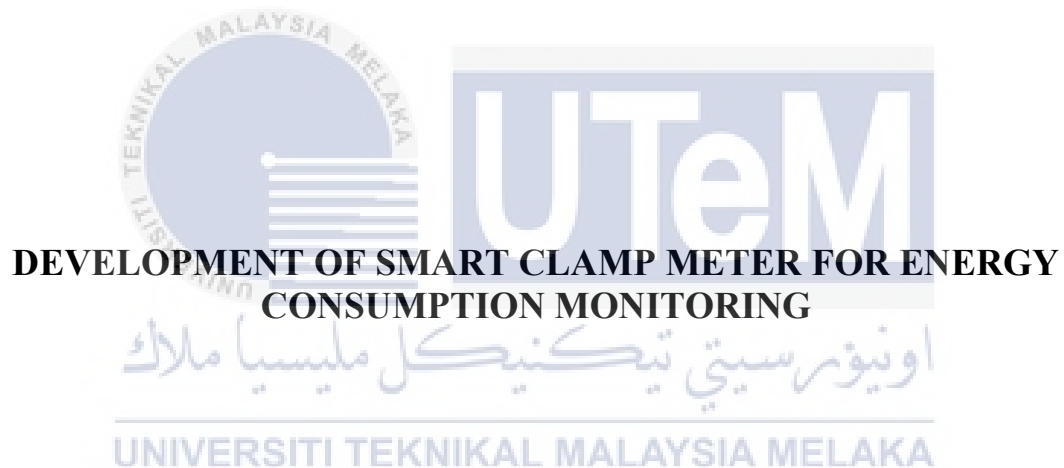**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF SMART CLAMP METER FOR ENERGY CONSUMPTION MONITORING

NURUL HUSNA BINTI MOHD RUSHLI

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

2023

DEVELOPMENT OF SMART CLAMP METER FOR ENERGY CONSUMPTION MONITORING

NURUL HUSNA BINTI MOHD RUSHLI

A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics)
with Honours

Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this project report entitled "Development of Smart Clamp Meter for Energy Consumption Monitoring" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	*Husna*
Student Name	:	Nurul Husna Binti Mohd Rushli
Date	:	*27/1/23*

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours.

Signature   : ....

Supervisor Name   :   Ts. Dr. Aliza Binti Che Amran

Date   :   27/1/2023

Signature   : ....

Co-Supervisor

Name (if any)

Date   : ....

DEDICATION

First and foremost, I want to thank Allah for giving me the opportunity to finish my report. Aside from that, I dedicate all my work to my loving parents, who inspire me and remind me to be patient. To my siblings who have always helped me when I've been away from home. My family always encourages me to keep going and work harder so that I can make my parents proud. I also dedicate my dissertation to all of my friends who have helped me during the process. I will always be grateful for everything they did to help me accomplish this project. Last but not least, thanks to all of the lecturers, particularly my supervisor, who always encourages me on and asks questions about the issues I have difficulty handling.

ABSTRACT

One of the most critical issues nowadays is energy consumption problem, especially electrical energy consumption. An effective technique to monitor this energy consumption is required for effective and optimal energy usage. Electrical energy monitoring can help users be aware of their energy use. At factories, machines electrical consumption are monitored to facilitate industries to minimize cost as well as the scheduling and application of appropriate preventive maintenance. The purpose of this project is to create a remote voltage and current monitoring system, so that any irregular pattern will help user to anticipate any potential problem in electrical system and implement corrections before it gets even worse. The objectives of this project, i.e. from design, construct and test phases were achieved successfully. A project prototype that integrates ESP32 with CT Sensor, Voltage sensor, an LCD and Node MCU was built to meet the project requirements. Basically, this project extends the function of a standard clamp meter with an additional function that will turn it into a smart clamp meter. It can monitor I and V online and real-time and has a data logging capability. The data collected by the voltage and current sensors are sent to a data logging device, and can be displayed at an android using Blynk apps. A number of experiments were carried out to test functionality of the smart meter. For comparisons, a real multimeter is used to measure current and voltage of the appliances to calculate error between smart meter readings and multimeter readings. An extender is proposed in order to ensure measurements using voltage and current sensor can be carried out with safety. The results show a variation of error percentage based on different appliances. The error percentage were found to be 0% for a battery bank, 8.7% for a table fan, 11.11% for a rice cooker and 13.6% for an electric kettle. These results give opportunity for improvement of the project. As a conclusion, a smart meter to monitor electrical consumption of appliances is successfully built and has a valueable benefit to technical operators of local companies to use the product to facilitate their maintenance or troubleshooting work at production line with less effort yet highly reliable.

ABSTRAK

Salah satu isu paling kritikal yang berlaku pada hari ini ialah penggunaan tenaga, terutamanya penggunaan elektrik. Teknik yang berkesan untuk memantau penggunaan tenaga ini amat diperlukan. Di kilang-kilang, pemantauan penggunaan tenaga membantu pihak pengurusan menggunakan tenaga secara optimal melalui penjadualan dan aplikasi penyelenggaraan pencegahan yang sesuai. Tujuan projek ini adalah untuk mencipta pemantauan voltan dan arus secara jarak jauh agar sebarang profil penggunaan tenaga yang tidak normal yang menggambarkan kemungkinan kepada permasalahan boleh diperbaiki sebelum ianya menjadi lebih teruk. Objektif projek yang bermula dengan mereka bentuk, membangunkan prototaip dan menguji keberkesanannya berjaya dicapai. Prototaip yang dihasilkan menggabungkan ESP32 dengan penderia CT, penderia voltan, LCD dan Node MCU agar ianya boleh memenuhi keperluan projek. Prototaip yang dibina memberikan nilai tambah ke atas meter pengapit yang sedia ada menjadi meter pengapit bijak. Ianya mampu mengikut voltan dan arus dan mempunyai keupayaan menyimpan dan memaparkan data menggunakan aplikasi Blynk. Beberapa eksperimen dijalankan bagi menguji keberfungsian meter bijak tersebut. Bagi tujuan perbandingan, multimeter digunakan untuk mengukur arus dan voltan peralatan bagi mengira anggaran ralat antara bacaan meter bijak dan bacaan multimeter. Satu alat "extender" digunakan agar pengukuran menggunakan penderia arus dan voltan boleh dilaksanakan dengan kaedah yang selamat. Hasil eksperimen menunjukkan kepelbagaian peratusan ralat bergantung kepada jenis perkakasan yang diukur. Peratusan ralat didapati 0% untuk bank bateri, 8.7% untuk kipas meja, 11.11% untuk periuk nasi elektrik dan 13.6% untuk cerek air elektrik. Dapatan ini membuka ruang bagi menambahbaik projek. Sebagai kesimpulan, satu meter bijak bagi mengukur penggunaan tenaga elektrik peralatan telah berjaya dibangunkan dan ianya mempunyai nilai yang tinggi kepada operator teknikal di syarikat-syarikat tempatan untuk menggunakan inovasi ini membantu mereka melaksanakan penyelenggaraan atau mengenal pasti masalah di kilang mereka dengan kos yang rendah tetapi mempunyai nilai kebolehpercayaan yang tinggi.

ACKNOWLEDGEMENTS

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IoT   -   Internet of Thing

CT Sensor   -   Current Transformers Sensor

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CHAPTER 1

INTRODUCTION

1.1   Background

Nowadays, innovation creates and develops swiftly. Innovations have the potential to improve people's lives and create a more sustainable and inclusive society. A few years ago, tracking functions involving human contact were tested in control systems. The most recent technological advance, the Internet of Things (IoT), has enhanced consumer standards of living and may reduce needless daily spending. Understanding the IoT basics will help in discussing the implementation.
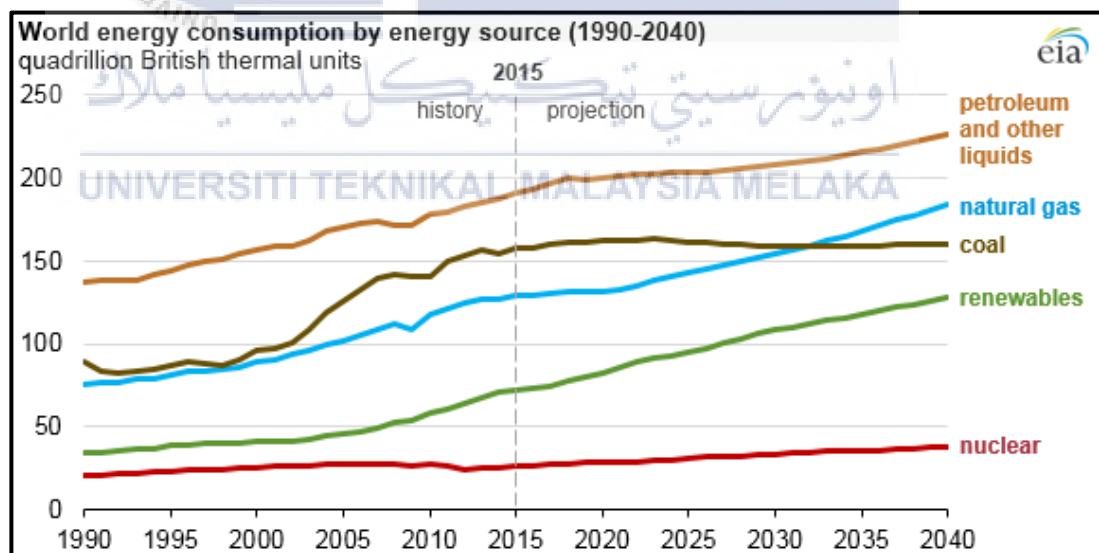
Figure 1.1: World energy consumption by energy source (EIA)

The main source of electricity is from non-renewable energy. As we all know the power plant use a non-renewable energy such as coal, oil, and neutral gas, nuclear to

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power up and produce electricity. Based on The U.S. Energy Information Administration, graph shown in figure 1 shown that Demand of non-renewable energy is higher than renewable energy due to demand of electricity usage.

It is essential to evaluate energy usage because it has operational costs. High-tech new services and goods may need to have their energy use assessed. Monitoring energy use may be beneficial in a variety of ways for industrial processes. It may aid in the appropriate scheduling and monitoring of preventative maintenance and energy consumption. Preventive maintenance may assist the home in managing its energy use.

For this project, it may be possible to modify a clamp meter, a test tool that combines a simple digital multimeter and a current sensor and connect it to a microcontroller to monitor energy usage online using the Internet of Things concept.

Predictive assessment and advanced methods may be used to analyze, collect, and examine the data in order to provide useful information in the form of reports, charts, and graphs. As a consequence, this real-time data analysis may aid utilities ecosystem firms in gaining important information about tracking energy use.

The initial concept for the energy monitoring system was triggered by expensive prices and problems with the current equipment. This is an effect of the pricey equipment and kind of microcontroller that was used. Despite the fact that certain items could seem cheap, the whole cost is substantial. Important components of this project are current transformers, a sensor for detecting alternating current, a voltage

sensor module for measuring AC voltage, and a microcontroller for tracking all inputs and outputs from the system.

1.2   Problem Statement

A local Small Medium Enterprise (SME) company, represented by a technician has come to meet with FTKEE researchers for a consultation. He came to get views and opinions from FTKEE researchers on the current problem that he was having with an induction motor used as a conveyor belt in one food packaging factory. It can be observed that the technician was able to describe technical problems that he was facing verbally, however no proper, and sufficient data were present to support his claims. Good data collection will lead to sufficient analysis, and the analysis findings will help the technician to make decisions on what are the steps need to be taken to solve the current problem.

In large manufacturing industries, Distributed Control System is used to assist the company management to run the production line. As we know, this system has a very comprehensive connectivity to all the production line machines and equipment, however the cost of a complete DCS is very high. Most of local SMEs could not afford such technology, and our developed prototype in this project could help to facilitate them in conducting online monitoring at an affordable price.

This project aims at building a simple prototype that extends function of a conventional clamp meter. The extended feature is its connectivity to the internet, making the electrical load monitoring easier and more convenient and at the same

time will assist the technician with meaningful set of data which enables proper analysis during troubleshooting.

