OPEN ACCESS
Kashf Journal of Multidisciplinary Research
Vol: 01 Issue 12 (2024)
P-ISSN: 3007-1992 E-ISSN: 3007-200X
https://kjmr.com.pk

ADVANCING LITHIUM-ION BATTERY MANAGEMENT: A PORTABLE ARDUINO-BASED HEALTH-MONITORING SOLUTION

Syed Saad Ali
Department of Electrical Engineering, Nazeer Hussain University, Karachi Sindh Pakistan
Shujaat Ali
School of Electrical and Information Engineering, Tianjin University, China
Muzammil Ahmad Khan
Computer Engineering Department, Sir Syed University of Engineering and Technology, Karachi Sindh Pakistan
Muhammad Muzzammil
Department of Electrical Engineering, Nazeer Hussain University, Karachi Sindh Pakistan
Muhammad Faraz Khan
Department of Electrical Engineering, Nazeer Hussain University, Karachi Sindh Pakistan
Khurram Iqbal
Department of Computer Science, Hamdard University, Karachi Sindh Pakistan
Syed Atir Iftikhar
Department of Computer Science, IQRA University, Karachi Sindh Pakistan
DOI: *https://doi.org/10.71146/kjmr142*

Article Info

Abstract

Lithium-ion batteries are mostly used in portable devices. The major purpose of enhancing the battery life is to implement a health analyzer to protect the battery from overcharging and explosions. The "Arduino based portable analyzer for real-time lithium-ion battery health monitoring" prototype deliver sustainable solution to address the battery monitoring and management. This prototype determines perfect specifications for the battery to verify the printed specifications. An LCD was placed in the system to demonstrate the cell capacity, voltage, and current parameters. This system focuses on the intelligent health monitoring of batteries using an Arduino Mega microcontroller. The charging and discharging stations of the two stations are designed to charge and analyze battery health. The discharging station was used to verify the battery health, and the charging station was used to charge the lithium-ion batteries. The IRLZ44N MOSFET was integrated with an Arduino gate pin for switching purposes. The system uses Arduino IDE software for software implementation. The microcontroller controls and monitors the processing measurements, and the implementation of this intelligent system increases the life span and thermal monitoring of lithium-ion batteries. Compared with previous studies, this system is economical and has increased efficiency in lithium-ion battery systems

