

Battery Management System for Dual-Chemistry Applications

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Abstract—With the rapid advancement of electrochemical storage technologies, efficient Battery Management Systems (BMS) have become indispensable for ensuring the safe, reliable, and optimal operation of energy storage solutions. This research focuses on designing a flexible and cost-effective BMS that supports lithium-ion and sodium-ion battery chemistries, primarily targeting nominal voltage ratings of 24V and 36V. The proposed BMS architecture incorporates an Arduino Nano microcontroller, integrated sensors, and control circuitry to monitor real-time parameters such as voltage, current, and temperature. Key features include a DIP switch for battery selection, voltage scaling using a divider network, and safe current and temperature sensing using ACS712 and LM35 sensors, respectively. The system displays critical data on a 16x2 LCD screen via I2C communication for enhanced usability. The BMS is particularly suited for applications such as electric vehicles, renewable energy systems, and portable electronics. Its modularity and adaptability offer a modern approach to managing diverse battery technologies with an emphasis on safety, performance, and affordability.

Index Terms—Battery Management System (BMS), Lithium-ion Battery, Sodium-ion Battery, Arduino Nano, Current Sensor (ACS712), Temperature Sensor (LM35), Voltage Divider, DIP Switch, MOSFET Switching, Real-Time Monitoring, Dual-Chemistry Support, Energy Storage Systems

I. INTRODUCTION

In recent years, energy storage has emerged as a critical component across numerous sectors including electric vehicles, portable electronics, and renewable energy systems. The growing reliance on rechargeable batteries necessitates using Battery

Management Systems (BMS) that can handle diverse operational and safety challenges. These include overcharging, over-discharging, temperature fluctuations, and current surges.

To address these challenges, this paper presents the design and development of a flexible, multi-chemistry BMS. The system is engineered to support lithium-ion and sodium-ion batteries, both of which have gained popularity due to their high energy densities and cost-effectiveness.

This prototype is particularly suitable for low-to-medium scale energy systems and is built around the Arduino Nano, enabling a low-cost, modular solution.

II. LITERATURE REVIEW

A range of battery chemistries and management strategies has been investigated in earlier research. Lithium-ion battery management systems (BMS) typically incorporate integrated circuits that utilize specific communication protocols, such as SMBus, CAN, or I2C. In contrast, sodium-ion batteries, which are relatively new, are becoming increasingly popular due to the widespread availability of sodium and their eco-friendly nature.

However, the majority of commercially available BMS solutions are tailored to a single type of battery chemistry and tend to be inflexible. Additionally, these systems are often proprietary and costly. Recently, the rise of open-source electronics and microcontroller-based frameworks has led to the creation of DIY BMS options that offer both customization and scalability. This project seeks to close the gap by developing a hybrid system that

3. Voltage Regulation and Power Supply Design

a) Voltage Regulation – LM7805

The LM7805 is a three-terminal linear regulator used to ensure a steady 5V power supply to the Arduino and peripherals. It converts 12V input into a regulated 5V output.

b) Boost Converter - Mini Boost Converter (U2)

Some components like the display may require slightly higher voltages for better contrast. The boost converter steps up the voltage as needed and offers flexibility when dealing with different power sources.



Fig. 4. Mini boost converter

These regulators maintain power stability and isolate sensitive digital components from voltage fluctuations in the battery.

4. Switching and Protection Mechanisms

a) IRF540N MOSFET

The IRF540N is an N-channel MOSFET used as a switch for load control. It allows high current flow and is triggered by a digital output from the Arduino. When thresholds are exceeded, the Arduino can cut off the current path by turning off the MOSFET.

b) Zener Diodes and Voltage Divider Network

Zener diodes (IN4733A) are added to protect analog pins from voltage spikes. The voltage divider reduces the battery voltage down to a safe level (under 5V) for the Arduino's analog inputs, enabling accurate voltage readings without damaging the board.