The extraction of data necessary to evaluate electric consumption, such as current and voltage, is made possible by the use of clamp meters. The data may also be monitored more often and effectively with the use of IoT. Thus, utilizing this technique has benefits that increase productivity and efficiency, which are difficult to obtain when extracting data manually.

The followings are the expected features of the project prototype: -

1. Ability to extract the data, which is voltage, current without break the circuit and exposed to high current.

2. To improve the real time data extraction by using IoT. More data can be collected compared to manual data recording. In manual data recording, the operator can only take one reading in a time interval of two to three seconds. With the help of technology, one data can be recorded in a very short time e.g. 1 milliseconds. This means automation realizes high data acquisition rate.

3. Limitation of exposure to danger during extraction of data.

4. To improve the efficiency and accuracy of data extraction using clamp meters and avoid human errors.

5. To improve the real time data extraction by using IoT and Blynk apps for monitoring.

6. With this technology, an operator does not need to be on site all the time to keep an eye on the clamp meter's display to see the current and voltage of their machines in real time. This initiative also will make users more aware of current

and voltage consumption, as well as assist in the daily monitoring of electricity power usage.

1.3   Project Objective

This project has a few objectives to develop a smart clamp meter for energy consumption monitoring. The following are the objectives:

1. To design and develop a GUI system that can monitor electrical energy consumption.
2. To save the monitored data online or can be view in offline mode.
3. To test the accuracy and reliability of the developed prototype.

1.4   Scope of Project

The main objective of this project will be to integrate a clamp meter with an IoT (Internet of Things) system so that the system can track power consumption regularly. In this project, hardware and software development will be merged. To develop the prototype with the necessary hardware parts, products like voltage module (VM) sensors and current transformer (CT) sensors may be used. In addition, an Arduino can automate the current tracking process, which will monitor the entire amount of energy consumed. Additionally, a liquid crystal display, or LCD, was included to show the clamp meter load's measuring capabilities. The variables that may be observed are current and voltage. The data is then delivered toward a smartphone via the Blynk application after the parameters may be communicated to an Arduino using a Wi-Fi module or an ESP32.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The existing systems that were employed for study and improved upon from the last research article will be the subject of the literature review. It will be concerned with and focused to the development of Arduino, which is chosen, and the Internet of Things (IoT). The research paper based on prior research that is relevant to this project, as well as a range of publications and journals that are relevant to this project, will then be discussed. The articles may concentrate on the techniques and tools used in everyday home and business operations, such as the clam meter and energy monitoring.

2.2 Clamp meter overview

Figure 2.1: Clamp meter

An electrical test device that combines with a basic digital multi-meter and has a current sensor is referred to as a clamp meter in figure 2.1. This tool is used to measure electrical data, including current and voltage. An electric meter with an adjustable jaw allows users to tighten a cable, wire, or other conductor across an electric circuit at any location. The current would then be monitored without being paused or disconnected after that. The magnetic field created by current may be detected, magnified, and measured as it passes through the conductor thanks to the ferrite iron hard jaw underneath its plastic mount. (Fluke Corporation, 2020)

2.2.1 Way clamp work

Once transformed into a value, an AC current may be read when the clamp meter's current transformer detects the presence of magnetic fluctuations. The interaction between current and the total vector current flow via the probe and through all of the conductors is what operates the clamp meter. Conductors may be clamped with the mouth to measure their current. When the couple wire passing between the jaws detects the current flowing through, the clamp meter operates. The secondary winding, which is linked across the meter's input shunt, may be likened to the iron core of a power transformer in this case. The meter's input will supply less current because of the disparity between the number of secondary windings wrapped around the core and the number of main windings wrapped around the core.

2.3 Overview of Existing Project

It will be emphasized and analyzed for this part based on earlier research. It will demonstrate how the project was used and developed based on the previous project in order to achieve the main objectives of the project. This will assist in determining

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the most effective way to enhance the use of smart meters for energy consumption monitoring in production and daily life. Based on the current project, it may also be possible to gain a deeper understanding of the issues and potential users for this project.

2.3.1 Energy consumption monitoring in smart home system

For this research, the researcher main objective is to find an alternative way to build a well-structured way that can be used on monitoring the energy consumption. They believe by having this system can help in tracking electricity used inside the household. For this research they focus on measuring the units of electricity that flow on appliance using the current sensor ACS712 and how it works. The data than collected by Thingspeak channel through either HTTP or web socket protocol via Node MCU from the data extraction sensed by ACS712. The Android application makes a GET/POST request to the database to collect data for processing. From the data it will predicts the electricity units with high accuracy and precision during data processing. It will automatically calculate the cost for energy consumption to the current date. This will help the consumer to monitor the status on the daily basis and help them to reduce the consumption to preserve electricity.

Figure 2.2: Flowchart of energy consumption monitoring in smart home
system (Hariharan, et.al., 2021**)**

2.3.2 IoT Based Building Energy Monitoring and Controlling System Using LoRa Modulation and MQTT Protocol

For the next research, the design for the energy monitoring system focusses on
monitoring and controlled it using the system called LoRa Modulation and MQTT
Protocol. The use of a database, communication networks, and other technologies to
collect, transmit, and conserve a vast amount of data in energy execution processes.

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In the execution of this study, there are three levels which perception, transportation, and application. The data will be extracted using an Arduino UNO microcontroller, Dragino LoRa Shield, ACS712 current sensor, ZMPT101B voltage sensor, and relay as part of a circuit. The designed circuit work to measure and control all the usage of electricity such as voltage, current and others based on the single-phase power line using LoRa Modulation. This project was cost effective and prove to function smoothly efficient.
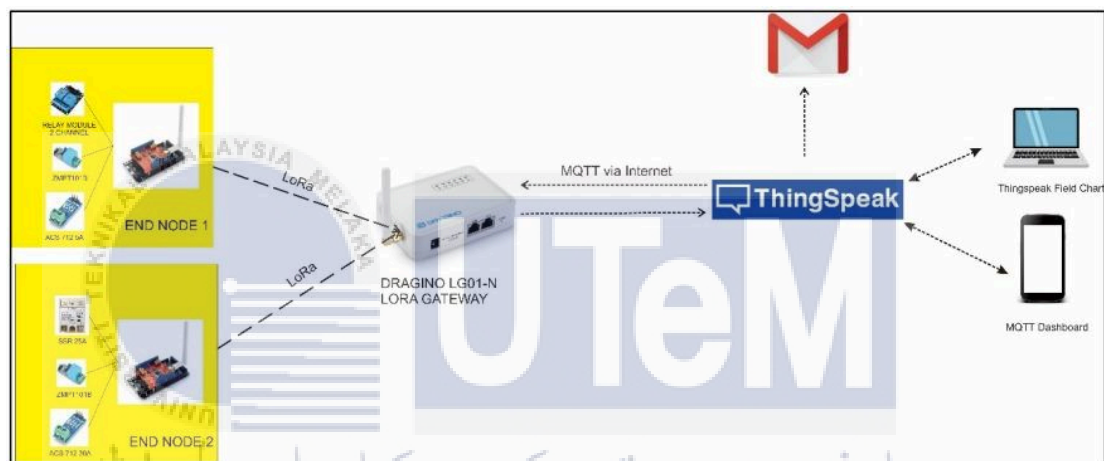
Figure 2.3: Block diagram of IoT Based Building Energy Monitoring and Controlling System Using LoRa Modulation and MQTT Protocol
(Ramelan, et.al, 2021)

2.3.3 Low-Cost Smart Energy Monitoring and Control System for Smart Buildings

In this project, the research was focus on building a low-cost design smart energy and control system. This project was designed using a component such ATmega8 microcontroller, ADE7753 energy meter IC, current sensor, and other cost-effective components. The main objective for this research to monitor and control to reduce the wastage of the electricity. This project also can be viewed real-time and most of the components are commercially available. The IC selected for this project, analog

device ADE7753 is used. It can extract all the voltage, current and power with high efficiency. The proposed system managed to achieve 12% reduction in power consumption compared to system that do not involve smart monitoring system.
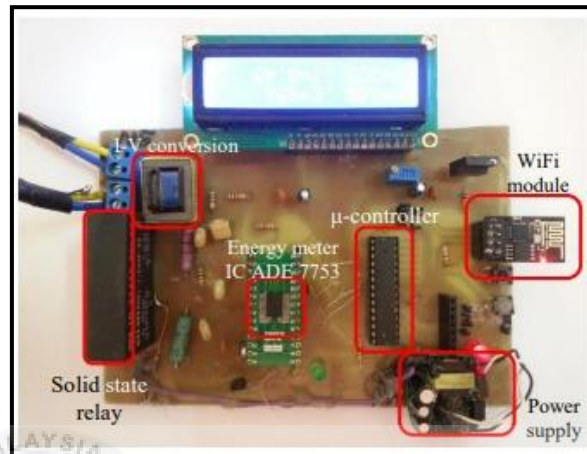
Figure 2.4: Prototype of Low-Cost Smart Energy Monitoring and Control System for Smart Buildings (Sohaib, et.al, 2016)

2.3.4 Home Energy Monitoring System using Wireless Sensor Network.

Home energy monitoring systems based on wireless networks were used in this research to aid power use in the residential sector be reduced by 20-40%. It calculates electronic appliance energy consumption in a residential environment and visualises it in more understandable formats. This project includes Zigbee and the IEEE 802.15.4 standard, which are the most helpful technologies for home application correlation. It used ACS712-30A current sensors from Xbee S2 modules as end devices and an Arduino Uno R3 as a controller to wirelessly transfer the measured energy usage data to a master node.
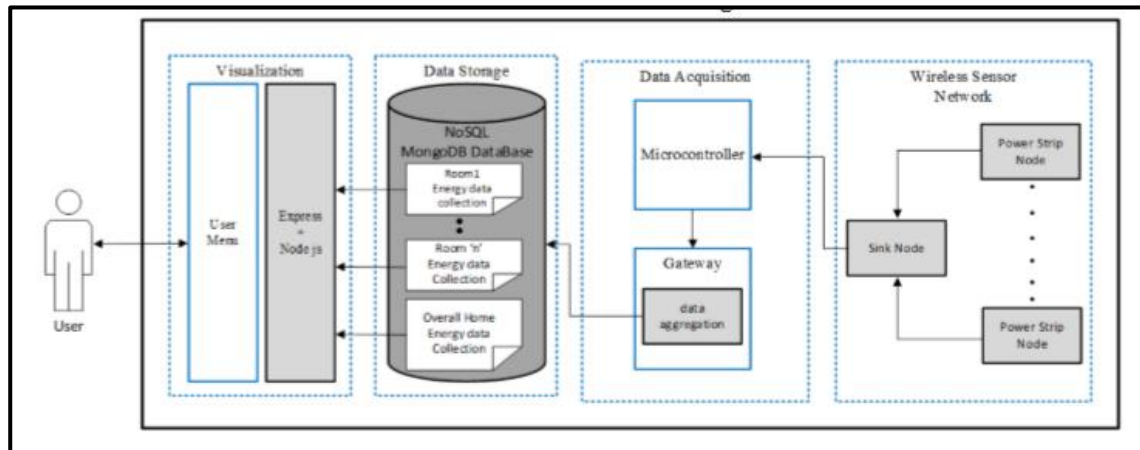
Figure 2.5: Architecture of proposed system (Shafique, et.al., 2018)

2.3.5 Iot Based Smart Energy Monitoring and Warning System

For this project, it was an IoT-based gadget that was built for this project to properly measure real power utilised by a load and report the data in real time to a database. Its continuously recording data on the amount of actual power consumption. IoT devices will send the data to cloud storage (database). In this project, current sampling uses a current transformer to measure current output while voltage sampling uses a potential transformer to measure voltage output. To communicate data to a cloud server, an Arduino Ethernet shield mini was utilised. It is based on the Ethernet chip ENC28J60and it's a standard Serial Peripheral Interface Ethernet controller (SPI).

