Faculty of Electrical and Electronic Engineering Technology

LORA BASED CABLE THEFT DETECTION SYSTEM FOR STREET LIGHTING

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Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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LORA BASED CABLE THEFT DETECTION SYSTEM FOR STREET LIGHTING

MUHAMMAD FIRDAUS BIN MOHAMMAD FAUZI

A project report submitted
in partial fulfillment of the requirements for the degree of
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DEDICATION

I would like to express my sincere gratitude and dedication to my beloved parents, Mr. Mohd Fauzi and Mrs. Noraini, whose constant support and heartfelt prayers have been the pillars of strength throughout my academic journey. Their unwavering encouragement has been a driving force behind my accomplishments. Additionally, I extend profound appreciation to my dedicated supervisor, Ir. Dr. Zul Hasrizal Bin Bohari, for his exemplary guidance and relentless support in advising and assisting me through the intricacies of this project. Their collective influence has played an instrumental role in shaping the successful completion of this endeavour.

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ABSTRACT

Cable theft in Malaysia has caused significant losses and damage for TNB. To address this issue, this project proposes a LoRa-based cable theft detection system for street lighting. The project aims to design and develop a cable theft detection system for street lighting based on long range wireless network (LoRa), implementing an Internet of Things, IoT and analyzing the performance of Lora. For this project, PC817 optocoupler was utilized to sense 240Vac. The hardware development includes a transmitter and receiver circuit. The transmitter uses arduino UNO as controller to communicate with optocoupler then transmit data using LoRa communication. The receiver uses ESP32 to interact with IoT platform. This project successfully implemented a cable theft detection system for street lighting, generating warning notification using IoT.

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ABSTRAK

Kecurian kabel di Malaysia telah menyebabkan kerugian dan kerosakan yang ketara kepada TNB. Untuk menangani isu ini, projek ini mencadangkan sistem pengesanan kecurian kabel berasaskan LoRa untuk lampu jalan. Projek ini bertujuan untuk mereka bentuk dan membangunkan sistem pengesanan kecurian kabel untuk lampu jalan berdasarkan rangkaian wayarles jarak jauh (LoRa), melaksanakan Internet of Things, IoT dan menganalisis prestasi Lora dan optocoupler. Untuk projek ini, optocoupler PC817 telah digunakan untuk mengesan 240Vac. Pembangunan perkakasan termasuk litar pemancar dan penerima. Pemancar menggunakan arduino UNO sebagai pengawal untuk berkomunikasi dengan optocoupler kemudian menghantar data menggunakan komunikasi LoRa. Penerima menggunakan ESP32 untuk berinteraksi dengan platform IoT. Projek ini berjaya melaksanakan sistem pengesanan kecurian kabel untuk lampu jalan, menjana pemberitahuan amaran menggunakan IoT.

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First and foremost, I would like to express my gratitude to my supervisor, Ir. Dr. Zul Hasrizal Bin Bohari, for his precious guidance, words of wisdom, and patience throughout this project.

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My highest appreciation goes to my parents, parents-in-law, and family members for their love and prayers during the period of my study. An honorable mention also goes to my friends, Muhd Zikri, for all the motivation and understanding. And to my mentor, Mohd Naim, thanks for your invaluable advice and support.

Finally, I would like to thank all the staff at the Faculty of Electrical Engineering, fellow colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being cooperative and helpful.

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LIST OF SYMBOLS

Ω	-	Ohm
%	-	Percentage
μF	-	Micro Farrad
Nm	-	Neuton meter
dBm	-	Decibels relative to one milliwatt

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LIST OF ABBREVIATIONS

V	-	Voltage
R_D	-	Limiting Resistor
R_L	-	Pull-Up resistor
I_F	-	Foward Current
V_{AC}	-	Volts Alternating Current
V_{DC}	-	Volts Dirrect Current
LoRa	-	Long-Range
C_{IN}	-	Incoming Capasitor
C_{OUT}	-	Outgoing Capasitor
$RSSI$		Received Signal Intensity Indicator
SNR		Signal to Noise Ratio
SF		Spreading Factor

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CHAPTER 1

INTRODUCTION

1.1 Background

The cases of cable theft from street lighting occur rather frequently each year in some locations, particularly in new residential areas. The country's extensive network of street lighting makes it impractical to monitor or install a sensor at every position. Vast highway regions need surveillance systems that can operate over great distances to detect cable theft when it occurs. Thus, this project proposes a cable theft detection system based on long range wireless network, LoRa. The project will be possible to track current data on an IoT platform and identify cable theft. By using LoRa, the data can be transmitted within a distance of about 150 meters. The system will be developed to monitor and generate feedback for sensor detection. Two sets of LoRa will be implemented as Transmitter and Receiver. The transmitter will sense the AC voltage at the location of the street lighting and report its findings to the receiver. Receiver will receive the data input and determine whether or not there has been a cable theft. The project will deal with the integrated monitoring system, which gives authorities accessibility all the times.

1.2 Problem Statement

Tenaga Nasional Berhad (TNB) is the biggest listed electricity firm in Southeast Asia with assets at MYR 182.60 billion and one of Malaysia's major street light providers. However, cable theft from street lighting frequently occurs in some locations every year, costing the government and TNB a significant amount of money. According to The Star news in 2012, between 2004 and 2011, cable thefts at TNB's sub-stations in the peninsula cost the company over MYR 170 million. This issue underscores the need for a more effective and innovative solution to curb such losses.

Street lighting without a surveillance system in new residential areas has also led to an increase in cable theft. Because there was no advanced system to monitor the cable serial in real time, authorities had to rely on reports from locals before taking any action. Mr. Bongani Mandla, director of electrotechnical services for the George Municipality, noted that damages often occur at night, leading to significant impacts such as load shedding. This problem emphasizes the necessity of a real-time monitoring system to protect infrastructure.

To address these issues, a LoRa-based cable theft detection system for street lighting is proposed. This approach aims to reduce the losses brought on by cable theft by enabling authorities to monitor cable activity via IoT platforms or social media, with a focus on new residential areas. The deployment of LoRa and the development of current sensor techniques will enhance the ability to detect and respond to cable theft promptly, thus ensuring the security and reliability of street lighting infrastructure.

This proposed solution aligns with several United Nations Sustainable Development Goals (UN SDGs). It supports Goal 9: Industry, Innovation, and Infrastructure by promoting the use of advanced technologies to build resilient infrastructure. It also aligns with Goal 11: Sustainable Cities and Communities by contributing to the creation of safe, resilient, and sustainable urban environments. Additionally, it supports Goal 16: Peace, Justice, and Strong Institutions by enhancing the capability of authorities to effectively monitor and respond to cable theft, thereby promoting just and peaceful societies.

1.3 Project Objective

The main aim of this project is to develop a prototype of LoRa based cable theft detection system for street lighting that can be readily installed by the authorities. The utilization of this approach has the potential to enhance the monitoring system for cable street lighting in addition to being able to assist the authorities in lowering the likelihood that cable theft would occur. The major justification for this project's development is listed below:

a) To design and develop a cable theft detection system for street lighting using Lora.

b) To implement an Internet of Things (IoT) on the system and display simple digital output of the optocoupler data on IoT dashboard.

c) To analyze the performance of Lora.

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1.4 Scope of Project

This project outlines the development of a prototype cable fault detection system utilizing an optocoupler circuit module. The project operates within a defined scope to ensure focused development and achievable goals. The core functionality relies on an optocoupler circuit built with the PC817 model, specifically chosen to detect the presence (or absence) of AC power. It's important to note that this project is confined to a controlled laboratory environment. Testing and deployment on actual street lighting infrastructure are beyond the scope of this initial development phase.

To achieve the desired functionalities, the project will involve constructing separate transmitter and receiver modules. These modules will communicate wirelessly using LoRa technology, a low-power, long-range data transmission protocol. The receiver module, the heart of the alert system, will utilize an ESP32 microcontroller. This powerful microcontroller serves as the bridge between the system and the Blynk IoT platform. Integration with Blynk allows for real-time data monitoring and notification functionalities. Users can be alerted of potential cable faults through the Blynk mobile app or even receive email notifications.

A crucial aspect of the project involves research and optimization. The project will investigate the impact of adjusting the limiting resistor (RD) within the optocoupler circuit. By analyzing the optocoupler's accuracy in detecting AC power under different limiting resistor values, the project aims to identify the optimal configuration for reliable fault detection. The specific resistor values and ranges tested will be carefully chosen based on the datasheet specifications of the PC817 optocoupler and the desired operating current for the circuit.

The project deliverables will encompass a fully functional prototype of the cable fault detection system. This includes the optocoupler circuit itself, the individual transmitter and receiver modules, the ESP32 microcontroller within the receiver module, and the LoRa communication capabilities enabling wireless data transmission. Additionally, the project will produce a comprehensive report detailing the research findings on how Lora is very usefull to monitoring such a large and complex situation. Finally, thorough documentation will be compiled, outlining the design considerations, the specific hardware components used, the software configuration process, and the testing procedures employed throughout the project development.

By establishing a well-defined scope that considers limitations and boundaries, this project ensures focused development efforts and achievable deliverables. The prototype system will serve as a valuable foundation for further research and refinement, paving the way for a robust cable fault detection system with real-world applications.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a concise summary of the research that was conducted in relation to the project of Lora Based Cable Theft Detection System. The study of Arduino microcontrollers, PC817 optocoupler, Internet of Things, and even the underlying principles and products that have been applied are the subjects of the literature review. It is also necessary to summarize the existing body of literature and locate the evidence that can provide solutions to the study objectives and issues.

2.2 Introduction Street Lighting System

An essential component of contemporary urban infrastructure is street lighting. Street lighting has been a vital part of urban development ever since the first streetlight was created in the 19th century [1]. During the night, streetlights offer lighting, enhancing visibility and enhancing safety for both automobiles and pedestrians. Studies have shown that well-lit streets can reduce traffic accidents and pedestrian injuries significantly [2]. Streetlights also help lower crime rates by discouraging criminal activities and enhancing residents' sense of security in cities [3]. Additionally, lighting improves the aesthetics of urban settings, making them more appealing and pleasurable for locals and tourists alike. But there are certain difficulties with street illumination. The need for street lighting has substantially grown due to the fast development of urban populations across the world, creating new difficulties for city planners and politicians [4]. These challenges include the high costs of installation and maintenance, energy consumption, and the increasing incidents

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of cable theft which disrupt service and cause economic losses [5]. Therefore, innovative solutions such as the implementation of IoT and long-range communication technologies like LoRa are essential to address these issues and improve the efficiency and reliability of street lighting systems [6].

2.2.1 Early History of Street Lighting

A streetlight, light pole, lamp pole, lamppost, streetlamp, light standard, or lamp standard is an elevated source of light on the side of a road or path. A platform for a train may feature lights like these. Lighting for urban streets either followed or occasionally led the way as urban electric power distribution extended throughout industrialized nations in the 20th century.

Early lamps were employed in the cultures of Ancient Greece and Ancient Rome, where light was primarily utilized for security, both to prevent wanderers from stumbling over obstacles and to deter would-be burglars. Oil lamps were widely used at the time because they offered a steady and mild light. A lantern Arius was a slave who was in charge of lighting the oil lights in front of Roman villas.

But as early as 500 B.C., Beijing's inhabitants may have been the first to deploy "fixed position lighting" as opposed to hand-carried torches and lamps, using hollow bamboo as a conduit, and naturally occurring gas vents to build a type of streetlamps [7].

Cities like Antioch illuminated its streets on the cusp of the Middle Ages, that persisted across the Arab Empire long before Europe [8]. Edwin Heathcote wrote: "The Romans lit the streets with oil lamps, and cities from Baghdad to Cordoba were similarly lit when most of Europe was living in what is now rather unfashionably referred to as the Dark Ages, but which was, from the point of view of street lighting, exactly that." [9].

The first public street lighting was created in the 16th century, and it quickly spread after the development of lanterns with glass panes, which significantly increased the amount of light. The Parisian Parliament mandated the installation and lighting of torches at each crossroads in 1588 [10]. In 1594, the police replaced the torches with lanterns. However, in the middle of the 17th century, it was common routine for travelers to hire a lantern-bearer if they had to move through the night along the winding, dark lanes [11]. In 1667, King Louis XIV gave the go-ahead for significant changes in Paris, including the installation and upkeep of lights on streets and at junctions as well as harsh penalties for stealing or vandalizing the fixtures [12]. By the end of the 17th century, Paris had more than 2,700 streetlights, and by 1730, that number had doubled.

In the early 1700s, public street lighting was introduced in London. Lanterns were erected all the way from Hyde Park to the Queen's Palace at Kensington, according to a diarist writing in 1712, lighting the streets during the dark hours [13].

Figure 2-1 Detail of Street Lighting from ParisIntroduction [13].

For detecting attempts to tamper with or cut cables, a security system known as a "cable theft detection system" has been developed. Using a combination of sensors and detecting techniques, the system keeps an eye on the cables and searches for any unexpected changes that may be indications of theft or tampering [14].

Cable theft is a significant problem in several industries, including energy distribution, telecommunications, and railway signaling. Cable theft might cause significant service disruptions, risk to public safety, and monetary losses. As a result, cable theft detection systems are necessary for the security and reliability of the cable network.

There are several types of cable theft detection systems, including GSM modem-based cable theft monitoring systems (CTMS), IntelliSense-enabled distributed street lighting control systems, PWM-based power cable anti-theft and monitoring systems, Electrical Parameter Monitoring Systems, Magnetic Field Detection Systems, RFID and

LoRa-Based Systems. The system to use depends on the needs and the specific application. Each system has advantages and restrictions unique to it.

2.2.2 Type of Cable Theft Detection System

2.2.2.1 Cable Theft Monitoring System (CTMS) Using GSM Modem

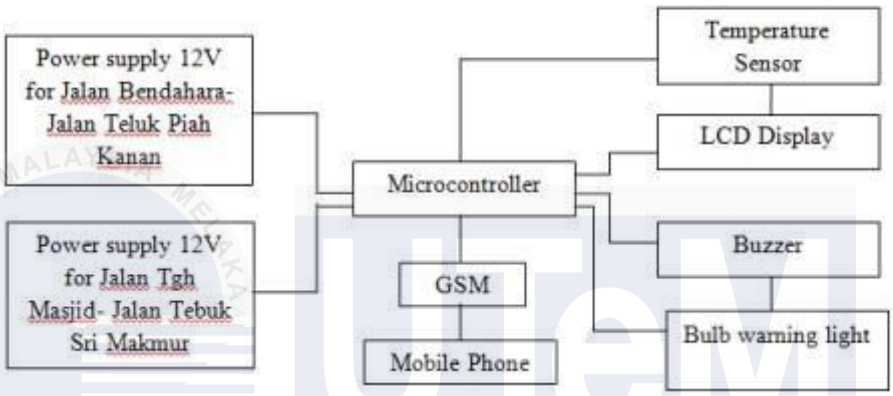

Figure 2-2 Overview of the project [15].

A cable theft monitoring system (CTMS) uses sensors and a GSM modem to detect any instances of cutting or tampering with cables. This system monitors the power, voltage, and current consumption of the cable network to function. It closely monitors any unusual changes that would indicate that a cable has been stolen or manipulated.

The system's components include sensors, a GSM modem, and a data collection system. The sensors are positioned throughout the whole length of the cable and are used to evaluate the electrical properties of the network. The data collecting system transports information from the sensors to the GSM modem, which then sends it via the cellular network to a centralized monitoring system.

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The central monitoring system analyses the data and uses it to look for any odd network changes. The system may be set up to notify the appropriate authorities when a suspected theft or tampering incident is discovered.

The advantages of a CTMS and GSM modem-based cable theft detection system are its high accuracy, dependability, and ability to identify a range of cable tampering methods. It is also less prone to false alarms when compared to other types of cable theft detection systems.

However, there are considerable disadvantages to the approach. It could need significant hardware and software expenditures, as well as professional installation and maintenance skills. Network coverage issues could potentially affect it in areas with poor cellular network service [15].

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2.2.2.2 Distributed Street Lighting Control System with IntelliSense

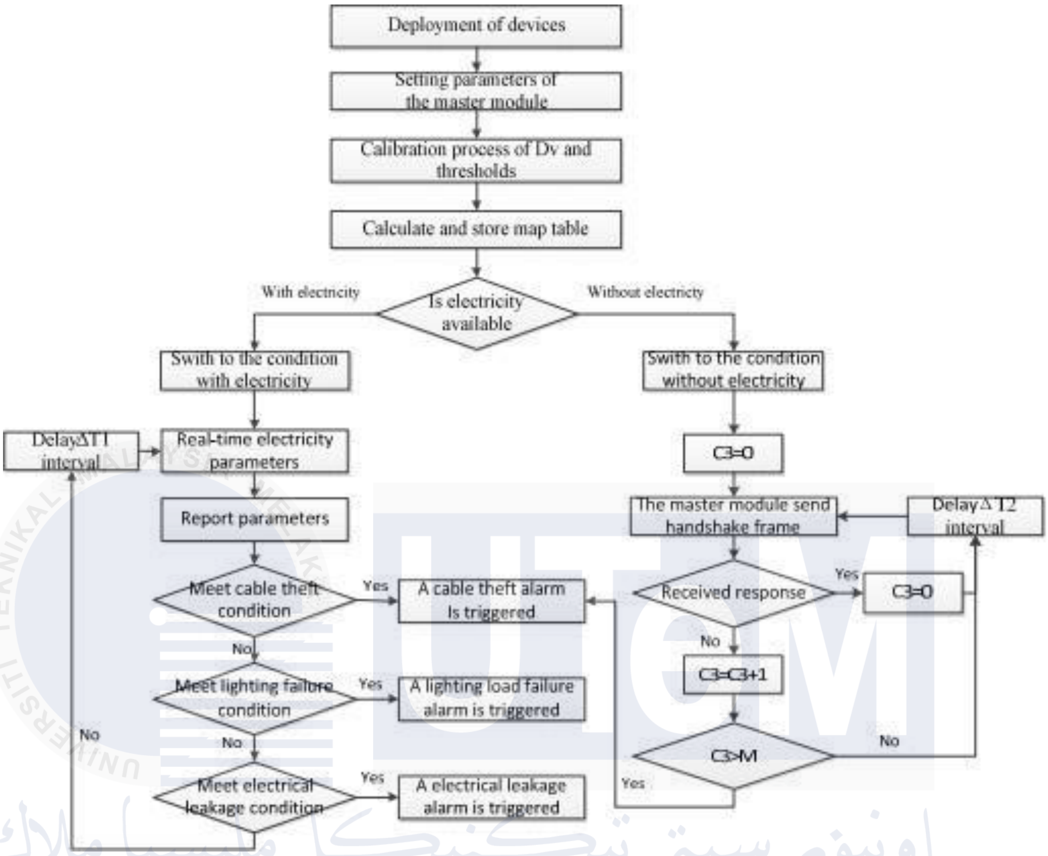

Figure 2-3 Process of cable theft detection [16].

