DESIGN AND IMPLEMENTATION OF IDENTICAL BATTERY IDENTIFICATION AND CLUSTERING SYSTEM (IBICS)

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering (BSEEE)

Department of Electrical and Electronic Engineering
Brac University
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Oct 2024

Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Approval

The Final Year Design Project (FYDP) titled “Design and implementation of Identical Battery Identification and Clustering System (IBICS)” submitted by

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of Summer, 2024 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering (BSEEE) on 24-10-2024.

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Ethics Statement

This project and research is conducted properly by maintaining academic protocol. Proper citation, reference and bibliography has been done. Also, a proper plagiarism check has been made in Turnitin to ensure the research more transparent and vibrant. The plagiarism report percentage has been showed 15%

Abstract/ Executive Summary

In the rapidly evolving world of electronics Li-ion battery packs are one of the most used and fundamental components to many impactful industries. Unfortunately, unbalanced cells within battery packs harm battery performance in the long run. This project aims to solve the battery pack performance by analyzing batteries' electrical parameters. To do so, we will be using machine learning and developing software peripherals that can easily check battery performance by analyzing its characteristics as errorless as possible. Also, this project will follow up on the industry standards laws and protocols while developing this whole system.

Keywords: Li-ion Batteries, Battery Pack, Electrical Parameter, Software peripherals,

Acknowledgement

We would like to show our warmest and deepest gratitude to those who have supported us in this whole project. Firstly, and for mostly, we are grateful to our project supervisors. Their sharp observation, expertise knowledge and valuable opinion make this project successful. Lastly, special thanks to group members whose relentless brilliant effort make this project success. Finally, we acknowledge our family members whose patience, dedication, motivation is with us in this whole project completion.

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Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

In recent years, with the increasing demand of battery powered equipment, demand for high quality and reliable battery packs is a must. As more and more heavy machines shifting towards electrification, such as EV and energy storage systems for home, more and more batteries are reaching their end of life [1]. Main reason for that is the difference in cell parameters in the battery pack. So, sophisticated monitoring of these cells is also becoming an important field of study. This paper presents a novel approach for better battery management through the implementation of Identical Battery Identification and Clustering Systems (IBICS). IBICS is designed to monitor the similarities in the individual batteries before they end up being a battery pack. It monitors the parameters in each cell and recommends the manufacturer whether this cell should be included in this particular pack or not. By clustering the similar batteries, IBICS is aiming to make more reliable battery packs, thus increasing the efficiency of the device using the battery pack.

1.1.1 Problem Statement

Our project's main goal is to make a more efficient battery pack for all kinds of equipment. In many industries, Li-ion battery packs are needed. Moreover, rapid adoption of EV is also changing the Li-ion battery usage rate. But with unbalanced cells within the battery pack, they often lack the reliability industry demands. Unbalanced battery packs often self-discharge and cannot be fully charged [2]. This negatively affects the device using the battery pack. When effects may be timid in small appliances, power intensive devices such as EVs and energy storage systems can face severe consequences for unbalanced battery packs.

To balance the battery packs, many techniques have been adopted by the industry such as capacitor based, inductor based or converter-based cell balancing [3]. But they all act as a monitoring system which comes into play after the battery pack is made. Moreover, they have high cost, complex control and often damage the cell life in the process. To overcome these challenges, our project's aim is to make a more cost-effective battery screening system which can help to balance the cells without damaging it in the process. Also, our system's goal will be to make a good battery pack right from the manufacturing process. It will not only help us to make a better-balanced battery pack, but also it will take away some load from the existing battery management system.

Our main challenge on this project is to make it more reliable than the existing technology while having the features like scalability and user friendly. Furthermore, today's industries demand more digital integration. Thus, our project should utilize the latest technology to make it more error free.

Overall, this project aims to make a system which utilizes the existing technology advantages while adding some more features for the betterment of users and the industry.

1.1.2 Background Study

In this era where every sector is leveraging the power of electricity, battery packs tend to become more durable and sophisticated. As the devices are becoming more power hungry and sensitive, little variation in battery parameters can have problematic consequences. So, to make a balanced battery pack, industry is coming up with various modern technologies. Among them, some design approaches emerged as frontrunners. They are active cell balancing and passive cell balancing.

On one hand, active cell balancing redistributes energy between cells in a battery pack[4]. This balancing technique does not bother with the chemical composition of the batteries. Rather they only distribute charge via transformers or DC-DC converters. This type of converter is efficient as they dont waste any energy of the battery. But the main drawback of this type of system is their complex circuit [5]. As they rely on many converters, they tend to become more complex.

On the other hand, passive cell balancing simply discharges the battery with over voltage. It does that by a simple discharging circuit. Thus, this is a cost-effective system to balance the batteries. But the main drawback of this system is that it can damage the battery as it is being discharged.

As we embark on this exploration, our objective is to delve into the complexity of both the design approaches and find a better solution. We also focused on the strengths offered by both the existing solutions.

Through the analysis of both the designs, we aim to provide the less damaging path of active cell balancing while making it cost effective like passive cell balancing. Our goal is to not make a battery pack monitoring system, rather a system that will make the monitoring system easier by providing a battery pack perfectly balanced.

1.1.3 Literature Gap

Despite advancements in battery management systems (BMS) and energy storage technologies, there remains a significant gap in the literature concerning the integration of dynamic clustering algorithms and real-time data analytics tailored specifically for large-scale Li-ion battery systems. While individual studies have explored aspects of battery monitoring or management techniques, limited research focuses on the advanced clustering methodologies and real-time performance analysis before the making of battery packs.

Existing literature primarily addresses traditional battery management strategies, such as basic cell balancing techniques, state of charge monitoring, or thermal management but often does not extend into advanced approaches like clustering that can dynamically cluster the batteries based on their similar characteristics. While these studies contribute valuable insights into battery monitoring, they frequently overlook the benefits of employing real-time, machine learning driven clustering strategies, especially in large and heterogeneous battery systems commonly used in electric vehicles (EVs), renewable energy storage, and grid applications.

Moreover, while some research explores real-time monitoring and algorithmic management for small battery systems or other storage technologies, there is a noticeable gap of research which focuses solely on clustering in the context of large-scale Li-ion battery systems. The unique demands of such systems, including the battery pack manufacturer and users make it a big scope for further research and development.

Additionally, current research has rarely acknowledged the cost-effectiveness and practical scalability of integrating advanced clustering with real-time data analytics for battery systems. While clustering approaches offer substantial improvements in terms of cell balancing, efficiency, and safety, their building and maintenance cost, as well as their complexity makes them out of reach of many consumers.

This gap in the literature points to the need for further research specifically targeting the integration of dynamic clustering techniques into large-scale Li-ion battery systems. By addressing this gap, we aim to make a system that will work hand in hand with the existing technologies while leveraging the full potential of machine learning algorithms.

1.1.4 Relevance to current and future Industry

The proposed project holds significant potential in current industry operations and future trends. It gives solutions to a very critical challenge faced by the industry in the contemporary world. By integrating modern technologies, this project has the potential to survive in future industry challenges too.

In the current industrial landscape, there is a growing demand for Li-ion battery packs. It is projected that around 9300 GWh energy worth of batteries will be required in the EV and energy storage system alone [6]. Thus, screening of the batteries in the battery pack is also necessary. As electrical equipment becomes more sophisticated day by day, having a balanced battery pack is what industry expects. Our project will come into play in this high demand market and our aim is to serve the industry in need.

Future lies in data analytics and machine learning technologies because of its extraordinary analytical power. Battery industry is no exception. As more and more industry focus is shifting towards machine learning, our machine learning based approach will surely be adaptable with future industry demand.

In a word, the impact of our project is high in both the battery manufacturing industry and electrical devices industry. Moreover, by integrating modern technologies, our project can cross the hurdles of future industry trends.

1.2 Objectives, Requirements, Specification and constant:

1.2.1. Objectives:

The objectives of this project are as follows:

- Develop a comprehensive system capable of evaluating and classifying Li-ion batteries based on performance metrics such as capacity, voltage, and current output. This will help the screening process by providing valuable information.

- Implement advanced artificial intelligence algorithms to monitor and predict battery health in real time. This includes utilizing machine learning models to analyze performance data and analyze the deviation of different batteries and find the similarities.
- Design a tool or software that enables quick and accurate identification of batteries with similar characteristics, such as voltage and current, to ensure balanced stacking. Properly matched batteries will be more reliable as there will be almost zero imbalance on parameters.

- Ensure that the battery stacking process adheres to industry standards and regulatory codes, such as those related to safety, efficiency, and sustainability. This involves creating guidelines that ensure compliance with established norms to minimize risks associated with improper stacking and to improve the operational integrity of the battery systems.

1.2.2 Functional and Nonfunctional Requirements

The interface will sustainably hold the batteries: One of the features of our suggested system should be the capacity to store batteries sustainably. This is crucial since the batteries will be charged and discharged frequently, and any interruption would slow down the entire process. Therefore, it's critical to make sure the battery holder is adequate and can hold the batteries firmly for an extended amount of time.

Charging and discharging the facility to a batch or lot of batteries: Similar batteries will be grouped together in batches by the suggested system according to certain criteria. The cycle of charging and discharging is one of the features. Both charging and discharging of the batteries must be possible with the system. A DC voltage supply that can charge the batteries should be included in the system. A load will be attached to the system for the discharge facility in order to empty the batteries. The determination regarding their similarity or dissimilarity will be based on the charging and discharging facilities.

Measuring voltage and current: The voltage and current are two attributes that determine the performance of the batteries. Our device will have two voltage and current sensors in both charging and discharging units to collect these data. Based on these measurements, our device will decide whether the battery is similar or not.

Information displaying system: On the suggested system, a display system is required for showing the measured information. This needs to be fastened to the hardware in order to display the collected data right away before it is stored and processed further.
Protection system overcharge, over-discharge, short circuit, and temperature test & protection:

Considering that our gadget has a charging mechanism, we must be ready to safeguard it against overcharging hazards.Li-ion batteries similarly have over discharge issues if they are discharged below a specific voltage threshold. The voltage range of an 18650 battery is 2.5V to 4.2V for safe and effective performance[7]. A comparable potential hazard is the short circuit current spike. The system could burn up from that. If this is not resolved, it will become a major issue. Therefore, the system needs a protection device that would guard against short circuit current. The problem with overheating is another possible danger that could harm the system. We are aware that the heating up problem with Li-ion batteries in particular is a major worry when charging[8]. In addition to heat-reducing devices, we need to monitor the temperature so that it doesn't exceed a specific threshold. 0 to 45 degrees Celsius is the ideal temperature range [9]. This needs to be kept an eye on. The battery could be harmed if there isn't an automated shutdown mechanism in place if the temperature rises above the ideal range.
Requirement of heat sink around the battery case:
It was previously mentioned that the ideal temperature range for 18650 batteries is between 0 and 45 degrees Celsius. Given that the battery has a maximum temperature of 45°C, a heat sink must be installed around the battery casing. This will prevent heat intake from widening the casing.

1.2.3 Specifications

Our proposed system will have the following specifications:

1. **Voltage Output:**
   Range: 3.7V to 4.2V
   Description: The battery must provide a stable output voltage within this range. 3.7V is the nominal voltage, and 4.2V is the fully charged state voltage.

2. **Current Output**
   Range: 0A to 0.6A
   Description: The battery should be capable of supplying a current ranging from 0 amps (no load) up to 5 amps (full load) as required by the connected device.

3. **Overvoltage Protection:**
   Maximum Voltage: Not more than 4.2V
   Description: The battery must have a protection circuit to prevent the voltage from exceeding 4.2V, which can prevent overcharging and potential damage.

4. **Undervoltage Protection:**
   Minimum Voltage: Not less than 3V (with an absolute minimum range of 2V to 3V)
   Description: The battery should include protection to prevent the voltage from dropping below 3V, which helps in avoiding deep discharge and extending battery life.

5. **Overcurrent Protection:**
   Current Threshold: 0.5A ± 0.2A
   Description: The battery must have a safety mechanism to cut off the current if it exceeds 0.5A by ±0.2A, protecting against overcurrent conditions that could damage the battery or connected devices.

6. **Temperature Monitoring and Protection:**
   Operating Range: 0°C to 45°C
   Description: The battery should be equipped with sensors to monitor its temperature and ensure it operates safely within the specified range. Protection mechanisms should trigger if the temperature goes beyond this range.

7. **Real-Time Data Monitoring:**
   Time Limit: Less than 100ms
   Description: The system should be capable of monitoring and reporting battery data (such as voltage, current, and temperature) in real-time with an update frequency of less than 100 milliseconds, ensuring timely detection of any anomalies.

8. **Physical Dimensions:**
   Diameter: 18mm
   Length: 65mm
   Description: The battery should conform to these dimensions to fit standard battery compartments, often referred to as 18650 battery size.

1.2.4 Technical and Non-technical consideration and constraint in design process

Technical considerations

1. When batteries are being charged, they will get hot. It is unavoidable. Due to the fact that cooling batteries during charging will reduce battery efficiency. [10]
2. The battery must be charged and discharged numerous times in order to perform cycle testing. It will take a great deal of time to complete[11].

3. After the screening process starts, the system must run continuously and without interruption. As a result, a basic limitation demands that before any additional actions or changes are made, the system must be given time to finish its screening process [12].
4. These rules are subject to change at any time because the project is linked to numerous standards and laws. As a result, changes to the system will need to be made in response to routine checks of the appropriate regulations and standards.
5. A precise and optimized algorithm must be developed that is accurate enough to cluster the batteries correctly. Without it, the whole system's performance will hamper.
6. The generated data has to be processed in real time to make the decision time fast and smooth. Delays in analysis can lead to suboptimal performance.
7. Additional power consumption by the IBICS should be kept minimal. So, we have to use components that are more power efficient.

Non- Technical Considerations:

1. The overall cost of the IBICS should be less than the benefits it provides. Only then will it create profits for the clients.
2. The product should be user friendly so that it can be operated easily by low skilled professionals. The data generated should also be easy to understand.

1.2.5 Applicable compliance, standards, and codes

The following standards apply to this project: [13][14][15]

Here’s a more detailed description of each of the standards listed:

1. **IEEE SA P2962**
   This is the IEEE recommended standard specifically focused on the installation, operation, maintenance, testing, and replacement of Li-ion batteries. It provides comprehensive guidelines to ensure the safe and effective deployment of Li-ion batteries across various industrial and commercial applications, emphasizing operational safety and longevity.

2. **IEC 62133:**
   An international standard that outlines the safety requirements for rechargeable Li-ion batteries, particularly those used in portable devices. It covers critical safety aspects such as overcharging, temperature control, and short-circuit protections, ensuring batteries meet the required safety benchmarks for consumer and industrial applications.

3. **IEC 62619:**
   This standard provides the safety and performance requirements for Li-ion batteries used in industrial applications. It defines testing protocols and safety features specific to large-scale battery systems, such as those used in electric vehicles (EVs), renewable energy storage, and backup power systems.

4. **UL-1642, 5th Edition:**
   This is a safety standard from Underwriters Laboratories (UL) that covers the requirements for Lithium Batteries. It ensures that lithium batteries meet specific safety criteria to prevent hazards like overheating, explosions, and leakage, particularly for consumer electronics and other small-scale applications.

5. **UL-9540, 2nd Edition:**
   The ANSI/CAN/UL Standard for Energy Storage Systems and Equipment Testing, this standard addresses the testing and certification requirements for energy storage systems (ESS) that include Li-ion batteries. It focuses on the performance, safety, and reliability of these systems, particularly when integrated into power grids or industrial environments.

6. **UL-9540A, 4th Edition**:
   This edition provides a test method for evaluating thermal runaway and its potential for fire propagation in battery energy storage systems. It is a critical standard for understanding and mitigating the risks associated with thermal runaway events, which occur when a battery overheats uncontrollably, leading to possible fires or explosions.

7. **IEC 61960-3:**
   This is a performance standard for rechargeable lithium-ion batteries, covering testing for key performance parameters such as capacity, energy density, and efficiency. It ensures that batteries meet minimum performance requirements for various applications, including consumer electronics and industrial uses.

8. **UN 38.3**:
   A transportation safety standard for lithium-ion batteries. It includes tests and criteria that batteries must meet to be shipped safely, including assessments of how batteries withstand extreme conditions like temperature variations, vibration, and shock during transit.

9. **IEEE 2030.2.1-2019:**
   This is a guide for the design, operation, and maintenance of battery energy storage systems (BESS), whether stationary or mobile, and their integration into electric power systems. It covers the safe and efficient management of large-scale energy storage systems used in renewable energy, grid stabilization, and backup power scenarios.

10. **IEC 60086:**
    A global standard that applies to primary batteries, meaning non-rechargeable batteries. It defines the specifications for the dimensions, voltage, and performance of batteries, ensuring they meet international interchangeability and safety standards.

11. **EN 60086-4:2000:**
    A European Union standard based on IEC 60086, this standard specifically applies to primary batteries and provides additional safety guidelines for lithium batteries. It ensures that batteries are designed and manufactured to meet stringent safety and performance requirements for use within the EU.

12. **ANSI C18.1M and ANSI C18.3M:**
    These are U.S. standards for portable primary cells and batteries, covering the design, testing, and performance requirements for both alkaline and lithium primary (non-rechargeable) batteries. These standards ensure that portable batteries used in consumer electronics, medical devices, and other applications meet safety and efficiency benchmarks.

1.3 Systematic Overview/summary of the proposed project

Our project is an innovative solution to address the problem regarding Li-ion battery parameters imbalance during stacking. It aims to make a stable Li-ion battery pack from the manufacturing process. Our goal is to act as a complement of the existing battery monitoring systems present in the industry. By making a more reliable battery pack, we can make a significant difference in electrical devices health and also reduce E-waste in the form of used batteries.

In an economic context, our project can play a vital role in increasing the service life of electrical appliances to EVs as well. Thus, it will save lots of money from maintenance cost and battery replacement costs. For the manufacturers also, this project will come in handy for most electric manufacturers as our devices will significantly reduce the cost of expensive battery monitoring systems. By using a balanced battery pack in the first place, they will have to depend less on BMS.

Overall, our project is good for both manufacturers and consumers for its unique idea and widespread usage. As the world is becoming more digital, our project has the ability to work under future changes and can adapt to it quickly.

1.4 Conclusion

The project titled “Identical Battery Identification and Clustering System” places a strong emphasis on making a balanced battery pack right from the manufacturing process. Rather than relying solely on battery management units, we aim to make a balanced battery pack which doesn't will not need rigorous monitoring. In light of current and future industry trends, we have defined our objectives and specifications. Additionally, we have abided by the standards and codes set by the IEEE. Furthermore, we have reviewed the existing literature to gain an understanding of other works in this field.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

In this chapter, we will be discussing the different types of design approach to make a better battery screening system. Throughout this chapter, we will critically discuss and analyze the different types of design approaches and try to figure out which one is better.

The Primary objective of this chapter is to analyze some design approaches to build a Li-ion battery screening system. By doing so, we are going to introduce you with different aspects of these two design approaches and discuss them briefly.

Firstly, we will identify the multiple design approaches involved in this project. Through substantial research and literature review, we identify several approaches by which our goal can be achieved. From them, we shortlisted two approaches which are optimum to reach our objectives.

Secondly, we will describe them in detail. After reviewing both the design approach thoroughly, we tried to summarize them and describe their working principle and characteristics. Moreover, we will analyze the design approaches and come up with the pros and cons of each design approach.

Overall, this chapter will focus on introduction, description and analysis of multiple design approaches present in our project. We will try to emphasize our observation on these two approaches with sufficient detail from literature review.

2.1 Identify multiple design approach

When it comes to designing an intelligent battery clustering system, we have to keep in mind several objectives to enhance its performance, safety and reliability. In this section we will discuss some key objectives and explore different design approaches to achieve them.

Battery screening system

Objective: Design and implementation of a system that can screen the individual battery cells before stacking them in the battery pack.

Design approaches

- **AI based screening:** Using machine learning algorithms to assess the battery information before stacking. This includes leveraging historical or real time data.
- **Electrochemical Testing:** This approach screens the electrochemical characteristics of a battery before stacking them. The characteristics include Impedance, capacity and other critical parameters.

Battery matching and clustering

Objective: Create a system to compare and cluster identical batteries based on their parameters.

Design approaches

- **Machine learning based classification:** This approach demands developing a machine learning based system that can determine the similarities between the batteries and cluster them accordingly. This approach takes decision based on the similarities in voltage state of health or current output of the battery and group them accordingly.
- **Manual approach:** This approach manually sorts out batteries based on their voltage or other parameters. It is not fully automated, rather is prone to human errors.

User friendly interface

Objectives: Develop an user friendly interface that will give better insight of the battery to the end users.

Design approaches

- **UI with real time data monitoring:** In this design approach, the user interface collects battery information such as voltage, temperature and usage pattern. It works with app based or web based data collection systems.
- **AI powered insights:** This design approach analyzes historical data and makes decisions based on the collected data.

By exploring this multiple design approaches, we can achieve the following objectives which will make a more reliable system. There are so many different ways to fulfill our objectives but the best approach will depend on unique requirements of the industry.

2.1 Describe multiple design approach

2.1.1 Design approach 1

Flowchart

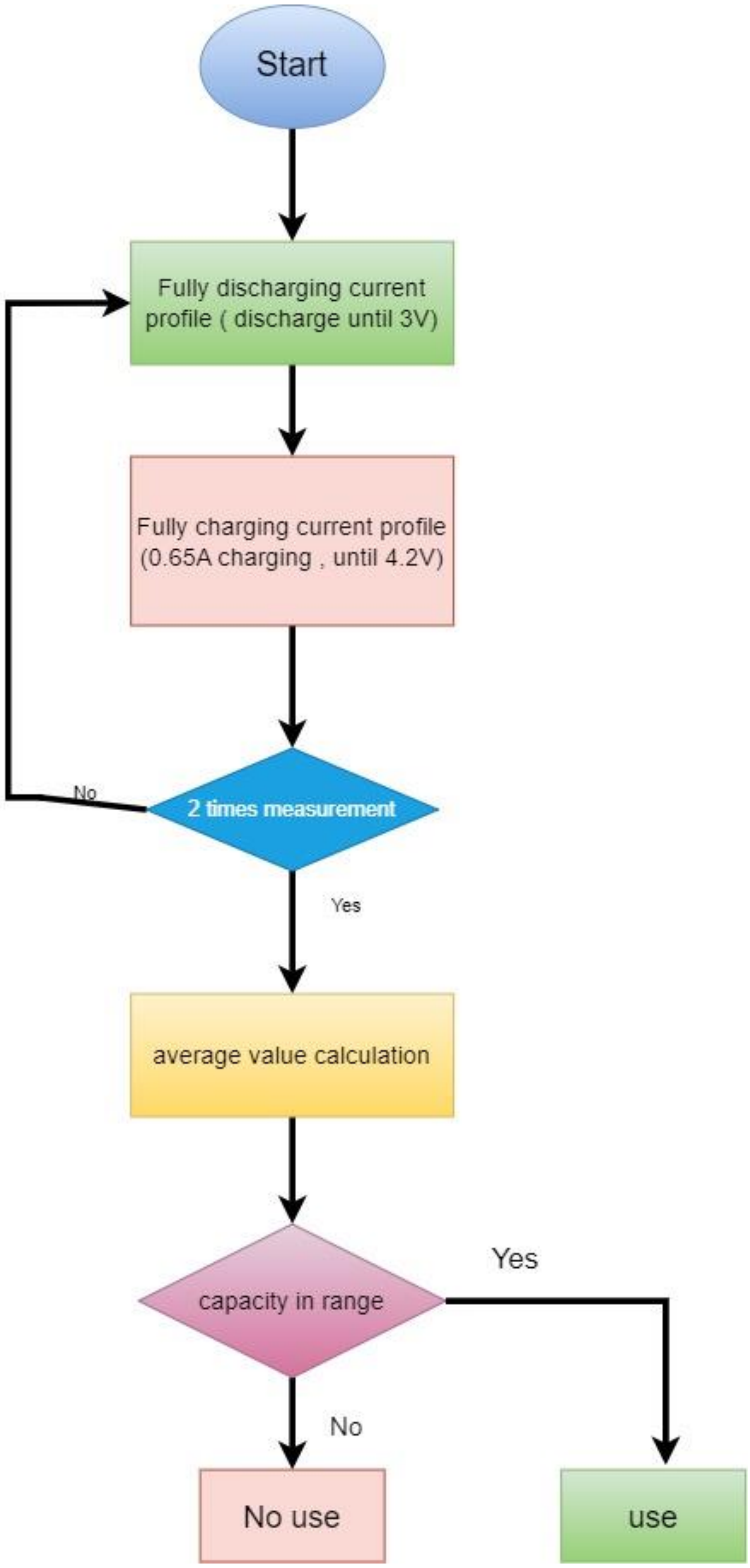

Figure 1: Design approach 1 flowchart

The flowchart presented in Figure 1 gives us the idea of how we will identify and cluster Li-ion batteries based on their similarities through the charging and discharging process. This method ensures that only batteries with acceptable performance characteristics are selected for use, while those with insufficient capacity are rejected. Initially the batteries are placed in the battery holder for verification. Then the batteries are fully discharged using a controlled current profile. The discharge is repeated two times, each time reducing the battery voltage to 3V. The value 2.8V is chosen because going below that can damage the battery. The discharging data is collected. Following the discharge process, the battery undergoes a full charging cycle. Battery is connected to a charging circuit which charges the battery fully until it reaches the voltage level 4.2V. The charging data is collected. To ensure the reliability of the measurements, the entire charge-discharge cycle is repeated twice. This is done so that the data is more accurate. After two complete charge and discharge cycles, the system calculates the average capacity of the battery. This average value provides an insight into the battery performance. Then the collected data is verified by machine learning algorithms to analyze if it falls into the safe deviation region. Finally, by analyzing the deviation, the algorithm makes a decision whether the battery is worthy to include in the battery pack.