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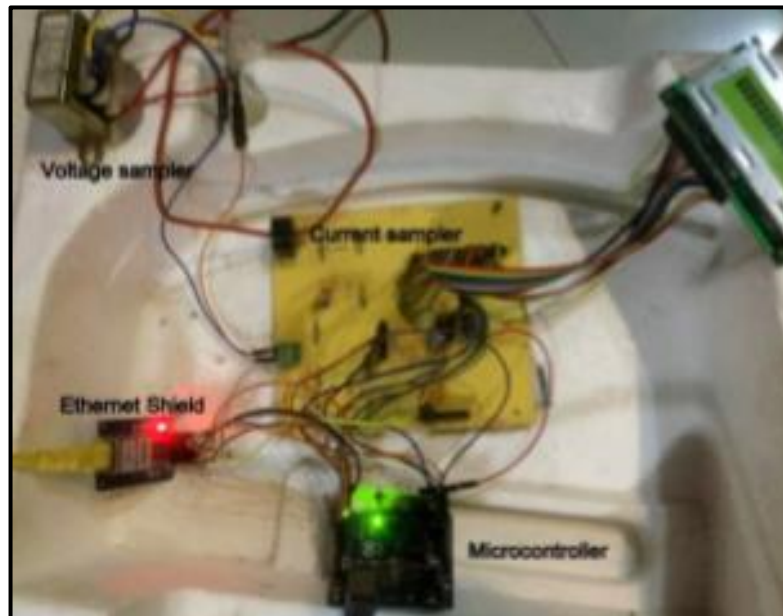
Figure 2.6: Design of the device showing its different components
(Sium, et.al., 2021)

2.3.6 Comparison among the Existing Projects

As for the research for the existing project, different researcher has different type of method and functionality. Based on the existing project, the two-researcher using microcontroller, Arduino Uno and one of it using ATmega8. Nowadays, a lot of researchers use Arduino Uno as it easy and cheap to buy. By comparing these three systems, we can see a lot of similarities and differences on the components and method use on Energy consumption monitoring. Based on Table 2.1, we can conclude that there are lot of method can be used to use on this project.

Table 2.1: Comparison between functionality the past projects

PAPER DETAILS (TITLE, AUTHORS, YEAR OF PUBLICATION)	PROTOTYPE		
	CURRENT / VOLTAGE SENSOR	MICROCONTROLLER	COMMUNICATION METHOD
"Energy consumption monitoring in smart home system", Hariharan, R & Agarwal, Reema & Kandamuru, Madhurya & Gaffar, Abdul, 2021.	Using ACS712 to measure current.	Used Arduino Uno as the microcontroller. -.	The data will process to Node MCU and send to database, Thingspeak
"IoT Based Building Energy Monitoring and Controlling System Using LoRa Modulation and MQTT Protocol" , Agus & Adriyanto, Feri & Brillianto Apribowo, Chico Hermanu & Ibrahim, M & Saputro, Joko & Setiawan, 2021.	Using ZMPT101B and ACS712 to measure voltage and current.	Used Arduino Uno as the microcontroller.	The communication to send data using Dragino LoRaShield.
"Low-Cost Smart Energy Monitoring and Control System for Smart Buildings." Sohaib, Sarmad & Sarwar, Ismail & Iftikhar, Mishaal & Mahmood, 2016.	Used energy meter ic, ADE7753 to measure the voltage, current and others.	ATmega8 microcontroller (to support SPI, UART, and I2C communication techniques.)	User control the connected device through website ESP8266 Wi-Fi module for wireless communication

			Wamp server (PHP and SQL as a database.) HTTP protocol is used for communication between server and Wi-Fi module. graphical user interface (GUI)
"Home Energy Monitoring System using Wireless Sensor Network." Shafique, Muhammad Tayyab & Kamran, Hassan & Arshad, Hafsa & Khattak, Hasan Ali, 2018.	ACS712 was used to measure current	Arduino Uno R3 as microcontroller	Xbee S2 modules is use as communication method.
"IoT Based Smart Energy Monitoring and Warning System." Sium, Farhan & Ghosh, Arnob & Al-Hossain, Md. Junaed, 2021.	Used current transformer to measure current output and uses a potential transformer to measure voltage output	For microcontroller, Arduino Ethernet shield mini was used.	Based on ENC28J60 Ethernet chip

2.4   Current Sensor (1N4148)

For this project, current sensor, plays an important role as one of the main and key components in measuring current thus it is important to understand the working principle of the current sensor in making this project successful. The measurement of AC current can be a bit complicated as it need a sensor as AC can cause the isolation problem with its noise coupled. With the use of Allegro Company's IN4148 module, such as in figure 2.2, it is possible to extract and conduct measurements more easily and safely. The usage of this module helps in this project as the main purpose is to switch the diode signal. This module is one of the most used and popular diodes as it is very competent and the price also reasonable. (Dzinavatonga, Kaitano. 2008).

This module works with the Hall-effect principle. In this context, Hall-effect current sensors (HECSs) are promising candidates, since they are tiny devices inherently featuring galvanic isolation from the sensed current, have good linearity, large dynamic range, and are compatible with standard silicon technologies. Based on the working principle of Hall-effect, the voltage across the edge perpendicular to both direct current and magnetic field can be triggered by a current-carrying conductor in a magnetic field. Current transformers (CTs) are AC current measuring devices that are simple, extremely sensitive, durable, and inexpensive. (Crescentini, Marco & Fatima, Syeda & Gibiino, Gian Piero. 2021).

Figure 2.7: IN4148 diode sensor current

2.4.1 Current Sensor (ACS712)

Based on Figure 2.3, current Sensor (ACS712) is one of popular sensor used for detecting and directing current flow. The principle utilize in this module is widely known ad have been use in different type of applications and field. This module consists of many functionalities such as over-current protection circuits, battery chargers, switching mode power supply, digital wattmeter, and programmable current sources are all included. Without impacting the system's performance, this sensor can be used to measure and calculate the amount of current applied to the conductor. It can be used to extract the information of the maximum AC and DC that can reach to 5A by reading the current signal via Arduino Analog I/O port. (Ratnawati, Nur & Sunardi, Sunardi. 2020).
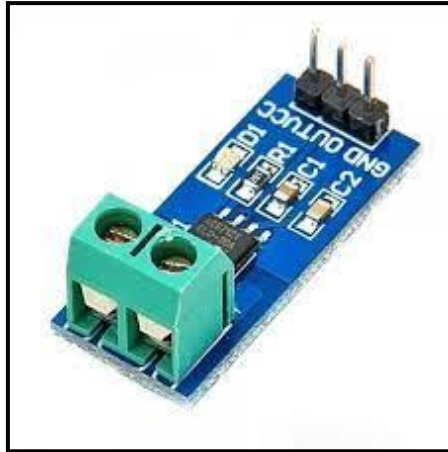
Figure 2.8: ACS712 5A current sensor

2.4.2 Voltage Sensor (ZMPT101B)

ZMPT101B which in figure 2.4, is a compact single-phase AC voltage sensor module based on the minuscule 2mA/2mA precision voltage transformer and it can help voltage transform ideal to measure the AC voltage. Based on the working principle of this module, it can reduce the input voltage from the red terminal by 5 times of the original voltage from the rule of resistance points of pressure. The operating voltage of this module is DC 5V-30V. However, because the Arduino UNO's maximum input voltage is 5V, the module's voltage input must not exceed 5V. Because the Arduino AVR processors have a 10 bit AD, dividing the 5V over 1023 bits gives this module a simulation resolution of 0.00489V. The voltage sensor module also will have an input voltage greater than 0.00489V multiplied by 5V, resulting in 0.02445V.
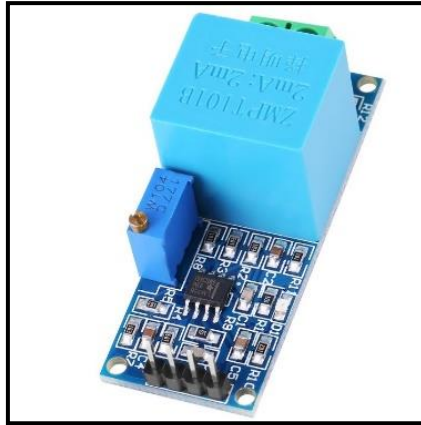
Figure 2.9: ZMPT101B voltage sensor

2.4.3 GSM Module

The SIM808 is a two-in-one unit with one GPS and one GSM. This device is built on the most recent SIMCOM GSM/GPS platform SIM808, and it supports the Quad-Band GSM/GPRS network as well as GPS satellite navigation. This results in exceptionally low nap energy consumption and is compatible with Li-Ion battery charging systems, providing for an adequate amount of idle time. It has a highly sensitive GPS receiver, as well as 22 control channels and 66 receiver channels. Also included is an A-GPS that may be used indoors.

Figure 2.10: GSM Module

2.4.4 Wi-Fi Module

The Wi-Fi module was going to be used in this project to build up the connection between Arduino and built apps interface. The working principle of this module is it will serve as a Wi- Fi adapter, wireless internet access interface to any microcontroller based design on its simple connectivity through Serial Communication or UART interface. This connection is needed to create the Energy Consumption Monitoring by relying into the Internet of Things. The voltage and current that was going to be extracted and measured from the network during monitoring. The information from Arduino will then be transmit through an Ethernet shield to the server.

2.5 Summary

The Wi-Fi module was going to be used in this project to build up the connection between Arduino and built apps interface. The working principle of this module is it will serve as a Wi- Fi adapter, wireless internet access interface to any microcontroller based design on its simple connectivity through Serial Communication or UART interface. This connection is needed to create the Energy Consumption Monitoring by relying into the Internet of Things. The voltage and current that was going to be extracted and measured from the network during monitoring. The information from Arduino will then be transmit through an Ethernet shield to the server.

CHAPTER 3

METHODOLOGY

3.1   Introduction

The construction procedures for the project named "Development of Smart Clamp Meter for Energy Consumption Monitoring" are explained in this chapter. It will concentrate on detailing the methods used to get the data. The project's implementations are then precisely pictured. The processes of the method which are investigating, analyzing, creating, and processing, can be shown using flowcharts and block diagrams to make the technique simpler to understand.

To meet the project's objectives, the process flow block diagram shown in Figure 3.1 below was evaluated. The hardware and software are divided into two parts in the block diagram. All necessary steps were presented throughout the whole process, from beginning to completion. The procedure is described below, and if any of the phases are skipped, the project may not have been able to achieve the goal of the proposal.

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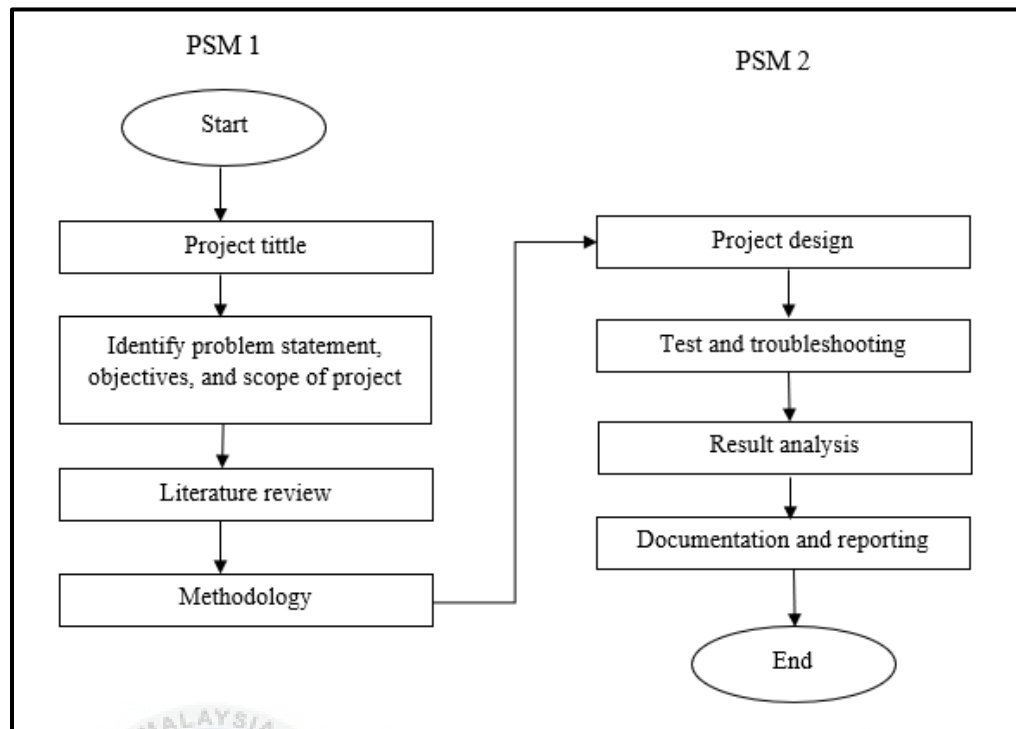
Figure 3.1: Overall flowchart of PSM

3.2 Hardware Development

Figure 3.2 displays a block diagram of the "Development of Smart Clamp Meter for Energy Consumption Monitoring" system purpose and flow.

