A

MINI PROJECT REPORT

ON

“POWER OVER ETHERNET (PASSIVE)”

FOR PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
MINI PROJECT SUBJECT
OF T.E. E&TC – 2019 COURSE, SPPU, PUNE

By

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PUNE INSTITUTE OF COMPUTER TECHNOLOGY
PUNE – 43

ACADEMIC YEAR: 2023 - 2024

Department of Electronics and Telecommunication Engineering

Pune Institute of Computer Technology, Pune – 43

CERTIFICATE

This is to certify that the Mini Project report entitled

Power over Ethernet (Passive)

has been successfully completed by

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Is a bona fide work carried out by them under the supervision of Dr. Pranav B. Pawar and it is approved for the partial fulfillment of the requirements for the Mini Project subject of T.E. E&TC – 2019 Course of the Savitribai Phule Pune University, Pune.

Prof. Pranav B. Pawar
Project Guide
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Dr.M. V. Munot
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Place: Pune
Date :

ACKNOWLEDGEMENT

We extend our gratitude to our Project Guide Dr. Pranav Pawar and Mr. Atul Sutar for their invaluable guidance, encouragement, and support throughout the duration of this project. Their expertise, mentorship, and unwavering commitment played a pivotal role in shaping our ideas and refining our approach.

We would like to express our sincere appreciation to the faculty members of the Department of Electronics and Telecommunication Engineering at Pune Institute of Computer Technology for their constant encouragement and insightful feedback.

Special thanks to our fellow classmates and colleagues for their collaboration, assistance, and constructive discussions, which enriched our understanding and enhanced the quality of our work.

We are deeply indebted to our families for their patience, understanding, and unwavering support during our academic pursuits. Their encouragement and belief in our abilities have been a constant source of motivation.

Lastly, we acknowledge the contributions of researchers, scholars, and practitioners whose work has inspired and informed our project. Their dedication to advancing knowledge and technology in the field of assistive communication for individuals with auditory impairments has been instrumental in shaping our research endeavors.

This project would not have been possible without the collective efforts, encouragement, and support of all those mentioned above. We are truly grateful for their invaluable contributions to our academic journey.

Rushikesh Patil

Mihir Sardesai

Rana Vanikar

ABSTRACT

In today's interconnected world, the demand for efficient and versatile networking solutions continues to grow. Power over Ethernet (PoE) has emerged as a transformative technology, addressing the evolving needs of modern networking environments. Traditionally, network devices such as IP cameras, wireless access points, VoIP phones, and IoT devices required separate power sources, often leading to complex and costly installations. However, PoE revolutionizes this paradigm by enabling both data and power transmission over a single Ethernet cable.

The project is cost efficient implementation of PoE which is compatible with standard as well as proprietary devices which work with Ethernet cables.

It enhances the user-friendliness by harnessing the power of ESP32 microcontroller for real-time monitoring and visualizing with the use of ACS712, InfluxDB and Grafana.

By leveraging PoE's centralized power delivery and real-time monitoring features, the project demonstrates its potential in various applications, including smart homes, power delivery in homes with old electrical standards, under-construction buildings, warehouses and data centers.

Through this abstract, we underscore the project's significant contribution to advancing connectivity, sustainability, and automation across a wide range of applications, including smart homes, legacy electrical infrastructure, construction sites, warehouses, and data centers.

Rushikesh Patil

Mihir Sardesai

Rana Vanikar

List of figures:

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Abbreviations

Symbol/word	meaning	Remark
PoE	Power over Ethernet	
IoT	Internet of Things	
IP	Internet Protocol	
VoIP	Voice over Internet Protocol	
CAT	Category	
WAP	Wireless Access Point	
PCB	Printed circuit Board	
IDE	Integrated Dev Environment	
WiFi	Wireless Fidelity	
RJ45	Registered Jack 45	
CAD	Computer Aided Design	

CONTENTS

Feasibility report

Title: Power over Ethernet (Passive)

Group members:

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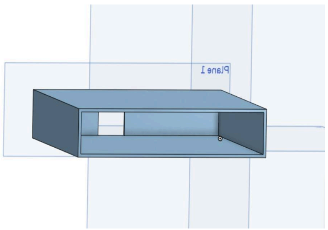
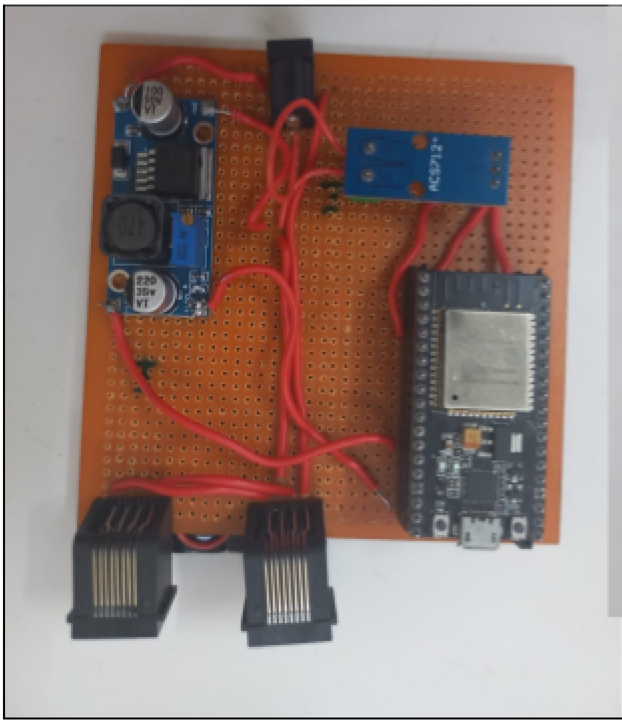
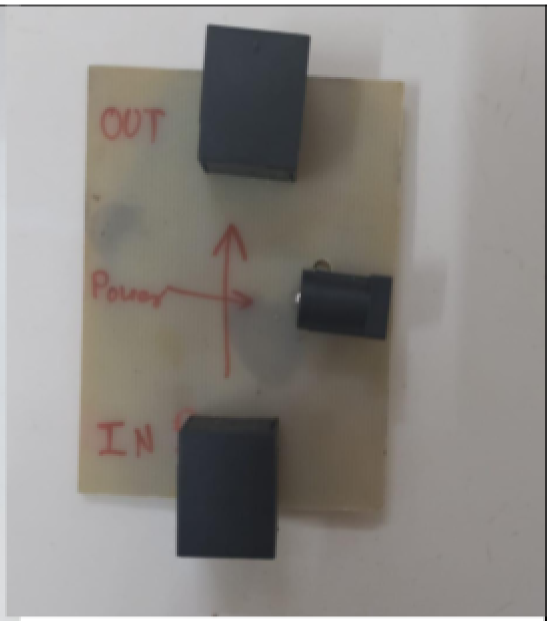
3) Rana Nilesh Vanikar 32368