This procedure ensures a systematic and reliable method for evaluating battery health and performance, facilitating the selection of batteries with sufficient capacity while excluding those that may underperform.

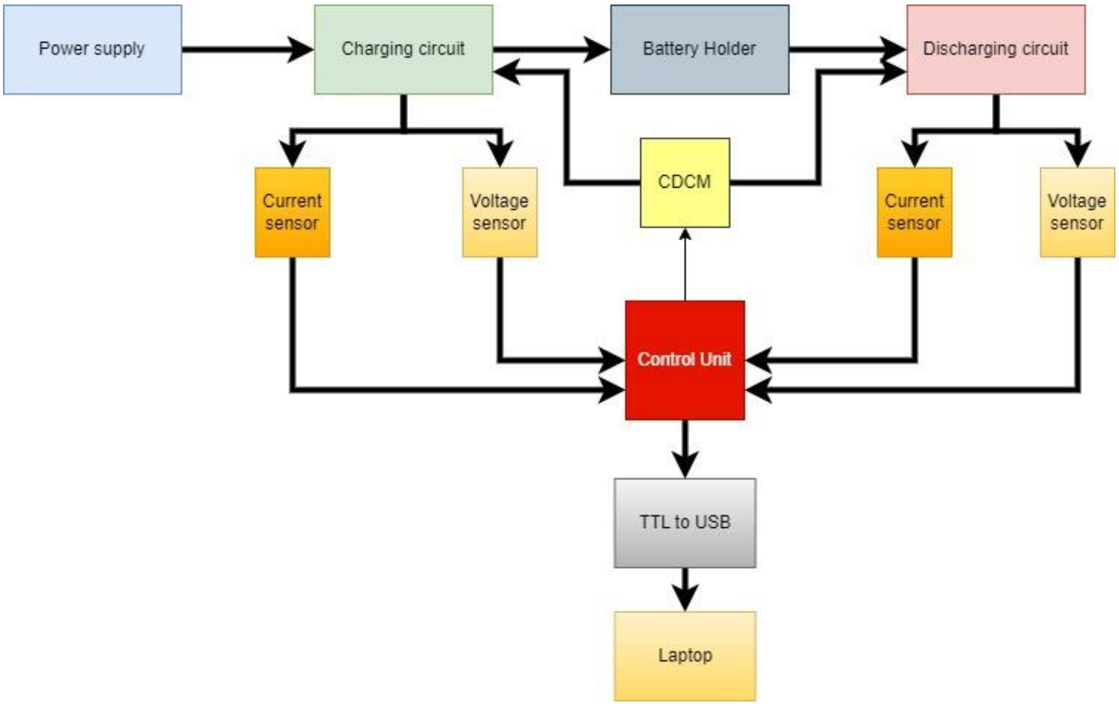

Figure 2: Design approach 1 block diagram

From this figure, we can see the system overview of our project. Main parts of this project involve charging circuit, discharging circuit and a control unit. The charging circuit charges the battery till 4.2V. Current and voltage sensor measures the data and sends it to the user interface. After the charging is completed, the battery is connected to the discharging circuit which discharges the circuit till the safe limit. This data is also stored in the user interface. The control unit here acts as a switcher to connect the battery to the charging and discharging circuit one after another.

2.1.2 Design approach 2

Flowchart

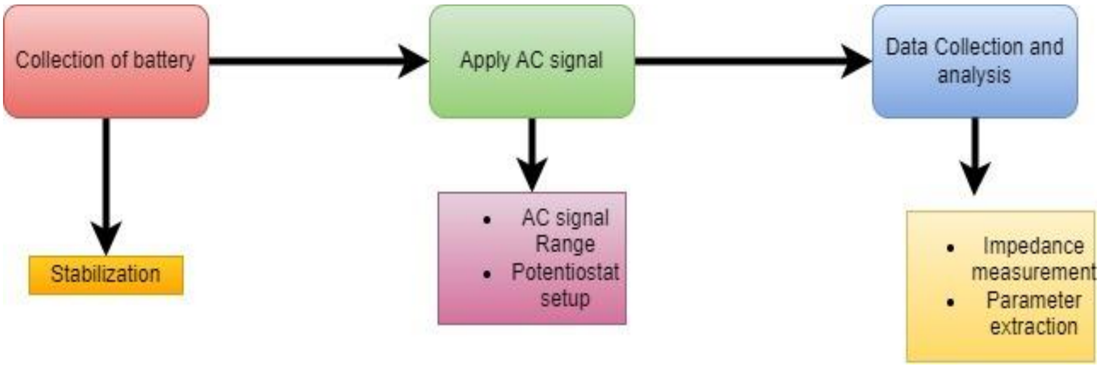

Figure 3: Design approach 2 flowchart

Our second design approach involves screening the batteries using the electrochemical impedance spectroscopy. It is a technique to screen the batteries based on their internal chemistry. In this process, AC signals are given to the batteries in different frequencies. As the AC signal hits the batteries, they react to that. This reaction is measured in terms of impedance. Then the data is collected. Based on the collected data, similar batteries are stacked in the battery pack.

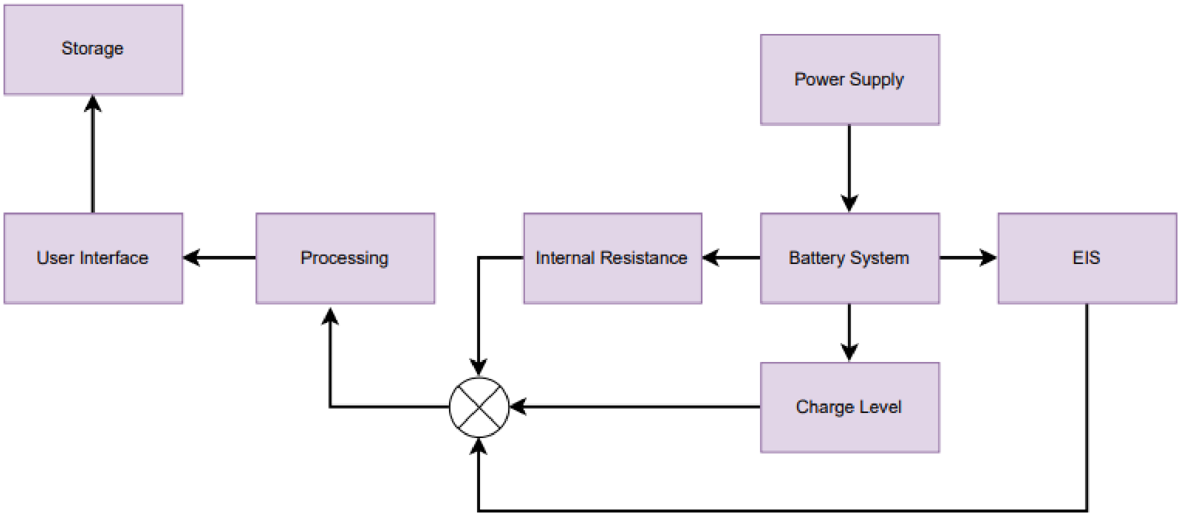

Figure 4: Design approach 2 block diagram

This design approach helps us to look inside the battery parameters without damaging it or taking it apart. By collecting data, this design approach uses machine learning algorithms to screen the batteries and find out the similarities in them. Thus, we can stack them in the battery packs.

2.2 Analysis of multiple design approach

Table 1: Internal and external parameters of Li-ion battery screening system

Factor	**Parameter**	**Design Approach 1**	**Design Approach 2**
Internal	Size	Compact	Bulky
	Weight	Less	High
	Circuitry	Less	High
External	Maintenance cost	Low	High

Table 2: Analysis of multiple design approach based on scalability

Factor	**Design Approach 1**	**Design Approach 2**
Scalability	Scalable	Scalable
Component	Less	More
Production time	Less	High

Table 3 : Analysis of multiple design approach based on accuracy

Factor	**Design Approach 1**	**Design Approach 2**
Data Accuracy	Low	High
Decision Accuracy	Medium	High
Internal parameter	Not Available	Available

2.3 Conclusion

In this chapter, we delved into the exploration of different design approaches to achieve our objectives in this project. Our primary aim was to understand and try different design approaches to find out the optimal solution. Throughout this project, we explored different design approaches. We understood the underlying working principle behind it and gave a description about that. By giving the description, we tried to give brief details of each design approach. Moreover, we analyzed the design approaches based on different criteria. We dived into different aspects of each approach from scalability to accuracy analysis. This analysis helped us to understand which approach is better for the users and manufacturer.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

In the rapidly evolving field of engineering, the application of modern engineering tools and IT tools is essential to the successful completion of any project. With the help of these tools, we can properly visualize and analyze the project's system behavior. For our project, we have used various types of engineering and tools so that we could get precise, effective solutions. This result helps us to come up with the optimized design solution before the implementation of the whole project. After evaluating various engineering and its tools, we selected the software combination that fit perfectly for our project in a virtual environment.

3.2 Select appropriate engineering and IT tools

Selecting appropriate engineering and IT tools is one of the fundamental requirements for ensuring a successful implementation of our project. These tools were carefully chosen based on the project's specifications and requirements. These specifications and requirements include the project's accuracy, efficiency, compatibility, and functionality. This strategic selection allowed for the effective implementation of the project's objectives while ensuring flexibility for potential enhancements. Following all the specifications and requirements, the tools we selected for our projects are:

1. Circuit simulation:
  - Proteus
  - Matlab Simulink

2. Programming language:
  - Python
  - PHP

3. Development Environment:
  - Visual Code Studio
  - Arduino IDE
  - Google Colab

3.3 Use of modern engineering and IT tools

3.3.1 Proteus

Proteus is an electronic design-based software that is normally used to build circuit schematics for testing a circuit's functionality. In our design approach, we implanted the whole circuit in proteus. The reason we implemented the whole circuit in proteus is because this way we can test the whole system at the sub-system level. In this way, we get a proper idea of whether our circuit runs accurately in hardware implantation. Proteus has debugging capabilities that help us identify any fatal error in our design. In this way, we get the accurate design. Also, in proteus, we can simulate different microcontrollers. That means in proteus we get all sorts of libraries to test our system efficiency in terms of different microcontrollers. Overall proteus gives us a general idea of our whole design.

PROTEUS

For our project proteus is a very advantageous tool for running the whole simulation. Some of the main advantages of proteus are:

- Firstly, proteus has a huge library collection which helps us to do trial and error on our project with different types of components.

- It has a debugging feature that helps us to identify the problem in the exact location. Depending on that we can take proper action to solve it and rightfully run the simulation.

- Another important advantage of the proteus is we can add an extra library. Sometimes some of the libraries are not available so in that case we can add additional libraries in proteus. This makes proteus a versatile tool for solving complex engineering problems.

Apart from the advantage, there are some shortcomings of the proteus. That's why we are using other tools to overcome those shortcomings. Those shortcomings are:

1. There are limitations to the free version. We cannot get the full output of the projects. We have to simulate our project sub-system-wise.

2. When simulating the complicated circuit proteus occasionally crashes which interrupts the working flow.

Overall proteus is a sophisticated software. With the help of this software, we can simulate our whole project properly. This tool helps us to visualize the final output of our project.

3.3.2 MATLAB

Matlab is a programming numeric platform that is used to analyze data, develop algorithms and create different types of models. In this project, we utilized MATLAB's Simulink function. This is a specialized tool within MATLAB for simulating, analyzing, and designing dynamic systems. Simulink allows us to model and simulate the behavior of complex systems using a block-diagram approach. This approach is especially useful for developing and testing the whole system in terms of controlling and signal processing.

The reason we are using MATLAB’s Simulink is to check the whole system’s output graph to justify whether our system design is accurate or not. Some of the other advantages of using MATLAB are:

- MATLAB’s Simulink has a user-friendly interface which helps to build the whole system with ease.
- MATLAB has a huge library collection and every one of its components can be editable numerically. That means we can numerically put values in each of the parts. This allows us to find out the more precise solution of the system.

Unlike other tools, MATLAB also has a negative impact on our project. Those are:

- It’s very difficult to design the whole system subsystems in MATLAB. If we want to design the subsystem then we have to create that subsystem from scratch by using mathematical equations. This will make the whole project extremely complicated and time-consuming.
- Despite its huge library, it has a limited customization option.

Therefore, MATLAB plays a critical role in confirming the system's accuracy by visually presenting the performance of the system as a whole through output graphs. This ensures that the design meets the required specifications.

3.3.3 ARDUINO IDE

Arduino Integrated Development Environment (IDE) is an open-source platform. This platform is used for writing, compiling, and uploading code to Arduino microcontroller boards. It provides a simple and user-friendly interface. The IDE supports C and C++ programming languages. That’s why we can easily control hardware peripherals. It comes with a vast library ecosystem that allows us to incorporate various pre-written codes for different sensors, modules, and functions. Which is making our development faster and more efficient.

The advantages of Arduino Ide are:

- Since the Arduino IDE interface runs on a fundamental coding language, it is easy to work with it.
- Another big advantage of Arduino ide is- the environment is open resource. So we can get the necessary help from online sources in terms of working with different types of hardware peripherals.
- Also, there is a serial monitoring section that works like a map. With the help of the serial monitoring values, we can identify whether our system is working perfectly or not.

Disadvantages of Arduino ide are:

- The only problem we face while working with Arduino IDE is debugging. Though we have serial monitoring, it is only applicable when the code is running. At that time we have to manually determine whether our system running correctly or not. But it cannot debug the whole code which is why it makes the whole process time-consuming.

In contrast, the Arduino IDE is an excellent tool for quick prototyping and development. The Arduino IDE helps us to make functional to those hardware peripherals accurately.

3.3.4 Visual Code (VS Code)

Visual Studio Code (VS Code) is a free and open-source code editor. This code editor was developed by Microsoft. It is widely used by developers for writing, debugging, and editing code in various programming languages. With the help of VS code, we were able to verify our hardware peripherals code and UI design code. The user-friendly interface allows us to work with various types of coding in one platform.

The editor's modularity allows us to customize the environment through extensions. Those added features are debuggers, language support, and themes. This tailors the development environment according to our project's requirements.

3.3.5 PHP (Hypertext Preprocessor)

PHP (Hypertext Preprocessor) is a popular open-source server-side scripting language widely used for web development. HTML is embedded within PHP which enables us to create a dynamic web page for the UI of the project. Since our project is database-driven, the PHP is executed on the server and the output is sent to the browser as plain HTML. This allows it to make a powerful tool for building a database-driven website.

Advantages of PHP:

- PHP’s syntax is easy and simple to understand. This allows us to develop a proper user-friendly interface for our project.
- For the small-scale interface, PHP offers the most effective web-based UI.
- PHP supports web hosting. This makes it easy to deploy applications without needing special server configurations.

The disadvantage of PHP:

- PHP’s error-handling mechanism is not as robust as other programming languages. Absent of these features makes debugging harder.
- PHP’s Security is vulnerable. That means breaching PHP-based development is easier.
- PHP is compatible with small or medium-scale applications. Its efficiency dropped in terms of handling high-level language.

Despite its disadvantages, PHP is a very effective web development resource in terms of other open resources in online.

3.3.5 XAMPP

XAMPP is an open-source software package that provides a local web server environment for testing and developing web applications. It simplifies the process of creating a server environment for developing PHP-based applications by bundling all the necessary components into a single package. It allows us to develop, test, and build websites on a local server. In Xampp we developed and tested our user interface’s functionality.

XAMPP

Advantages of XAMPP are:

- XAMPP is easy to configure. Here all the necessary packages such as Apache, MySQL, PHP, and Peri are in a single bundle. That helps to set up our UI environment with ease.
- XAMPP control panel is easy to use. That allows us to configure our ui into the local server very quickly.

Disadvantages of XAMPP are:

- XAMPP is primarily designed to operate in the local network. This makes tools not secure.
- Since XAMPP runs different types of packages into a single bundle, that means a powerful interface is needed to run the tools.

In summary, XAMPP is a highly accessible and versatile tool for the local development of PHP.

3.4 Conclusion

The use of modern engineering and IT tools integration is the key to the successful execution of our project. These tools not only enhanced our ability to visualize and analyze complex data but also helped us to develop the whole project. By leveraging those tools, we have implemented an efficient and precise system. Each of the tools has some advantages and shortcomings. To overcome each of those shortcomings we use multiple engineering tools. After going through every option, we successfully implemented our project according to our project’s objectives and specifications.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

In this project, four principal components have been identified, each of which can be implemented through a range of methodologies. The selection of an appropriate method requires careful consideration of the respective advantages and disadvantages associated with each approach. The components are as follows:

Subsystem 1: Charging Circuit

- Constant Current Charging: Uses a fixed current to charge the battery until it reaches the target voltage.
- Constant Voltage Charging: Maintains a steady voltage while decreasing the current as the battery approaches full charge.
- Pulse Charging: Provides intermittent bursts of charging current to reduce heat generation and improve battery life.
- Trickle Charging: Provides a small current to keep the battery fully charged once it reaches full capacity.

Subsystem 2: Discharging Circuit

- Constant Current Discharge: Maintains a fixed current during the discharge process for accurate capacity testing.
- Constant Power Discharge: Keeps the power level constant while discharging, simulating real-world applications.
- Pulse Discharge: Applies intermittent discharging cycles to mimic real operating conditions.
- Programmable Electronic Load: Allows for customizable discharge profiles based on specific testing requirements.

Subsystem 3: Microcontroller System

- Arduino-Based Control: Using an Arduino board for basic monitoring and control tasks.

- ESP32-Based Control: Incorporates Wi-Fi and Bluetooth for wireless data transmission.
- Raspberry Pi Control: Offers more processing power for advanced data analysis and control algorithms.
- External ADC Integration: Uses high-precision external ADCs for improved measurement accuracy.

Subsystem 4: Sensors and Fault Protection

- Voltage Measurement: Measures battery voltage using voltage dividers or specialized ICs.
- Current Sensing: Hall-effect or shunt-based sensors to monitor charging and discharging currents.
- Temperature Monitoring: Tracks battery temperature with thermistors or digital temperature sensors.
- Overcurrent and Overvoltage Protection: Implements fuses, MOSFETs, and thermal cutoffs to protect the system from faults.

Subsystem 5: Data Analysis and User Interface

- Real-Time Data Acquisition: Uses software like LabVIEW or Python for data logging.
- Graphical User Interface (GUI): Develops custom GUIs with Python (Tkinter, PyQt) or web-based tools for data visualization like HTML5, PHP and JavaScript (XAMPP).
- Remote Monitoring: Allows data transmission to a cloud platform for off-site analysis.
- Automated Reporting: Generates reports and visualizations automatically based on collected data.

4.2 Optimization of multiple design approach

Subsystem 1: Charging Circuit

Method	Performance	Cost	Complexity	Other Considerations
Constant Current Charging	Fast charging speed, good for large batteries	Moderate	Low, straightforward	Can cause heating at higher currents

Constant Voltage Charging	Safe charging, protects battery life	Moderate	Low to moderate	Ideal for Li-ion batteries
Pulse Charging	Reduces heat, extends battery life	High	Moderate	Requires precise control
Trickle Charging	Maintains full charge without overcharging	Low	Low	Suitable for standby systems

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Subsystem 2: Discharging Circuit

Method	**Performance**	**Cost**	**Complexity**	**Other Considerations**
Constant Current Discharge	Accurate for capacity testing	Moderate	Low to moderate	Useful for lab testing and battery profiling
Constant Power Discharge	Simulates real-world conditions	Moderate to high	Moderate	Requires precise power control circuits
Pulse Discharge	Mimics dynamic loads, reduces heat	High	Moderate to high	Suitable for stress testing and performance simulation
Programmable Electronic Load	Highly customizable, versatile for various tests	High	High	Ideal for advanced testing and research

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Subsystem 3: Microcontroller System

Method	**Performance**	**Cost**	**Complexity**	**Other Considerations**
Arduino-Based Control	Basic control, good for simple monitoring	Low	Low	Limited processing power

ESP32-Based Control	Wireless communication, advanced features	Moderate	Moderate	Suitable for IoT applications
Raspberry Pi Control	High processing power, advanced analytics	High	High	Supports complex algorithms and AI-based data processing
External ADC Integration	High accuracy in measurement	Moderate to high	Moderate to high	Requires additional components and integration

Subsystem 4: Sensors and Fault Protection

Method	Performance	Cost	Complexity	Other Considerations
Voltage Measurement	Basic voltage reading	Low	Low	Voltage divider is simple but less accurate than ICs
Current Sensing	Accurate current measurements	Moderate to high	Moderate	Hall-effect sensors offer isolation but are more expensive
Temperature Monitoring	Tracks temperature reliably, crucial for safety	Low to moderate	Low to moderate	Digital sensors are more accurate but thermistors are cheaper
Overcurrent and Overvoltage Protection	Protects system from damage, improves safety	Moderate	Moderate	MOSFETs and thermal cutoffs offer robust protection

Subsystem 5: Data Analysis and User Interface

Method	Performance	Cost	Complexity	Other Considerations

Real-Time Data Acquisition	High accuracy in real-time data capture	Moderate to high	Moderate to high	Software-dependent, requires integration with hardware
Graphical User Interface (GUI)	Intuitive data visualization for users	Low to high	Moderate to high	Web-based tools offer flexibility; Python-based offers customization
Remote Monitoring	Allows off-site analysis	Moderate to high	High	Requires cloud infrastructure
Automated Reporting	Convenient, generates insights automatically	Moderate	Moderate to high	Reduces manual effort, requires good software implementation

4.3 Identify optimal design approach

4.3.1 Charging Subsystem

The TP4056 charging module was selected for the charging circuit due to its constant current/constant voltage (CCCV) charging profile, which is specifically designed for lithium-ion batteries. The module includes essential protection features such as overcharge and short-circuit protection, making it an optimal solution for charging 18650 Li-ion batteries. Given the need for reliability and affordability in this project, the TP4056 strikes a balance between cost-efficiency and robust performance, ensuring safe and effective battery charging.

4.3.2 Discharging Subsystem

For the discharging circuit, a power resistor was employed for consistent load dissipation, alongside a MOSFET for switching control. The MOSFET allows the Arduino to regulate discharge operations based on sensor data. A Schottky diode was added for its fast switching and low forward voltage drop, which helps protect the circuit during switching operations. The same voltage and current sensors (INA219 and voltage sensor module) are used to monitor real-time discharge parameters, providing accurate feedback to the system and facilitating safe battery testing. The OLED display visualizes these readings, offering users immediate access to voltage, current, and discharge status.

4.3.3 Fault Protection and Safety

In this subsystem, fault protection is managed by the combination of a Schottky diode and the Arduino-controlled MOSFET. The Schottky diode prevents reverse current flow, while the Arduino acts as the central controller, monitoring sensor data to detect faults such as overcurrent or overheating. The Arduino, using sensor inputs from the INA219 and the DHT11 temperature sensor, responds to potential faults by cutting off charging or discharging through the MOSFET. This layered approach ensures a robust and responsive fault management system, reducing the risk of damage to the batteries and circuit.

4.3.4 Data Logging and Analysis

Data collection and logging are handled through the Arduino's serial monitor, with Python used for further data analysis and presentation. The Arduino continuously streams sensor data, which is logged and analyzed to detect patterns or faults during both charging and discharging cycles. The final output is displayed on a graphical user interface (GUI) developed in XAMPP, providing an intuitive interface for real-time monitoring and post-analysis of battery performance. This integration of real-time data acquisition with machine learning models allows for efficient identification of optimal batteries for stacking and other operations.

This design approach ensures that the system operates safely and effectively, leveraging a combination of cost-efficient components and precise monitoring for optimal performance in battery management.