This depicts a hardware block diagram for project "Development of Smart Clamp Meter for Energy Consumption Monitoring," which includes three main operations which input, process, and output. Arduino UNO, current transformer sensor, voltage sensor, LCD display, Wi-Fi module, Blynk applications, and power supply are the components used in this project.
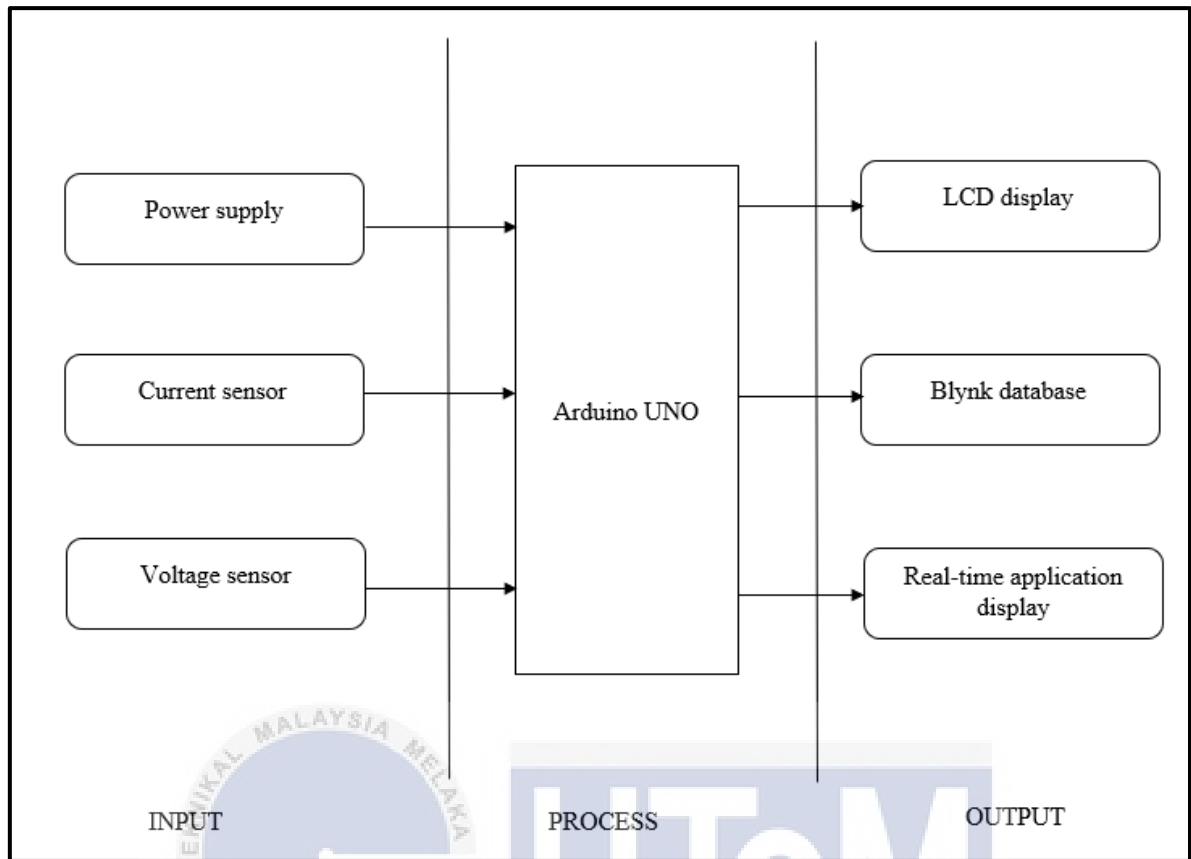
Figure 3.2: Block diagram of "Development of Smart Clamp Meter for Energy Consumption Monitoring"

3.2.1 Arduino UNO
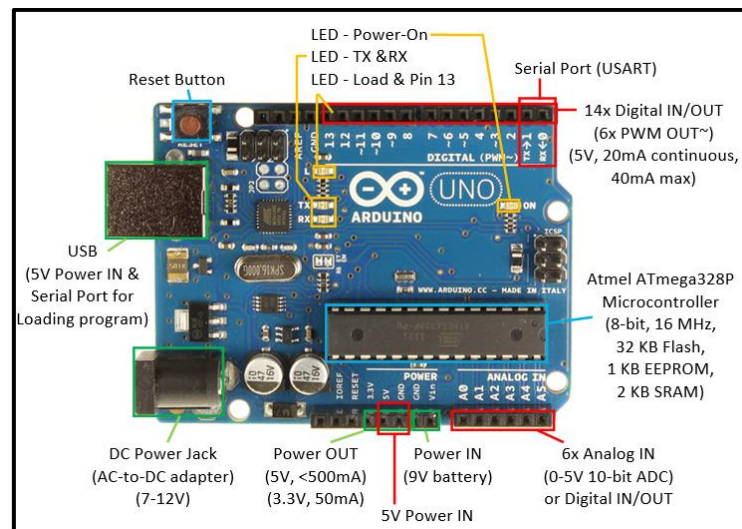
Figure 3.3: Arduino UNO with labelling

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The official Arduino UNO board, complete with labelling, is shown in Figure 3.3. A microcontroller is used by the multifunctional electronics device known as the Arduino UNO to control a networked device. The primary function of the Arduino UNO in this project is to operate the entire system and build a CT sensor to get a value from the measurement. The advantage of the Arduino UNO is that it can be programmed without the aid of an external programmer. I/O pins from Arduino are made available to the microcontroller for use in the circuit.

3.2.2 Current Transformer Sensor

A current transformer sensor is a device that measures alternating current in this project. Without the need for high-voltage electrical work, the current transformer sensor is clearly designed for do-it-yourselves, since it may be clipped directly on the live or neutral cable entering the building.

A current transformer has a primary winding, a magnetic core, and a secondary winding, much like any other transformer. When it comes to whole-building monitoring system, the primary winding is the live or neutral wire that enters the building and passes through the current transformers' entrance. Many turns of tiny wire are wound into the secondary winding, which is stored within the transformer case. A magnetic field is created in the core by the alternating current flowing in the primary, which generates a current in the secondary winding circuit.

The non-invasive AC current sensor is identified by the model SCT-013-000 (100A max) as figure 3.4 below. It has no internal burden resistance, but a transient voltage

suppressor limits the output voltage if the burden is accidentally disconnected. It can generate sufficient electricity to fully power a 5 V input. however, the observed current, can be fixed to its maximum value of 100 A C, and the maximum current sensor RMS value that the sensor can handle is 100A.
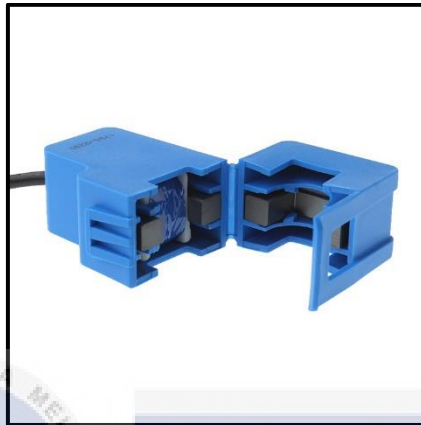
Figure 3.4: SCT-013-000 AC current sensor

3.2.3 Voltage Sensor

A voltage sensor is a device that measures and calculates the amount of voltage present in an object. The AC or DC voltage level can be determined using voltage sensors.

The ZMPT101B AC Single Phase voltage sensor module is based on a ZMPT101B voltage transformer with high precision. The ZMPT101B AC Voltage Sensor is perfect for DIY applications that require accurate AC voltage measurement through the use of a voltage transformer. The analogue output of the ZMPT101B AC Single Phase Voltage Sensor Module can be adjusted. It also has good voltage and power measuring consistency. ZMPT101B is likewise very efficient and precise.

3.2.4 LCD Display

Module for electronic display LCD (Liquid Crystal Display) screens have a wide range of uses. A 16x2 LCD is a simple module that can be found in a wide range of appliances and circuits. The 16x2 LCD enables for the display of 16 characters per line on two lines.

The 224 distinct characters and symbols can be displayed on the 16x2 smart alphanumeric dot matrix display. In this LCD, there are two registers which are command and data. In the project "Development of Smart Clamp Meter for Energy Consumption Monitoring," the screen will show the value of the measurement current and voltage at the load.

Figure 3.5: LCD Display 16x02

3.2.5 Wi-fi Module
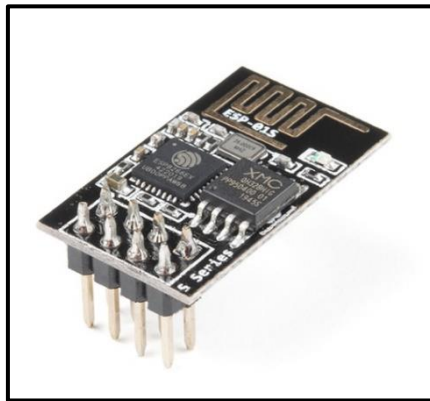
Figure 3.6: Wi-Fi Module

Based on Figure 3.6, the Wi-Fi Module is one of the newest microcontrollers with open-source platform capabilities, and because it is open source, it may be programmed with a variety of software. The Wi-Fi Module is a great microcontroller that comes with a wealth of functionality and is quite simple to code using either the Arduino IDE or the LUA programmer. The system's sensor is also I2C compatible, making it easier to communicate with the microcontroller without the necessity of any additional components.

The Wi-Fi Module, despite having almost all the capabilities of a simple Arduino, it also lacks input and output ports, limiting the user's ability to use additional inputs and outputs with the device. For both systems, it uses the same device, but they are different versions which both versions have the identical functionality, but the only changes are the device's size and USB port.

3.2.6 Blynk Apps

Blynk is an open-source mobile app for the Internet of Things that offers a variety of services aimed only at the development of IoT apps. This project uses Blynk since it can control a variety of microcontrollers and devices over the Internet. It's an advanced technological dashboard that makes it easy to create a realistic work interface just by manipulating devices. It also is a cross-platform app that can be used on both iOS and Android devices.

Blynk was created with the Internet of Things in mind which it can manage appliances from afar, save data, visualize it, display sensor data, and do a variety of other analytical tasks. By simply utilizing the concept of drag-and-drop widgets, a realistic surface as an advanced dashboard may be created. It also supports the user's chosen hardware or microcontroller. Blynk will prepare the user on the web regardless of whether the Arduino or any other processor is connected to the Internet via the ESP8266 chip, Ethernet, or the Internet of Things.

In this system, the Blynk Application is utilized to provide the measurement value data from this project. It can also send a notification if anything occurs, such as an increase in energy consumption.

3.2.7 Power Supply

This project needs two types of 3.7 V operational voltage cells. it will provide power supply to all of the systems that relate to the Arduino UNO system, current transformer sensor, voltage sensor, LCD and Wi-Fi module system.

