Faculty of Electrical Technology and Engineering

DEVELOPMENT OF AN IOT-BASED SOLAR POWERED AUTOMATED ROOF CLOTHESLINE SUSPENSION USING A MICROCONTROLLER

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Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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Date :

DEDICATION

I want to extend my sincere gratitude to my family, with a special mention to my father, Lahapi bin Mapiare, and mother, Ijami binti Rasa, for their constant and unwavering support that has shaped my journey and fuelled my ambitions. Your advice and enduring love have provided the foundation for my dreams. I want to express my gratitude to another significant person, my best friend, Syafika Syazana. I am also thankful for the unwavering support and companionship of my partner, Mirza Shazli, who has been my constant source of encouragement. Special appreciation goes to my housemates during my degree life, particularly the members of Juhlas. Additionally, I want to acknowledge the invaluable role played by my close friend during my degree, who has been my rock through thick and thin, offering enduring support and strength. As I end my final year project, I want to thank everyone who has supported me during this process. During these moments of uncertainty, your presence, understanding, and guidance have been extremely helpful. This completion is not simply about completing a project; instead, it is about recognizing the influence that each of you has had on my creative and personal journey. Thank you for being there, and here's to many achievements in the future!

ABSTRACT

In the contemporary era, individuals, regardless of gender, often face challenges managing household tasks such as laundry due to busy schedules. Traditional clotheslines that require manual labour become impractical, especially when people forget to retrieve clothes during rain, leading to wet garments. This project addresses this issue by introducing an IoT-based solar-powered automated roof clothesline system. Various components collaborate to achieve the desired functionality. The Blynk application serves as the user interface, enabling monitoring and control. A rain sensor detects rainfall, preventing clothes from getting wet. Temperature and humidity sensors provide environmental data, allowing the system to optimize drying based on weather conditions. Integration of a solar panel facilitates the use of renewable energy, reducing dependence on conventional power and promoting environmental sustainability. Servo motors automate the extraction and expansion of the clothesline roof. The microprocessor processes inputs from these sensors, executes commands, and provides feedback through the Blynk application, ensuring an effective system operation. The project achieves its goals and serves as an example of utilizing IoT technology to address common issues, emphasizing eco-friendly solutions and a sustainable approach to laundry management. Future enhancements, such as adding a fan and a conveyor system, offer additional benefits, especially for individuals busy with household tasks. The project demonstrates the potential of technology to improve efficiency and environmental responsibility, presenting a holistic approach to modernizing daily tasks.

ABSTRAK

Dalam era kontemporari, individu, tanpa mengira jantina, sering menghadapi cabaran menguruskan tugasan rumah seperti cucian di kerana jadual yang sibuk. Ampaian tradisional yang memerlukan kerja manual menjadi tidak praktikal, terutamanya ketika orang lupa mengambil pakaian semasa hujan, menjadikan pakaian basah. Projek ini menyelesaikan masalah ini dengan memperkenalkan sistem bumbung ampaian automatik tenaga solar berasaskan IoT. Pelbagai komponen bekerjasama untuk mencapai fungsi yang diinginkan. Aplikasi Blynk berperanan sebagai antara muka pengguna, membolehkan pemantauan dan kawalan. Sensor hujan mengesan hujan, mencegah pakaian basah. Sensor suhu dan kelembapan menyediakan data alam sekitar, membolehkan sistem mengoptimumkan pengeringan berdasarkan keadaan cuaca. Integrasi panel solar memudahkan penggunaan tenaga boleh diperbaharui, mengurangkan bergantung kepada tenaga konvensional dan menggalakkan kelestarian alam sekitar. Motor servo mengautomatikkan mekanisme pengeluaran dan pengembangan bumbung tali pengering. Mikropemproses memproses input dari sensor-sensor ini, melaksanakan arahan, dan memberikan maklum balas melalui aplikasi Blynk, memastikan operasi sistem yang berkesan. Projek ini mencapai matlamatnya dan berperanan sebagai contoh penggunaan teknologi IoT untuk menangani masalah umum, menekankan penyelesaian mesra alam dan pendekatan lestari dalam pengurusan cucian. Dengan matlamat untuk mengoptimumkan pengeringan dan perlindungan pakaian, penambahbaikan masa depan seperti penambahan kipas dan sistem konveyor memberikan manfaat tambahan, terutamanya kepada individu yang sibuk dengan tugasan rumah. Projek ini menunjukkan potensi teknologi untuk meningkatkan kecekapan dan tanggungjawab alam sekitar, mempersembahkan pendekatan holistik dalam memodenkan tugas-tugas harian.

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LIST OF ABBREVIATIONS

LCD	-	Liquid Crystal Diode
LDR	-	Light Dependent Resistor
DC	-	Direct Current
AC	-	Alternating Current
Wi-Fi	-	Wireless Fidelity
Li-Ion	-	Lithium Ion
USB	-	Universal Serial Bus
VCC	-	Voltage Control Centre
GND	-	Ground
PWM	-	Pulse Width Modulation
IDE	-	Integrated Development Environment
IoT	-	Internet of Things Light
LED	-	Emitting Diode
API	-	Application Programming Interface
I/O	-	Input/Output
HVAC	-	Heating, Ventilation, Air Conditioning

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CHAPTER 1

INTRODUCTION

1.1 Background

The Internet of Things (IoT) paradigm refers to a system of interconnected devices outfitted with computational capability (smart objects), identifiable and capable of transferring data over a network without human interaction. The concept underlying this paradigm is the pervasive presence of smart devices, which achieve common objectives by cooperating and interacting with humans [1].

Smart Home is an example of an Internet of Things (IoT) application domain. Mainly, smart home automation processes that manage interactions with home devices and integrate all their (potentially conflicting) services present new challenges and necessitate modern engineering practices, software platforms, and artificial intelligence [2].

Solar energy is radiation from the Sun capable of producing heat, inducing chemical reactions, and generating electricity. The total quantity of solar energy incidents on Earth is vastly more than the world's current and anticipated energy demands. This highly diffused source has the potential to meet all future energy demands if it is harnessed correctly. In contrast to the finite fossil fuels coal, petroleum, and natural gas, solar energy is anticipated to grow in popularity as a renewable energy source in the 21st century due to its inexhaustible supply and non-polluting nature [3].

1.2 Addressing Global Warming Through IoT-Based Solar Powered Automated Roof Clothesline Suspension Project

Global warming is a significant problem that negatively affects our environment. It occurs when heat-trapping atmospheric gases cause the Earth's temperature to rise. Using non-renewable energy sources such as coal, oil, and natural gas is one of the primary causes of global warming. These sources emit substantial carbon dioxide, contributing to the problem. Innovative and long-term solutions must be investigated to address this issue. This report proposes an IoT-based solar-powered automated roof clothesline suspension system as a practical method for combating global warming. This system provides an efficient means of promoting energy efficiency and addressing climate change by utilizing renewable energy sources, optimizing resource utilization, and reducing carbon emissions. Implementing this solution can pave the way for a greener and more sustainable future while demonstrating the potential of IoT technologies in addressing environmental challenges.

1.3 Problem Statement

Malaysia is a country situated in the equatorial zone with a tropical climate that experiences a variety of climatic variations, including rain, heat, and so forth. Uncertain weather swept across the nation, bringing humid and dry days, hot afternoons in some regions, and torrential rains and lightning storms in other areas. Unpredictable weather conditions, such as rainy days, can make it difficult for individuals to dry clothing outdoors in modern times [4]. Clotheslines have long been a popular method for drying clothes worldwide. People today still widely used clothing directly to the hot sun on a clothesline to dry them using the traditional method [5]. It is considered the most accessible, least expensive, and most effective method of drying clothing [5].

Sometimes, when it rains, people frequently neglect to remove their clothes from the clothesline. Working individuals will struggle to remember this due to the brief time to handle their work and daily activities. Most people in the country are familiar with the flexibility in clothing management at the clothesline. However, for individuals who are away throughout the day due to being somewhere else, such as the office, the management of clothes on the hanger becomes rigid, disrupting the focus of their daily routine [4]. Moreover, the reliance on non-renewable energy sources, such as electricity or gas-powered dryers, has adverse environmental effects, contributing to users' high energy costs.

The project proposes developing an automated clothesline roof system powered by renewable energy that allows users to control and monitor. The system should also be capable of adjusting its position depending on weather conditions, such as the presence of sunlight or rain. The system will be designed to be energy-efficient and environmentally friendly, using solar power to charge the battery that powers the Microcontroller and the automated system. The system will be designed to be safe, reliable, and easy to use, addressing the challenges faced by traditional clothesline systems.

1.4 Project Objective

The main aim of this project is to create an IoT-based solar-powered automated roof clothesline suspension system using a microcontroller. Specifically, the objectives are as follows:

a) To design and develop an energy-efficient and environmentally friendly automated clothesline system powered by solar energy.

b) To develop a system that can be remotely monitored through a Blynk application, allowing users to manage their laundry tasks conveniently.

c) To analyse the performance of the system in terms of its functionality and reliability.

1.5 Scope of Project

To eliminate any possibility of confusion regarding the outcome of this project due to certain limitations and restrictions, the project's scope has been defined as follows:

a) Implementing rain, humidity, temperature, and light sensors to detect the environment and prevent clothes from getting wet during bad weather.

b) The data will be collected in real-time and displayed in the Blynk Application.

c) Implement a mechanism where the roof will extract water if it is not raining and expand if it is raining.

d) Solar power is utilized for the system’s operation.

e) Only applicable for landed house area.

1.6 Report Structure and Organization

Chapter 1 serves as the foundation for the study, offering a background on the project and establishing key objectives derived from the identified problem statement. It sets the tone for the subsequent chapters by providing a clear context for the research.

Chapter 2 delves into the literature surrounding the Internet of Things (IoT) and its transformative impact, particularly in home automation, focusing on clothes drying. The review explores past initiatives on automating clothesline suspensions, considering hardware and system aspects. This chapter establishes the theoretical framework and contextualizes the project within existing research.

Chapter 3 outlines the systematic approach to designing, developing, and evaluating the IoT-based solar-powered automated roof clothesline suspension. It encompasses the selection of hardware and software, delineating system design steps, and providing insight into prototyping and testing procedures. The methodology chapter ensures a comprehensive understanding of the project's implementation process.

Chapter 4 focuses on the presentation and analysis of the results derived from the ‘Development Of an IoT-Based Solar Powered Automated Roof Clothesline Suspension Using A Microcontroller.’ The discussion delves into the system’s effectiveness, offering a nuanced exploration of its implications and potential applications.

The final chapter serves as the culmination of the study, highlighting the successful implementation of the IoT-based automated clothesline suspension system. It reaffirms the achievement of project goals, including solar-powered efficiency and integration with the Blynk application. The chapter also reflects on the system's reliability, adaptability to weather conditions, and user-friendly design. Limitations and recommendations are discussed, positioning the project as a model for eco-friendly solutions and demonstrating the potential of IoT technologies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In recent years, the Internet of Things (IoT) has emerged as a transformative technology connecting diverse devices. The Internet of Things (IoT) generally refers to objects that can be uniquely identified and represented virtually in Internet-based structures [6]. This connectivity has opened new avenues for innovation, especially in home automation. One area where IoT has the potential to revolutionize daily household tasks is clothes drying. Traditional methods of clothesline suspension often require manual intervention and are subject to weather conditions. The concept of automated clothing dryers has been introduced previously. Prior research and initiatives have explored various methods for automating clothesline suspensions. The research is based on a study conducted within five years of the project's execution. It can be utilized as a reference. Additionally, the applicability of the search strategy to the actual undertaking will be evaluated and determined. For the hardware for assembly in this project, it is necessary to consider the pros and cons of the hardware and system. Finally, previous study outcomes and procedures will be compared and assessed to ensure they serve as this project's most accurate and relevant data source.

2.2 Understanding Global Issue Related To This Project

To successfully implement the Internet of Things (IoT)-based solar-powered automated roof clothesline suspension project, it is vital to have a comprehensive understanding of the global problem of global warming and its effects on the environment. Global warming is one of the most significant challenges of the 21st century. If efforts are made to transform current energy systems, their most severe impacts may still be avoided. Renewable energy sources have a high potential for displacing greenhouse gas emissions from the combustion of fossil fuels and mitigating climate change. Renewable energy sources can contribute to social and economic development, energy access, a secure and sustainable energy supply, and a reduction in the harmful effects of energy provision on the environment and human health if appropriately implemented [7]. Integrating IoT technology into a solar-powered automated roof clothesline suspension system enables energy optimization and resource efficiency, thereby contributing to the fight against global warming by reducing reliance on nonrenewable energy sources and promoting sustainable practices. Understanding the gravity of the global warming problem and the significance of renewable energy sources sets the groundwork for the project's applicability and potential positive impact in addressing this urgent global issue.

2.3 Internet of Things (IoT)

The Internet, a powerful tool in globalization, has enabled humans to communicate, share, and gain access to knowledge on a worldwide scale, regardless of distance. The Internet connects computer systems with various capabilities, such as desktops, laptops, and cell phones. However, going beyond the obvious. The Internet of Things connects gadgets and items to the Internet, each other, and computer systems. The Internet of Things (IoT) is a growing paradigm that uses Internet technology to enable communication and data collecting between electronic devices, objects, and sensors to improve the quality of life [8].

2.4 Smart Roof Clothesline System

An innovative roof clothesline system is a roofing system that can open or close the roof when rain occurs. The roof can be monitored and controlled by the user using a smartphone.

This system adopts the smart home concept, where implementing this system requires some hardware and software. Performance analysis is necessary to know the quality of the system that has been implemented [9].

2.5 Solar Energy

Solar energy has the most potential as a natural-renewable energy source for a green future; it has a lower environmental impact than conventional energy sources [10]. Solar energy is commercially exploited to provide benefits in the form of various products and capabilities applying a range of technologies. It can also be stored or transformed into a range of clean fuels and contributes energy to manufacture different energy-intensive products [11].

2.6 Smart Home

A smart home system is an application system that integrates technology and services dedicated to the home environment with specific functions designed to provide the inhabitants with comfort, convenience, energy savings, and security. Smart home systems typically consist of control devices, monitoring, and automation of some devices or home appliances that can be accessed through websites using laptops and smartphones. The intelligent home system consists of several supporting components that interact with each other. A house is a smart home with an internal network, intelligent control, and home automation—various innovative home system applications with multiple features as future home concepts. The created applications are distinguished by each function and purpose [9].

2.7 Previous Related Project

To better understand this project, I dug deeper into my prior study on projects with a similar concentration on using the Internet of Things (IoT). This information will be extremely useful in the project's execution and completion. As a result, this section gives background information on a comparable endeavor that addresses similar laundry-related issues.

2.7.1 Android-based Prototype of Automated Cloth Hanger Using Arduino

Sanji Muhammad Sidik, Hermawaty proposed this project to tackle the problem of managing clotheslines and drying clothes when the weather changes. Their main goal was to create a prototype model of an automatic clothesline using an Android-based Arduino. The essential advantage of this project is that the automated cloth hanger can effectively handle the task, making it easier for someone busy with other work and unable to tend to the clothesline simultaneously [12].

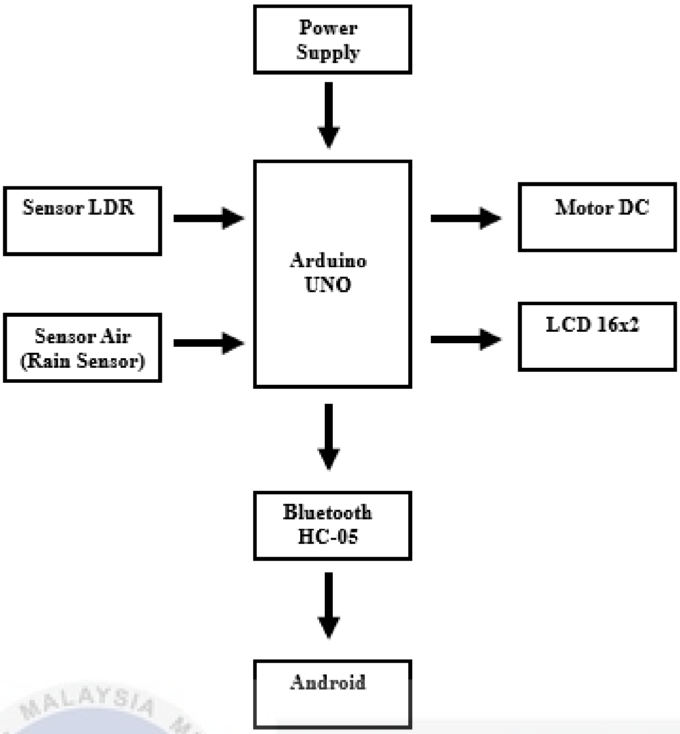


Figure 2.1 Block Diagram of Android-based Prototype of Automated Cloth Hanger

Figure 2.1 shows that the author only used two sensors, a Light Dependent Resistor (LDR) and a Rain Sensor, connected to the Arduino board. Both sensors would detect the weather and transmit the information to an Arduino. LCD 16x2 is used to display the weather, whether bright or dark, while DC Motor is used to pull back or extend the clothesline. If the sensors malfunction, users can control the system via an Android device connected to the Bluetooth HC-05 module.

