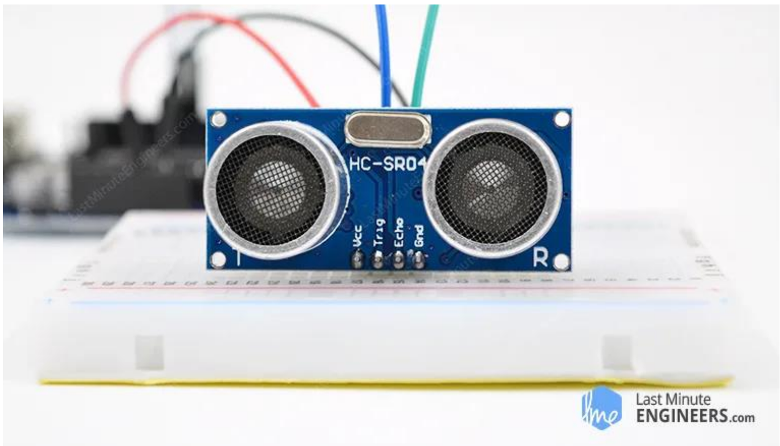


Figure 4.3 Picture of ultrasonic sensor HC-SR04

The HC-SR04 ultrasonic distance sensor is made up of two ultrasonic transducers.

One operates as a transmitter, converting the electrical impulses into ultrasonic sound pulses at 40 KHz. The other serves as a receiver, listening for sent pulses. When the device receives these pulses, it generates an output response whose width is proportionate to the distance between the receiver and the item in front of it. With an accuracy of 3 mm, this sensor delivers excellent non-contact range detection between 2 cm and 400 cm (13 feet). Because it runs on 5 volts, it may be immediately linked to an Arduino or any other 5V logic microcontroller.

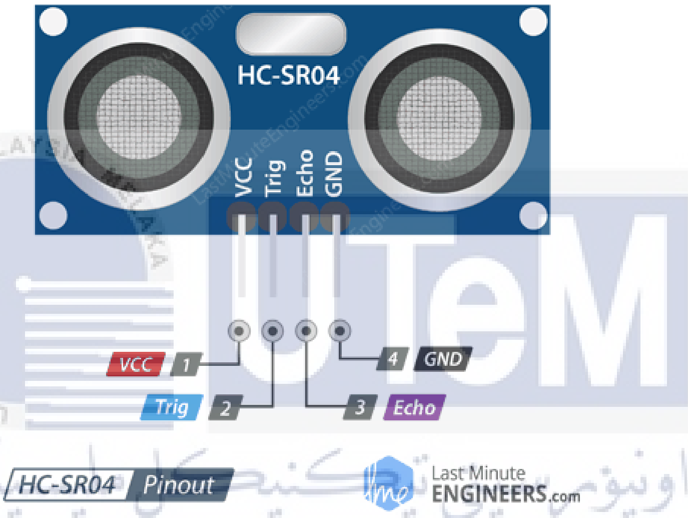


Figure 4.4 Ultrasonic Sensor HC-SR04 Pinout Diagram

Table 4.1 the Ultrasonic Sensor HC-S04 PinOut description

VCC	activates the HC-SR04 ultrasonic sensor You may link it to the Arduino's 5V output
Trig (Trigger)	The pin is used to initiate ultrasonic sound waves. The sensor launches an ultrasonic burst by holding this pin HIGH for 10 seconds.
Echo	when the ultrasonic burst is broadcast, the pin rises high and stays high until the sensor hears an echo, at which point it drops low. The distance may be estimated by measuring how long the Echo pin remains high.

GND	grounded pin. Connect it to the Arduino's ground pin.

Below are its requirements and technical specifications:

Operating Voltage	DC 5V
Operating Current	15mA
Operating Frequency	40KHz
Max Range	4m
Min Range	2cm
Ranging Accuracy	3mm
Measuring Angle	15 degrees
Trigger Input Signal	10µS TTL pulse
Dimension	45 x 20 x 15mm

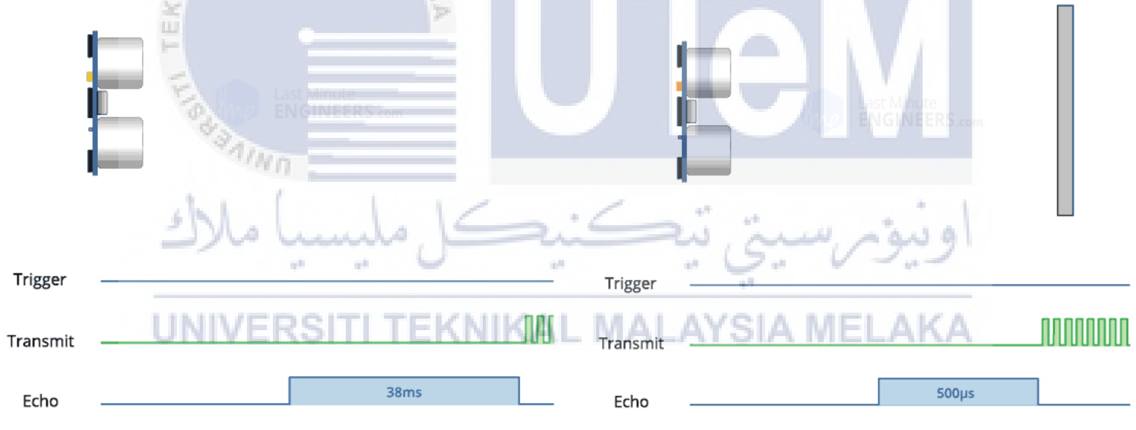


Figure E - The working system of Ultrasonic Sensor HC-SR04

Everything starts when the trigger pin is set HIGH for 10 microseconds. The sensor responds by sending an ultrasonic burst of eight signals at 40 kHz. This 8-pulse sequence is specifically intended to detect transmission pulses from surrounding ultrasonic noise. These eight ultrasonic pulses go away from the transmitter via the air. Meanwhile, the echo pin is set to HIGH to start the echo-back signaling. If those pulses are not deflected, the echo signal times out and drops to zero after 38 milliseconds (38 milliseconds). As a result, a pulse of 38ms shows that there is no blockage within the sensor's range.

If the reflected pulses are received, the echo pin goes low as soon as the signal is received. This causes a pulse to be generated on the echo pin, the width of which ranges from 150 s to 25 ms depending on the time it takes to capture the signal.

4.2.3 MPU6050 Vibration Sensor

Figure 4.5 MPU6050 Sensor Vibrations

MPU6050 sensor module is complete 6-axis Motion Tracking Device. It combines 3-axis Gyroscope, 3-axis Accelerometer and Digital Motion Processor all in small package. Also, it has additional feature of on-chip Temperature sensor. It has I2C bus interface to communicate with the microcontrollers. It has Auxiliary I2C bus to communicate with other sensor devices like 3-axis Magnetometer, Pressure sensor etc. If 3-axis Magnetometer is connected to auxiliary I2C bus, then MPU6050 can provide complete 9-axis Motion Fusion output.