Tools required	Testing possibility	Controller	Cost
Hardware/components: PCB, Zero PCB, copper cladding, jumper wires, Ethernet RJ45 CAT5 cable, DC jack & plug, ethernet jack	**Hardware: Yes** PCB tracks and ethernet cable tester	**ESP32 microcontroller**	**Rs 900/-**
Software: EasyEDA, Arduino IDE, Docker, InfluxDB, Grafana	**Software: Yes**	**N/A**	**Rs 0/-**
Tools available within campus or outside:	**Sensors required**	**Signal conditioning if any**	
PCB Printing Facility Ethernet cables RJ45 CAT5 Ethernet tester Soldering station ACS712 current sensor	ACS712	No	**Rs 0/-**
Applications:	**PCB Design & Fabrication**	**Datasheets/ application notes available**	
PoE can be implemented in PoE enabled and Non-PoE devices in old infrastructures, warehouses, data centers to power IoT devices, WAPs & IP Cameras. It also enables monitoring the power usage.	Yes available on campus as well as in nearby region	Yes	

Mechanical design	**Enclosure design**	**Demonstration**	
Length: 115mm Breadth: 107mm Height: 25mm Thickness: 1.5mm Power Input Window: 15x15mm		At present 3D model is present, ready to print	

Title of project: Power over Ethernet(Passive)





Electric specification

Input specifications: As much as required, upto 48W of power tested i.e. up to 24V input voltage
Output specifications: As much as required up to 48W of power tested i.e. up to 24V output voltage
Features if any: Cost efficient PoE, User friendly monitoring & visualisation, centralised power delivery & versatile applications

Mechanical specification

Length: 115mm
Breadth: 107mm
Height: 25mm
Thickness: 1.5mm
Power Input Window: 15x15mm

Rs 900/- excluding cost of ethernet cables

Group members:

32352	**Rushikesh Patil**
32359	**Mihir Sardesai**
32368	**Rana Vanikar**

Mini Project

Class & Batch : TE7 N7 **Group No. : N7-4**

Synopsis

on

"Power over Ethernet (Passive)"

Submitted By

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Project Guide

Dr. Pranav B. Pawar

Mr. Atul Sutar

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PUNE INSTITUTE OF COMPUTER TECHNOLOGY

Academic Year : 2023 - 2024

1. Project Title: Power over Ethernet (Passive)

2. Introduction/ Motivation:

Power over Ethernet (PoE) has transformed device powering and connectivity in modern communication systems by integrating power and data transmission over Ethernet cables. Despite its benefits, there are significant gaps in current PoE technology.

Our project aims to enhance PoE to improve efficiency, reliability, and compatibility across various applications. We'll identify existing problems, like inefficient power delivery and device compatibility issues, then develop innovative solutions.

We'll create a separate output PCB to ensure compatibility between PoE-enabled and non-PoE devices, using wider tracks for power and data transmission. Additionally, we'll explore new technologies to optimize power delivery and enhance device interoperability.

Through rigorous testing, we'll evaluate our solutions' effectiveness in improving PoE functionality, aiming for widespread adoption and practical use across industries. Ultimately, our project aims to provide network administrators with efficient device power consumption monitoring capabilities.

3. Literature Survey / Prior work:

Paper	Description	Conclusion
[1]	PowerOver Ethernet (PoE) Technical Overview	Lester Shen's Power Over Ethernet (PoE) Technical Overview highlights its key components, Ethernet cable standards, and power standards. PoE is crucial for efficient powering devices over Ethernet networks, and its evolution, including PoE+, UPoE, and higher-power PoE, expands its applications. Collaboration between IT and facilities staff is essential for PoE network management.
[2]	An Efficient Power Over Ethernet (PoE) Interface With Current-Balancing and Hot-Swapping Control	The abstract presents a new PoE interface architecture that makes use of all four pairs of a CAT5 cable in order to provide more power. To ensure optimal power delivery, this architecture has a current-balancing control block to equalize currents in the cable. A hot-swapping control block is also included to safeguard electronics against voltage spikes and inrush current during hot-plugging incidents. In order to minimize power loss, the interface limits voltage and current using effective regulatory loops. The findings of the experiment show that all cable pairs have balanced currents and that the protective systems are efficient in hot-plugging situations.

[3]	“What is Power Over Ethernet (PoE)” online article by Cisco	Power over Ethernet (PoE) technology, developed by Cisco in 2000, enables the delivery of DC power and data transmission over copper Ethernet cabling. It has been standardized by IEEE and the Ethernet Alliance, leading to IEEE 802.3af (Type 1) in 2003, IEEE 802.3at (PoE+) in 2009, and IEEE 802.3bt (4PPoE) in 2018. PoE offers several benefits, including cost reduction, energy savings, flexibility in device placement, and safety by intelligently protecting network equipment. Its increasing power capacities open up new applications, such as LED lighting, security systems, monitors, and air conditioners. The integration of data and power over Ethernet cables facilitates the transition to Ethernet-based industrial control systems.
[4]	Power over Ethernet technology online article by Office of Energy Efficiency and Renewable Energy U.S.	The article provides an overview of Power-over-Ethernet (PoE) technology, focusing on its evolution and significance. It highlights the integration of power and data transmission over a single cable and native power monitoring capabilities. The text also discusses PNNL studies on PoE, which address market confusion and specification needs, focusing on system architecture and cable selection's impact on energy performance. The text also discusses lessons learned from PNNL studies, such as the development of design tools for building DC electrical distribution systems. It also references relevant reports and articles, and suggests future research directions, such as exploring PoE system architectures, optimizing cable characteristics, and developing standardized guidelines for PoE deployment.

4. Problem Definition and Objectives:

- This helps enhancing cost efficiency, network reliability and performance, capacity planning and ultimately environmental sustainability
- Developing a scalable and efficient system for monitoring power consumption in PoE setups.
- Implementing a solution that allows for real-time data collection and analysis to detect anomalies and optimize energy usage.
- Providing stakeholders with actionable insights through intuitive visualization dashboards.
- Enhancing the reliability and performance of PoE infrastructure by identifying potential issues early and proactively managing power distribution.