2.7.2 Design of Laundry Box as Supporting Smart Laundry System Based on Internet of Things

According to Muhammad Rizki, Surya Michrandi Nasution, and Anggunmeka Luhur Prasasti [13], this project introduces the concept of a laundry box designed to assist individuals who cannot find time to go to the laundry. The laundry box allows stores for clothes to pile up and become mouldy.

The laundry box used multiple sensors, including a colour, weight, and humidity sensor. The colour sensor detects the colour of the clothes inside the laundry box, providing an output of 1 for coloured clothes and 0 for white garments. This information assists in organizing and sorting the laundry effectively. The humidity sensors measure the humidity level of the clothes within the laundry box, ensuring that the clothes remain free from mould caused by excessive moisture. The weight sensor precisely calculates the amount of laundry in the box by weighing the items in grams. Antares receives all sensor data in real-time, enabling effective administration and monitoring of the washing box. The laundry box notifies the laundry service when the laundry is prepared for pickup and instructs them to pick up the laundry from the address provided.

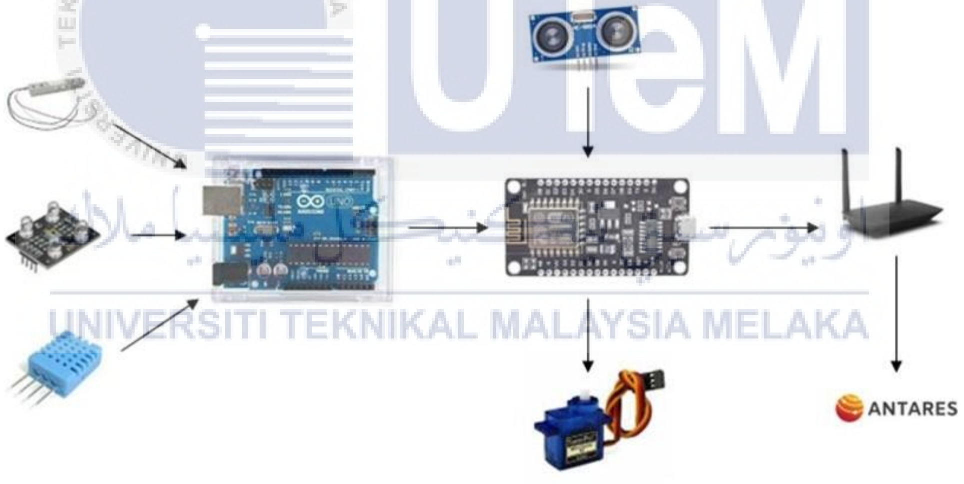


Figure 2.2 Block Diagram of Smart Laundry System

Figure 2.2 illustrates the components of the intelligent laundry system, which consists of four devices, each with its specific function. These devices include a weight sensor for calculating the weight of clothes, a colour sensor for determining clothing colour, a humidity sensor for measuring clothing moisture, and an ultrasonic sensor for measuring distance.

Arduino will control each sensor's operation to process the data generated by these sensors. The processed data will then be wirelessly transmitted through the node using the internet network. The data sent to the Antares platform will include humidity data in percentage (%), the accumulated weight data in grams (g), and the colour data represented by 1 for coloured clothes and 0 for colourless (white) clothes.

2.7.3 Automatic Clothing Drying Using Rain Sensors and LDR Sensors Based on Arduino UNO

The author of this project, Athaya Atsiq, Andryan Gunawan, and Amin Alqudri Dwi Nugraha [14], explains that during the rainy season, most individuals feel anxious while drying their clothing. This anxiety will increase when garments are dried outside the home and the home is absent. The author developed the concept of creating an automatic device clothesline. The device incorporates an Arduino Microcontroller. Rain- and light-dependent resistor sensors are connected to the Uno. This instrument detects ambient weather using a rain sensor and an LDR sensor. When the sensor does not see the light, the tool will interpret that it will rain, causing it to attract clotheslines in a protected area. When the sensor detects sunlight, the tool will determine the warm surrounding climate and move the clothesline to an exposed area. While the rain sensor detects raindrops, it is raining.

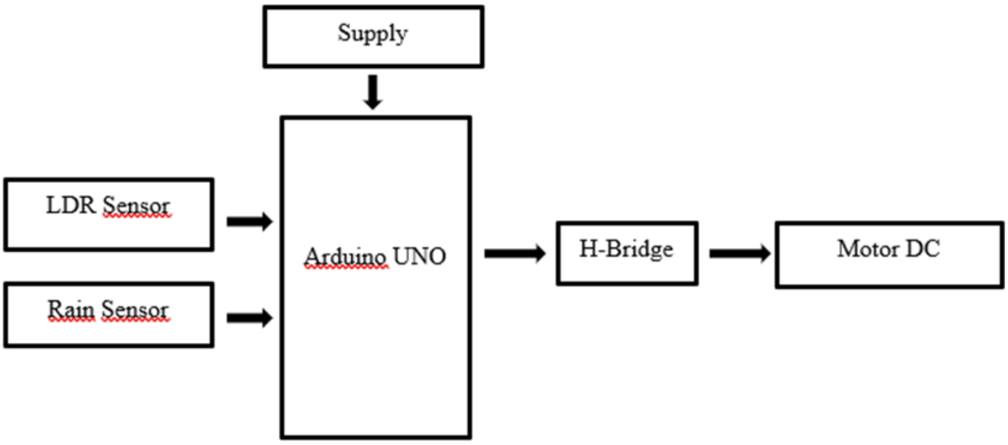


Figure 2.3 Block Diagram of Automatic Clothing Drying

Figure 2.3 demonstrates how the concept employs rain and light sensors as input to find both light and water. When the light sensor senses light, it will extend the clothesline. If the rain sensor detects water, it will move the clothesline inside. To regulate the motor's spin using an H-Bridge circuit. Ports ~12 and ~13 are connected to the H-Bridge circuit. Therefore, the Arduino program uses the C language to turn the motor. In this manner, Arduino can control this circuit.

2.7.4 Intelligent Drying Rack System based on Internet of Things

According to Xiao Xing, Chong Zhang, Jieming Gu, Yixin Zhang, Xinrun Lv, and Zihan Zhuo [15], it was aiming at the inconvenience of the traditional outdoor drying racks in the current society that the collection of clothes due to weather changes is inconvenient. The authors' concept is an intelligent ring rack that can be operated manually and remotely via a touch screen, associated hardware circuits, and a mobile phone application, which can control the extension and recycling of a clothes drying rod, as well as the automatic drying and storage of clothes. It enhances the intellectual level of the drying rack and is easy to use. The issue where the drying rack cannot dry the wet garments and must be manually stored is resolved.

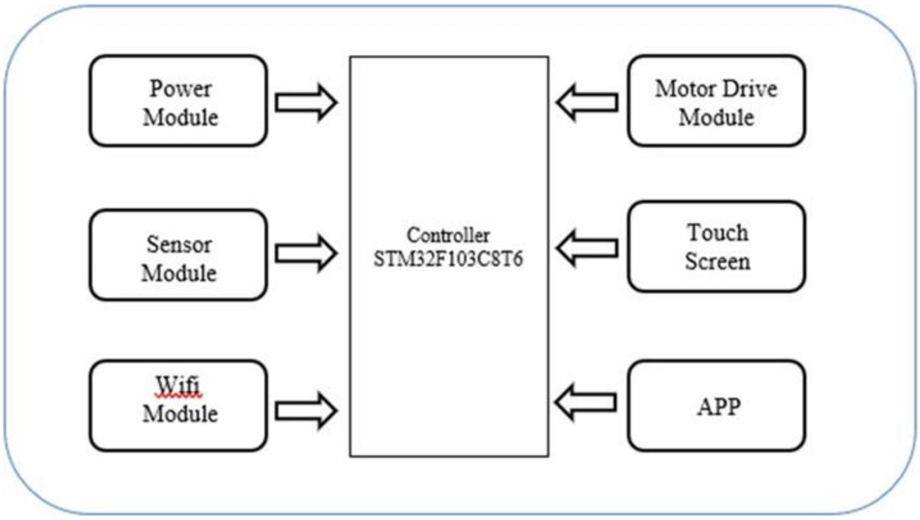


Figure 2.4 Transmission Diagram of Smart Drying Rack

Figure 2.4 demonstrates that the system selects the STM32F103C8T6 Microcontroller as the main control chip to control the electrical component, completing the hardware interaction with the OneNET cloud platform, the DHT11 temperature and humidity sensor achieving the intelligent perception of the clothes drying environment, the A4955 stepping motor achieving the power supply of the drying rack, and the DM542 limit switch completing the power supply of the drying rack. The sensor achieves the drying rack's limit protection. The touch screen lets the operator manually intelligently maintain the rack's terminal. The environment and clothing status data obtained by the sensor monitoring are transmitted to the single-chip microcomputer for processing and evaluation, combined with the Internet of Things to manage the data. Then, the intelligent drying rack is commanded to execute.

2.7.5 Smart Clothesline System Based on Internet of Things (IoT)

According to Zakiah Mohd Yusoff, Zuraida Muhammad, Amar Faiz Zainal Abidin, KA Nur Dalila, Noor Fadzilah Razali, Masmaria Abdul Majid, and KK.Hasan, household chores or extra work hours prevent one from managing clothing [16]. The authors' primary goal for this project was to create an intelligent clothesline that prevents clothing from being drenched in the rain. For this experiment, a rain sensor is used to detect the presence of water. The smart textile line will contract and expand when the rain sensor detects precipitation. The ambient air was measured using capacitive humidity and temperature sensors. It modifies the capacitance to deliver the digital signal to the data port.

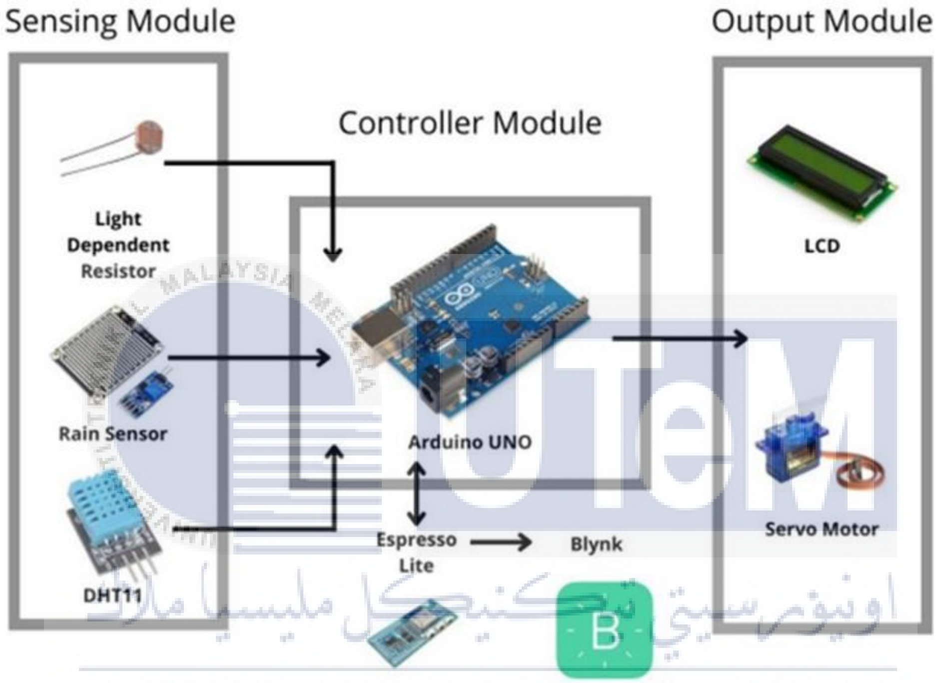


Figure 2.5 Block Diagram of Smart Clothesline System

Figure 2.5 demonstrates that this project also employs Espresso Lite to transmit notifications to the user via the Blynk application. All the sensors, including the Light Dependent Resistor (LDR), rain sensor, and temperature and humidity sensor, will be inputs and provide data to the Arduino Uno Microcontroller. Then, Arduino Uno will compute all the possibilities and determine whether to compress or expand the smart clothesline; this information will be sent to the user's mobile phone via the Blynk application.

2.8 Similar Project

Based on table 2.1 shows the comparison of the previous project, highlighting the references, features, advantages, and disadvantages.

Table 2.1 Comparison Table of Previous Project

No	Reference	Features	Advantage(s)	Disadvantage(s)
1	Android-based Prototype of Automated Cloth Hanger Using Arduino [12].	The Bluetooth HC-05 module-connected smartphone canmanually control an automatic clothesline.	Straightforward implementation, making it simple to install and employ.	Dependence on an energy source that cannot be sustained in long-term energy consumption.
2	Design of Laundry Box as Supporting Smart Laundry System Based on Internet of Things [13].	The NodeMCU is employed to gather data from all sensors and transmit it directly to the cloud in Real-time.	Incorporates a load cell capable of measuring the weight of clothes in real-time.	Higher costs are incurred due to using multiple sensors forits operation.
3	Automatic Clothing DryingUsing Rain Sensors and LDR Sensors Based on Arduino [14].	The clothesline automatically extends when it detects light and retracts when it detects water.	Timesaving because the system automatically retracts the clothes to a protected area.	Not suitable for every household.

4	Intelligent Drying Rack System based on Internet of Things [15].	The innovative drying rack can be operated manually and remotely through a mobile phone APP.	Can be utilized in varioussettings.	Costly to implement.
5	Smart Cloth line System Based on Internet of Thing (IoT) [16].	The mechanical components of the fabric line contract and expand in response to rain, returning to their expanded state when the rain ceases. Additionally, the system automatically sends anotification to the user's phone when it rains.	1. Easy to implement in every household. 2. Low-Cost.	The system has the limitation of being able to send notificationsonly without the capability to control the system remotely

2.9 Summary

According to studies undertaken for a prior project, several methods exist to protect garments against rain. The knowledge gained from this research can significantly contribute to achieving the primary goals at each stage of the project's development. Several considerations must be made, including selecting suitable components, their associated costs, and deployment strategies. It is essential to recognize that every undertaking has its advantages and disadvantages. However, a project must be pursued and implemented if it can benefit society.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This project section describes the approach to designing, developing, and evaluating a microcontroller-based IoT-based solar-powered automated roof clothesline suspension. It includes hardware and software selection, system design, prototyping, and testing procedures, among other key implementation steps. It is also essential for gaining a comprehensive understanding of the project flowchart. By adhering to this methodology, the project intends to ensure the successful implementation of the automated clothesline suspension following the best practices and industry standards.

3.2 Project Flowchart

Creating a systematic and streamlined workflow chart is essential for determining and ensuring the success of a project. A carefully organized and adequately prepared plan is critical to the success of any endeavor. Following the completion of the planning phase, the next stage is to do extensive research. The project's implementation becomes more manageable by simplifying complex parts through thorough analysis, allowing for discovering and preventing potential issues. The project's design develops, and it is followed by flawless execution. After a project's completion, a complete analysis assesses its efficacy and success.

3.3 Project Implementation Flowchart

Figure 3.1 shows the planning process. Defining project objectives is the first step in establishing clear execution objectives. This project seeks to design and develop an energy-efficient and environmentally friendly automated clothesline system that utilizes solar energy as its primary energy source. A comprehensive analysis and review of numerous factors are conducted to achieve the established objective requirements. In addition, the project's scope is defined to set its boundaries and limitations, assuring a focused and well-defined approach to implementation. By explicitly defining the project's objectives and scope, the way to develop an innovative and sustainable clothesline system is clear.

Figure 3.1 Project Workflow

3.4 System Operation Flowchart

According to Figure 3.2, the system's first stage is connecting to Wi-Fi. Once the connection is established, the system generates sensor values and presents them on the user's dashboard. When the sensor detects rain, it sends input data to the Microcontroller. If the rainfall exceeds the threshold value, the clothesline will compress. The clothesline will expand if the water sensor detects more raindrops than the threshold value. Simultaneously, the device will continue to read the humidity and temperature values of the surroundings for user monitoring. A Microcontroller named Arduino Uno will be used to coordinate the system. This Microcontroller will process sensor information to determine if the system should be compressed or extended. The system will then alert the user via their mobile phone, the Blynk application.