Figure 3.7: Battery Lithium

3.3 Software Development

Programming is an important part of the process's overall operation. The Arduino IDE is a component of software that allows users to programme any Arduino board.The flow chart for the entire procedure in the "Development of Smart Clamp Meter for Energy Consumption Monitoring" is shown in Figure 3.8.
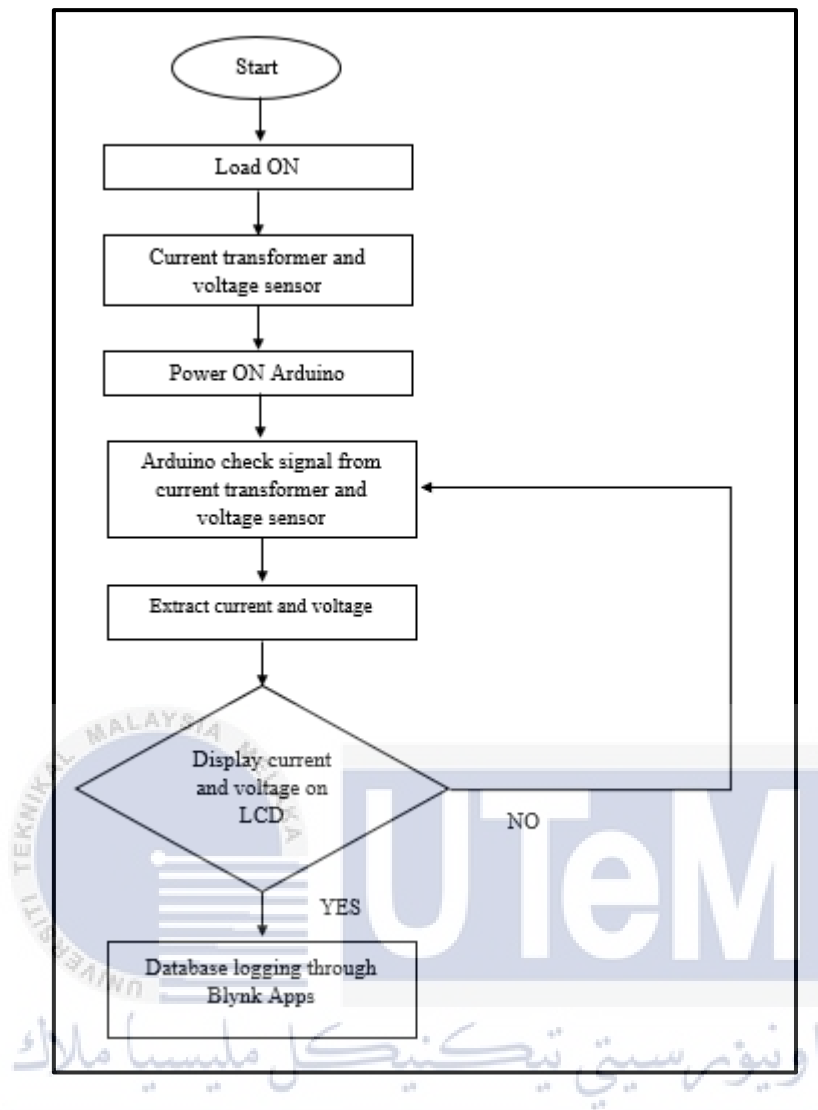
Figure 3.8: Flow chart of "Development of Smart Clamp Meter for Energy Consumption Monitoring"

3.4 GUI Design

Based on figure 3.9, it is a graphical user interface initial design that I have done. So, it will clearly display the value for voltage, current and the power consumption that were used. So, user can know all those details to use their power usage wisely.

Figure 3.9: Blynk apps screen

3.5   Data Collection
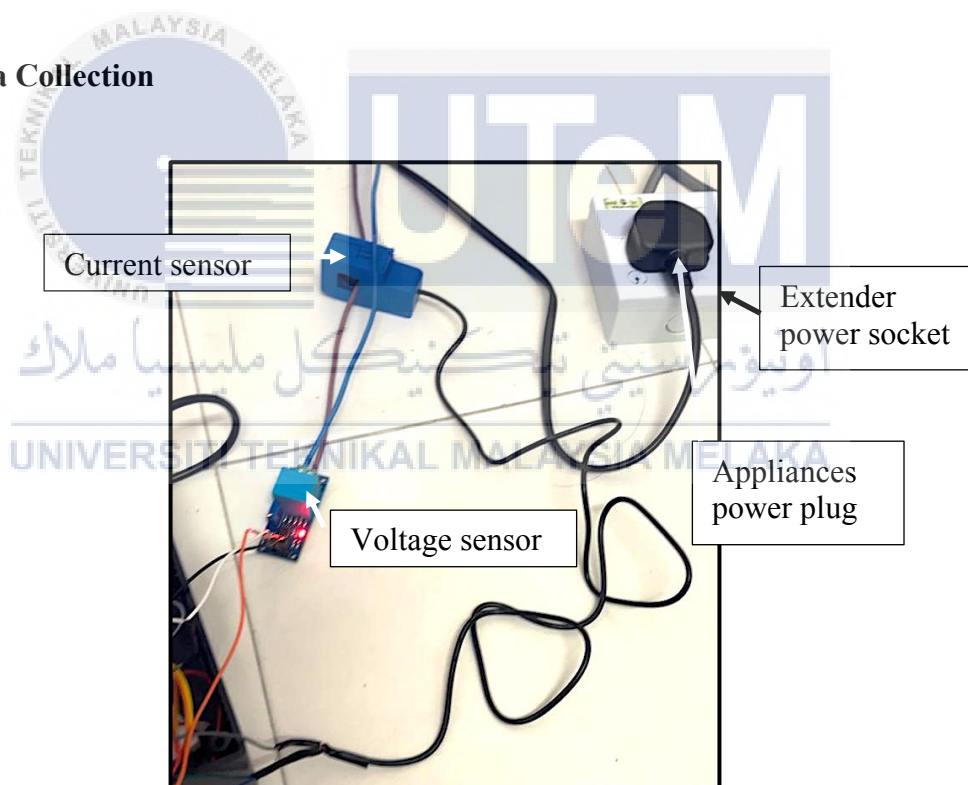
Figure 3.10: CT sensor and voltage sensor

CT sensor will be clamped at live wire. Only the live cable must be connected to a

CT clamp. This is because the magnetic field from the reverse current flow in the

neutral cable will cancel out the field on the live cable if it surrounds the whole cable, including live, neutral, and earth, resulting in a net zero reading. Voltage sensor will be connected to live and neutral wire as well. Refer to Figure 3.13 for the full connections. Both live and neutral will be connected to voltage sensor because it will connect differently through live and neutral wire to extract the data.
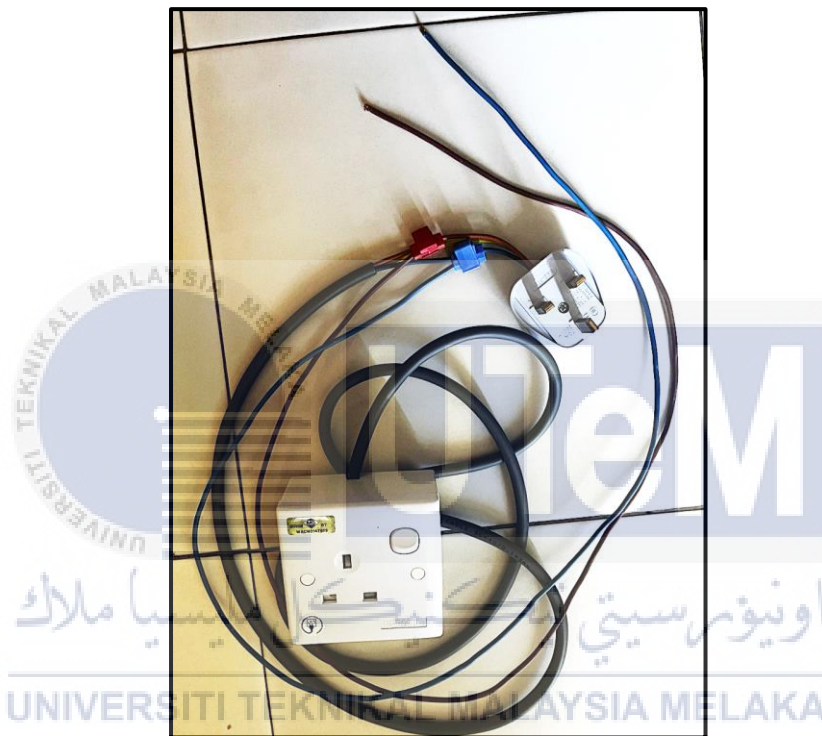
Figure 3.11: The Extender

An extender as Figure 3.11 was created for some purpose. Its first purpose is to make data collection easier and convenient. Its second purpose is to save up user time because they did not have to waste their time to cut the wire or making modifications for the data collection. Finally, this extender also can avoid the load from damages because the load will be plug in at extender and user did not have to cut the load wire.
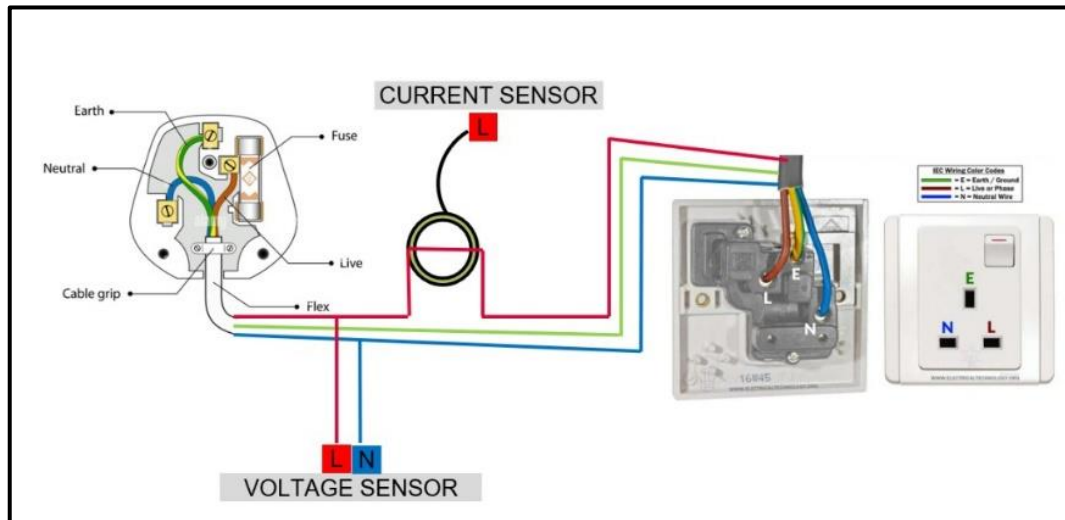
Figure 3.12: The Extender Schematic

3.6 Summary

Hardware such as an Arduino UNO microcontroller, CT Sensor, voltage sensor, LCD, and Node MCU are used in the "Development of Smart Clamp Meter for Energy Consumption Monitoring" project. The flow chart in Figure 3.13 represented the main programme implementation. The analysis and performance of the "Development of Smart Clamp Meter for Energy Monitoring Consumption" will be covered in the next chapter, as well as reflection on the results.

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CHAPTER 4

RESULTS AND DISSCUSSION

4.1   Introduction

The outcome of the "Development of Smart Clamp Meter for Energy Consumption Monitoring" projects are explained in this chapter. This chapter will discuss the outcomes that were tabulated and the data that were analyzed.

Energy monitoring system will be using CT sensor and voltage sensor which CT sensor will measure the value of current consumption by using current root mean square (IRMS) and voltage sensor will measure the AC voltage. The root-mean-square (rms) voltage of a sinusoidal source of electromotive force (Vrms) is used to characterize the source and it is the voltage squared time average's square root.