5. Block Diagram:

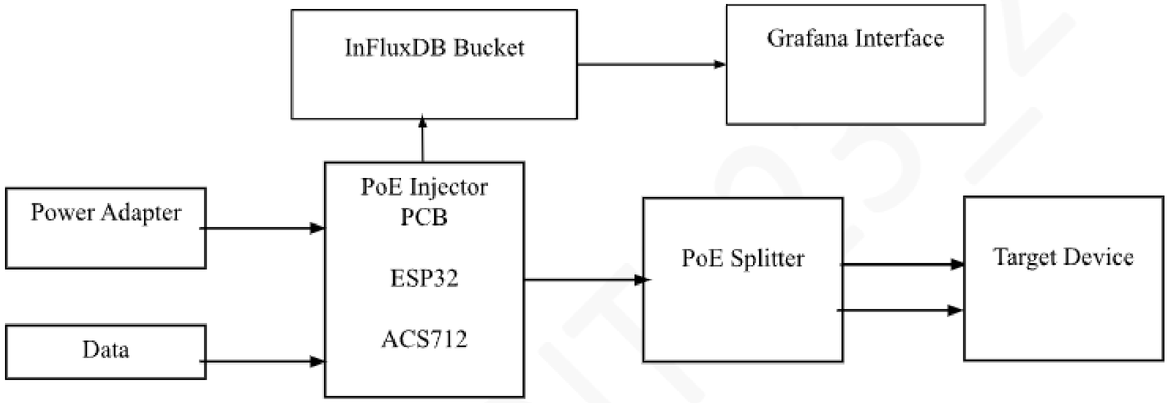

Fig 5.1: Block Diagram of Project

- Power Adapter: Official rated power adapter of target device, we used a 12V adapter of WAP.
- Data: Input data through PoE from a network switch.
- PoE Injector PCB: encloses ESP32, ACS712 current sensor and power injector circuitry, combines & sends data & power on same ethernet cable.
  ACS712 measures current sent through output cable sends the data to ESP32/ESP8266 which in turn uploads the data to InFluxDB bucket. Fetched through bucket Grafana visualizes the data.
- PoE Splitter: an optional PCB used to split power and data from PoE cable and feed it target Non-PoE device. This module can be omitted for PoE compatible devices.

6. Hardware Requirements:

Following table gives the details about software required

Table 2.1: Hardware Requirements

Sr No.	Hardware Required	Specifications	Quantity
1.	PCB	Generic	01
2.	Zero PCB	Generic	01
3.	Jumper Wires	Generic	As required
4.	Ethernet RJ45 CAT5 cable	Generic	As required
5.	DC Jack and Plug	Generic	02 pairs
6.	Ethernet Jack	8P8C	04
7.	ACS712 sensor	5A	01
8.	NodeMCU ESP32S	Generic	01
9.	Buck Converter	LM2596S	01

7. Software Requirements:

Following table gives the details about software required

Table 2.2: Software Requirements

Sr No.	Software Required	Applications
1.	EasyEDA	PCB & Circuit Design
2.	Arduino IDE	Coding ESP for uploads
3.	InFluxDB	Real-Time Database
4.	Grafana	Visualisation of data
5.	Docker	Increase scalability and isolation
6.	Azure Virtual Machine	Increase accessibility and security

8. References:

[1]. Shen, Lester. (2019). PowerOver Ethernet (PoE) Technical Overview.

10.13140/RG.2.2.11680.53769.

[2]. Z. Xiao, "An Efficient Power Over Ethernet (PoE) Interface With Current-Balancing and Hot-Swapping Control," in IEEE Transactions on Industrial Electronics, vol. 65, no. 3, pp. 2496-2506, March 2018, doi: 10.1109/TIE.2017.2739693.

keywords: {Bridge circuits;Logic gates;MOSFET;Voltage control;IEEE 802.3 Standard;EPON;Current-balancing;current sharing;hot-plugging;hot-swapping;power over ethernet (PoE)},

[3]. “What is Power Over Ethernet (PoE)” https://www.cisco.com/c/en/us/solutions/enterprise-networks/what-is-power-over-ethernet.html

[4]. U.S. Department of Energy. (n.d.). Power over Ethernet technology. Retrieved from https://www.energy.gov/eere/ssl/power-over-ethernet-technology, [2016].

CHAPTER 1: Introduction

1.1 Background

Power over Ethernet (PoE) integrates power and data transmission over Ethernet cables, standardized by IEEE 802.3af, 802.3at (PoE+), and 802.3bt (PoE++) standards. It eliminates the requirement for separate power cables in devices like IP cameras and VoIP phones, simplifying installation and reducing costs. PoE injects power into Ethernet cables alongside data signals, enabling devices to receive power directly from the cable without additional power sources. Its convenience, cost-effectiveness, and flexibility have made it popular in networking, telecommunications, and IoT applications.

1.2 Relevance

Power over Ethernet (PoE) is highly relevant to Electronics and Communication Engineering (ECE) and its associated domains due to its pivotal role in modern communication systems. PoE embodies the integration of power and data transmission, which is fundamental in these fields. Exploring PoE provides insights into networking infrastructure, energy efficiency, and real-time data monitoring, essential elements of communication engineering. Additionally, PoE's applications in areas like IoT and automation demonstrate its interdisciplinary significance, offering solutions to contemporary challenges in communication systems. Overall, PoE enriches our understanding of integrated communication systems, aligning with the core principles of ECE.

1.3 Literature Survey

Table 1.1 : Literature Survey

Paper	Description	Conclusion
[1]	PowerOver Ethernet (PoE) Technical Overview	Lester Shen's Power Over Ethernet (PoE) Technical Overview highlights its key components, Ethernet cable standards, and power standards. PoE is crucial for efficient powering devices over Ethernet networks, and its evolution, including PoE+, UPoE, and higher-power PoE, expands its applications. Collaboration between IT and facilities staff is essential for PoE network management.

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1.4 Motivation

In old infrastructures which did not consider power delivery to devices at unusual places like the middle of corridor, outer corner of building(for CCTVs, power delivery is a big challenge in this case and often requires extension cords installed afterwards. So, installing separate lines for data & power becomes a task and investment. Instead what if we supplied power & data together on one cable to up low power devices like WAPs, CCTVs, IP Cameras & occupancy sensors. Less research work & material was found on this topic. Thus, much exploration has to be done in this sector as it would greatly reduce cabling costs for short length device communications.

1.4.1 Identification of Gaps and Limitations

In reviewing existing literature and research, several gaps and limitations were identified in the current understanding and implementation of Power over Ethernet (PoE). These include inconsistencies in device costs, compatibility issues with legacy devices, and challenges in optimizing energy efficiency in PoE networks.

1.4.2 Justification for Undertaking the Project

The decision to undertake this project was motivated by the pressing need to address the identified gaps and limitations in PoE technology. As highlighted in the previous sub-section, there is a clear need for standardization, interoperability improvements, and enhanced energy management solutions in PoE deployments.

1.4.3 Importance of Finding Solutions

The significance of finding solutions to the identified gaps and limitations cannot be overstated. Efficient power delivery, seamless integration with existing infrastructure, and optimization of energy consumption are crucial for the widespread adoption and effective utilization of PoE technology across various applications.

1.4.4 Further Work and Improvisation

Moreover, there is ample opportunity for further improvisation and enhancement of PoE technology. By delving deeper into power delivery standards, exploring innovative energy management techniques, and leveraging advancements in networking technologies, significant advancements can be made in the reliability, efficiency, and scalability of PoE systems.

In conclusion, this section underscores the importance of addressing gaps, limitations, and the need for further work in PoE technology. By providing a clear justification for the project and outlining areas for improvement, it sets the stage for the subsequent sections of the report.

1.5 Aim

1.5.1 Aim

This project aims to enhance Power over Ethernet (PoE) technology to improve its cost efficiency, reliability, and interoperability across various applications. By addressing key challenges in PoE deployment, the project seeks to contribute to its widespread adoption and optimization for practical use in diverse industries and domains at low costs and enables smart monitoring inorder to help network administrators to monitor, visualize and audit power consumption of devices.

