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A Minor Project Proposal
On
BATTERY MONITORING SYSTEM

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ABSTRACT

Battery safety and management considering Nepal's growing adoption of renewable energy systems and electric vehicles. The increasing deployment of lithium-ion battery packs, particularly $LiFePO_4$ cells, presents significant risks including thermal runaway, overcharging, and cell imbalance, which can lead to catastrophic failures. Existing battery management solutions in the Nepali market are limited by high costs, lack of real time monitoring, and insufficient safety. This project proposes an efficient battery monitoring system designed specifically for 4S $LiFePO_4$ battery configurations common in Nepali applications. The system leverages voltage divider networks and analog multiplexing technologies to provide real time cell voltage tracking and enable proactive safety interventions. The hardware incorporates an ESP32 microcontroller, 74HC4051 analog multiplexer, precision voltage dividers, and temperature sensing, while the software integrates Arduino IDE programming with digital filtering algorithms. The system features user-friendly OLED display output, innovative battery monitoring system that prevents battery failures through early detection of anomalies, extending battery lifespan automated safety protocols.

Keywords: Battery Monitoring System, $LiFePO_4$, Voltage Monitoring, Cell Balancing, ESP32, Analog Multiplexing, Temperature Sensing, Safety Protocols, Renewable Energy, Nepal Power Infrastructure

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ABBREVIATION

ADC	Analog to Digital Converter
BMS	Battery Management System
BMoS	Battery Monitoring System
DAC	Digital to Analog Converter
ESP32	Espressif Systems 32-bit Microcontroller (Wi-Fi/Bluetooth)
GPIO	General Purpose Input/Output
KiCAD	Ki Computer Aided Design
LiFePO4	Lithium Iron Phosphate
NTC	Negative Temperature Coefficient (thermistor)
PCB	Printed Circuit Board

1. INTRODUCTION

1.1. Background

Battery Monitoring Systems (BMoS) ensure real time monitoring, safety protection, and reliable performance of 4S $LiFePO_4$ battery configurations. These batteries are widely used across Nepal in households, electric rickshaws, solar backup systems, rural electrification projects, and small industries. Developing a cost-effective and locally optimized BMoS helps improve safety, reduce reliance on imported systems, and support Nepal's growing transition toward renewable and battery-based energy solutions.

1.2. Problem Statement

Nepal has reported over 150 battery related incidents in the last three years due to improper battery handling and inadequate monitoring. Existing BMS solutions in the Nepali market are mostly imported, expensive costing between NPR 15,000 to 30,000, and often incompatible with local electrical conditions.

1.3. Objectives

1. To design and develop a cost effective with in NPR 5000, locally manufacturable Battery Monitoring System optimized for 4S $LiFePO_4$ configurations used in Nepali solar and small scale energy storage systems.
2. To implement real time monitoring features including individual cell voltage tracking, temperature sensing, and state of charge estimation using precision voltage divider networks and multiplexing technologies.

1.4. Scope of Project

This project focuses on the design, development, and testing of 4S $LiFePO_4$ battery applications in Nepal. It consider real time monitoring, basic safety protection, and modular design using components readily available in the local market. The system is intended for educational, solar, and small electric mobility applications.

2. LITERATURE REVIEW

2.1. Open Source Battery Management System (SmartBMS)

A GitHub project Open Source Battery Management System, developed by Sergio Ghirardelli [1], was designed to protect battery cells against overvoltage and undervoltage conditions. In this architecture, the voltage and temperature values of each individual cell were continuously acquired by dedicated cell modules based on microcontrollers (Arduino Mega) .
Thus, Project demonstrated a modular and open-source approach with each cell module which are costly modules.

2.2. Low Cost Battery Management System for Photovoltaic Applications

Ethman *et al.* [2] presented the design and development of a low cost Battery Management System (BMS) for low-power applications in photovoltaic (PV) systems. The study highlighted that energy storage remained one of the major challenges in renewable energy systems due to the intermittent nature of PV generation. BMS kits were analyzed, simulated, tested, and upgraded to overcome their performance limitations.

2.3. Low Cost Battery Management System for Solar

Sharma, Adhikari, and Karki [3] proposed a low cost battery management system for solar applications in Nepal. Their study emphasizes monitoring battery voltage to prevent overcharging and deep discharging, which are major causes of battery degradation. The system demonstrates that microcontroller based solutions can be effectively implemented at low cost, making them suitable for rural and small scale energy systems.