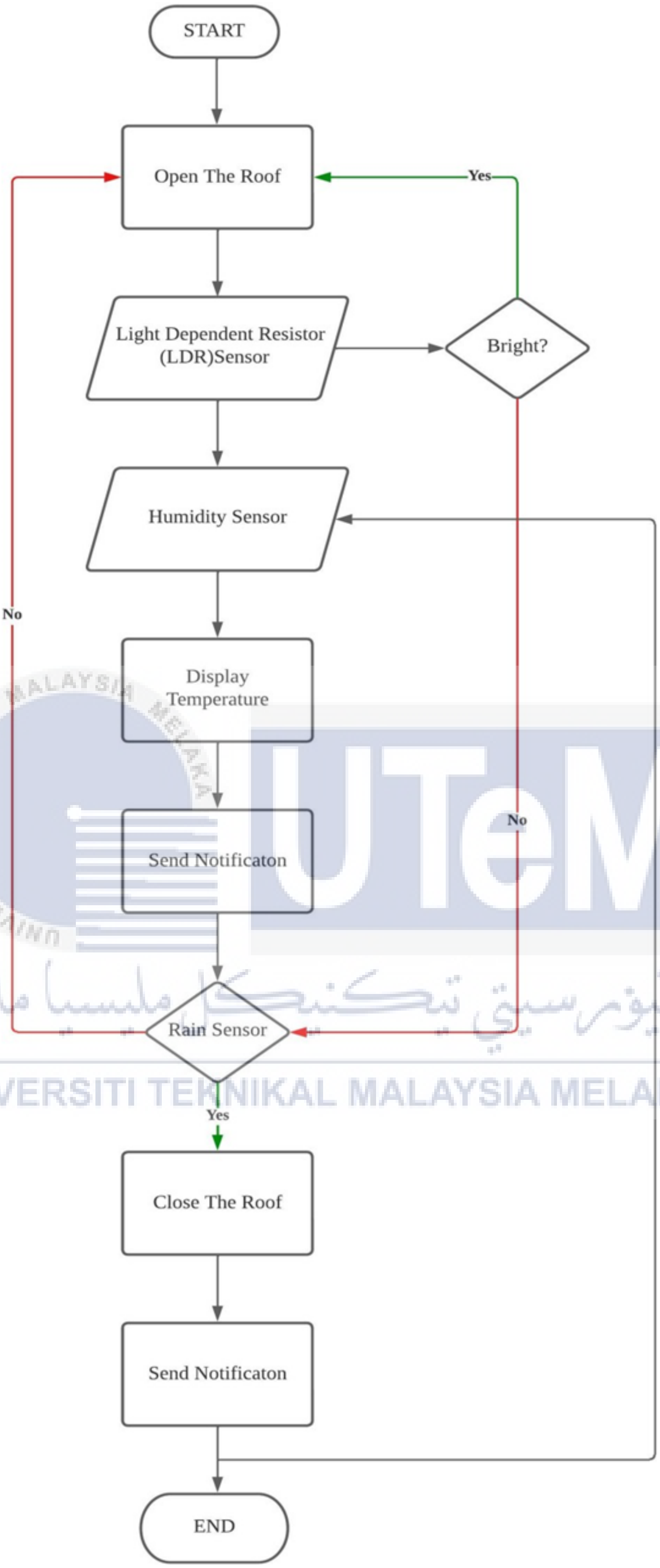


Figure 3.2 Flowchart of System Operation

3.5 Project Block Diagram

Figure 3.3 depicts the system's input and output components. The input components are a DHT22 sensor, an LDR sensor, and a rain sensor. The DHT22 sensor measures the surrounding area's temperature, humidity, and a specific brightness level. The LDR sensor modifies its resistance depending on the amount of precipitation detected.

The primary function of the rain sensor is to determine whether it is currently raining. It functions similarly to a variable resistor, decreasing resistance as water builds up on the board.

The output component of the system comprises servo motors with a 180-degree range of motion. The servo motors are connected to potentiometers whose resistance value changes in response to the movement of the motors. Once the motor shaft reaches the desired position, the potentiometer stops moving, signifying that the desired goal has been reached. The control unit, a Microcontroller NodeMCU ESP8266, evaluates the circumstance and determines whether the motion should be to the right or left.

The solar panels power the system's sensors, actuators, and control unit (NodeMCU ESP8266). Renewable energy makes the system self-sufficient and minimizes the system's dependency on traditional power sources.

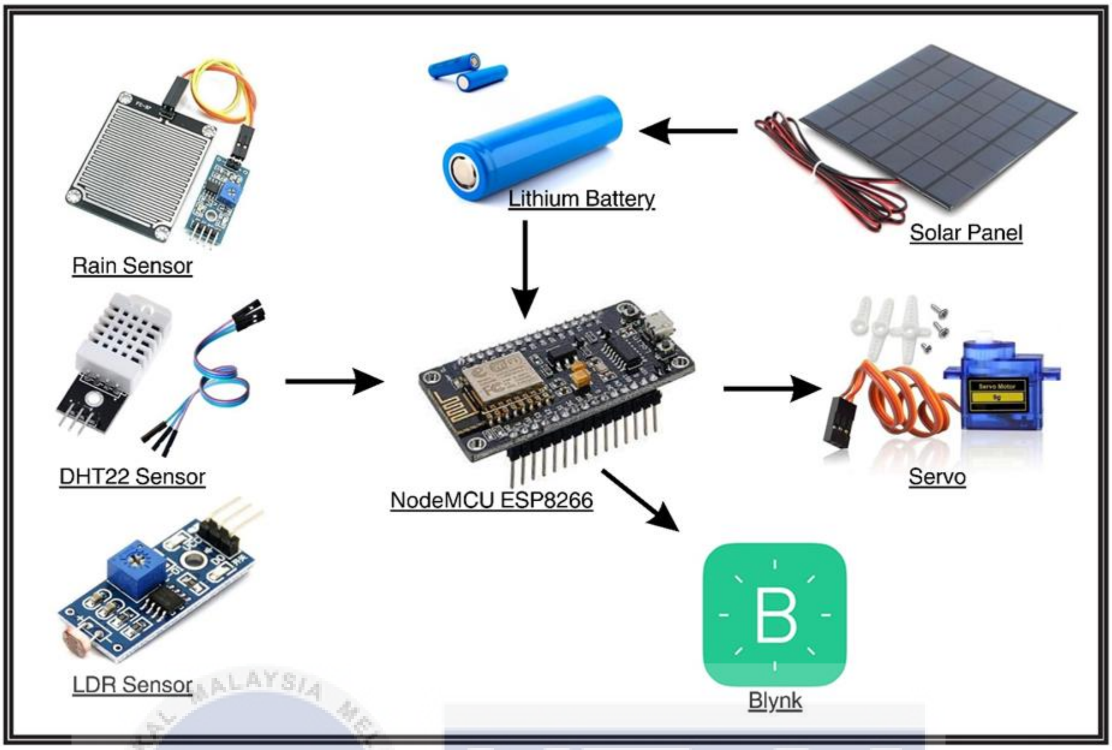


Figure 3.3 Block Diagram of The Project

3.6 Project Schematic Diagram

The wiring connections between the solar panel, battery, NodeMCU ESP8266, sensors, and servo motor are depicted in Figure 3.4. These connections are the system's essential electrical interconnections. The solar panel is connected to the battery, enabling the battery to charge and store solar energy. The battery powers NodeMCU ESP8266, sensors, and servo actuator. This wiring configuration guarantees a reliable power supply to all system components, allowing for streamlined operation and communication.

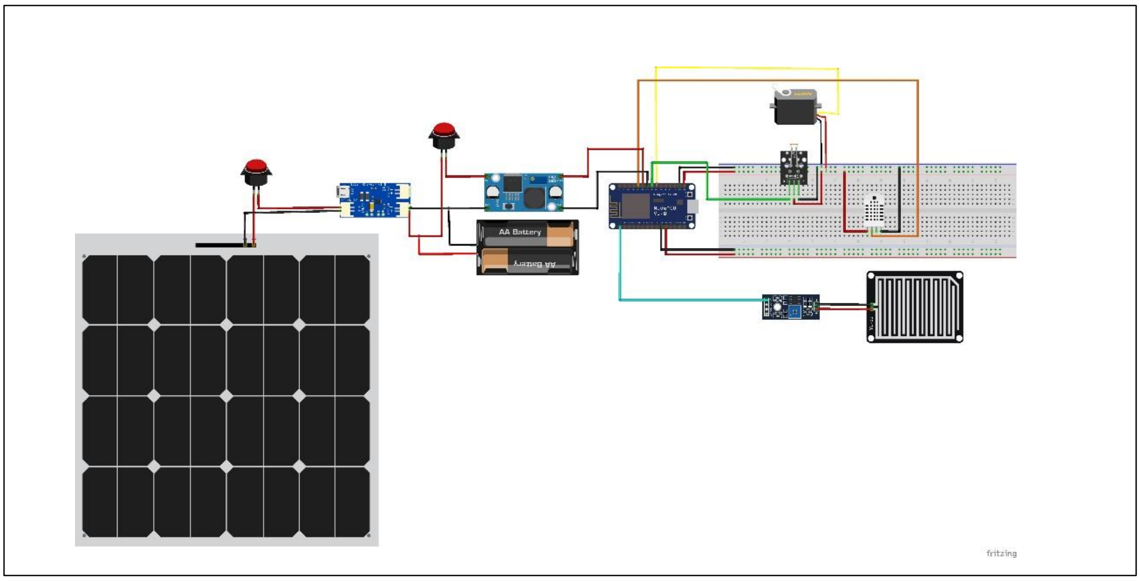


Figure 3.4 Schematic Diagram of the Project

3.7 Hardware Specifications

3.7.1 Rechargeable Li-Ion Battery for Solar Panel

Lithium-ion batteries power the lives of millions of people each day. From laptops and cell phones to hybrids and electric cars, this technology is growing in popularity due to its lightweight, high energy density, and ability to recharge [17]. The project relies heavily on the rechargeable Li-Ion battery, an energy storage solution for the solar panel system. The system described allows for the effective utilization of solar energy by storing any surplus power produced by the solar panel during periods of intense sunlight. During periods of low sunlight or at night, the battery stores energy and offers a steady power supply to the system. The system is designed to maintain uninterrupted functionality of the sensors, motors, control unit, and ESP8266 Wi-Fi module, even without solar power. The project relies on the rechargeable Li-Ion battery to improve its autonomy, reliability, and ability to function independently. This battery is a crucial component in utilizing renewable energy for the project. The Li-Ion Battery is visualized in Figure 3.5.

Figure 3.5 Li-Ion Battery

3.7.2 TP4056 Lithium Battery Charger Module

The TP4056 chip is a single-cell lithium-ion battery charger that protects the cell from over and under-charging. It includes two status outputs that indicate charging in process and charging complete, as well as a programmable charge current of up to 1A [18]. The TP4056 Lithium Battery Charger Module is an essential component in the project as it is responsible for regulating the charging process of the lithium battery through the utilization of the solar panel's power. It highlights the importance of ensuring the efficient and safe charging of the battery. The module incorporates overcharge prevention, over-discharge protection, and short-circuit protection to assure the battery's safety. The device is powered by a solar panel, its primary energy source. During the day, the solar panel charges the device's lithium battery. By utilizing renewable energy from the solar panel, the system ensures a reliable and sustainable power source, allowing it to run autonomously. The charger module is visualized in Figure 3.6.

Figure 3.6 Charger Module

3.7.3 Solar Panel

A solar panel, also known as a photovoltaic panel, transforms sunlight into electricity via the photovoltaic effect. It comprises numerous solar cells made of semiconductor materials, usually silicon, that generate an electric current when exposed to sunlight. The photons in sunlight stimulate the electrons in the semiconductor, causing an electric current to flow. Solar panels are joined to form modules, and many modules can be linked to make an array. Direct current (DC) power can be converted to alternating current (AC) using an inverter. Solar panels are a renewable and sustainable energy source, producing power without emitting pollutants and relying on the sun's abundant energy. In contrast to the 1950s and 1960s, when solar panels were just 10% efficient, today's solar panels can convert about 20% of the energy [19]. The solar panel is visualized in Figure 3.7.

Figure 3.7 Solar Panel

3.7.4 Stepper Down

The SMPS module described is a Buck Converter Switching Power Module with an adjustable output voltage range of 1.25V to 35VDC and a wide input voltage range of 3.2V to 40VDC. This step-down converter requires the input voltage (Vin) to be more significant than the output voltage (Vout) plus 1.5V. It features an onboard multiturn potentiometer for precise output voltage adjustment, with clockwise rotation increasing the output voltage and counterclockwise rotation decreasing it. The module has a maximum output current of 3A peak and 2A continuous, with an output voltage ripple of less than 30 and a switching frequency of 65KHz. It is rated at a maximum efficiency of 92%, a power rating of 10W, and can operate within a temperature range of -45ºC to +85ºC. The module's dimensions are 43mm x 21mm x 14mm. The stepper down is visualized in Figure 3.8.

Figure 3.8 LM2596 3A Step-Down Converter

3.7.5 NodeMCU ESP8266

The NodeMCU ESP8266 development board has the ESP-12E module, featuring a 32-bit LX106 RISC microprocessor with RTOS support and adjustable clock frequency. It has 128 KB RAM and 4MB Flash memory, making it ideal for IoT projects. The board can be powered via a Micro USB jack and VIN pin, supporting UART, SPI, and I2C interfaces [20]. The NodeMCU ESP8266 is visualized in Figure 3.9

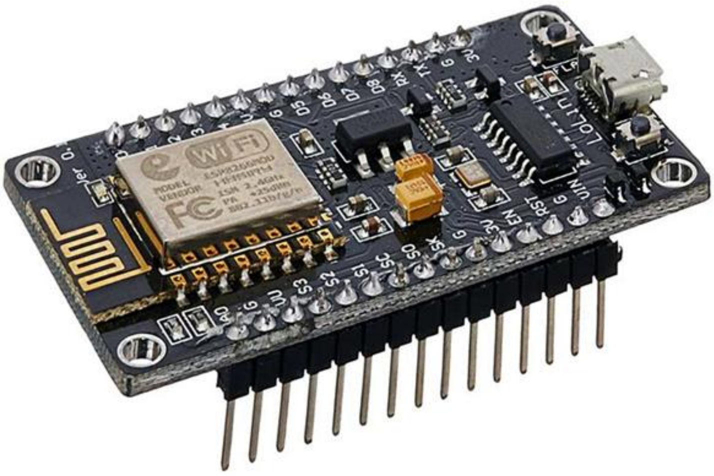


Figure 3.9 NodeMCU ESP8266 Board

3.7.6 Rain Sensor

A rain sensor is a switching device to detect rainfall [21]. It functions similarly to a switch, and the operating concept of this sensor is that whenever there is rain, the switch is generally closed. The sensor is typically composed of a moisture-sensitive plate or surface capable of detecting water droplets or changes in conductivity produced by rain. When rain is detected, the sensor sends a signal to the connected system, which causes appropriate actions, such as turning off sprinklers, activating windscreen wipers, or changing home automation settings to account for the weather. Rain sensors are designed to save water, improve safety, and promote energy efficiency by automatically responding to changing weather conditions. The rain sensor is visualized in Figure 3.10.

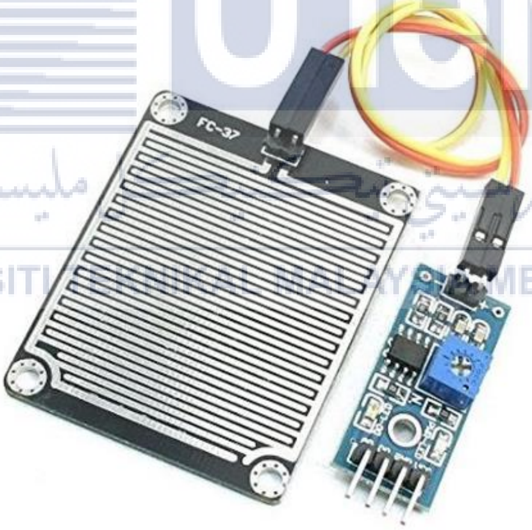


Figure 3.10 Rain Sensor

Table 3.1 shows the pin configuration of the rain sensor. In this configuration, the VCC pin connects to the 5V supply voltage, the GND pin to the ground, the D0 pin to a digital pin to produce a digital output, and the A0 pin to an analog pin to obtain an analog output.

Table 3.1 Pin Configuration of Rain Sensor

No.	**Name**	**Function**
1	VCC	Connect supply voltage of 5V
2	GND	Connect to Ground
3	D0	Digital pin to get digital output
4	A0	Analog pin to get analog output

3.7.7 DHT22 Humidity and Temperature Sensor

Figure 3.11 shows the DHT22 sensor, also known as AM2302, is a digital temperature and humidity sensor that offers precise readings in various conditions. It measures the temperature with a thermistor and a capacitive humidity sensor. The sensor connects with a Microcontroller through a single-wire digital interface, providing temperature measurements with an accuracy of 0.5°C and humidity readings with an accuracy of 2-5%. It has a wide voltage range and low power consumption, making it suited for various applications such as weather monitoring, HVAC systems, home automation, and indoor climate management. The DHT22 sensor is simple and provides a cost-effective temperature and humidity measurement solution.

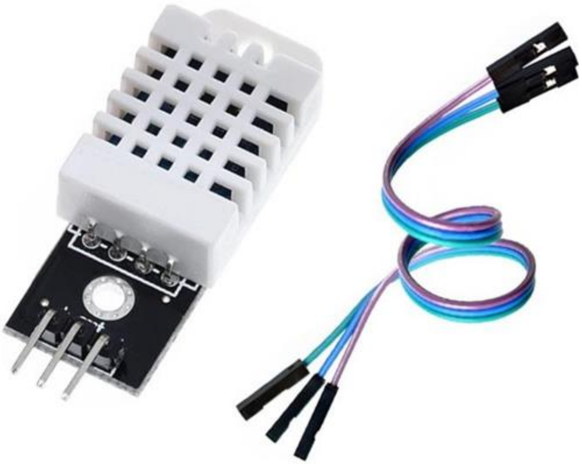


Figure 3.11 DHT22 Sensor

Table 3.2 lists the DHT22's technical specifications. It contains details regarding the operating voltage, temperature, and humidity range. Specifically, the operating voltage ranges between 3.3V and 5.5V. The temperature range is accurate to within 0.5°C from - 40°C to 80°C. In addition, the humidity range extends from 0%RH to 99.9%RH with a precision of 2%RH at 25°C.

