SEMESTER PROJECT REPORT

Instrumentation and Measurements

PREPARED FOR :

SIR HARIS ATAULLAH

Made by:

Huzaifa Zafar
Maira Waheed
Hajra Bibi

Table of Contents

S No.	Topic	Page No.
1.	Introduction to BMS	3
2.	Objective	3
3.	Background and Motivation	4
4.	Working principle of batteries	4
5.	BMS Functionality	5
6.	Components	6
7.	Architecture	8
	7.1 Charging system	8
	7.2 Balancing system	9
	7.3 Controller and Display	10
8.	Circuit Diagram	13
9.	Testing and Results	14
10.	Conclusion	14

Introduction

The Battery Management System plays a crucial role in overseeing and controlling the charging and discharging of rechargeable lithium-ion batteries, ensuring their safe and efficient operation. This electronic regulator monitors various parameters such as voltage, current, temperature, state of charge, state of health, and the remaining useful life of individual cells within the battery pack. By collecting and analyzing this data, the BMS mitigates risks, optimizes battery performance, and executes tasks like charge/discharge control and cell balancing. In this project, three lithium-ion batteries are employed to develop a BMS for a 12V system, leveraging the high specific energy, energy density, open circuit voltage, and low self-discharge characteristics of lithium-ion batteries.

The purpose of BMS is managing lithium-ion batteries, emphasizing their sensitivity to charging and discharging parameters. Lithium-ion batteries, widely used in portable electronics, demand precise control to prevent issues like overcharging-induced swelling or explosion and deep discharge leading to failure. The ideal lithium-ion battery charger requires mechanisms for stabilizing voltage and current, along with a voltage balancing system for multiple cells in series. The introduction sets the stage for the project's focus on designing a circuit that not only facilitates the charging of lithium-ion batteries in series but also incorporates a balancing system for enhanced safety and longevity.

Objective

Our project's core objectives revolve around crafting a robust Battery Management System (BMS) tailored for a 12V system, leveraging the distinct characteristics of lithium-ion batteries. Primarily, we aim to ensure efficient charging and discharging control, meticulously regulating voltage and current for optimal battery performance and extended lifespan. A key focus is the implementation of sophisticated cell balancing to evenly distribute charge among individual cells, mitigating risks associated with overcharging and enhancing overall system longevity.

Safety enhancement is another crucial goal, with the BMS actively monitoring parameters like state of charge, state of health, and temperature to prevent issues such as overcharging-induced swelling. The BMS will also facilitate seamless integration with various 12V applications, ensuring compatibility and adaptability across diverse devices. A user-friendly interface will provide real-time battery status updates and alerts, allowing for manual interventions when needed. Additionally, we aim to enhance energy efficiency, exploring sustainable features and scalability for potential future advancements in battery technology or system expansions. Overall, our 12V BMS project aims to contribute to the dynamic landscape of energy storage technology by meeting immediate needs while prioritizing safety, longevity, and adaptability.

Background and Motivation

In today's landscape dominated by portable electronics and the expanding electric vehicle market, the efficiency and safety of lithium-ion batteries are critical. These batteries, essential to our daily lives, require precise control over charging and discharging processes. Envision a future where lithium-ion batteries not only provide exceptional energy density but also redefine safety and longevity standards, transcending current norms. Our Battery Management System (BMS) project is born within this innovative framework. The BMS acts as an electronic guardian overseeing and controlling the charging and discharging of lithium-ion batteries. It monitors critical parameters such as voltage, current, temperature, state of charge, state of health, and the remaining useful life of individual cells within the battery pack. Through meticulous data analysis, the BMS optimizes battery performance, mitigates risks, and executes tasks like charge/discharge control and cell balancing.

Our project focuses on leveraging lithium-ion battery characteristics to develop a BMS for a 12V system. The use of three lithium-ion batteries underscores our goal to pioneer a solution surpassing conventional standards. Beyond immediate benefits, this project provides valuable experience in power management, laying the groundwork for future projects in this domain. The challenges and successes encountered during BMS development offer insights into the complexities of power systems. As we navigate through this project, the gained knowledge extends beyond a singular application, encompassing broader implications in energy storage and distribution. The project's emphasis goes beyond immediate concerns, acknowledging the inherent sensitivity of lithium-ion batteries to charging and discharging parameters. As our project unfolds, it aligns with academic goals while serving as a stepping stone for future endeavors. The power management experience gained is not just an isolated achievement but a precursor to skills and experiences shaping our future projects in the dynamic field of energy technology.