2.4. Accuracy Considerations in Microcontroller-Based Voltage Measurement

Patel [4] analyzed accuracy considerations in microcontroller-based voltage measurement systems. The research identifies key factors affecting measurement accuracy, including analog-to-digital converter (ADC) resolution, reference voltage stability, and noise. Precise voltage measurement is necessary to determine battery condition and operating limits.

3. Feasibility Study

3.1. Technical Feasibility

The proposed Battery Monitoring System is technically feasible using standard electronic components and standard design practices. An ESP32 based controller with voltage dividers, analog multiplexing, temperature sensing, and OLED visualization provides reliable real-time monitoring of battery parameters.

3.2. Economical Feasibility

The estimated total cost of around NPR 5,000 makes the system economically available. The use of low cost components and open-source tools reduces production expenses, offering a affordable alternative to imported BMS units priced at NPR 15,000–30,000.

3.3. Operational Feasibility

The system is simple to install and operate, low maintenance and basic technical skills. Its low power consumption, can operates under common voltage fluctuation conditions.

3.4. Hardware Feasibility

All required hardware components such as the ESP32, multiplexer, DHT11 Temperature Sensor Module, and OLED display are readily available in local markets in Nepal. The circuit can be assembled using breadboards or basic PCBs without the need for specialized manufacturing equipment.

3.5. Software Feasibility

The system software is developed using the Arduino IDE (open source), C++ for firmware implementation, analog processing, timing. AdafruitSSD1306 and AdafruitGFX libraries are used for OLED control. KiCad EDA is employed for schematic and PCB design. Project documentation with LaTex and version control Git/GitHub.

4. Requirement Study

4.1. Hardware Requirements

ESP32 Microcontroller

The ESP32 is a low cost and power microcontroller featuring integrated WiFi and Bluetooth. It provides multiple GPIO pins, a 12 bit ADC, DAC support, and communication interfaces such as SPI, I^2C, and UART. Its processing capability and connectivity make it suitable for real-time battery monitoring and data handling in this BMoS project.

Figure 4.1: ESP32 Microcontroller board

74HC4051 Analog Multiplexer

The 74HC4051 is an 8 channel analog multiplexer that enables measuring multiple analog signals using a single ADC pin. It is useful for sequential cell voltage monitoring in a 4S $LiFePO_4$ configuration.

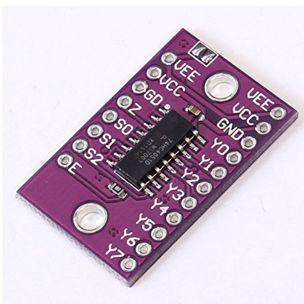

Figure 4.2: 74HC4051 Analog Multiplexer IC

LM741 Operational Amplifier

The LM741 operational amplifier used as a unity gain buffer in the system. It ensures accurate analog measurements by offering high input impedance and stable output.

Figure 4.3: LM 741 Operational Amplifier IC

OLED Display (128×64)

The OLED display module provides a compact, low power graphical display which communicates over I^2C. It displays real time battery parameters such as cell voltages, temperature, total pack voltage, and system status.

Figure 4.4: OLED Display Module

Temperature Sensor Module(DHT11)

The DHT11 is a basic, low cost digital sensor that measures both temperature and humidity, making it popular for simple electronics projects.

Figure 4.5: Temperature Sensor Module (DHT11)

4.2. Software Requirements

Arduino IDE

The Arduino IDE is used for firmware development, uploading, debugging, and serial monitoring.

KiCad EDA

Used for schematic capture and PCB layout design.

Programming Language (C++)

For analog signal processing, I^2C communication, timing, safety checks etc.

Required Libraries

Such as Adafruit SSD1306 and Adafruit GFX for OLED control.

Testing Tools

Arduino Serial Monitor, multimeter, oscilloscope for measurement validation.

Documentation Tools

Markdown, version control (Git/GitHub), and diagram tools for maintaining project docs.

5. SYSTEM ARCHITECTURE AND METHODOLOGY

5.1. Theoretical Background

Battery Monitoring Systems (BMoS) enhance safety, longevity, and performance for widely used 4S $LiFePO_4$ batteries in Nepal's households, transport, and solar projects. Developing an affordable, locally-optimized BMoS reduces import dependence and supports the national shift to renewable energy.