Table 3.2 Technical Specification of DHT22

Model	DHT22
Operating Voltage	3.3V ~ 5.5 V
Temperature Range	-40°C ~ 80°C / ±0.5℃
Humidity Range	0%RH ~ 99.9%RH / ±2%RH (25°C)

Table 3.3 lists the hardware connections between the DHT22 Sensor and the Arduino UNO Board. In this configuration, the VCC pin must be connected to the 5V supply voltage, the GND pin must be connected to the ground, and the DOUT pin must be connected to a digital pin to obtain the digital output.

Table 3.3 Hardware Connection

No.	Sensor	Arduino	Description
1	VCC	5V	Power input
2	GND	GND	Power ground
3	DOUT	D2	Digital data output

3.7.8 Light Dependent Resistor (LDR) Sensor

Based on Figure 3.12, Photoresistors, also known as light-dependent resistors (LDR), are light-sensitive devices commonly used to detect the presence or absence of light and measure the intensity of light [22]. The analog output and digital output pins indicated on the board as A0 and D0 have a connection. The resistance of the Light Dependent Resistor (LDR) reduces when there is light. A higher light intensity translates to a lower LDR resistance. The sensor features a potentiometer knob for adjusting the sensitivity of the LDR to light. The four input pins on the proposed sensor are VCC, GND, digital pin D0, and analog pin A0. When immediate replies are required, the sensor's signal is transmitted to the Microcontroller via digital pin D0.

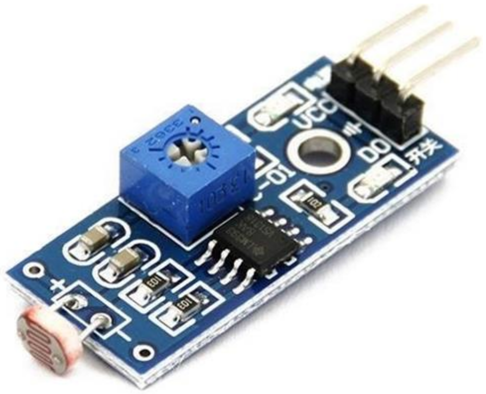


Figure 3.12 Light-Dependent Resistor Sensor

The terminal configuration of the Light Dependent Resistor is illustrated in Table 3.4. The VCC pin should be connected to the 5V supply voltage, the GND pin should be connected to the ground, the D0 pin should be connected to a digital pin to obtain a digital output, and the A0 pin should be connected to an analog pin to get an analog output in this configuration.

Table 3.4 Pin Configuration of LDR Sensor

Name	**Function**
VCC	Connects supply voltage of 5V
GND	Connects to ground
D0	Digital pin to get digital output
A0	Analog pin to get analog output

3.7.9 Servo Motor MG996R

Figure 3.13 depicts the MG996R servo motor. High-torque, metal-gear servo motors like the MG996R are made for robots, RC cars, and other applications that need robust and accurate motion control. Because of its muscular build, quick speed, and broad operating voltage range, it is a well-liked option for professionals and enthusiasts. The MG996R servo is a robust and dependable device that can handle various demanding jobs. Applications for the MG996R servo motor include robotics, remote-controlled boats, model airplanes, RC cars, and other projects requiring robust and accurate motion control. It is also used in camera gimbals, industrial automation, and other mechanical systems that position objects accurately and with excellent torque [23].

Figure 3.13 Servo MG996R

The servo motor pin-out is depicted in Table 3.5, where the orange wire is connected to the PWM to drive the motor. The red wire connects the 4.8V (5V) +VCC power supply to this MG996R servo terminal. The brown wire is subsequently connected to the earth.

Table 3.5 Servo Motor Pin-Out

Wire Color	**Function**
Orange	A PWM signal is sent through this wire to drive the motor.
Red	Powers the motor typically +5V is used.
Brown	Connects to Ground

The servo motor's technical specifications are detailed in Table 3.6. MG996R servo motors usually run at +5V of voltage. It draws 2.5 A of current at 6 V. At 4.8V, its stall torque is 9.4 kg/cm, and at 6V, it can reach a maximum of 11 kg/cm. The motor rotates at a speed of 0.17 seconds for every 60 degrees. It turns from 0 to 180 degrees using metal gears. The weight of the motor is 55 grams. The package also contains screws for installation and gear horns.

Table 3.6 Technical Specification of Servo Motor

Required Power	+5V
Operating Speed	60 degrees in 0.17 sec
Weight	55 gm
Current	2.5A
Rotation	0°-180°

3.8 Software Specifications

3.8.1 Arduino IDE

Figure 3.14 depicts the Arduino IDE (Integrated Development Environment), a software platform for programming and developing applications for Arduino boards. It provides a user-friendly interface for creating, building, and uploading code to the Arduino Microcontroller. The IDE supports the Arduino programming language, a simplified version of C/C++. Its built-in functions and libraries simplify hardware interfacing and facilitate rapid prototyping. Additionally, the IDE includes a serial monitor for monitoring and communicating with the Arduino board.

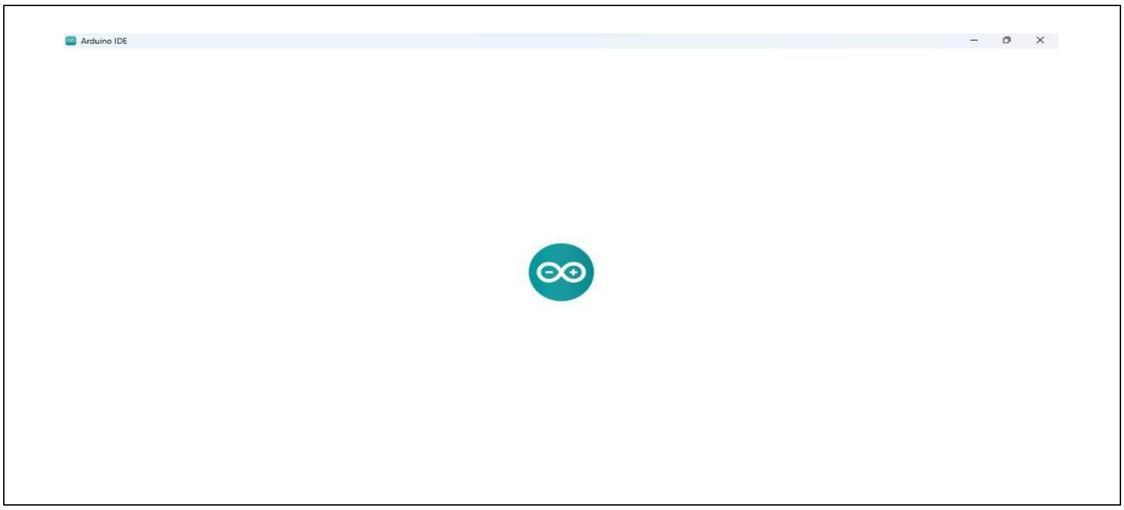


Figure 3.14 Arduino UNO Start-Up

3.8.2 Blynk Application

Figure 3.15 demonstrates Blynk, a mobile software enabling users to design custom user interfaces and manage the Internet of Things (IoT) devices using smartphones or tablets [24]. Users can quickly connect their IoT devices, such as an Arduino or Raspberry Pi. to the Blynk App through Bluetooth or Wi-Fi and control different aspects of their projects. The software offers a user-friendly interface where widgets may be added, modified, and connected to operations. It allows users to monitor sensor data, toggle switches, display information, and send commands to their IoT devices. Figure 3.16 shows the Blynk application interface.

Figure 3.15 Blynk Application Icon

Figure 3.16 Blynk Interface Example

3.9 Hardware Development

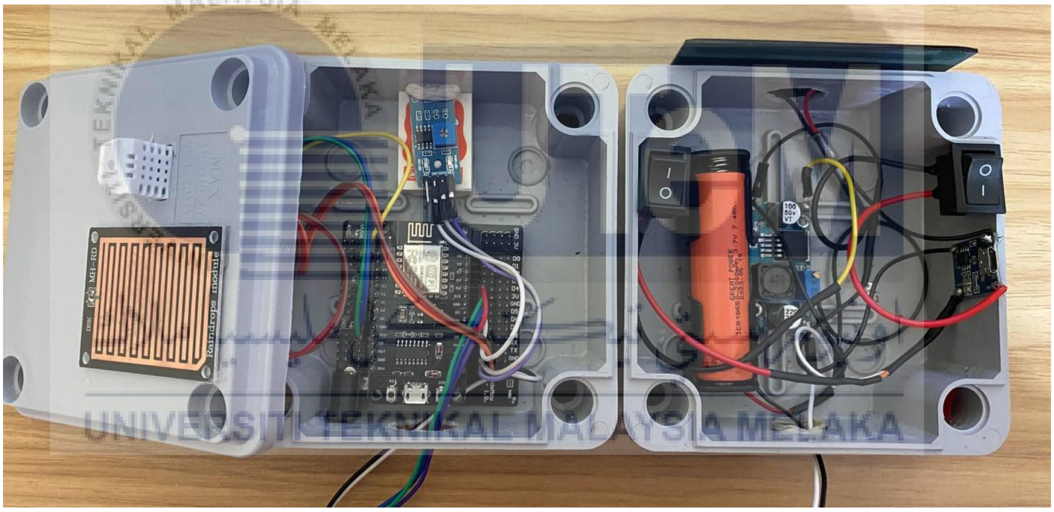


Figure 3.17 Hardware Configuration

The project's hardware configuration is shown in Figure 3.17, organized inside a junction box. The rain plate, solar panel, and DHT22 sensor are positioned outside the box and are responsible for receiving external inputs and sending out related outputs. In particular, the solar panel fulfils the dual functions of producing power and recharging the battery to enable continuous operation.

3.10 Software Development

The project dashboard on the mobile application, which uses the Blynk platform, is shown in Figure 3.18. Blynk is a specialized program that enables data storage and visualization, shows sensor data, and remotely controls devices. This project displays the values obtained from input sensors, allows users to manually operate the clothesline system by pressing a button, and alerts when it gets dark or rains outside. Blynk uses a device-specific authentication token IDE programming. Blynk receives sensor values instantaneously once linked to Wi-Fi and shows them on the application. Apart from the sensor values, the dashboard has a rain gauge widget, a light LED indicator, a temperature and humidity display LCD, and a button that allows users to control the servo to retrieve or extend the roof manually.

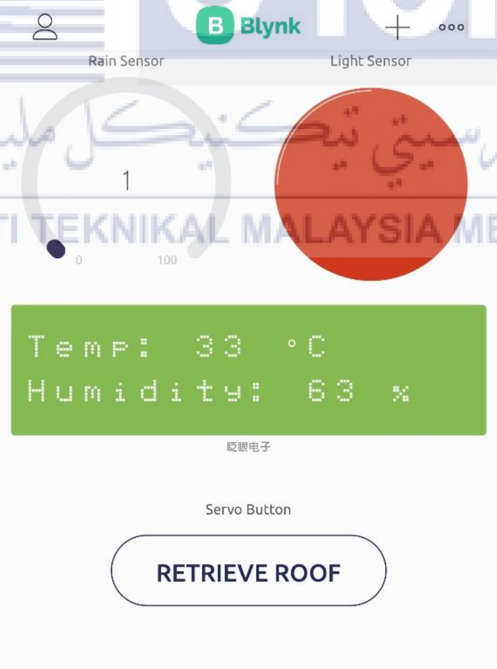
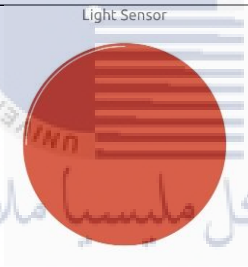
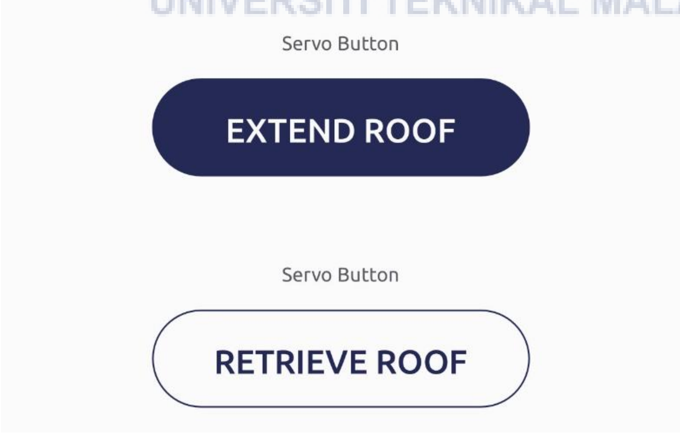


Figure 3.18 Blynk Interface

Table 3.7 Widget on Blynk

Widget	**Function**
 Rain Value	Display the rain value, detect if the raindrop is more or less the threshold value, and notify the user.
 Temperature and Humidity	Display temperature for the user to monitor. The unit for temperature is Celsius (°C), and the unit for humidity is Percent (%).
 Light	Changes in colour if sunlight is detected
 Servo Button	Users can manually press the button to retrieve or extend the clothesline.

3.11 Prototype Development

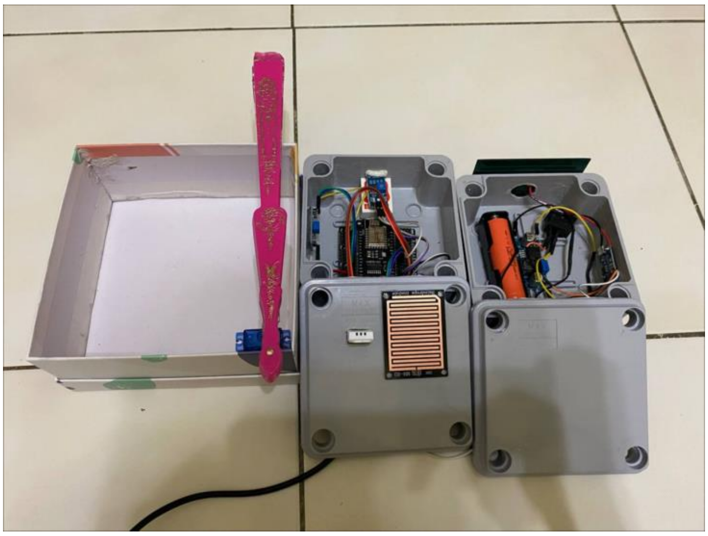


Figure 3.19 Draft Prototype Design

A box was used to represent the clothesline in the initial prototype shown in Figure 3.19, and a hand fan was added to symbolize the roof.

Figure 3.20 Final Prototype Design

A further improvement is made to the initial prototype shown in Figure3.20 using a 3D-print design for both body and roof.

3.12 Summary

This section details the methodology for designing, developing, and evaluating a Microcontroller-based IoT solar-powered automated roof clothesline suspension system. Key steps such as hardware and software selection, system design, prototyping, and testing procedures are outlined. The comprehensive project flowchart enhances understanding, emphasizing adherence to best practices and industry standards for successfully implementing the automated clothesline suspension.

CHAPTER 4

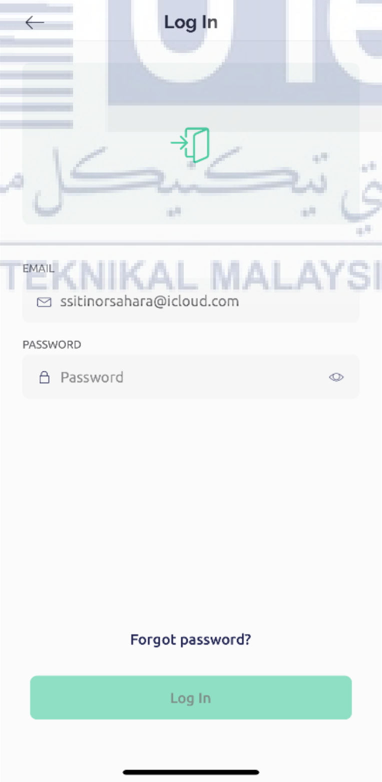
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results, analysis, and discussion on the 'Development of an IoT-Based Solar Powered Automated Roof Clothesline Suspension Using a Microcontroller' to evaluate its effectiveness.

4.2 Project Integration

4.2.1 Login to Blynk



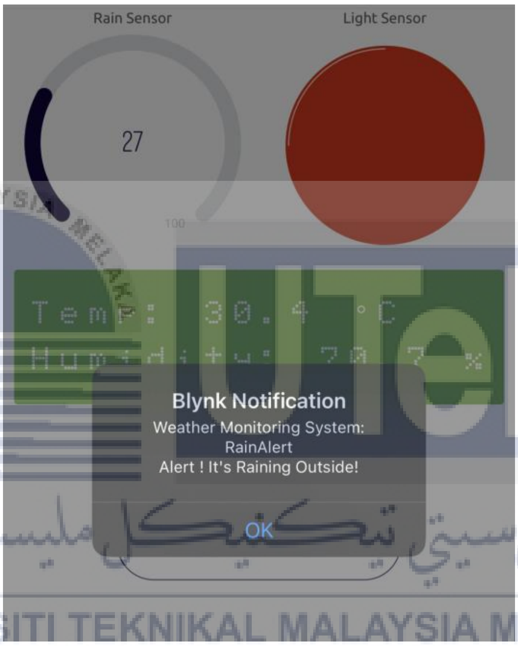
EMAIL
ssitinorsahara@icloud.com

PASSWORD
Password

Figure 4.1 Login Page on Blynk

To enhance security measures, users must log into their Blynk account by entering their email and password, as demonstrated in Figure 4.1. This login mechanism ensures a secure access point. Moreover, users can monitor their clothesline from various devices to stay connected even when using a different mobile phone.