A cable theft detection system for a distributed street lighting control system with IntelliSense employs sensors and advanced technology to detect any attempts to cut or tamper with street lighting cables. The system works by monitoring the street lighting network's voltage, current, and power usage and searching for any unexpected deviations that would indicate cable theft or manipulation.

The system's components include sensors, a data collection system, and a centralized control system. The sensors are used to assess the electrical properties of the network and are distributed throughout the length of the street lighting wires. The data that

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the data collecting system collects from the sensors is analyzed and used by the centrally controlled system to look for any anomalous changes in the network [17].

Using intelligent technologies like artificial intelligence and machine learning algorithms, the system evaluates the data and looks for any trends or irregularities that may indicate cable theft or tampering. When it notices a possible theft or tampering activity, the system may also be set up to alert the relevant authorities.

One advantage of a cable theft detection system for a distributed street lighting control system with intelligence is its high accuracy and reliability as well as its capacity to recognize various cable tampering approaches. It is also less prone to false alarms when compared to other types of cable theft detection systems [18].

However, there are considerable disadvantages to the approach. It could need significant hardware and software expenditures, as well as professional installation and maintenance skills.

2.2.2.3 Development of a Power Cable Anti-Theft and Monitoring System Base on PWM.

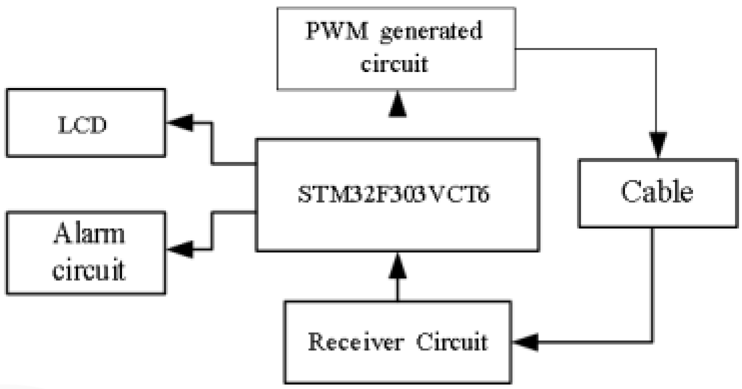

Figure 2-4 Architecture diagram of system [19].

As part of the creation of a power cable anti-theft and monitoring system, PWM technology is utilized to detect any attempts to cut or tamper with the power line. To run the system, a high-frequency signal is transmitted across the cable, and the reflected signal is then measured. When the cable is cut or tampered with, the signal that is reflected changes, and the system detects the change and activates an alert or warning.

The system's components include a PWM generator, a signal amplifier, a transmission line, and a signal receiver. The PWM generator produces a high- frequency signal, which the signal amplifier then amplifies and sends across the transmission line. The signal receiver receives the reflected signal and processes it to check for any signal changes. The system, which is designed to be put down the length of the power cord, has a PWM generator, signal amplifier, and signal receiver all at one end. The system can be powered by a battery or by the power line itself.

The advantages of a PWM-based power cable anti-theft and monitoring system are affordability, ease of installation, and the ability to detect various cable tampering methods.

It is also less prone to false alarms when compared to other types of cable theft detection systems.

However, there are considerable disadvantages to the approach. It might not work well in settings with a lot of background noise or interference, and it might not be able to pick up on subtle cuts or tampering attempts.

2.2.2.4 Electrical Parameter Monitoring Systems.

These systems detect cable theft by monitoring changes in electrical parameters such as current, voltage, and impedance. Sudden changes in these parameters can indicate a cable cut or theft.

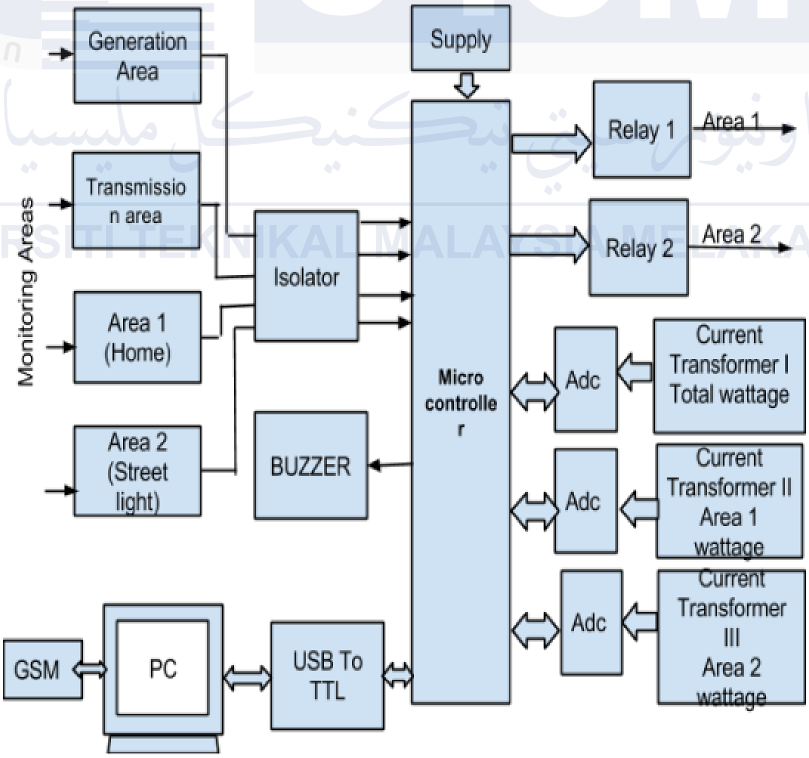

Figure 2-5 Block Diagram Power Theft Detection System [20].

2.2.2.5 Magnetic Field Detection Systems.

These systems detect changes in the magnetic field around the cable, which occur when the cable is cut or manipulated. Sensors placed along the cable route can detect changes in the magnetic field and trigger an alarm if significant deviations are observed.

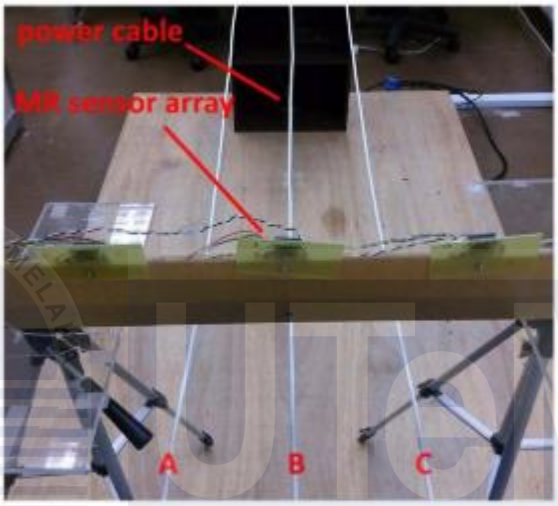

Figure 2-6 Laboratory setup

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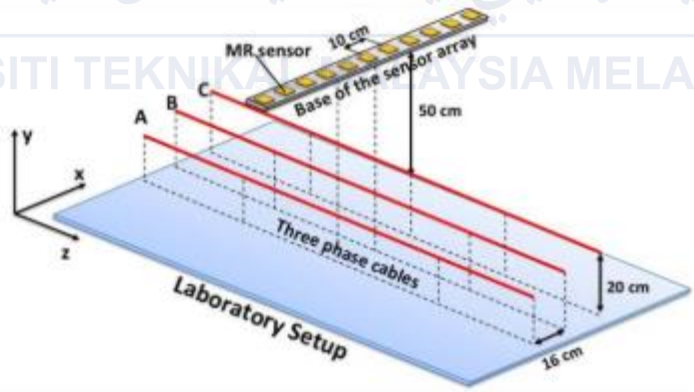

Figure 2-7 Schematic diagram of the laboratory setup.

Figure above are testbed including Magnetoresistive (MR) magnetic sensors and three-phase power cables for testing and verifying the detection and inspection technology [21].

2.2.2.6 RFID and LoRa-Based Systems.

RFID (Radio Frequency Identification) and LoRa (Long Range) technologies can be used for wireless monitoring and detection of cable theft. Placing RFID tags along the cable allows for periodic scanning and detection of any missing segments. While LoRa Technology modules can transmit data over long distances with low power consumption, making them ideal for monitoring infrastructure like street lighting.

2.3 Comparison between types of cable fault detection.

Table 2.1 Comparison fault detection.

Technique	Sensitivity	Implementation Complexity	Cost	Range	Application Examples
Current Monitoring	High	Medium	Low	Limited	Electrical grids, street lighting
Voltage Monitoring	Medium	Low	Low	Limited	Power distribution networks
Magnetic Field	High	High	Medium	Limited	Security systems
Impedance	High	High	High	Limited	High-value power lines
RFID	Medium	Medium	Medium	Limited	Secure installations
LoRa	Medium	Medium	Low	Long-range	Remote infrastructure monitoring
GSM Modem	Medium	Low	Medium	Wide-area	Remote monitoring systems
PWM	High	High	High	Limited	Industrial applications

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2.4 Summary

This chapter has reviewed the history of street lighting and various technological approaches to cable theft detection. It highlights the evolution from simple lighting methods to sophisticated systems integrating GSM modems, intelligent sensors, PWM technology, electrical parameter, magnetic field and RFID with LoRa-Based systems to enhance the security of street lighting infrastructure. Each method offers unique advantages, contributing to the development of a robust cable theft detection system using modern technologies. With the additional ideas included earlier, this project has been challenged to produce a more sophisticated and quality system, which is the result of a combination of LoRa, GSM and electrical parameters.

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CHAPTER 3

METHODOLOGY

3.1 Methodology

In this chapter, the format of the proposal will be covered. The research project's approach is explained in this chapter. The conceptual features of the software component, the hardware component, and the project implementation components are all covered in this chapter.

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3.2 Project Flow Chart

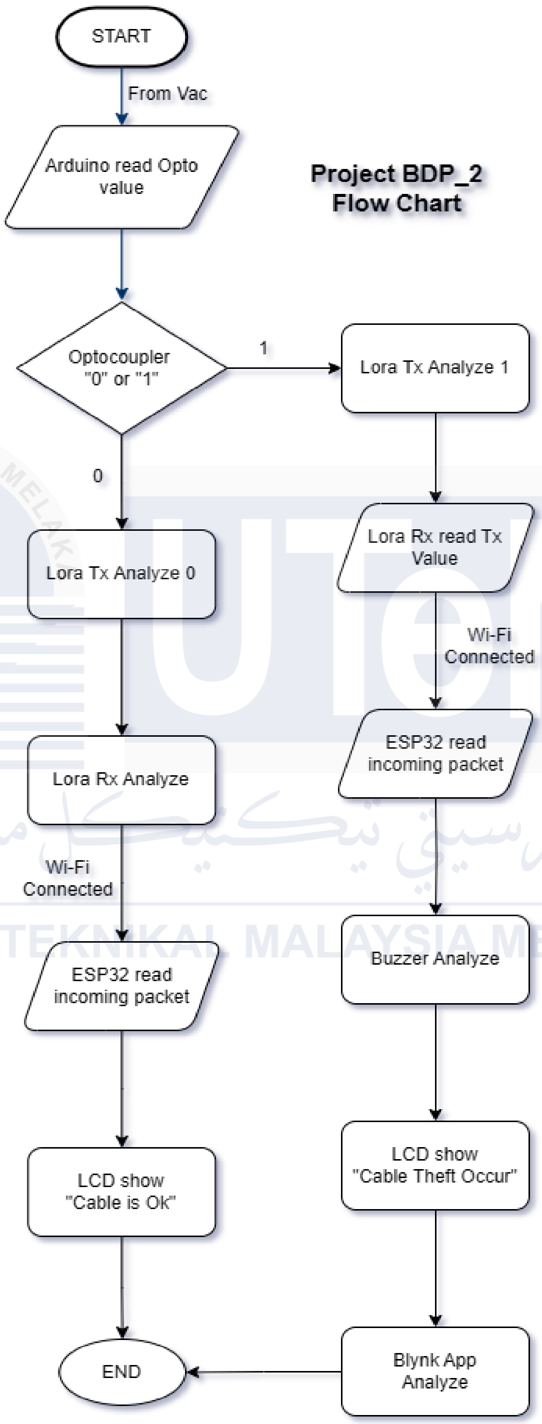

Figure 3-1 Full Project Flow Chart.

Figure 3-1 illustrates the approach flowchart, which has been divided down into three primary operations to accomplish the three goals of this research study. The optocoupler module circuit was first intended to detect the presence of AC power. Secondly, the optocoupler will be connected to the transmitter to construct the transmitter circuit. Lastly, receive by receiver circuit using Lora communication.

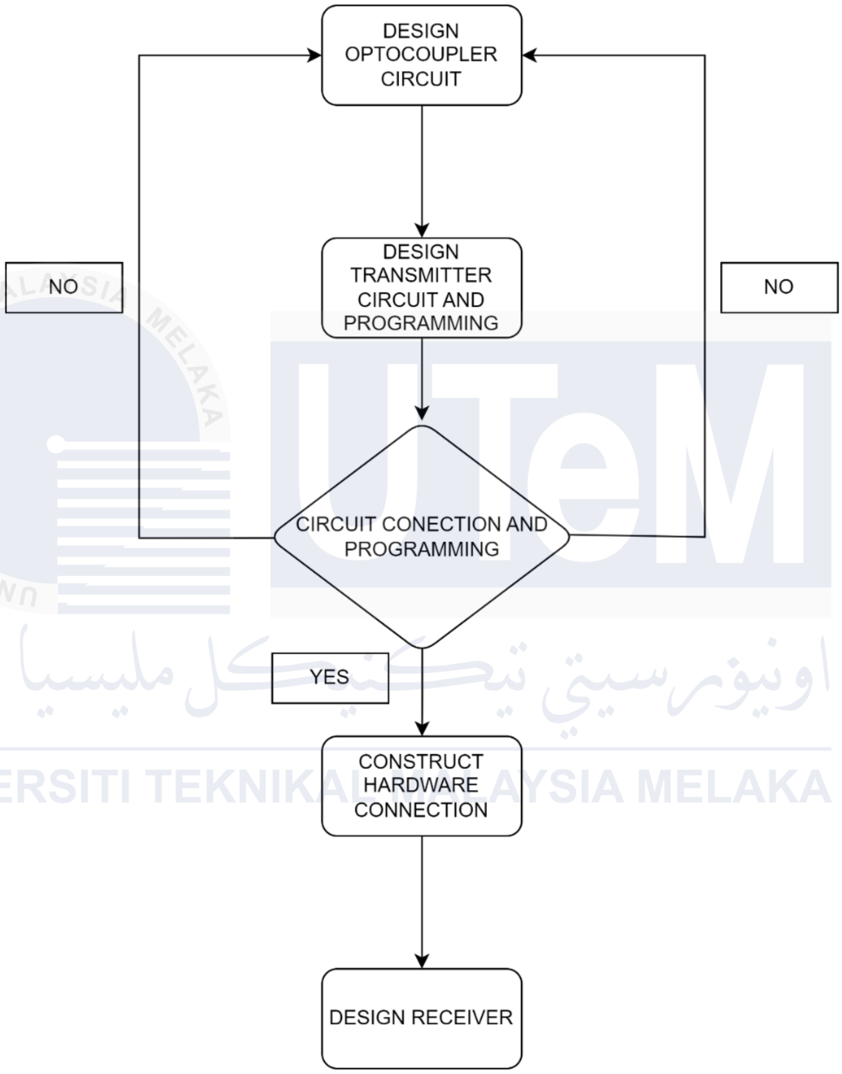

Figure 3-2 Optocoupler and transmitter circuit design flowchart.

Figure 3-2 provides a detailed explanation of the whole process used to create the optocoupler and transmitter circuit's hardware and software. Next, the Internet of Things (IoT) will be implemented by building the receiver circuit utilizing an ESP32 microcontroller.