5.2. System Design

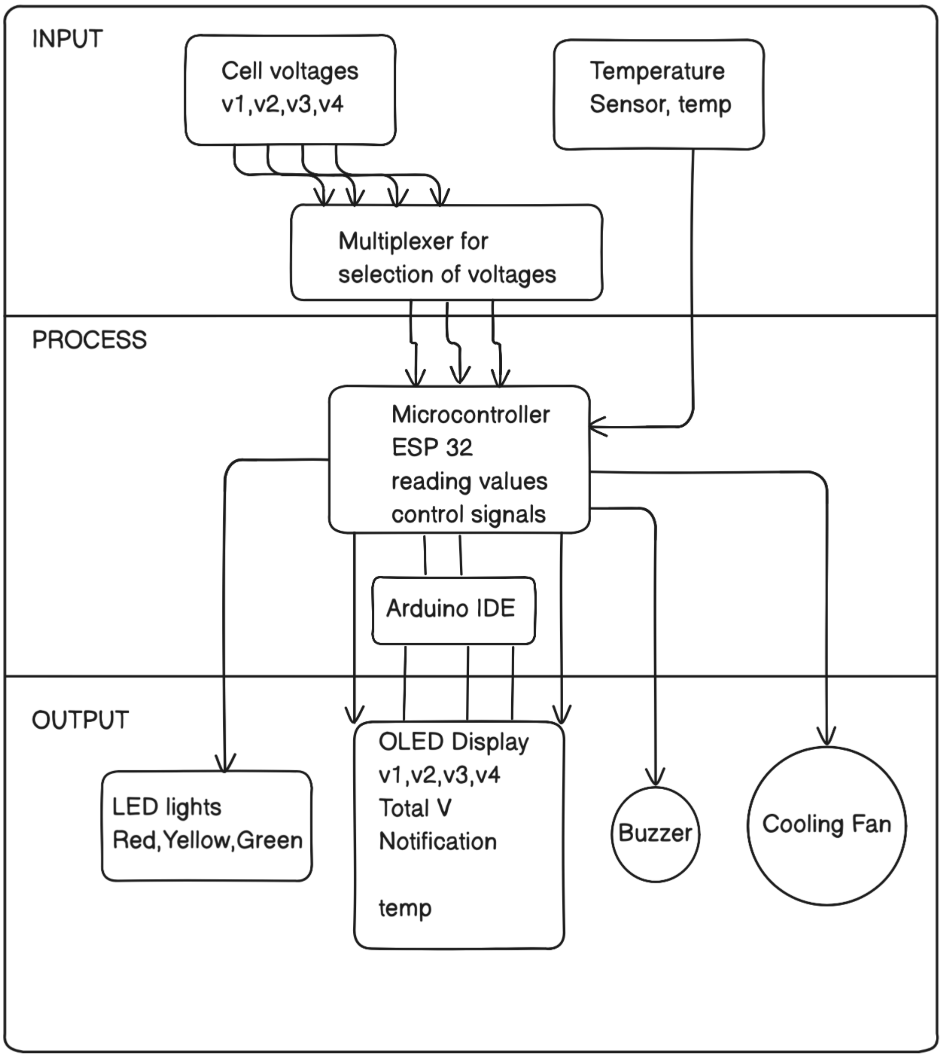

Figure 5.1: System Design

5.3. Flow Chat

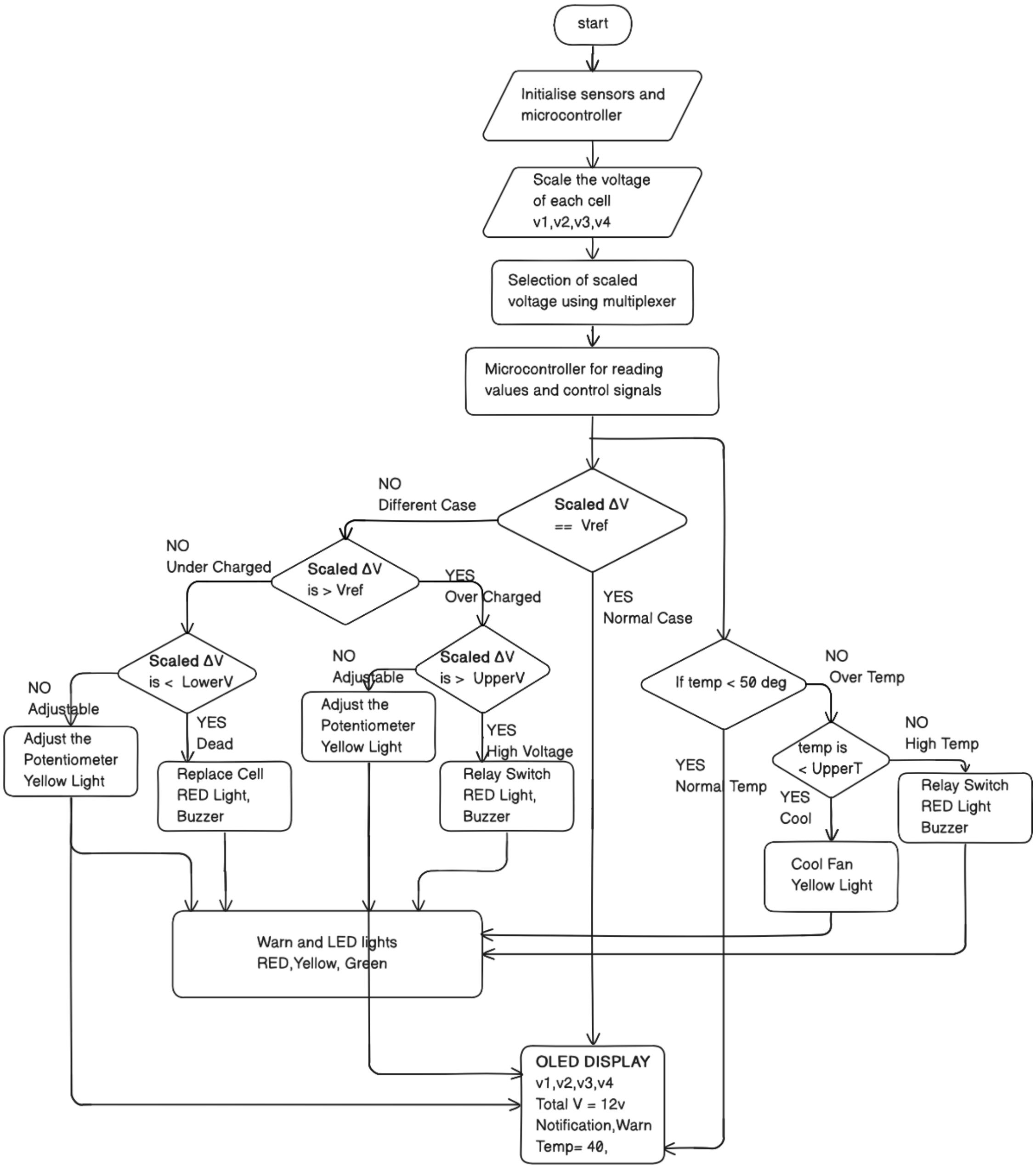

Figure 5.2: Flow Chat

5.4. Circuit Diagram

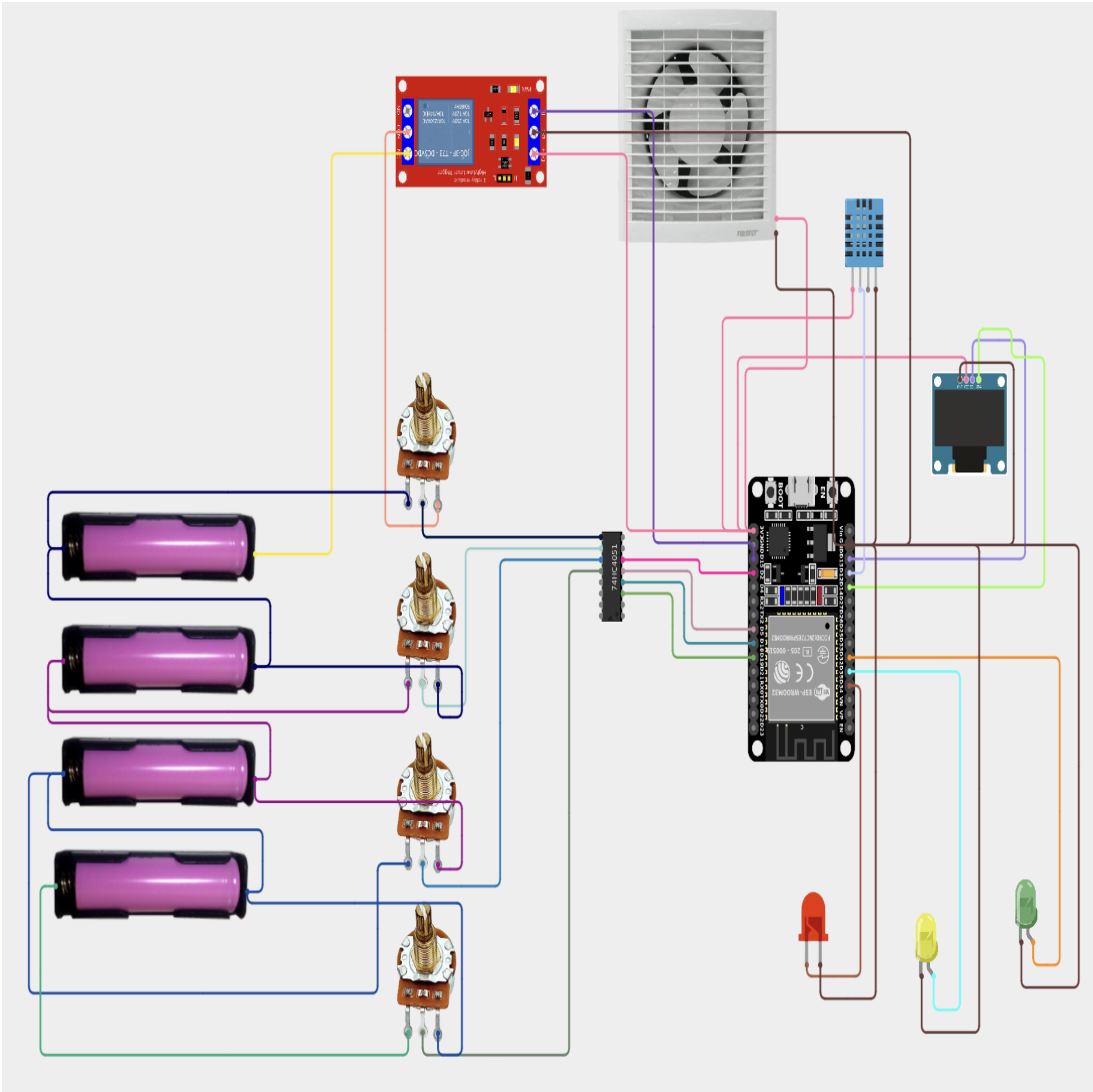

Figure 5.3: Circuit Diagram

6. IMPLEMENTATION DETAILS

6.1. System Design and Implementation

The Battery Monitoring System (BMoS) for $LiFePO_4$ batteries is designed as sensing layer to take reading of individual voltage of each cells and temperature data. the interface layer provides human interaction and external communication through an OLED display, status LEDs, buzzer alerts, and a serial port.

Temperature measurement is implemented using a Temperature sensor Module(DHT11).

The microcontroller platform selection was a key decision in the system design. While the ESP32 offers built-in Wi-Fi and Bluetooth, higher clock speed, more memory. The integrated hardware architecture combines the battery pack, voltage dividers(Potentiometer). To handle the multiple voltage channels and a temperature sensor, a 74HC4051 8-channel analog multiplexer is employed. Multiplexer output is buffered by the op-amp before reaching the ESP32's ADC input. Digital pins from the ESP32 control the multiplexer and drive the interface components, including LEDs, a buzzer, and an OLED display. The system is powered by the battery pack through a regulated 3.3V supply using an LD1117V33 voltage regulator, which ensures stable operation under varying input conditions.

Overall, this system design and hardware integration methodology provides a robust, accurate, and reliable Battery Monitoring System considering the Nepali market, addressing both technical requirements and practical constraints related to local component availability and operating conditions.

