**Analog and Digital Communication**

**LOVELY PROFESSIONAL UNIVERSITY**

PROJECT REPORT

ON

**IOT-based Battery Management System (BMS)**

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**ABSTRACT**

The battery management system (BMS) is a critical component of electric and hybrid electric vehicles. The BMS ensures safe and reliable battery operation by monitoring and controlling charge, state of health, and cell balancing., state monitoring and evaluation, charge control, and cell balancing are functionalities that have been implemented in BMS. As an electrochemical product, a battery acts differently under different operational and environmental conditions. The uncertainty of a battery’s performance poses a challenge to the implementation of these functions. This paper addresses concerns for current BMSs. State evaluation of a battery, including state of charge, state of health, and state of life, is a critical task for a BMS. Through reviewing the latest methodologies for the state evaluation of batteries, the future challenges for BMSs are presented and possible solutions are proposed as well.

As it ensures the safety and reliability of battery operations. BMSs are responsible for monitoring battery state, controlling charging, and managing cell balancing. As batteries exhibit varying behaviors under different conditions, accurately evaluating states like charge, health, and lifespan is challenging but crucial. This report explores the design and functionality of a BMS that measures battery voltage, percentage, and charging status through a 5V analog input from a BMS module. We address the challenges in current BMS implementations and highlight potential solutions.

**INTRODUCTION**

In this project, we design and develop a Battery Status Monitoring System using the ESP8266 microcontroller and Arduino IoT Cloud. This system enables remote monitoring of battery voltage and charge percentage, providing users with real-time information about the battery’s charging and discharging status from anywhere in the world. Such a system proves highly beneficial for monitoring critical battery metrics remotely, enhancing both convenience and safety.

The battery is a fundamental component in any electronic system, as it powers the entire operation. Monitoring battery voltage levels is essential to prevent damage due to improper charging and discharging cycles, which can lead to battery degradation or complete system failure. Typically, Battery Management Systems (BMS) are implemented in electrical and electronic devices to oversee battery properties such as voltage, current, and temperature and to include safety mechanisms like an auto cut-off system. These systems are especially important for the safe handling of Lithium-Ion and Lithium Polymer batteries, known for their high energy density and specific handling requirements.

Conventional BMS solutions are limited to monitoring battery conditions and alerting the user through local indicators. In contrast, this project integrates Internet of Things (IoT) technology, allowing battery status notifications to reach users remotely. By utilizing IoT, users can check battery metrics on their smartphones or computers via a cloud-based dashboard, enabling easy access to battery data from any location.

The IoT-based Battery Monitoring System developed here uses a NodeMCU ESP8266 board to transmit battery status data to the Arduino IoT Cloud. The cloud-based dashboard displays real-time battery voltage and charge percentage in both charging and discharging states, giving users a comprehensive overview of their battery’s condition, remotely and conveniently.

Battery Management Systems are pivotal in applications where safe battery operation is required. A BMS monitors various parameters to optimize battery performance, maintain longevity, and prevent overcharging or depletion. In this project, a custom BMS was developed for monitoring battery voltage, charge percentage, and charging status. This system has potential applications in mobile devices, electric vehicles, and renewable energy storage solutions.

* Objective: To design a BMS capable of monitoring voltage, battery percentage, and charging status using an analog input.
* Importance: Ensures efficient battery management, extending battery life and enhancing safety.
* Applicability: Suitable for systems that rely on battery operation, such as electric vehicles, portable electronics, and energy storage systems.
* Scope: This report focuses on hardware setup, software implementation, and application in real-time monitoring.
* Relevance: Given the rapid adoption of battery-powered devices, efficient battery management systems are more crucial than ever.
* Work Plan: Design, assemble, and program the BMS, followed by testing and analysis.
* Implementation: A practical implementation utilizing an ESP module, voltage divider, and LCD display for real-time monitoring.