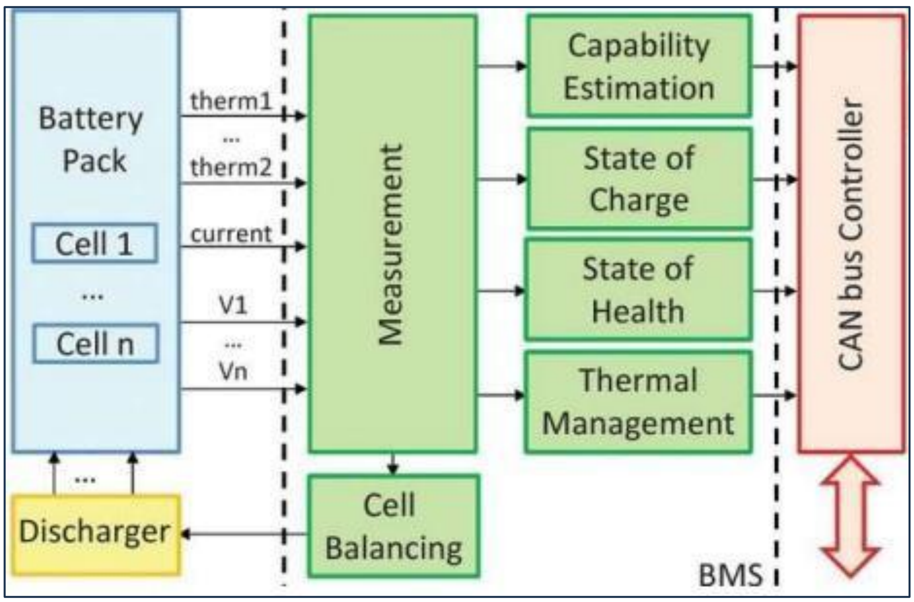
Working Principle of Batteries

The fundamental working principle of lithium-ion batteries revolves around electrochemical reactions that occur within the battery cells during both charging and discharging phases. Comprising an anode and cathode separated by an electrolyte, lithium-ion batteries utilize materials such as graphite for the anode and metal oxides for the cathode. During the charging process, an external voltage prompts lithium ions to migrate from the cathode to the anode through the electrolyte, where they are absorbed and stored. Conversely, during discharging, these stored lithium ions move back to the cathode, generating an electric current that powers electronic devices. The use of a reversible electrochemical reaction allows lithium-ion batteries to be charged and discharged multiple times.

An essential component in the working of lithium-ion batteries is the separator, which physically separates the anode and cathode while facilitating the passage of lithium ions. The voltage of the battery cell is determined by the materials used for the anode and cathode, while the energy storage capacity relies on the number of lithium ions that can be stored in these materials. Safety features, including battery management systems (BMS), are integrated to monitor and control parameters like overcharging and overheating, ensuring the secure and efficient operation of lithium-ion batteries in various applications, from portable electronics to electric vehicles.

BMS Functionality

The diagram illustrates the Battery Management System, showcasing its essential functions for the efficient operation of lithium-ion batteries. The BMS ensures safety through continuous monitoring of parameters such as temperature, voltage, and current, preventing overcharging and overheating.



Primary Functions:

1. **Safety**
   - Continuous monitoring of temperature, voltage, and current for safe battery operation.
   - Prevents overcharging and overheating to maintain safe operating conditions.
2. **Performance**
   - Optimization maintains lithium-ion battery State of Charge (SoC) within defined charge limits.
   - Ensures optimal performance by regulating SoC between minimum and maximum thresholds.

3. **Health Monitoring and Diagnosis**
    - Utilizes collected data points (temperature, voltage, current) to estimate State of Charge (SoC) and State of Health (SoH) of the battery pack.
        - SoC indicates available energy, determining the distance a vehicle can travel before requiring a charge.
        - SoH measures the current condition of the battery in comparison to its original capacity, indicating suitability for the intended application.
4. **Communication**
    - Responsible for communication with Electronic Control Units (ECU) within the vehicle.
    - Relays crucial data parameters to the motor controller, ensuring smooth vehicle operation.

Components

- **Current Sensor**

  It sense the current drawn from the battery bank and is displayed on the LCD.