6.2. Cost Estimation

Table 6.1: Cost Estimation of Components for Battery Monitoring System

S.N	Component Name	Quantity	Unit Cost (Rs.)	Total Cost (Rs.)
1	ESP32 Tool Kit	1	1000	1000
2	74HC4051 Multiplexer IC	1	200	200
3	LM741 Operational Amplifier	4	80	320
4	OLED Display	1	500	500
5	Temperature Sensor	1	500	500
6	Resistors (Different Values)	1 box	500	500
7	Ceramic Capacitors (0.1µF)	5	25	125
8	Electrolytic Capacitor (10µF)	2	25	50
9	LEDs (Red, Green, Yellow)	5	10	50
10	Breadboard (for prototyping)	1	350	350
11	Jumper Wires (40 pieces)	1 pack	200	200
12	LIPO4 Battery (4 pieces)	4	150	600
13	Potentiometer (4 pieces)	4	100	400
			Grand Total	**4,795**

6.3. Schedule

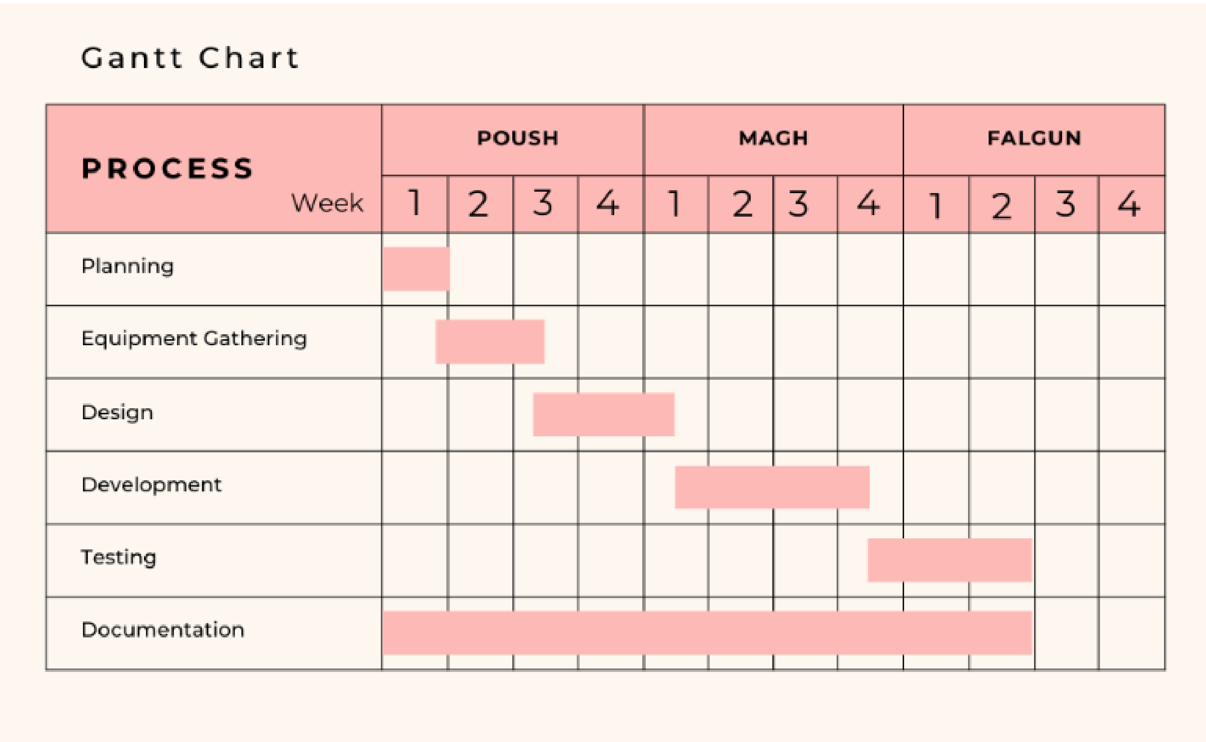

Figure 6.1: Gantt Chart

7. Expected Outcomes

Based on our project objectives, the expected outcomes of the Battery Monitoring System (BMoS) project are

1. A fully operational 4S $LiFePO_4$ battery monitoring prototype under NPR 5,000, considering voltage scaling via precision dividers, a 74HC4051 multiplexer, and an OLED interface. It uses locally manufacturable, affordable solutions for education, solar, and small scale electric mobility in Nepal.

2. A reliable real time monitoring of individual cell voltages (±1%), temperature (±2°C), and Performance is documented through test reports and comparative analysis, confirming technical viability for local renewable energy applications.

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