**CIRCUIT DIAGRAM**

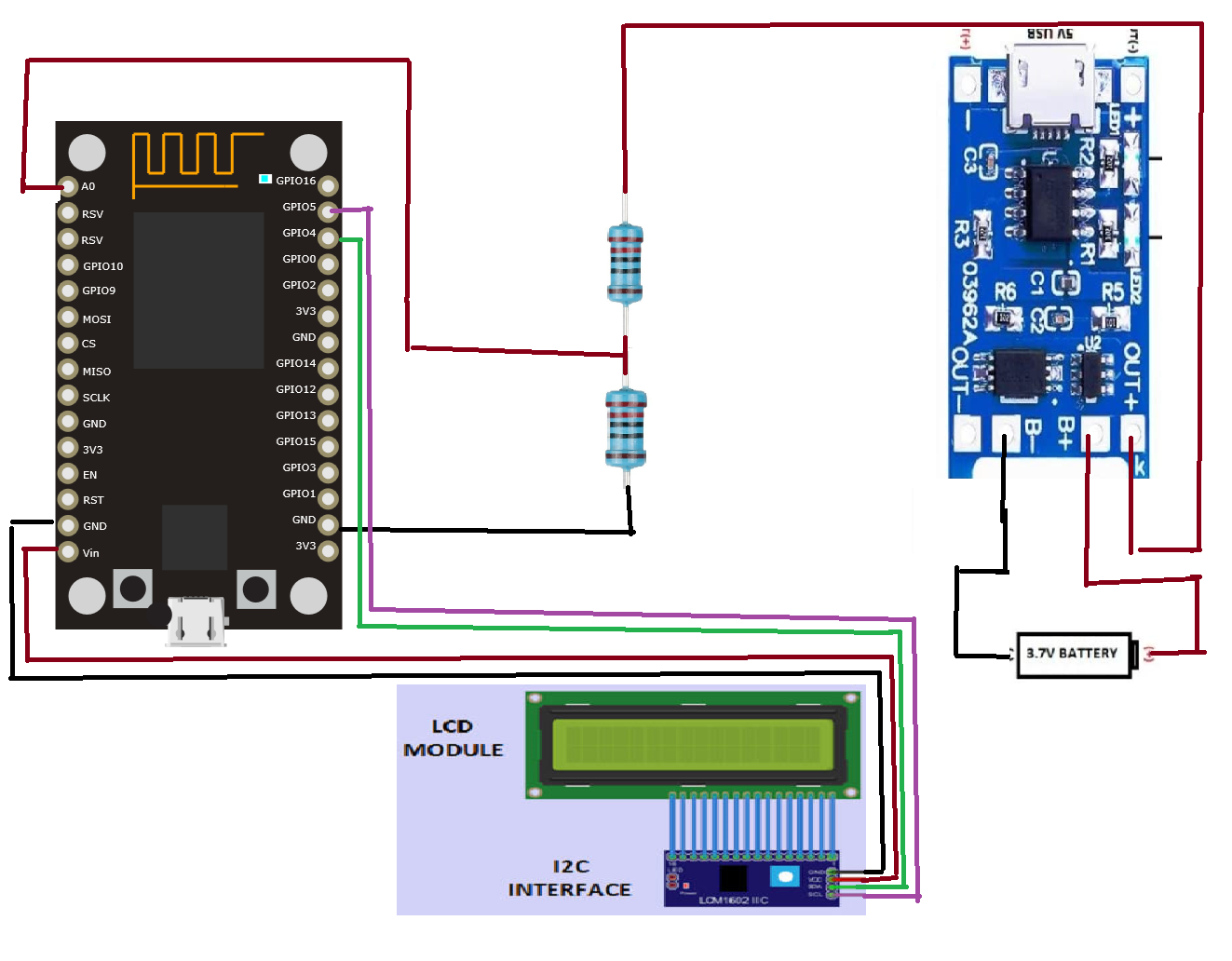
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Figure1[5]: Circuit Diagram of BMS with ESP8266 and TP4056 and 18650 Battery