4.2.2 Blynk Notification

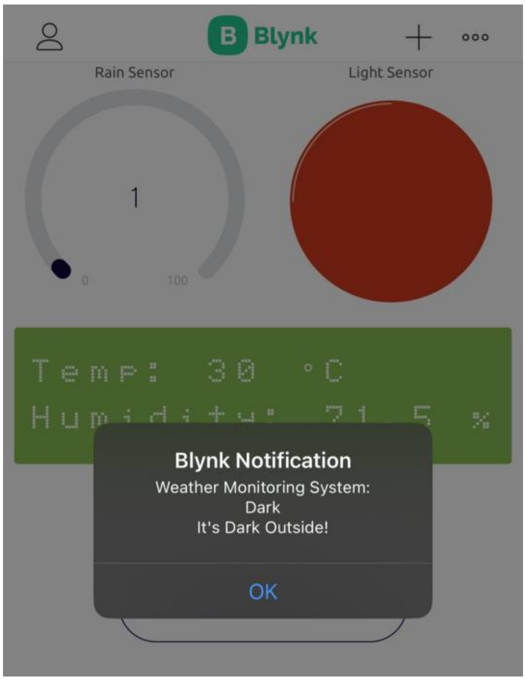


Temp: 30.4 °C
Humidity: 70.7 %

Blynk Notification
Weather Monitoring System:
RainAlert
Alert ! It's Raining Outside!

Figure 4.2 Notification when Rain is Detected

Figure 4.2 illustrates the notification system when the detected water level surpasses the predefined threshold value. In this scenario, the system triggers a notification to alert the user about the excessive water condition.



Temp: 30 °C
Humidity: 71 5 %

Blynk Notification
Weather Monitoring System:
Dark
It's Dark Outside!

Figure 4.3 Notification when Dark Environment is Detected

Figure 4.3 showcases the notification mechanism when the system identifies a dark environment. Like water detection, a notification is sent once when the system detects darkness. Importantly, there is no repetition of notifications. The system returns to its initial state after catching water or dark conditions, and subsequent notifications are sent only when these conditions are detected again, preventing unnecessary or repetitive alerts.

4.3 Data Analysis

This section will delve into the performance test conducted on the prototype and analyse the obtained results. Reliability, which gauges how consistently a method measures something, was a focal point of this assessment. The reliability of the system was assessed using the Test-retest method, providing valuable insights into the consistency of its measurements and functionality. Various data were systematically collected, and the subsequent results underwent thorough interpretation and analysis to offer a comprehensive evaluation of the system's performance.

4.3.1 Results of Performance and Functionality Test

4.3.1.1 The accuracy of temperature and humidity sensors is achieved by comparing the data value with forecast and measured data.

Table 4.1 Temperature and Humidity Test in Ayer Keroh, Melaka, at 1.00 p.m.

Day	Weather Component	Weather Forecast	Measured Data
1 (01/01/2024)	Temperature	31.00	30.70
	Humidity	81.00	79.20
2 (02/01/2024)	Temperature	32.00	31.80
	Humidity	70.00	69.30
3 (03/01/2024)	Temperature	31.00	30.60
	Humidity	68.00	67.80
4 (04/01/2024)	Temperature	30.00	29.80
	Humidity	71.00	70.00
5 (05/01/2024)	Temperature	30.00	30.80
	Humidity	77.00	76.00

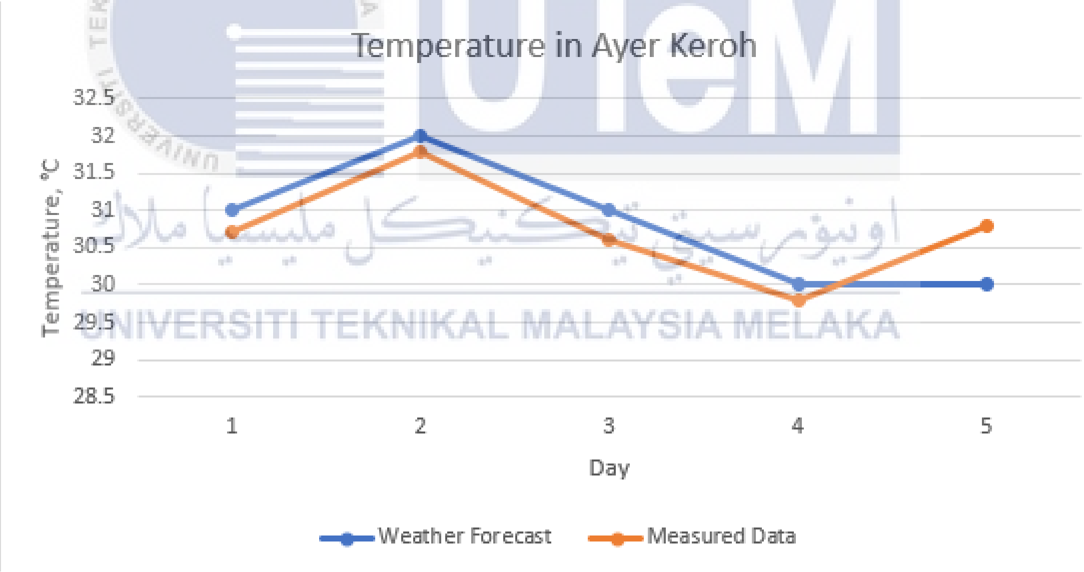


Figure 4.4 Graph Day against Temperature

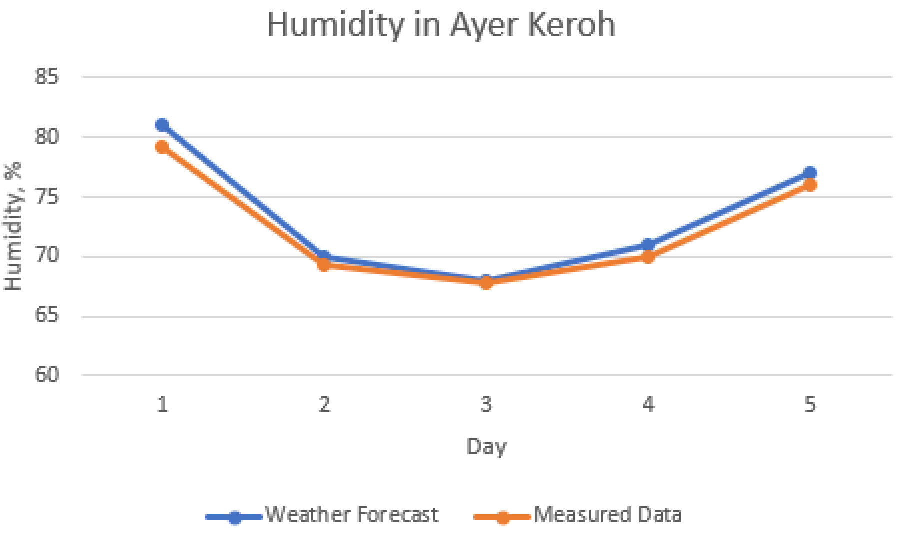


Figure 4.5 Graph Day against Humidity

Based on Table 4.1, it is apparent that there is a minimal discrepancy in the values, as the obtained data closely corresponds with the forecast for both temperature and humidity. The slight variance in values among the collected data implies that the sensor can be deemed accurate, as shown in Figure 4.4 and Figure 4.5.

4.3.1.2 Functionality Test and Results

Table 4.2 Functionality Test of the System

No.	Test Type	Main Purpose	Additional Knowledge Gain	Variables	Material Tested	Output Measurement
1	Rain Drop Test Results	To test how much raindrop is needed to activate the system	The system corresponds to the value of water and its threshold value.	Millilitre, ml	Rain Sensor Board	Activation of NodeMCU ESP8266 Board
2	Shield Extended Time Results	To know the average time required to cover up the clothes from rain.	-	Activation of the shield	Shield	Time, Second
3	Shield Retrieve Time Results	To know the average time, require retrieving back the shield.	-	Activation Shield	Shield	Time, seconds
4	Light Test Results	To test how much distance is needed to send the triggered notification.	The notification corresponds to the distance of the light	LED	Light Sensor module	Time, second
5	Blynk Connection Results	To know the success rate of the connection	Need to make sure Wi-Fi is available beforehand	Wi-Fi availability	Connection	Success rate

1. Rain Drop Test Results

Table 4.3 Rain Drop Test Results

Test Number	Millilitre, ml	Activation of the system (ON/OFF)
1	0	OFF
2	0.10	ON
3	0.15	ON
4	0.20	ON
5	0.25	ON
6	0.30	ON
7	0.35	ON
8	0.40	ON
9	0.45	ON
10	0.50	ON
Result	**System 100% Success**	

According to Table 4.3, the system's activation threshold was set at a minimum value of 0.1ml and above. When the system detects an amount exceeding 0.1ml, it triggers the roof extension to shield the clothes from getting wet. Conversely, if the detected quantity falls below 0.1ml, the system maintains its initial condition without activating the protective extension.

2. Shield Extended Time Results

Table 4.4 Shield Extended Time Results

Test Number	Times, Seconds(s)
1	5.50 s
2	5.59 s
3	5.54 s
4	5.54 s
5	5.60 s
6	5.53 s
7	5.58 s
8	5.60 s
9	5.54 s
10	5.50 s
Result (average, seconds)	**5.55 s**

Table 4.4 presents the duration, measured in seconds, for the roof to extend in response to the user's rain sensor activation or manual closure. The average time for the roof to fully develop is recorded at 5.55 seconds.

3. Shield Retrieves Time Results

Table 4.5 Shield Retrieves Time Results

Test Number	Time, Seconds (s)
1	5.67 s
2	5.67 s
3	5.53 s
4	5.73 s
5	5.78 s
6	5.80 s
7	5.63 s
8	5.70 s
9	5.75 s
10	5.65 s
Result (Average, seconds)	**5.69 s**

Table 4.5 presents the duration, measured in seconds, required for the complete retrieval of the roof. This retrieval occurs in response to either the absence of water detected at the rain sensor or manual initiation by the user. The average retrieval time is recorded at 5.69 seconds.

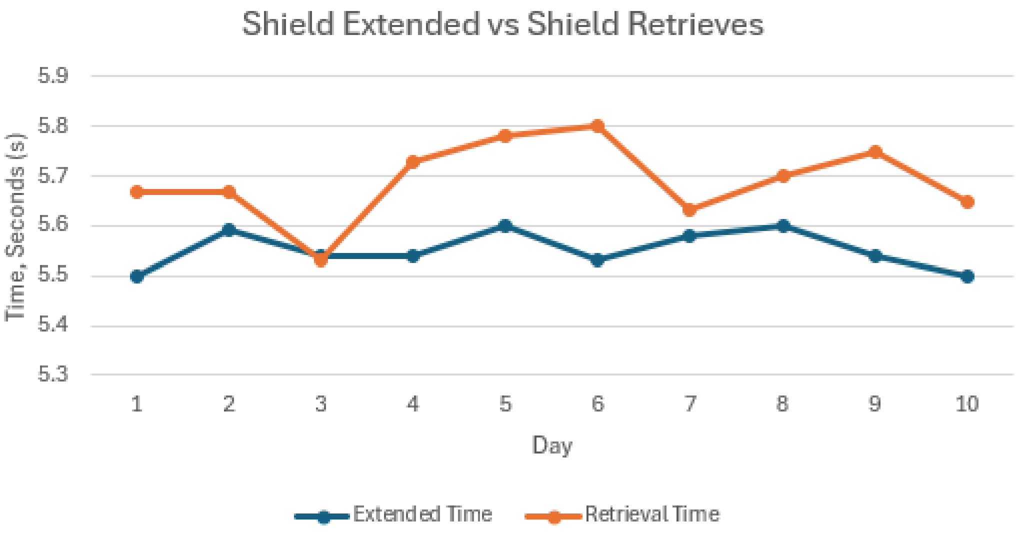


Figure 4.6 Shield Extended against Shield Retrieves

Examining the graph in Figure 4.6, the shield retrieval time is compared against the extended time of the shield. The retrieval process takes slightly longer to reach its full position when compared to the extension time. This delay can be attributed to the additional loads imposed on the roof during retrieval.

4. Light Test Results

Table 4.6 Light Test

Test Number	Distance(cm)	LED Indicator (ON/OFF)
1	0	ON
2	5	ON
3	10	ON
4	15	ON
5	20	OFF
6	25	OFF
7	30	OFF
8	35	OFF
9	40	OFF
10	45	OFF

To assess the light sensor during testing, use a flashlight and move it closer or farther away from the LDR sensor to achieve varied exposure levels. The distances were measured in centimetres (cm), as shown in Table 4.6, to ensure a diverse range of results.

5. Blynk Connection Test Results

Table 4.7 Blynk Connection Test Results

Test Number	**Connection (Success/Failure)**
1	Success
2	Success
3	Success
4	Success
5	Success
6	Success
7	Success
8	Success
9	Success
10	Success
Result	**System 100% Success**

Table 4.7 confirms the successful completion of all Blynk connection tests, indicating that the system is fully operational and ready for use.

4.3.2 Quantitative Survey

This section entails the analysis of results derived from an online survey involving 35 respondents, conducted as an integral part of the project. The survey is critical in understanding user perspectives and preferences related to the proposed system. By posing targeted questions regarding the weather in respondents' regions, their current methods for drying clothes, the utilization of laundry services, the presence of dryers in their houses, and instances of forgetting clothes on the clothesline, the survey aims to gather insightful data. Notably, the survey concludes with a key question probing respondents' willingness to purchase an intelligently automated system that uses renewable energy to protect clothes from getting wet. This comprehensive set of inquiries is pivotal for shaping the project, ensuring alignment with user needs, and ultimately enhancing the effectiveness and user acceptance of the IoT-based solar-powered automated roof clothesline suspension system. The survey findings will inform strategic decisions, address user concerns, and contribute to the project's overall success.

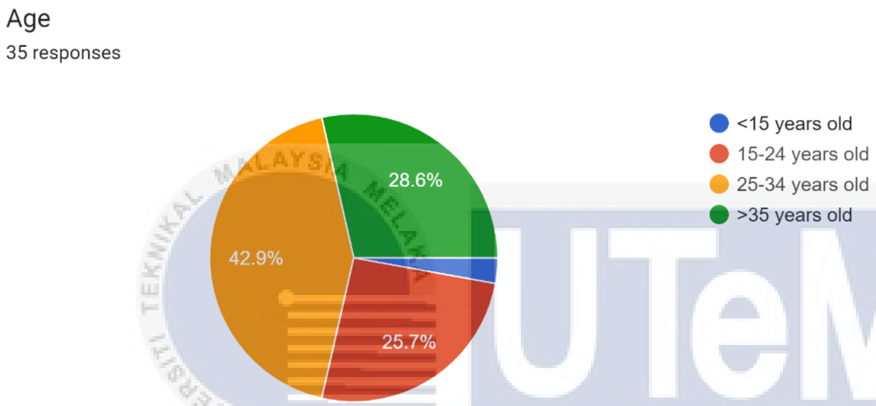


Figure 4.7 The Age of the Respondents

The graph depicts the age distribution of survey respondents, showcasing a diverse range of participants due to the online nature of the survey. Among the findings, 25.7% of respondents are aged 15-24, 42.9% fall within the 25-34 age bracket, and 28.6% are above 34 years old. The inclusive accessibility of the online survey platform is reflected in the varied representation of age groups among the participants.

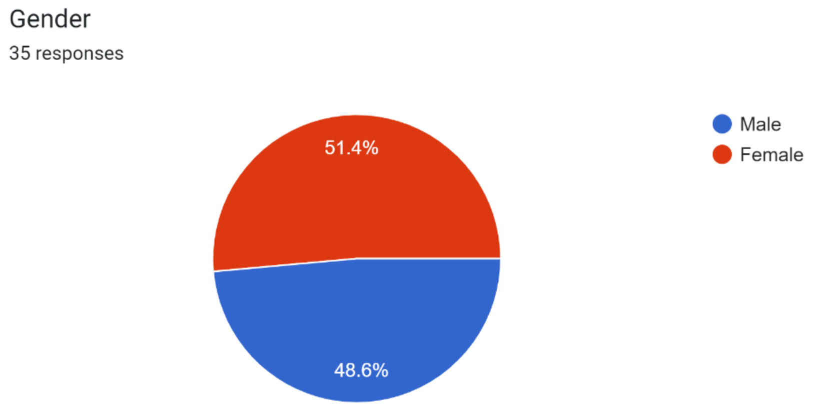


Figure 4.8 Gender of the Respondent

The chart above illustrates the gender distribution of survey participants, revealing that 51.4% of respondents are female, while the remaining participants are male. The higher percentage of female participants can be attributed to the fact that laundry washing and hanging processes are typically handled by females, leading to a greater interest in the new system among women compared to men. This gender-based disparity underscores the relevance and appeal of the system to those primarily responsible for these household tasks.