Operating Voltage	5V (typical)
Accelerometer Range	±2g, ±4g, ±8g, ±16g
Gyroscope Range	±250°/s, ±500°/s, ±1000°/s, ±2000°/s
Temperature Range	-40 to +85°C
Absolute Maximum Acceleration	Up to 10,000g

Figure 4.6 MPU6050 Vibration sensor operating requirement

The MPU6050 consist of 3-axis Gyroscope with Micro Electro Mechanical System(MEMS) technology. It is used to detect rotational velocity along the X, Y, Z axes as shown in below figure

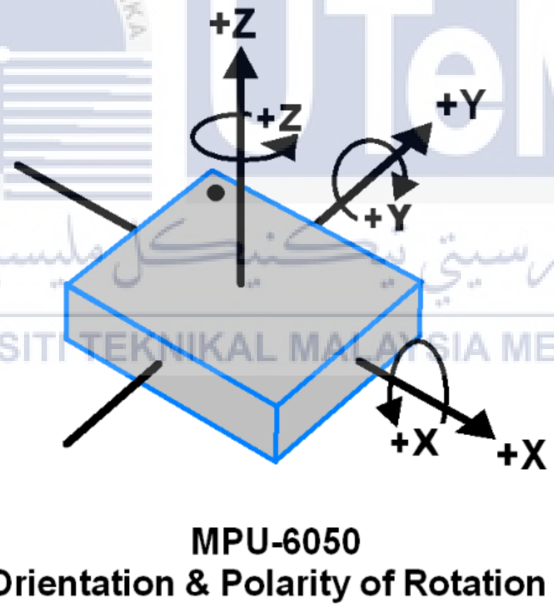


Figure 4.7 MPU6050 Orientation & Polarity of Rotation

- When the gyros are rotated about any of the sense axes, the Coriolis Effect causes a vibration that is detected by a MEM inside MPU6050.
- The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate.
- This voltage is digitized using 16-bit ADC to sample each axis.

- The full-scale range of output are +/- 250, +/- 500, +/- 1000, +/- 2000.
- It measures the angular velocity along each axis in degree per second unit.

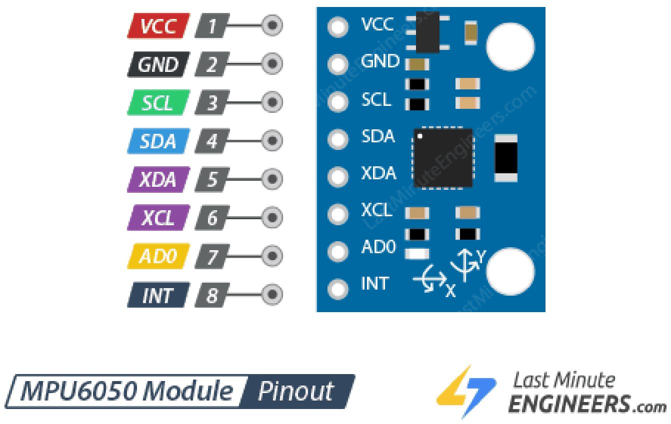


Figure 4.8 MPU6050 pinOut Diagram

Table 4.2 MPU6050 vibration sensor Pinout description

VCC	Supply power to the components
GND	Ground pin
SCL	The I2C interface for serial clock pin
SDA	The I2C interface for serial data pin
XDA	Data line for I2C external and connecting for external sensors
XCL	external I2C clock line.
AD0	It may change the I2C address of the MPU6050 module. It can be used to avoid conflicts between the module and other I2C devices, or to connect two MPU6050s to the same I2C bus. The I2C address is 0x68HEX while the ADO pin is not connected; when it is connected to 3.3V, the I2C address changes to 0x69HEX.
INT	the I/O Pin (Interrupt Output Pin). When gestures, panning, zooming, scrolling, tap detection, or shake detection are detected, the MPU6050 can be set to generate an interrupt.

Operating Voltage	5V (typical)
Accelerometer Range	±2g, ±4g, ±8g, ±16g
Gyroscope Range	±250°/s, ±500°/s, ±1000°/s, ±2000°/s
Temperature Range	-40 to +85°C
Absolute Maximum Acceleration	Up to 10,000g

4.2.4 Supply Voltage

Figure 4.9 Mini capsule powerbank

For the power supply by using a lightweight powerbank and easy to carry . it has Support Pass -Through Technology for examples: Charge your Mobile while recharging the power bank. With built in capacity of 5000mAh. This power supply has a type C male connection.

Specifications and requirements:

Table 4.3 specification and requirements of power bank

Port type	type C (male)
Battery capacity	5000mAh
Rated capacity	5000mAh
Output	5V/1.5A(Max)
Input	5V/1.5A(Max)
Product size	80*33*26mm
Product weight	78g

4.2.5 Arduino Software IDE

Arduino IDE is an open-source software, designed by Arduino.cc and mainly used for writing, compiling & uploading code to almost all Arduino Modules. It is available for all operating systems such as MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role in debugging, editing, and compiling the code. A range of Arduino modules available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro and many more. Each of them contains a microcontroller on the board that is programmed and accepts the information in the form of code. This environment supports both C and C++ languages.

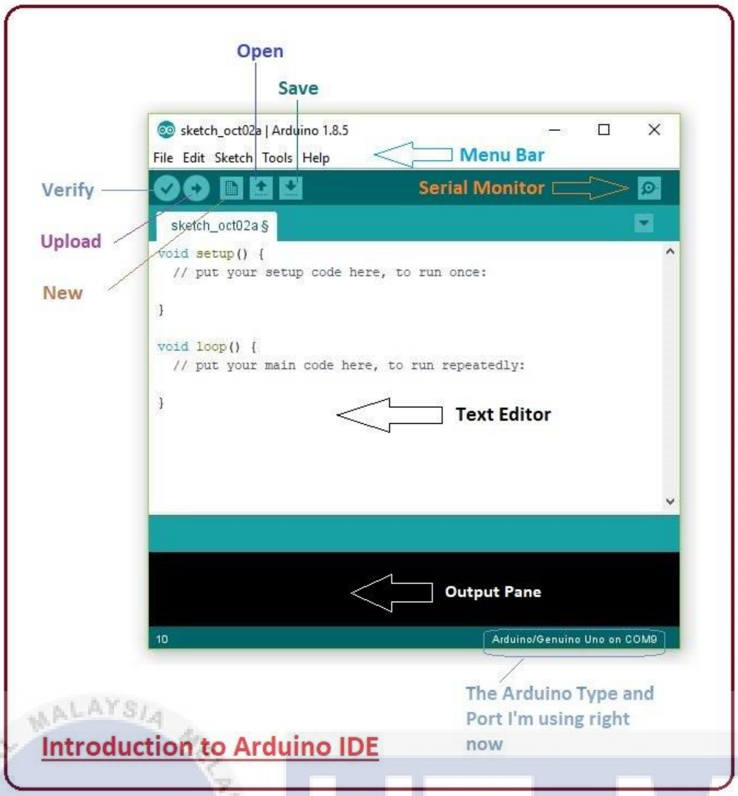


Figure 4.10 introduction of how to use the Arduino IDE software

4.2.6 Blynk Applications

The software interface, visualising or the story teller of the data from the IoT devices in form of human readable format such as alert, notification and dashboard and analytics interfaces. We can find the app in from of mobile app, desktop app or web app. The Internet technology, such as Wi-Fi, Ethernet, Cellular (GSM/GPRS, 3G, 4G, 5G) and Satellite.