1.5.2 Objectives

1. Understanding Problems: Figure out what's not working well with PoE right now. Is it not delivering power efficiently? Are devices not working together like they should? Or they're costly and have a compatibility issues We need to find out.

2. Coming up with Solutions: Once we know what's wrong, let's think ways to fix it, maybe we can improve how power is sent, improve compatibility between devices, or explore new technologies to enhance PoE functionality.

3. Testing Our Ideas: We will put our ideas to the test. We will see if they really make PoE work better. Does it save power? Does it make devices work together without problems? We need to find out if our ideas are any good.

1.7 Technical Approach

Talking about compatibility, as our device should be compatible with PoE enabled as well as Non-PoE devices we needed a separate output PCB which would make non-PoE devices compatible and can be kept aside for PoE enabled devices. For this we needed some wider tracks on output PCBs for power and data.

CHAPTER 2: Block Schematic and Requirements

2.1 Introduction

We needed a compatible and IoT enabled PoE to transfer power & data to non-PoE devices. To enhance it using IoT we used NodeMCU ESP32 and ACS712 current sensor to read the current. We used Docker, containerized InfluxDB & containerized Grafana to monitor, load real-time data and display using Grafana on Docker containers to enhance scalability and introduce isolation.

2.2 Block Diagram

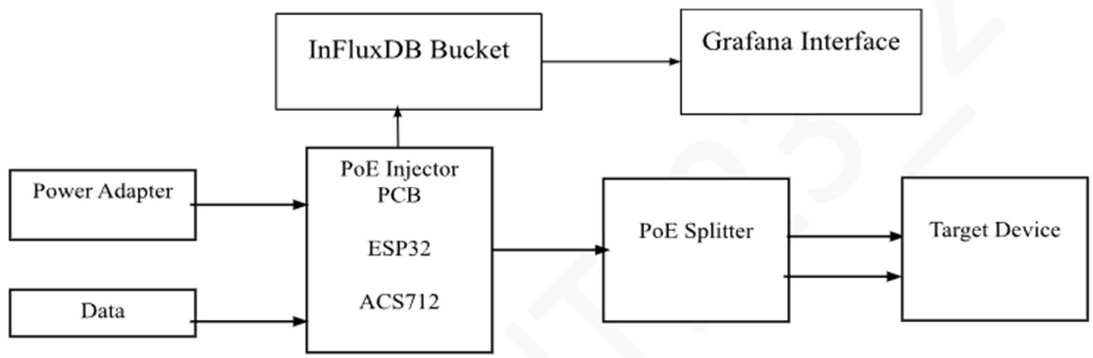

Fig.2.1. Block schematic of a PoE

- Power Adapter: Official rated power adapter of target device, we used 12V adapter of WAP.
- Data: Input data through PoE from a network switch.
- PoE Injector PCB: encloses ESP32, ACS712 current sensor and power injector circuitry, combines & sends data & power on same ethernet cable.
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-

2.3 Requirements

a) Hardware Requirements:

Following table gives the details about hardware required

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b) Software Requirements:

Following table gives the details about software required

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Sr No.	Software Required	Applications
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2.	Arduino IDE	Coding ESP for uploads
3.	InFluxDB	Real-Time Database
4.	Grafana	Visualisation of data
5.	Docker	Increase scalability and isolation
6.	Azure Virtual Machine	Increase accessibility and security

2.4 Selection of sensors and major components

Project's major parts include current sensor, so there are various current sensors available in the market- SCT-013-030 Non-invasive AC Current Sensor Clamp Sensor, ZMCT103C AC Current Sensor Module and ACS712, out of which ACS712 is able to measure AC & DC. Thus, ACS712 is the most appropriate one out of the available options as other options are measuring AC.

In microcontrollers, available options are Arduino Nano, ESP32 & ESP8266 out of which we coded a ESP32/ESP8266 sketch for capturing and uploading data in InfluxDB bucket.

Table 2.3: Microcontroller Comparison Table

Microcontroller	WiFi	Cost
Arduino Nano	Yes	~700/-
ESP32	Yes	~400/-
ESP8266	Yes	~200/-

The reason for choosing ESP32/ESP8266 is because it consumes low cost. These are the low-cost microcontrollers with WiFi module available in the market.

CHAPTER 3: System Design

3.1 Design & Components

3.1.1 Power over Ethernet (Passive) Concept:

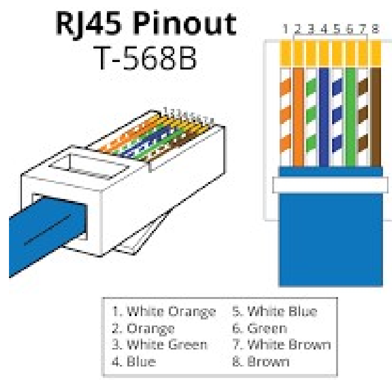

Fig 3.1: RJ45 wiring diagram

The basic concept of implementing PoE Is using the unused pair of wires in a standard RJ45 CAT5 ethernet cable. In RJ45 CAT5 cable the wires 4, 5, 7 and 8 i.e blue, blue white pair and brown, brown white pair are unused and are kept for future use and innovations.
PoE is basically using these cables for power transmission.

3.1.2 ESP32 Microcontroller:

The ESP WROOM microcontroller, powered by the Tensilica Xtensa LX6 architecture, is a powerful central processing unit (CPU) for embedded applications. Its dual-core processor and extensive connectivity options make it ideal for real-time data processing and monitoring. The microcontroller's clock frequency is governed by an external crystal oscillator, offering substantial processing power. Its total program and data memory size significantly impact performance and storage capacity. Key pins include GPIO ports for general-purpose input/output operations, serial communication protocols for seamless data exchange, and peripheral interfaces for user interaction.

3.1.3 DC jack and plug:

These are essential components in electronic devices for supplying and transmitting direct current (DC) power. The DC jack is a cylindrical metal socket with electrical contacts, designed with a center pin or sleeve configuration for proper power supply. The DC plug, also known as a power plug or power connector, is the mating connector that inserts into the DC jack to establish an electrical connection and supply power to the device. The jack and plug are designed to ensure a secure connection, minimizing the risk of accidental disconnection and ensuring reliable power delivery. Some DC jacks may also incorporate locking mechanisms or retention features for enhanced stability.

3.1.4 ACS712 Current Sensor 5A:

It is a Hall-effect-based linear current sensor designed for precise measurement of DC and AC currents. It is optimized for applications like power monitoring, motor control, battery management, and energy efficiency systems. The sensor uses the Hall Effect principle to detect the magnetic field generated by the current-carrying conductor, converting it into a voltage proportional to the current. It provides a linear analog output voltage, simplifying interfacing with microcontrollers and other electronic components. The sensor also features low offset and drift characteristics, ensuring accurate measurements over time and temperature variations. It operates over a wide supply voltage range, offering flexibility in system design and compatibility with various power sources. The ACS712 is compact, making it easy to integrate into space-constrained designs or existing systems.