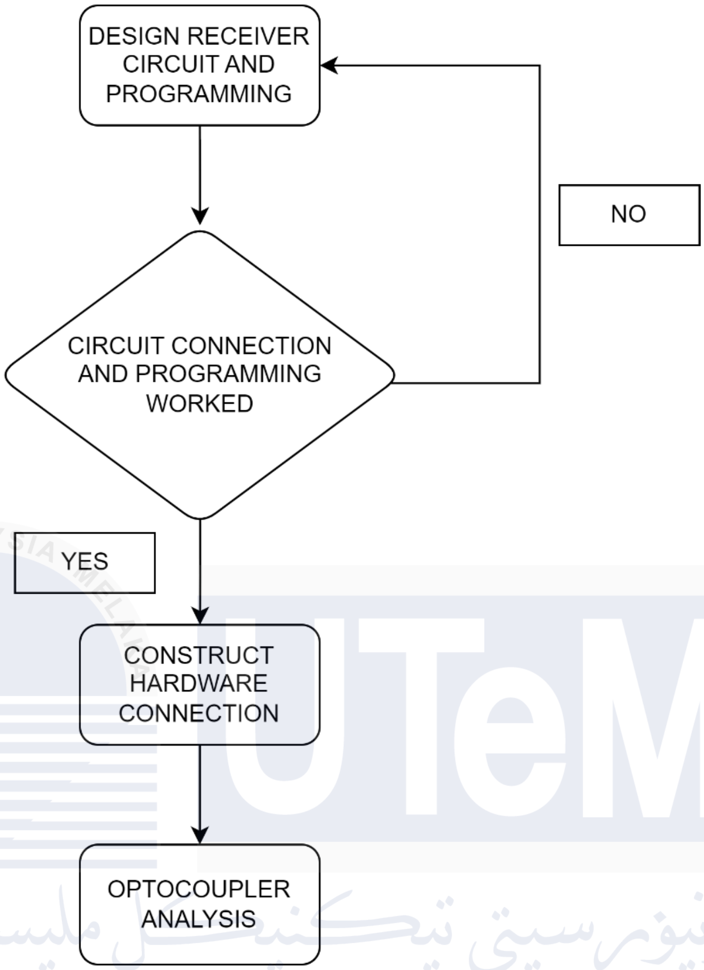

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Figure 3-3 Receiver circuit design flowchart.

Figure 3-3 is the receiver circuit that is designed to trigger an alert when cable theft happens or when the AC electricity is switched off. Describe more receiver circuit design operations and basic programming to locate the library of the component used.

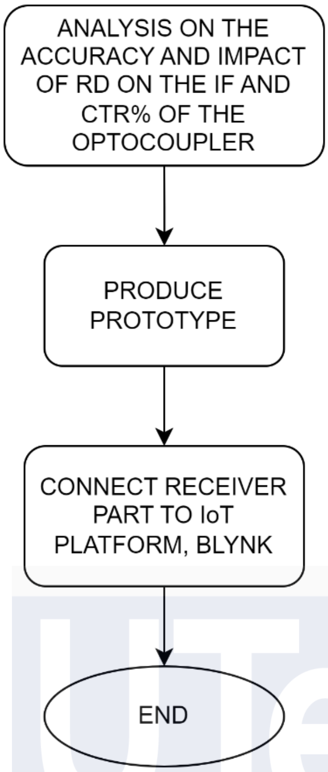

Figure 3-4 Analysis of optocoupler flowchart.

Figure 3-4 shows the analysis of the optocoupler component parameters' accuracy and the impact of limiting resistor (RD) on forward current (IF) and current transfer ratio (CTR%). Further information on the components that were utilized in the project and covering them in detail.

3.3 Software Used

Several different types of software have been utilized in the development of this project. The software is installed to provide various functionalities and instructions for the project's development. Proteus, the Blynk mobile application, and the Arduino IDE are the software used in this project.

3.3.1 Arduino IDE

The Arduino IDE software is essential for project development because it offers a straightforward and easy-to-use platform for interacting with and programming Arduino microcontrollers. Developers are able to control and modify different hardware components by writing, compiling, and uploading code to Arduino boards. The Arduino IDE offers a variety of built-in functions, libraries, and examples that simplify the development process. Furthermore, the Arduino IDE comes with a serial monitor that lets programmers interact with their Arduino boards, keep an eye on sensor data, and troubleshoot their code. All things considered, the Arduino IDE software simplifies the project development process by providing a full range of resources and tools for programming and communicating with Arduino microcontrollers.

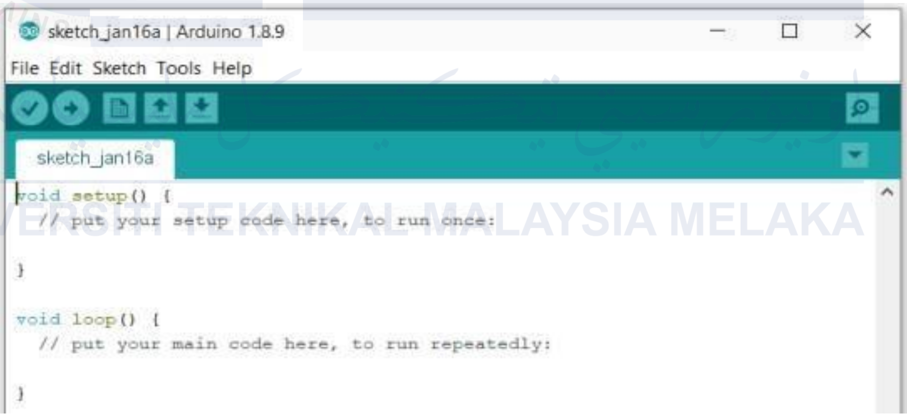

Figure 3-5 Arduino IDE workspace.

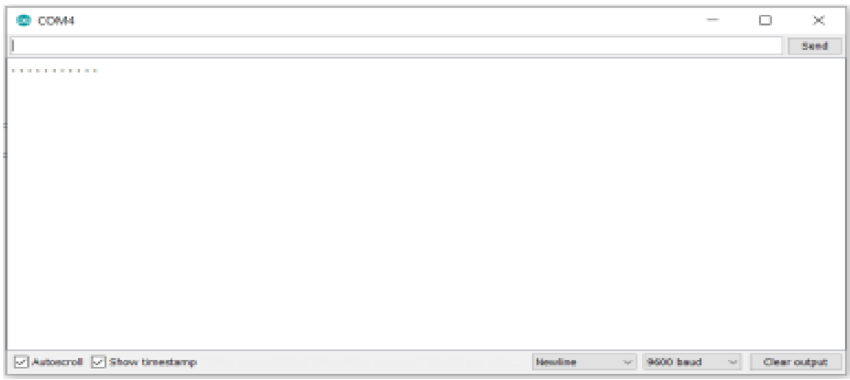

Figure 3-6 Serial monitoring of Arduino IDE.

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3.3.2 Proteus

An electronic circuit or system may be designed, simulated, and tested using software called Proteus. Before implementing circuit designs in actual hardware, users can construct and analyze them in a virtual environment. Microcontrollers, sensors, and other electrical devices are just a few of the many components that Proteus offers. These components are readily used in circuit designs. Before moving on with the actual implementation, users may test the circuit's functionality, simulate its behavior, and debug any possible faults using the program. Proteus is a useful tool for engineers, students, and enthusiasts working on electronic projects because of its extensive simulation capabilities [22].

There are many sections in the library of ISIS. Sources, signal generators, switches, displays, loads like motors and lamps, discrete components like resistors, capacitors, inductors, and transformers, semi-conductor switches, relays, microcontrollers, processors, sensors, and more are all included. Probes for real-time monitoring of circuit parameters are also included.

ARES offers through-hole and surface mount PCB designs with a maximum of 14 inner layers. It has the imprints of several discrete component types, including headers, connectors, transistors, ICs, and others. The routing methods available to the PCB Designer are both automated and manual. The ISIS design may be directly translated to ARES, which includes microcontrollers, microcontrollers, sensors, and other components.

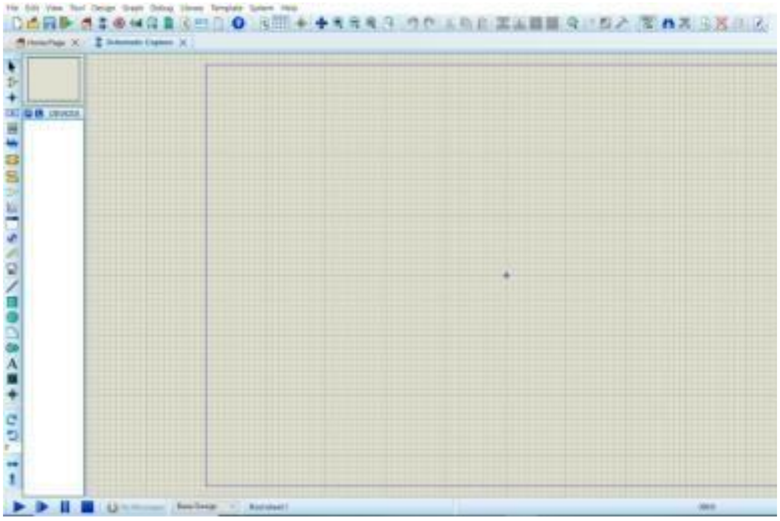

Figure 3-7 ISIS schematic interface.

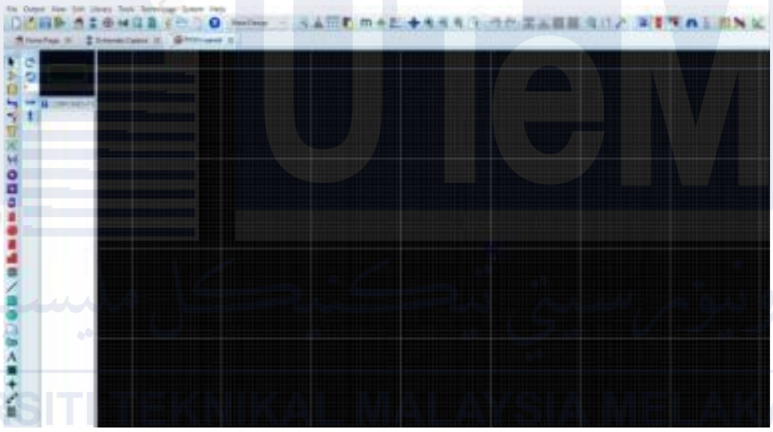

Figure 3-8 ARES schematic interface.

3.3.3 Blynk Application

Arduino, Raspberry Pi, and NodeMCU devices may be controlled online with the Blynk app, an Internet of Things platform for iOS and Android smartphones. By gathering and providing the appropriate widget address, this program generates a graphical user interface (GUI) or human machine interaction (HMI). The program may be used to do a variety of tasks, including storing and visualizing data, presenting sensor data, and remotely managing devices. The three primary parts of this platform are Blynk App, Blynk Server, and Blynk Libraries. This makes it possible to create excellent project interfaces by employing a variety of available application widget kinds. Every kind of communication between devices, from smartphones to hardware connectivity, is managed by the Blynk Server function. It works well with many different devices and is a free source. Lastly, libraries handle all incoming and outgoing instructions and provide server communication for all popular hardware platforms.

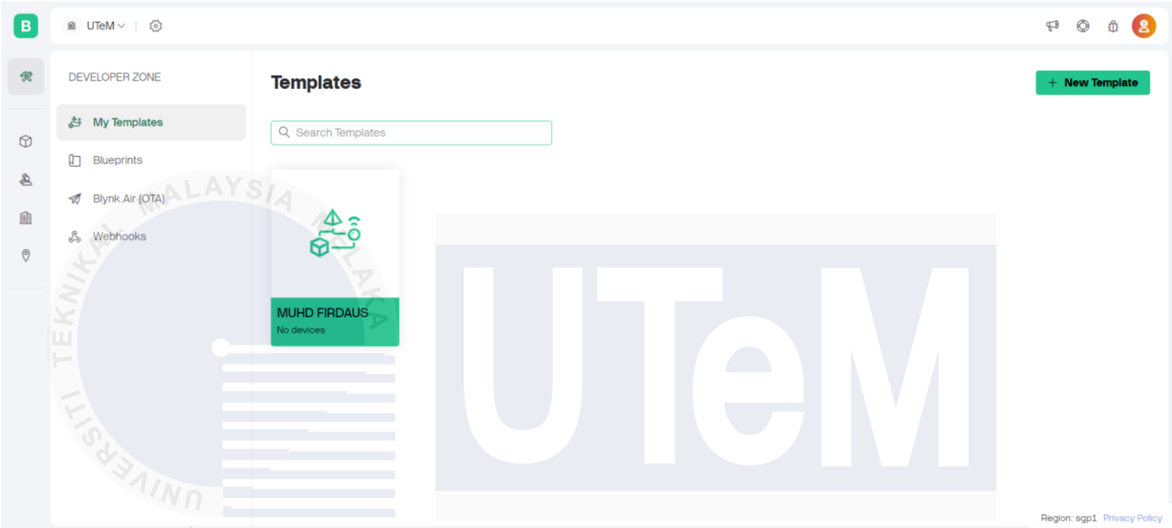

Figure 3-9 Blynk dashboard on PC.

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3.4 Electrical Hardware Design

In this subsection, the design of electronics is explained. In order to detect cable theft, the optocoupler PC817 requires an electronic system that can detect the presenceof AC voltage. Three primary blocks will be used in this project: the optocoupler module, the transmitter block, and the receiver block.

3.4.1 Optocoupler Module Design Illustration

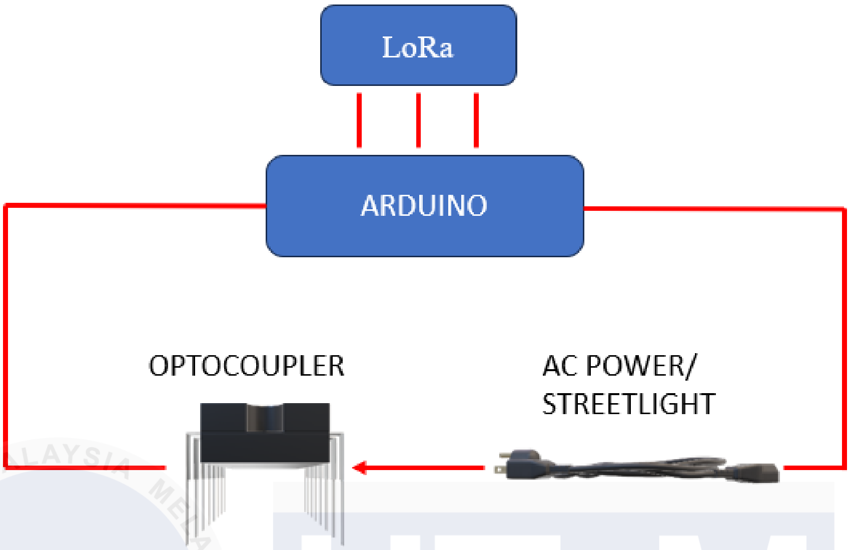

Figure 3-10 Optocoupler block diagram illustration.

In this project, optocoupler circuit will act as the AC voltage sensor. To develop the optocoupler circuit, PC 817 SHARP has been used. One popular optocoupler that may be used to detect 240 VAC (alternating current) is the PC817. A phototransistor and light emitting diode are optically connected in the PC817. Its lowest CTR is 50% at an input current of 5 mA, and its input-output isolation voltage is 5000Vrms. Two 1N4007 diodes, which provide the rectifier configuration for converting the AC power into DC voltage, were located on the LED side of the optocoupler module. To smooth the signal, the input capacitor (Cin) was employed at 470uF. 33k ohm was used as the limiting resistor (RD) to generate 7.24mA for the forward current (IF). In contrast, the transistor side of the optocoupler was composed of a 10k pull-up resistor (RL) and an output capacitor (Cout) of 10uF. To get the collector current (IC) to be 0.33 mA, the RL value was selected. For the PC817 optocoupler, the RD and RL were methodically constructed to achieve a current transfer ratio (CTR%) of around 50%.

3.4.2 Optocoupler Circuit Design Using Proteus

After the circuit has been finalized in the form of block diagram, the circuit is continued to be redrawn in the Proteus software accordingly to all specifications require for every component so that the circuit could work and give the expected output later. The circuit must be rectified by two diodes, preferably 1N4007, in order to convert the AC voltage into DC voltage because the optocoupler must perceive the 240 AC voltage. The optocoupler's LED side was equipped with a 33kΩ resistor in order to supply 7.24mA for the forward current (I_F), or the current passing through the LED. The collector current (I_C) was set to 0.33mA by setting the pull-up resistor (R_L)to 10kΩ. Since the PC817 is able to operate at the minimum 50% CTR value at 5mA, the forward current (I_F) and collector current (I_C) values will then be used to construct the current transfer ratio (CTR%) approximation by 50%. The CTR value inthis circuit is 46%. The components list and circuit design are shown in Table 3.1 and Figure 3-11.

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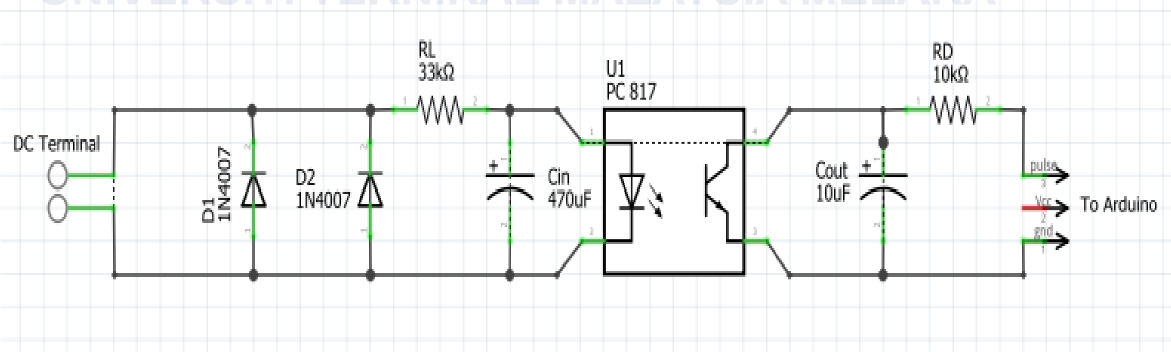

Figure 3-11 Optocoupler circuit module design using Fritzing [23].