5. Display and User Interface

The 16x2 LCD (Fig. 5) with I2C backpack is used to display real-time data like voltage, current, and temperature. The I2C interface allows communication using only two wires (SDA, SCL), conserving digital I/O pins for other uses.



Fig. 5. LCD display

The display updates at regular intervals and offers immediate visual feedback, especially useful during debugging or user monitoring.

6. DIP Switch Configuration and Multi-Chemistry Support

The DIP (Fig. 6) switch serves as a simple user interface allowing the user to choose between battery chemistries or voltage profiles. The Arduino reads the state of these switches on startup and configures operational limits accordingly.

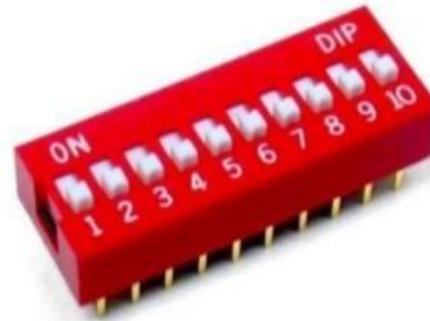


Fig. 6. DIP switch

This configuration enables the same BMS hardware to be used with different types of batteries, enhancing flexibility and reducing costs. For instance, if the DIP switch is set to lithium mode, the voltage cutoff values are different compared to sodium mode.

IV. DESIGN METHODOLOGY

A. Requirement Analysis The design process began with identifying the requirements of a dual-chemistry BMS. The system needed to monitor key battery parameters, support different voltages, be reconfigurable without hardware changes, and be built with cost-effective components.

B. Component Selection Each component was selected based on availability, affordability, compatibility, and power efficiency. The Arduino Nano was chosen as the controller due to its ease of programming and community support. The ACS712 and LM35 were selected for sensing due to their linear output and accuracy.

B. System Prototyping Before physical implementation, the design was tested using Tinkercad simulations. These simulations verified the accuracy of sensor readings and switching operations. A prototype was later developed on a breadboard, allowing real-time validation of the circuit logic.

V. SYSTEM WORKFLOW AND ARCHITECTURE

The complete system follows a modular workflow (Fig. 7) :

1. Data Acquisition – Sensors continuously monitor voltage, temperature, and current.
 2. Data Processing – The Arduino reads analog signals, calculates values, and checks for safety thresholds.
 3. Control Logic – If any value exceeds predefined limits, the Arduino disables the load via the MOSFET.
 4. Data Output – Real-time values are displayed on the LCD for the user.
 5. User Configuration – Based on DIP switch inputs, the system adjusts its operating limits.
- Each module is independently testable, improving system maintainability and scalability.