3.1.5 Buck Converter 5V:

The LM2596S is a step-down (buck) switching voltage regulator integrated circuit (IC) manufactured by Texas Instruments. It is used in electronic circuits to reduce a higher input voltage to a lower output voltage, making it ideal for applications requiring power efficiency and voltage regulation. The LM2596S Buck Converter Circuit includes an input voltage (Vin) that can handle input voltages ranging from a few volts above the desired output voltage up to 40V, adjustable output voltages using external components like resistors, an inductor to store and transfer energy, a diode to prevent reverse current flow, an output capacitor to reduce output voltage ripple, feedback resistors (R1 and R2) to set the output voltage, and a switching transistor and control circuitry to regulate the output voltage efficiently. The LM2596S offers high efficiency, wide input voltage range, adjustable output voltage, internal overcurrent protection, thermal shutdown features, and compact size for easy integration into various electronic designs.

3.1.6 Arduino IDE:

The Arduino Integrated Development Environment (IDE) is a software platform used by makers, hobbyists, and professionals for programming microcontroller-based projects. It offers a user-friendly interface and tools to simplify the process of writing, compiling, and uploading code to various Arduino-compatible boards, including the ESP32 and ESP8266. Key features include a code editor with syntax highlighting, auto-indentation, and code completion, a library manager for easy search and management of libraries, a board manager for easy board selection and configuration, a serial monitor tool for real-time communication between the microcontroller and computer, an upload tool for flashing compiled code onto the microcontroller, and examples and tutorials to help users get started with programming their Arduino-compatible boards.

We used the Arduino IDE with ESP32/ESP8266, and followed these steps:

1. Install libraries for interfacing with the ACS712 sensor and communicating with InfluxDB.
2. Write code in the Arduino IDE, initializing the sensor, reading current values, establishing a connection to the InfluxDB database, and uploading data using HTTP requests.
3. Compile and upload your code, checking for errors, and uploading it to the ESP32 or ESP8266 board using the upload tool.

By leveraging the Arduino IDE's intuitive interface and powerful features, we utilised WiFi module on ESP32/ESP8266 to upload data to real time database called "Bucket" in InFluxDB.

3.1.7 InFluxDB:

InfluxDB is an open-source time-series database designed to efficiently handle high volumes of time-stamped data from various sources, including IoT devices, sensors, monitoring systems, and applications generating real-time metrics. It offers time-series data storage, high write performance, scalability, and a SQL-like query language called InfluxQL. It allows users to define retention policies and continuous queries to automatically expire and delete old data based on specified criteria. InfluxDB integrates with other tools and platforms, such as visualization tools like Grafana, alerting systems like Kapacitor, and data ingestion frameworks like Telegraf. In your project, InfluxDB was used to store real-time data collected from ESP32/ESP8266 microcontroller-based devices, enabling efficient monitoring, tracking, and analysis of environmental conditions, system performance, and insights for further analysis and decision-making.

3.1.8 Grafana:

Grafana is an open-source analytics and visualization platform that allows users to create customized dashboards for monitoring and analyzing time-series data. It supports integration with various data sources, such as InfluxDB, Prometheus, Elasticsearch, and MySQL, providing a comprehensive view of system metrics and performance. Grafana excels at visualizing time-series data, allowing users to plot metrics over time, zoom in on specific time ranges, and apply functions for aggregation and downsampling. It offers a wide range of visualization options, including line graphs, bar charts, heatmaps, gauges, and more. Users can customize colors, scales, annotations, and other settings to customize their visualizations. Grafana also provides alerting capabilities, allowing users to define thresholds and conditions for triggering alerts based on monitored metrics. It supports role-based access control (RBAC), allowing administrators to define user roles and permissions for accessing and editing dashboards. By leveraging Grafana's powerful visualization capabilities and integration with InfluxDB, the project was able to create dynamic dashboards for real-time monitoring and analysis of current, voltage, and power consumption data.

3.1.9 Mechanical Enclosure:

Designed a CAD Model for enclosure for circuitry using Onshape online CAD Design Tool.

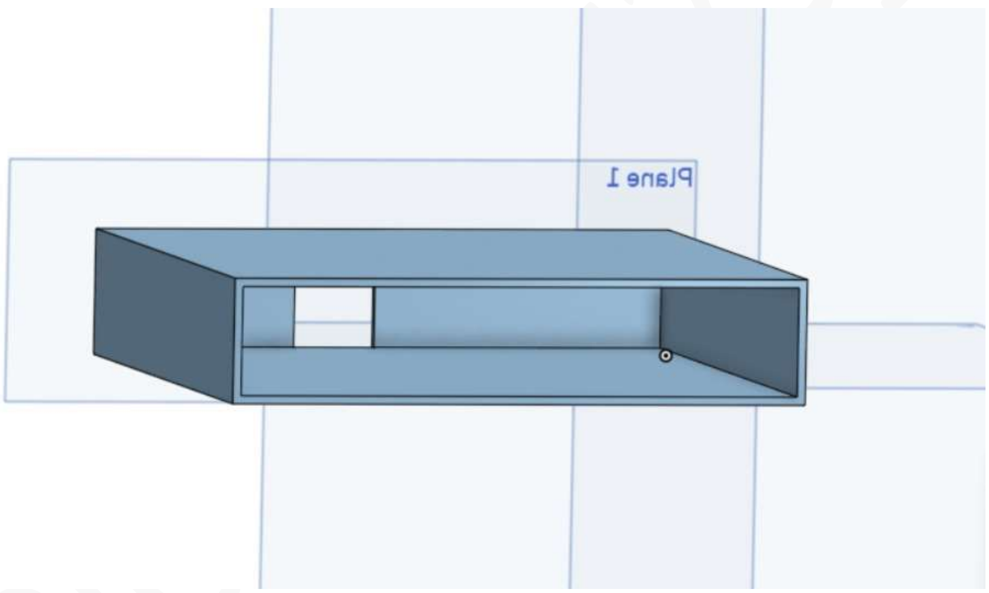

Fig 3.2: Enclosure for Input PCB

Table 3.1: Input enclosure Dimensions

Sr. No.	Part	Dimensions(in mm)
1.	Whole Input PCB	115x107
2.	Thickness	1.5
3.	DC Plug Window	15x15

CHAPTER 4: Implementation, testing and debugging

4.1 Implementation on the breadboard

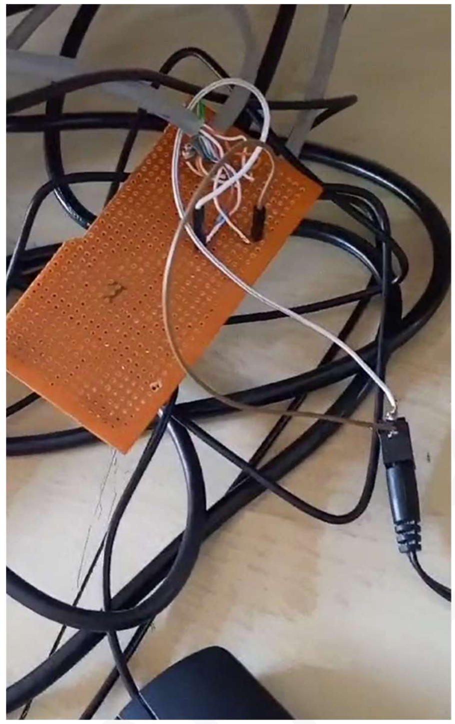

Fig 4.1 Zero PCB Implementation

Implementation of basic circuitry enough to complete the task, circuit done on zero PCB with help of jumper wires