Table 3.1 List of component for optocoupler module.

No	Components	Quantity
1	Optocoupler PC817	1
2	1N4007 Diode	2
3	33kΩ (RD)	1
4	10kΩ (RL)	1
5	10µF Cout	1
6	470µF Cin	1

3.4.3 Optocoupler Circuit Design and Fabrication

There were two types of drawing that needed to be done in the Proteus software. First was the standard configuration of the circuit while the other one was layout of the circuit that will be printed on the UV board. Component connections between these two circuits are intertwined in a manner so critical that a single mistake might cause the entire circuit to malfunction, or worse, stop working altogether. So, every connection was configured carefully to each end before developing the PCB layout afterwards. The circuit layout design in Proteus is shown in Figure 3-12 and Figure 3-13 below with their respective labels [24].

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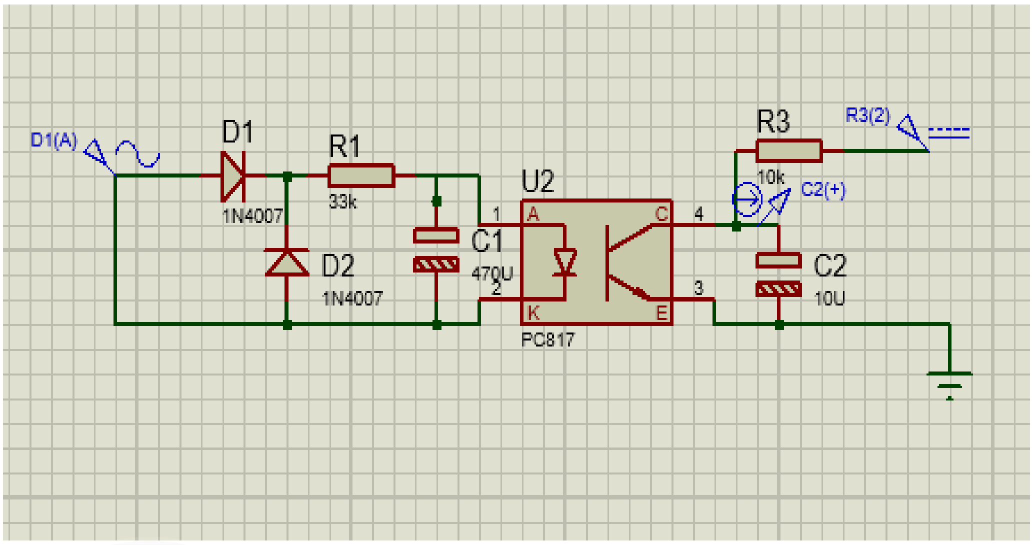

Figure 3-12 Schematic diagram for the optocoupler module

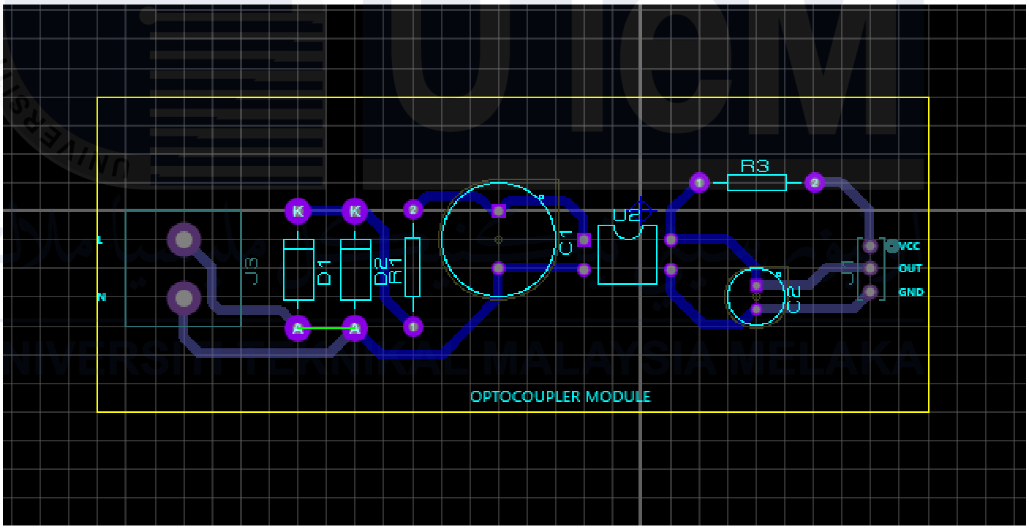

Figure 3-13 PCB layout of the optocoupler module

3.4.4 Transmitter Components Design

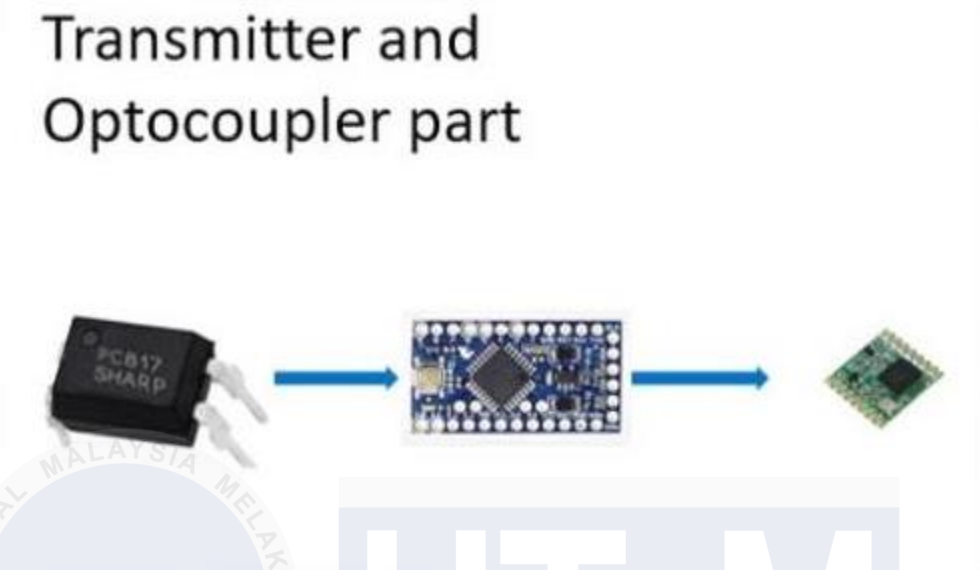

Figure 3-14 Transmitter components.

The transmitter block was composed of an optocoupler module, an Arduino Pro Mini 3.3V, and a LoRa RFM 95. After getting the digital output from the optocoupler module, the transmitter is configured to send the data to the receiver block. The optocoupler and LoRa RFM 95 could be powered by the Arduino Pro Mini's 3.3V VCC supply. This project is a good fit for LoRa RFM 95 as it can send and receive data over long distances.

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Table 3.2 Optocoupler I/O pin configuration.

Optocoupler Module	Arduino Pro Mini 3.3V
V+	3.3V
GND	GND
Po	D6

Table 3.3 LoRa RFM 95 I/O configuration.

LoRa RFM 95	**Arduino Pro Mini 3.3V**
3.3V	VCC
GND	GND
DIO 0	D2
MISO	D12
MOSI	D11
SCK	D13
NSS	D10
RESET	D9

3.4.5 Receiver Components Design

Figure 3-15 Receiver components.

The receiver block is a crucial part of the project as it has to be able to transmit digital data and generate alerts on the Blynk application. The receiver block will consist of the LCD I2C, ESP 32 microcontroller. LoRa RFM 95, and buzzer. After the transmitter

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transmits data, the receiver receives it and sends it to the Blynk IoT platform. The Wi- Fi module that the ESP 32 provides will enable communication between the receiver and the IoT platform. The buzzer will then sound either when the AC power is switched off or when the digital output is set to "1."

The optocoupler's digital output, which indicates the cable state, will be shown on the LCD. When the digital output is received as "0," the LCD will display "cable is okay," and when the digital output is obtained as "1," it will display "theft detected." When the digital output is set to "1," the Blynk application allows users to monitor their data on the dashboard and send warning notifications via email and mobile Blynk console.

Table 3.4 LCD 12C I/O pin configuration.

LCD I2C	**ESP 32**
VCC	3.3V
GND	GND
SDA	D21
SCL	D22

Table 3.5 Buzzer I/O pin configuration.

Buzzer	**ESP 32**
INPUT	D26
GND	GND

Table 3.6 LoRa RFM 95 I/O configuration on ESP 32.

LoRa RFM 95	ESP 32
3.3V	3.3V
GND	GND
DIO 0	D2
MISO	D19
MOSI	D23
SCK	D18
NSS	D5
RESET	D14

3.4.6 LoRa Based Cable Theft Detection System IoT Integration Process

The optocoupler module is used in this project to identify possible cable theft by detecting when the AC power is switched off. The aim is to produce a cautionary message and distribute it using email and an Internet of Things platform. In order to accomplish this, the optocoupler module is connected to the Wi-Fi application Blynk via the ESP32 board. This functionality's necessary coding is created and put into use.The details are in Figure 3-16.

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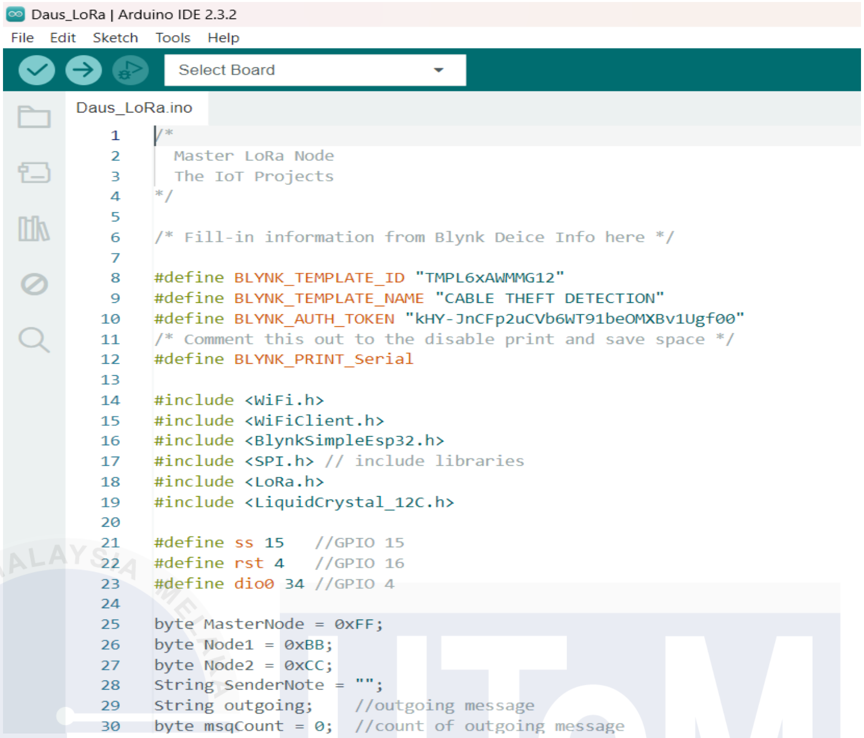

Figure 3-16 Declaration and define line code in Arduino IDE.

After the code had been developed successfully, it was uploaded to the ESP32 microcontroller, which allowed it to connect to the Blynk application. The dashboard involved in the Blynk program is used to show cable status for monitoring purposes. There is a visual depiction in the figure below.

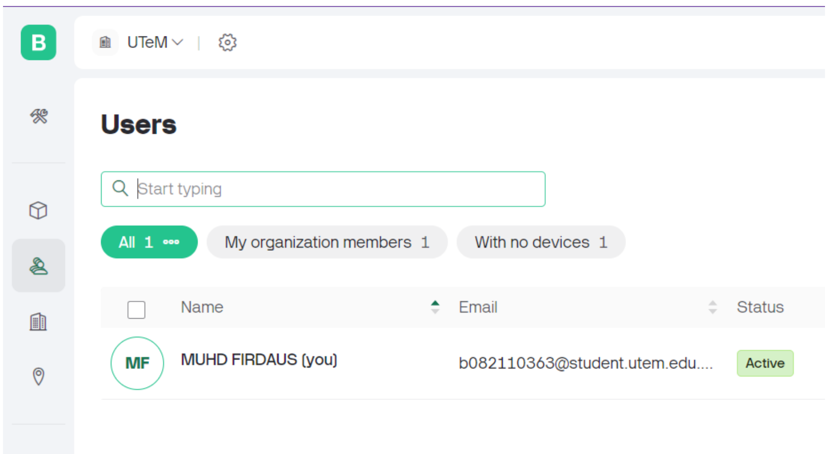

Figure 3-17 Cable theft detection status on Blynk dashboard.

3.5 Lists of Components

The parts utilized in this project, such as the 3.3V Arduino Pro Mini and ESP32 microcontrollers, will be covered in this section. There will also be discussion of other parts, like the LoRa RFM95 module and a buzzer.

3.5.1 Arduino UNO

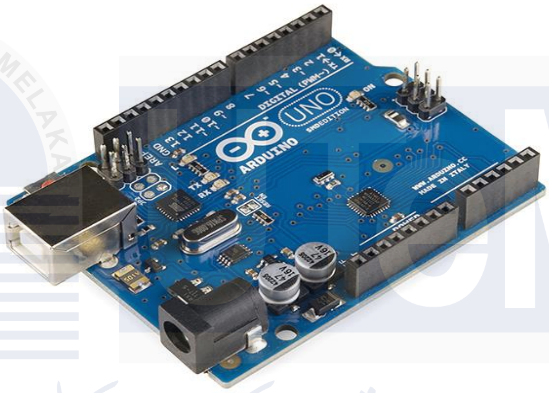

Figure 3-18 Arduino UNO.

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The Atmega328P chip is used in an Arduino Uno microcontroller board. It is a versatile and widely-used development board designed for general-purpose applications and rapid prototyping. The Arduino Uno includes built-in USB connectivity and an onboard voltage regulator, making it user-friendly and suitable for projects that require a direct USB connection for programming and power.

The Arduino Uno board contains a 16 MHz quartz crystal, 6 analog inputs, and 14 digital input/output ports. Additionally, it features an onboard USB-to-serial converter, allowing it to connect to a computer without the need for external components. The board can be programmed using the Arduino IDE, and it supports serial communication protocols such as I2C, SPI, and UART for interfacing with other hardware.

One of the Uno board's defining characteristics is its ease of use, which makes it a popular choice for educational purposes and prototyping. The board operates at 5V but can accept input voltages ranging from 7V to 12V through its barrel jack or 5V via USB, offering flexibility in power sources. It is frequently used in robotics, home automation, IoT, and interactive art projects. Its slightly larger size allows for more onboard features, making it a robust and beginner-friendly platform for a wide range of applications.

The Arduino Uno is an excellent choice for projects that prioritize ease of use, compatibility, and expandability. Its additional features and built-in USB connectivity make it particularly suitable for desktop-based development and applications where accessibility and convenience are essential [25].

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3.5.2 ESP32 Module

Figure 3-19 ESP32 module.

The ESP32 module's processing power, wireless connectivity options, memory configurations, GPIO pins, analog-to-digital conversion capabilities, and low-power consumption make it a compelling choice for developers creating innovative and efficient

IoT devices. Its affordability, ease of use, versatility, and growing community support further solidify its position as a leading microcontroller platform for the ever-evolving Internet of Things landscape.

The ESP32 microcontroller is particularly well-suited due to its ultra-low-power consumption capabilities. This is achieved through several features including dynamic power scaling, multiple power modes, and fine-grained clock gating. These features allow the ESP32 to be configured for minimal power usage in scenarios like sensor hubs where data collection only needs to occur in response to specific events. Additionally, a low-duty cycle operation can further reduce power consumption. The power amplifier output can also be adjusted to strike a balance between power usage, data transmission speed, and communication range.

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Beyond its low-power features, the ESP32 boasts a high level of integration, requiring only around 20 external components for Wi-Fi and Bluetooth IoT applications. This is because the ESP32 incorporates various components on-chip, including antenna switch, RF balun, power amplifier, low noise receive amplifier, and filters. This integration translates to a smaller required Printed Circuit Board (PCB) footprint. Furthermore, the ESP32's single-chip, fully integrated radio and baseband utilizes CMOS technology and sophisticated calibration circuits. These features eliminate the need for external circuit adjustments and compensate for environmental changes, ultimately reducing the need for expensive and specialized Wi-Fi testing equipment during mass production of ESP32-based products [25], [26].

3.5.3 Buzzer

Figure 3-20 Buzzer.

The addition of sound characteristics to this project or system may be accomplished with the help of a buzzer, which is a compact yet effective component. Due to the fact that it has a very small and compact 2-pin construction, it can be readily utilized on breadboard, Preboard, and even on PCBs. Because of this, it is a component that is commonly employed in many electronic applications.

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There are two main types of buzzers available for purchase. The buzzer that can see here is a basic design that, when used, emits a constant beweeps sound. The second kind, called a preset buzzer, will be bigger than this one and sound a Beep. It emits a beep. It had an oscillating circuit within, which is why sound was emanating from it. However, the one displayed here is the one that is most frequently used since it is simple to modify with the assistance of other circuits to fit into our application.

For this project, a DC power source with a voltage range of 4V to 9V is needed for the buzzer. Instead of using a 9V battery, it is advised to utilize a controlled +5V or +6V DC supply. Usually, the buzzer is wired to a switching circuit so that it can be turned on and off as needed [27].