  Specification:

Parameters	5A Module	20A Module	30A Module
Supply Voltage (VCC)	5Vdc Nominal	5Vdc Nominal	5Vdc Nominal
Measurement Range	-5 to +5A	-20 to +20A	-30 to +30A
Voltage at 0A	VCC/2 (Nominally 2.5Vdc)	VCC/2 (Nominally 2.5Vdc)	VCC/2 (Nominally 2.5Vdc)
Scale Factor	185mV per Amp	100mV per Amp	66mVper Amp
Chip	ACS712ELC-05A	ACS712ELC-10A	ACS712ELC-30A

- **Relay**

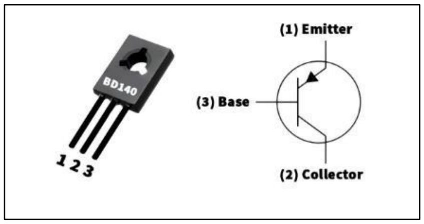
  Relay in BMS is used to cut out the system from over temperature and over charging or for safety from draining battery.

- **Arduino UNO**

Controller used for calculating the parameters like voltages, current, temperature, State of charge , State of health of the Lithium - ion batteries. ARDUINO Uno also used for safety of the batteries. If the charges of the batteries goes to minimum or maximum value.

- **BD140**

The BD140 is an NPN bipolar junction transistor (BJT) commonly used in audio amplifiers and drivers for general purpose applications. It belongs to a transistor family that includes BD135, BD136, and BD139. The BD140 is preselected in DC current gain and comes in a SOT-32 plastic package.



- **Voltage Sensor**

Voltage Sensors are used for calculating the voltages of every battery and is displayed on the LCD and are interface with controller. It senses the voltage from the battery and this voltage value is displayed on the LCD.

Inputs

- GND- This is often where you connect the low side of the voltage you're measuring.
- VCC- The is where you connect the high side of the voltage you're measuring.

Outputs

- S: This connects to your Arduino analog input.
- Negative - This connects to your Arduino ground.
- Positive - This is often not connected.

Caution: This is often an equivalent electrical point as your Arduino ground.

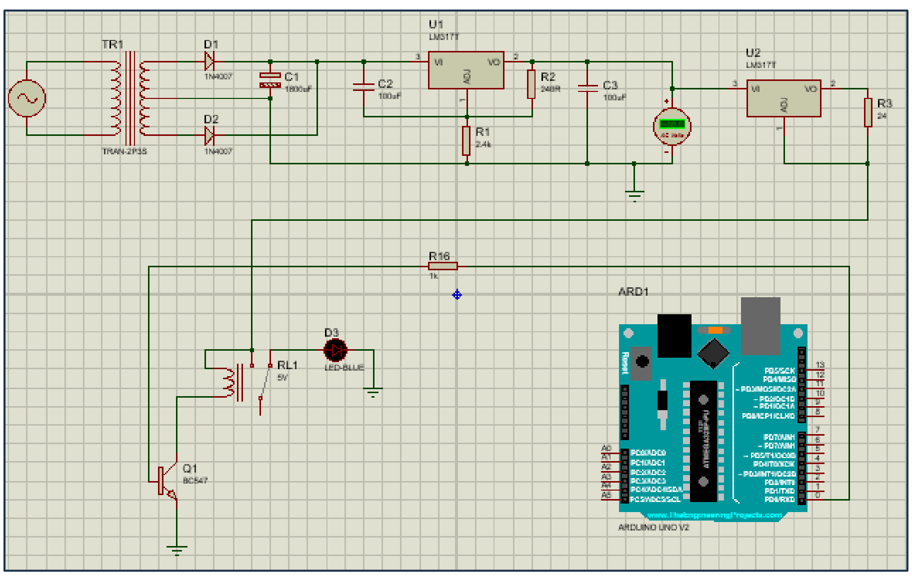
Architecture

The architecture of our Battery Management System (BMS) for the 12V lithium-ion battery configuration is meticulously designed to ensure the safety, performance, and longevity of the batteries. The BMS integrates two indispensable systems: a sophisticated balancing system and a regulated charging system. The balancing system utilizes a circuit with a regulated zener diode (TL431) and a power transistor, actively preventing overcharging and overheating. It employs a relay mechanism triggered by voltage discrepancies, equalizing voltage levels across connected lithium-ion cells. Simultaneously, the charging system, managed through an intelligent circuit with an LM317 regulator, meticulously controls voltage and current, enhancing overall battery health. The relay, driven by a bipolar junction transistor (BJT) acting as a diode, ensures efficient and safe charging cycles by timely activation and deactivation based on impulses received at the zero pin. Together, these integrated systems form a holistic BMS architecture, providing robust safeguards against overcharging and overheating while optimizing the overall health and performance of lithium-ion batteries in diverse applications.