4.2 Testing, Debugging.

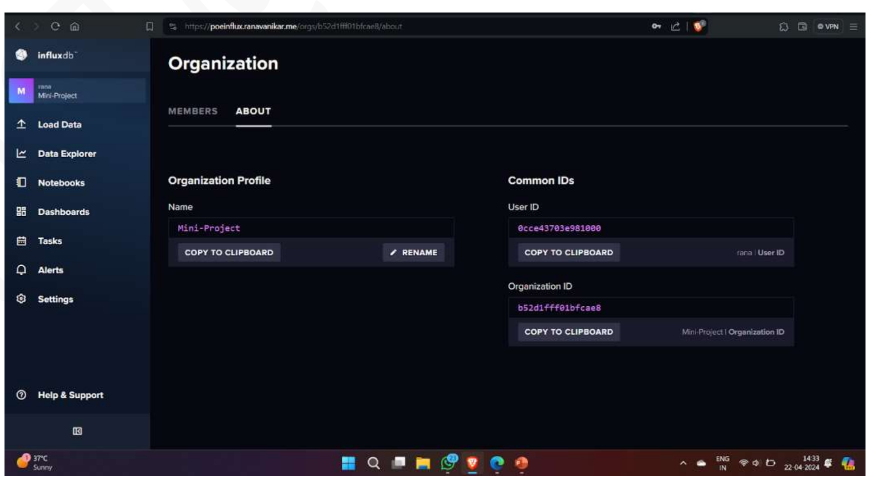

Fig 4.2 Debugging of InFluxDB and Grafana connection

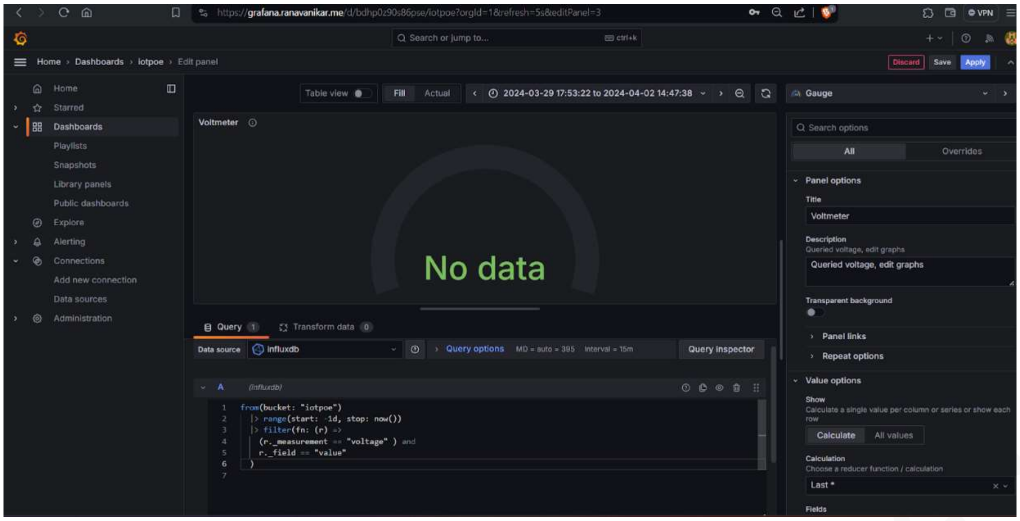

Fig 4.3 Debugging query to fetch data from Bucket

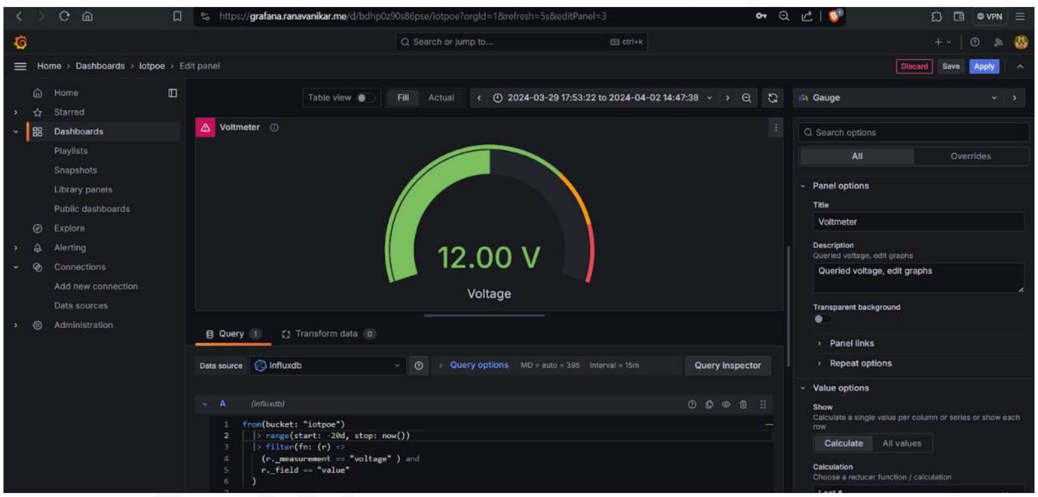

Fig 4.4 Panel settings and final output after querying

4.3 Simulation results, observation table

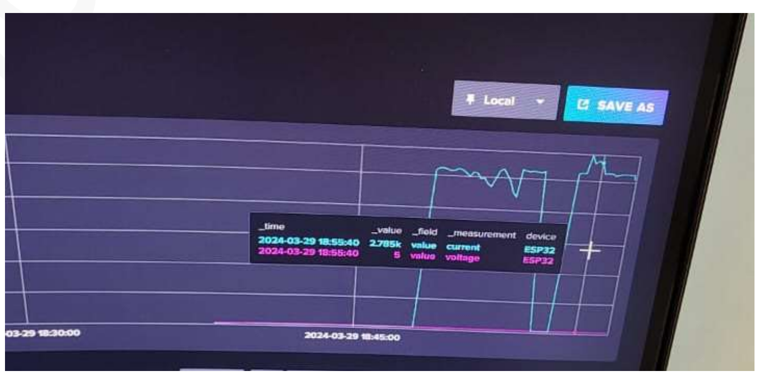

Fig 4.5 InFluxDB Graph and Query selecion

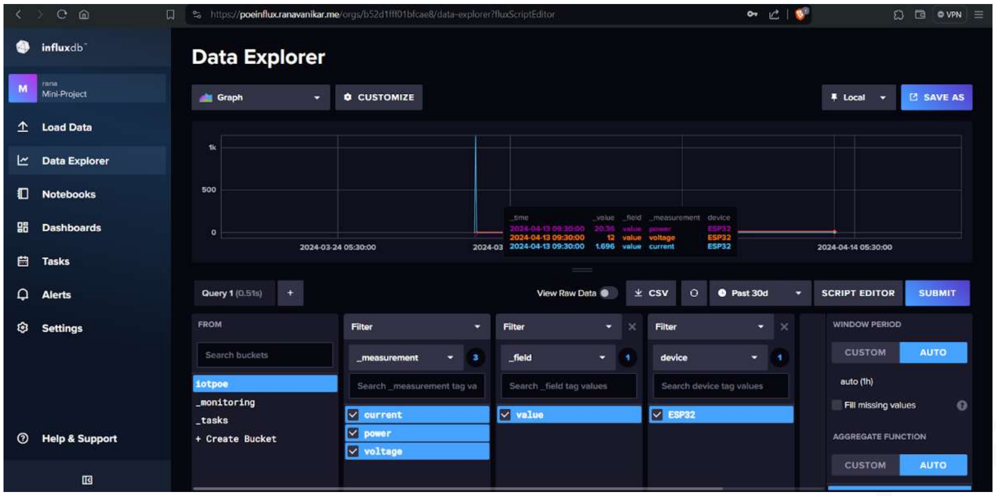

Fig 4.6 Results from InFluxDB

4.4 PCB design

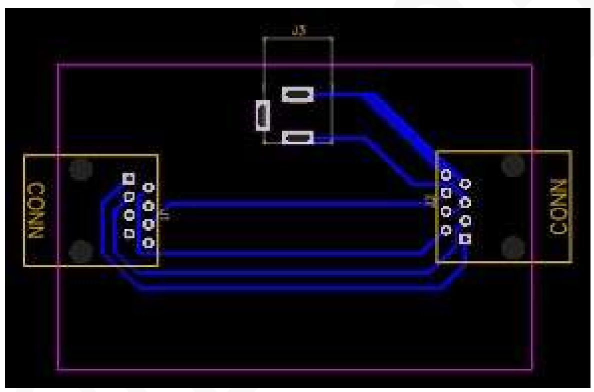

Fig 4.7 PCB design

PCB designed using EasyEDA online software. Printed in college PCB making facility.