3.5.4 RFM95 – Low Power Long Range Transceiver Module

Figure 3-21 LoRa RFM95 module.

Based on the image above, the module is an RFM95W LoRa radio frequency transceiver module. It is designed for wireless communication applications and is particularly well-suited for long-range, low-power transmissions. Here's a breakdown of its key features:

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a) LoRa Technology: This module utilizes LoRa, a proprietary modulation technique specifically developed for low-power, long-range communication. LoRa enables extended range and improved resistance to interference compared to traditional modulation schemes.

b) Radio Frequency (RF) Transceiver: The RFM95W module functions as both a transmitter and receiver, allowing it to send and receive data wirelessly. It operates in license-free ISM (Industrial, Scientific, and Medical) bands, typically around 868 MHz or 915 MHz depending on the region.

c) Low-Power Consumption: One of the significant advantages of LoRa technology is its power efficiency. The RFM95W module is optimized for low-power operation, making it suitable for battery-powered applications where extending battery life is crucial.

d) Range: Depending on various factors like signal strength, antenna configuration, and environmental conditions, the RFM95W module can achieve communication ranges exceeding 2 kilometers with basic setups. In ideal conditions, the range can be even greater.

e) Simple Interface: The RFM95W module typically uses a Serial Peripheral Interface (SPI) for communication with a microcontroller, simplifying integration into various development boards and projects.

f) Applications: Due to its long-range and low-power features, the RFM95W module finds applications in various scenarios, including:

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- Smart agriculture: Sensor data collection from remote fields
- Industrial automation: Wireless communication in industrial settings
- Smart metering: Data transmission from utility meters
- Remote monitoring: Environmental monitoring in remote locations
- Asset tracking: Tracking the location of objects over long distances

Overall, the RFM95W LoRa radio frequency transceiver module offers a compelling solution for developers working on low-power, long-range wireless communication projects across diverse applications [28], [29], .

3.6 Summary

This chapter lays out the plan for how the research will be conducted. The overall approach is broken down into three main steps. The first step involves designing a circuit with an optocoupler module that can both detect AC power and connect to a transmitter. The second step details how to build both the optocoupler and transmitter circuits, including hardware and software components. Finally, the third step focuses on the receiver circuit, built with an ESP32 microcontroller. This receiver circuit will be designed to trigger alerts for cable theft or power outages, analyze the action of optocoupler components, and explore how Lora can transmit and receive in various condition. The chapter also covers the specific components used and their functions, along with a general overview of the project's software, hardware, and implementation.

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CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter explains in detail the analysis process of the proposed LoRa Based Cable Theft Detection System for Street Lighting in order to achieve the three objectives of this research work. First, to design and develop a cable theft detection system for street lighting using Lora. This project's also implement an Internet of Things (IoT) on the system and display simple digital output of the optocoupler data on IoT dashboard, which indicates whether cable theft is taking place. Lastly, to determine how well the cable theft system performs overall in terms of distance and battery consumption. These parameter data will be gathered, and the results will be analyzed.

4.2 Software Design

The software designed was made by an online website called Proteus Simulation. The hardware can be built and run or tested directly via online if it has an Internet connection. The main components that must be available are the Microcontroller, Arduino UNO, optocoupler PC817 and Lora RFM915 for transmit circuit. For the receiver circuit is ESP32, Lora RFM915, buzzer, LCD I2C. The Figure 4-1 and Figure 4-2 shows the simulation diagram.

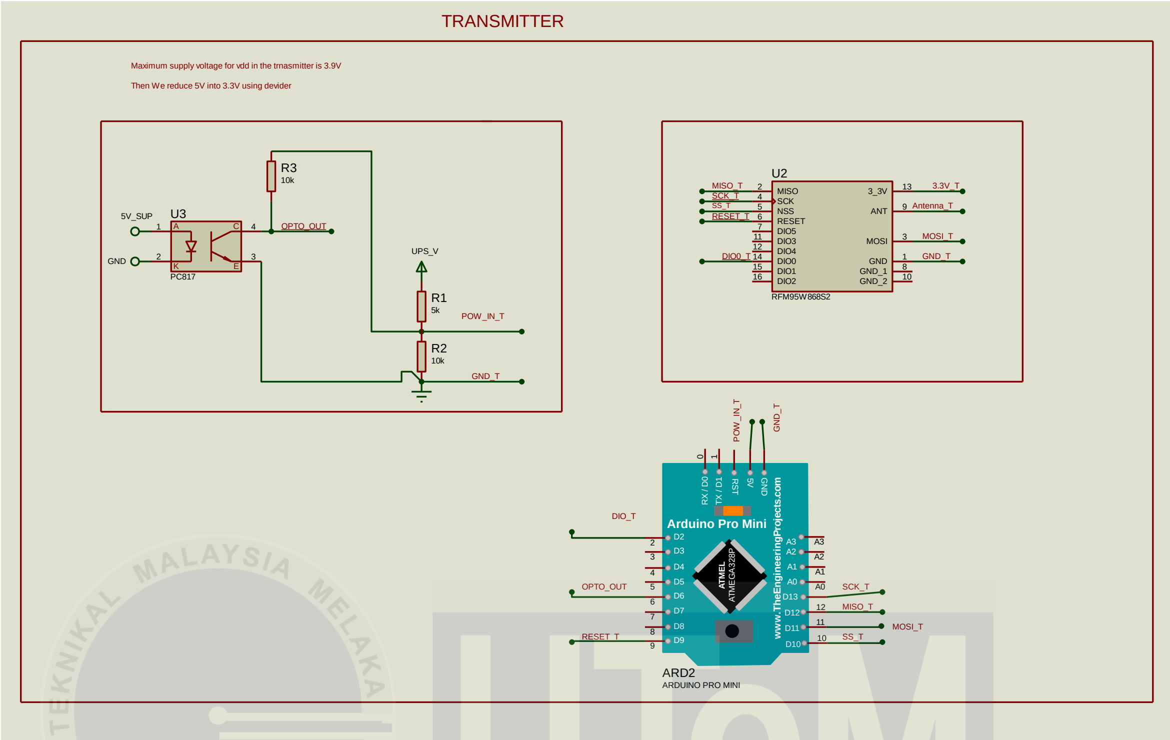

Figure 4-1 Transmitter Simulation

At the top left from the simulation above is a optocoupler circuit with some protection such as diod, resistor and capacitor. The protection used to step down the voltage followed the specification for arduino to receive. Arduino will analyze the present of incoming data from optocoupler then transmit the data to receiver circuit using Lora Tx communication.

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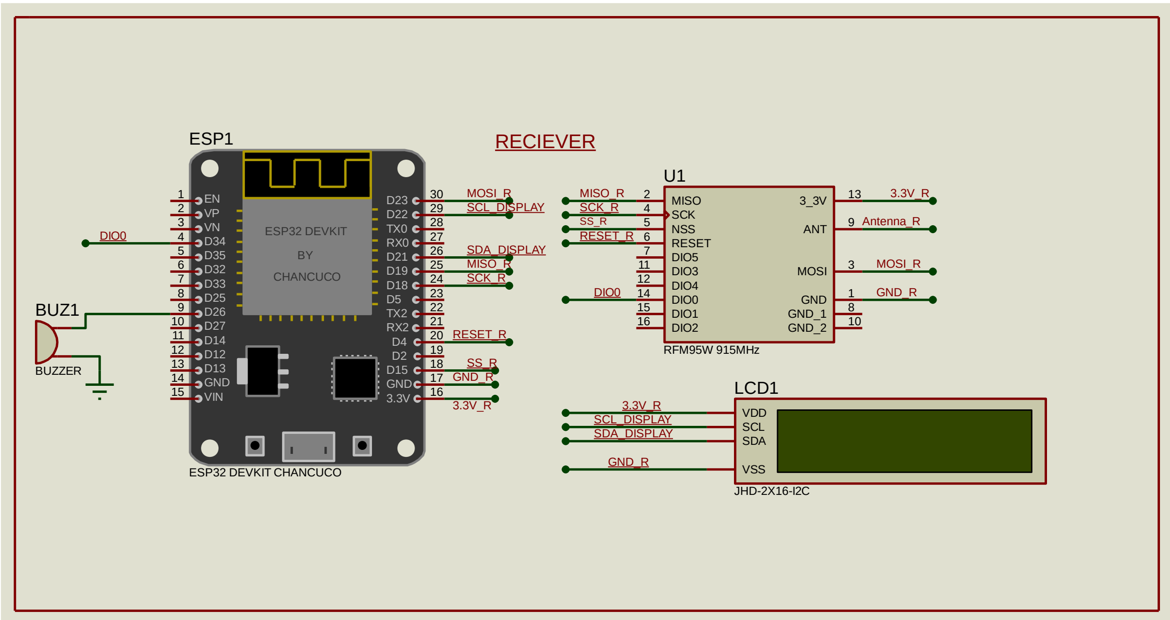

Figure 4-2 Receiver Simulation

In receiver part, Lora Rx communication will analyze by ESP 32 to active the buzzer, LCD and Blynk. LCD will show either the condition of cable is in good condition or not. Blynk application will function when ESP 32 are connected to the same internet.

4.3 Hardware Design

This system aims to improve a safety for overhead or underground cable by adding a touch of IoT, ensuring it to easier monitoring. If the Cable theft was detected, Blynk console will operate to show the data.

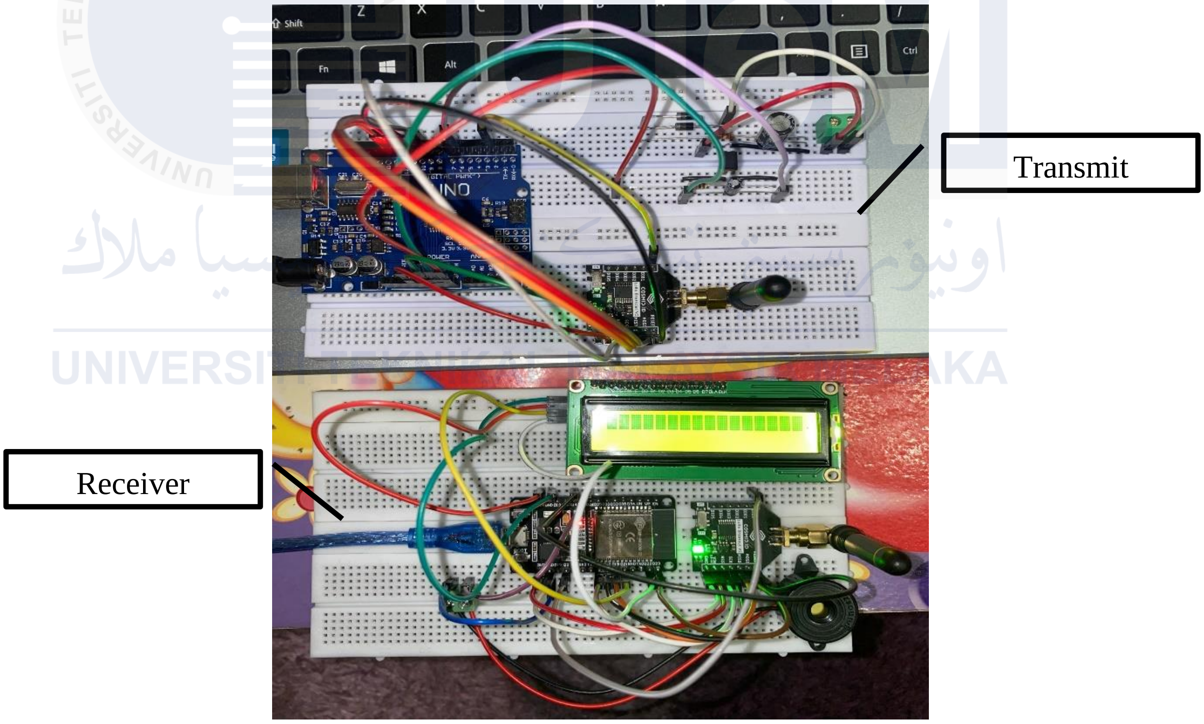

Figure 4-3 The Hardware of the syatem

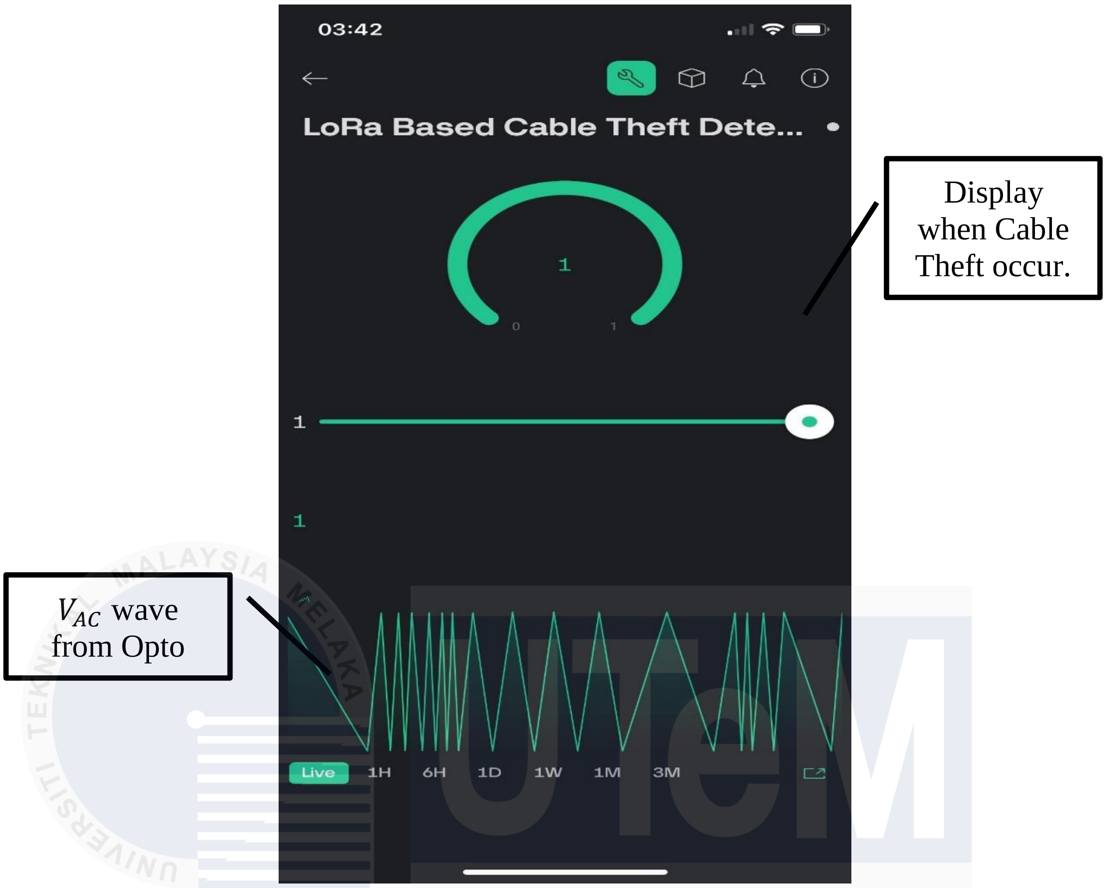

Figure 4-4 The interface of Blynk apps

4.4 Arduino Instruction

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The coding for this project utilizes the Arduino Integrated Development Environment (IDE) software. Most modern operating systems provide support for this open source programming language, which is based on C and C++. A comprehensive understanding of the C++ programming language is essential for effectively modifying programming instructions. The microcontroller employed in this project is the ESP8266 Wi Fi shield. It was specifically chosen due to its enhanced capabilities compared to the Arduino UNO. Notably, it possesses a comparable number of analog and digital input pins. The following Arduino code is utilized to simulate the Proteus software. This Arduino code is responsible for providing instructions to various components, including the optocoupler, buzzer, LCD, Lora, enabling them to operate according to the predetermined plan.

Figure 4-5 Transmit Code

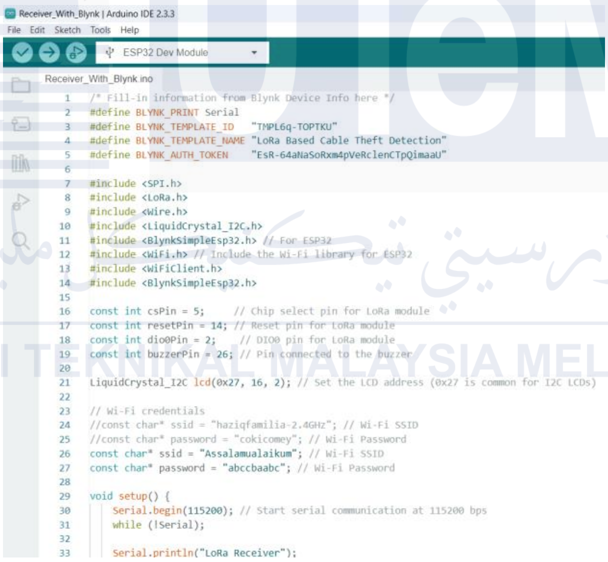

Figure 4-6 Receiver Code

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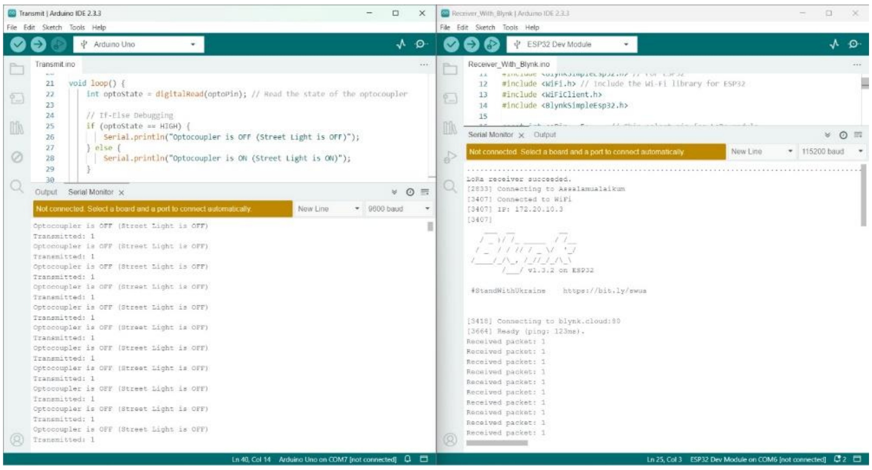

Figure 4-7 Both serial monitor output

4.5 Results and Analysis

4.5.1 Optocoupler

Pull-up resistors (RL) and limit resistors (RD) are both commonly used electronic components that serve distinct purposes in circuits. Here's a breakdown of their individual functions:

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Pull-Up Resistor (RL):

a) Function: A pull-up resistor provides a default high logic level (usually connected to the positive voltage rail) to an input pin of a digital integrated circuit (IC) like a microcontroller.

b) Purpose:

- Prevents floating inputs: Without a pull-up resistor, an input pin can be left in an indeterminate state (neither high nor low) due to leakage currents or external noise. This can lead to unpredictable behavior in the circuit.