4.4 Performance evaluation of developed solution

Test Case 1: Charging Performance

The charging performance of the developed system was evaluated by subjecting the lithium-ion batteries to the charging protocol established through the TP4056 module. Initial tests yielded inconsistent readings, attributed to faulty battery conditions and possible connection errors. To rectify this, affected components were replaced, ensuring optimal functionality. Upon re-testing, the system successfully maintained the desired charging parameters, adhering to the predefined cut-off limits for voltage and current. The implementation of the charging algorithm effectively prevented overcharging, confirming the reliability of the charging subsystem. It is important to note that the charging process required a significant amount of time, consistent with the characteristics of lithium-ion batteries, which generally necessitate longer durations to reach full capacity. Additionally, data logging was performed, generating CSV files that captured key metrics throughout the charging cycle. This data was seamlessly transmitted to the user interface, providing clear visibility into the charging process.

Test Case 2: Discharging Performance

In parallel, the discharging performance of the system was assessed using the configured discharging circuit comprising a power resistor, MOSFET, Schottky diode, and integrated sensors. Similar to the charging phase, initial tests revealed some discrepancies in the readings, primarily due to the use of suboptimal battery conditions. Following the replacement of faulty components, the system exhibited consistent performance in discharging the battery, effectively adhering to the cut-off thresholds established for voltage and current. The monitoring system accurately reflected real-time discharge data on the OLED display, ensuring user awareness of operational conditions. As with the charging process, the discharging procedure also required a considerable amount of time to complete, reflecting the inherent properties of lithium-ion technology. Data was logged throughout the discharging process, with the resultant CSV files providing a comprehensive overview of performance metrics. This data was subsequently sent to the graphical user interface, facilitating further analysis and visualization.

Overall, both test cases demonstrated that the developed solution is capable of effectively managing both charging and discharging processes for lithium-ion batteries, ensuring operational safety and data integrity throughout the cycles, despite the time-intensive nature of the processes.

4.5 Conclusion

The optimal design solutions for each subsystem have been carefully selected based on the project's requirements. For the charging subsystem, a fixed current charging module was chosen, while a constant load power resistor was employed for the discharging circuit. The 18650 lithium-ion battery was selected as the primary test case due to its extended cycle life, making it an ideal candidate for this application. Voltage and current sensors were integrated to ensure compatibility with the chosen microcontroller unit (MCU). The Arduino platform was selected as the MCU due to its cost-effectiveness, reliability, and capability to handle the necessary tasks. This MCU is used in conjunction with sensors and MOSFETs to manage charging and discharging, providing an additional layer of protection against faults. These safety mechanisms are complemented by the integration of modules that offer fault protection features.

For data collection and logging, Python was utilized, with data analysis performed on a laptop interfacing with a server-based graphical user interface (GUI) developed using XAMPP. Machine learning models were employed to screen the collected data, facilitating the identification of optimal batteries for stacking purposes. Following the selection of the optimal design solution, all necessary testing procedures were conducted to evaluate the system's performance and functionality.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

After verifying the design of our battery screening system, we proceeded to develop a hardware implementation of the project. Given the limitations in our capacity to test batteries and collect large volumes of data for machine learning training, we opted for a scaled-down prototype. This version retains all essential features of the complete system, effectively demonstrating the core functionalities of our charging and discharging subsystems, as well as the monitoring and fault protection mechanisms.

The scaled-down prototype includes key components such as the TP4056 charging module, INA219 current sensor, voltage sensor module, OLED display, and DHT11 temperature sensor. While the industrial version would be more robust and automated, this prototype effectively performs the same tasks, validating our design and approach. We have collected sufficient data to serve as a proof of concept, ensuring that the system operates as intended.

With the collection of more data, we aim to train machine learning models that can facilitate faster screening of batteries, improving the efficiency of our testing processes. By limiting the scope of our testing, we have focused on the critical functionalities required for effective battery screening. This approach allows us to assess the system's performance and reliability in a controlled environment, laying the groundwork for future developments and potential enhancements in a more automated industrial setting.

5.2 Completion of final design

For our prototype design we have chosen to execute the following tasks:

- Charge 18650 li-ion batteries
- Discharge 18650 li-ion batteries
- Measure parameters in a controlled environment
- Upload the data to web server
- Analysis using ML to find similarity

The full system prototype is shown below:

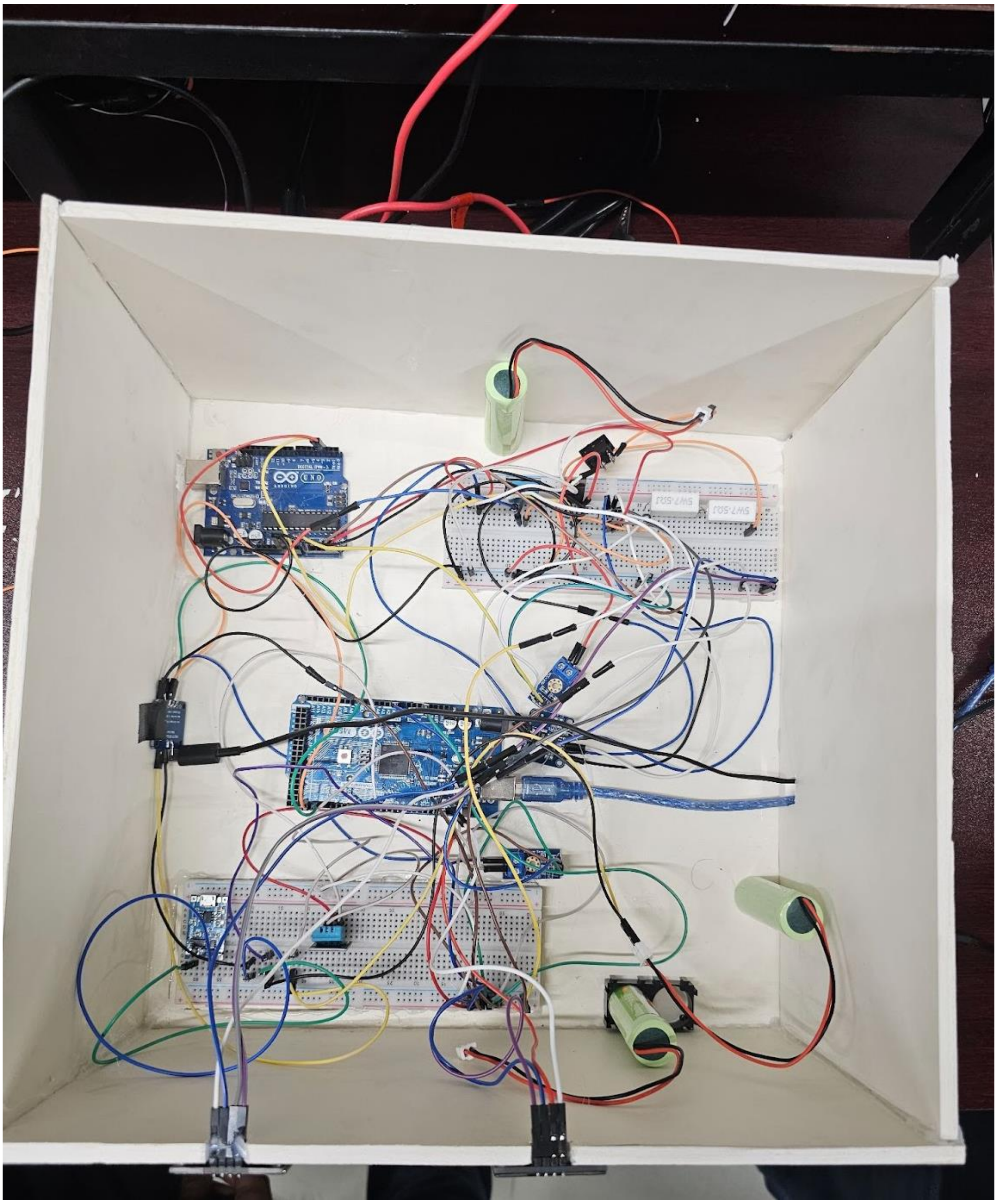


Figure 5: Full System Prototype

A prototype has been developed based on the system’s block diagram, which visually represents the design and illustrates the relationships among various components. The prototype serves as a physical implementation aimed at testing and evaluating the system's performance. A detailed description of each part of the prototype is provided, outlining the specific functions and features of each component, as well as their interactions to achieve the system's overall objectives. The development process involved transforming the conceptual block diagram into a tangible, operational system, enabling testing and iterative refinement. This approach facilitates a deeper understanding of the system’s capabilities and limitations, allowing for necessary adjustments prior to full-scale implementation.

5.2.1 Charging Module

The TP4056 is a linear lithium-ion battery charger IC that is well-suited for single-cell applications. It employs a constant-current/constant-voltage charging technique with a fixed output voltage of 4.2V, making it suitable for safely charging standard lithium-ion batteries. The IC is designed to work with both USB power sources and wall adapters, providing versatility in power supply options. Its internal power MOSFET architecture eliminates the need for an external blocking diode, simplifying the circuit design. Additionally, the TP4056 features thermal regulation to control the charge current, preventing overheating during high ambient temperatures or high-power operation.

The module includes status indicator LEDs that signal different charging states, such as active charging and charge completion. The charge current can be adjusted by selecting an appropriate value for the programming resistor (RPROG), with a typical configuration supporting a range of current settings from 130mA to 1A. The module also integrates protection features, such as over-current and deep-discharge prevention.

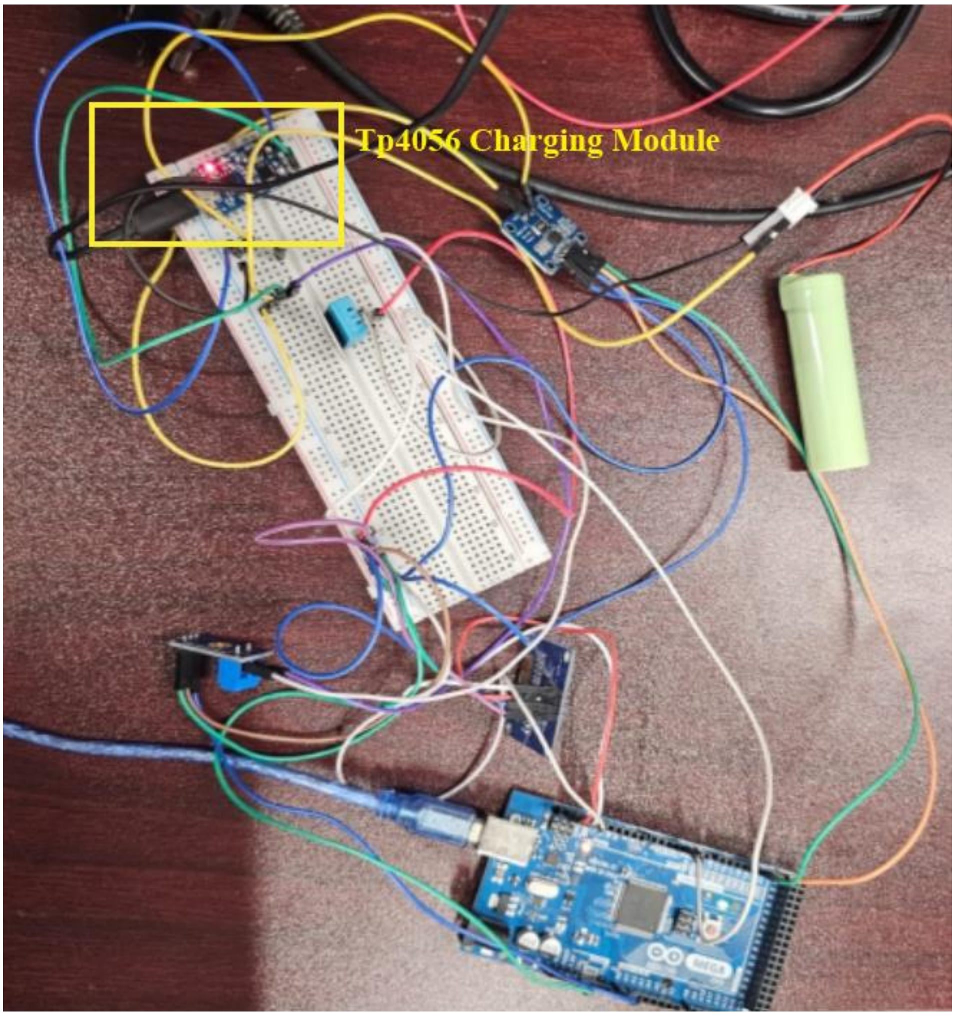


Figure 6: Tp4056 Charging Module

5.2.2 Charging Circuit

The designed circuit integrates the TP4056 charging module with a comprehensive monitoring system for evaluating battery charging characteristics. The core of the system is an Arduino microcontroller, which facilitates data acquisition and control. The circuit employs a voltage sensor to monitor the battery's voltage, ensuring the charging process remains within safe limits. An INA219 current sensor is included to measure the current flow during charging and discharging cycles, providing insight into the system's efficiency and battery health. A DHT11 sensor is used to monitor environmental temperature and humidity, which can influence battery performance, allowing for adaptive adjustments based on real-time conditions.

Data from these sensors are displayed on an OLED screen, which serves as a user interface, providing continuous updates on parameters such as voltage, current, and temperature. The Arduino microcontroller collects data from the sensors, processes it, and outputs the results to the OLED, offering real-time feedback on the charging process. This configuration enables a comprehensive assessment of the charging conditions, including safety checks for overvoltage, overcurrent, and temperature regulation. The system thus provides a practical approach for monitoring and optimizing the battery charging process while using low-cost, widely available components.

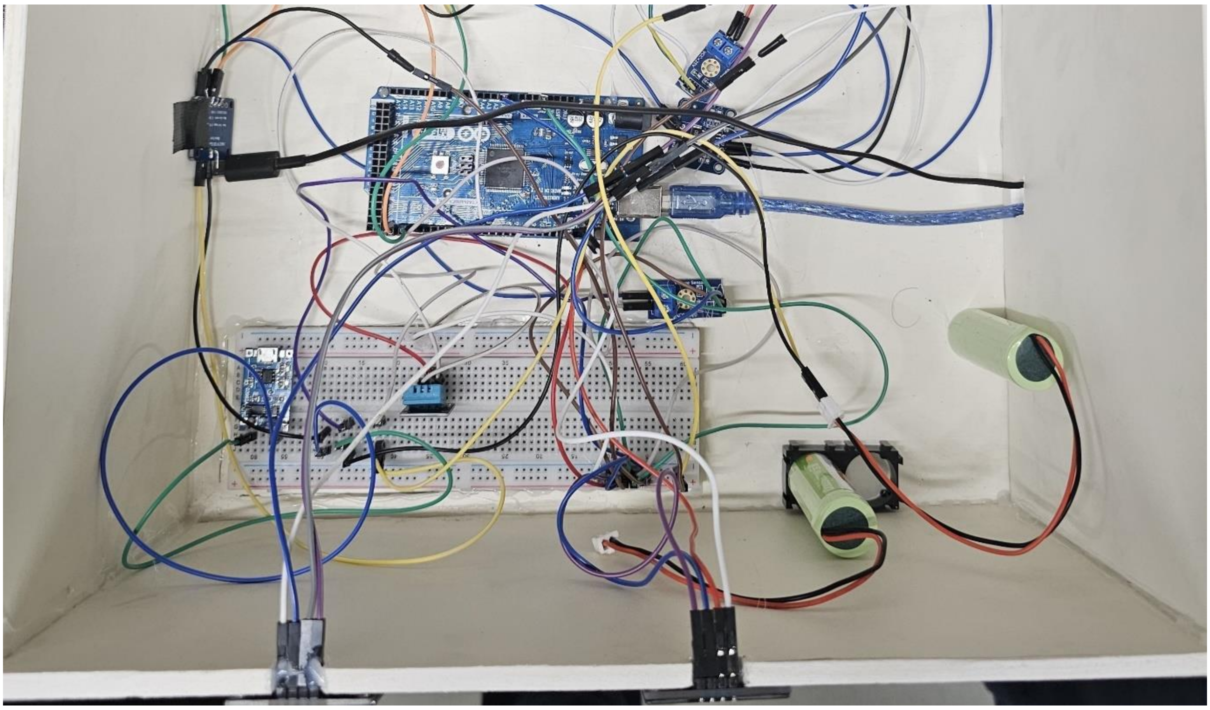


Figure 7: Charging Circuit

5.2.3 Discharging Circuit

The discharging circuit is designed similarly to the charging configuration, with key adaptations for safely managing the battery discharge process. At the core of this circuit is the Arduino microcontroller, which monitors discharge parameters and controls the discharging mechanism. Two 5W power resistors are connected in series to form the load, providing a stable resistive path for discharging the battery. The resistors are controlled by a MOSFET, which is connected to one of the Arduino's PWM (Pulse Width Modulation) pins, enabling precise control over the discharging process. By adjusting the duty cycle of the PWM signal, the Arduino can regulate when to initiate and stop discharging based on battery voltage or other criteria.

To ensure safety during operation, a Schottky diode is incorporated into the circuit to prevent potential reverse current flow, protecting the components from damage. The same set of monitoring sensors from the charging circuit—namely, the voltage sensor, INA219 current sensor, DHT11 temperature and humidity sensor, and OLED display—are used here to provide real-time feedback. The Arduino collects data from these sensors to monitor voltage drop, current flow, and temperature during the discharge cycle, displaying this information on the OLED screen. This integrated setup enables continuous tracking of the discharging process, facilitating analysis of battery performance under load while ensuring the safety and longevity of the system.

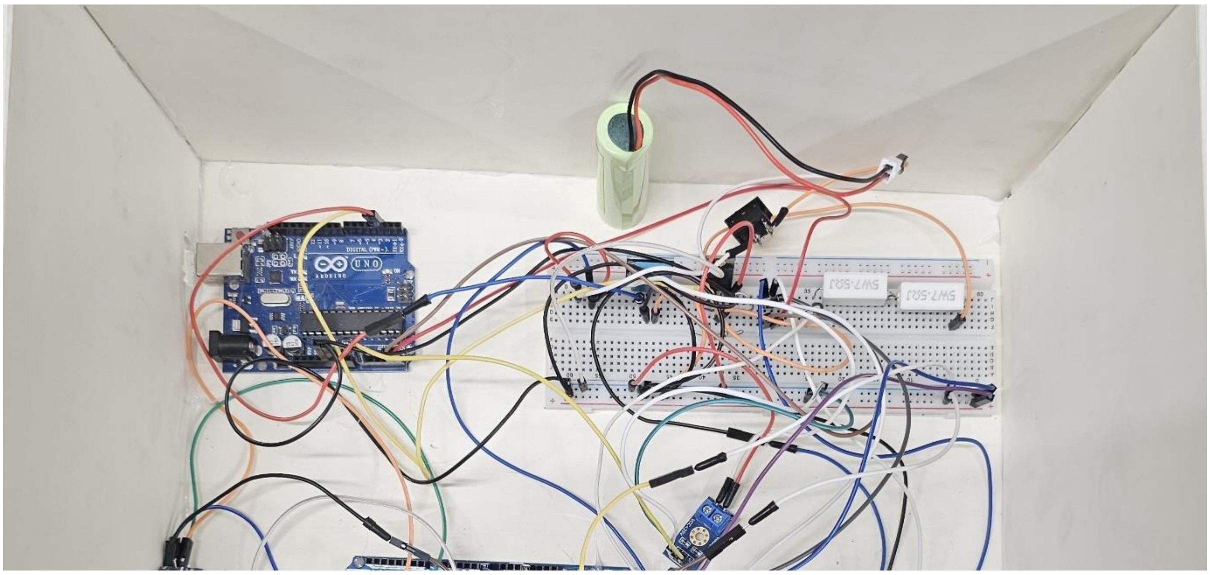


Figure 8: Discharging Circuit

5.2.4 Control Unit

The control unit of the battery screening system is composed of two microcontroller boards, an Arduino Mega and an Arduino Uno, working together to manage the sensors, MOSFET, and physical switches. This dual-microcontroller setup is employed to distribute the processing load and manage different tasks more efficiently. The Arduino Mega, with its larger number of input/output pins and higher memory capacity, is designated for handling the data acquisition from multiple sensors, including the voltage sensor, INA219 current sensor, and DHT11 temperature sensor. It processes these inputs in real-time to monitor the battery's charging and discharging states, and updates the OLED display with the current status of the system.

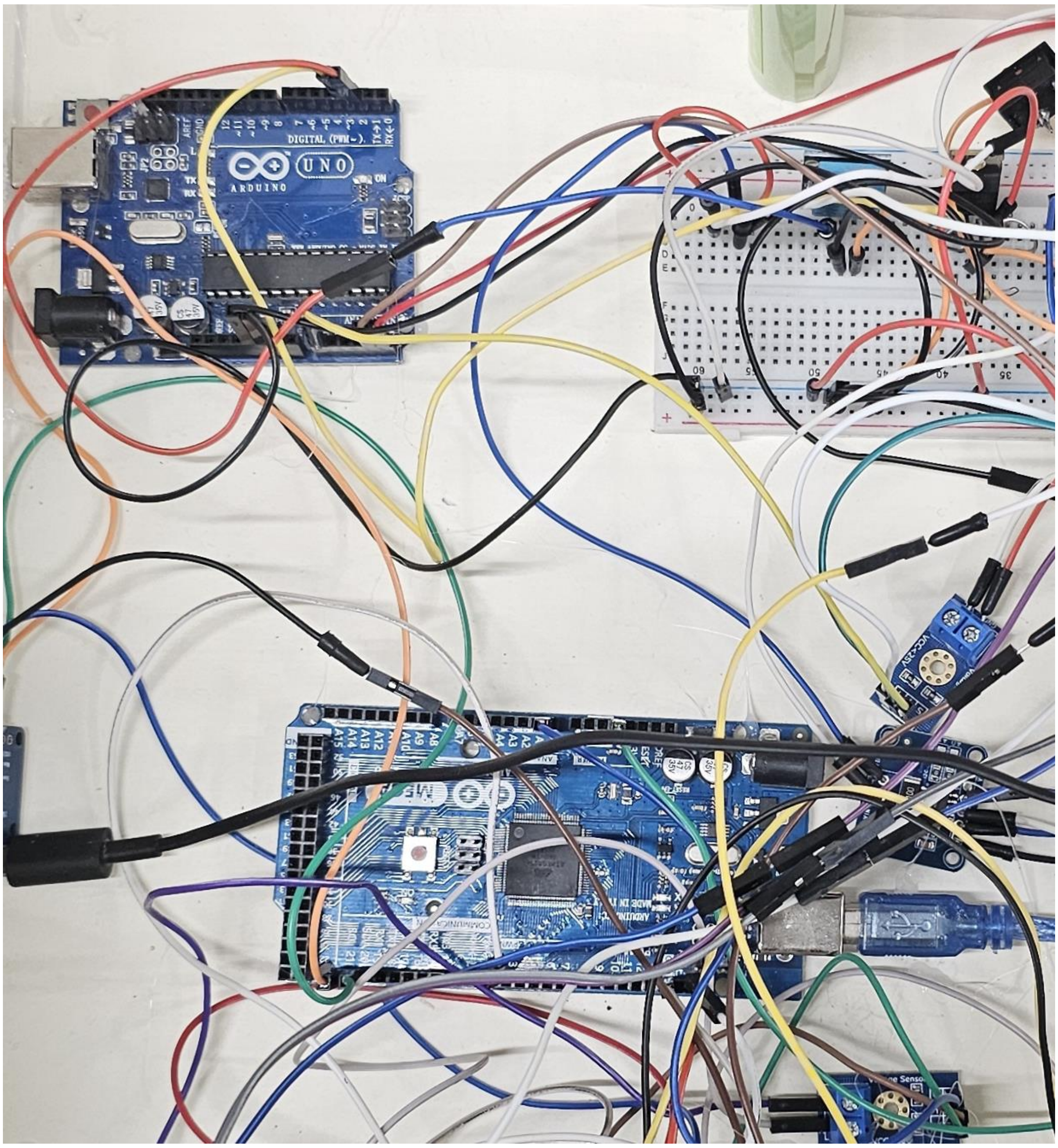


Figure 9: Control Circuit

Meanwhile, the Arduino Uno is utilized for executing control tasks, such as managing the MOSFET through the PWM signal to regulate the discharge process and handling user inputs from physical switches for starting, stopping, or resetting the system. This division of responsibilities ensures that sensor data processing and control tasks do not interfere with each other, leading to more reliable operation. The two Arduinos communicate through a serial interface, allowing the Mega to send status information to the Uno and receive control commands in return. This modular design enhances the flexibility and scalability of the system, allowing for easy integration of additional sensors or control elements if needed

5.2.5 Status Indication

For status indication, the system utilizes two OLED displays that provide real-time feedback on both the charging and discharging processes. The first OLED is dedicated to displaying charging statistics such as battery voltage, current flow, and temperature conditions, allowing users to monitor the health and safety of the battery during the charging cycle. The second OLED presents similar information for the discharging process, including voltage drop across the load, discharge current, and ambient temperature, offering insights into the battery's performance under load conditions.