**WORKING**

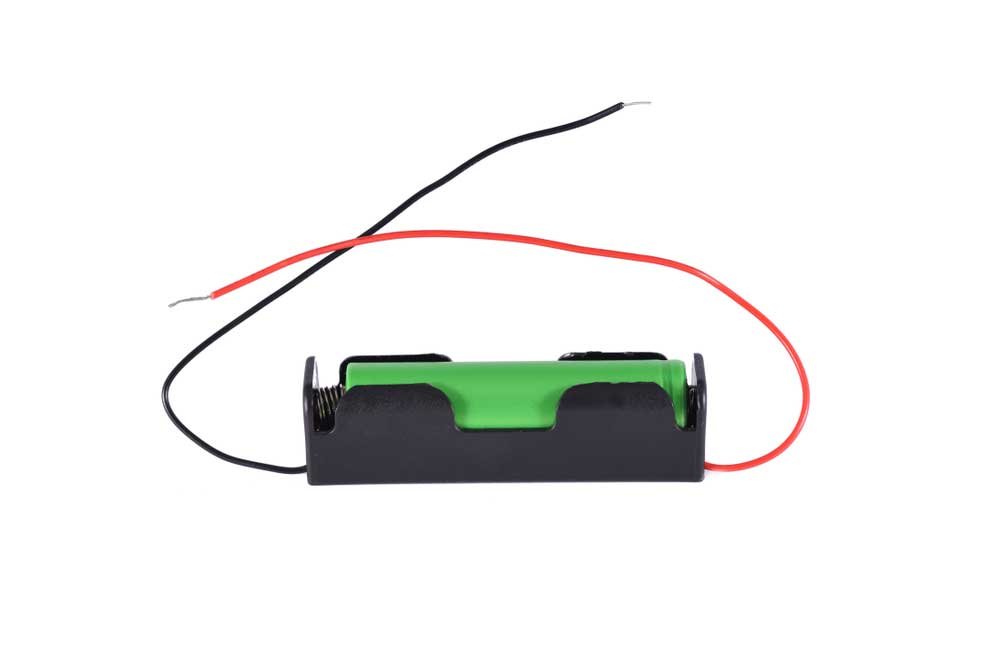
We design a simple system to monitor battery voltage, battery percentage, and the charging and discharging status using the Arduino IoT Cloud. A microcontroller is required to send these values to the IoT platform, and for this purpose, we chose the NodeMCU ESP8266. This affordable and widely used board includes a built-in WiFi chip, enabling it to connect to a WiFi network and upload data to the cloud server seamlessly.

For charging the battery, we are using the TP4056 module. This module is well-suited for Lithium-Ion batteries, as it includes a built-in battery management system to ensure safe charging and discharging. Alternatively, an MCP73831 IC could be used in place of the TP4056 module.

Since the NodeMCU ESP8266 chip only supports an analog input voltage of up to 3.3V, and Lithium-Ion batteries can reach up to 4.2V, we employ a voltage divider network to reduce the input analog voltage. This allows safe monitoring of battery voltage without damaging the microcontroller[5].

1. lithium-ion battery

A lithium-ion battery or Li-ion battery is a rechargeable battery. These Lithium-ion batteries are widely and commonly used for portable electronics and electric vehicles

 Figure 2:lithium-ion battery

In a Li-ion battery, the ions move from the negative electrode to the positive electrode while discharging, and vice versa when charging. It uses an intercalated lithium compound at the positive electrode and graphite at the negative electrode. This battery has a high energy density, no memory effect, and low self-discharge.

2.Node MCU

The NodeMCU ESP8266 is a low-cost development board based on the ESP8266 WiFi chip, ideal for Internet of Things (IoT) projects.



Figure 3: NodeMCU ESP8266

It features built-in WiFi capabilities, allowing devices to connect to wireless networks. With a 32-bit processor running up to 160 MHz, it supports digital I/O, PWM, and analog input. The board includes a USB-to-serial converter for easy programming through a computer. It’s compatible with the Arduino IDE[1], making development user-friendly. The NodeMCU has a compact form factor and can be powered via USB. It offers around 512 KB to 1 MB of flash memory and 160 KB of RAM. The board supports Lua scripting but is more commonly programmed in C++ using the Arduino ecosystem. With a range of GPIO pins, it interfaces well with sensors, actuators, and other components. The NodeMCU is widely used in DIY and hobbyist IoT projects due to its versatility and affordability.

3. Voltage Divider Network Circuit

When the battery is fully charged, the maximum voltage is 4.2V and the discharge cut-off voltage is 2.8V. Once this is clear, any voltage lesser than 3.3V will be easily supported by ESP8266 Analog Pin.

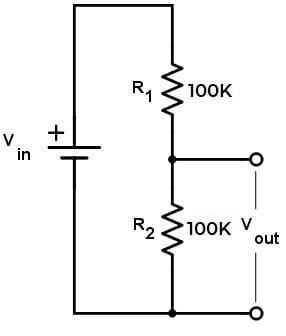


Figure 3: Voltage Divider Network Circuit

So, we will first step down to the upper voltage level. So, to do that I will use a Pair of 100K resistors. It will convert the source voltage from 4.2V to 2.1V. Similarly, the cut-off voltage is also stepped down from 2.8V to 1.4V. Now, both upper and lower voltage is supported by a NodeMCU ESP8266 Analog pin[2].