- Defines default state: By connecting the input pin to a high logic level through the resistor, the pull-up resistor defines a known default state for the input. This simplifies circuit design and ensures consistent operation.
- Value selection: The value of the pull-up resistor needs to be chosen carefully. It should be high enough to ensure a clear high logic level for the input pin but low enough to limit current consumption. Typical values for pull-up resistors range from 1 kΩ to 100 kΩ.

Limit Resistor (RD):

a) Function: A limit resistor is used to limit the current flowing through a component in a circuit.

b) Purpose:

- Current protection: Limit resistors prevent excessive current from flowing through a component, protecting it from damage. This is crucial for components with current limitations, such as LEDs or optocouplers.
- Voltage control: In some cases, limit resistors can also help regulate the voltage across a component by influencing the current flow.
- Value selection: The value of the limit resistor depends on several factors, including:
- Operating voltage: The voltage supply of the circuit needs to be considered.
- Component specifications: The current rating of the component being protected dictates the required current limitation.
- Desired brightness (for LEDs): The value of the limit resistor affects the brightness of LEDs.

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Key Differences:

a) Location: Pull-up resistors are typically connected between an input pin and the positive voltage rail, while limit resistors can be found in various locations within a circuit depending on the component they are protecting or the voltage they are controlling.
b) Function: Pull-up resistors define a default state for inputs, while limit resistors control current flow through components.

From this analysis, the limiting resistor (RD) will be changed in this experiment to analyze the optocoupler's accuracy. The resistance values of the limiting resistors (RD) that will be tested are 33k ohm, 100k ohm, and 220k ohm. Figure 4-1 and table 4.1 illustrate the various values of the pull-up resistor (RL) and limiting resistor (RD) that will be analyzed.

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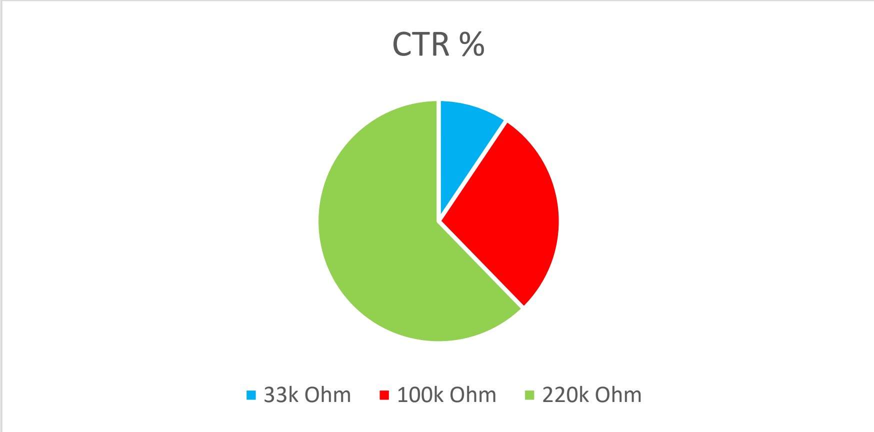
Table 4.1 The variation of components and characteristics.

R_D Value	R_L Value	CTR %	I_F (mA)
33k Ohm	10k Ohm	46	7.24
100k Ohm	10k Ohm	138.2	2.388
220k Ohm	10k Ohm	304.15	1.085



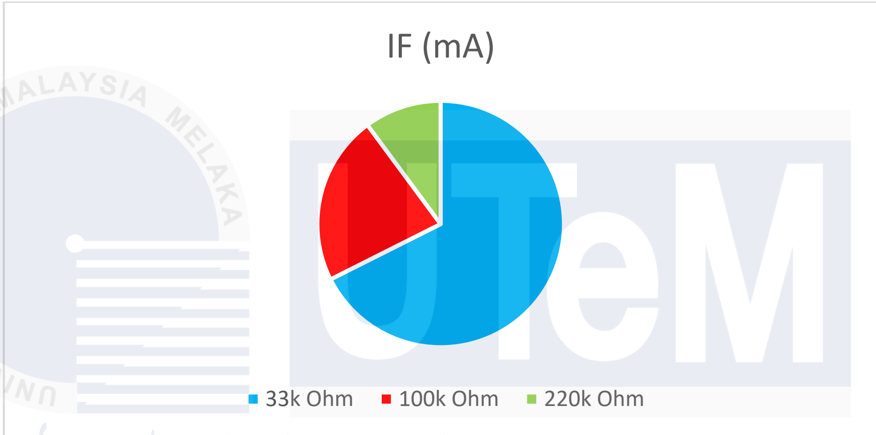


Figure 4-8 Result for CT.

This result used to know the exact safety for optocoupler to receive 240Vac from street lighting and the safer for Arduino UNO to receive between 0-5V from output of optocoupler. The pie chart illustrates the Current Transfer Ratio (CTR) and Forward Current (IF) for an optocoupler circuit using different resistor values: 33kOhm, 10kOhm, and 22kOhm. The CTR (%) section of the chart shows the efficiency of the optocoupler in transferring current from the input to the output, with each resistor value contributing to varying levels of performance. The IF (mA) section represents the forward current required to achieve optimal operation, highlighting how different resistor values impact the current flow through the optocoupler. This data is crucial for understanding the relationship between resistor values, CTR, and IF, which helps in optimizing the optocoupler's sensitivity and accuracy in detecting cable theft for the LoRa-based system.

4.5.2 LoRa Range Test

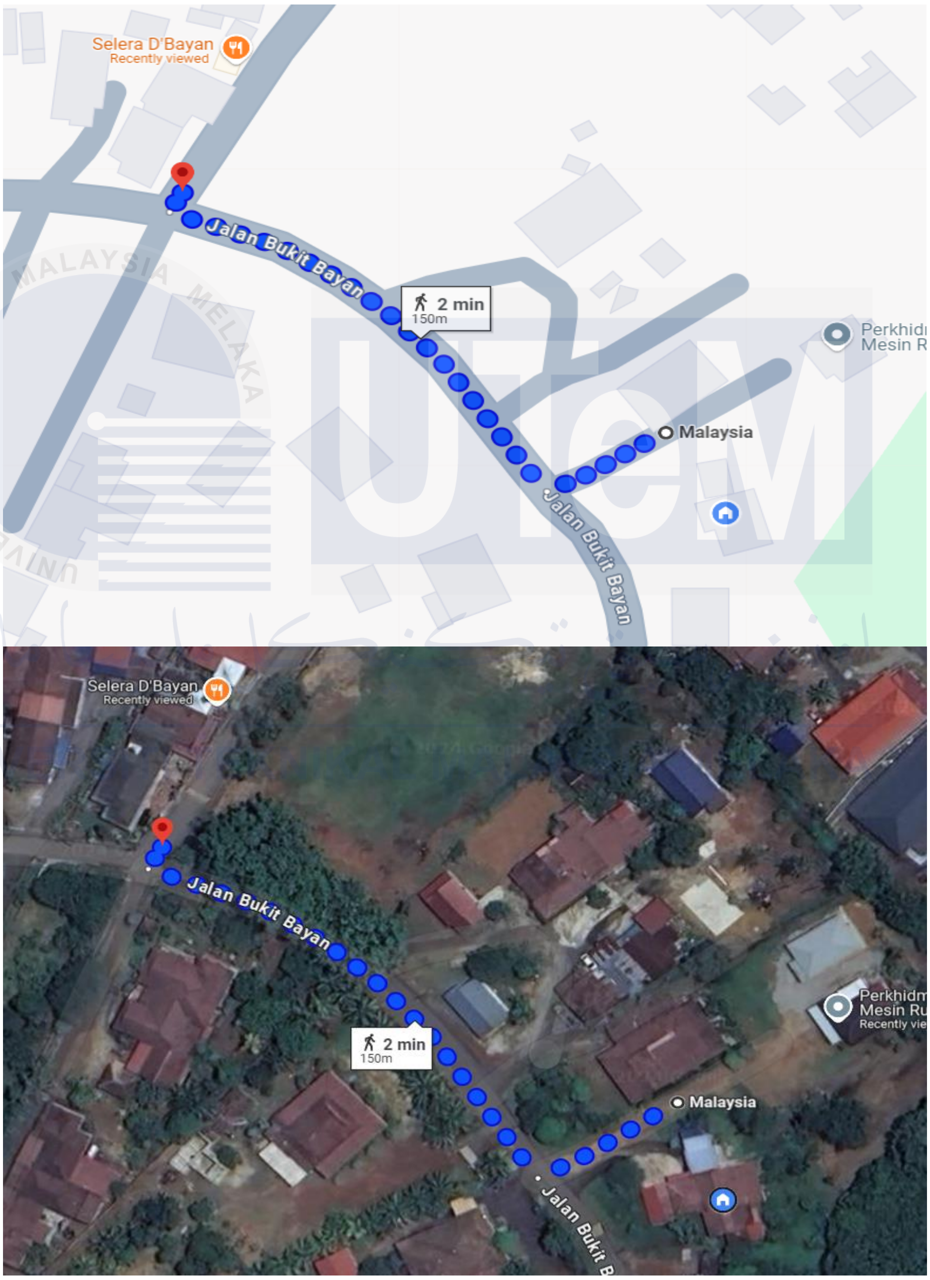


Figure 4-9 Maps view

This test used to check the capabilities of LoRa technology over a distance of 150 meters was conducted. The test involved using two LoRa devices, where one acted as a transmitter and the other as a receiver. Both devices were set up with configurations, such, as operating on the frequency band and employing the same spreading factor. The testing was carried out in an environment. To assess the strength and quality of the LoRa signal two metrics were monitored; Received Signal Intensity Indicator (RSSI) and Signal to Noise Ratio (SNR).

Table 4.2 Lora Range Result.

Distance from Receiver Node (in meter)	Signal to Noise Ratio (SNR) (in dB)	Received Signal Strength Indicator (RSSI) (in dBm)
3	10	-77
21	2	-102
45	8	-66
110	4	-108
120	4	-101

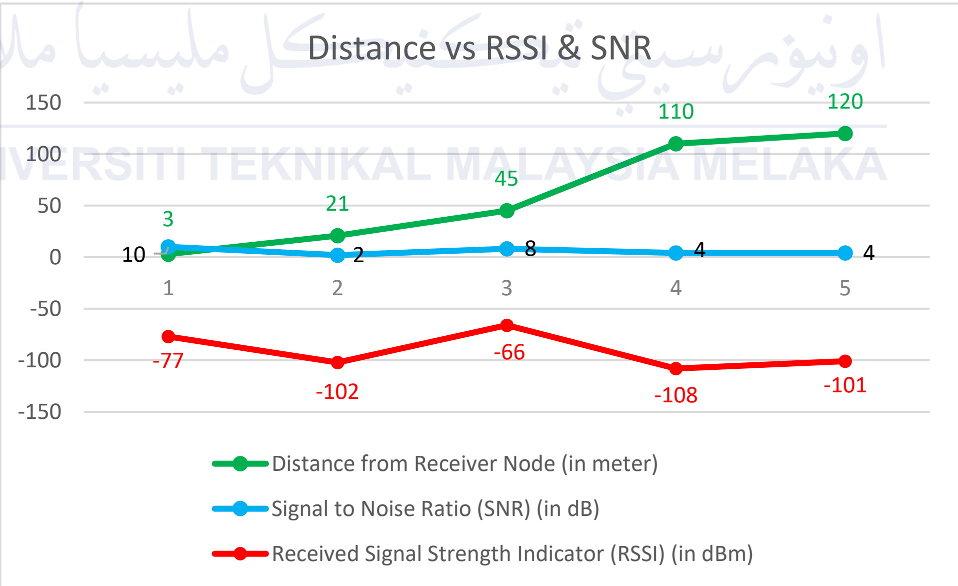


Figure 4-10 Graph Distance vs RSSI & SNR

The results obtained from the test are presented in Table 4.2 and Figure 4.8 were extremely positive. The RSSI values consistently remained betweem -30 dBm to -120 dBm indicating a dependable LoRa signal throughout the testing area. The RSSI = -30 dBm is a very strong signal and -120 dBm is a very weak signal. [30]. The SNR results demonstrated a signal to noise ratio that consistently exceeded the recommended threshold of 0 dB. Typicaly, LoRa SNR values are between -20 dB and +10 dB [30]. A value closer to +10 dB means that the received signal is less corrupted. Moreover, throughout the range of 150 meters that were tested all messages were successfully delivered without any loss or corruption, at a 100% success rate.

4.5.3 Battery Consumption for LoRa

In this project, both transmit and receive part have 2 parallel battery 3.7V LI-ION which consume 3000mAh of battery of each. The result was performed by transmit the data with difference interval. The result also shown the value of current used when transmit the data. Combining sleep mode for both the transmitter (TX) and receiver (RX) can significantly reduce power consumption and extend battery life. Here’s how the battery consumption and battery life will look for different transmission intervals (1 second, 30 seconds, 1 minute, 1 hour, and 1 day), assuming a 3000 mAh battery, SF7, +14 dBm TX power, and sleep mode for both TX and RX.

Table 4.3 Battery Consumption Result

Transmission Interval	TX Average Current (mA)	RX Average Current (mA)	Total Average Current (mA)	Battery Life (Hours)	Battery Life (Days)
1 second	85	0.2	85.2	35.2	1.47
30 seconds	2.83	0.2	3.03	990.1	41.3
1 minute	1.42	0.2	1.62	1851.9	77.2
1 hour	0.024	0.2	0.22	13416.8	559
1 day	0.001	0.2	0.22	14925.4	621.9

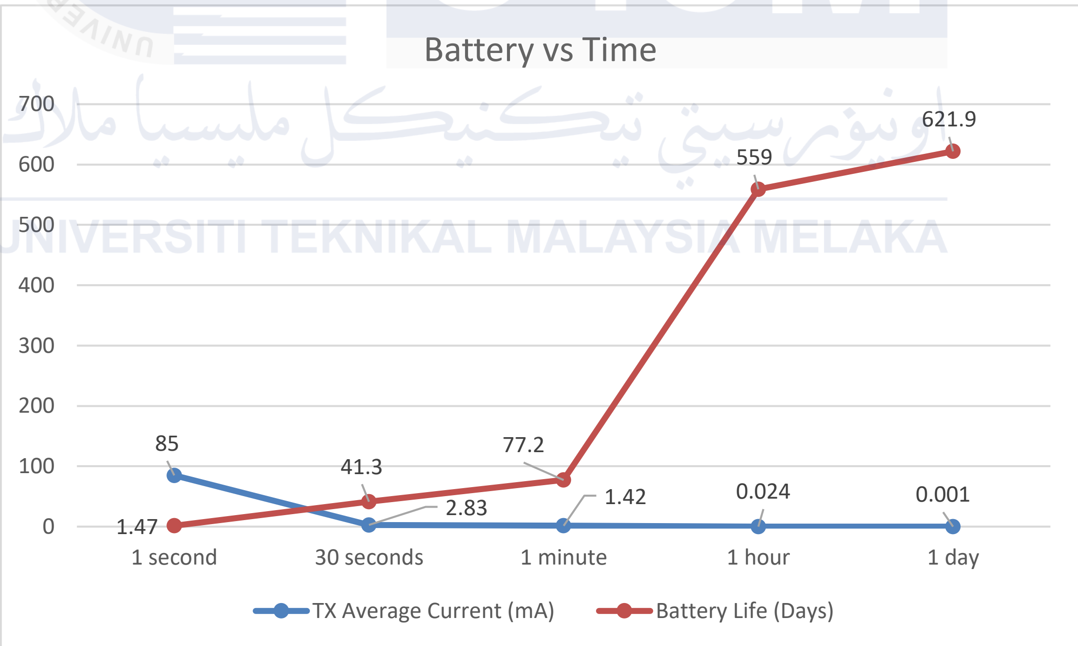


Figure 4-11 Result Battery vs Time

The graph illustrates the relationship between battery life (in days) and TX average current (in mA) for different transmission intervals (1 second, 30 seconds, 1 minute, 1 hour, and 1 day) when using sleep mode for both the transmitter (TX) and receiver (RX). As the transmission interval increases, the TX average current decreases significantly, leading to a substantial increase in battery life. For example, at a 1-second interval, the TX average current is 85 mA, resulting in a battery life of only 1.47 days, while at a 1-day interval, the TX average current drops to 0.001 mA, extending the battery life to 621.9 days. This demonstrates that longer transmission intervals and the use of sleep mode are highly effective in optimizing power efficiency, making the system suitable for either real-time monitoring (with shorter intervals) or long-term deployment (with longer intervals).