The charging circuit begins with an alternator supplying alternating current (AC) to a central-tapped transformer. This AC is

Charging Circuit

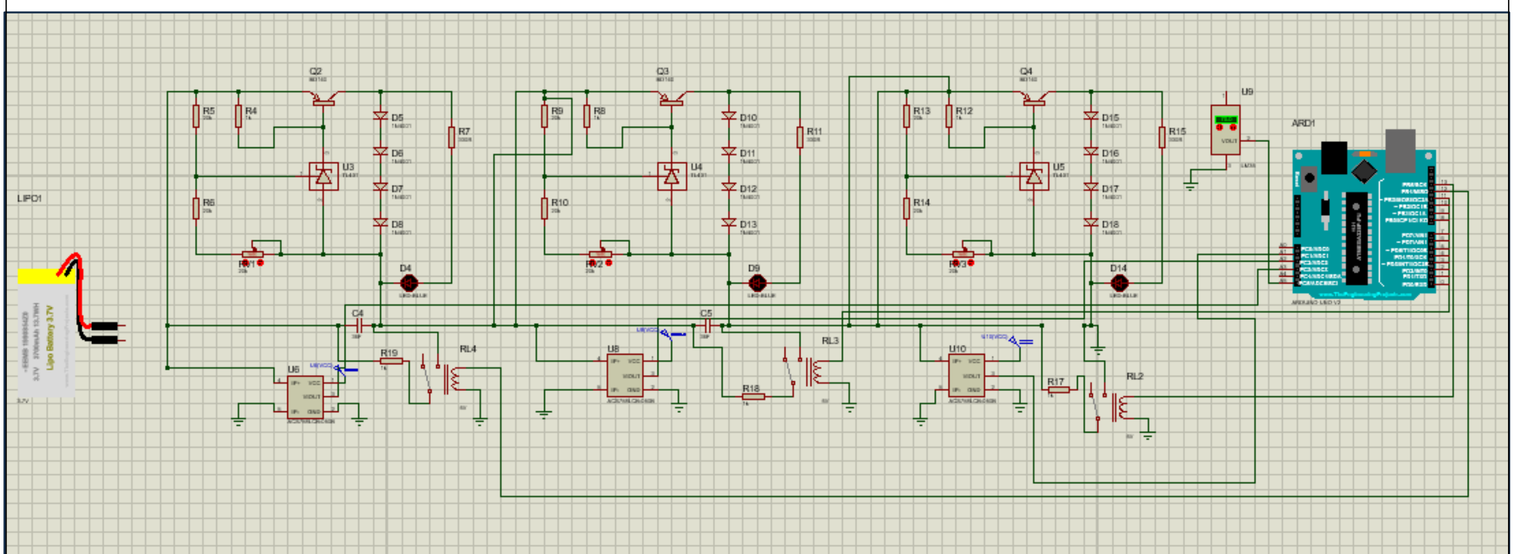
then rectified into direct current (DC) using diodes. To ensure a stable DC output, capacitors are employed for effective filtering. The rectified and filtered DC voltage, now free from excessive ripples, is then regulated to 12V using an LM317 voltage regulator. The regulated voltage is further processed through a coupling capacitor before passing through a 24-ohm resistor. This resistor acts as a current-setting component, establishing the desired charging current at 500 mA. The current then flows through to a relay, a crucial element in the circuit. The relay is activated by impulses reaching the zero pin of a bipolar junction transistor (BJT), initiating a response in which the BJT functions as a diode. This diode-like behavior creates a path from the collector to ground, disrupting the magnetic field and resulting in the activation of the relay. This relay, in turn, plays a pivotal role in the overall functioning of the charging circuit.