It will display the entire power used by the system for the apparent power. Consequently, the system's Vrms and Irms aid in calculating the apparent power of the tested load using the (4.1).

$$kVa = Vrms \times Irms$$

(4.1)

The apparent power of an electrical system is represented by KVA, whereas the true power is represented by KW. Due to the difference between AC and DC circuits, its use in electrical circuits varies. Since the current does not go out of phase in a DC circuit, the kW and kVA are equal.

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4.2   Circuit Diagram
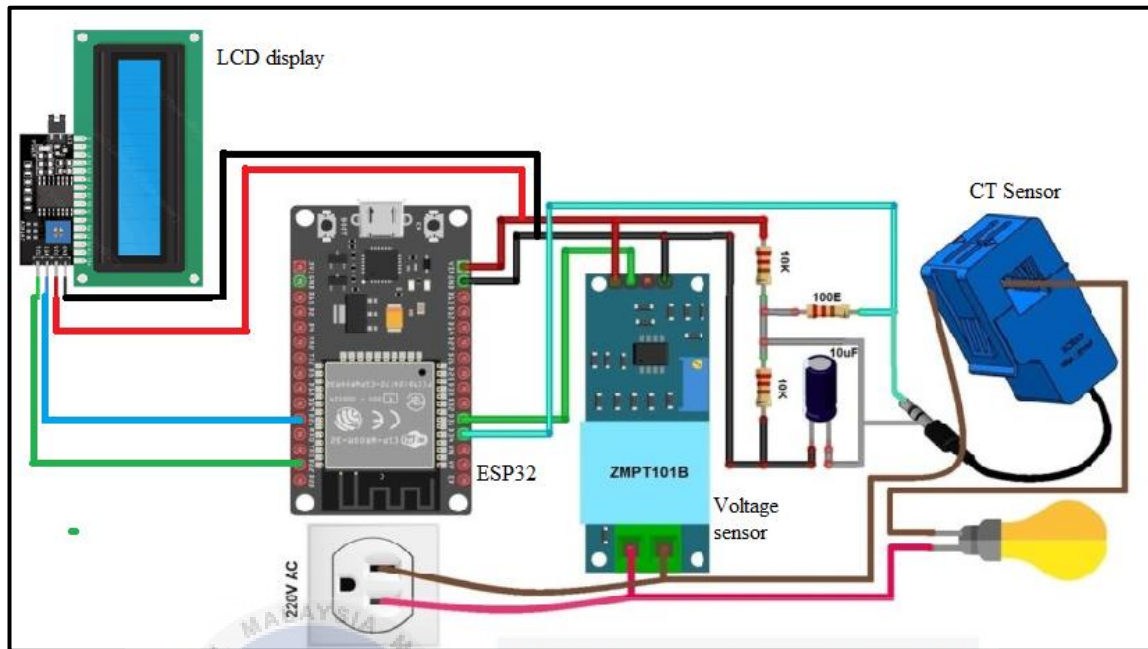
Figure 4.1: Circuit diagram with label

4.3   Prototype

A few procedures were taken to construct the circuit prototype. Voltage Sensor, CT Sensor, Wi-Fi Module, and LCD are the components that are utilized to configure the circuit.
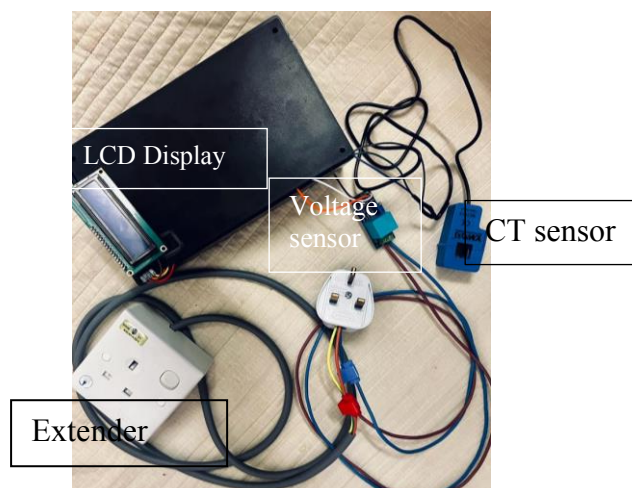
Figure 4.2: Completed prototype

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4.4 Results

This project has been put to the test using four different kinds of loads and various power inputs. To ensure that the finding result is precise to the objective and to demonstrate that this measurement is reliable and accurate, the power value must be compared to the theoretical value and measurement experiment value.

By using multimeter, the theoretical value for current can be collect and for voltage value, the theoretical value is 240V which value for ac voltage. So, based on voltage and current value, the apparent power can be calculated by using (4.2).

$$Power = Voltage \times Current$$

(4.2)

By having the theoretical value and measured value, percentage error calculation can be done by using the (4.3).

$$Percentage\ error\ (\%)$$
$$= \frac{|Experimental\ value(E) - Theoretical\ value(T)|}{|Theoritical\ value(T)|} \times 100$$

(4.3)

4.4.1 Result testing

Different type of load were used to get the test of results. So, the data were taken based on Current measured (A), Voltage measured (V), Apparent power (W) and Power consumption (kWh).

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Type of load	Current measured (A)	Voltage measured (V)	Apparent power(W)	Power consumption(kWh)
Table fan	0.094A	247.736V	23.402W	0.023kWh
Rice cooker	0.073A	249.134V	18.068W	0.018kWh
Powerbank	0.062A	243.359V	15.169W	0.015kWh
Kettle	0.090A	244.653V	22.062W	0.022kWh

Table 4.1: Result Testing with Different Type of Load

4.4.2 Load of table fan

The figures show the results of power consumption by a table fan.

Figure 4.3: Power consumed by table fan through Blynk apps

Table 4.2: Comparison of Theoretical and Technical Value for table fan

	Theoretical	Measured Value	%Error
Irms	I= 0.104 A	0.094 A	E = (TC-MV)÷MV×100 E = (0.104A-0.094A) ÷0.094A×100

			E = 10.64%
Vrms	V=240V	247.736 V	E = I(240-247.736)÷247.736×100 E = 3.12%
Apparent Power	P = I × V P = 0.104 × 240 P= 24.96W	23.402 W	E = (25-23.402)÷23.402×100 E = 6.83%
Power Consumption	kWh=(P×T) ÷ 1000 kWh= (25×1) ÷ 1000 kWh= 0.025kWh	0.023kWh	E = (0.025-0.023) ÷0.023×100 E =8.70 %

4.4.3 Load of rice cooker

The figures show the results of power consumption by a rice cooker.
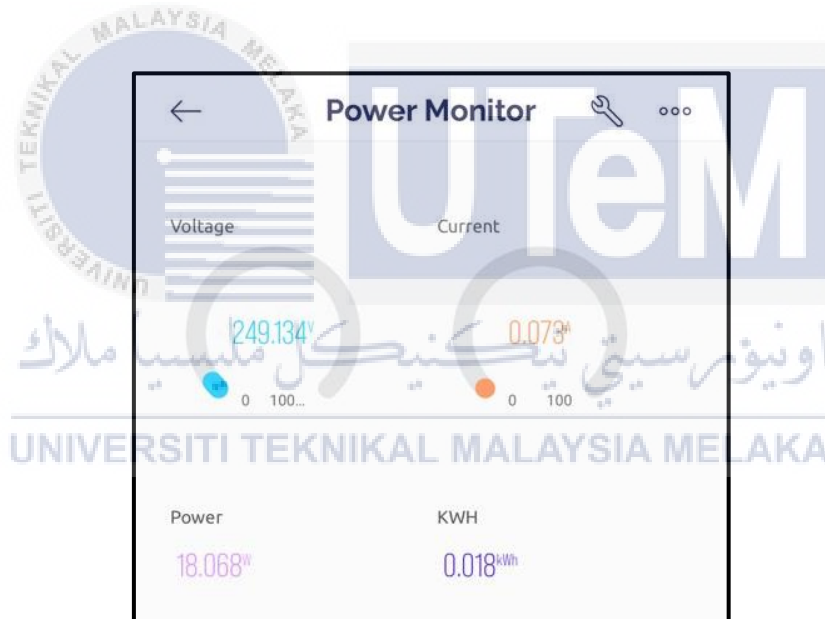
Figure 4.4: Power consumes by rice cooker through Blynk apps

Table 4.3: Comparison of Theoretical and Technical Value for rice cooker

	Theoretical	**Measuring Value**	**%Error**
Irms	I= 0.083 A	0.073 A	E = (TC-MV)÷MV×100 E = (0.083A-0.073A) ÷0.073A×100 E = 14.16%

Vrms	V=240V	249.134 V	E = (240-249.134) ÷249.134×100 E = 3.67%
Apparent Power	P= I × V P=0.083 × 240 P=19.92W	18.068 W	E = (20-18.068÷18.068×100 E =10.69%
Power Consumption	kWh=(P×T) ÷ 1000 kWh= (20×1) ÷ 1000 kWh= 0.020kWh	0.018kWh	E = (0.020-0.018)÷0.018×100 E =11.11%

4.4.4 Load of powerbank

The figures show the results of power consumption by a powerbank.
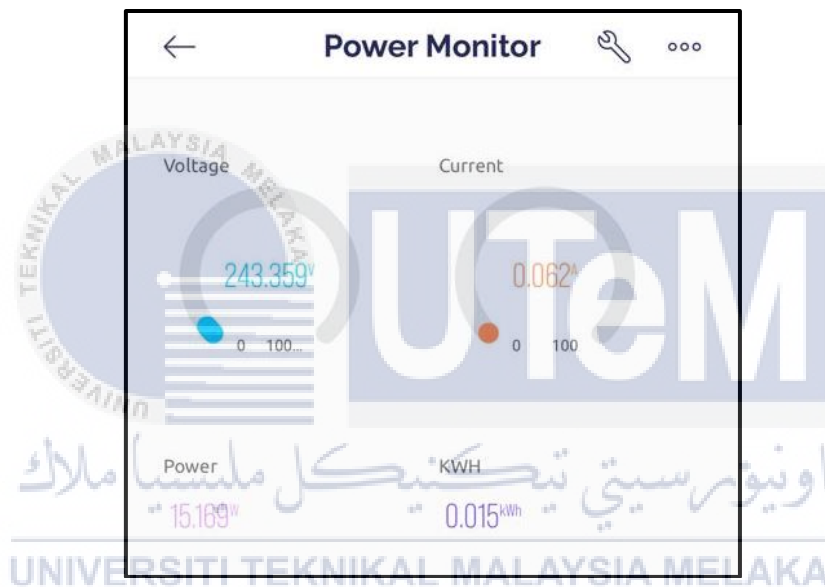
Figure 4.5: Power consumes by powerbank through Blynk apps

Table 4.4: Comparison of Theoretical and Technical Value for powerbank

	Theoretical	**Measuring Value**	**%Error**
Irms	I= 0.0625 A	0.062 A	E = (T-M) ÷M×100 E = (0.0625-0.062A)÷0.062A×100 E = 0.8 %
Vrms	V=240V	243.359 V	E = (240-243.359÷243.359×100 E = 1.38%
Apparent Power	P= I × V P= 0.0625 × 240 P= 15W	15.169 W	E = (15-15.169)÷15.169×100 E = 1.11%

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| Power Consumption | kWh=(P×T)÷1000
kWh= (15×1) ÷1000
kWh= 0.015kWh | 0.015kWh | E = (0.025-0.015)÷0.015×100
E = 0% |

4.4.5 Load of electric kettle

The figure below show the results of power consumption by a kettle.
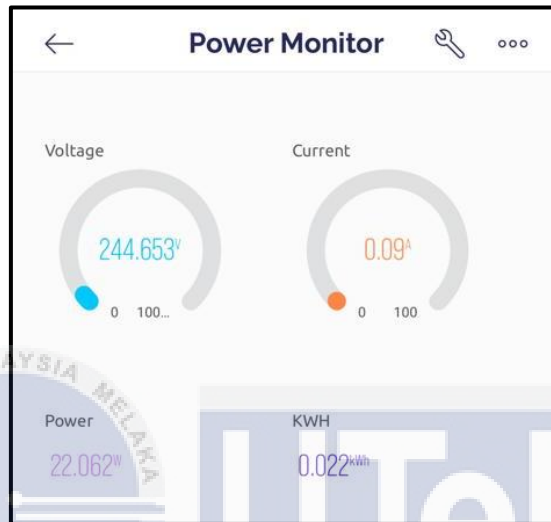
Figure 4.6: Power consumes by electric kettle through Blynk apps

Table 4.5: Comparison of Theoretical and Technical Value for kettle

	Theoretical	Measuring Value	%Error
Irms	I= 0.104 A	0.090 A	E = (TC-MV)÷MV×100 E = (0.104A-0.090A) ÷0.090A×100 E = 15.56%
Vrms	V=240V	244.653 V	E = (240-244.653)÷244.653×100 E = 1.90%
Apparent Power	P= I × V P= 0.104 × 240 P= 24.96W	22.062 W	E = (25-22.062)÷22.062×100 E = 13.32%
Power Consumption	kWh=(P×T)÷1000 kWh= (25×1)÷1000 kWh= 0.025kWh	0.022kWh	E = (0.025-0.022)÷0.022×100 E = 13.63%

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4.5   Analysis of Result

This is a study of all experimental outcomes in relation to theoretical calculations. This part will describe how the project "Development of Smart Clamp Meter for Energy Monitoring Consumption" compared theoretical calculation and experiment value.