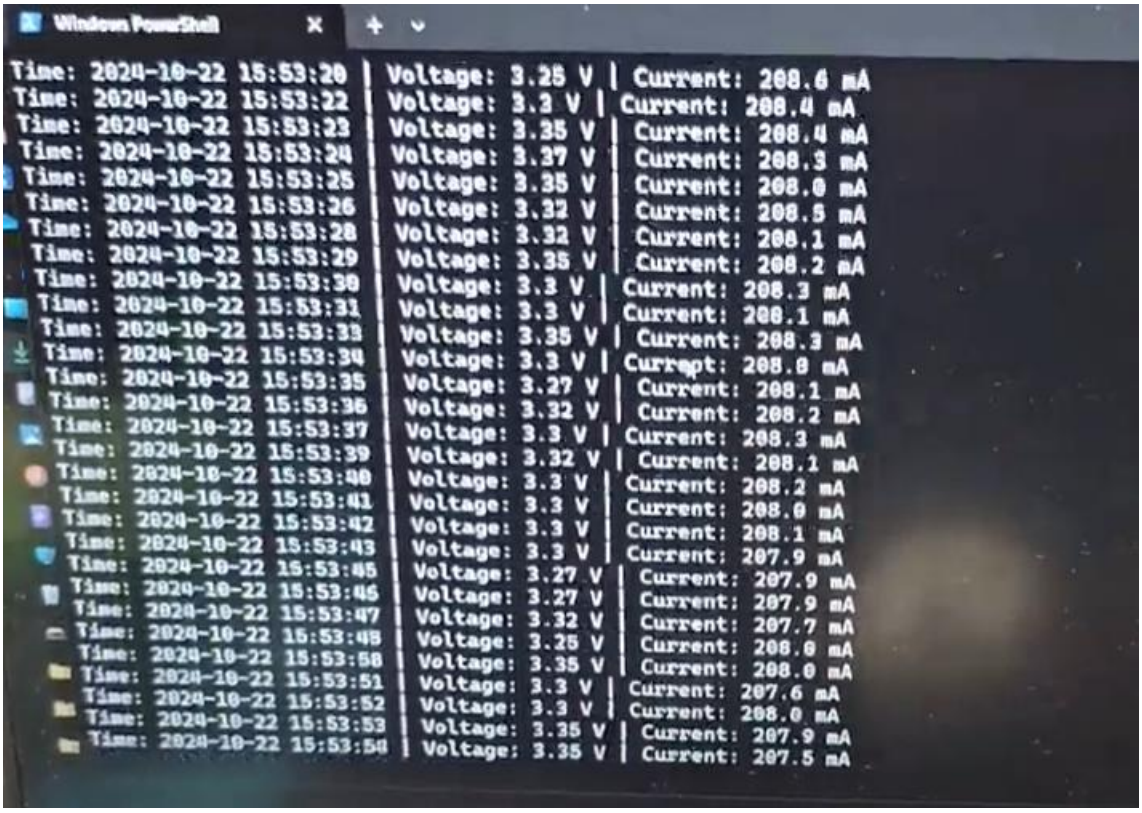
In addition to the OLED displays, the system also outputs data to the laptop's serial monitor via the Arduino's USB interface. This allows for more detailed data logging and analysis by displaying a continuous stream of sensor readings and system status updates. The use of both OLEDs and the serial monitor ensures that all key parameters are easily accessible, enabling effective monitoring and control. This multi-level status indication enhances user interaction by providing comprehensive information in different formats, catering to both on-device monitoring and detailed analysis through the serial interface.

```
Voltage:    3.91 V
Temp:       28.9 C
Humidity:   72.0 %
Current:    149.6 mA
```

Figure 10: Charging Status

```
Status: Discharging
Voltage: 3.27
Current: 207.4
Temp:    28.9
Hum:     70.0
```

Figure 11: Discharging Status



```
Time: 2024-10-22 15:53:20 | Voltage: 3.25 V | Current: 208.6 mA
Time: 2024-10-22 15:53:22 | Voltage: 3.3 V | Current: 208.4 mA
Time: 2024-10-22 15:53:23 | Voltage: 3.35 V | Current: 208.4 mA
Time: 2024-10-22 15:53:24 | Voltage: 3.37 V | Current: 208.3 mA
Time: 2024-10-22 15:53:25 | Voltage: 3.35 V | Current: 208.0 mA
Time: 2024-10-22 15:53:26 | Voltage: 3.32 V | Current: 208.5 mA
Time: 2024-10-22 15:53:28 | Voltage: 3.32 V | Current: 208.1 mA
Time: 2024-10-22 15:53:29 | Voltage: 3.35 V | Current: 208.2 mA
Time: 2024-10-22 15:53:30 | Voltage: 3.3 V | Current: 208.3 mA
Time: 2024-10-22 15:53:31 | Voltage: 3.3 V | Current: 208.1 mA
Time: 2024-10-22 15:53:33 | Voltage: 3.35 V | Current: 208.3 mA
Time: 2024-10-22 15:53:34 | Voltage: 3.3 V | Current: 208.0 mA
Time: 2024-10-22 15:53:35 | Voltage: 3.27 V | Current: 208.1 mA
Time: 2024-10-22 15:53:36 | Voltage: 3.32 V | Current: 208.2 mA
Time: 2024-10-22 15:53:37 | Voltage: 3.3 V | Current: 208.3 mA
Time: 2024-10-22 15:53:39 | Voltage: 3.32 V | Current: 208.1 mA
Time: 2024-10-22 15:53:40 | Voltage: 3.3 V | Current: 208.2 mA
Time: 2024-10-22 15:53:41 | Voltage: 3.3 V | Current: 208.0 mA
Time: 2024-10-22 15:53:42 | Voltage: 3.3 V | Current: 208.1 mA
Time: 2024-10-22 15:53:43 | Voltage: 3.3 V | Current: 207.9 mA
Time: 2024-10-22 15:53:45 | Voltage: 3.27 V | Current: 207.9 mA
Time: 2024-10-22 15:53:46 | Voltage: 3.27 V | Current: 207.9 mA
Time: 2024-10-22 15:53:47 | Voltage: 3.32 V | Current: 207.7 mA
Time: 2024-10-22 15:53:48 | Voltage: 3.25 V | Current: 208.0 mA
Time: 2024-10-22 15:53:50 | Voltage: 3.35 V | Current: 208.0 mA
Time: 2024-10-22 15:53:51 | Voltage: 3.3 V | Current: 207.6 mA
Time: 2024-10-22 15:53:52 | Voltage: 3.3 V | Current: 208.0 mA
Time: 2024-10-22 15:53:53 | Voltage: 3.35 V | Current: 207.9 mA
Time: 2024-10-22 15:53:54 | Voltage: 3.35 V | Current: 207.5 mA
```

Figure 12: Serial Monitor of the System

5.3 Evaluate the solution to meet desired need

Following the completion of the hardware implementation, the subsequent phase focused on testing and evaluating the performance of the battery screening system prototype. To conduct a thorough assessment, the following test cases were defined:

- Accuracy testing of voltage and current measurements
- Analysis of charging and discharging cycles
- Monitoring and regulation of temperature
- Detection of faults and implementation of safety measures
- Real-time transmission of data to the monitoring platform

These test cases were designed to comprehensively evaluate the system's capability to meet the specified requirements and ensure reliable operation in practical applications.

5.3.1 Accuracy testing of voltage and current measurements

As part of the sensor accuracy validation, the system's voltage and current measurements, as well as other sensor readings, were thoroughly tested. To verify the accuracy, the readings from the voltage sensor, INA219 current sensor, and DHT11 temperature sensor were compared against a reliable multimeter. The multimeter served as the reference standard, and each sensor's output was cross-checked to ensure consistency and precision. The results demonstrated that the sensors provided accurate readings within an acceptable error margin when compared to the multimeter's measurements. This verification process confirmed that the sensors are capable of delivering reliable data, validating their suitability for monitoring the battery's charging and discharging processes.

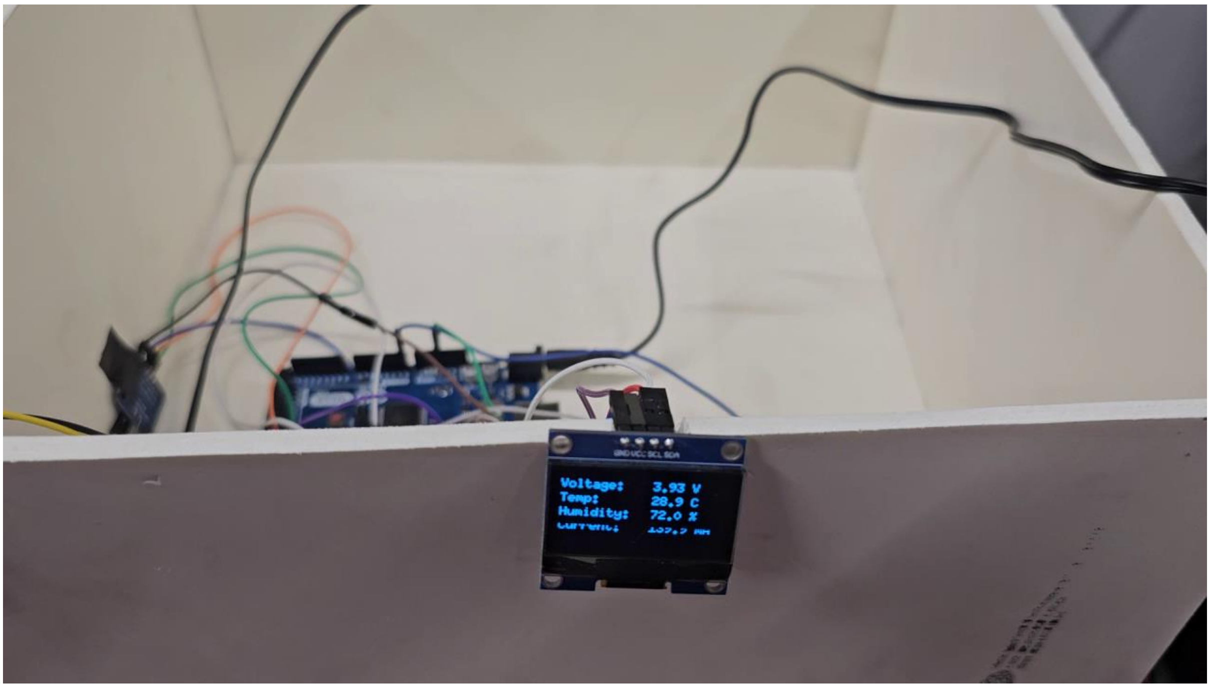


Figure 13: Verifying Sensor Reading

5.3.2 Analysis of charging and discharging cycles

For the analysis of the charging and discharging cycles, brand new 18650 lithium-ion batteries were tested using our developed system. The system was able to charge and discharge the batteries safely, with no faults or irregularities observed throughout the testing process. During these cycles, key parameters such as voltage, current, and temperature were continuously monitored, and the data was displayed in real-time on the OLED screens while also being logged onto CSV files for later review. The logged data was subsequently analyzed by plotting graphs of the charging and discharging curves, allowing for a comprehensive assessment of the battery's performance characteristics, such as capacity retention, charge efficiency, and thermal behavior. This data-driven approach ensured a thorough evaluation of the system’s ability to safely manage battery operations while providing valuable insights into the battery's condition over repeated cycles.

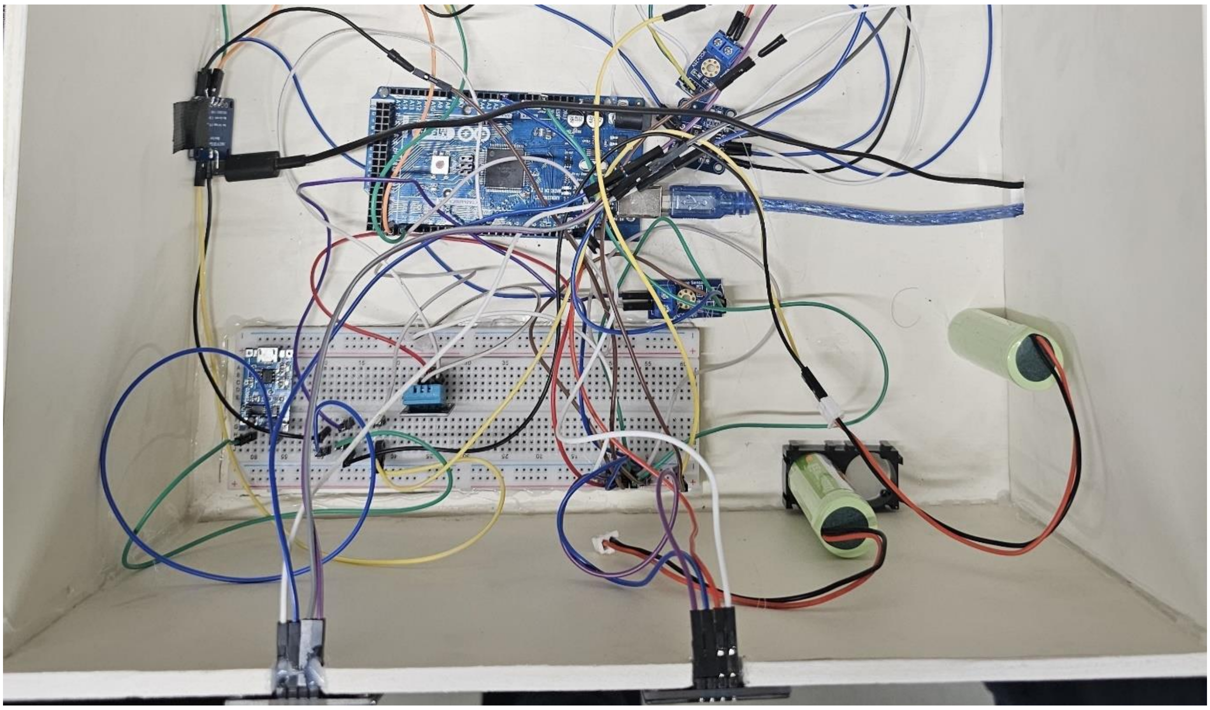
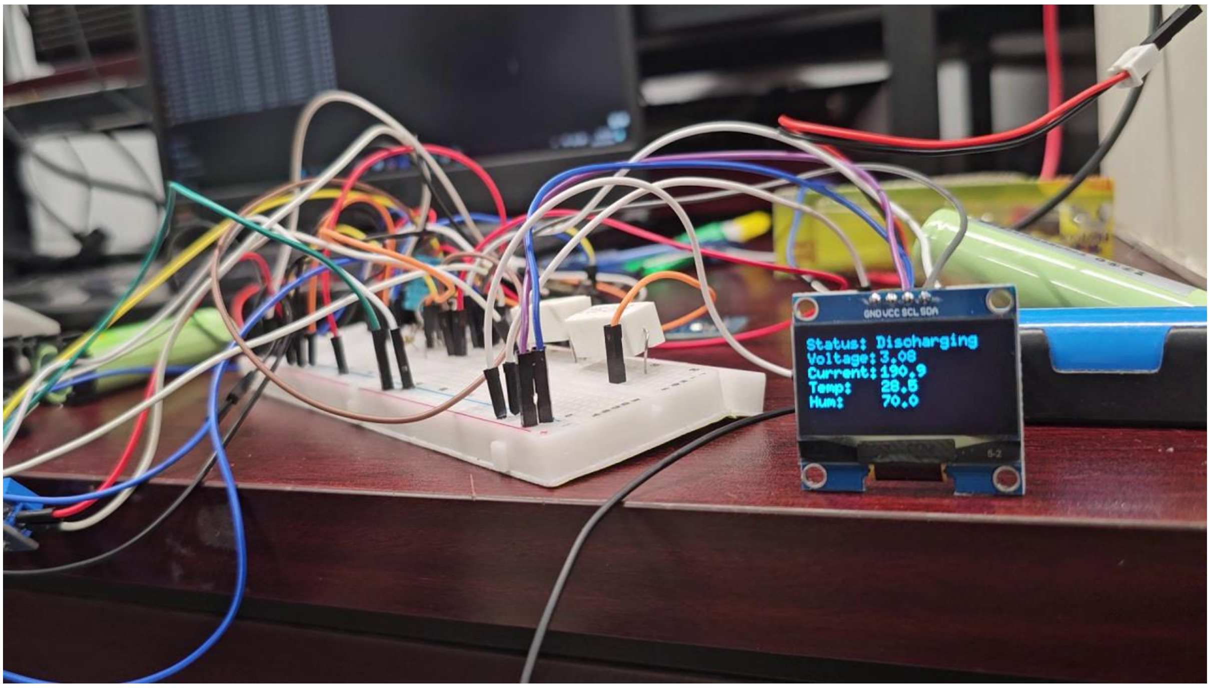


Figure 14: Battery Charging



```
Status: Discharging
Voltage:3.08
Current:190.9
Temp:    28.5
Hum:     70.0
```

Figure 15: Battery Discharging

Charging and discharging graphs are:

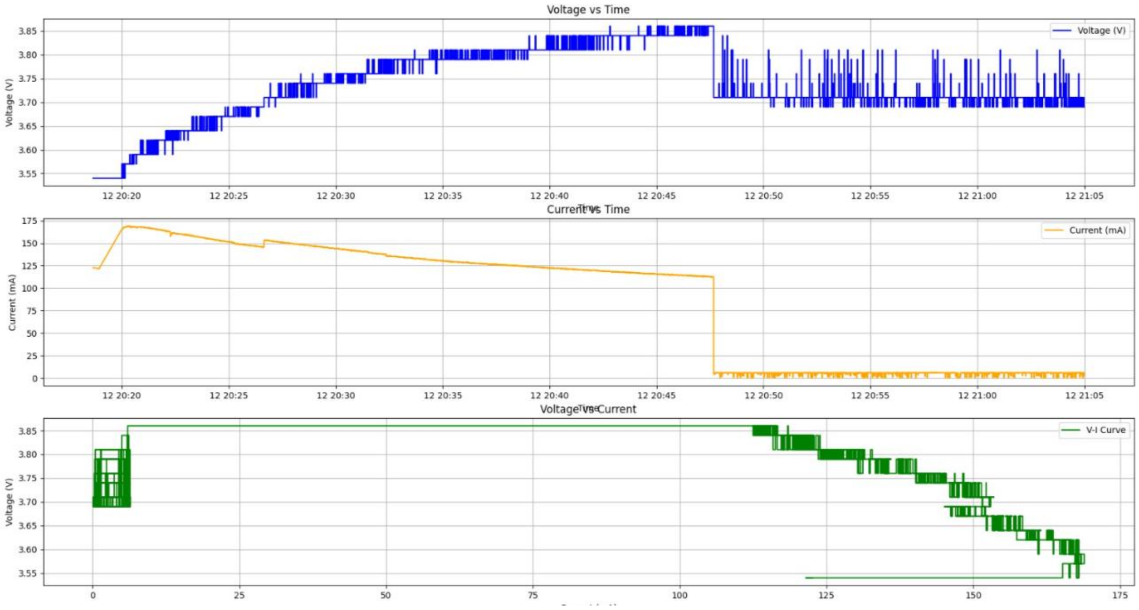


Figure 16: Battery Charging Graph

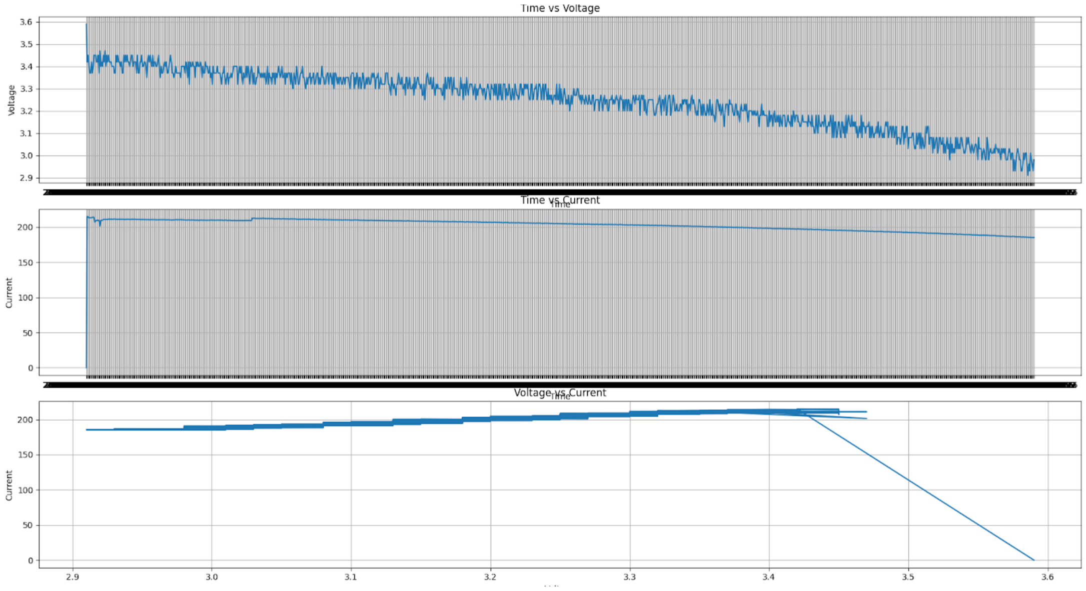
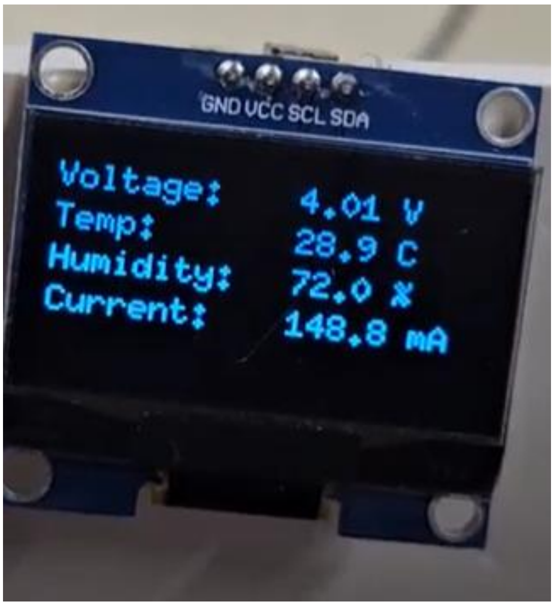


Figure 17: Battery Discharging Graph

5.3.3 Monitoring and regulation of Temperature

To effectively monitor and regulate temperature during the charging and discharging processes, the DHT11 sensor was strategically placed adjacent to the battery. This placement allowed for continuous real-time monitoring of the battery's temperature throughout the operation. Importantly, the recorded temperature remained within safe thresholds, indicating that the system operated without overheating. The charging and discharging processes were managed in a way that prevented excessive current draw, which is crucial for maintaining thermal stability.

Furthermore, the laboratory environment was controlled using air conditioning, ensuring that ambient temperature fluctuations did not impact the battery's performance. The combination of these measures contributed to a safe operational environment, aligning with best practices for lithium-ion battery management systems. Overall, the effective temperature monitoring and regulation reinforced the safety and reliability of the charging and discharging cycles, confirming the system's suitability for handling 18650 lithium-ion batteries under controlled conditions.



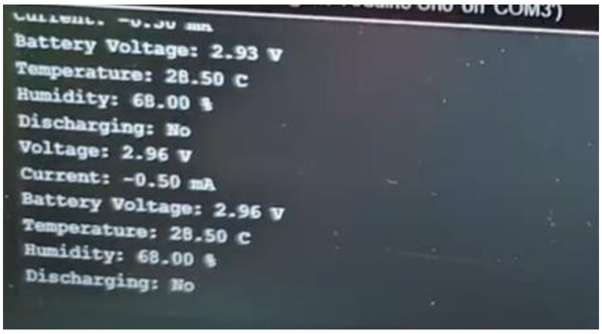
```
Voltage:    4.01 V
Temp:       28.9 C
Humidity:   72.0 %
Current:    148.8 mA
```

Figure 18: Temperature in Oled

5.3.4 Detection of faults and implementation of safety measures

In our system, the detection of faults and implementation of safety measures were paramount to ensuring reliable operation. The control unit, comprising Arduino microcontrollers, was designed to monitor the battery's voltage closely. When the battery voltage dropped to a predetermined threshold, the microcontroller safely cut off power to the MOSFET, thereby preventing over-discharge, which can damage lithium-ion batteries. During the charging process, the TP4056 module actively manages the charging conditions and indicates the status through LED indicators, clearly showing whether the charging is active or inactive.