4. BMS Module (TP4056)

A 5V BMS (Battery Management System) is a circuit designed to manage and protect the performance of 5V battery-powered devices, typically lithium-ion or lithium-polymer batteries. It ensures the safe operation of the battery by monitoring key parameters like voltage, current, temperature, and state of charge. The BMS balances the charge across individual cells to prevent overcharging or overdischarging, which could damage the battery or reduce its lifespan. It provides overvoltage, undervoltage, and overcurrent protection, helping prevent safety risks like overheating or fires. The system also provides short-circuit protection and manages charging cycles efficiently. Some 5V BMS units include a low-voltage cutoff to disconnect the battery when

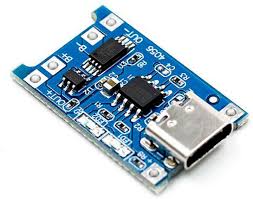


Figure 3: BMS Module (TP4056)

it drops below a certain threshold. Often used in portable electronics, solar power systems, and electric vehicles, a 5V BMS helps improve battery performance and longevity. The BMS can be integrated with a charging circuit for automated charging. Many 5V BMS modules are compact and designed to be cost-effective, making them ideal for DIY projects. A well-designed 5V BMS ensures that the battery system remains reliable and safe throughout its lifetime.

5. LCD Display with I2C Module

An LCD Display with I2C Module combines a standard 16x2 or 20x4 LCD screen with an I2C communication interface, simplifying wiring and control. The I2C module uses only two data pins (SDA for data and SCL for clock), reducing the number of connections required compared to traditional parallel LCD connections. This makes it easier to control the display with microcontrollers like Arduino while saving valuable GPIO pins.

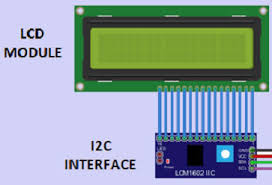


Figure 3: LCD Display with I2C Module

The I2C module also typically includes backlight control for better visibility. It supports multiple devices on the same bus, allowing several LCDs or sensors to be controlled simultaneously. The display can show text, numbers, and simple characters. The I2C interface also allows for easier programming and more efficient memory usage. Many LCD displays with I2C modules have adjustable brightness and contrast. This setup is commonly used in embedded systems and IoT projects for status updates or data visualization. The I2C LCD is a cost-effective, compact, and versatile solution for many display needs.

**SOFTWARE CODE**

#include <Wire.h>

#include <LiquidCrystal\_I2C.h>

#include <ESP8266WiFi.h>

#define BLYNK\_TEMPLATE\_ID "TMPL3ymYfC8Ef"

#define BLYNK\_TEMPLATE\_NAME "Battery Management System "

#define BLYNK\_AUTH\_TOKEN "Your Auth Token"

// Initialize the I2C LCD (Address 0x27, 16x2 LCD)

LiquidCrystal\_I2C lcd(0x27, 16, 2);

int chargingPin = 2; // Digital pin connected to the TP4056 charging status

bool isCharging;     // Variable to store charging status

// Wi-Fi credentials

const char\* ssid = "OnePlus Nord 2";        // Replace with your Wi-Fi SSID

const char\* password = "11111111"; // Replace with your Wi-Fi password

void setup() {

  // Initialize serial communication

  Serial.begin(9600);

// Initialize LCD

  lcd.init();

  lcd.backlight(); // Turn on LCD backlight

// Configure the charging status pin

  pinMode(chargingPin, INPUT);

  // Connect to Wi-Fi

  WiFi.begin(ssid, password);

  while (WiFi.status() != WL\_CONNECTED) {

    delay(500);

    Serial.print(".");

  }

  Serial.println("Connected to Wi-Fi");

// Delay for setup

  delay(1500);

}

void loop() {

  // Read charging status from the TP4056 module

  isCharging = digitalRead(chargingPin);

// Print charging status to Serial Monitor

  Serial.print("Charging Status: ");

  if (isCharging) {

    Serial.println("ON");

  } else {

    Serial.println("NO");

  }

  // Read the battery voltage (assuming a voltage divider for 3.3V analog reference)

  int sensorValue = analogRead(A0);

  float voltage = (sensorValue \* 3.3) / 1024 \* 2; // Adjust the calculation based on your hardware

  // Calculate battery percentage (adjusted for 2.8V to 4.2V range)

  float bat\_percentage = mapfloat(voltage, 2.8, 4.2, 0, 100);

  if (bat\_percentage >= 100) {

    bat\_percentage = 100;

  }

  if (bat\_percentage <= 0) {

    bat\_percentage = 1;

  }

  // Display battery voltage, percentage, and charging status on the LCD

  lcd.setCursor(0, 0);  // Set cursor to the first row

  lcd.print("Volt: ");

  lcd.print(voltage, 2);  // Display voltage (2 decimal places)

  lcd.print("V");

  lcd.setCursor(0, 1);  // Set cursor to the second row

  lcd.print("Bat per: ");

  lcd.print(bat\_percentage, 0);  // Display battery percentage (integer)

  lcd.print("%");

  lcd.setCursor(10, 1);  // Set cursor for charging status

  lcd.print("Chg: ");

  if (isCharging) {

    lcd.print("ON");