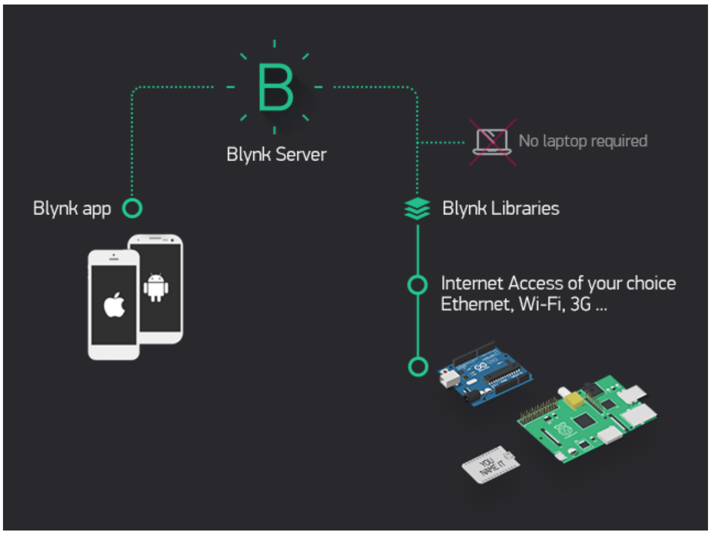


Figure 4.11 Diagram of Blynk application

Blynk is one of the easiest IoT platform ever exist on the planet. Their solution, has most complete IoT components, which are:

- **Things**: They provide Blynk Arduino libraries - to enable the communication between the cloud and devices.
- **Middleware**: They provide Blynk Server - responsible for all the communications between the smartphone and the things.
- **App**: They provide Blynk app - we can create stunning dashboard or interfaces, using its various widgets.
- **Internet**: not provided by them, we can choose which technology we want to use on the Things, such as WiFi (ESP32), Cellular (SIM900 GSM) or Ethernet (ENC28J60).

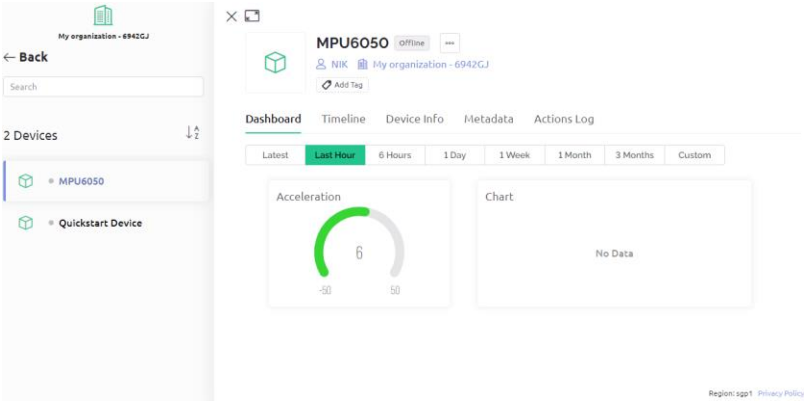


Figure 4.12 MPU6050 Gauge measurement

4.3 Step and Procedure of System Development

This system is particularly about how the system work and the process to interprete the data from hardware to software implementations. This system provided 3 type of system to get of flexibility of system using based on experiment testing. The 3 type of system use the same microcontroller that is Hibiscus Sense v1.0 ESP32 to transfer and process the data needed.

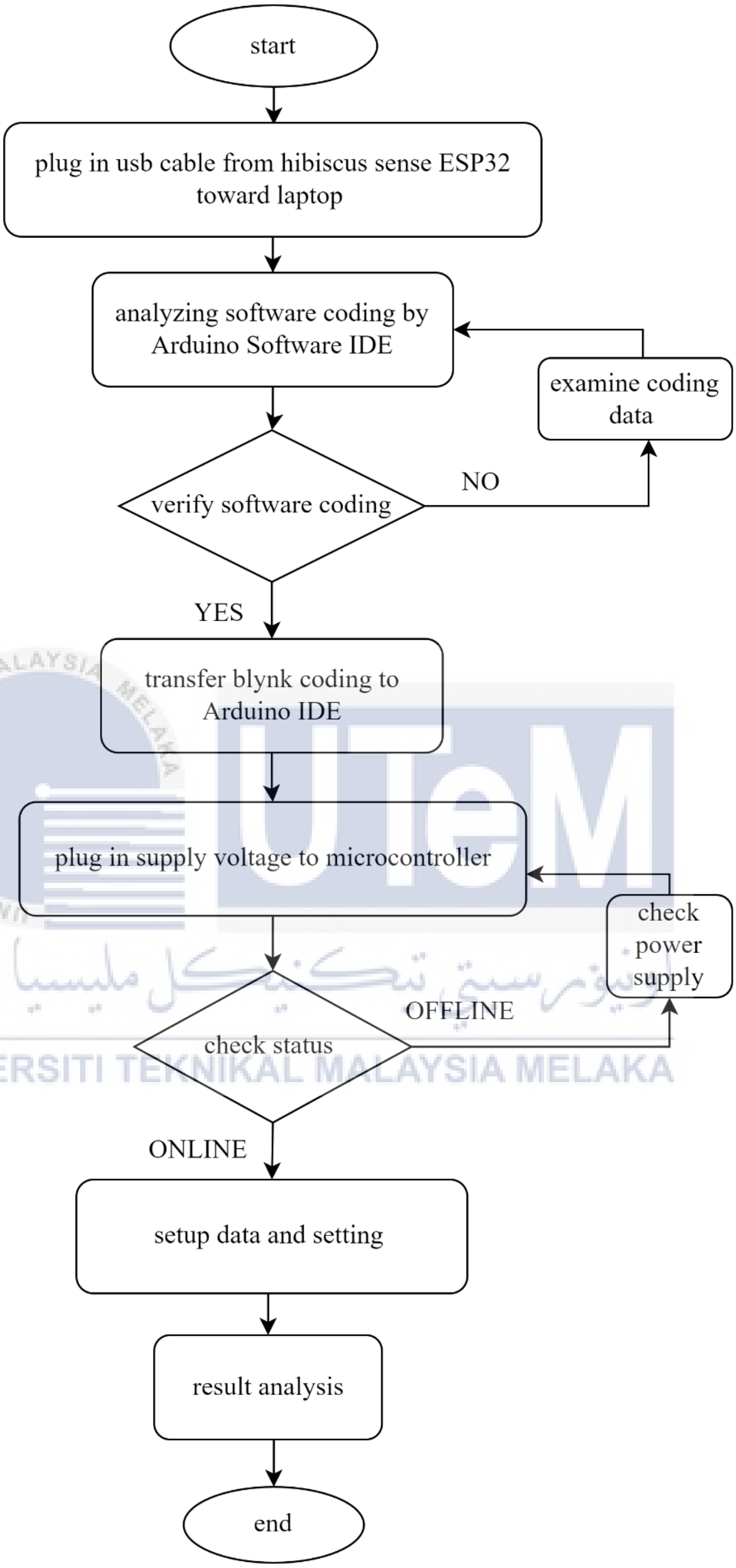


Figure 4.13 flowchart system of single vibration systems

This system is applied for single vibration system. This system plug in the the system with cable to the USB laptop to configure the data coding making to Arduino IDE software platform. Next, verify the software coding. If successful transfer the blynk coding to the Arduino IDE Software because to activate the coding for wifi platform, if not check the pin connection or examine the data coding. After that, connect the supply voltage at the microcontroller which is ESP32 that have type-C port to power on the sensor and microcontroller itself. This connection is using wifi, so the blynk app will pop up the system is offline or online. If offline, check the supply power on the powerbank. If online, can setup the system in the blynk application and analysis the data and trend when the system test is begin to running.