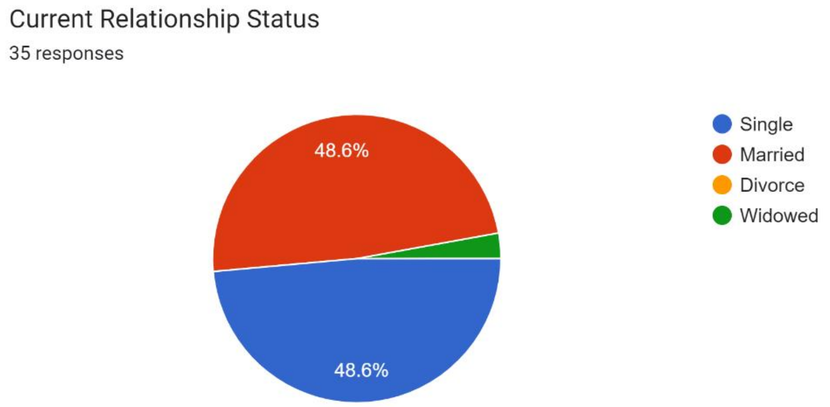


Figure 4.9 Current Relationship Status of the Respondents

This graph illustrates that among 35 responses, 48.6% are single, another 48.6% are married, and the remaining individuals fall into the 'widowed' category, showcasing the distribution of marital status within the surveyed population.

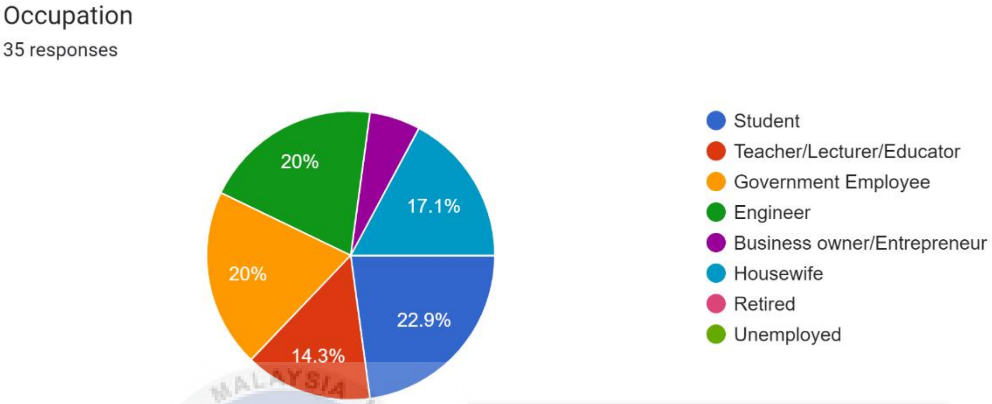


Figure 4.10 Occupation of the Respondents

This graph represents the occupational distribution of 35 respondents. It shows that 20% are engineers, 20% are government employees, 14.3% are in teaching roles, 22.9% are students, and 17.1% are homemakers. The high percentage of students might indicate easier survey accessibility, influencing their overrepresentation in the responses compared to other occupational groups.

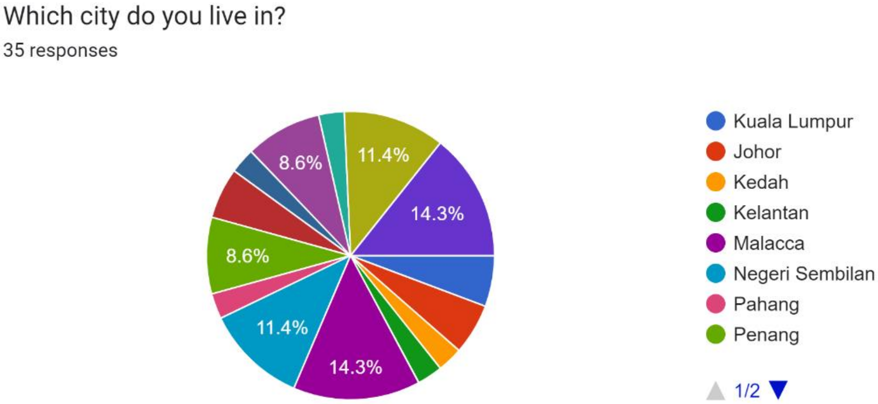


Figure 4.11 City the Respondents live

The graph displays the cities where the respondents reside, showcasing various towns across Malaysia.

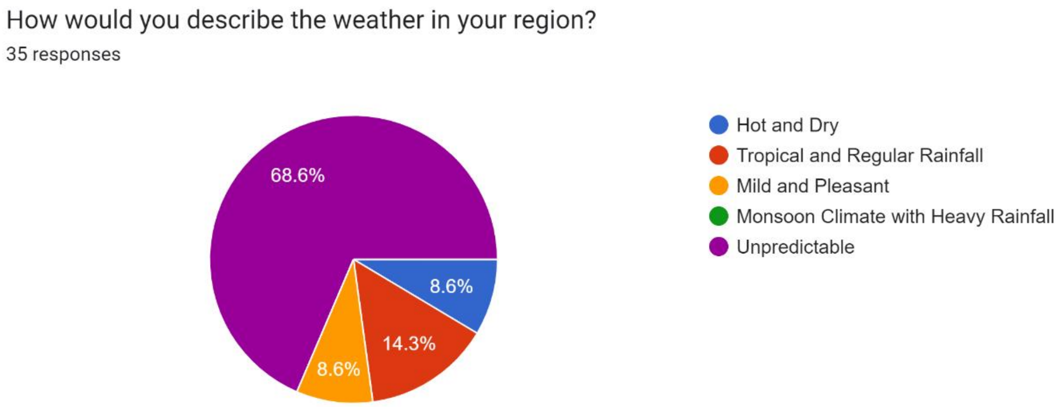


Figure 4.12 Weather in the Respondent’s Region

This graph illustrates the perceptions of weather among respondents. The majority, 68.6%, find their city's weather unpredictable. Additionally, 8.6% experience hot and dry conditions, 14.3% have tropical weather with regular rainfall, and another 8.6% describe their climate as mild and pleasant.

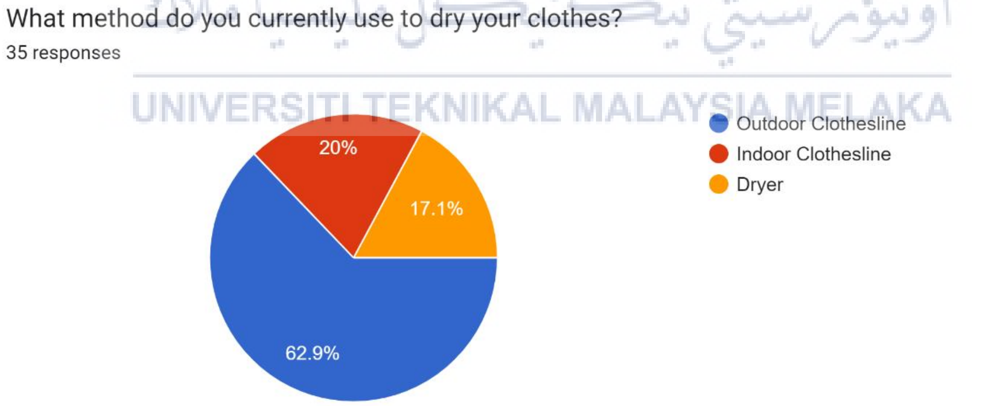


Figure 4.13 Method Respondents used to dry clothes.

The graph depicts preferred methods for drying clothes: 62.9% opt for outdoor clotheslines, likely due to their conventional nature—and another 20% use indoor clotheslines, possibly indicative of limited outdoor space in remote areas.

Additionally, 17.1% utilize dryers, suggesting a preference among those living in apartments where outdoor drying space might be restricted.

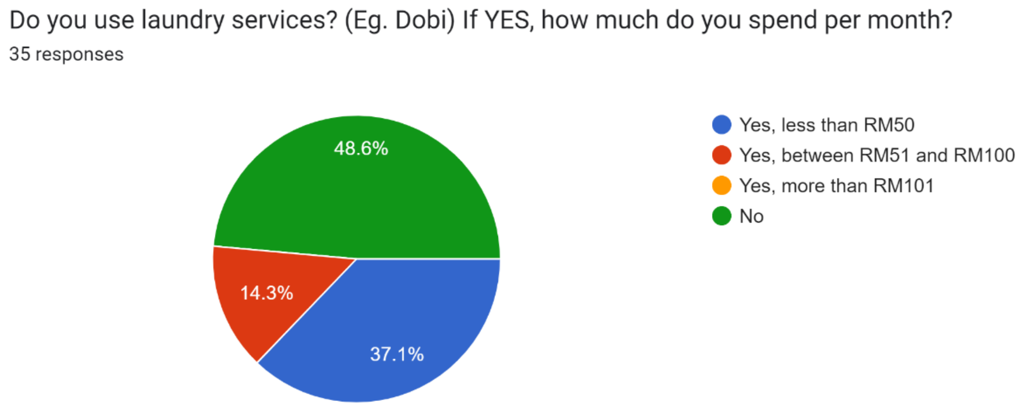


Figure 4.14 Laundry Services

The questions aim to ascertain respondents' usage of laundry services and their corresponding expenditure if they opt for such services. Notably, 48.6% of participants indicated that they do not use laundry services, citing the reason as the perceived high cost. On the other hand, 37.1% affirmed their utilization of laundry services, with the majority (37.1%) reporting an expenditure of less than RM50 per month. Additionally, 14.3% of respondents disclosed monthly spending between RM51 and RM100 on laundry services.

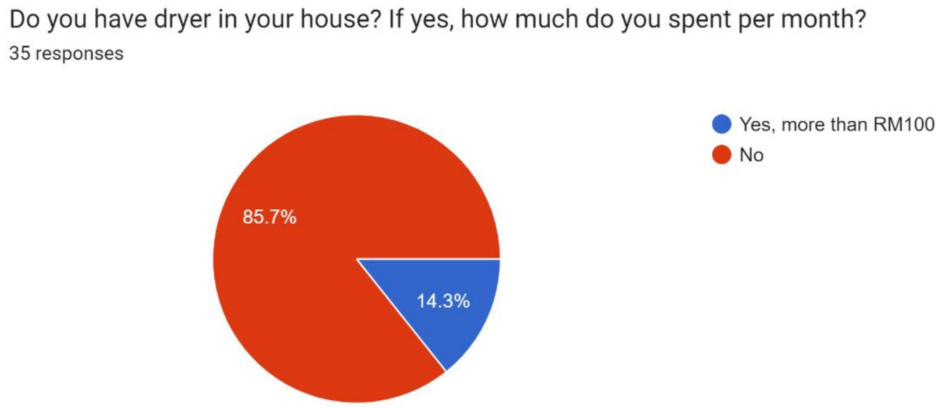


Figure 4.15 Dryer

The inquiry seeks to ascertain respondents' household dryer usage and associated costs. According to the findings, 85.7% of respondents chose not to use dryers, citing the cost of installation as a barrier. In contrast, 14.3% of respondents chose to use dryers and reported spending RM100 or more only on dryer power costs. This finding demonstrates a preference among most respondents to avoid using dryers due to their perceived high installation cost.

Figure 4.16 Forgotten about laundry

Respondents in this survey were asked if they had ever forgotten about their washing on the clothesline. According to the findings, 54.3% of respondents reported forgetting regularly, implying a possible link to heavy workloads or exhaustion after work. Furthermore, 14.3% reported occasional forgetfulness, while 31.4% said they rarely fail, which could be attributed to indoor clothesline systems or dryers.

Figure 4.17 Purchase the System

Regarding whether respondents would consider purchasing an automated system capable of intelligently preventing their clothes from becoming drenched using a renewable energy source, 94.3% indicated a positive inclination. On the contrary, the remaining respondents opted for a more tentative "maybe."

4.4 Summary

The findings, analysis, and discussion from the project "Development of an IoT-Based Solar Powered Automated Roof Clothesline Suspension Using a Microcontroller" are presented in this chapter. A comprehensive performance and functionality test and a quantitative survey with a wide range of respondent demographics demonstrate accurate sensor readings and successful system functionality. Potential consumers are generally favorable about the study; 94.3% indicate they want to buy the automated system.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the IoT-based automated roof clothesline suspension system driven by solar energy has been successfully implemented, which is a noteworthy accomplishment in solving environmental issues, encouraging energy efficiency, and improving user convenience. The system's efficacy in offering a sustainable and user-friendly solution is demonstrated by its capacity to harvest renewable energy, modify its location in response to weather, and interface smoothly with a Blynk application.

The project's goals were successfully met, including creating an automatic clothesline system that runs on solar energy and is energy efficient. The Blynk application's remote monitoring features give customers easy management over their washing chores. The reliability analysis further confirms the system's usefulness and efficacy.

By incorporating temperature, light, humidity, and rain sensors, the system effectively protects the garment from getting wet during adverse weather conditions, demonstrating its versatility and user-friendly design. The Blynk application's real-time data collection and display improve user awareness and control.

In addition to addressing the drawbacks of conventional clothesline systems, the roof extraction and expansion mechanism based on weather conditions and the use of solar power also contribute to environmental sustainability. It is crucial to remember that the system's applicability is limited to areas with landed houses.

The project's success shows how IoT technologies can be used to develop creative, environmentally beneficial solutions for common problems. The automatic clothesline system is a role model for encouraging eco-friendly behavior, using available resources best, and providing a more effective and sustainable laundry management method.

5.2 Potential for Commercialization

The solar-powered automated roof clothesline suspension system, equipped with weather monitoring capabilities, has great promise for commercialization. The project's use of IoT, solar power, and weather sensors aligns with current market trends and consumer preferences as the demand for intelligent and environmentally friendly solutions continues to increase.

The unique technology has commercial uses beyond individual residences, offering opportunities in other sectors. The incorporation of meteorological data into agriculture has the potential to optimize irrigation and crop management, resulting in reduced water use and improved yields. The solar-powered elements of the system in the energy sector can be utilized to achieve sustainable energy solutions, thereby aiding in the generation and distribution of renewable energy. The transportation and urban planning industries have the potential to leverage weather data to enhance the efficiency of routes, schedules, and infrastructure development.

Furthermore, additional potential income sources for commercialization exist, such as data licensing and collaborations with private sector entities. Effective weather data management is critical to organizations and industries that depend on precise environmental information, as it possesses inherent value. Engaging in partnerships with private entities to leverage data could significantly improve the project's economic feasibility.

Nevertheless, achieving a harmonious equilibrium between commercialization and the overarching objective of guaranteeing the availability and practicality of weather data is imperative. Aligning with global initiatives tackling climate change involves prioritizing sustainability and ensuring fair access. Projects that prioritize delivering valuable environmental insights while simultaneously promoting economic benefits have the potential to generate a mutually beneficial outcome for both commercial success and the overall welfare of society and the planet.

5.3 Future Works

For future enhancements to the system, several features could be considered to optimize clothes drying and protection further:

i. The addition of a fan to the system might speed up the drying of clothing. The fan feature of the system ensures that garments dry faster while also protecting them from becoming wet, meeting user preferences for more effective laundry management.

ii. Setting a conveyor system in place could give clothing additional reliability. The clothesline could move outside in bright, sunny weather for best drying results and automatically retract inside the garage in rain or darkness to protect clothing from inclement weather.

iii. An automatic fan activation option might accompany the clothesline's motion. The fan activates automatically when the clothesline retracts within, serving two purposes: shielding clothing from the weather and assisting in the drying process.