The first experiment used a table fan, whose power consumption input was 0.025 kWh whereas the measured value was 0.023 kWh with an error rate of 8.70%. The second experiment used a rice cooker, with a theoretical power consumption value of 0.020 kWh and a measured value of 0.018 kWh. The rice cooker's error rate as a percentage is 11.11%. In addition, the theoretical value for a kettle's power consumption is 0.025 kWh, however the measured value is 0.022 kWh, with a 13.63% error rate. Then, by using powerbank, with a theoretical power consumption value of 0.015 kWh and a measured value of 0.015 kWh which it managed to get 0% of percentage error.

All of this error occurs because nature of energy loss and efficiency of electrical components of the created product to test the current and voltage of the electrical object. During the extraction of the data, the energy loss might have disrupted the accuracy of the project and it became less efficient during the real time data extraction. Better calibration and improvement of the circuit of the project might avoided some of the error and improve the data extraction.

As a result of the analysis experiment, the experimental value will always introduce error, which may be stated as either an absolute error or an error percentage. By

choosing an instrument that is appropriate for the specific measurement application and calibrating the device against a standard, the mistake may be avoided. The project's main objective of reading the collected data straight into the IoT system has been achieved.

4.6   Cost Estimation

To manage and monitor project expenses in accordance with the designated project spending budget, a cost estimate is crucial. The "Development of Smart Clamp Meter for Energy Consumption Monitoring" projects had an overall cost of RM 121.70, and the table below lists the components that went into the pricing.

Table 4.6: Cost Estimation

NO	COMPONENT NAME	PRICE (RM)
1	Electrolytic Capacitor 10uF	1.00
2	Resistor 10kΩ	1.00
3	Resistor 100Ω	1.00
4	Female To Male (FM) Jumper	4.60
5	Male To Male (MM) Jumper	3.70
6	Female To Female (FF)	5.00
7	Heat shrink tube 1 Meter 4.5mm	0.80
8	ARDUINO 12C Serial LCD 16×2	12.80
9	AC Voltage Sensor Module ZMPT101B (Single Phase)	8.90
10	9V Battery Holder	3.80
11	RV2.5 Multicore Wire (Black 1 Meter)	4.00
12	RV2.5 Multicore Wire (Red 1 Meter)	4.00
13	9V Supercell battery	2.90
14	Node MCU ESP32	25.00
15	Current Transformer (SCT-013-000)	27.20

16	Solderless breadboard 400 holes	4.50
17	Black Plastic Electronics Project Box	11.50
	Total (RM)	121.70

4.7 Problem Encountered and Solutions Taken

There were some problems during the project's design and construction phases. At the beginning of the project, Arduino UNO was implemented as the main microcontroller used for tracking all inputs and outputs from the system. However in the middle of the project timeline, the initial Arduino UNO was changed to Node MCU. This was because the latter microcontroller has a built-in wifi and do not have the module only. Through our experience, it is found that it will be easier to build the program and the circuit by focusing on only one microcontroller. Thus decides to use it.

The NodeMCU that were used initially was equipped with ESP 8266. However the board only have one analogue pin. In the project design, at least two analogue pins are needed in order for the data can be read from current sensor and voltage sensor and sent to the microcontroller. So at first, Arduino UNO were used again however the program already completed for ESP8266 NodeMcu. To complete the project, we have decided to move on onto the NodeMCU with ESP32 and have made a few changes on some of the libraries and pin assignment in order to use the same program.

During the data collection or data extraction also, it was a little bit complicated with voltage and current calibration value because need to try and error to get the most accurate results value.

4.8   Summary

The efficiency of the "Development of Smart Clamp Meter for Energy Consumption Monitoring" project's execution is explored. The performance of the CT Sensor and voltage sensor has been tested via several experiments. The data collected were further analyzed to understand the functionality of the developed prototype. The experiment's findings, which revealed a few design flaws that adversely affected the functioning of both sensors, were satisfactory. Overall, the project able successfully completed and the system achieves its goals.

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CHAPTER 5

CONCLUSION AND FUTURE RECOMMENDATION

5.1   Introduction

This chapter discusses how the "Development of Smart Clamp Meter for Energy Consumption Monitoring" initiatives have been implemented from design proposal, prototype development and integration, and finally prototype testing. In addition, this chapter will describe various recommendations and future work that may be used to enhance the project by any interested researchers.

5.2   Project Conclusion

The growth of the Internet of Things (IoT) has become a trend in enhancing human quality of life. Electricity parameters, including current and voltage, are measurable with a clamp meter or any other measurement technology that available today. Using an ammeter (a measurement tool to measure current) may requires the tool to be connected in series with the load. This will involve circuit modification to the load. However, another technology is available without interrupting the circuit, and that is by using a clamp meter. This is the main objective of this project. One of the project's design requirements is for electrical technician to be able to be fastening the measuring meter to an electrical device without further modification.

Second important feature of the prototype is its ability to display all measured currents in real-time mode. The data recording procedure is carried out by supplying a communication device that uses the Internet of Things to transport data across the

network. This design framework was able to be developed and it generates a product of consistently high quality.

As a conclusion of this project, based on the obtained data and analysis, it can be said that the "Development of Smart Clamp Meter for Energy Consumption Monitoring" project could detect and measure the value of electrical loads and display it on a smart phone with the aid of internet connection. Any electrical device may utilize the designed system. The prototype has been designed, created and tested as well. From the testing data analysis, the results show that this project can accurately detect and calculate power used by the measured device. However, to create a more reliable system with more valuable features, more improvements may be done. This will be discussed in the next subchapter.

5.3 Future work recommendations

This project can be improved in a few different ways. The list of suggestions is presented as follows:

- The prototype should collect the experimental data during the product was used in daily activities and while fully functioning to get the actual power consumption of the product tested.

- Different type of sensor with better tolerance might give a better result and decrease error in the reading.

- Improvement in the circuit and prototype to include direct wire to check the current as already did in the voltage sensor.

- Data collection should be done by calculating the average value of each data.

5.4   Commercialization of the prototype

The developed prototype in this project has good potential commercialization values. As mentioned earlier, our research group was approached by a local Small Medium Enterprise (SME) company, represented by a technician. He came to get views and opinions from FTKEE researchers on the current problem that he was having with an induction motor used as a conveyor belt in one food packaging factory. With the invention of this prototype, technicians will be able to describe the technical problems provided with sufficient data to support their claims. Good data collection will lead to sufficient analysis, and the analysis findings will help the technician to make decisions on what are the steps need to be taken to solve the current problem.

The designed prototype is an extension of a conventional clamp meter. The extended feature is its connectivity to the internet, making the electrical load monitoring easier and more convenient and at the same time will assist the technician with meaningful data for proper analysis.

Most of local SMEs could not afford high-end technology such as DCS. The developed prototype in this project could help to facilitate them in conducting online monitoring and troubleshooting machines at an affordable price. Therefore, this project has a huge commercialization potential, and it will be worthwhile to be further explored by researchers in near future.

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APPENDICES

Appendix A   Datasheet of Arduino UNO

Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.

Revision 3 of the board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V

Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Schematic & Reference Design

EAGLE files: arduino-uno-Rev3-reference-design.zip (NOTE: works with Eagle 6.0 and newer)
Schematic: arduino-uno-Rev3-schematic.pdf
Note: The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.
External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.
The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.
The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.

- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication using the SPI library.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- **TWI: A4 or SDA pin and A5 or SCL pin.** Support TWI communication using the Wire library.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and ATmega328 ports. The mapping for the Atmega8, 168, and 328 is identical.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.
The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno from the **Tools > Board** menu (according to the microcontroller on your board). For details, see the reference and tutorials.
The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).
You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.
The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available . The ATmega16U2/8U2 is loaded with a DFU bootloader, which can be activated by:

- On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2.
- On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader). See this user-contributed tutorial for more information.

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload. This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

Appendix B   Datasheet of Current Transformers Sensor

Split core current transformer — YHDC

Model: SCT-013   **Rated input current: 5A/100A**

Characteristics: Openning size: 13mm*13mm,
Non-linerity±3% (10%—120% of rated input current)
1m leading wire, standard Φ3.5 three core plug output.
Current output type and voltage output type (voltage output
type built-in sampling resistor)

Purpose: Used for current measurement, monitor and protection for AC motor,
lighting equipment, air compressor etc

Core material: ferrite

Mechanical strength: the number of switching is not less than 1000 times(test at 25℃)

Safty index: Dielectric strength(between shell and output)1000V AC/1min
Fire resistance property: In accordance with UL.94-Vo
Work temperature: -25℃—+70℃

Outline size diagram: (in mm)

Front View   Side View   Schematic diagram
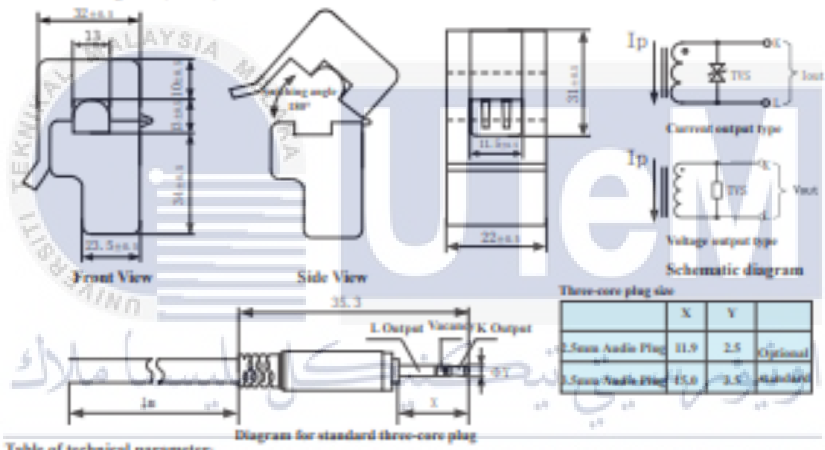
Diagram for standard three-core plug

Three-core plug size	X	Y	
2.5mm Audio Plug	11.9	2.5	Optional
3.5mm Audio Plug	15.0	3.5	Standard

Table of technical parameter:

Model	SCT-013-000	SCT-013-005	SCT-013-010	SCT-013-015	SCT-013-020
Input current	0-100A	0-5A	0-10A	0-15A	0-20A
Output type	0-50mA	0-1V	0-1V	0-1V	0-1V
Model	SCT-013-025	SCT-013-030	SCT-013-050	SCT-013-060	SCT-013-000V
Input current	0-25A	0-30A	0-50A	0-60A	0-100A
Output type	0-1V	0-1V	0-1V	0-1V	0-1V

※ Output type: voltage output type built-in sampling resistor, current output type built-in protective diode.