Moreover, the overall circuit was engineered to operate within specified safety limits throughout the testing phases. All monitored readings remained below their rated specifications, ensuring that no safety thresholds were exceeded. This careful design approach not only safeguards the battery's health but also enhances the system's reliability, highlighting the effectiveness of both hardware and software in managing lithium-ion battery operations safely. The incorporation of these fault detection and safety features underscores the importance of rigorous safety protocols in a battery screening system.



```
Battery Voltage: 2.93 V
Temperature: 28.50 C
Humidity: 68.00 %
Discharging: No
Voltage: 2.96 V
Current: -0.50 mA
Battery Voltage: 2.96 V
Temperature: 28.50 C
Humidity: 68.00 %
Discharging: No
```

```
Status: Low V
Voltage:2.93
Current:-0.6
Temp:   28.5
Hum:    68.0
```

Figure 19 & 20: Status Checking

5.3.5 Real Time data transmission to web server

We established a serial communication protocol with our Arduino MCU and confirmed that data is being successfully sent to our laptop which then can transmit to a web server at a sampling rate of approximately one second through python. The transmitted data includes voltage, current, temperature and mAh values measured directly from the hardware sensors. Figure below illustrates the web server displaying this data along with the battery charging and discharging graph. Therefore, the web server functioned as intended.

Identical Battery Identification and Clustering System (IBICS)
ATC 4 Group 4 EEE499C

VOLTAGE (V)
3.92 V

CURRENT (mA)
327.00 mA

TEMPERATURE (°C)
34.00 °C

CHARGE LEVEL (MAH)
961.00 mAh

Figure 21: User Interface showing real time data

5.3.6 Machine Learning Evaluation

The dataset utilized for training the models was obtained from the Hawaii Natural Energy Institute, which investigated 14 NMC-LCO 18650 batteries, each with a nominal capacity of 2.8 Ah. These batteries underwent cycling up to 1000 times at a constant temperature of 25°C, employing a Constant Current-Constant Voltage (CC-CV) charge protocol, with a charge rate of C/2 and a discharge rate of 1.5C. The dataset encompasses performance metrics for the 14 batteries throughout their cycles, comprising a total of 15,064 data points. Selected features for model training include critical operational parameters such as Discharge Time (s), Voltage Decrement (3.6-3.4V), Maximum Voltage during Discharge (V), Minimum Voltage during Charge (V), Time at 4.15V (s), Time at Constant Current (s), and Charging Time (s), all of which are indicative of the batteries' condition.

Prior to model training, input features were standardized using a Standard Scaler to normalize the data. This scaling is essential for algorithms such as linear regression and neural networks, which are sensitive to the magnitude of the features. The dataset was subsequently divided into training and testing subsets with an 80-20 split, where 80% of the data was allocated for model training and the remaining 20% was reserved for performance evaluation.

Notably, we identified a similar dataset that aligned with the data we were collecting through our project hardware. Given the challenges associated with gathering such a substantial volume of data independently, we opted to utilize this existing dataset for our model training and evaluation. Multiple machine learning models were trained and tested using this dataset, and the results are summarized as follows:

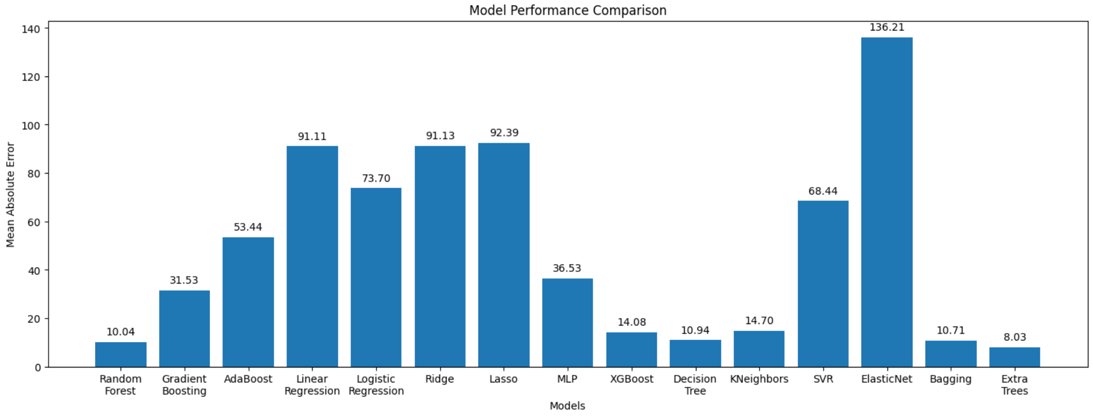


Figure 22: ML model training comparison

Based on the comparison of machine learning models used to predict the Remaining Useful Life (RUL) of a battery, the best performing model is the Extra Trees model, which achieved a Mean Absolute Error (MAE) of 8.16. This indicates that the Extra Trees model can estimate the RUL of a battery with an average error of around 8 cycles. In the context of battery management, this level of accuracy is quite impressive, as it implies that the predicted RUL will typically deviate from the actual RUL by no more than 8 charge-discharge cycles, which can be crucial for optimizing battery usage and preventing unexpected failures.

The input features used for this prediction include important battery performance metrics such as Discharge Time, Decrement in Voltage, Maximum and Minimum Voltage during Discharge and Charge, and various time-based characteristics related to voltage and current. These variables provide a comprehensive view of the battery's operating conditions, which allows the Extra Trees model to capture the complex patterns and dependencies between these features and the battery's RUL. This accuracy makes the Extra Trees model a reliable tool for estimating battery lifespan and improving the efficiency of battery health monitoring systems.

5.4 Conclusion

In conclusion, the development of our battery screening system has resulted in a comprehensive design that effectively meets our project requirements for battery charging and discharging. The hardware setup and process flow have been successfully implemented, demonstrating the system's capability to efficiently screen batteries by conducting charging and discharging operations.

The system has provided relevant data to the user interface while ensuring thorough data collection, establishing a solid proof of concept and validating the effectiveness of our approach. This project not only addresses our immediate needs but also lays the groundwork for future enhancements, particularly in leveraging machine learning models for faster battery screening. Overall, the completed design signifies a substantial advancement in our battery screening capabilities and sets the stage for potential innovations in the field.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

The demand for dependable and high-performing battery packs has increased due to the rapid growth of sectors like portable electronics, renewable energy storage, and electric vehicles (EVs). The 18650 lithium-ion battery is essential to various applications for its high energy density, robustness, and extensive use in battery pack manufacturing. A crucial step in ensuring battery packs' lifetime, safety, and effectiveness is checking individual 18650 cells prior to integration. By identifying faulty cells, this screening lowers the chance of failure and guarantees that only premium batteries are utilized in battery pack construction.

The effects of a screening system for 18650 batteries particularly the battery pack production is important. Impact analysis is essential for understanding how the screening method affects battery pack manufacturing, product quality, and overall dependability. We can estimate improvements in the identification of faulty cells, decrease in production inefficiencies, and increase the performance and safety of the finished battery packs by examining the results of the screening system.

The system's part in reducing hazards including thermal runaway, irregular voltage, and premature capacity degradation etc. are frequent problems with inadequately screened battery cells. It will also assess the operational and financial advantages, including a decrease in warranty claims, a reduction in recalls, and an improvement in the reputation of the companies who provide dependable and high-quality battery packs.

Project sustainability of installing a screening system for 18650 batteries in the production of battery packs is also of great importance. The capacity of the system to function effectively over an extended period of time while serving both economic and environmental objectives is referred to as project sustainability. Evaluating the screening system's effects on resource use, energy consumption, trash production, and total operating expenses is important as sustainable manufacturing methods gain global attention.

Through early detection of defective cells, the screening system helps to reduce material loss by preventing their inclusion in battery packs. It will also assess energy efficiency by taking into consideration the system's power needs in relation to its output. The study will also monitor the system's compliance with recycling and environmentally friendly production methods, as well as the decrease in hazardous waste from faulty batteries.

6.2 Assess the impact of Solution

Societal Impact

The impacts of the battery screening system are far reaching and it affects several sectors of our life. By ensuring the use of high quality, efficient and safe batteries the relevant systems assist in the improvement of the technological reliability, environmental sustainability and overall safety of the consumers. The key impacts of the battery screening system are described below,

1. **Technical Advancement:**

Battery screening systems play a crucial role in broadening the boundaries of modern technology ensuring the performance and quality of the batteries that power innumerable technologies. This has a profound impact on society as it allows new applications and refine the functionality of in-use technologies.

> **Improved Consumer Electronics**: In the case of consumer electronics the reliable batteries are very crucial for the trouble free operation of the devices like laptops, high performance flashlights and cameras. Battery screening makes sure that these

technologies work properly which will ensure a more advanced, long lasting and powerful tech user experience for the consumers.

Electric Vehicles: The 18650 battery model is widely used in electric vehicles like Tesla EVs and in electric bicycles. Battery screening systems make certain that the batteries used in these vehicles have rated capacity, optimal charging speed and required longevity for having great performances of these devices. As the screening system is supporting the enhancements of performance of EV batteries, it is indirectly spanning the shift towards the adaptation of EVs in the mass population. This shift has a great impact on society by ensuring the use of more clean and energy efficient vehicles.

Power Tools & industrial equipment:
18650 batteries are used in the industrial equipment and in the power tools. In these devices the performance and reliability of the device are important for optimal use. Screening systems make sure that the batteries are up to the required rating so that these devices can provide high performance in the demanded areas like construction, logistics and manufacturing.

2. **Economic Growth and job creation**:
Battery screening systems contribute in the field of economic growth, specially in the industries that heavily depend on the 18650 batteries e.g., consumer electronics and transport sector.

Boosting battery industry:
the increasing demand of the 18650 batteries in many sectors create the demand of more advanced manufacturing techniques and quality control devices. Battery screening systems make sure that the manufacturers provide reliable and high-performance batteries which make the industry better. This enhanced reliability of the industry creates more battery manufacturers, battery technology developing companies and testing facilities.

Job creation:
the demand for battery screening systems generates new job opportunities in the field of engineering, manufacturing, quality assurance and R&D. The more the demand of batteries increases, there will be growing demand for professionals who are adept at testing, screening and certifying batteries. This demand will contribute to job creation in the field.

Lower operational costs:
Properly screened 18650 batteries will provide long lifespans and better performance. So by using well scanned batteries the companies that depend on battery powered systems will be able to lower the maintenance and replacement cost. This will result in the cost saving in the business which will help generate batter revenue and more investments which will ultimately cause a boom in the economy.

3. **Consumer trust and confidence**:

The dependability of the 18650 batteries is very important for keeping up the consumers' trust especially in the field of personal devices, EVs and other crucial technologies. Battery screening systems helps to increase the product reliability that strengthens consumer confidence in various ways:

Reliable consumer electronics: 18650 batteries power the high-performance consumer electronics like laptops, cameras and wireless devices. Screening systems make sure that the batteries provide a consistent amount of power over time lowering the possibility of battery related failures. Consumers will trust brands that use well scanned, high-quality batteries, creating customer satisfaction and repeated purchase.

Electric vehicle adaptation: For the people who own EVs, the performance and durability of the batteries are very crucial for overall better user experiences. The 18650-battery screening system ensures that the batteries that are used are reliable and long lasting. This will resolve the concerns about battery degradation and enhance trust in the EVs. This will eventually increase the trust of the people on the EVs and encourage them to buy more EVs in the future.

Longer lifespans of products: well, scanned 18650 batteries used in the consumer electronics will last longer improving the longevity of the product they power. This implies that the customers get more value from their purchase.

4. **Access to energy and connectivity:**

Well-scanned 18650 batteries increase access to energy in both the urban and remote areas which support social & economic development via making energy and technology solutions more accessible.

Portable power solutions:

portable power banks commonly use 18650 batteries which are used to power laptops, smartphones and other devices. In the areas where the grid power is unreliable, these power banks provide alternative means to stay connected and productive. Screening system guarantees that these portable power providing devices deliver reliable power to properly access communication, education and digital services.

Energy storage solution

In the off grid and remote areas the 18650 batteries are used as means of energy storage for solar power systems and other renewable setups where the energy production is intermittent in nature [16]. Screening system ensures that the batteries are reliable, capable and durable for storing energy for a longer period of time. This will improve the access to electricity in the remote off-grid areas.

Emergency preparedness

In the time of disasters and other emergency situations 18650 batteries can be used in the portable lights, radios and other necessary devices. The reliability of these batteries are crucial in the emergency situation when power is not available. Screening system can ensure that these batteries are well functional when they are needed. This will enable the people to stay connected and updated in the critical time.

6.2.1 Environmental Impacts

The 18560-battery screening system plays a significant role in the betterment of the environment as the system's role is pivotal in ensuring the production and use of environment friendly, efficient and durable lithium-ion batteries. By ensuring the performance and quality of 18650 batteries, screening systems help lower the waste, resource consumptions and aiding the transition towards renewable energy.

1. **Reduction in battery waste and e-waste**:

   high quality batteries that are well screened last longer and perform well eliminating the need for frequent replacement of batteries. This helps in reducing the environmental impacts related to the disposal of used or defective batteries. Pulsed current charging and screening can extend battery lifespan by around 50-80% compared to traditional charging and screening methods specially in electric vehicles and grid storage systems [17].

   Extend battery lifespan

   high quality batteries that are well screened last longer and perform well eliminating the need for frequent replacement of batteries. This helps in reducing the environmental impacts related to the disposal of used or defective batteries.

   E-waste reduction

   Batteries are well known and seen components of e-waste Screening system ensures that the batteries used in the devices such as laptops, power tools and EVs have long lifespan eventually contributing to less amount of e-waste generation. As the materials used inside the 18650 batteries are hazardous materials, reducing e-waste means that it prevents contamination of the environment. In 2018, approximately 97,000 tonnes of lithium-ion batteries (LIBs) were recycled globally using screening systems [18].

2. **Resource conservation**

The production process of the 18650 batteries requires raw materials like lithium, nickel, cobalt and graphite. These resources are not abundant in nature and often they are gained by environmentally damaging mining. Screening systems assist in the mitigation of environmental impact by making sure that only the efficient and high-quality batteries are produced allowing the conservation of resources.

Efficient use of materials

Efficient use of raw materials are ensured by the screening system by verifying that only the well manufactured batteries reach the market. Batteries that fail in the early lifespan waste the energy and resources used in the production, transportation and disposal of them. Screening systems lower the demand for replacement batteries and conserve valuable resources.

Reducing mining demand

When batteries last for longer periods and perform reliably then the need for raw materials e.g. lithium & cobalt used for production of 18650 are reduced. This results in less mining activity which often causes deforestation, water pollution and ecosystem degradation.

3. **Reduction of greenhouse gas**:
   Long lasting and high quality 18650 batteries help in the reduction of greenhouse gas emission in multiple ways. Battery screening systems make sure that the 18650 batteries used in the EVs and renewable energy storage systems perform properly. Both the technologies are helping in reducing carbon emission significantly.

Electric Vehicles

18650 batteries are used in EVs e.g. in the Tesla cars. Screening of batteries ensures that the most efficient and long lasting ones are used in the EVs thus the performance of Evs improves which results in longer ranges and better efficiency. The increased number of EVs powered by the properly scanned batteries reduces the number of internal combustion engine vehicles on the road. According to the European Environment Agency (EEA), the lifecycle of EVs leveraging effective battery screening can lower GHG emissions by 17–30% compared to ICE vehicles, with reductions estimated to reach up to 73% by 2050 as the energy grid becomes greener [19].

Energy storage for clean power:

battery screening guarantees that batteries used in the energy storage systems are able to store renewable energy efficiently. Improving the reliability of the energy storage scanning system ensures that renewable energy replaces the fossil fuel-based energy production system which plays a pivotal role in cutting greenhouse gas emission.

4. **Improved recycling efficiency**

Battery screening system also plays a pivotal role in the recycling of 18650 batteries. Batteries that have higher quality and longer life cycles are easier to recycle. Because there is a good probability that they contain hazardous materials.

Facilitating Circular economy

screening system ensures that only the relatively more efficient and durable batteries are in the circulation. This makes the recycling process easier when the batteries reach the end of their life. This helps in the development of a circular economy where materials are reused and recycled more efficiently which reduces the demand for virgin materials and reduces the environmental impact of resource extraction. Studies suggest that screening can lead to increased battery life by 20% to 30% depending on the quality of the screening process [20]. this will facilitate the circular economy for sure.

Higher recovery rates
screening system ensures the higher recovery rates of the valuable materials from lithium-ion batteries. Batteries that have been screened properly after manufacturing are likely to be in good condition at the time of recycling. This makes it easier to extract elements like lithium, nickel and cobalt for reuse purposes. This helps the environment contamination from mining and e waste.

6.2.2 Impact on health and safety

18650 batteries used in medical devices such as portable oxygen concentrators, defibrillators and insulin pumps. In such applications the safety and dependability of the batteries are critical for the health and well being of the patients.

Ensuring medical device safety
screening system makes sure that the batteries used in the medical devices are of highest reliability and quality. In healthcare the battery failure can have life threatening consequences such as defibrillators not working during an emergency. Screening of batteries can lower the risk of such failures to a significant amount protecting the patient’s life.

Reliable operation of life saving equipment
Medical devices must operate reliably and continuously. The devices that use 18650 batteries must be well screened so that there is no unexpected power failure and performance degradation making sure that the crucial medical equipment functions properly when needed.

Prevention of battery failure and accidents
One of the most significant health and safety benefits of the battery screening system is that it prevents battery failures e.g. overheating, thermal runaway, explosions and fires. These failures can pose serious risks for the users of consumer electronics and EVs.

Reduced risk of explosion and fire
Lithium-ion batteries can easily explode or catch fire if they are not manufactured or operated correctly. Screening systems aid in identifying the batteries with defects such as poor-quality materials and internal short circuits that can lead to dangerous failures. By preventing defective batteries from reaching the consumer's screening system lower the possibility of battery related accidents.

Thermal runaway mitigation
Thermal runaway happens when a battery overheats uncontrollably often resulting in fire and explosion. Screening systems test batteries for their thermal stability and make sure that they

can function safely under various conditions such as high temperature or heavy use. This lowers the risk of thermal runaway.

6.2.3 Legal and cultural Consequence

1. **Obedience to Regulations**

Manufacturers of batteries are subject to a number of national and international laws, particularly in sectors like energy storage, electric vehicles (EVs), and consumer electronics. By ensuring that 18650 batteries adhere to these regulations, screening methods assist businesses lower their legal risks while safeguarding customers.

Abiding with Safety Standards

In many areas, batteries production has to follow safety standards established by regulatory organizations e.g. the European Union's CE mark, Underwriters Laboratories (UL), and the International Electrotechnical Commission (IEC). Screening systems verify that 18650 batteries meet these requirements, guaranteeing their safety for use in gadgets and automobiles. For not facing consequences like legal suing, product recalls, and prohibitions from entering markets may motivate the producers to follow standards.

Customs and Import Laws

Due to the possible safety risks that lithium-ion batteries present, many countries have strict laws for 18650 battery importation. By ensuring that only tested, high-quality batteries are exported abroad, screening lowers the possibility of failing customs checking. Batteries that don't adhere to import safety regulations may be seized, costing manufacturers money and harming their brand.

2. **Product reliability and protection**:

Laws Protecting Consumers

Laws protecting consumers make sure that producers guarantee the dependability and safety of their goods. Companies can avoid legal liability for product defects or hazardous failures by screening 18650 batteries. Under consumer protection laws, manufacturers may be sued or fined when unscreened, defective batteries cause harm. By ensuring that only reliable and safe batteries are used in products, screening systems can protect manufacturers from claims of product liability. If dangerous or defective batteries injure people or damage property, there may be serious legal consequences.

Reduced Lawsuit Risk

Product liability lawsuits may arise from battery failures that cause harm or death, such as explosions or fires. screening of 18650 batteries reduces the possibility of failures of 18650 batteries, thus protecting businesses from expensive legal disputes. Manufacturers can protect themselves from liability claims by proving that they strictly follow testing protocols.

6.3 Evaluate the sustainability

The **SWOT analysis** provided for the 18650 battery screening system project highlights key aspects of its sustainability, allowing us to analyze its long-term viability and potential challenges:

Strengths

1. Increased Battery Life: Screening systems aid in ensuring that only high-quality batteries are marketed, which provide longer-lasting products. This increases sustainability by reducing the frequency of replacements and lowering electronic waste.

2. Cost-Effectiveness: The efficiency gotten from identifying faulty or substandard batteries early in the process reduces costs related to returns, product recalls, and legal disputes. Cost-effectiveness can also promote more sustainable production practices.

3. Market Demand: There is a significant demand for high-quality lithium-ion batteries particularly in sectors like electric vehicles, renewable energy, and consumer electronics. A sustainable battery screening process can make sure continuous supply of reliable batteries, meeting market needs while promoting resource efficiency.

Weaknesses

High Initial Cost: The complexity and expense in implementing an effective battery screening system may hinder initial adoption. While this creates a barrier to sustainability in the short term, companies that invest in high-quality screening systems may see long-term savings in the form of reduced waste and enhanced product lifespan.

1. **Complex Manufacturing Process**: Adopting a screening system adds complexity to the manufacturing process. However, if properly managed this complexity can lead to long-term sustainability by making sure that fewer defective batteries reach the market reducing the overall environmental impact.

Opportunities

1. **Sustainability**
   There is an increasing emphasis on sustainable energy solutions. As lithium-ion batteries are crucial to clean energy technologies (like EVs and renewable energy storage), a well screening system contributes to the sustainable management of

resources by providing fewer defective batteries which lead to less waste and reduced environmental impact.

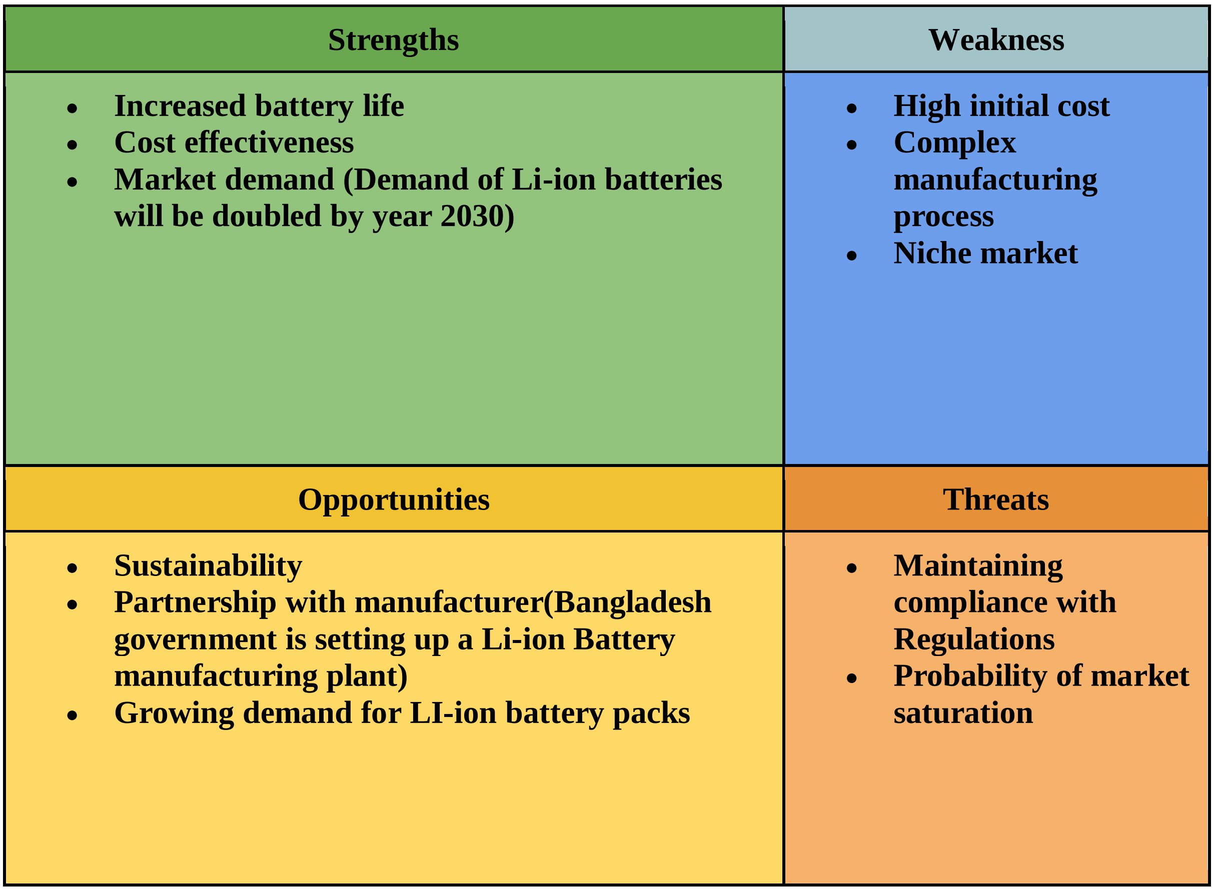
2. **Partnership with Manufacturers**
   Partnering with manufacturers to adopt the screening system into their production processes offers opportunities to the system scaling. These partnerships can help create industry-wide standards for sustainability and quality.

3. **Growing Demand for Li-ion Battery Packs**: With growing demand for energy storage in both consumer electronics and EVs implementing screening systems ensures reliable performance and helps to meet sustainability targets by increasing battery lifespan and efficiency.