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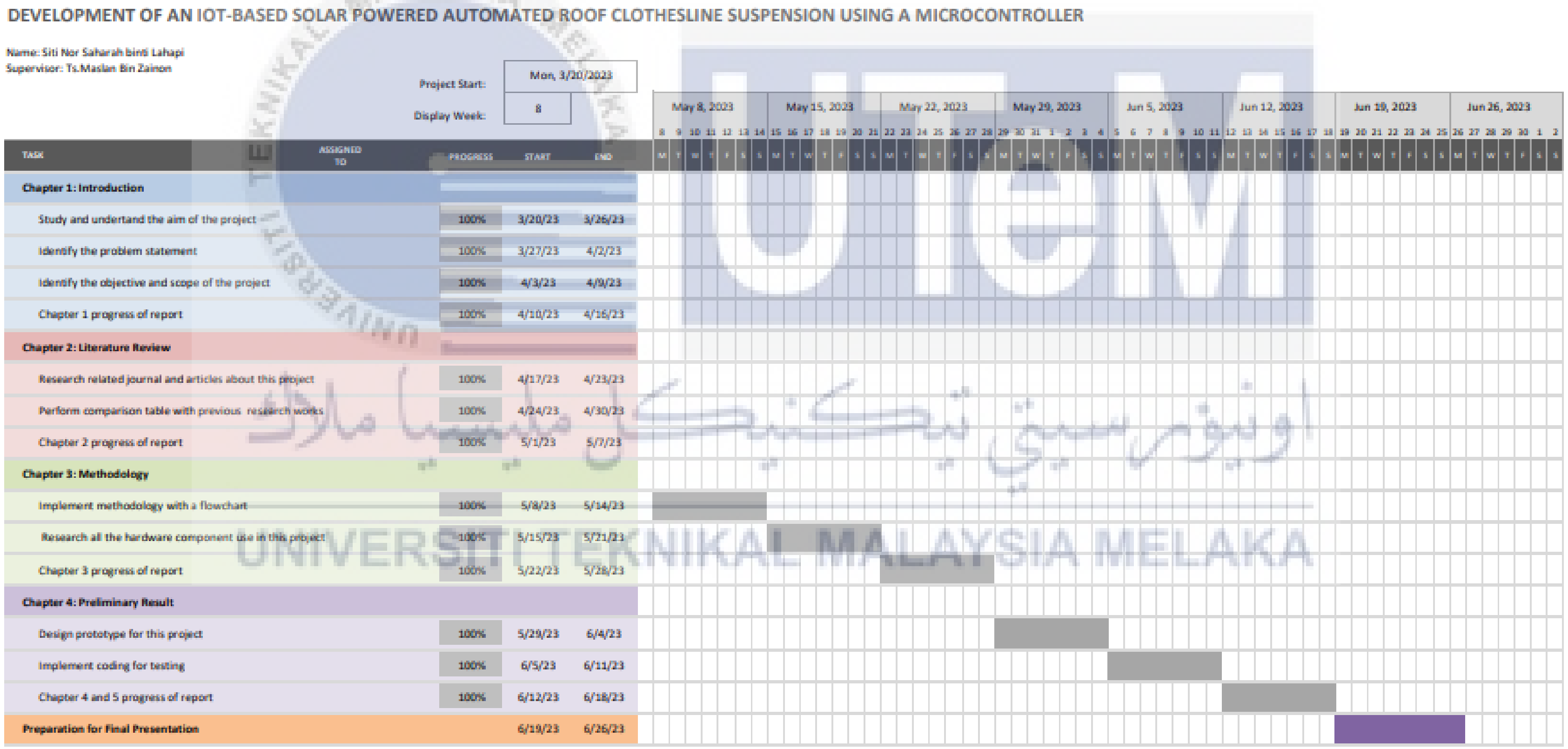
APPENDICES

Appendix A Gantt Chart PSM 1



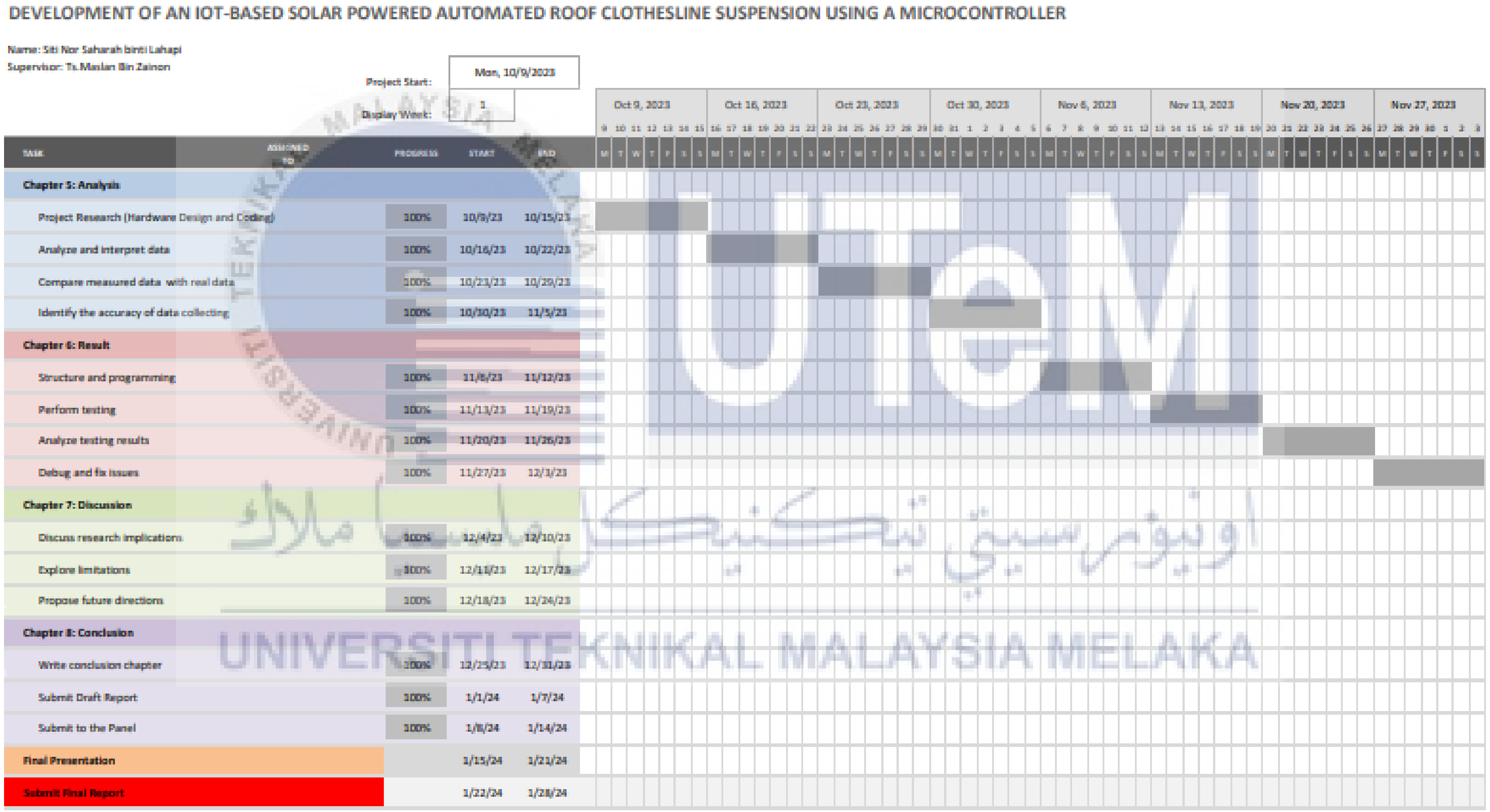
DEVELOPMENT OF AN IOT-BASED SOLAR POWERED AUTOMATED ROOF CLOTHESLINE SUSPENSION USING A MICROCONTROLLER

Name: Siti Nor Saharah binti Lahapi
Supervisor: Ts.Maslan Bin Zainon

Project Start: Mon, 3/20/2023
Display Week: 8

TASK	ASSIGNED TO	PROGRESS	START	END
Chapter 1: Introduction				
Study and undertand the aim of the project		100%	3/20/23	3/26/23
Identify the problem statement		100%	3/27/23	4/2/23
Identify the objective and scope of the project		100%	4/3/23	4/9/23
Chapter 1 progress of report		100%	4/10/23	4/16/23
Chapter 2: Literature Review				
Research related journal and articles about this project		100%	4/17/23	4/23/23
Perform comparison table with previous research works		100%	4/24/23	4/30/23
Chapter 2 progress of report		100%	5/1/23	5/7/23
Chapter 3: Methodology				
Implement methodology with a flowchart		100%	5/8/23	5/14/23
Research all the hardware component use in this project		100%	5/15/23	5/21/23
Chapter 3 progress of report		100%	5/22/23	5/28/23
Chapter 4: Preliminary Result				
Design prototype for this project		100%	5/29/23	6/4/23
Implement coding for testing		100%	6/5/23	6/11/23
Chapter 4 and 5 progress of report		100%	6/12/23	6/18/23
Preparation for Final Presentation			6/19/23	6/26/23

Appendix B Gantt Chart PSM 2



DEVELOPMENT OF AN IOT-BASED SOLAR POWERED AUTOMATED ROOF CLOTHESLINE SUSPENSION USING A MICROCONTROLLER

Name: Siti Nor Saharah binti Lahapi
Supervisor: Ts.Maslan Bin Zainon

Project Start: Mon, 10/9/2023
Display Week: 1

Oct 9, 2023 | Oct 16, 2023 | Oct 23, 2023 | Oct 30, 2023 | Nov 6, 2023 | Nov 13, 2023 | Nov 20, 2023 | Nov 27, 2023

TASK	ASSIGNED TO	PROGRESS	START	END
Chapter 5: Analysis				
Project Research (Hardware Design and Coding)		100%	10/9/23	10/15/23
Analyze and interpret data		100%	10/16/23	10/22/23
Compare measured data with real data		100%	10/23/23	10/29/23
Identify the accuracy of data collecting		100%	10/30/23	11/5/23
Chapter 6: Result				
Structure and programming		100%	11/6/23	11/12/23
Perform testing		100%	11/13/23	11/19/23
Analyze testing results		100%	11/20/23	11/26/23
Debug and fix issues		100%	11/27/23	12/3/23
Chapter 7: Discussion				
Discuss research implications		100%	12/4/23	12/10/23
Explore limitations		100%	12/11/23	12/17/23
Propose future directions		100%	12/18/23	12/24/23
Chapter 8: Conclusion				
Write conclusion chapter		100%	12/25/23	12/31/23
Submit Draft Report		100%	1/1/24	1/7/24
Submit to the Panel		100%	1/8/24	1/14/24
Final Presentation			1/15/24	1/21/24
Submit Final Report			1/22/24	1/28/24

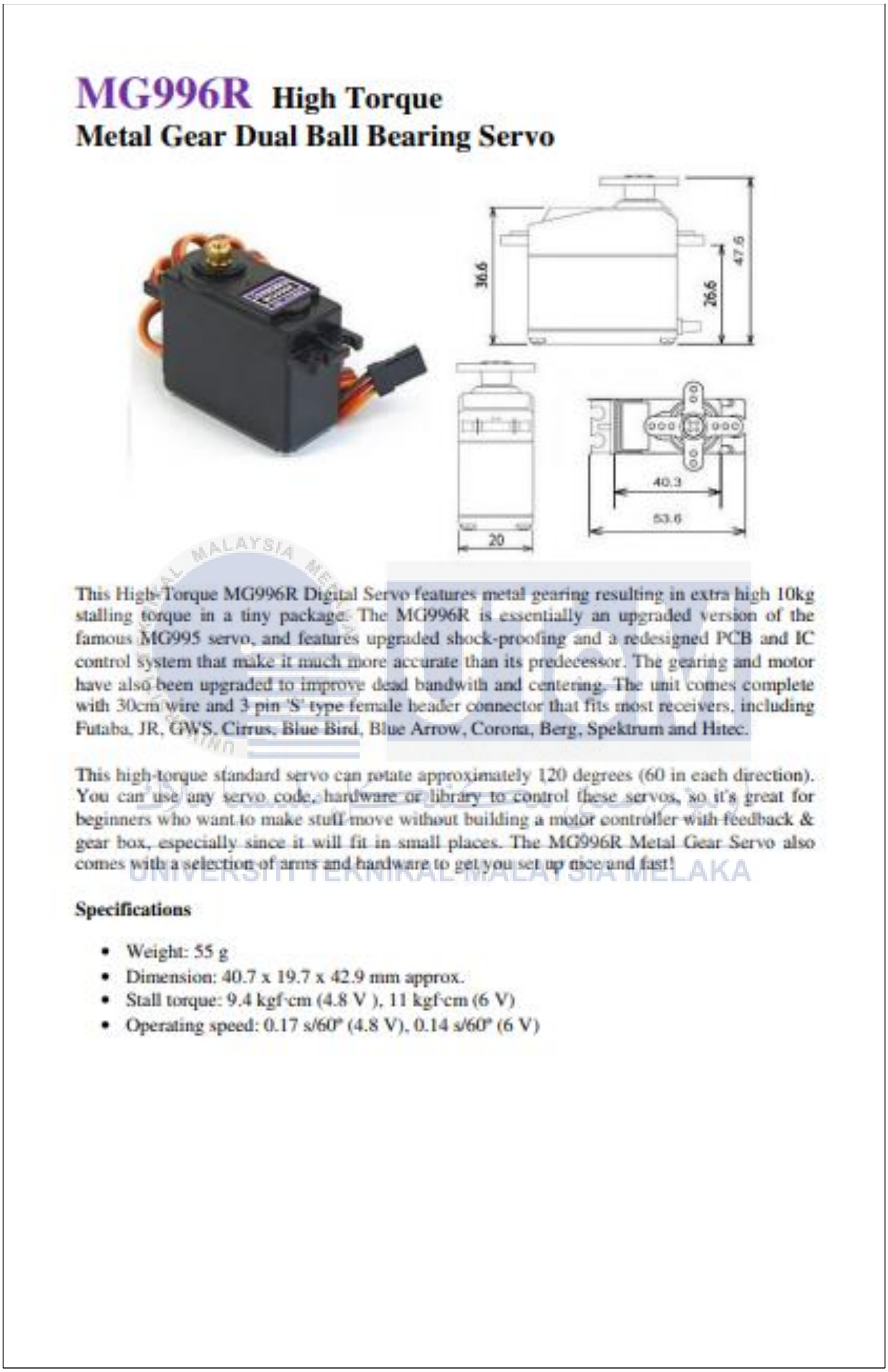
Appendix C Source Code

```
#define BLYNK_TEMPLATE_ID "TMPL6wYrDxCMw"
#define BLYNK_TEMPLATE_NAME "Weather Monitoring System"
#define BLYNK_AUTH_TOKEN "bJcFlslSxCvibK5L-zIvQWMAN_Bt0G7L"
#define BLYNK_PRINT Serial

#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <Servo.h>
#include <DHT.h>
#include <DHT_U.h>

char auth[] = BLYNK_AUTH_TOKEN;  //Enter your Auth token
char ssid[] = "sitinorsahara";   //Enter your WIFI name
char pass[] = "12345678";        //Enter your WIFI password

#define LDR D5
DHT dht(D4, DHT22);
Servo myservo;
BlynkTimer timer;

bool alert = false;
float threshold = 10;

int x = 0;  // signal from blynk
int y = 0;  // rain sensor
int z = 0;  // ldr sensor

void setup() {
  Serial.begin(9600);
  Blynk.begin(auth, ssid, pass, "blynk.cloud", 80);
  myservo.attach(D6);
}

BLYNK_WRITE(V1) {
  int value = param.asInt();

  if (value == 0) {
    x = 0;
  } else if (value == 1) {
    x = 1;
  }
}
```

```
void moveServo(int targetPosition) {
  int currentPosition = myservo.read();
  int step = (targetPosition > currentPosition) ? 1 : -1;

  while (currentPosition != targetPosition) {
    myservo.write(currentPosition);
    currentPosition += step;
    delay(15); // Adjust the delay for smoother movement
  }
}

void loop() {
  Blynk.run();

  float t = dht.readTemperature();
  float h = dht.readHumidity();
  int rain = analogRead(A0);
  int rainValue = map(rain, 0, 1023, 100, 0);

  int LDRvalue = digitalRead(LDR);
  if (LDRvalue == 1) {
    WidgetLED LED(V4);
    LED.on();
    Blynk.logEvent("dark");
    Serial.println("It's Dark, a sign of heavy rain");
    z = 1;
  } else {
    WidgetLED LED(V4);
    LED.off();
    Serial.println("It's Bright!");
    z = 0;
  }

  Serial.print("Temperature: ");
  Serial.print(t);
  Serial.print(" °C   ");

  Serial.print("Humidity: ");
  Serial.print(h);
  Serial.println(" %");
```

```
  if (rainValue > threshold) {
    Blynk.logEvent("rainalert");
    Serial.println("It's Raining!");
    y = 1;
    alert = true;
  } else {
    Serial.println("It's not raining");
    y = 0;
    alert = false;
  }

  if (x == 1 || y == 1) {
    moveServo(180);
  } else {
    moveServo(0);
  }

  Blynk.virtualWrite(V0, rainValue);
  Blynk.virtualWrite(V2, t);
  Blynk.virtualWrite(V3, h);
  delay(2000);
}
```

Appendix D Data Sheet MG996R Digital Servo



MG996R High Torque
Metal Gear Dual Ball Bearing Servo

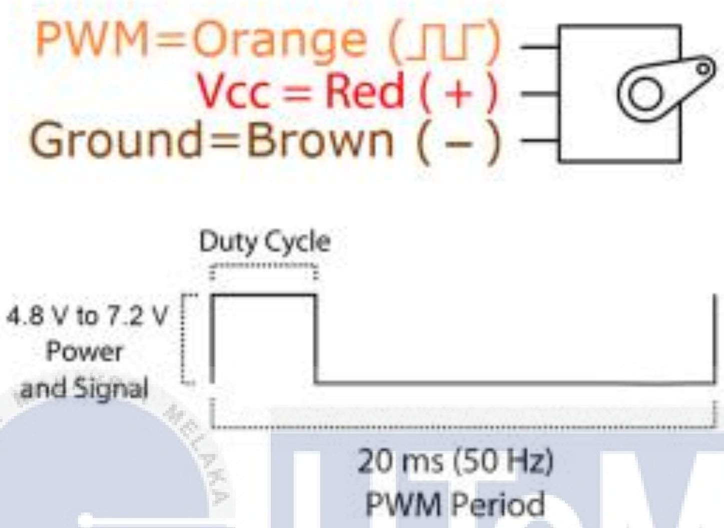
This High-Torque MG996R Digital Servo features metal gearing resulting in extra high 10kg stalling torque in a tiny package. The MG996R is essentially an upgraded version of the famous MG995 servo, and features upgraded shock-proofing and a redesigned PCB and IC control system that make it much more accurate than its predecessor. The gearing and motor have also been upgraded to improve dead bandwith and centering. The unit comes complete with 30cm wire and 3 pin 'S' type female header connector that fits most receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum and Hitec.