Balancing Circuit

Balancing the voltage of lithium-ion batteries is of paramount importance to ensure their optimal performance and longevity during the charging process. Uncontrolled overcharging can pose significant risks, including swelling, explosions, or overall battery failure. To address these concerns, a sophisticated circuit has been developed, incorporating a regulated Zener diode (TL431) and a power transistor. Specifically designed for lithium-ion battery cells connected in series, the circuit includes tuning resistors for precise adjustment of the cut-out voltage. An LED indicator has been integrated to signal the completion of the charging process, providing visual feedback to the user. A relay is a key component in this system, activated when one or more batteries reach a different voltage level. This relay acts as a balancing mechanism, utilizing resistors to maintain uniform voltage levels across all connected batteries.

A potentiometer allows for the setting of a specific voltage level, determining when the system should halt the discharging process. Safety measures are further enhanced by the inclusion of a temperature sensor, which prevents overheating. If the temperature surpasses a predefined threshold, the charger automatically shuts down. The zero pin receives impulses that reach the base of a bipolar junction transistor (BJT), causing it to function as a diode. This diode-like behavior creates a path from the collector to ground, activating the relay through the magnetic field. In addition to these safety features, a button has been incorporated to initiate the charging process. Before commencing charging, the circuit intelligently checks whether charging is necessary, ensuring an efficient and demand-driven charging cycle.



Controller and Display

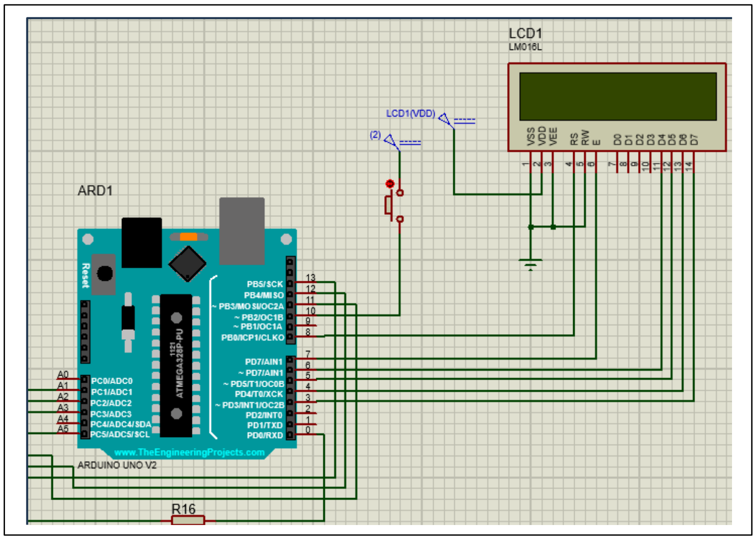
Arduino here serves the purpose of managing a battery system, including monitoring and balancing multiple batteries. The system incorporates various sensors to measure parameters such as individual battery voltages, current flow, and temperature. It utilizes an LCD display to provide real-time information about the battery voltages and current values. The code includes logic for balancing the batteries by selectively activating relays based on the voltage levels of individual batteries. Additionally, the system incorporates safety features to detect overheating and excessive current, triggering actions such as disconnecting batteries or shutting down the system to prevent potential damage. The code demonstrates a comprehensive battery management system designed for monitoring, balancing, and ensuring the safety of a multi-battery setup.

Code:

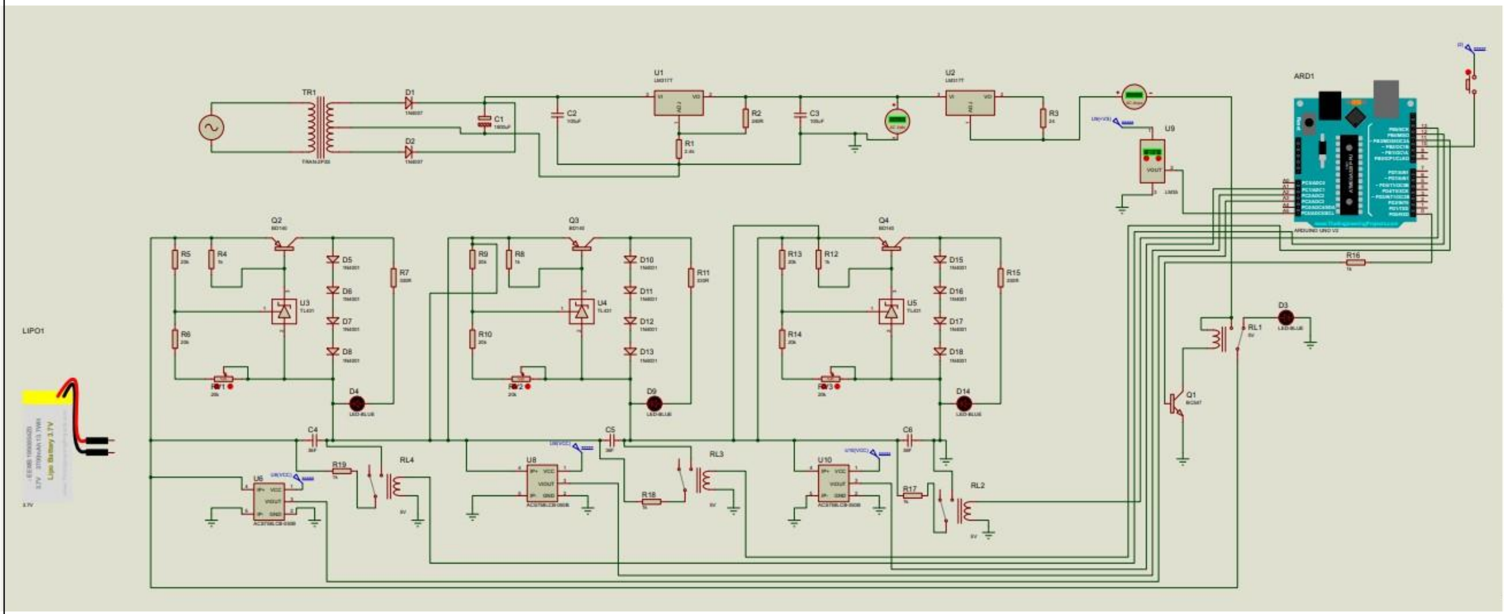
```
#include <LiquidCrystal.h>
// Define the LCD connections
const int rs = 8;
const int en = 7;
const int d4 = 6;
const int d5 = 5;
const int d6 = 4;
const int d7 = 3;
// Initialize the LiquidCrystal library with the LCD pins
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
// Define the pins names
const int chargeButtonPin = 10;
const int voltageSensorPinV1 = A1;
const int voltageSensorPinV2 = A2;
const int voltageSensorPinV3 = A3;
const int currentSensorPin = A4;
const int tempSensorPin = A5;
const int Char_Discharge_Pin = 0;
const int Battery1Pin = 13;
const int Battery2Pin = 11;
const int Battery3Pin = 12;
const int maxCurrent = 500;

float Battery1Voltage, Battery2Voltage, Battery3Voltage;
float Current_Value;
float Temp_Value;

void setup() {
  // Set PB3 (Charge Button Pin) as an input
  pinMode(chargeButtonPin, INPUT);
  // Set A1, A2, and A3 as inputs for analog voltage sensors
  pinMode(voltageSensorPinV1, INPUT);
  pinMode(voltageSensorPinV2, INPUT);
  pinMode(voltageSensorPinV3, INPUT);

  // Set A4 as an input for the ACS712 current sensor
  pinMode(currentSensorPin, INPUT);

  // Set A5 as an input for the LM35 temperature sensor
  pinMode(tempSensorPin, INPUT);

  // Set digital pins 11, 12, 13, and 0 as outputs
  pinMode(Battery2Pin, OUTPUT);
  pinMode(Battery3Pin, OUTPUT);
```