Threats

1. **Maintaining Compliance with Regulations**: Regulatory standards related to battery safety and environmental impact are always evolving. If the screening system fails to follow these regulations it could be unsustainable due to not following frequent updates.

2. **Probability of Market Saturation**: As there are competing technologies or alternatives to lithium-ion batteries coming to market then there could be a reduction in the growth of the 18650-battery market. This could limit the long-term sustainability of the screening system if it becomes obsolete in a changing market



Strengths	Weakness
• Increased battery life • Cost effectiveness • Market demand (Demand of Li-ion batteries will be doubled by year 2030)	• High initial cost • Complex manufacturing process • Niche market
Opportunities	**Threats**
• Sustainability • Partnership with manufacturer(Bangladesh government is setting up a Li-ion Battery manufacturing plant) • Growing demand for LI-ion battery packs	• Maintaining compliance with Regulations • Probability of market saturation

Figure 23: SWOT Analysis

6.4 Conclusion

Based on the **SWOT analysis**, the sustainability of the 18650-battery screening system project is promising especially because of strengths like increased battery life, cost-effectiveness, and rising market demand. These factors support sustainability by reducing waste, enhancing product reliability, and improving resource efficiency. However, the project must solve weaknesses such as the high initial cost and complex manufacturing processes. Making use of opportunities like the growing demand for batteries and focusing on partnerships will further increase the system's sustainability. Threats like regulatory challenges and market saturation need to be mitigated by ensuring the system remains compliant and adaptable to changing market conditions. Overall, the project has strong potential for contributing to sustainable battery production and long-term industry viability.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

Engineering project management is one of the key and fundamental aspects of an engineering project. It is the strategic plan for the whole project's completion, from start to finish. Without an effective strategic plan, a project cannot be completed successfully. For ensuring a successful project, proper coordination between these plans and implementation is the key. We also follow a proper strategy for the completion of our project successfully in the designated time. We planned all of our strategies through Gantt charts, logbooks and work flowcharts. In this chapter, we will elaborate our whole project management plan.

7.2 Define, plan and manage engineering project

The project timeline is divided into 3 parts: EEE499P, EEE499D and EEE499C. We have been working according to those timelines. To track the progress of these 3 timelines we are taking the help of Gantt charst. These Gantt charts help us to keep track of the milestones of this project each week from EEE499P to EEE499C. We also used tables to keep track of every member's responsibility throughout this whole project. Those Gannt charts and responsibilities table are shown below:

7.2.1 Plan for EEE499P

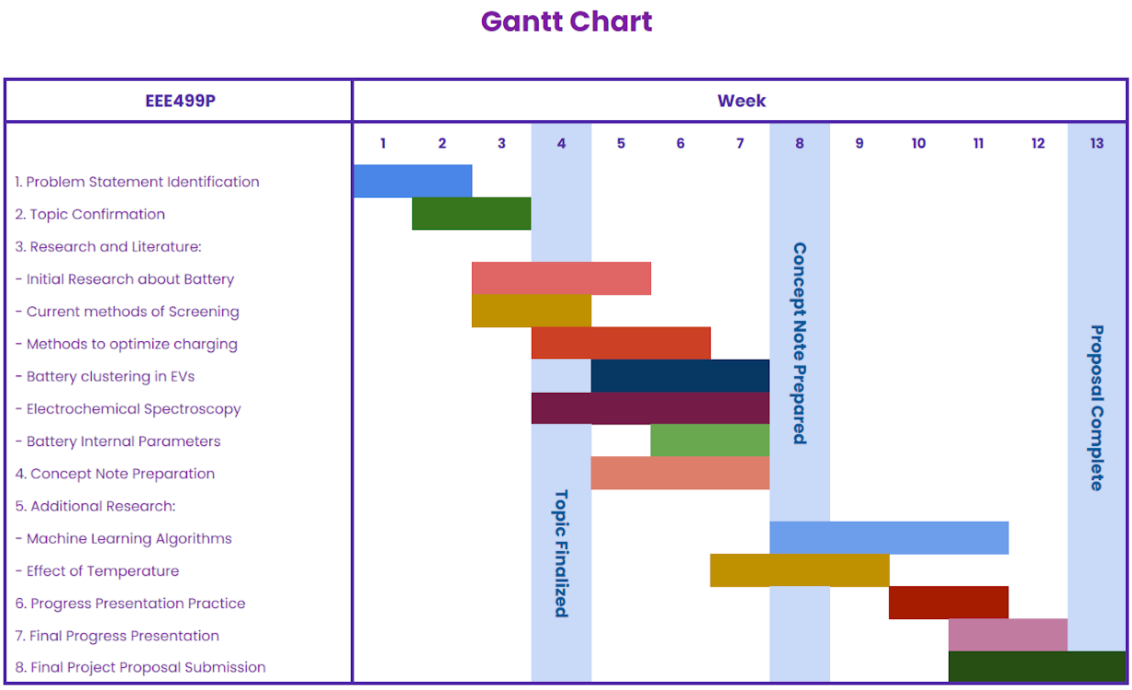


Figure 24: Gantt Chart for EEE499P

Now, the table for group members' responsibilities for EEE499P are:

Responsibilities	**Juhayaer**	**Abdullah**	**Irtiza**	**Enamul**
Identifying the problem statement	✓	✓	✓	✓
Topic Confirmation	✓			✓
Maintaining Logbook		✓		
Arranging Meetings with ATC Panel	✓	✓		
Arranging Meetings with Group Members	✓	✓	✓	✓
Concept Note	✓	✓	✓	✓
Additional Research			✓	✓
Simulation of Design using Battery Design Studio		✓		
Simulation of Design using MATLAB/Simulink	✓			
Simulation of Design using Open Battery Simulation (OBS)			✓	
Simulation Data Analysis				✓
Gathering Additional Data	✓			
Outcome Matching with Simulation	✓	✓	✓	✓
Simulation Validation	✓	✓	✓	✓
Prototype Testing	✓	✓	✓	✓

7.2.2 Plan for EEE499D

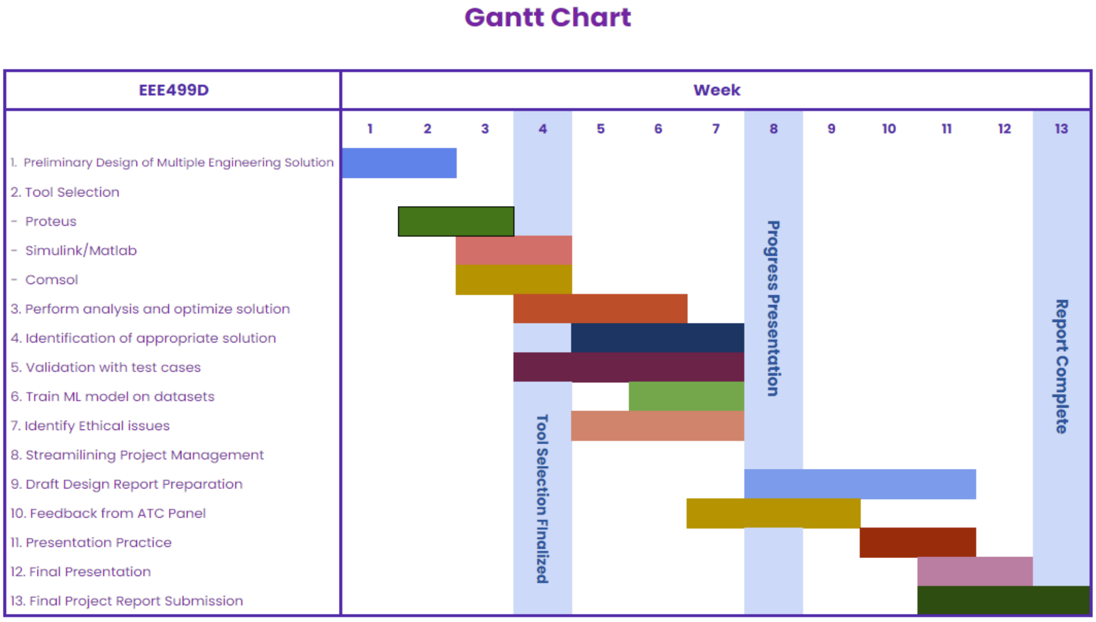


Figure 25: Gantt Chart for EEE499D

Now, the table for group members' responsibilities for EEE499D are:

Responsibilities	Juhayaer	Abdullah	Irtiza	Enamul
Identifying the problem statement	✓	✓	✓	✓
Topic Confirmation	✓			✓
Maintaining Logbook		✓		
Arranging Meetings with ATC Panel	✓	✓		
Arranging Meetings with Group Members	✓	✓	✓	✓
Concept Note	✓	✓	✓	✓
Additional Research			✓	✓
Simulation of Design using Proteus		✓		

Simulation of Design using MATLAB/Simulink	✓			
Simulation of Design using Comsol			✓	
Simulation Data Analysis				✓
Gathering Additional Data	✓			
Outcome Matching with Simulation	✓	✓	✓	✓
Simulation Validation	✓	✓	✓	✓
Prototype Testing	✓	✓	✓	✓

7.2.3 Plan for EEE499C

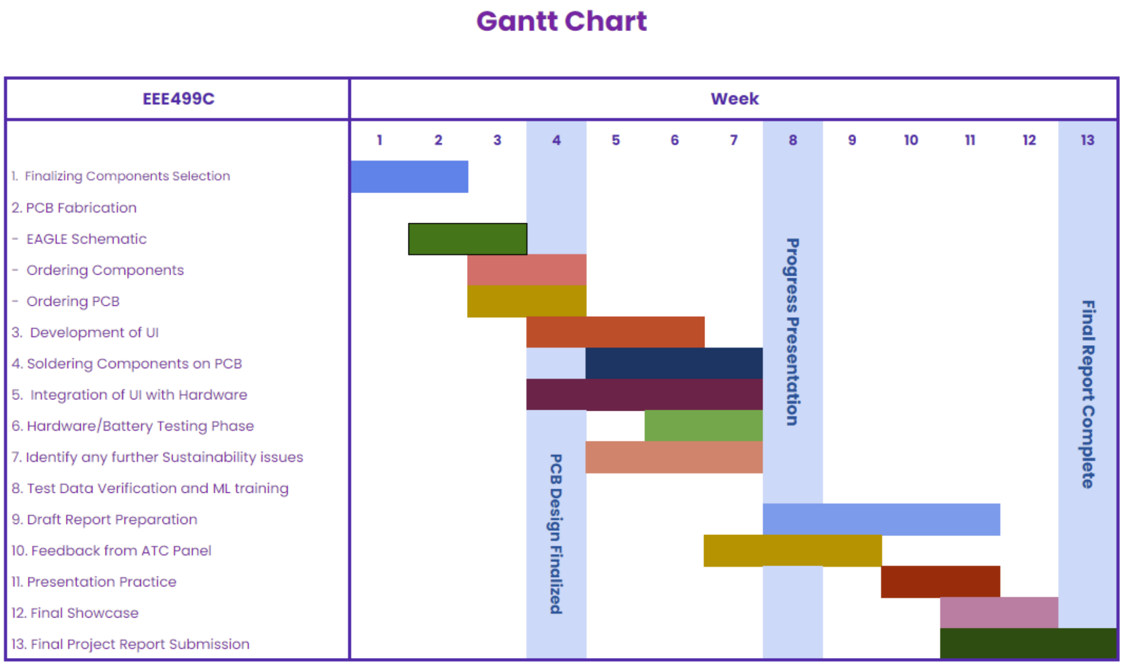


Figure 26: Gantt Chart for EEE499P

Now, the table for group members' responsibilities for EEE499C are:

Responsibilities	**Juhayaer**	**Abdullah**	**Irtiza**	**Enamul**
Finalize Component Selection	✓	✓	✓	✓
Components Verification	✓	✓	✓	✓
Development of UI	✓		✓	
Hardware Implementation	✓	✓	✓	✓
Data Analysis	✓	✓	✓	✓
Draft Report Demonstration	✓	✓	✓	✓
Initial Completion of the project	✓	✓	✓	✓
Verify hardware data with simulation	✓	✓	✓	✓
Designing Structure for the project	✓	✓	✓	✓
Synchronizing structure design with hardware setup	✓	✓	✓	✓
Final Testing	✓	✓	✓	✓

So, these are the project plans for this engineering project.

7.3 Evaluate project progress

We have evaluated EEE499P, EEE499D, and EEE499C through workflow diagrams. Those diagrams work as the methodology of our whole project in each stage.

7.3.1 Stage-1(EEE499P) Evaluation:

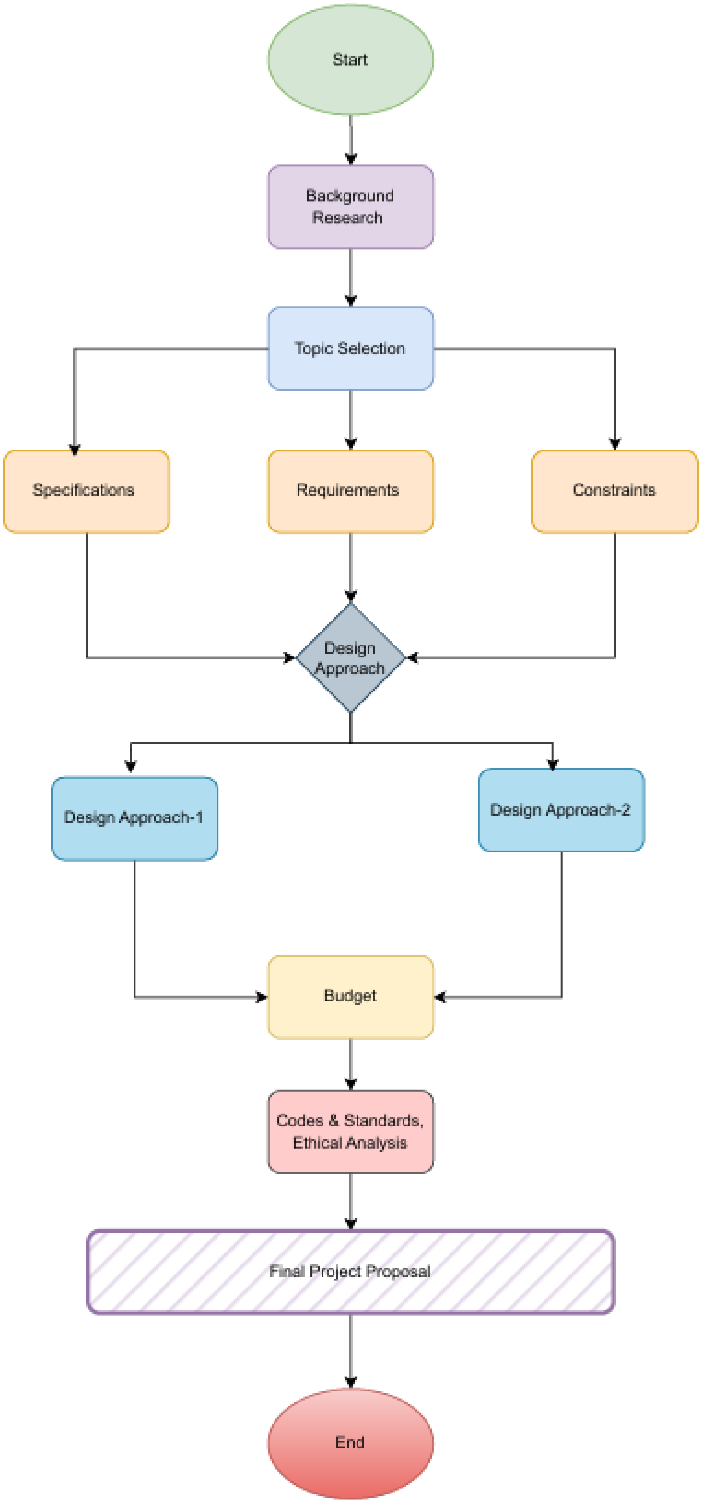


Figure 27: Roadmap EEE499P

We started our whole project before doing background research. We had gone through all sorts of industrial ideas. Among all of the industrial ideas, we have selected identical battery identification and battery clustering systems. The reason we chose this field is to work with because li-ion battery pack is one of the most used components in impactful industries. So unbalanced cells within battery packs can decrease the performance of the battery pack in the long run. So, it will be impactful if we solve this problem by analyzing the battery characteristics.

After selecting the topic, we are gone through the specifications, requirements and constraints of this project. Considering all the points we have come up with two design approaches. After that we analyze those design approaches budget. The budget was analyzed based on the availability of those components. Lastly, we go through codes, standards, and ethical aspects that are heavily connected with our project. Thus, we finalize our complex engineering problem.

7.3.2 Stage-2(EEE499D) Evaluation:

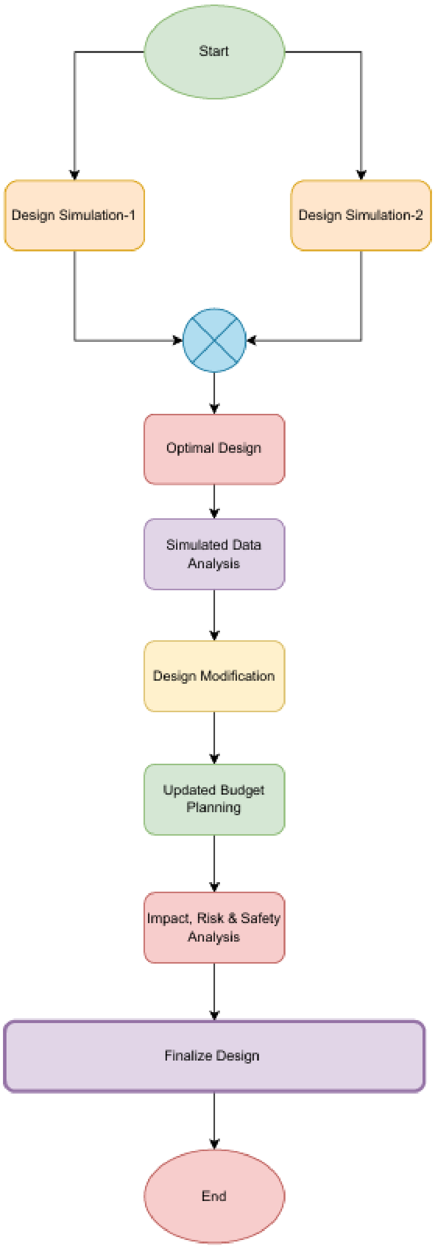


Figure 28: Roadmap of EEE499D

In stage 2 we simulated both of our design approaches by using software and IT tools. From both of the designs, we determined our optimal design for the project. According to that, we have analyzed the data from the optimized design. To make the design more optimized we modified our design by using software tools. Since we have modified our design that means the budget of the modified design will be increased. We had calculated the budget with current market costing. Lastly, we had research or modified design impact, risk, and safety factors. Finally, we have come conclusion with our final design that we will later implement on stage 3. In this way, stage 2 of our project is ended.

7.3.2 Stage-3 (EEE499C) Evaluation:

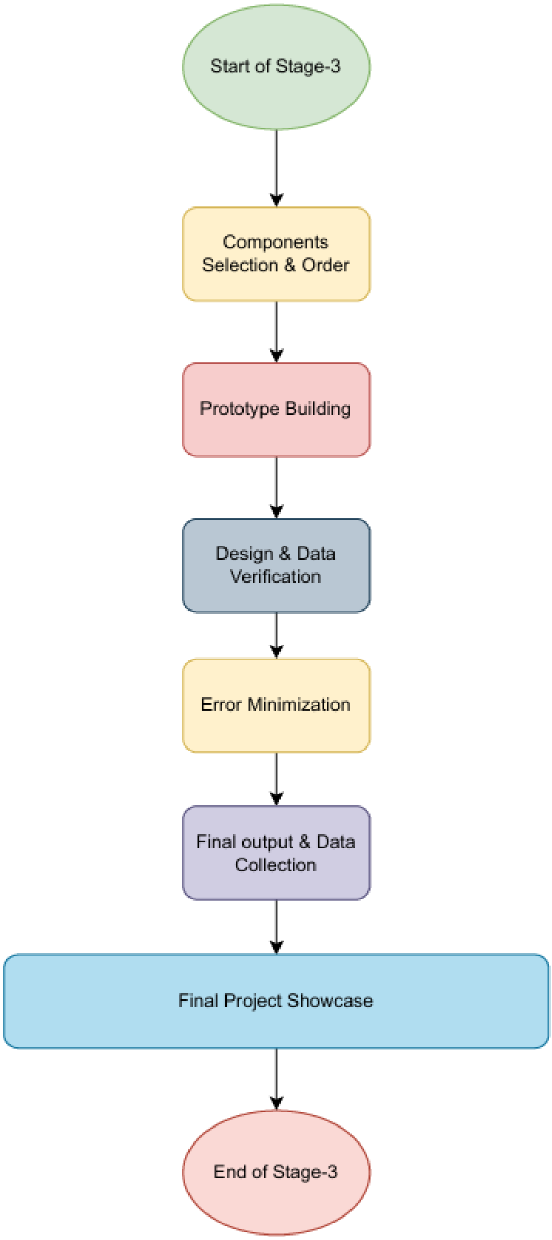


Figure 29: Roadmap for EEE499C

We selected and ordered our components immediately after the start of stage 3. We build a prototype of our project after that. Then we verify our design. After getting some errors, we tried to minimize them. We collected data for the report after minimizing those errors accurately. Lastly, we will demonstrate the prototype of our project in front of the respected board members. In this way, our whole project work will be concluded

7.4 Conclusion

Project Management is the important dimension of completing a project effectively and successfully. There are many ways for project managing but we selected Gantt chart, table and flowchart for our project management tools. We divided our whole project timeline into three stages. Each of the stage has been maintained sequentially. Thus, an effective, budget friendly and optimized project has been successfully implemented within given time period.

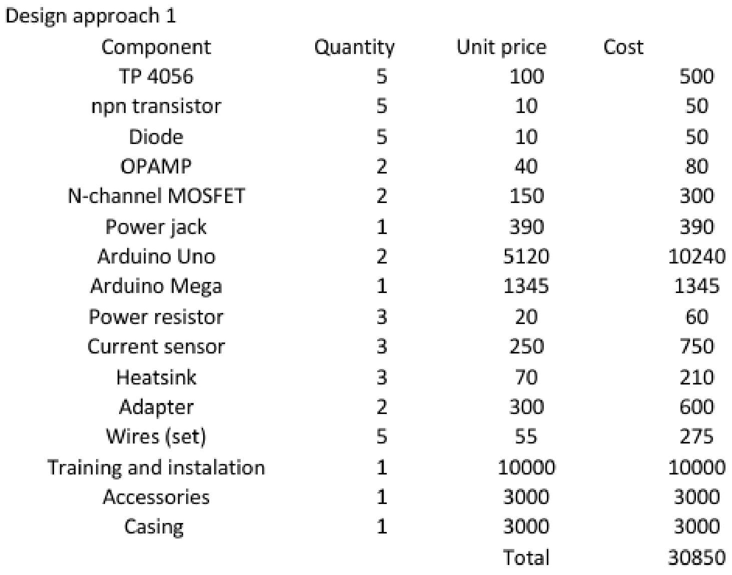
Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

Economic analysis is the process of assessing the cost and benefits of the process. It tells how viable this project is economically. In this chapter we will see the costs of different phases in this project and return on investment. We also found out which design approach is better in terms of economic analysis.