This high-torque standard servo can rotate approximately 120 degrees (60 in each direction). You can use any servo code, hardware or library to control these servos, so it's great for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. The MG996R Metal Gear Servo also comes with a selection of arms and hardware to get you set up nice and fast!

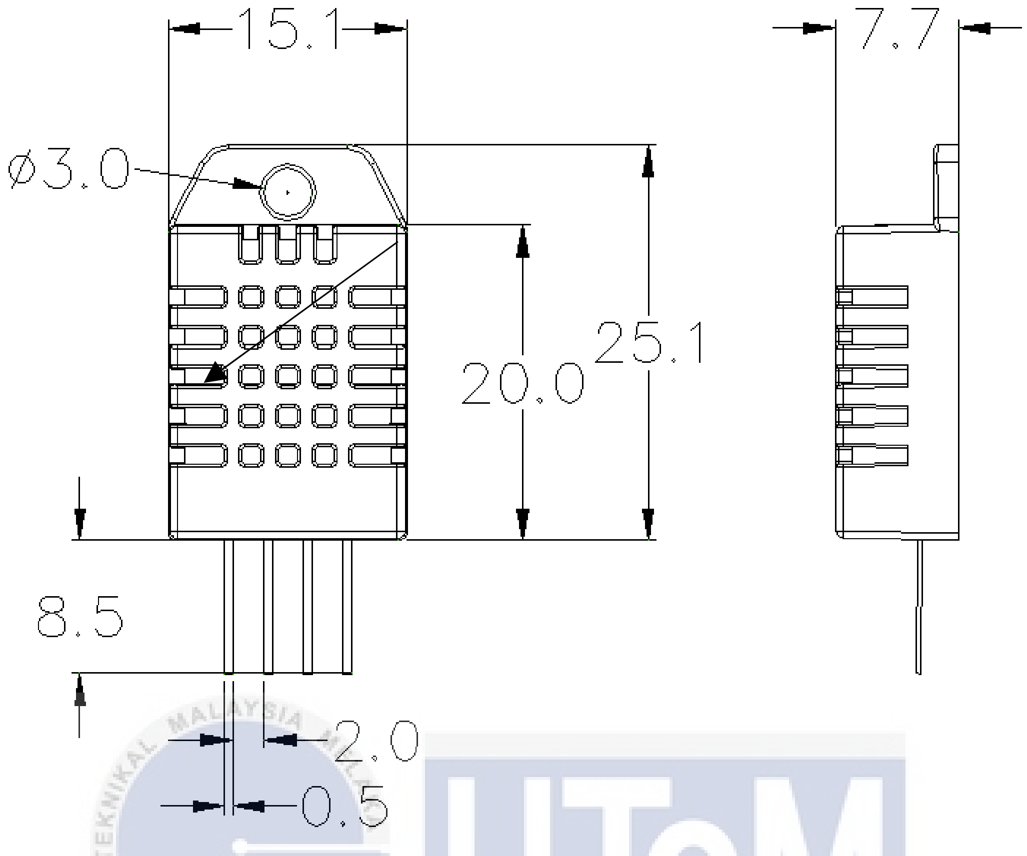
Specifications

- Weight: 55 g
- Dimension: 40.7 x 19.7 x 42.9 mm approx.
- Stall torque: 9.4 kgf·cm (4.8 V), 11 kgf·cm (6 V)
- Operating speed: 0.17 s/60° (4.8 V), 0.14 s/60° (6 V)

- Operating voltage: 4.8 V a 7.2 V
- Running Current 500 mA – 900 mA (6V)
- Stall Current 2.5 A (6V)
- Dead band width: 5 µs
- Stable and shock proof double ball bearing design
- Temperature range: 0 ℃ – 55 ℃



Appendix E Data Sheet DHT22



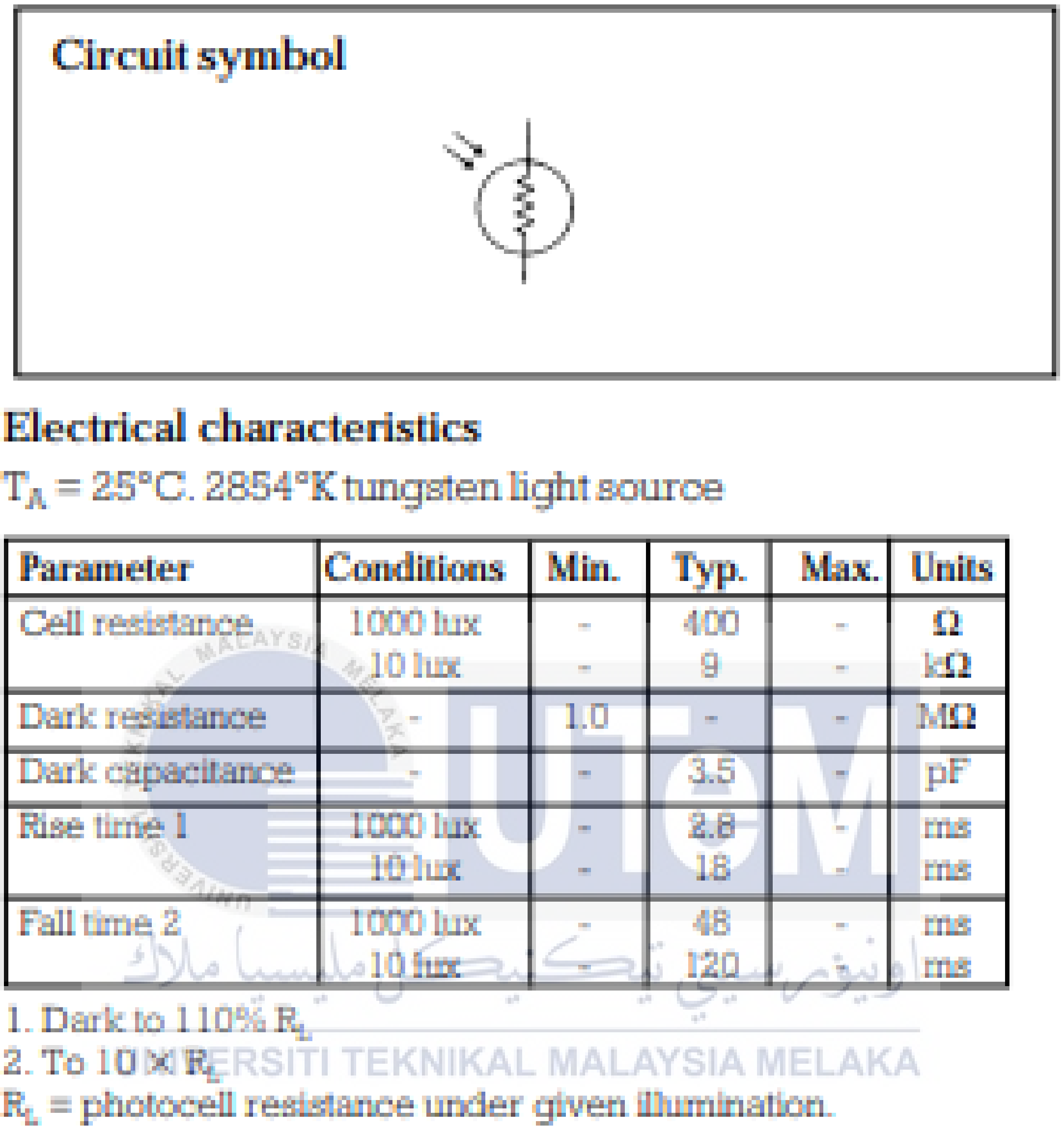
Pin sequence number: 1 2 3 4 (from left to right direction).

Pin	**Function**
1	**VDD --- power supply**
2	**DATA--signal**
3	**NULL**
4	**GND**

Technical Specification

Model	DHT22
Power supply	3.3-6V DC
Output signal	digital signal via single bus
Sensing element	Polymer capacitor
Operating range	humidity 0-100%RH; temperature -40~80Celsius
Accuracy	humidity +-2%RH (Max +-5%RH); temperature <+-0.5Celsius
Resolution or sensitivity	humidity 0.1%RH; temperature 0.1Celsius
Repeatability	humidity +-1%RH; temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH
Long-term Stability	+-0.5%RH/year
Sensing period	Average: 2s
Interchangeability	fully interchangeable
Dimensions	small size 14*18*5.5mm; big size 22*28*5mm

Appendix F Data Sheet LDR Sensor



Circuit symbol

Electrical characteristics

T_A = 25°C. 2854°K tungsten light source

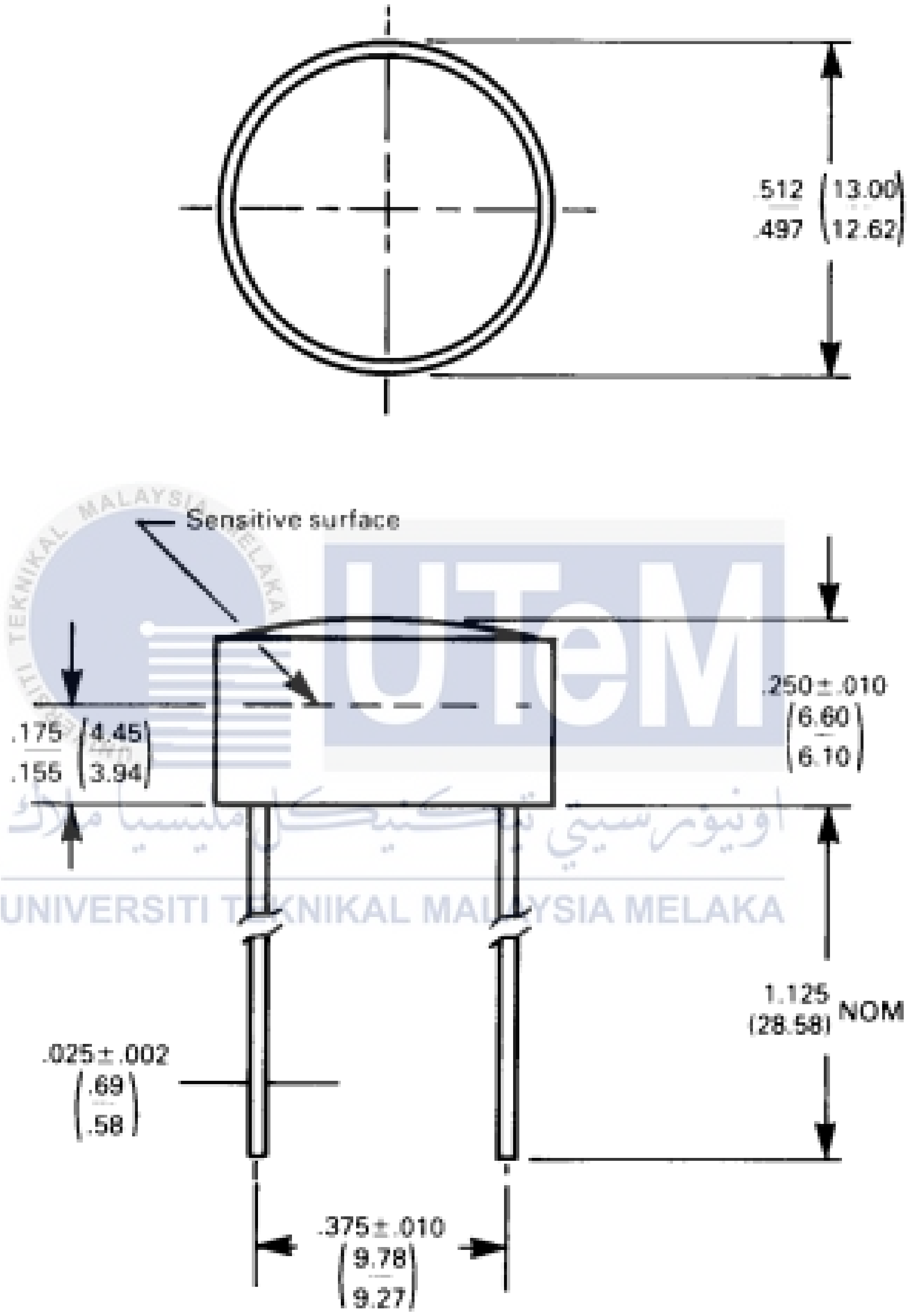
Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	1000 lux 10 lux	- -	400 9	- -	Ω kΩ
Dark resistance	-	1.0	-	-	MΩ
Dark capacitance	-	-	3.5	-	pF
Rise time 1	1000 lux 10 lux	- -	2.8 18	- -	ms ms
Fall time 2	1000 lux 10 lux	- -	48 120	- -	ms ms

1. Dark to 110% R_L

2. To 10 × R_L

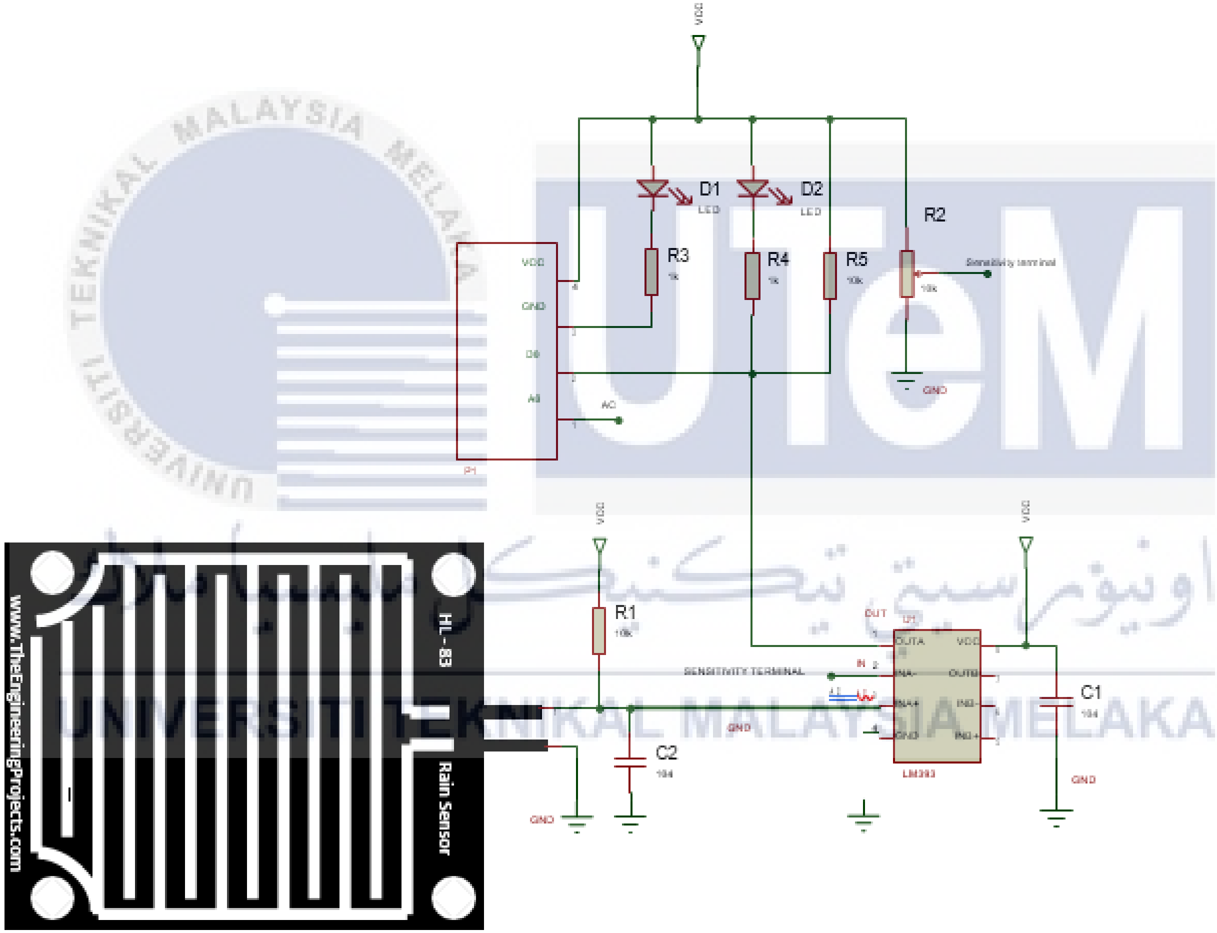
R_L = photocell resistance under given illumination.

Dimensions



Units in inches (millimetres)

Appendix G Data Sheet Rain Sensor



DEVELOPMENT OF AN IOT-BASED SOLAR POWERED AUTOMATED ROOF CLOTHESLINE SUSPENSION USING A MICROCONTROLLER

by Siti Nor Saharah Lahapi

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