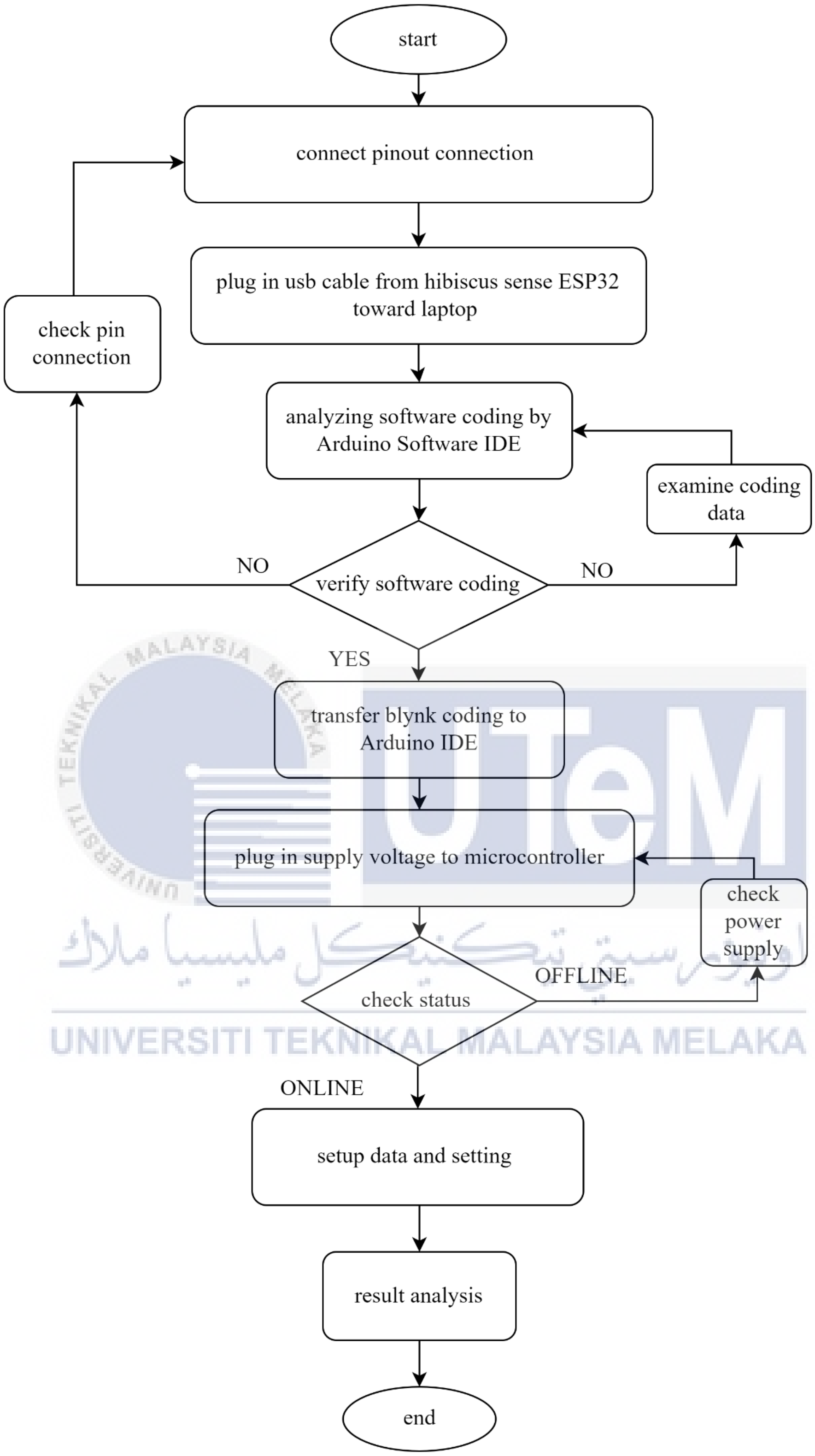


Figure 4.14 flowchart how the single vibration with Ultrasonic system work

This system starts with connect the pin connection of microcontroller with Ultrasonic sensor. Then, plug in the the system with cable to the USB laptop to configure the data coding making to Arduino IDE software platform. Next, verify the software coding. If successful transfer the blynk coding to the Arduino IDE Software because to activate the coding for wifi platform, if not check the pin connection or examine the data coding. After that, connect the supply voltage at the microcontroller which is ESP32 that have type-C port to power on the sensor and microcontroller itself. This connection is using wifi, so the blynk app will pop up the system is offline or online. If offline, check the supply power on the powerbank. If online, can setup the system in the blynk application and analysis the data and trend when the system test is begin to running.

4.3.1 Single vibration system

This system is using only Hibiscus Sense v1.0 ESP32. This system stand alone to measure and carry out the acceleration 3 axis by MPU6050 inside the ESP32 microcontrollers and the temperature when vibrations occurs during system test.

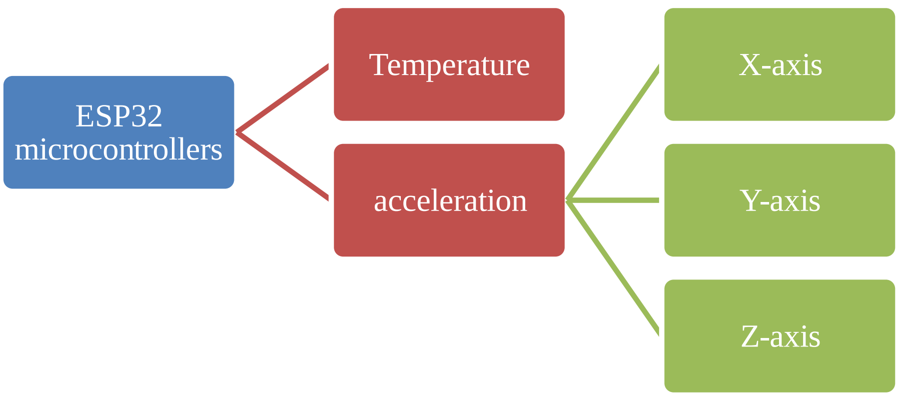


Figure 4.15 single vibration system output program

This system do not have pin out connection because the microcontroller have include the MPU6050 sensor to figure out the vibration detection and also measure out the temperature of the rotary machine. So this system just need the supply voltage to the microcontroller to power on the system. So the power bank only is used for this system within connection of type-C cable.

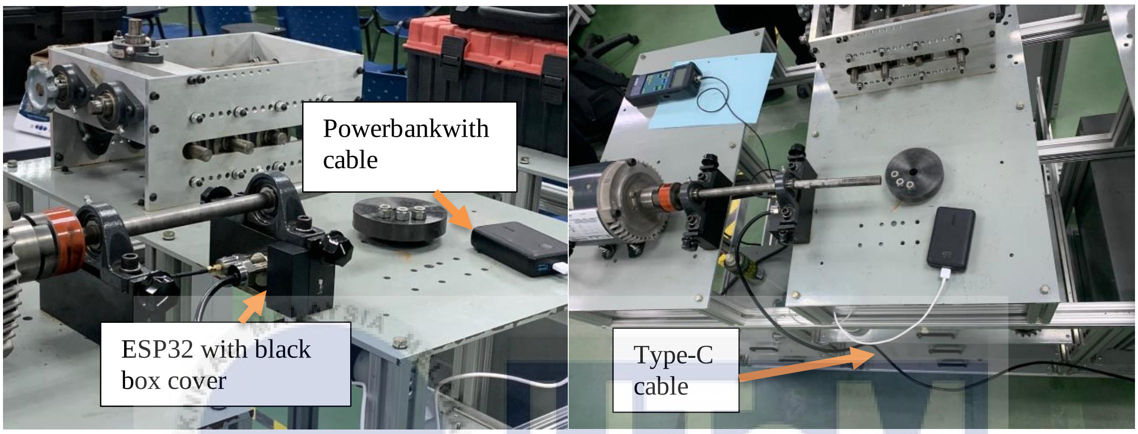


Figure 4.16 the single vibration system setup on rotary machine

4.3.2 Single vibration with Ultrasonic sensor system

This system includes Hibiscus sense ESP32 with Ultrasonic sensor. This system is to carry out the acceleration of 3 axis with temperature and distance by the chart below:

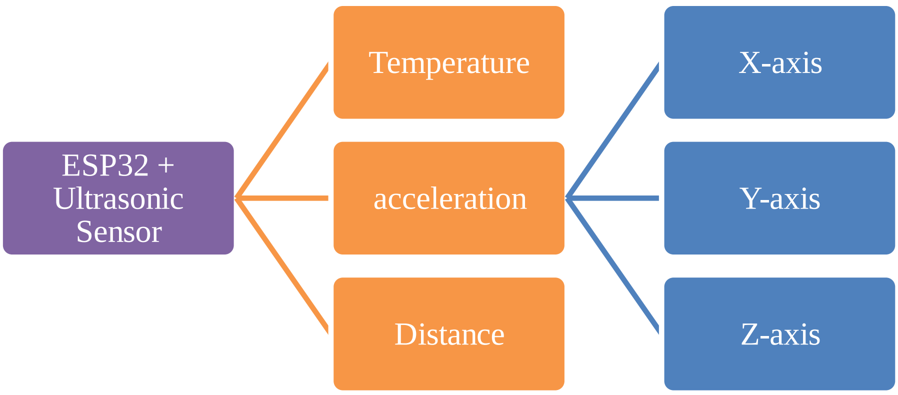


Figure 4.17 Single vibration system with Ultrasonic Sensor system ouput program

This system starts with connect the pin connection of microcontroller with Ultrasonic sensor. Then, plug in the the system with cable to the USB laptop to configure the data coding making to Arduino IDE software platform. Next, verify the software coding. If successful transfer the blynk coding to the Arduino IDE Software because to activate the coding for wifi platform, if not check the pin connection or examine the data coding. After that, connect the supply voltage at the microcontroller which is ESP32 that have type-C port to power on the sensor and microcontroller itself. This connection is using wifi, so the blynk app will pop up the system is offline or online. If offline, check the supply power on the powerbank. If online, can setup the system in the blynk application and analysis the data and trend when the system test is begin to running.

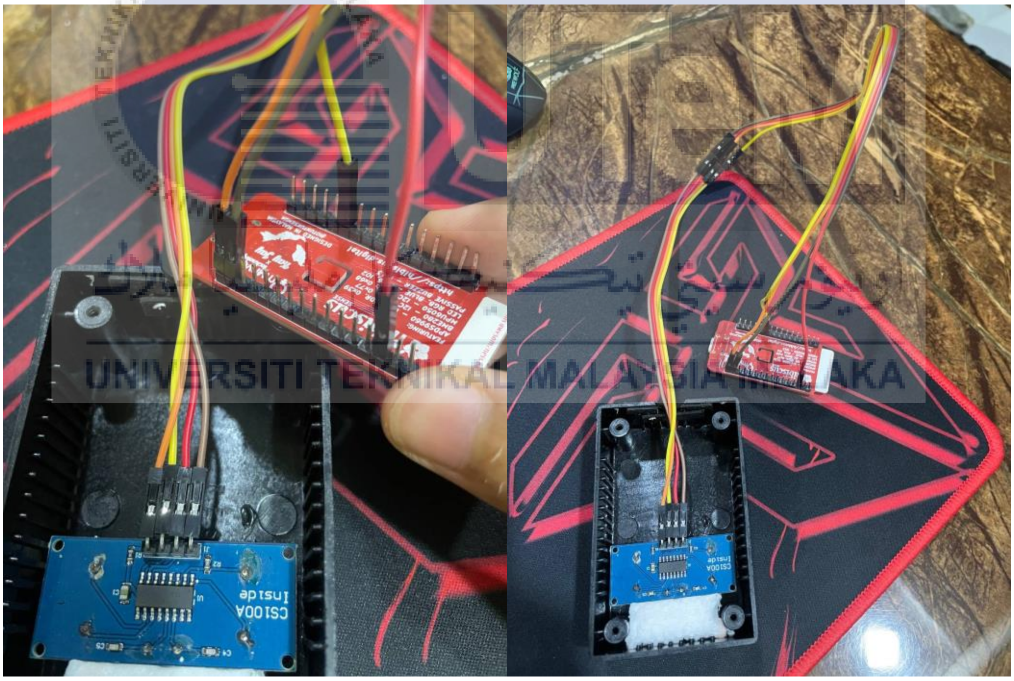


Figure 4.18 Pin connection of ultrasonic sensor with Hibiscus Sense v1.0 ESP32

From the figures above, this connection system is based from the PinOut diagram of Ultrasonic sensor and Hibiscus Sense ESP32. In the convenience way by using the color of jumper can identify for boths Pinout. The brown wire of both components is GND (Ground), the red one for ultrasonic is Echo pin and for ESP32 is GPI 36 (General Purpose Input 36), the yellow wire is trigger for ultrasonic and GPIO 17 (General Purpose Input/Output 17), for the last one, orange is VCC (Supply Power) and VIN (Voltage In) for ultrasonic and ESP32.

Table 4.4 Jumper wire connection of Ultrasonic Sensor with Hibiscus Sense ESP32

Jumper wire color	MPU6050 sensor Pinout connection	Hibiscus sense ESP32 pin connection
Brown	GND (Ground)	GND (Ground)
Red	Echo Pin	GPI 36
Yellow	Trigger	GPIO 17
Orange	VCC (Power Supply)	VIN (Voltage In)

By the figure below, by using type C to type C cable male to female port connect the male port cable to the Hibiscus Sense ESP32. Then, connect the power bank with female port cable.