  } else {

    lcd.print("NO");

  }

  delay(1000);  // Update every second

  lcd.clear();  // Clear LCD for the next display cycle

}

// Function to map float values

float mapfloat(float x, float in\_min, float in\_max, float out\_min, float out\_max) {

  return (x - in\_min) \* (out\_max - out\_min) / (in\_max - in\_min) + out\_min;

}

**APPLICATIONS**

1.Electric Vehicles (EVs):

Battery Management Systems are essential in EVs to monitor battery health, optimize charging cycles, and prevent thermal runaway. They ensure the longevity of batteries and improve vehicle performance. For example, Tesla employs advanced BMS in its EVs to enable rapid charging while preserving battery health.

2.Renewable Energy Systems:

In solar and wind energy systems, BMS plays a vital role in managing energy storage units (e.g., Lithium-ion or Lead-acid batteries). It ensures the batteries store excess energy efficiently and provides reliable power during periods of low generation. Real-world implementations include BMS in off-grid solar systems used in rural electrification projects.

3.Data Centre

DFUN Provides the best solution in UPS & Data Center which can cover almost all UPS applications. The solution is very flexible, customer can select different solutions for different project requirements. With built-in web page, customers can realize real-time monitoring the battery status in a price-competitive way. We also provide central BMS system for large multi-site applications.

4. [Utilities](https://www.dfuntech.com/Utilities-id43680147.html)

DFUN provides targeted [Battery Monitoring System](https://www.dfuntech.com/Battery-Monitoring-System-pl45427887.html) for DC distribution applying in Power Plants, utilities and Substations. The solution can monitor both Ni-Cd and VLA/VRLA cell. What's more, it can easily integrate into existing system by using SNMP, Modbus and 4G to centralize monitoring.

5.[Telecom](https://www.dfuntech.com/Telecom-Site-id42680147.html)munication

DFUN offers Battery Monitoring System for various Telecommunication applications. DFUN BMS ensures the stable operation of telecommunications by comprehensively supervising and maintaining the base station power backup battery.

6.[Transport](https://www.dfuntech.com/transport.html)ation

As a real-time online program designed for use in the field of transport, DFUN Battery Monitoring System displays the status of the vehicle's power supply system and the emergency backup power supply for the stations (SOC, SOH, etc.) in real-time[2].

7.[E](https://www.dfuntech.com/EV-Charger-Energy-Management-id47580147.html)nergy Storage

A battery safety monitoring system is essential for the development of the energy storage industry. The Battery Monitoring System helps to improve the power and energy efficiency of battery packs, reduce the costs associated with their application, and ensure the safety and reliability of energy storage devices.

8.[Oil & Gas](https://www.dfuntech.com/Chemical-Oil-Gas-id41680147.html)

Designed for the high protection application. With waterproof, fireproof, and anti-corrosion features. Real-time online monitoring 2/12V Lead-Acid batteries and 1.2V Ni-Cad batteries. Let the battery always stay in the best condition and helps customers reduce the battery's risk.

**CONCLUSION**

We Done the IoT-Based Battery Management System (BMS) project successfully addressed key challenges in battery monitoring and management through the integration of modern IoT technologies. By leveraging the capabilities of the ESP8266 microcontroller and Arduino IoT Cloud, we developed a system capable of monitoring critical battery parameters—such as voltage, charge percentage, and charging status—in real time and remotely. This not only enhances user convenience but also improves battery safety and longevity.

Through this project, we achieved the following milestones:

* Designed and implemented a functional hardware and software system for remote monitoring.
* Enhanced our understanding of IoT technology, microcontroller programming, and battery safety protocols.
* Demonstrated practical applications of BMS in electric vehicles, renewable energy storage, and other industries.

This project highlights the importance of smart monitoring systems in ensuring safe and efficient use of batteries, which is crucial as we transition to a more electrified and sustainable future. Our learnings and achievements in this project lay a strong foundation for further exploration into advanced battery management systems and their diverse applications.

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4. Chatzakis J, Kalaitzakis K, Voulgaris NC, Manias SN. Designing a new generalized battery management system. IEEE transactions on Industrial Electronics. 2003 Oct 7;50(5):990-9.

5. The Battery Status Monitoring System utilizing the ESP8266, Arduino, and IoT Cloud for real-time monitoring and management of battery parameters is detailed on iotprojectsideas.com.