Fig 4.8: Etching the PCB

4.5 Final project photograph and working

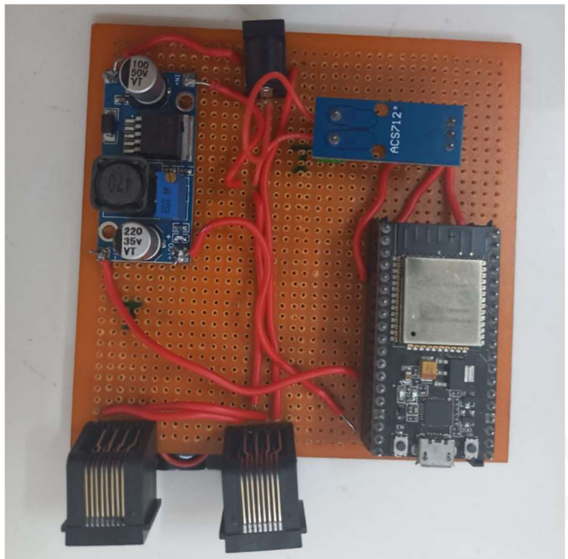

Fig 4.9: Injector PCB

The PoE Injector combines the data and power, it also measures current using ACS712. Voltage being constant, ESP32 takes power from buck converter having output 5V and uploads data to InFluxDB bucket and the next steps.

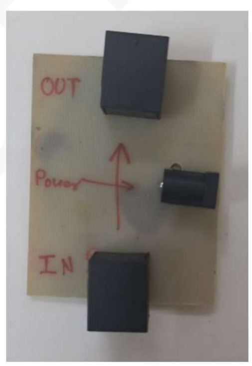

Fig 4.10: PoE Splitter PCB

The PoE Splitter takes input as power+data separates power and data for Non-PoE compatible devices. Works on same principle as Injector. Separating cables of 4, 5, 7 & 8 out of input ethernet cable.