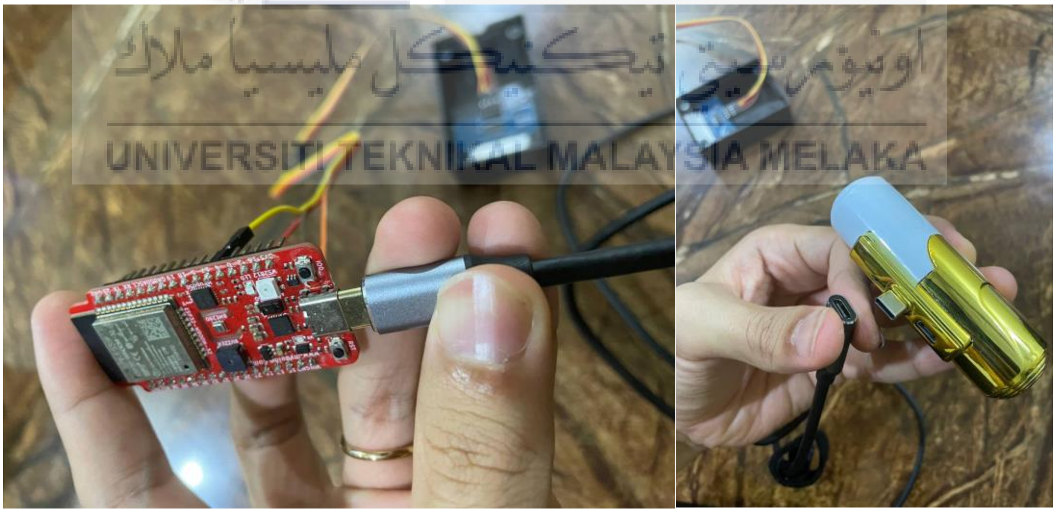


Figure 4.19 the connection of power supply to microcontroller

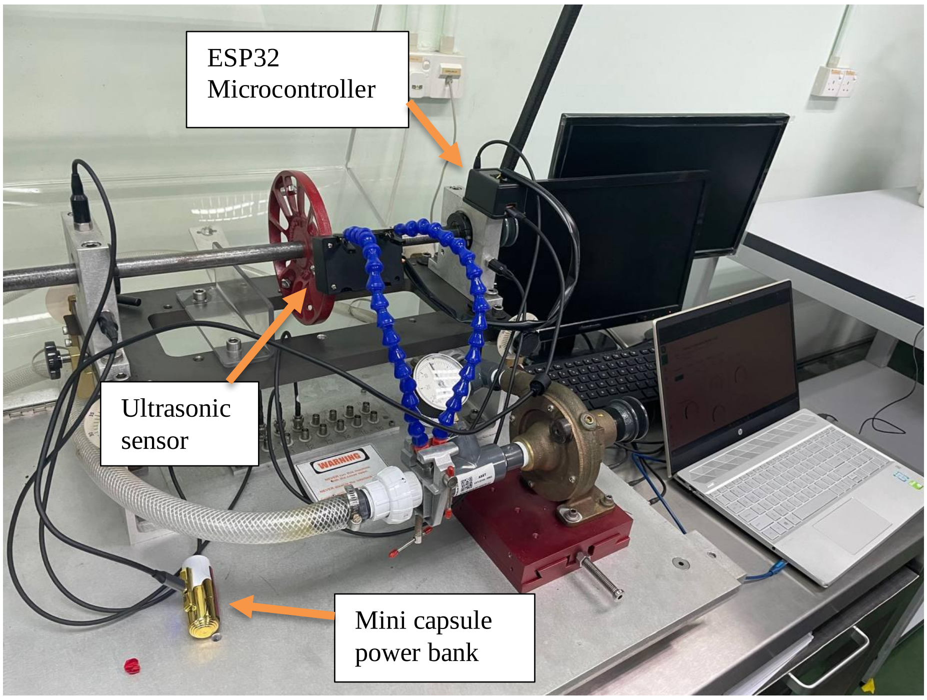


Figure 4.20 the interfaces of system wiring connection on the lab session

The power supply from the power bank will flow through the type C cable to the Hibiscus Sense ESP32. Then, the ESP32 will turn on by seeing the LED. The voltages will also transfer to the Ultrasonic Sensor through jumper wires to make sure the both component can function together at the same time.

4.3.3 Double vibration system

This double vibration system is to known the sustainability of both 3 axis accelerometer and to make comparison the diffenrence value of this vibration system. This system also can compare the temperature for ESP32 and MPU6050 sensor. This system can be measure the data and result by observe the live data on the blynk application platform.

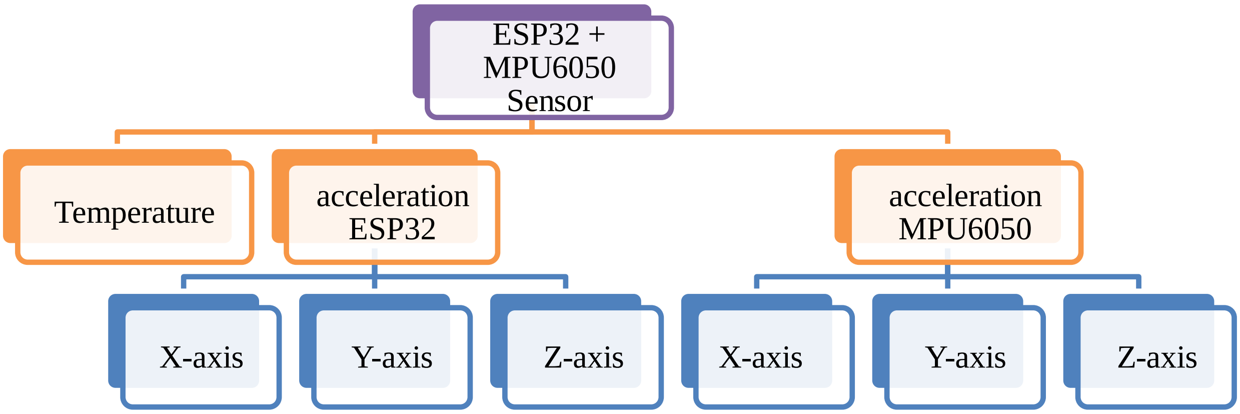


Figure 4.21 ouput program for double vibration system

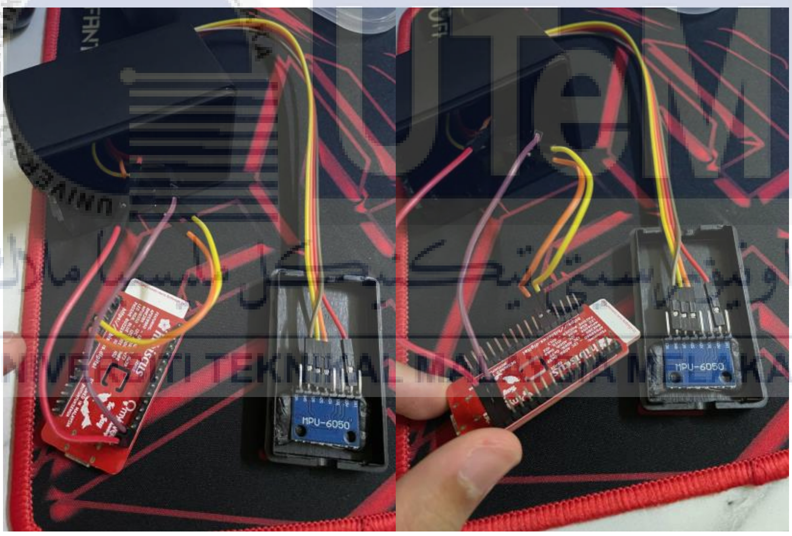


Figure 4.22 pin connection of MPU6050 sensor with Hibiscus Sense ESP32

This system is using 2 vibration type of sensor that is MPU6050 in the Hibiscus Sense and and another MPU6050 sensor alone . From the figures above, this connection system is based from the PinOut diagram of MPU6050 Sensor and Hibiscus Sense ESP32. In the convenience way by using the color of jumper can identify for boths Pinout. The brown wire of both components is GND (Ground), the red one for MPU6050 sensor is ADO pin and for ESP32 is GPI 36 (General Purpose Input 36), the yellow wire is Serial Clock Pin (SCL) for MPU6050 sensor and GPIO 17 (General Purpose Input/Output 17), for the last one, orange is Serial Data (SDA) and VIN (Voltage In) for MPU6050 sensor and ESP32.

Table 4.5 Jumper wire connection of MPU6050 Sensor with Hibiscus Sense ESP32

Jumper wire color	MPU6050 sensor Pinout connection	Hibiscus sense ESP32 pin connection
Brown	GND (Ground)	GND (Ground)
Red	ADO PIN	GPI 36
Yellow	SCL (Serial clock pin)	GPIO 17
Orange	SDA (Serial Data)	VIN (Voltage In)

Figure 4.23 double vibration system setup on the machine vibrations

This setup including the MPU6050 sensor and Hibiscus Sense ESP32 by using power supply that is mini capsule powerbank to power on the microcontroller with sensor to trigger the vibrations detection when the machine is running or rotating. It will trigger and detect the vibration of the machineto transfer the data through Blynk platform monitoring.

4.4 Results and Analysis of Data

This result was taken by using the Blynk applications with supporting guidance of coding motion detection to detection of vibration in several minutes to get the result shown in below figure. the interpreted data show of accelerometer gyroscope with aid of x,y,z axis of both ESP32 or MPU6050 sensor This data show to measure the sensitivity of vibration temperature and distance of some objects.