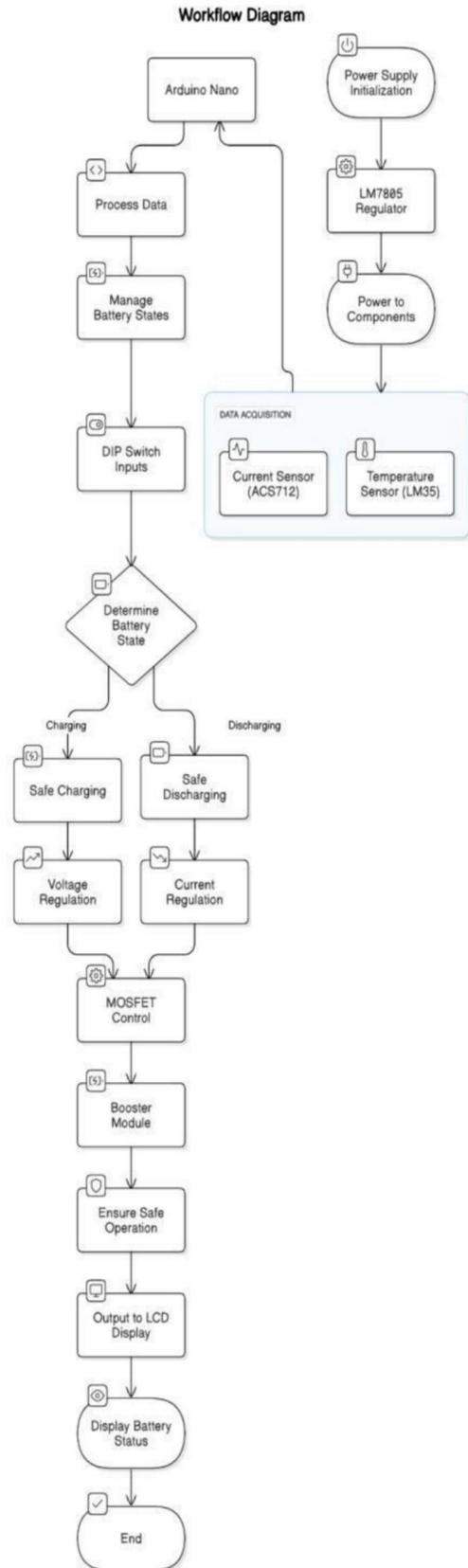


Fig. 7. Workflow diagram

The real-time display is managed using a 16x2 I2C LCD. This display reduces the number of required digital pins and simplifies wiring. Parameters displayed include voltage, current, and temperature.

X. TESTING PROCEDURES

The system was tested under both normal and fault conditions. During testing, lithium-ion and sodium-ion battery packs were connected, and behavior under charge/discharge cycles was monitored.

Simulated faults were introduced using resistive loads and heat sources. Overcurrent was tested by applying high loads, while temperature response was checked using a soldering iron near the LM35.

All sensor outputs were cross-verified using external tools such as digital multimeters and temperature probes.

XI. EXPERIMENTAL RESULTS

The BMS was able to identify and operate with both battery chemistries, changing threshold logic based on DIP switch input. Voltage measurements were consistent within $\pm 2\%$ error compared to multimeters. The ACS712 performed well with low and medium current loads, though minor noise was observed during high-current discharge. This was mitigated through software averaging.

The LM35 responded accurately to temperature changes, and the MOSFET reliably triggered shutdowns when thresholds were breached.

XII. CHALLENGES AND LIMITATIONS

One challenge encountered was voltage instability due to resistance on the breadboard. This led to occasional analog noise and unreliable readings. Moving to a PCB design is expected to alleviate these issues.

Another limitation is the accuracy of the ACS712, especially in low-current scenarios. Future designs may benefit from Hall-effect sensors with better resolution. Also, the DIP switch could be replaced with a more intuitive configuration interface.

XIII. APPLICATIONS AND SCALABILITY

This BMS prototype is ideal for:

- Electric bicycles and scooters
- Solar power storage units
- Educational demonstrations
- Portable medical or IoT devices

Due to its open-source nature, the system can be scaled with additional features such as:

- Bluetooth communication
- Battery balancing
- Data logging via SD card
- Cloud connectivity

XIV. APPLICATIONS AND FUTURE SCOPE

This flexible BMS design can be implemented in electric bicycles, small electric vehicles, portable solar inverters, and educational projects. Its adaptability makes it suitable for both research and low-scale commercial deployment.

Future enhancements include wireless communication (via Bluetooth or LoRa), implementation of SOC (State of Charge) algorithms, fault logging, and support for additional chemistries. Passive and active cell balancing methods can also be added.

XV. FUTURE ENHANCEMENTS

While the current system addresses basic monitoring and control, future iterations may include:

- Integration with mobile apps via Bluetooth
- Support for multiple battery packs in parallel
- Enhanced fault detection and logging
- Machine learning for predictive maintenance

Additionally, replacing the Arduino Nano with more powerful boards (e.g., ESP32) could enable wireless data transmission and cloud analytics.

XVI. CONCLUSION

This paper presents a complete implementation of a flexible, low-cost Battery Management System capable of supporting both lithium-ion and sodium-ion chemistries. The modular design, user configuration, and real-time monitoring make it ideal

for modern energy applications. The research validates the feasibility of affordable BMS designs without compromising safety or performance.

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