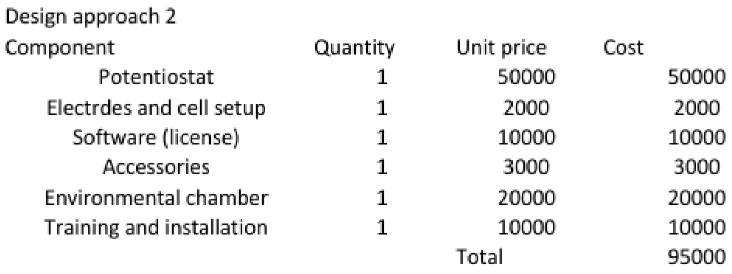
8.2 Economic analysis

Estimated budget:



Design approach 1

Component	Quantity	Unit price	Cost
TP 4056	5	100	500
npn transistor	5	10	50
Diode	5	10	50
OPAMP	2	40	80
N-channel MOSFET	2	150	300
Power jack	1	390	390
Arduino Uno	2	5120	10240
Arduino Mega	1	1345	1345
Power resistor	3	20	60
Current sensor	3	250	750
Heatsink	3	70	210
Adapter	2	300	600
Wires (set)	5	55	275
Training and instalation	1	10000	10000
Accessories	1	3000	3000
Casing	1	3000	3000
		Total	30850



Design approach 2

Component	Quantity	Unit price	Cost
Potentiostat	1	50000	50000
Electrdes and cell setup	1	2000	2000
Software (license)	1	10000	10000
Accessories	1	3000	3000
Environmental chamber	1	20000	20000
Training and installation	1	10000	10000
		Total	95000

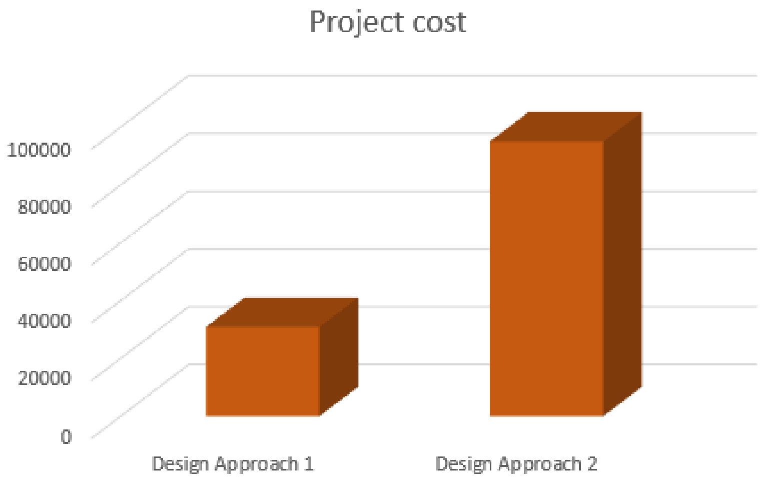


Figure 30: Budget Comparative analysis

After comparing the budget of both design approaches, we get to know design approach 1 is more cost effective than design approach 2.

Cost analysis

The following list given below breaks down the different phases of this project for our optimum design approach. This includes costs from different areas such as research and development, hardware components, software development, labor costs, ongoing maintenance, updates, customer support, marketing, sales expenses, and Value Added Tax (VAT). **[All the costs are calculated in Taka]**

1. Research and development:

- Market Research - 30000
- Concept development - 20000
- prototyping - 30000
- Testing - 25000

Total - 105000

2. **Hardware components cost-** 20850 (per device)
Assuming 100 devices to be made and sold
Total hardware cost - 2085000

3. Software components

- Server storage - 10000 (per month)

Per year cost = 120000

4. **Software development**
    - Development of AI tools, algorithms, UI - 40000

5. **Labor cost (cost period: 6 months)**
    - Engineers - 100000
    - Software developer - 50000
    - Project manager - 90000

    Total - 240000
6. **Maintenance cost (per year)**
    - system updates - 20000
    - Bug fixes - 10000
    - hardware repair - 35000

    Total - 65000
7. **Upgradation cost (per year)**
    - New feature, algorithm - 25000
8. **Marketing and sales cost:**
    - Advertising - 20000
    - Trade shows - 15000

    Total - 35000
9. **Miscellaneous expenses**
    - Unexpected machine repair - 5000
    - Employee shortage (outsourcing)-10000
    - Replacement of parts - 5000

    Total - 20000

10. **VAT (5% of overall cost) -** 33542

Therefore, Total estimated cost (Including 1st year operation) - 704392

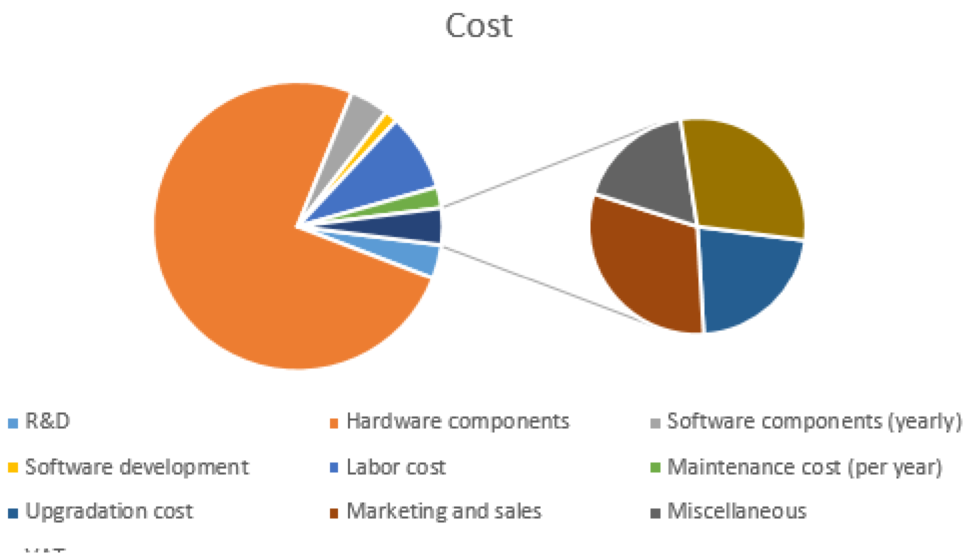


Figure 31: Initial cost sector wise breakdown

Revenue

The following list given below is different sectors of revenue from our proposed project. This includes revenue from product sells and outside sells.

1. **Product sell**

   Assuming 100 units sold at 34650/unit in 1st year.
   Sell revenue - 3465000

2. **Maintenance service**

   Providing maintenance service to 20% buyers (per servicing cost - 3000) - 60000

3. **Licensing software**

   Licensing AI driven algorithms and new updates (estimated 20 license per year, per license fee- 500) - 10000

Total revenue: 3535000

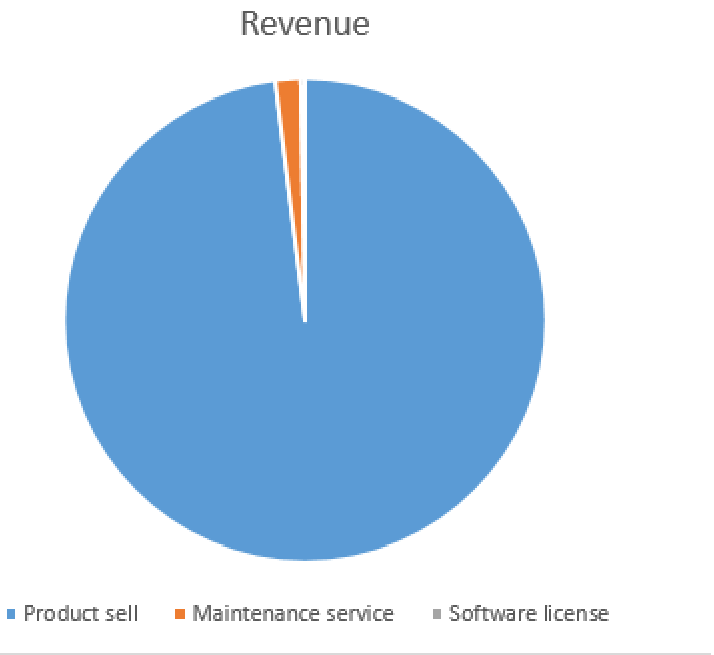


Figure 32: Revenue sectors breakdown

8.3 Cost benefit analysis

Initial setup cost of our project - 2768542
Operating expenses per year - 100000
Overall cost - **2868542**

Revenue from year 1 - **3535000**

Net profit = 3535000 (Total benefits) - 2868542(Overall cost) = 666458

Return on Investment
(ROI): ROI = [Profit earned / Cost of the investment] *100%

ROI = [666458 / 2868542] *100% = 23.2%

Break Even point

Assuming 100 products have been made, the tentative break even point of our project is shown in the graph below:

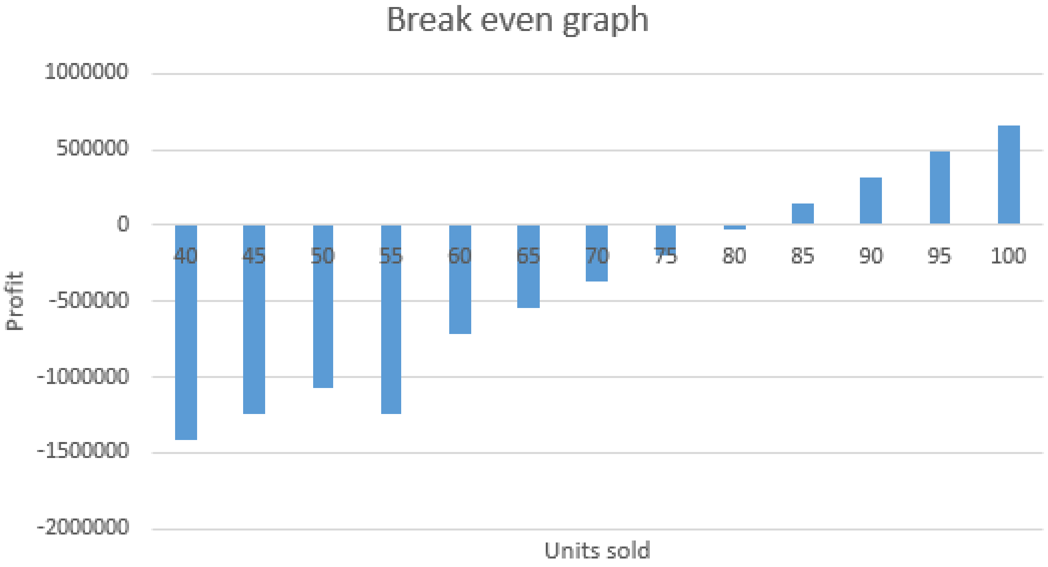


Figure: Units sold vs profit graph

Global li-ion battery market size projected CAGR is 14.20% from 2023 to 2032[21]. So, our estimated product sale growth rate is around 7%. With increased sales, our maintenance revenue should also grow by 6% and software licensing revenue growth rate is projected at 20%. Based on that, our tentative revenue growth is expected to be like below.

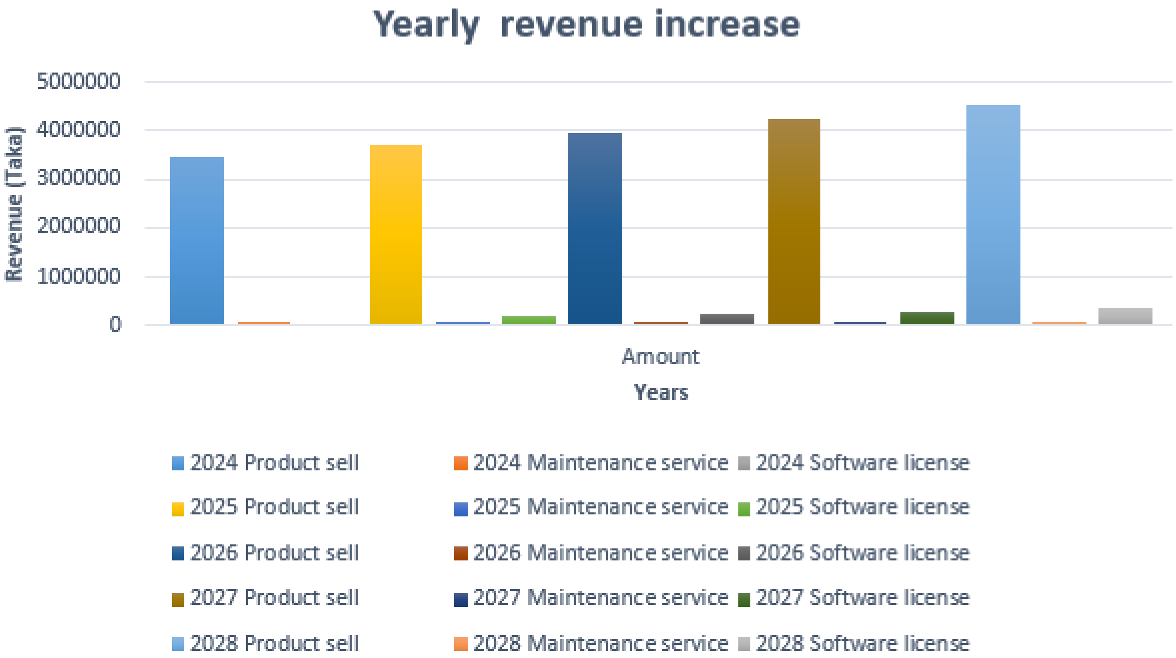


Figure 33: Year by year revenue growth

8.4 Evaluate economic and financial aspects

Economic aspects

- **Cost savings:** Unbalanced Li-ion batteries can cause problems in the device as well as the battery pack. With our system, users can screen and cluster the similar batteries, making the battery pack more stable. This increases device efficiency and reliability. Thus reduces the maintenance cost of the device. Below graph shows the reduction of battery pack maintenance cost in an EV over 5-year timeline:

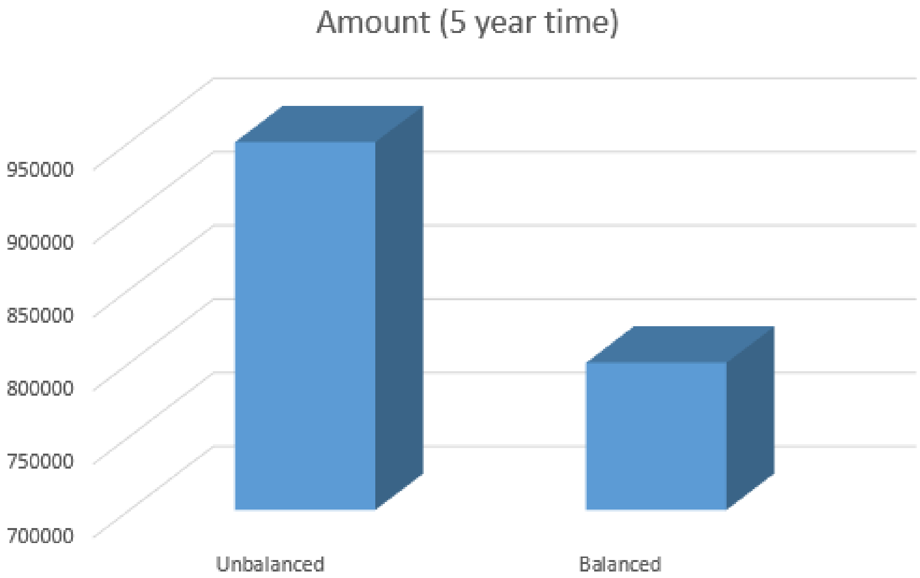


Figure 34: Maintenance cost of balanced and unbalanced battery packs in an EV

- **Job creation:** This project can provide job opportunities for local people in the form of engineers, technicians and managers. This will contribute to reduce unemployment in our country.

Financial aspects

- **Initial investment and operational expenses:** Bangladesh's relatively lower labor cost and large market gives a significant advantage to set up this kind of business. Also, software development cost can be controlled in a minimal rate.
- **Government initiative:** As an emerging country, the Bangladesh government is planning to set up a li-ion battery manufacturing company in Bangladesh [22]. Thus, our project can grab the opportunity and work hand in hand with the government to make durable Li-ion battery packs.

8.5 Conclusion

In this chapter, we analyzed various economic analyses of the project and thus came to the conclusion that our project has the potential to become a value driven innovative company which is economically viable and sustainable. It can be financially viable for a company as well as beneficial for the buyer as well.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

Ethical considerations and professional responsibilities are important dimensions of an engineering project. This aspect not only makes the project technically developed but also adheres to the industry standards and societal values. So, considering those ethics and Professional Responsibilities for our project, we completed our project accordingly. This chapter will highlight those ethical and professional responsibilities that are assumed by the team.

9.2 Idntify ethical issues and professional responsibility

The following ethical issues and professional responsibilities have been identified by the team. The issues applied to our project are discussed below:

- Clear Communication.
- Transparency.
- User-Friendly system and impactful.
- Laws and regulation.
- Feedback Mechanism.

9.3 Apply ethical issues and professional responsibility

1. **Clear Communication:**

   Clear communication is essential in any technological development project. Since we are working with a battery system there could be inherent some risk factors. Those risk factors could be overheating, chemical leakage and electrical hazards. All stakeholders, researchers, and engineers must be fully aware of these potential risks. A comprehensive communication plan should be established to ensure that safety protocols are disseminated effectively. Furthermore, educational materials should be provided to everyone. Those materials can be safety guidelines, training sessions, or workshops. These materials will them to make everyone understand the potential risks of the system. It also helps them to know how to prevent those risks.

2. **Transparency:**

   Transparency is critical for fostering trust among stakeholders. There will be a huge amount of important data generated in this project. The system must ensure that all battery characteristics data is accurately presented and easy to verify. The user interface provides users with clear access to data logs. Transparency also involves documenting the methodologies used for data collection for this project. It will allow researchers to trace the system's outcome. Additionally, any limitations or uncertainties in the data or algorithms should be openly communicated. This enables researchers and stakeholders to understand the full system functionality and limitations properly. So if in the system there is a flaw in any section, the engineers can resolve it with ease. This will make a transparent understanding of this project.

3. **User-friendly system and impactful:**

   This project needs to be designed with the end user in mind. To do so, A user-friendly interface is required. This enables all types of researchers and stakeholders to interact with the system intuitively, without the need for extensive technical knowledge. This includes easy-to-read graphs and charts for analyzing battery performance. Also, it could include simple navigation which allows users to interact with this whole system very effectively. Also, the UI will have a clear alert ability for any critical battery conditions. This critical battery condition includes overheating or overcharging. The system should also provide clear insights based on the data collection. For example, it should highlight potential issues in the charging and discharging curves in the temperature trends. To create an impactful user-friendly design, we need to ensure that users get a clear view of battery health and performance. This feature will ultimately be contributing to better research outcomes and safer applications.

4. Laws and regulations:

As our system deals with data collection and analysis, it is important to maintain laws and regulation . Since we aim to design our system into industry quality, it means maintaining all the proper relevant laws and regulation is essential.As our system has involvement with data collection that means General Data Protection Regulation (GDPR) laws are applicable. All types of data collection, storage and personal data are the main concerns of the General Data Protection Regulation (GDPR).Furthermore, compliance with environmental regulations needs to be addressed. Because batteries contain hazardous materials. This hazardous material must be handled and disposed of properly. The system must also comply with health and safety standards. It ensures that users are protected from potential hazards like electric shocks, battery leakage or overheating. The team must stay up-to-date with evolving regulations in these areas to ensure ongoing compliance.

5. **feedback Mechanism:**

Implementing a robust feedback mechanism is vital for the continuous improvement of the IBICS system. This mechanism should allow all types of users to get feedback easily and anonymously. The feedback mechanism can help identify any types of issues related to the system. Improvement suggestions or raised concerns can evolve the system's functionality and safety. The system should also have a version that can control or update the log. This way users can see what changes have been made based on feedback. This will further promote transparency. Being open to feedback not only helps in improving the system but also builds trust with users. In this way, they feel their concerns are valued and addressed.

9.4 Conclusion

In summary, the success of the IBICS project hinges upon ethical considerations and professional responsibility. With proper communication every one of the involved parties is certain to know about potential risks and safety measures that have been put for such hazards. Confidence, trust is built by transparency that only comes with accurate and verifiable data. When a system is relevant and easy to use, roles of researchers or stakeholders are strongly supported when using battery performance parameters to make informed decisions. Run by complying the relevant rules & regulations from legal issues of any project. Encouraging you to be eco-friendly and ensuring that the users are safe. Finally, strong feedback mechanisms pave way for continuous improvement fostering a culture of transparency and adaptability. By following these moral and professional standards, the IBICS system may provide viable secure battery identification and clustering solutions. It is a win-win for not only the scientific community but also to the mainstream

Chapter 10: Conclusion and Future Work.

10.1 Project summary/Conclusion

This project acts as a leap towards making a better and balanced battery pack. By integrating machine learning algorithms in the project, we strive to identify and cluster Li-ion battery packs in such a way that will be mostly fault proof. We have reviewed several design approaches to find the optimal solution that will help us to reach our objectives and requirements. Moreover, we have analyzed the economic feasibility of the project to ensure sustainability as well as making it affordable for the consumers. Extensive research and effort have been put into the project to make it more durable and reliable.

10.2 Future work

Though our project acts as a robust and durable project, there are several things that can improve the project's features. There is potential to further improve the data collection and battery balancing techniques. Some potential future improvements are given below:

1. **Duration of the screening:** After the screening process is completed and the battery pack is made, they will be used. After the usage of these battery packs, they can become unbalanced again. So further testing has to be done to analyze after how much time should the batteries be screened again.
2. **Fast charging:** Though there is some limitation in charging the batteries as charging them too fast can potentially weaken them. But with technological advancement we may charge them faster without damaging them. This will significantly reduce the time to screen the batteries.
3. **Temperature effect on the batteries:** Though our screening process includes temperature to some extent, effects of temperature during the screening is still to be explored.

Chapter 11: Identification of Complex Engineering Problems and Activities

11.1: Identify the attribute of complex engineering problem (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	√
P3	Depth of analysis required	√
P4	Familiarity of issues	
P5	Extent of applicable codes	√
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	√

11.2: Provide reasoning how the project address selected attribute (EP)

P1. Depth of knowledge required:

For this design project, we need a deep understanding of engineering fundamentals and specialized knowledge in certain fields. That is why planning the project a good amount of research literature was studied to gather relevant information. The literature we go through those are specially related with batteries internal electrical parameters. We also go through different sensors and different data sheets to get an idea of their functionality very precisely. Programming knowledge is also required to design the user interface of this project and control the microcontroller.

P2. Range of conflicting requirements:

There are some constraints in our project. We have to keep the device temperature low, but at the same time charging increases the temperature. To control these constraints, we have to add some additional parts in our project in order to get proper output. This will make this project stable.

P3. Depth of analysis required:

Data collected from field surveys and research literature were analyzed and 2 alternate design approaches were proposed and compared. After a comprehensive deep analysis, the best-optimized design has been selected. This optimized design also needs to satisfy the specifications, requirements, and constraints of the IBICS project.

P5. Extent of applicable codes:

Several codes apply to the project. Since we are working with electrical projects the means some international standards and codes need to be followed. We have studied these codes and standards which are relevant to our IBICS project. Some of them are subject to change on a regular basis.

P7. Interdependence:

For proper functioning of the project, charging, discharging and serial data collection must work accordingly. Any failure in one sub system can create problem in the overall efficiency of the project

11.3 Identify the attribute of complex engineering activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	

11.4 Provide reasoning how the project address selected attribute (EA)

A1. Range of resource

Our project is cable of finding out batteries performance by analyzing battery parameters through machine learning. To do so we have to search out necessary resources by going through existing literature review and stakeholder. Also, we have to explore all components and sensors dataset whether it satisfy our project’s specifications, requirements and constraints.

A2. Level of Interaction

There will be interaction between different levels for this project. Interaction between us, the market, and the stakeholders is necessary for this project. Their interaction is a fundamental requirement for project success.

A4. Consequences for society and the environment

After the implementation of the project, there will be a noticeable impact of the project on both the society and environment. In the medical arena, many equipment use batteries, whose voltage level is very crucial. A slight decline in the voltage level in crucial moments can cost the life of the patient. So, the battery screening system can ensure the rated output voltage of the battery pack, ensuring the optimal performance of the medical equipment. Besides the system can be used in recycling the used battery. Upon screening the used battery, this battery can be used to make secondary battery packs. This recycling of the used battery can have a positive impact on the environment.