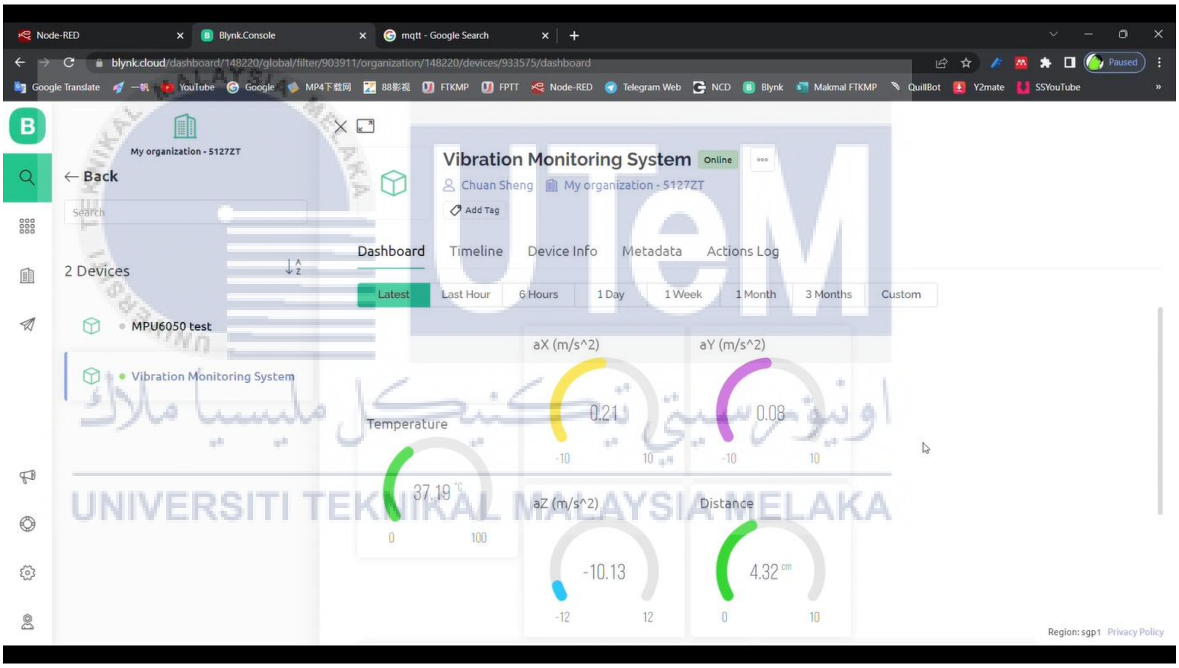


Figure 4.24 the result for single vibration system and single vibration system with ultrasonics sensor

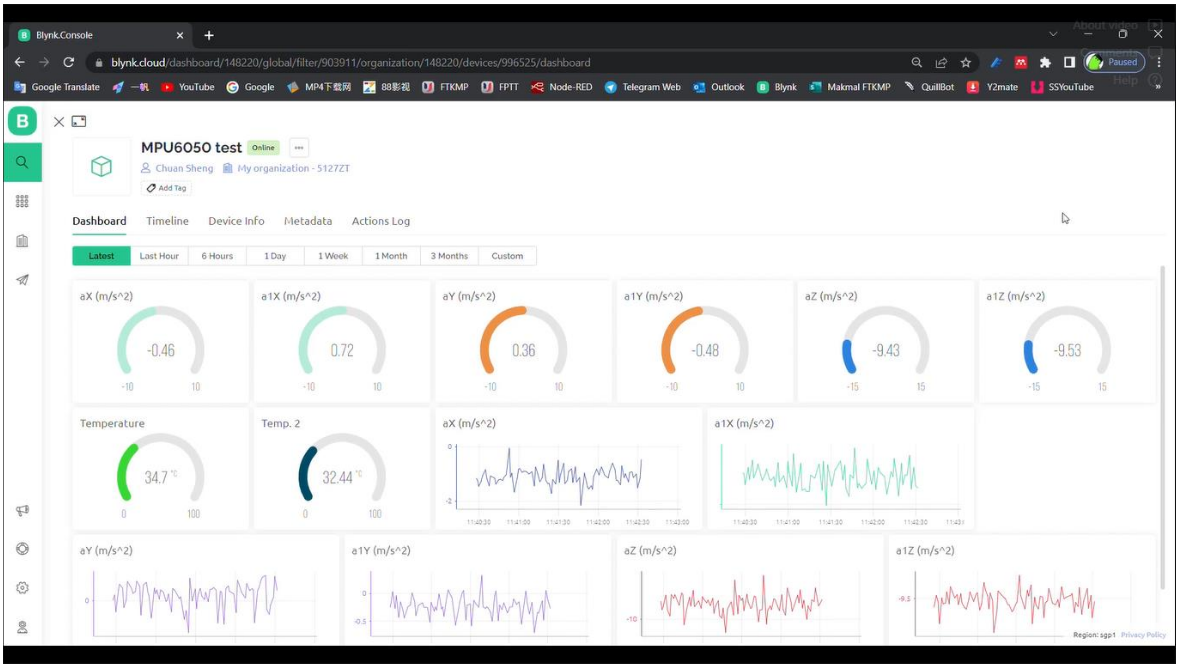


Figure 4.25 the result and data for double vibration system

4.5 Summary

According to the above, an accelerometer is a sensor that measures changes in the rate at which an object moves. The mass "squeezes" the piezoelectric and MEMS material due to the force created by vibration or change in motion (acceleration), resulting in an electrical charge proportional to the force exerted. To put it another way, the charge is inversely proportional to acceleration since force and mass are both constant. A variety of devices, from space stations to mobile phones, make use of accelerometers, so chances are you already have one.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this paper, we demonstrated the potentials of IoT for smart maintenance. We explained how IoT can help the condition monitoring and fault diagnosis of rotating machinery using vibration analysis. Further, vibration sensing has been investigated and the new generation of MEMS accelerometers has been introduced. We discussed the superiority of MEMS accelerometers on legacy piezoelectric accelerometers and their importance in the future of smart maintenance. We proposed to make rotating equipment to IoT enabled devices by adding hardware to them. According to the requirements, the hardware was designed and developed. This hardware can measure vibrations with 2.5 kHz sampling rate in the range of ±3 g and send them in real-time to a specified server on the cloud. This way the machine will be able to send its vibration status to the server and the maintenance engineers will be able to monitor it anytime, anywhere. The developed hardware has been evaluated by comparing the results of online and local data measurements at the same time. The results of the evaluation have been proved to be very precise. This paper will prove the concept of using IoT enabled sensors in predictive maintenance to overcome some gaps in the commonly used methods of condition monitoring of rotating machinery. The results can be extended to a larger scope of equipment, faults, and parameters.

