PROJECT ABSTRACT

IoT Battery Health and State-of-Charge Monitor for LiFePO4 Packs

An ESP32-based battery monitor for a 12V 100Ah LiFePO4 pack: INA219 current sensing, 4S cell-balance taps, NTC temperature, coulomb-counted SoC with rest-voltage recalibration, SoH health tracking, over-temperature relay cutoff and a local web dashboard. Delivered built-to-order with prototype, firmware, dashboard, report, PPT and viva kit.

01. Title

IoT Battery Health and State-of-Charge Monitor for LiFePO4 Packs.

02. Introduction / Background

Lead-acid and lithium battery packs in solar installations, e-rickshaws and UPS systems die early when nobody watches their health: a single weak cell drags the whole 4S string down, over-discharge damages the pack, and the owner discovers the damage only when the load dies. A proper battery monitor turns the invisible visible — current in and out, per-cell voltage spread, temperature and cumulative cycle count — so the user can act before a cell is destroyed. This project builds that monitor as a working prototype: an ESP32 with an INA219 current sensor sits in series with a 12V 100Ah LiFePO4 pack, balance taps report each cell's voltage, an NTC watches temperature, and the firmware integrates current over time (coulomb counting) to report state-of-charge, corrected at rest by the LiFePO4 open-circuit voltage curve. A relay provides an armed over-temperature cutoff, and everything is visible on a local web dashboard and a 16x2 LCD.

03. Problem Statement

Without monitoring, cell imbalance, over-discharge and over-temperature silently destroy battery packs, and SoC is at best a voltmeter guess. The project addresses this with a complete sensing chain: high-side current sensing, per-cell voltage taps, temperature sensing, a coulomb-counting SoC algorithm with OCV recalibration, health estimation and a protection cutoff — all demonstrable on hardware and dashboard.

04. Objectives

- Sense pack current bidirectionally with an INA219 high-side sensor (±3.2 A range, 0.1 mA resolution per datasheet).
- Read individual 4S cell voltages through ADC-safe divided balance taps and report the max cell spread in millivolts.
- Compute state-of-charge by coulomb counting with recalibration against the LiFePO4 open-circuit-voltage curve at rest.
- Estimate state-of-health from cycle count and capacity fade against the 100 Ah design rating, graded GOOD / DEGRADED.
- Implement an over-temperature cutoff: NTC-driven relay output that disconnects the load at 60 °C (configurable) with fault latching.

- Serve live readings on the ESP32-hosted CellScope dashboard (SoC ring, 24-hour charge/discharge chart, cell-balance panel) and a 16x2 LCD.
- Deliver the complete student kit: prototype, firmware, calibration procedure, wiring docs, report, PPT and viva Q&A.;

05. Proposed Methodology

The INA219 is wired in series on the high side; 4S balance taps are divided to ADC-safe levels; an NTC thermistor sits on cell 2. The ESP32 samples voltage and current at approximately 1 Hz and applies a two-point calibration from the buyer's own measurement procedure. Current samples are integrated for coulomb counting, and SoC snaps to the LiFePO4 OCV lookup table whenever the pack rests, countering integration drift. Cell voltages are compared against the group mean; excess spread flags the cell. Cycle counting accumulates full-equivalent cycles for the SoH estimate. The NTC drives the over-temperature logic with a latched FAULT state until manual reset. Firmware is written in the Arduino framework for the ESP32; the dashboard is a single-file HTML/CSS/JS app hosted by the ESP32.

06. System Architecture / Working

The INA219 sits in series with the pack; balance taps feed divided cell voltages to the ADC. The ESP32 samples at ~1 Hz, calibrates, and integrates current for SoC, recalibrating at rest via the OCV curve. Cell spread is computed per cycle; SoH tracks cycles against the 100 Ah rating. The NTC reading crossing 60 °C de-energises the relay and latches FAULT. All readings are served on the CellScope dashboard over Wi-Fi and mirrored to the 16x2 LCD, which shows voltage, SoC, current and temperature at the rig itself.

07. Hardware / Software Requirements

- ESP32 development board (Arduino framework)
- INA219 current sensor module; 4S balance taps with resistor dividers
- NTC thermistor; 5V relay module (10 A contacts, design scope)
- 16x2 LCD (I2C); 12V 100Ah LiFePO4 4S demonstration pack
- HTML/CSS/JS dashboard hosted on the ESP32; buck converter for pack-powered supply

08. Expected Outcomes

A working prototype monitoring a 12V 100Ah LiFePO4 pack; ESP32 firmware with calibration procedure; the CellScope dashboard and LCD status; wiring diagram and component list; a report on coulomb counting, the OCV curve, calibration and test procedure; PPT and viva Q&A.; Design targets: SoC typically ±3–5% after buyer calibration (a design target, not a measured claim), ~1 Hz sampling, 60 °C cutoff.

09. Applications

- Solar home-system battery health monitoring
- E-rickshaw and UPS pack supervision
- Teaching battery-management concepts in labs

10. Future Scope

- Active cell balancing stage

- Cloud logging and phone alerts
- Adaptation kits for other pack voltages and capacities