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Table 4.4 Difference performance for Lora

Mode	SF	Tx Power	Range (km)	Battery Life
Low Power (Efficient)	7	+14 dBm	2-5	~59
Balanced	9	+14 dBm	5-8	~40
Maximum Range	12	+20 dBm	10-15	~14

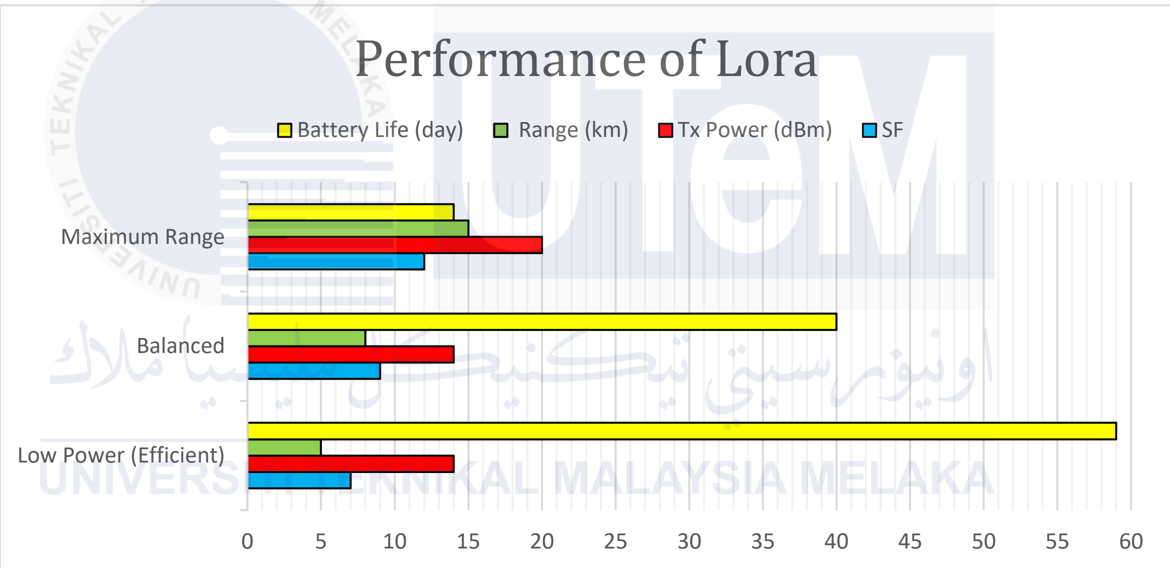

Figure 4-12 Performance of Lora

The graph illustrates the performance of LoRa in terms of battery life (in days) and range (in kilometers) for different TX power levels (dBm). It categorizes performance into three modes: Maximum Range, Balanced, and Low Power (Efficient). As the TX power increases, the range of the LoRa module improves, but this comes at the cost of higher battery consumption, reducing battery life. Conversely, operating at lower TX power levels (e.g., 10 dBm) maximizes battery life by minimizing power consumption, making it ideal for low-power, efficient applications, albeit with a shorter range. The Balanced mode offers a compromise between range and battery life, providing moderate performance for both parameters. This graph highlights the trade-off between range and battery consumption in LoRa-based systems, emphasizing the importance of selecting the appropriate TX power level based on the application's requirements.

4.6 Summary

The project titled "LoRa-Based Cable Theft Detection System for Street Lighting" represents a significant advancement in addressing the persistent issue of cable theft in street lighting systems. The primary objective is to develop a low-power, long-range prototype system that can be easily deployed by authorities, regardless of their geographical location. Leveraging LoRa (Long Range) wireless networks, renowned for their low power consumption and extensive range capabilities, the system is ideal for urban infrastructure applications like street lighting. The project begins by reviewing existing cable theft detection systems and proposes a more effective solution using LoRa technology, ensuring robust and reliable monitoring of vast areas with minimal energy consumption.

A key focus of the project is the integration of the Internet of Things (IoT) into the system. By implementing IoT, the project enables real-time monitoring and alert capabilities through an IoT dashboard, which displays digital outputs from optocoupler sensors. This real-time data transmission is crucial for immediate detection and response to cable theft incidents, significantly reducing the time it takes for authorities to react. Additionally, the project evaluates the accuracy of the optocoupler, a critical component that detects changes in cable signaling to identify potential theft. This evaluation involves testing the optocoupler's performance under different conditions by varying the limiting resistor (RD) values, such as 33k ohm, 100k ohm, and 220k ohm. These experiments, detailed in Figure

4-7 and Table 4.1, are essential for fine-tuning the system's sensitivity and ensuring accurate detection without false positives.

The project also emphasizes battery optimization by combining sleep mode for both the transmitter (TX) and receiver (RX) with LoRa's low-power capabilities. By adjusting the transmission intervals (e.g., 1 second, 30 seconds, 1 minute, 1 hour, or 1 day) and using SF7 (Spreading Factor 7) with +14 dBm TX power, the system achieves a balance between real-time monitoring and long-term battery life. For instance, at a 1-minute transmission interval, the system can operate for approximately 77.2 days on a 3000 mAh battery, while a 1-hour interval extends the battery life to 559 days. This optimization ensures the system is both energy-efficient and sustainable, making it suitable for long-term deployment in urban environments.

In summary, the LoRa-based cable theft detection system is a comprehensive solution that addresses both technical and practical challenges associated with cable theft. By leveraging advanced wireless communication technology, IoT integration, and battery optimization techniques, the project provides a powerful tool for authorities such as Tenaga Nasional Berhad (TNB), the Public Works Department (JKR), and the Malacca Municipal Council (MBMB) to enhance their monitoring capabilities and reduce economic losses caused by cable theft. The project's focus on accuracy, reliability, and energy efficiency ensures that the system can operate effectively in diverse environmental conditions, offering a scalable and sustainable solution for urban infrastructure protection. This innovative use of technology not only combats cable theft but also aligns with sustainable development goals by promoting efficient resource use and reducing operational disruptions.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this thesis project focused on the development of the LoRa Based Cable Theft Detection System using Optocoupler and IoT Platform. The goal was to offer real-time detection and monitoring to guarantee ideal conditions and to aid in preventing street lighting cable theft.

This technology offers a comprehensive and reliable respond to the challenges faced by authorities and utility companies in ensuring the uninterrupted operation of the infrastructure supporting street lighting. The system makes use of the long-range and low-power features of LoRa technology to monitor and identify cable theft in an efficient manner. It is made feasible for this preemptive strategy to prevent theft and minimize disruptions to street lighting systems.

This method is even more successful since optocoupler technology has been included in it. By serving as an isolator, the optocoupler maintains the integrity and dependability of the detecting system. The optocoupler increases the system's capacity to detect cable theft correctly and guards against any interference by separating the electrical impulses between the detection circuit and the main system. With this connection, any illegal efforts to theft the street lighting cables are certain to be quickly discovered and dealt with.

The cable theft detection system is made more convenient and accessible by the use of Blynk, an intuitive smartphone application. Authorities and utility companies may use Blynk to remotely monitor the condition of the street lighting infrastructure and get real-time notifications in the case that there is any manipulation of the cables. This makes it possible to respond and intervene quickly, cutting down on the amount of time needed to handle theft occurrences and lowering the risk to public safety. Blynk's user-friendly interface facilitates efficient navigation and feature utilization by streamlining system administration and operation.

All things considered, the optocoupler and Blynk integrated LoRa based cable theft detection system provides a complete defense against cable theft in street lighting infrastructure. The system's cutting-edge technology offers a proactive approach to detecting and preventing theft, guaranteeing the continuous provision of public lighting services. The use of Blynk increases user accessibility and convenience, while the inclusion of optocoupler technology improves system dependability. Authorities and utility companies may greatly reduce the effects of cable theft by putting this creative approach into practice, which will enhance safety and security in metropolitan areas.

5.2 Potential for Commercialization.

The project holds significant potential for commercialization with entities such as Tenaga Nasional Berhad (TNB), the Public Works Department (JKR), and the Malacca Municipal Council (MBMB). For TNB, which is the largest electricity utility in Malaysia, the implementation of a smart cable fault detection system can drastically reduce operational costs and downtime associated with street lighting maintenance. The ability to quickly and accurately detect faults can lead to faster repairs, minimizing the duration of outages and enhancing the reliability of street lighting infrastructure. This can also improve customer satisfaction and reduce the costs associated with manual inspections and prolonged faults.

For JKR, which is responsible for the construction and maintenance of public infrastructure, the smart cable fault detection system can streamline maintenance operations and enhance safety. The system can provide real-time data and alerts about cable faults, allowing for proactive maintenance and timely interventions. This can help prevent accidents and reduce the risk of electrical hazards, thereby ensuring the safety of both the public and maintenance personnel. The efficiency gained through this system can also translate into cost savings and better allocation of resources, allowing JKR to focus on other critical infrastructure projects.

MBMB, as the municipal council responsible for the administration and management of Malacca, can benefit from the enhanced efficiency and reliability of street lighting provided by the smart cable fault detection system. This can lead to better-lit streets, improving public safety and the overall aesthetic appeal of the city. Additionally, the implementation of such a system aligns with smart city initiatives, showcasing Malacca as a forward-thinking city that leverages technology to improve public services. The reduced downtime and maintenance costs can also result in financial savings for the municipal council, which can be reinvested into other community projects and services.

Overall, the commercialization potential of the smart cable fault detection system is substantial, offering tangible benefits in terms of cost savings, operational efficiency, safety, and public satisfaction for TNB, JKR, and MBMB.

5.3 Future Works

For future improvements, the LoRa Based Cable Theft Detection System for Street Lighting can be enhanced as follow:

i) **Implementation of Solar Energy as a Power Supply:**

To enhance the sustainability and efficiency of the LoRa-Based Cable Theft Detection System, integrating solar energy as a primary power source is a promising improvement. Solar panels can be installed alongside streetlights to harness renewable energy, reducing reliance on traditional batteries and minimizing maintenance costs. By incorporating energy storage solutions such as rechargeable batteries or supercapacitors, the system can operate seamlessly during nighttime or low-light conditions. Additionally, pairing solar energy with low-power modes for the LoRa module and sensors during idle periods will further optimize energy consumption, ensuring the system remains operational for extended durations without frequent recharging or battery replacements.

ii) **Integration with Smart City Platforms and Predictive Analytics:**

The system can be integrated with smart city platforms to provide a holistic view of urban infrastructure, including street lighting, traffic management, and public safety systems. This integration would enable better resource allocation and coordination among city services. Furthermore, incorporating machine learning algorithms and predictive analytics can significantly enhance the system's effectiveness. By analyzing historical data and identifying patterns, the system can predict high-risk areas or times for cable theft, allowing authorities to take proactive measures. Machine learning can also enable the system to adapt to new theft patterns, improving its accuracy and responsiveness over time.

iii) **Enhanced Detection Sensitivity and Environmental Resilience:**
Future improvements should focus on increasing the system's sensitivity and accuracy in detecting cable theft. This can be achieved by refining the optocoupler's performance and optimizing detection algorithms to reduce false positives and improve response times. Additionally, the system should be designed to withstand harsh environmental conditions, such as extreme temperatures, humidity, and rain, by using weatherproof enclosures and ruggedized components. Incorporating self-diagnostic features to detect and report hardware or software malfunctions will ensure the system remains reliable and operational in diverse environments, further enhancing its effectiveness in real-world scenarios.

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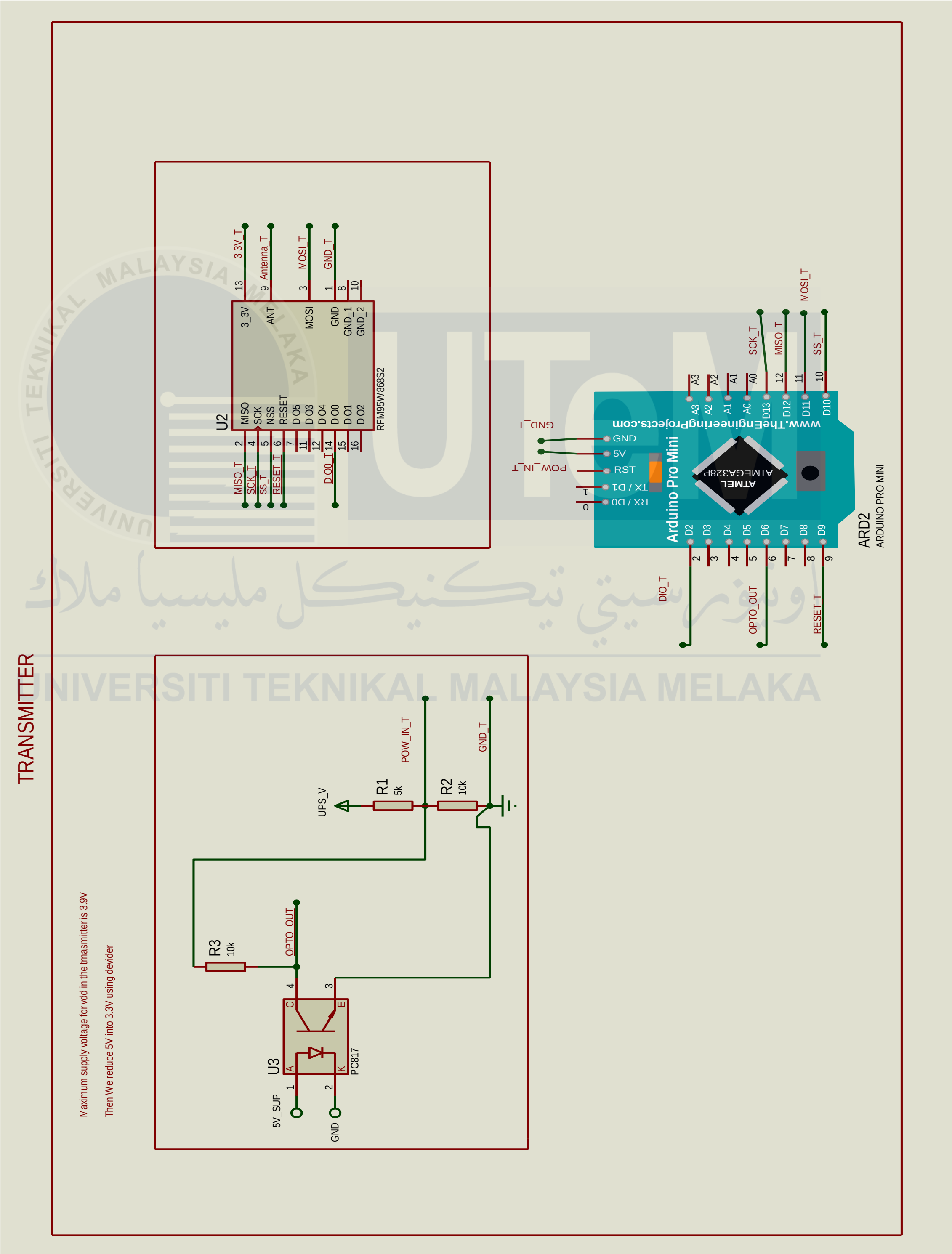
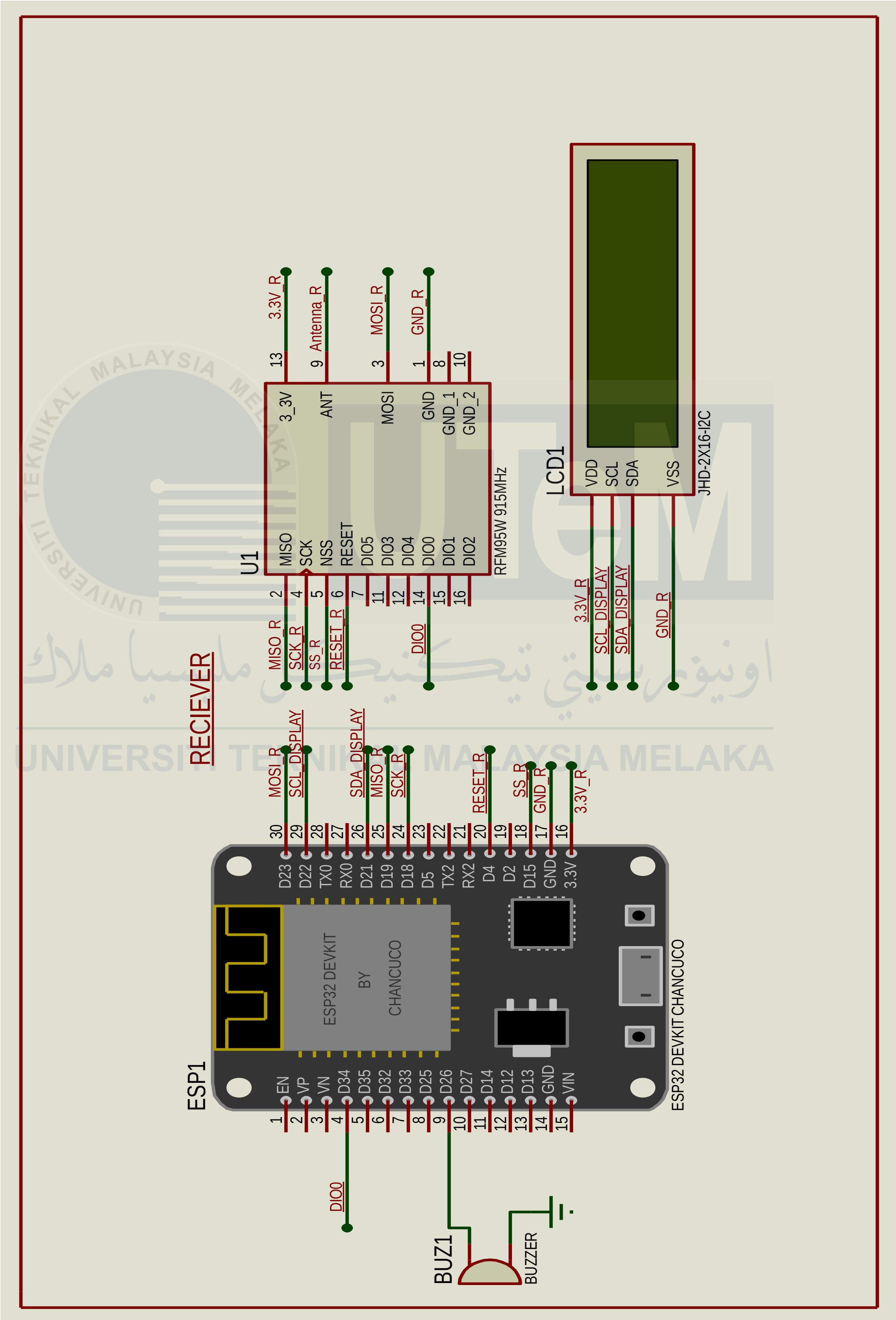
APPENDICES