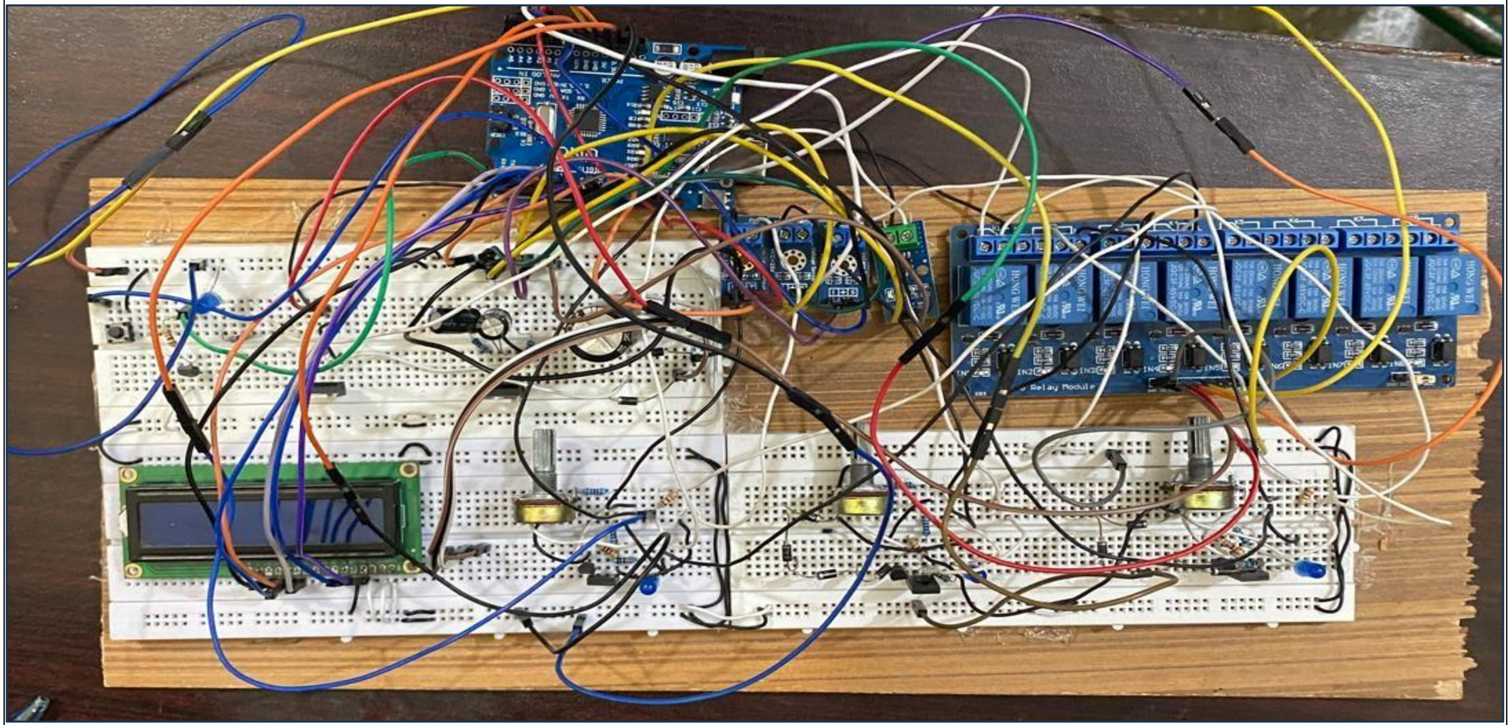
```
  pinMode(Battery1Pin, OUTPUT);
  pinMode(Char_Discharge_Pin, OUTPUT);

  // Set up the LCD columns and rows
  lcd.begin(16, 2);

  // Display the project title
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Battery");
  lcd.setCursor(0, 1);
  lcd.print("Management");
  delay(500);
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("System Project");
  delay(500);  // Wait for 2 seconds

  // Display the names of contributors
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Made by:");
  lcd.setCursor(0, 1);
  lcd.print("Azlaan, Bilal");
  delay(500);  // Wait for 1 seconds
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Abdullah");
  lcd.setCursor(0, 1);
  lcd.print("and Laiba");
  delay(500);  // Wait for another 1 seconds
  Serial.begin(9600); //Start Serial Monitor to display current read value on Serial monitor
}
void loop() {
  Battery1Voltage = analogRead(voltageSensorPinV1);
  Battery2Voltage = analogRead(voltageSensorPinV2);
  Battery3Voltage = analogRead(voltageSensorPinV3);

  Current_Value = analogRead(currentSensorPin);

  Temp_Value = analogRead(tempSensorPin);

  Battery1Voltage = (Battery1Voltage * 5.0) / 1023.0;
  Battery2Voltage = (Battery2Voltage * 5.0) / 1023.0;
  Battery3Voltage = (Battery3Voltage * 5.0) / 1023.0;
  Current_Value = (Current_Value * 5.0) / 1023.0;
  Temp_Value = (Temp_Value * 0.48876);  // Convert to degrees Celsius
   // Battery balancing logic
  if (Battery1Voltage > Battery2Voltage && Battery1Voltage > Battery3Voltage) {
    // Battery 1 has the highest voltage, turn on its relay
    digitalWrite(Battery1Pin, HIGH);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Balancing Battery 1");
    // ... (optionally display balancing message on LCD)
  } else if (Battery2Voltage > Battery1Voltage && Battery2Voltage > Battery3Voltage) {
    // Battery 2 has the highest voltage, turn on its relay
    digitalWrite(Battery2Pin, HIGH);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Balancing Battery 2");
    // ... (optionally display balancing message on LCD)
  } else if (Battery3Voltage > Battery1Voltage && Battery3Voltage > Battery2Voltage) {
    // Battery 3 has the highest voltage, turn on its relay
    digitalWrite(Battery3Pin, HIGH);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Balancing Battery 3");
```

```
      // ... (optionally display balancing message on LCD)
    } else {
      // No battery needs balancing, turn off all relays
      digitalWrite(Battery1Pin, LOW);
      digitalWrite(Battery2Pin, LOW);
      digitalWrite(Battery3Pin, LOW);
    }
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Battery Voltage:");
    lcd.setCursor(0, 1);
    lcd.print("B1: ");
    lcd.print(Battery1Voltage);
    lcd.print("V");
    delay(500);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Battery Voltage:");
    lcd.setCursor(0, 1);
    lcd.print("B2: ");
    lcd.print(Battery2Voltage);
    lcd.print("V");
    delay(500);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Battery Voltage:");
    lcd.setCursor(0, 1);
    lcd.print("B3: ");
    lcd.print(Battery3Voltage);
    lcd.print("V");
    delay(500);
    if (Temp_Value > 50) {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Overheating Detected!");
      lcd.setCursor(0, 1);
      lcd.print("Disconnecting Battery");
      delay(500);
      digitalWrite(Battery1Pin, LOW);
      digitalWrite(Battery2Pin, LOW);
      digitalWrite(Battery3Pin, LOW);
    }
   if (Current_Value > maxCurrent) {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("High Current Detected!");
      lcd.setCursor(0, 1);
      lcd.print("Shutting Down...");
      delay(500);  // Optional delay for message display
      // Turn off all relays and other outputs for safety
      digitalWrite(Battery1Pin, LOW);
      digitalWrite(Battery2Pin, LOW);
      digitalWrite(Battery3Pin, LOW);
      digitalWrite(Char_Discharge_Pin, LOW);
      // Trigger a controlled shutdown of the Arduino
      asm volatile ("  jmp 0");  // Jump to the reset vector
    } else {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Battery Connected:");
      lcd.setCursor(0, 1);
      lcd.print("Current: ");
      lcd.print(Current_Value);
      lcd.print(" mA");
    }
    delay(1000);
```