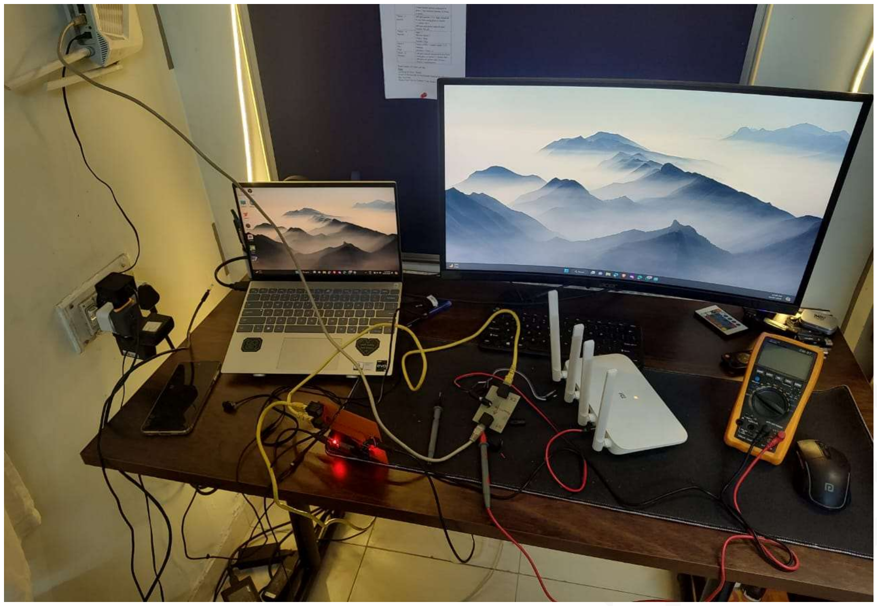

Fig 4.11 Final Design

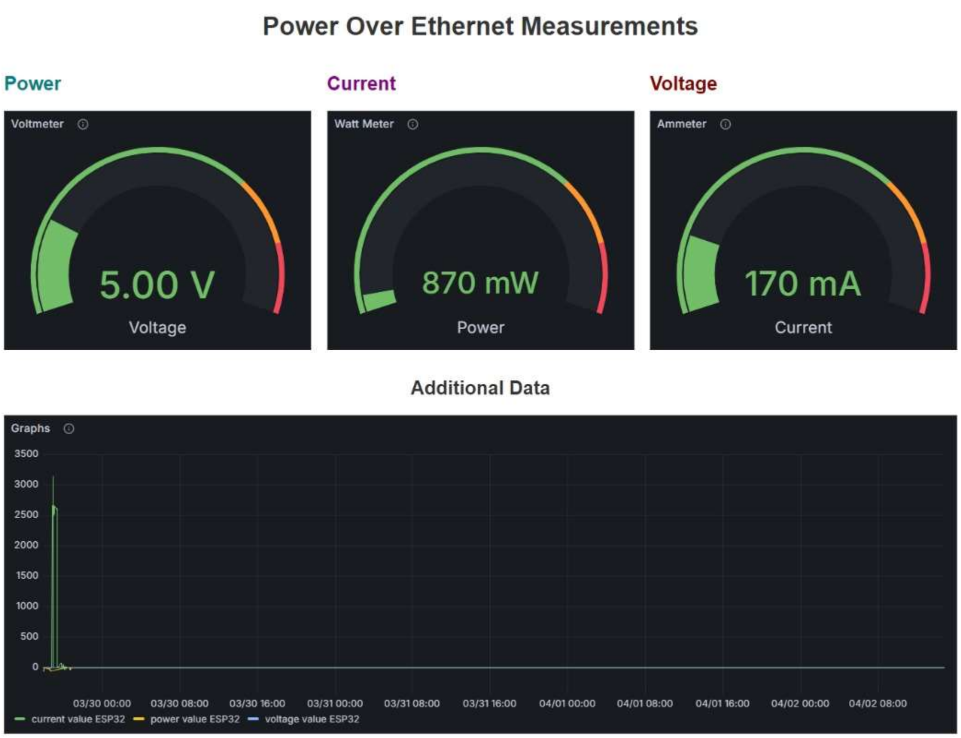

Fig 4.12: Grafana Panel

CHAPTER 5: Results and Discussion

Through a meticulous combination of qualitative and quantitative analysis, we explored various aspects of Power over Ethernet (PoE) technology. Our investigation involved comprehensive testing, including breadboard testing, PCB testing, and simulation, to evaluate the performance of proposed solutions.

Fig 5.1 Monitoring panel on Grafana showing voltage, power, current and their fluctuations on time series graph

In our project, we utilized Grafana, a powerful monitoring and visualization tool, to display and analyze the readings obtained from our PoE experiments. Grafana enabled us to create intuitive and informative dashboards that depicted various metrics, such as power consumption, voltage levels, and device status, in real-time.

In our experiments, we focused on optimizing power transmission efficiency. We designed specific voltage and current regulation techniques to ensure consistent and reliable power distribution to connected devices. During breadboard testing, we observed promising results, with the designed values closely aligning with expected outcomes. However, upon transitioning to PCB testing, slight deviations were noted, primarily attributed to impedance variations and parasitic capacitances. To address this, we refined our PCB designs to minimize impedance mismatches and optimize signal integrity, resulting in improved performance alignment between simulations and practical testing. Furthermore, compatibility issues with legacy devices were addressed through the development of universal PoE interfaces. In our qualitative assessments, we found that these interfaces facilitated seamless integration with both PoE-enabled and non-PoE devices, enhancing network interoperability. However, quantitative analysis revealed discrepancies in compatibility with certain non-standard devices during PCB testing. This deviation stemmed from differing power requirements and communication protocols. To mitigate this, we proposed firmware updates or additional hardware modifications to ensure broader compatibility across diverse device types.

In summary, our qualitative and quantitative analyses provided valuable insights into the performance, compatibility, and cost-effectiveness of PoE technology. By combining rigorous testing methodologies with iterative design refinements, we have made significant strides in enhancing PoE's reliability, interoperability, and affordability. Moving forward, continual refinement of our solutions and collaborative efforts towards standardization will be essential in realizing the full potential of PoE technology in modern communication infrastructures.

6. Conclusions

The project aimed to create a cost-efficient PoE solution that integrates with various Ethernet devices, enhancing user-friendliness and real-time monitoring capabilities. The system, which includes the ESP32 microcontroller, ACS712 sensor, InfluxDB, and Grafana, was tested in various applications such as smart homes, legacy electrical infrastructure, construction sites, warehouses, and data centers. The findings highlight the transformative impact of PoE technology in advancing connectivity, sustainability, and automation. The system simplifies installations and reduces complexity in diverse settings. Despite challenges like hardware compatibility and software integration complexities, iterative testing and collaboration were successful. The project lays the foundation for future research and development to optimize performance, expand compatibility, and explore new applications for PoE technology. This project contributes significantly to power delivery and monitoring, influencing industry and academia.

Future Scope

In our project's future scope, we aim to advance Power over Ethernet (PoE) technology to transfer higher power levels, up to 90 watts, enabling the direct charging of laptops and other high-power devices through Ethernet cables. This enhancement not only expands the versatility of PoE but also opens up exciting possibilities for powering a broader range of devices, eliminating the need for separate power adapters. By integrating this capability with advanced energy management techniques and renewable energy sources, we can create more efficient and sustainable PoE systems, as reduction in additional cables ultimately reduces cabling costs. Through collaboration and standardization efforts, we aim to drive the widespread adoption of PoE technology, contributing to a more connected, efficient, and sustainable future.

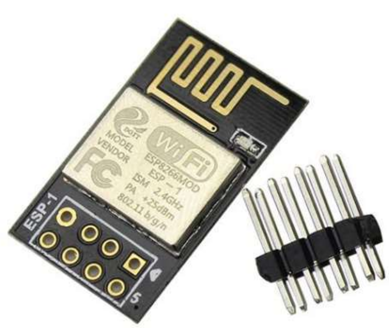

Figure 5.2: ESP-1

7. Bill of Material

1. ESP32
2. ACS712 Current Sensor
3. Copper Cladding
4. DC Jack & Plug
5. Ethernet Jack
6. Other miscellaneous costs

Total: 900/-

8. References

[1]. Shen, Lester. (2019). PowerOver Ethernet (PoE) Technical Overview. 10.13140/RG.2.2.11680.53769.

[2]. Z. Xiao, "An Efficient Power Over Ethernet (PoE) Interface with Current-Balancing and Hot-Swapping Control," in IEEE Transactions on Industrial Electronics, vol. 65, no. 3, pp. 2496-2506, March 2018, doi: 10.1109/TIE.2017.2739693.
keywords: {Bridge circuits;Logic gates;MOSFET;Voltage control;IEEE 802.3 Standard;EPON;Current-balancing;current sharing;hot-plugging;hot-swapping;power over ethernet (PoE)},

[3]. "What is Power Over Ethernet (PoE)" https://www.cisco.com/c/en/us/solutions/enterprise-networks/what-is-power-over-ethernet.html

[4]. U.S. Department of Energy. (n.d.). Power over Ethernet technology. Retrieved from https://www.energy.gov/eere/ssl/power-over-ethernet-technology, [2016].

9. Datasheets

1. ACS712 Sensor Datasheet:
   https://www.sparkfun.com/datasheets/BreakoutBoards/0712.pdf

2. NodeMCU ESP32S Datasheet:
   https://docs.ai-thinker.com/_media/esp32/docs/nodemcu-32s_product_specification.pdf

3. InFluxDB Documentation:
   https://docs.influxdata.com/

4. Grafana Documentation
   https://grafana.com/docs/