5.2 Recommendations

i. Microscopic batteries for MEMS systems

Microscopic batteries, integratable or integrated with microelectromechanical systems or other microscopic circuits, including a MEMS microcircuit, and methods of microfabrication of such microscopic batteries are disclosed, among which comprise closed system microscopic batteries for internal storage of electricity using interval reactants only, which comprise microscopic electrodes, electrolyte and reservoir for the electrolyte.

ii. Increase Reliability

Unwanted sound and vibration can be destabilizing influences that affect a wide variety of industries—from consumer electronics and automobiles to costly industrial equipment. Vibration can simply cause discomfort to a vehicle passenger, system operator, or end user, or, at the other end of the spectrum, even lead to catastrophic failure. Drivetrain systems can fracture. Anti-lock braking systems can fail. Heavy machinery can move off a foundation and spew hazardous chemicals or gases. Abnormal levels of vibration and noise can be early indicators of an internal problem, such as imbalance, angular or parallel misalignment, or wear or looseness of roller bearings, drive belts, or gears.1 If left unchecked, excess vibration can cause additional, even irreparable damage. Quickly identifying and eliminating the cause of unwanted vibrations can help manufacturers avoid a range of downstream repercussions, including negative consumer reviews, operator disruption, costly product repairs or redesigns, and bodily injury. Comprehensive sound and vibration analysis can help manufacturers proactively prevent hazardous levels of sound and vibration and reactively evaluate the root cause of a product or system failure

5.3 Project Potential

The goal of this proposed model was to establish vibration measurement and analysis using the MPU6050 triple-axis accelerometer and a WI-FI module to transmit sensor data. The sensor data can be studied in MATLAB software by drawing curves, but this goal is not met due to a lack of MATLAB to Arduino and WI-FI module interface. It is preferable to use a GSM module rather than a Wi-Fi module to discover a more evolved method. As a result of using the GSM module, it is possible to obtain sensor data from a greater distance. It's tough to connect many I2C-interface devices to a single SDA and SCL pin on an Arduino. Because the Hibiscus Sense ESP32 is used in this model, the difficulty of power supply via wireless means that the process will be easier and less complex if the MEMS battery or Li-ion Battery is employed. Also, utilising arduino to collect more precise data while reducing the program's delay, which also helps to boost the speed of data transfer to the server. It would be more beneficial to analyse the data using the lab view.

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APPENDICES

ESP32_motion detection code - Notepad

File Edit Format View Help

```
#include <Adafruit_MPU6050.h>
#include <Adafruit_Sensor.h>
#include <Wire.h>

Adafruit_MPU6050 mpu;

void setup(void) {
  Serial.begin(115200);
  while (!Serial)
    delay(10); // will pause Zero, Leonardo, etc until serial console opens

  Serial.println("Adafruit MPU6050 test!");

  // Try to initialize!
  if (!mpu.begin()) {
    Serial.println("Failed to find MPU6050 chip");
    while (1) {
      delay(10);
    }
  }
  Serial.println("MPU6050 Found!");

  //setupt motion detection
  mpu.setHighPassFilter(MPU6050_HIGHPASS_0_63_HZ);
  mpu.setMotionDetectionThreshold(1);
  mpu.setMotionDetectionDuration(20);
  mpu.setInterruptPinLatch(true);       // Keep it latched.  Will turn off when reinitialized.
  mpu.setInterruptPinPolarity(true);
  mpu.setMotionInterrupt(true);

  Serial.println("");
  delay(100);
}

void loop() {

  if(mpu.getMotionInterruptStatus()) {
    /* Get new sensor events with the readings */
    sensors_event_t a, g, temp;
    mpu.getEvent(&a, &g, &temp);

    /* Print out the values */
    Serial.print("AccelX:");
    Serial.print(a.acceleration.x);
    Serial.print(",");
    Serial.print("AccelY:");
    Serial.print(a.acceleration.y);
    Serial.print(",");
    Serial.print("AccelZ:");
    Serial.print(a.acceleration.z);
    Serial.print(", ");
    Serial.print("GyroX:");
    Serial.print(g.gyro.x);
    Serial.print(",");
    Serial.print("GyroY:");
    Serial.print(g.gyro.y);
    Serial.print(",");
    Serial.print("GyroZ:");
    Serial.print(g.gyro.z);
    Serial.println("");
  }

  delay(10);
}
```


APPENDIX A: Coding adafruit for ESP32 motion detection

Table 1. Summary of the characteristics of the accelerometers commonly used in the literature.

N° [1]	Name [2]	Price (€) [3]	Acceleration Range (g) [4]	Frequency Range (Hz) [5]	Spectral Noise (µg/√Hz) [6]	Operation Temperature (°C) [7]	Structural Type [8]	Type [9]
1	3713B112G [33]	2070.0	±2.0	[0.00, 250]	22.90	[−54, +121]	Wind Turbine [34]	Tri, M
2	356B08 [35]	1610.0	±50.0	[0.50, 5000]	40.00	[−54, +77]	Bridge Crane [36]	Tri, P
3	356A45 [37]	1410.0	±50.0	[0.70, 7000]	125.00	[−54, +85]	Forward Swept Wing [38]	Tri, P
4	356B18 [39]	1300.0	±5.0	[0.50, 3000]	11.40	[−30, +77]	Motorbike Speedway Stadium [40]	Tri, P
5	KB12VD [41]	828.0	±0.6	[0.30, 2000]	0.06	[−20, +80]	Concrete School Building [42]	Uni, P
6	3711B1110G [43]	870.0	±10.0	[0.00, 1000]	107.90	[−54, +121]	Railroad Bridges [44]	Uni, M
7	KS48C [41]	750.0	±6.0	[0.25, 130]	0.60	[−20, +120]	Footway Bridge [45]	Uni, P
8	393B12 [46]	820.0	±0.5	[0.15, 1000]	1.30	[−54, +82]	Historical Masonry Structures [47]	Uni, P
9	393A03 [48]	710.0	±5.0	[0.50, 2000]	2.00	[−54, +121]	Brick Masonry Constituents [49]	Uni, P
10	352A24 [50]	540.0	±50.0	[1.00, 8000]	80.00	[−54, +121]	Hallow Square Beams [51]	Uni, P
11	352C33 [52]	380.0	±50.0	[0.50, 10,000]	39.00	[−54, +93]	Bridges [53]	Uni, P
12	ADXL335 [54]	10.7	±3.6	[0.50, 550]	300.00	[−40, +85]	Bridges [55]	Tri, M
13	LIS344ALH [56]	12.0	±2.0	[1.00, 500]	50.00	[−40, +85]	Steel beam [57]	Tri, M
14	MPU9250 [3]	5.8	±16.0	[0.24, 500]	300.00	[−40, +85]	Steel Pile and Column [58]	Tri, M
15	MPU6050 [59]	5.4	±16.0	[0.24, 500]	400.00	[−40, +85]	Building Model [60]	Tri, M

Notes: [1] Sensor number. [2] Sensor name. [3] Sensor price: the prices are obtained from retailers (VAT excluded). [4] Acceleration range: the maximum acceleration amplitude capacity of the sensors. [5] Frequency range: the accurate, readable range of frequencies. [6] Spectral Noise: the power spectral density of noise per unit of bandwidth (1 Hz). [7] Operational temperature: temperature range where the sensor works accurately. [8] Structural type: where the sensors are used. [9] Type: Uni stands for uniaxial, Tri for triaxial, P for piezoelectric and M for MEMS (uniaxial accelerometers are only capable of sensing vibration from one axis, while triaxial ones can sense vibrations from all of the directions).

APPENDIX B: The characteristics of the accelerometer commonly used

Rujukan Kami (Our Ref):
Rujukan Tuan (Your Ref):
Tarikh (Date): 31 Januari 2021

Chief Information Officer
Perpustakaan Laman Hikmah
Universiti Teknikal Malaysia Melaka

Melalui

Dekan
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Dengan segala hormatnya merujuk kepada perkara di atas.

2. Dengan ini, dimaklumkan permohonan pengkelasan tesis yang dilampirkan sebagai TERHAD untuk tempoh **LIMA** tahun dari tarikh surat ini. Butiran lanjut laporan PSM tersebut adalah seperti berikut:

Nama pelajar: ALI ZAINUL ABIDIN BIN KAMARUDIN

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3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULIT.

Sekian, terima kasih.

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