Circuit Diagram





Testing and Results

Our Battery Management System (BMS) underwent rigorous testing to evaluate its safety features, balancing mechanisms, and overall performance. Activation of the charging circuit, monitored by the LED indicator, initiated a comprehensive examination. The BMS actively regulated temperature, voltage, and current during the charging cycle, preventing overcharging and overheating. Relay mechanisms responded adeptly to voltage discrepancies, ensuring uniform voltage levels across connected batteries. The sophisticated circuit, featuring a regulated Zener diode and power transistor, demonstrated its effectiveness in promoting battery longevity and preventing overcharging. Safety measures, including a temperature sensor, added an extra layer of protection, automatically shutting down the system in response to detected overheating.

The Arduino-based monitoring system provided real-time updates on the LCD, displaying battery voltages and current values. The code's logic for selective relay activation based on voltage levels worked seamlessly, contributing to efficient energy management. Safety features, such as disconnecting batteries or system shutdown in response to excessive current, were successfully tested and proven effective. In summary, the testing results affirm the robustness of our BMS design, showcasing its ability to safeguard against overcharging and overheating while ensuring efficient energy management and user-friendly functionality. This collaborative effort stands as a valuable contribution to enhancing the safety and performance of multi-battery setups in various applications.

Conclusion

The presented Arduino battery management system is a comprehensive and collaborative effort designed to effectively monitor and balance multiple batteries in real-time. With a LCD display, the system provides instant updates on voltage and current values, ensuring efficient energy management. Its innovative approach to battery balancing involves dynamically adjusting relays based on voltage differentials among batteries, showcasing a thoughtful and adaptive design. Safety features, including overheating and high current detection, contribute to the overall reliability of the system, safeguarding the batteries from potential damage. The integration of temperature and current sensors adds sophistication, allowing the system to proactively respond to emerging issues. This project not only serves as a robust solution for enhancing the performance and safety of multi-battery setups but also exemplifies a well-engineered solution with a focus on efficiency and user-friendly functionality. It stands as a valuable asset for applications requiring dependable energy storage and management.