Appendix A   Transmit Simulation



Appendix B Receiver Simulation



Appendix C Transmit Code

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

const int optoPin = 2; // Digital pin connected to optocoupler output
const int loraCS = 10; // Chip select pin for LoRa
const int loraReset = 9; // Reset pin for LoRa

void setup() {
    Serial.begin(9600); // Start serial communication at 9600 bps
    pinMode(optoPin, INPUT); // Set optocoupler pin as input

    // Initialize LoRa
    LoRa.setPins(loraCS, loraReset); // Set the CS and Reset pins
    if (!LoRa.begin(915E6)) { // Set frequency to 915 MHz
      Serial.println("LoRa initialization failed!");
      while (1); // Halt the program if LoRa initialization fails
    }
    Serial.println("LoRa Transmit Ready");
}

void loop() {
    int optoState = digitalRead(optoPin); // Read the state of the
optocoupler

    // If-Else Debugging
    if (optoState == HIGH) {
        Serial.println("Optocoupler is OFF (Street Light is OFF)"
);
    } else {
        Serial.println("Optocoupler is ON (Street Light is ON)");
    }

    // Transmit the optocoupler value
    LoRa.beginPacket();
    LoRa.print(optoState); // Send the optocoupler state (0 or 1)
    LoRa.endPacket();

    // Debugging: Print the transmitted value
    Serial.print("Transmitted: ");
    Serial.println(optoState);

    delay(100); // Wait for a second before the next transmission
}
```

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Appendix D Receiver Code

```
/* Fill-in information from Blynk Device Info here */
#define BLYNK_PRINT Serial
#define BLYNK_TEMPLATE_ID   "TMPL6q-TOPTKU"
#define BLYNK_TEMPLATE_NAME "LoRa Based Cable Theft Detection"
#define BLYNK_AUTH_TOKEN    "EsR-64aNaSoRxm4pVeRclenCTpQimaaU"

#include <SPI.h>
#include <LoRa.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <BlynkSimpleEsp32.h> // For ESP32
#include <WiFi.h> // Include the Wi-Fi library for ESP32
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

const int csPin = 5;      // Chip select pin for LoRa module
const int resetPin = 14; // Reset pin for LoRa module
const int dio0Pin = 2;    // DIO0 pin for LoRa module
const int buzzerPin = 26; // Pin connected to the buzzer

LiquidCrystal_I2C lcd(0x27, 16, 2); // Set the LCD address (0x27 is common
for I2C LCDs)

// Wi-Fi credentials
//const char* ssid = "haziqfamilia-2.4GHz"; // Wi-Fi SSID
//const char* password = "cokicomey"; // Wi-Fi Password
const char* ssid = "Assalamualaikum"; // Wi-Fi SSID
const char* password = "abccbaabc"; // Wi-Fi Password

void setup() {
    Serial.begin(115200); // Start serial communication at 115200 bps
    while (!Serial);

    Serial.println("LoRa Receiver");

    // Connect to Wi-Fi
    WiFi.begin(ssid, password); // Start Wi-Fi connection
    while (WiFi.status() != WL_CONNECTED) { // Wait for connection
        delay(500);
        Serial.print(".");
    }
    Serial.println("Connected to Wi-Fi");

    // Initialize LoRa
```

```
    LoRa.setPins(csPin, resetPin, dio0Pin);
    if (!LoRa.begin(915E6)) { // Set frequency to 915 MHz
        Serial.println("LoRa receiver failed. Check your connections.");
        while (1);
    }
    Serial.println("LoRa receiver succeeded.");

    // Initialize the LCD
    lcd.begin();
    lcd.backlight(); // Turn on the backlight
    pinMode(buzzerPin, OUTPUT); // Set buzzer pin as output
    lcd.setCursor(0, 0);
    lcd.print("Welcome To");
    lcd.setCursor(0, 1);
    lcd.print("LoRa Transiver");

    // Initialize Blynk
    Blynk.begin(BLYNK_AUTH_TOKEN, ssid, password); // Use Wi-Fi for
communication
}

void loop() {
    // Try to parse packet
    //Serial.println("Checking for packets..."); // Debugging line
    int packetSize = LoRa.parsePacket();
    if (packetSize) {
        // Received a packet
        //Serial.println("Packet received!"); // Debugging line
        String receivedText = "";
        while (LoRa.available()) {
            receivedText += (char)LoRa.read(); // Read the packet
        }
        Serial.print("Received packet: ");
        Serial.println(receivedText);

        // Display the received AC status on the LCD
        // Sound the buzzer if AC status is 0 (off)
        if (receivedText == "1") {
            lcd.clear();
            lcd.setCursor(0, 0);
            lcd.print("Cable Status: ");
            lcd.print(receivedText);
            lcd.setCursor(0, 1);
            lcd.print("Cable Theft !!!");
            tone(buzzerPin, 1000); // Sound the buzzer at 1000 Hz
            delay(1000); // Sound for 1 second
            noTone(buzzerPin); // Stop the buzzer
```

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```
        } else {
            lcd.clear();
            lcd.setCursor(0, 0);
            lcd.print("Cable Status: ");
            lcd.print(receivedText);
            lcd.setCursor(0, 1);
            lcd.print("Cable is OK");
            noTone(buzzerPin); // Ensure buzzer is off if AC is on
        }

        // Send the received status to Blynk
        Blynk.virtualWrite(V0, receivedText); // Send data to virtual pin V0
on Blynk
    }

    Blynk.run(); // Run Blynk
    delay(1000); // Wait for a second before checking for new packets
}
```

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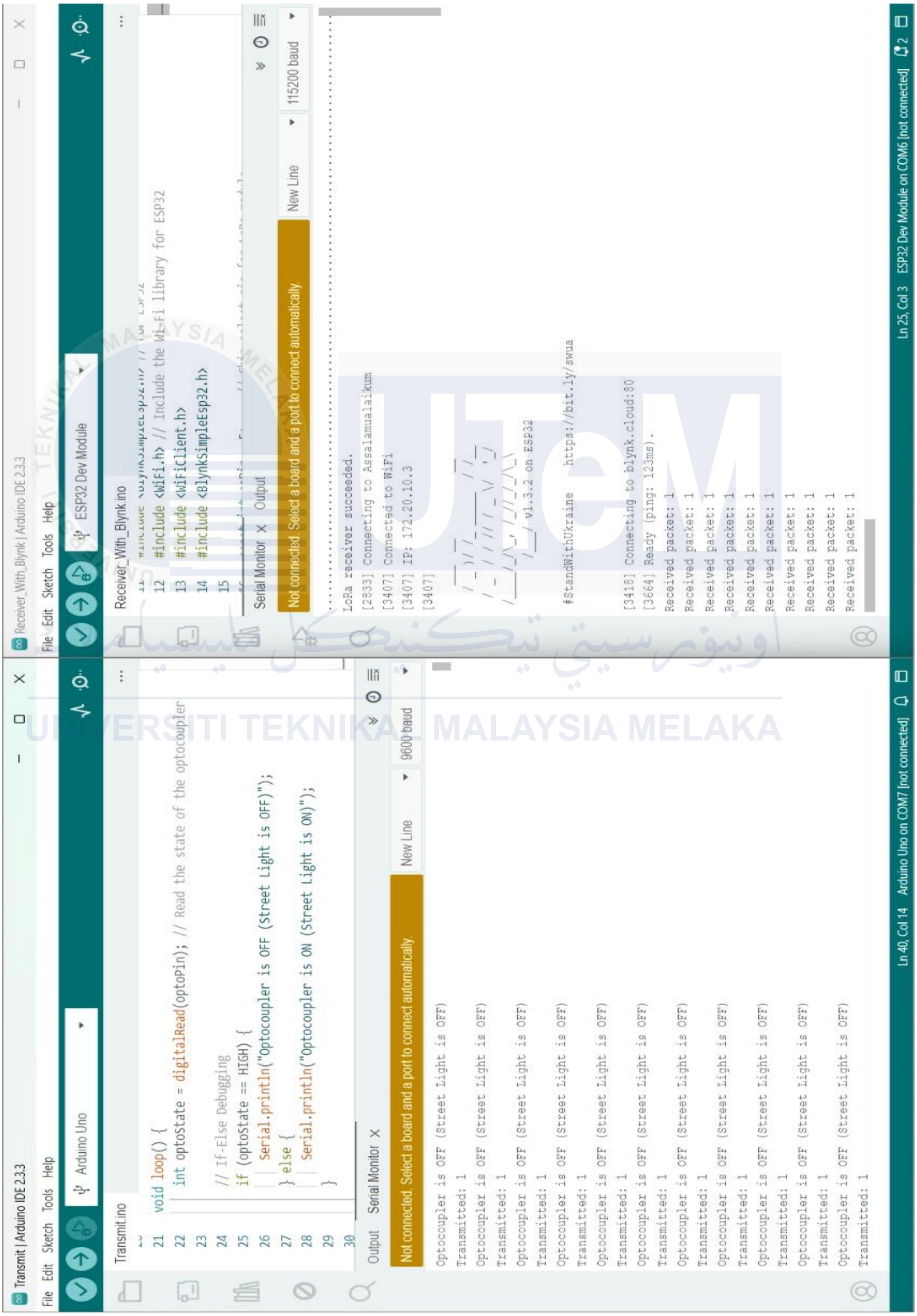
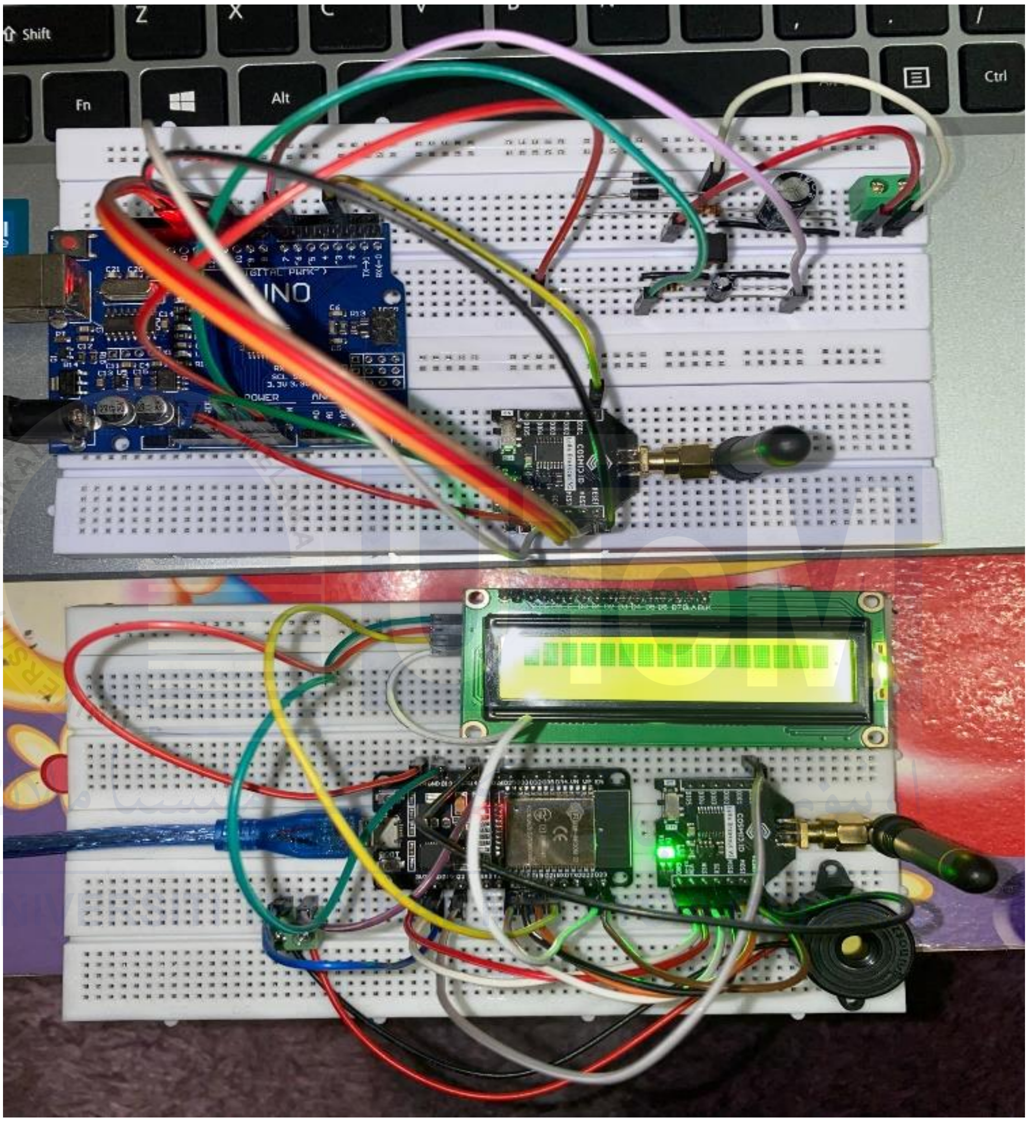
Appendix E Both serial monitor output



Appendix F   Hardware and Blynk Console




03:42
LoRa Based Cable Theft Dete...
1
0
1
1
1
Live
1H
6H
1D
1W
1M
3M

Appendix G LoRa RFM95(W) 915MHz Features

HOPERF ELECTRONIC

RFM95/96/97/98（W）

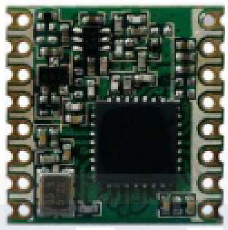
RFM95/96/97/98(W) - Low Power Long Range Transceiver Module V1.0

GENERAL DESCRIPTION

The RFM95/96/97/98(W) transceivers feature the LoRaTM long range modem that provides ultra-long range spread spectrum communication and high interference immunity whilst minimising current consumption.

Using Hope RF's patented LoRaTM modulation technique RFM95/96/97/98(W) can achieve a sensitivity of over -148dBm using a low cost crystal and bill of materials. The high sensitivity combined with the integrated +20 dBm power amplifier yields industry leading link budget making it optimal for any application requiring range or robustness. LoRaTM also provides significant advantages in both blocking and selectivity over conventional modulation techniques, solving the traditional design compromise between range, interference immunity and energy consumption.

These devices also support high performance (G)FSK modes for systems including WMBus, IEEE802.15.4g. The RFM95/96/97/98(W) deliver exceptional phase noise, selectivity, receiver linearity and IIP3 for significantly lower current consumption than competing devices.



RFM95/96/97/98(W)

KEY PRODUCT FEATURES

- LoRaTM Modem.
- 168 dB maximum link budget.
- +20 dBm - 100 mW constant RF output vs. V supply.
- +14 dBm high efficiency PA.
- Programmable bit rate up to 300 kbps.
- High sensitivity: down to -148 dBm.
- Bullet-proof front end: IIP3 = -12.5 dBm.
- Excellent blocking immunity.
- Low RX current of 10.3 mA, 200 nA register retention.
- Fully integrated synthesizer with a resolution of 61 Hz.
- FSK, GFSK, MSK, GMSK, LoRaTM and OOK modulation.
- Built-in bit synchronizer for clock recovery.
- Preamble detection.
- 127 dB Dynamic Range RSSI.
- Automatic RF Sense and CAD with ultra-fast AFC.
- Packet engine up to 256 bytes with CRC.
- Built-in temperature sensor and low battery indicator.
- Modue Size：16*16mm

APPLICATIONS

- Automated Meter Reading.
- Home and Building Automation.
- Wireless Alarm and Security Systems.
- Industrial Monitoring and Control
- Long range Irrigation Systems

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Appendix H Gantt Chart PSM-1

Table 5.1 Gantt Chart.

Progress	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
BDP 1 briefing by JK PSM, FTKEE														
Discussion and verification the project title														
Submit the selected topic to Supervisor														
Identify the problem statement and objective with Supervisor														
Completing CH-1 (Introduction, Problem Statement, Objective, Scope)														
Finding journal and article that related to the topic														
PSM 1 progress 1 submission														
Completing CH-2 (Literature Review)														
Completing CH-3 (Methodology)														
Design circuit in Fritzing and Proteus software														
Simulation circuit in Proteus software														
PSM 1 progress 2 submission														
Correction for CH-1, CH-2 and CH-3														
Finalize the PSM 1 Report														
Construct PSM 1 Presentation Slide														
BDP 1 Presentation and Assessment														
Report Submission														

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