Tel: 86-13933609279   Fax: 86-7929499-804   skype:macymeng1
Web (China): www.yhdc.com   Web (Latvia): www.yhdc.lv

APPENDIX C Datasheet of Voltage Sensor

Qingxian Zeming Langxi Electronic   www.micro-transformer.com

ZMPT101B
Current-type Voltage Transformer
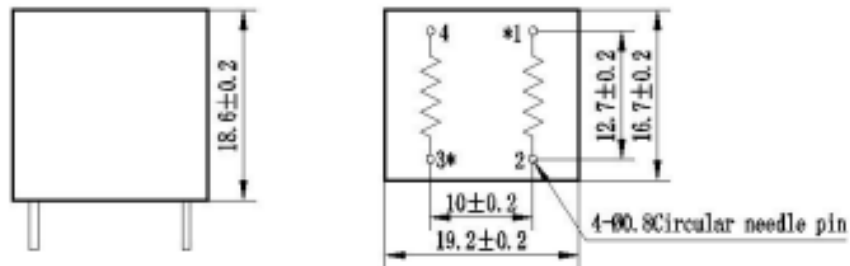
Small size, high accuracy, good consistency, for voltage and power measurement

Structural parameters:

Remarks: primary input: 1, 2 pins   secondary output: 3, 4pins
Or
primary input:: 3, 4 pins   secondary output::1, 2pins
"*" Same polarity

Front view   **Bottom view**

The main technical parameters:

Model	ZMPT101B
Rated input current	2mA
Rated output current	2mA
turns ratio	1000:1000
phase angle error	≤20′ (input 2mA, sampling resistor 100Ω)
operating range	0~1000V 0~10mA (sampling resistor 100Ω)
linearity	≤0.2%(20%dot~120%dot)
Permissible error	-0.3%≤ f ≤+0.2% (input 2mA, sampling resistor 100Ω)
Isolation voltage	4000V
application	voltage and power measurement
Encapsulation	Epoxy
installation	PCB mounting (Pin Length>3mm)
Operating temperature	-40℃~+60℃
Case Material	**ABS (Note: ABS CASE is NOT available for wave-soldering)**

Tel: 86-25-52601870   E-mail: zm@zeming-e.com

Direction for use:

Figure I   **Figure II**

$$U_o = \frac{U_i}{R'} \cdot R$$

U_i: Input voltage to output voltage
R': limiting resistor
R: sampling resistor
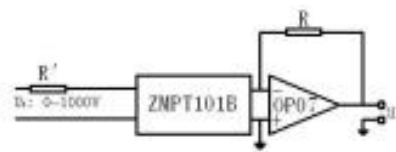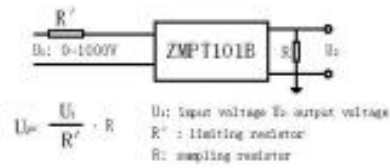
1. The typical usage of the product is for the active output (Figure I). R' is a limiting resistor, R is a sampling resistor.
2. The product can be directly through the resistance sampling, easy to use (Figure II).

APPENDIX D Datasheet of LCD Display

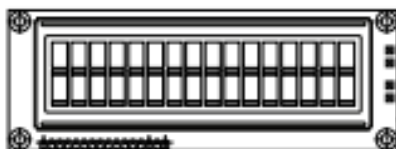## VISHAY
www.vishay.com

LCD-016N002L1

Vishay

16 x 2 Character LCD

FEATURES
- Type: Character
- Display format: 16 x 2 characters
- Built-in controller: ST 7066 (or equivalent)
- Duty cycle: 1/16
- 5 x 8 dots includes cursor
- + 5 V power supply (also available for + 3 V)
- LED can be driven by pin 1, pin 2, pin 15, pin 16 or A and K
- N.V. optional for + 3 V power supply
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT

MECHANICAL DATA

ITEM	STANDARD VALUE	UNIT
Module Dimension	122.0 x 44.0	
Viewing Area	99.0 x 24.0	
Dot Size	0.92 x 1.10	mm
Dot Pitch	0.98 x 1.16	
Mounting Hole	115.0 x 37.0	
Character Size	4.84 x 9.66	

ABSOLUTE MAXIMUM RATINGS

ITEM	SYMBOL	STANDARD VALUE			UNIT
		MIN.	TYP.	MAX.	
Power Supply	V_{DD} to V_{SS}	- 0.3	-	7.0	V
Input Voltage	V_I	- 0.3	-	V_{DD}	

Note
- $V_{SS} = 0$ V, $V_{DD} = 5.0$ V

ELECTRICAL CHARACTERISTICS

ITEM	SYMBOL	CONDITION	STANDARD VALUE			UNIT
			MIN.	TYP.	MAX.	
Input Voltage	V_{DD}	$V_{DD} = + 5$ V	4.7	5.0	5.3	V
Supply Current	I_{DD}	$V_{DD} = + 5$ V	-	1.0	1.5	mA
Recommended LC Driving Voltage for Normal Temperature Version Module	V_{DD} to V_L	- 20 °C	-	-	5.2	V
		0 °C	-	-	4.5	
		25 °C	4.2	4.2	-	
		50 °C	3.8	-	-	
		70 °C	3.5	-	-	
LED Forward Voltage	V_F	25 °C	-	4.2	4.6	V
LED Forward Current - Array	I_F	25 °C	-	260	520	mA
EL Power Supply Current	I_{EL}	$V_{EL} = 110 V_{AC}$, 400 Hz	-	-	5.0	mA

OPTIONS

PROCESS COLOR						BACKLIGHT			
TN	STN Gray	STN Yellow	STN Blue	FSTN B&W	STN Color	None	LED	EL	CCFL
x	x	x	x	x		x	x	x	

For detailed information, please see the "Product Numbering System" document.

DISPLAY CHARACTER ADDRESS CODE

Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
DD RAM Address	40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F

INTERFACE PIN FUNCTION

PIN NO.	SYMBOL	FUNCTION
1	V_{SS}	Ground
2	V_{DD}	+ 3 V or + 5 V
3	V_0	Contrast adjustment
4	RS	H/L register select signal
5	R/W	H/L read/write signal
6	E	H → L enable signal
7	DB0	H/L data bus line
8	DB1	H/L data bus line
9	DB2	H/L data bus line
10	DB3	H/L data bus line
11	DB4	H/L data bus line
12	DB5	H/L data bus line
13	DB6	H/L data bus line
14	DB7	H/L data bus line
15	A/Vee	+ 4.2 V for LED (Rx = 0 Ω)/negative voltage output
16	K	Power supply for B/L (0 V)

DIMENSIONS in milimeters
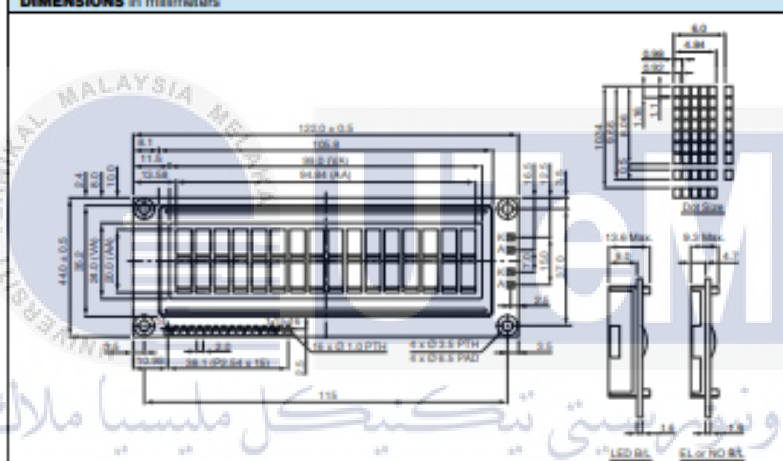
APPENDIX E Coding of "Development of Smart Clamp Meter for Energy Consumption Monitoring"

```cpp
#define BLYNK_PRINT Serial
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,16,2);
#include "EmonLib.h"    //https://github.com/openenergymonitor/EmonLib
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

#define BLYNK_TEMPLATE_ID "TMPLlok2tGUE"
#define BLYNK_DEVICE_NAME "Power Monitor"
#define BLYNK_AUTH_TOKEN "Hwh8IPdH2OSP7OFSWnH5WG8EtllfXJMX"

EnergyMonitor emon;

#define vCalibration 119.7
#define currCalibration 0.52

BlynkTimer timer;

char auth[] = "Hwh8IPdH2OSP7OFSWnH5WG8EtllfXJMX";
char ssid[] = "NurulHusna";
char pass[] = "nurulhusna1234";

//initialized millis and kWh
float kWh = 0;
unsigned long lastmillis = millis();
```

```
void myTimerEvent()
{
  emon.calcVI(20, 2000);
  kWh= emon.apparentPower*1 /1000;
  yield();
  Serial.print("Vrms: ");
  Serial.print(emon.Vrms, 2);
  Serial.print("V");
  Serial.print("\tIrms: ");
  Serial.print(emon.Irms, 4);
  Serial.print("A");
  Serial.print("\tPower: ");
  Serial.print(emon.apparentPower, 4);
  Serial.print("W");
  Serial.print("\tkWh: ");
  Serial.print(kWh, 5);
  Serial.println("kWh");

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Vrms:");
  lcd.print(emon.Vrms, 2);
  lcd.print("V");
  lcd.setCursor(0, 1);
  lcd.print("Irms:");
  lcd.print(emon.Irms, 4);
  lcd.print("A");
```
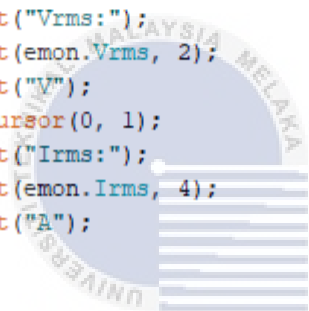
```
  delay(2500);

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Power:");
  lcd.print(emon.apparentPower, 4);
  lcd.print("W");
  lcd.setCursor(0, 1);
  lcd.print("kWh:");
  lcd.print(kWh, 4);
  lcd.print("W");

  delay(2500);

  lastmillis = millis();

  Blynk.virtualWrite(V0, emon.Vrms);
  Blynk.virtualWrite(V1, emon.Irms);
  Blynk.virtualWrite(V2, emon.apparentPower);
  Blynk.virtualWrite(V3, kWh);
  }

void setup()
  {
    Serial.begin(9600);
    Blynk.begin(auth, ssid, pass,"blynk.cloud", 80 );
    lcd.begin(16, 2);

    emon.voltage(35, vCalibration, 1.7); // Voltage: input pin, calibration,phase_shift
    emon.current(34, currCalibration); // Current: input pin, calibration.

    timer.setInterval(5000L, myTimerEvent);
    lcd.init();
    lcd.backlight();
    lcd.setCursor(3, 0);
    lcd.print("IoT Energy");
    lcd.setCursor(5, 1);
    lcd.print("Meter");
    delay(3000);
    lcd.clear();
    }

void loop()
{
Blynk.run();
timer.run();
}
```

APPENDIX F Gantt Chart

A. Gantt Chart Final Year Project I

No	Activities	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Registration of Project Tittle	▓														
2	Meeting with Supervisor	▓	▓		▓	▓					▓		▓	▓		
3	Internet and library research			▓	▓	▓	▓	▓								
4	Proposal draft							▓								
5	Study on project					▓	▓	▓								
8	Chapter 1 write up							▓		▓						
9	Chapter 2 write up								MID-SEMESTER BREAK							
10	Chapter 3 write up												▓	▓		
11	PSM 1 Presentation														▓	

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B. Gantt Chart Final Year Project II

No	Activities	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	PSM 2 Talk	■														
2	Meeting with Supervisor				■	■		■					■	■		
3	Prototyping			■	■	■	■	■								
4	Testing and troubleshooting							■		■	■	■	■	■		
5	Result and analysis										■	■	■	■		
8	Chapter 4 write up							■	M I D - S E M E S T E R B R E A K	■	■	■	■			
9	Chapter 5 write up									■	■	■	■	■		
10	Submit Report														■	■
11	PSM Presentation														■	