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Appendix

Arduino Uno Code:

```
#include <Wire.h>
#include <Adafruit_INA219.h>
#include <U8glib.h>
#include <DHT.h>

// INA219 instance
Adafruit_INA219 ina219;

// OLED display instance (U8glib)
U8GLIB_SH1106_128X64 u8g(U8G_I2C_OPT_NONE);

// DHT11 sensor
#define DHTPIN 2       // DHT11 data pin connected to Digital Pin 2
#define DHTTYPE DHT11  // Define sensor type
DHT dht(DHTPIN, DHTTYPE);

// Pins
const int mosfetPin = 3;  // MOSFET gate connected to Digital Pin 3
const int voltageSensorPin = A0;  // Voltage sensor connected to Analog Pin A0

// Constants
const float voltageSensorMaxVoltage = 25.0;  // Max measurable voltage by the
sensor
const float voltageSensorMaxADC = 1023.0;    // Max ADC value for 10-bit
resolution

// Variables
float busVoltage_V = 0;
float current_mA = 0;
float voltage = 0;
bool discharging = false;
float temperature = 0;
float humidity = 0;

void setup() {
  // Start serial communication
  Serial.begin(9600);

  // Initialize INA219 sensor
  if (!ina219.begin()) {
    Serial.println("Failed to find INA219 chip");
    while (1) { delay(10); }
  }
```

```
  ina219.setCalibration_16V_400mA();  // Adjust INA219 range for expected
current

  // Initialize OLED display
  u8g.setFont(u8g_font_6x10);  // Set smaller font for OLED

  // Initialize MOSFET pin as output
  pinMode(mosfetPin, OUTPUT);
  digitalWrite(mosfetPin, LOW);  // Ensure MOSFET is off initially

  // Initialize DHT11 sensor
  dht.begin();

  // Show a startup screen on OLED
  u8g.firstPage();
  do {
    u8g.drawStr(10, 30, "IBICS System");
    u8g.drawStr(10, 40, "Initializing...");
  } while (u8g.nextPage());
  delay(2000);  // Display startup message for 2 seconds
}

void loop() {
  // Measure data from INA219
  busVoltage_V = ina219.getBusVoltage_V();
  current_mA = ina219.getCurrent_mA();

  // Measure battery voltage using the voltage sensor
  int sensorValue = analogRead(voltageSensorPin);
  voltage = (sensorValue / voltageSensorMaxADC) * voltageSensorMaxVoltage;

  // Measure temperature and humidity from DHT11
  temperature = dht.readTemperature();
  humidity = dht.readHumidity();

  // Control the MOSFET (discharging process)
  if (voltage > 3.0) {  // Only discharge if the battery voltage is above a
safe threshold
    digitalWrite(mosfetPin, HIGH);  // Turn MOSFET on
    discharging = true;  // Set discharging status to true
  } else {
    digitalWrite(mosfetPin, LOW);   // Turn MOSFET off
    discharging = false;  // Set discharging status to false
  }

  // Update OLED display
  u8g.firstPage();
  do {
```

```
    // Format variables for display
    char buffer[20];

    // Display discharging status
    if (discharging) {
      u8g.drawStr(0, 10, "Status: Discharging");
    } else {
      u8g.drawStr(0, 10, "Status: Low V");
    }

    // Display bus voltage (INA219)
    dtostrf(voltage, 4, 2, buffer);
    u8g.drawStr(0, 20, "Voltage: ");
    u8g.drawStr(50, 20, buffer);  // Properly formatted value

    // Display current (INA219)
    dtostrf(current_mA, 4, 1, buffer);  // Fewer decimal places
    u8g.drawStr(0, 30, "Current: ");
    u8g.drawStr(50, 30, buffer);

    // Display temperature (DHT11)
    dtostrf(temperature, 4, 1, buffer);  // Fewer decimal places
    u8g.drawStr(0, 40, "Temp: ");
    u8g.drawStr(50, 40, buffer);

    // Display humidity (DHT11)
    dtostrf(humidity, 4, 1, buffer);  // Fewer decimal places
    u8g.drawStr(0, 50, "Hum: ");
    u8g.drawStr(50, 50, buffer);

  } while (u8g.nextPage());  // This ensures the display updates properly

  // Print data to the Serial Monitor for debugging
  Serial.print("Voltage: "); Serial.print(voltage); Serial.println(" V");
  Serial.print("Current: "); Serial.print(current_mA); Serial.println(" mA");
  Serial.print("Battery Voltage: "); Serial.print(voltage); Serial.println("
V");
  Serial.print("Temperature: "); Serial.print(temperature); Serial.println("
C");
  Serial.print("Humidity: "); Serial.print(humidity); Serial.println(" %");
  Serial.print("Discharging: "); Serial.println(discharging ? "Yes" : "No");

  delay(1000);  // Update every 1 second
}
```

Arduino Mega Code:

```
#include <Wire.h>
#include <U8glib.h>
#include <DHT.h>
#include <Adafruit_INA219.h>  // Include the INA219 library

// Initialize OLED display
U8GLIB_SH1106_128X64 u8g(U8G_I2C_OPT_NONE);  // Use SH1106, will adapt to
128x48

// Define DHT11 sensor parameters
#define DHTPIN 2        // Pin where the DHT11 is connected
#define DHTTYPE DHT11   // DHT 11
DHT dht(DHTPIN, DHTTYPE);  // Initialize DHT11

// Voltage sensor pin
float voltageSensorPin = A0;  // Analog pin for the voltage sensor

// Initialize the INA219
Adafruit_INA219 ina219;

void setup() {
  // Initialize Serial for debugging
  Serial.begin(9600);

  // Setup U8glib display
  u8g.setFont(u8g_font_6x10);  // Set a small font to fit the 128x48 display

  // Initialize DHT11
  dht.begin();

  // Initialize INA219
  if (!ina219.begin()) {
    Serial.println("Failed to find INA219 chip");
    while (1);
  }

  // Show the initial message "Beginning process"
  showText("Beginning process", 1000);

  // Show the message "Charging"
  showText("Charging...", 2000);
}

void loop() {
  // Measure battery voltage using the voltage sensor
  int sensorValue = analogRead(voltageSensorPin);
```

```
  float measuredVoltage = sensorValue * (5.0 / 1023.0);  // Get the voltage on
analog pin (0-5V)
  float batteryVoltage = measuredVoltage * 5;  // Scale up by 5x to match the
module's 0-25V range

  // Measure temperature and humidity
  float temperature = dht.readTemperature();  // Read temperature in Celsius
  float humidity = dht.readHumidity();        // Read humidity

  // Check if any reads failed and exit early
  if (isnan(temperature) || isnan(humidity)) {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }

  // Measure current and power using INA219
  float current_mA = ina219.getCurrent_mA();  // Get current in mA
  float power_mW = ina219.getPower_mW();      // Get power in mW

  // Display the battery voltage, temperature, humidity, and current on the
OLED
  u8g.firstPage();
  do {
    // Draw voltage
    u8g.setFont(u8g_font_6x10);  // Set font size
    u8g.drawStr(0, 12, "Voltage:");
    u8g.setPrintPos(70, 12);
    u8g.print(batteryVoltage, 2);
    u8g.print(" V");

    // Draw temperature
    u8g.setPrintPos(0, 24);
    u8g.drawStr(0, 24, "Temp:");
    u8g.setPrintPos(70, 24);
    u8g.print(temperature, 1);
    u8g.print(" C");

    // Draw humidity
    u8g.setPrintPos(0, 36);
    u8g.drawStr(0, 36, "Humidity:");
    u8g.setPrintPos(70, 36);
    u8g.print(humidity, 1);
    u8g.print(" %");

    // Draw current
    u8g.setPrintPos(0, 48);
    u8g.drawStr(0, 48, "Current:");
    u8g.setPrintPos(70, 48);
```

```
    u8g.print(current_mA, 1);
    u8g.print(" mA");

  } while (u8g.nextPage());

  // Debug output to Serial
  Serial.print("Battery Voltage: ");
  Serial.print(batteryVoltage);
  Serial.print(" V, Temperature: ");
  Serial.print(temperature);
  Serial.print(" C, Humidity: ");
  Serial.print(humidity);
  Serial.print(" %, Current: ");
  Serial.print(current_mA);
  Serial.println(" mA");

  // Delay before the next measurement
  delay(2000);  // Increase delay to give the sensors time to stabilize
}

// Function to show a single line of text with a delay
void showText(const char* message, int delayTime) {
  u8g.firstPage();
  do {
    u8g.setFont(u8g_font_6x10);  // Set font size
    u8g.drawStr(20, 24, message);  // Center the text for better visibility
  } while (u8g.nextPage());

  delay(delayTime);  // Wait for the specified time before clearing the screen
}
```

Discharging Data Log:

```
import csv
import serial
import time
import threading
import sys

# Configure the serial port (adjust 'COM3' and '9600' based on your setup)
ser = serial.Serial('COM3', 9600, timeout=1)

# CSV file setup
csv_file = 'battery_data_log.csv'
header = ['Time', 'Voltage (V)', 'Current (mA)']
```

```
# Create/open CSV file and write the header
with open(csv_file, 'w', newline='') as f:
    writer = csv.writer(f)
    writer.writerow(header)

# Function to read data from serial and log into CSV
def log_data():
    while ser.is_open:
        try:
            # Read serial data
            line = ser.readline().decode('utf-8').strip()
            if line:
                # Parse relevant data from the serial string
                if "Voltage" in line:
                   voltage_str = line.split(":")[1].strip()[:-1]  # Remove 'V'
                elif "Current" in line:
                  current_str = line.split(":")[1].strip()[:-2]  # Remove 'mA'
                    # Record the time and log data into CSV
                    timestamp = time.strftime('%Y-%m-%d %H:%M:%S')
                    voltage = float(voltage_str)
                    current = float(current_str)

                    # Display the data in the command line
                    print(f"Time: {timestamp} | Voltage: {voltage} V |
Current: {current} mA")

                    # Append data to CSV
                    with open(csv_file, 'a', newline='') as f:
                        writer = csv.writer(f)
                        writer.writerow([timestamp, voltage, current])

        except KeyboardInterrupt:
            print("\nLogging stopped.")
            break
        except Exception as e:
            print(f"Error: {e}")
            break

# Function to check for user input to stop logging
def check_for_stop():
    while True:
        # Wait for user input (e.g., 'q' to quit)
        user_input = input().strip().lower()
        if user_input == 'q':
            print("User requested to stop logging.")
            ser.close()  # Close the serial port
            sys.exit()
```

```
# Start the logging and input listening in separate threads
if __name__ == "__main__":
    # Start logging data in a thread
    logging_thread = threading.Thread(target=log_data)
    logging_thread.daemon = True
    logging_thread.start()

    # Check for user key press in another thread
    input_thread = threading.Thread(target=check_for_stop)
    input_thread.daemon = True
    input_thread.start()

    # Keep the main thread alive until logging is stopped
    try:
        while logging_thread.is_alive():
            time.sleep(1)
    except KeyboardInterrupt:
        print("\nProgram terminated.")
        ser.close()
```

Charging Data Log:

```
import serial
import csv
import pandas as pd
import time

# Set up the serial connection
ser = serial.Serial('COM3', 115200, timeout=1)
time.sleep(2)  # Wait for the serial connection to initialize

# CSV file setup
csv_filename = 'current_voltage_log.csv'
excel_filename = 'current_voltage_log.xlsx'

# Initialize variables
current_mA = None
sensor_voltage = None

# Open CSV file for writing
with open(csv_filename, mode='w', newline='') as csvfile:
    csv_writer = csv.writer(csvfile)
    csv_writer.writerow(["Timestamp", "Current (mA)", "Sensor Voltage (V)"])

    try:
```

```
        while True:
            # Read a line from the serial monitor
            line = ser.readline().decode('utf-8').strip()

            if line:
                # Extract values from the serial output
                if "Current" in line:
                    current_mA = float(line.split(": ")[1].split(" ")[0])
                elif "Sensor Voltage" in line:
                    sensor_voltage = float(line.split(": ")[1].split(" ")[0])

                 # Ensure both current and voltage are captured before logging
                    if current_mA is not None and sensor_voltage is not None:
                        # Get the current timestamp
                        timestamp = time.strftime('%Y-%m-%d %H:%M:%S')

                        # Log the data to the CSV file
                  csv_writer.writerow([timestamp, current_mA, sensor_voltage])
            csvfile.flush()  # Flush the file buffer to ensure data is written

       print(f"Logged data: {timestamp}, {current_mA} mA, {sensor_voltage} V")

    except KeyboardInterrupt:
        print("Data logging stopped by user.")

# Convert CSV to Excel
df = pd.read_csv(csv_filename)
df.to_excel(excel_filename, index=False)

print(f"Data saved to {csv_filename} and {excel_filename}")
```

ML Code:

```
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_absolute_error
from sklearn.svm import SVR
from sklearn.tree import DecisionTreeRegressor
from sklearn.neural_network import MLPRegressor
from sklearn.neighbors import KNeighborsRegressor
from sklearn.linear_model import LinearRegression, LogisticRegression, Ridge,
Lasso, ElasticNet
from sklearn.ensemble import RandomForestRegressor, GradientBoostingRegressor,
AdaBoostRegressor, BaggingRegressor, ExtraTreesRegressor
from xgboost import XGBRegressor
from sklearn.preprocessing import StandardScaler
```

```
from sklearn.cluster import KMeans, DBSCAN


battery_df = pd.read_csv("/content/Battery_RUL.csv")
battery_df = battery_df.dropna().drop(['Cycle_Index'], axis=1)
battery_df.head()



X = battery_df.drop('RUL', axis=1)
y = battery_df['RUL']
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)
X_train, X_test, y_train, y_test = train_test_split(X_scaled, y,
test_size=0.2)


base_models = {
    'Random\nForest': RandomForestRegressor(),
    'Gradient\nBoosting': GradientBoostingRegressor(),
    'AdaBoost': AdaBoostRegressor(),
    'Linear\nRegression': LinearRegression(),
    'Logistic\nRegression': LogisticRegression(max_iter=1000),
    'Ridge': Ridge(),
    'Lasso': Lasso(),
    'MLP': MLPRegressor(max_iter=10000),
    'XGBoost': XGBRegressor(),
    'Decision\nTree': DecisionTreeRegressor(),
    'KNeighbors': KNeighborsRegressor(),
    'SVR': SVR(),
    'ElasticNet': ElasticNet(),
    'Bagging': BaggingRegressor(),
    'Extra\nTrees': ExtraTreesRegressor()
}
results = {}
for name, model in base_models.items():
    print(name.replace("\n", ""))
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)
    results[name] = mean_absolute_error(y_test, y_pred)

plt.figure(figsize=(18, 6))
bars = plt.bar(results.keys(), results.values())
for bar in bars:
    yval = bar.get_height()
 plt.text(bar.get_x() + bar.get_width()/2, yval + 2, f'{yval:.2f}',
ha='center', va='bottom')
plt.title('Model Performance Comparison')
plt.xlabel('Models')
```

```
plt.ylabel('Mean Absolute Error')
plt.show()

file_path = 'Battery_RUL.csv'
battery_data = pd.read_csv(file_path)
selected_features = battery_data[['Discharge Time (s)', 'Charging time (s)',
'Max. Voltage Dischar. (V)', 'Min. Voltage Charg. (V)']]
scaler = StandardScaler()
scaled_features = scaler.fit_transform(selected_features)
kmeans = KMeans(n_clusters=3, random_state=42)
battery_data['KMeans_Cluster'] = kmeans.fit_predict(scaled_features)
dbscan = DBSCAN(eps=0.5, min_samples=5)
battery_data['DBSCAN_Cluster'] = dbscan.fit_predict(scaled_features)
plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
plt.scatter(battery_data['Discharge Time (s)'], battery_data['Charging time
(s)'], c=battery_data['KMeans_Cluster'], cmap='viridis')
plt.title('K-Means Clustering: Discharge Time vs Charging Time')
plt.xlabel('Discharge Time (s)')
plt.ylabel('Charging Time (s)')
plt.colorbar(label='Cluster')
plt.subplot(1, 2, 2)
plt.scatter(battery_data['Discharge Time (s)'], battery_data['Charging time
(s)'], c=battery_data['DBSCAN_Cluster'], cmap='plasma')
plt.title('DBSCAN Clustering: Discharge Time vs Charging Time')
plt.xlabel('Discharge Time (s)')
plt.ylabel('Charging Time (s)')
plt.colorbar(label='Cluster')
plt.show()
plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
plt.scatter(battery_data['Max. Voltage Dischar. (V)'], battery_data['Min.
Voltage Charg. (V)'], c=battery_data['KMeans_Cluster'], cmap='viridis')
plt.title('K-Means Clustering: Max Discharge Voltage vs Min Charge Voltage')
plt.xlabel('Max. Voltage Dischar. (V)')
plt.ylabel('Min. Voltage Charg. (V)')
plt.colorbar(label='Cluster')
plt.subplot(1, 2, 2)
plt.scatter(battery_data['Max. Voltage Dischar. (V)'], battery_data['Min.
Voltage Charg. (V)'], c=battery_data['DBSCAN_Cluster'], cmap='plasma')
plt.title('DBSCAN Clustering: Max Discharge Voltage vs Min Charge Voltage')
plt.xlabel('Max. Voltage Dischar. (V)')
plt.ylabel('Min. Voltage Charg. (V)')
plt.colorbar(label='Cluster')
plt.show()
```

Server-Side Code for Data Receving:

```php
<?php

if ($_SERVER['REQUEST_METHOD'] === 'GET') {

    if (isset($_GET['dcv'])) {

        // Database connection details
        define('DB_SERVER', 'localhost');
        define('DB_USERNAME', 'root');
        define('DB_PASSWORD', '');
        define('DB_DATABASE', 'fydp');

        $db = new mysqli(DB_SERVER, DB_USERNAME, DB_PASSWORD, DB_DATABASE);

        // Check connection
        if ($db->connect_error) {
            die("Connection failed: " . $db->connect_error);
        }

        // Get the current time
        $current_time = time();

        // Fetch the start time from the database (assume it's stored in a
table called `config`)
        $result = $db->query("SELECT `start_time` FROM `config` LIMIT 1");

        if ($result && $row = $result->fetch_assoc()) {
            $start_time = $row['start_time'];

            // Calculate the elapsed time (current time - start time)
            $elapsed_time = $current_time - $start_time;
        } else {
            // If no start time found, this is the first entry, so set the
start time
            $start_time = $current_time;
            $elapsed_time = 0;

            // Store the start time in the database for future use
            $db->query("INSERT INTO `config` (`start_time`) VALUES
('$start_time')");
        }

        // Prepare and execute the statement to insert data into the
`collected` table
        $stmt = $db->prepare("INSERT INTO `collected` (`time`, `elapsed_time`,
`dcv`, `dci`, `temp`, `cl`) VALUES (?, ?, ?, ?, ?, ?);");
```

```
        $stmt->bind_param("ssssss", $current_time, $elapsed_time,
$_GET['dcv'], $_GET['dci'], $_GET['temp'], $_GET['cl']);
        $stmt->execute();

        // Optionally, you can also insert the data into another table (as in
your original code)
        $stmt2 = $db->prepare("INSERT INTO `datatable` (`time`, `dcv`, `dci`,
`temp`, `cl`) VALUES (?, ?, ?, ?, ?);");
        $stmt2->bind_param("sssss", $current_time, $_GET['dcv'], $_GET['dci'],
$_GET['temp'], $_GET['cl']);
        $stmt2->execute();

        echo "Success";

    } else {
        echo "Failure: Missing data parameters";
    }

} else {
    echo "Failure: Invalid request method";
}

?>
```

FYDP (P) FALL 2023 Summary of Team Log Book/Journal

Group No - 04

Project Title: Design and Implementation of Identical Battery Identification and Clustering System (IBICS)

Date// Time	Attendance	Summary of the meeting	Responsible	Atc's Comment
10.10.2023	**All**	Brainstorming about topics	**All**	**To do more research and bring more topics**
17.10.2023	**All** **All**	Topic finalization	**All** **All**	• **To do more literature review on the finalized topic.** • **To prepare a draft about finalized topic**
19.10.2023	**All**	• Presentation of draft concept note • Progress presentation slides were shown	**All**	**In specification:** 1. Input voltage 220V should be removed. 2. Internal resistance should be quantified. 3. Temperature range expressed in the specified range 4. Life cycle should not be in specification 5. Thermal test not in the specification section, rather in the requirement section. **In constraints:** Constraints should be changed, as they seem like requirements. **Design Approach:** Have to draw block diagrams for both main and alternative designs.

1.11.2023	**All**	• Changes have been made to the draft concept note and showed to the panel • Literatures were shown	**All**	**Suggestions:** 1.The problem statement is vague, need to be more specific. Before the problem statement bit of background info & image (18650 battery image) is needed. Slide. 2.Short circuit current detection goes to requirement from specification. 3.In specification, instead of AA battery the tentative dimensions of the battery are needed 4.In specification, removing software monitoring add real time data monitoring and add time limit to it (persistence of human vision) 5.In constraints, replacing the phrase ‘temperature difficulties’ by ‘no heat regulation if the battery heated up while charging’. Also, to protect surrounding circuitry heat sink can be added.
8.11.2023	**All**	Final concept note was shown to the ATC panel	**All**	**Suggestions:** 1.From constraint section ‘massive data handling’ will go to requirement. 2.Ordinary looking gantt chart . 3.Coloring should be added to design approach 1 block diagram. 4.In case of identical 18650 battery clustering what percentage of similarity will be entertained (e.g., plus minus 5mA)? (Engineering Literature Investigation required). 5.Elaboration on standards and codes

15.11.2023	**All**	• New methods were discussed with ATC panel about completing the project	**All**	**Suggestions:** 1.Accepted similarity percentage (voltage, internal resistance) for New 18650 battery clustering (Formulating research Hypothesis for this purpose) 2.More literature investigation on the similarity percentage is required for clustering retired 18650 batteries. 3.Finding relevant standards involved in clustering new 18650 batteries 4.Correction in the design diagram: powering up individual blocks is not required. 5.Bill of material. (Start looking for hardware blocks that are required in the project)
22.11.2023	**All**	• Literature review was done and shown to the ATC panel • Discussion about the feasibility of using k-means clustering method in our project	**All**	**Suggestions:** • Finding the standard deviation on battery clustering from the given dataset in the paper. • Analyze the graphs • EIS simulation literature review is required to perform the design approach 2 software simulation • Further modification is needed in the current block diagram **Probable research hypothesis**:

				A hardware & simulation-based approach to determine the standard deviation of similarity criteria(output voltage) for clustering new 18650 batteries in a pack.
29.11.2023	All	- Standard deviation was shown to the ATC panel. - Discussion about stakeholder	All	**Suggestions:** Prepare the slides for the upcoming final fydp-p presentation for fall 2023 semester.
6.12.2023	All	Preparation about final presentation and final report	All	Read the already found literatures in details to integrate in the report
13.12.2023	All	The final report draft is shown and discussed	All	- Build more graphic Gaant chart - Build a fever chart - Build an estimated budget for design approach 2

FYDP (D) SPRING 2024 Summary of Team Log Book/Journal

Group No – 04

Date/ Time	Attendance	Summary of the meeting	Responsible	Atc's Comment
23.01.2024	**All**	- Brainstorming about the topic's Simulation	**All**	- **To simulate the subsystems in relevant software.**
30.01.2024	**All**	- Showed design 1 sub-systems	**All**	- **Need to work on component-wise**

		simulation on MATLAB to the ATC.		**in every sub-system**
06.2.2024	**All**	• Showed the subsystem simulations according to the component in proteus	**All**	• **Proper Calculation is required according to the specification.**
13.02.2024	**All**	• Showed the calculations of some sub-systems	**All**	• **Further calculation is needed to specify the component parameters in the sub-systems.** • **Check if the calculation satisfies our specifications and requirements by doing back calculations.**
20.02.2024	**All**	• Calculation Showed. • All the sub-systems simulation of design-1 showed.	**All**	• **Run the whole design-1 system by connecting all the systems.** • **Show charging and discharging graphs of the whole system.**
27.02.2024	**All**	• Showed the final output of design-1. • Show the progress presentation slide.	**All**	• **Advised to make some changes in the slides and naming the sub-systems.** • **Brainstrong for design-2's simulation.**
Mid-Week				
5.03.2024	**All**	• Showed the multiple simulation	**All**	• **Advised to work with COMSOL and MATLAB simulation**

		softwares for alternate design.		**software for design-2.**
26-03-2024	**All**	- COMSOL simulation graph showed	**All**	- **Need to work with COMSOL simulation graph's output curves.**
02-04-2024	**All**	- COMSOl final output graph showed. - Also, for justification MATLAB graph showed.	**All**	- **Need to remove marker from MATLAB's graph for clear understanding.**
9-04-2024	**All**	- Used machine learning algorithm to get the similarities	**All**	- **To see the source dataset and prepare for real battery testing**
16-04-2024	**All**	- Showed the complete design to the ATC	**All**	- **Fine-tune the design to meet the requirements**
23-04-2024	**All**	- Final Simulation output graph showed for both designs. - Final presentation slides showed to ATC4	**All**	- **Need to plot components calculation as a graph.**

FYDP (C) SUMMER 2024 Summary of Team Log Book/Journal

Group No – 04

Date/ Time	Attendance	Summary of the meeting	Responsible	Atc's Comment

9/6/24	All	• Discussed about project update • Mock presentation	All	• Work on the prototype design
16/6/24	All	• Discussed about sourcing the components	All	N/A
23/6/24	All	• Discussed about the new components	All	N/A
30/6/24	All	• Provided updates on hardware subsystems	All	• Try to integrate the sub systems
7/7/24	All	• Showed the User Interface to ATC • Provided hardware updates	All	• Need to collect more battery information to build dataset • User interface has to be improved
14/07/24	All	• Design approach 2 was discussed • Improved User interface is showed	All	N/A
25/8.24	All	• Integration of hardware sub system faced problems	All	• Need to integrated as soon as possible • Damaged components must be ordered fast

1/9/24	All	• Machine learning algorithms were shown • Generated data of charging and discharging cycle	All	• More data is required
8/9/24	All	• Faced problem in discharging circuit	All	• Discharging circuit has to be rebuild • Show a draft report
15/9/24	All	• Draft of final report is presented	All	N/A
22/9/24	All	• Updated and more data is shown	All	N/A
29/9/24	All	• Integration of the sub system successfully done	All	• Casing has to be built
6/10/24	All	• Casing is built • 2nd draft of report is shown	All	• Casing needs some upgradation • Wiring should be built more compactly
13/10/24	All	• Upgraded casing is shown and approved • Compact wiring	All	N/A
20/10/24	All	• Mock presentation • Final report is aproved	All	N/A