Keywords: *portable, lithium-ion batteries, health monitoring, prototype.*

Introduction

Lithium-ion batteries powered electric vehicles. This study focuses on the testing of lithium-ion batteries for implementation in cars. This study investigated techniques to evaluate Lithium-ion batteries for efficient operation [1]. This study focuses on lithium-ion battery capacity. This study investigates battery techniques to assess their effect and examines measures to improve the performance and increase the life of the battery. [2]. Rise in energy requirements and implementation of sustainable solutions. Lithium-ion batteries are smart energy-storage equipment with reliable and safe operation. Thermal and temperature issues are also considered in this study. Health management is a major issue that must be addressed. This study investigated the temperature parameters and framework to reduce the thermal effects [3]. Reliable operation is required for the longevity of lithium batteries. The Accurate state of the health prediction model utilizing the Gaussian process predicts the future battery information. Forty-eight lithium-ion batteries were considered for the prediction and study [4]. Lithium-ion battery management and monitoring play an important role in longevity. Challenges, such as thermal and temperature, were considered in this study for modern advancement. This study examines the advancement in promoting battery prognostics and health management utilizing deep learning methods [5]. The maximum utilization of lithium batteries is mostly for electric vehicles. This study describes the construction of an intelligent system for a health analyzer using an STM32 controller. The heat and charge parameters improve the battery efficiency. The integration of Internet of Things (IoT)-based systems predicts maintenance using optimization techniques [6]. Growth in electrical vehicles across the globe. The use of IoT-based automatic systems is an innovative technology. These vehicles use lithium batteries, but there is a need to implement a battery management system to increase the battery life [7]. The batteries depend on charging and discharging. Proper monitoring of batteries is required, and this study provides a study regarding the construction of economical and IoT electronic dummy load management systems using microcontrollers to check the state of charge and health. The system checks for a reduction in the voltage level and evaluates the battery capacity and health. Real-time data are transmitted to web and mobile applications to track battery performance. The results show that the effective and reliable state of charge and health parameters are used to monitor the battery [8]. The global focus has been on sustainable renewable-based power generation. To store this sustainable power, lithium-ion batteries are used to optimize battery operation and efficiency. The battery needs to monitor overcharging to ensure its longevity. The integration of internet of things with long rage (LoRa) monitor and transmit the power, charge and temperature parameters to the server. An Objective Modular Network Testbed (OMnet++) was configured and simulated to monitor the battery. A carrier frequency of 433 Megahertz with 125 kHz and 2 decibel power transmission was considered for the study [9]. Preventive maintenance and charge monitoring of batteries are required for optimal battery solutions. The ESP8266 Arduino microcontroller is linked to the engine and battery to measure the current and voltage compared to the revolutions per minute [10]. An Arduino Nano was integrated into the system to control the power parameters. The charger sample analyzed using the software resulted in 83.3% efficiency after using the designed system [11]. The Internet of Things (IoT)-based battery management prototype was designed in this study to address the losses using a smart system. To monitor the heat damage charges that harm the efficiency and longevity of the battery [12]. Lithium batteries are rarely used compared with conventional batteries owing to their efficiency and longevity. This study focused on fast charging by utilizing fuzzy logic for the observation and demonstration of real-time parameters. This monitoring system increased the efficiency of battery charging by 23.3 %. Arduino and MATLAB Simulink analyze the parameters for quick charging [13]. Electric vehicles use lithium batteries as their energy system. These energy systems require a nonstop monitor to save battery life. To decrease the thermal effect, battery management is required to overcome the fire protection [14]. Lithium-ion batteries require diagnostic tools to ensure efficient operation. This study focused on the color change of the battery electrolyte for the health of the battery using an advanced optical sensor system. The sensors included a photodiode and an LED integrated with a printed circuit board system to check the battery conditions. This system uses different experimental methods and techniques to diagnose the electrolyte color and cell performance [15]. Most electric cars use battery storage systems to manage cars. Internet of Things (IoT)-based battery management is required to maintain safe and optimized operation. The cloud-constructed system analyzes charge and health utilizing innovative algorithms. This algorithm analyzes abnormal conditions in the battery system. The battery charging parameters were analyzed to protect the battery from overcharging. Battery overcharging emits gases, including oxygen and hydrogen, which decrease battery lifespan [16]. This study focuses on the experimental setup of the TP100 lithium battery for the integration and implementation of a wind turbine system in Soweto, South Africa. The research findings show that lithium-ion batteries can be used for the optimum storage of wind turbine energy. The 160 kVA Three phase cloud management system considers for the study using BMS software [17]. This study demonstrates the development and application of seven-level active neutral-point-clamped invertor topologies for high-efficiency and voltage control. The inverter components included eight switches, two capacitors, and two diodes. Using these components, the inverter gains the voltage parameters, and the capacitor balances the voltage for efficient equipment operation. This study performed comprehensive analyses to manage the voltage and power parameters. The experimental and simulation results show that the drive and inverter performance increases and significantly stores renewable energy in batteries [18]. An automatic solar-powered irrigation system was designed in this study. The system includes 20-watt solar panel, 5-watt motor and 1200 mAh lithium battery to store renewable power [19]. An Internet of Things Arduino-based monitoring and control system was considered in this study to manage the load. The findings demonstrate that this automatic system switches the extra load during peak hours and saves energy to increase utility bills [20]. Battery management of the voltage is very important to ensure the proper supply of power. To avoid battery and load failures, data-driven approaches were considered in this study to model the Gaussian process using a machine learning system. The result shows that the mean square error model is considered with an IoT-based system to collect the battery voltage and temperature parameters using the respective sensors [21]. This study focuses on battery management systems for electric cars. The system includes current, temperature, and voltage sensors integrated with an Arduino to monitor the battery temperature and switch the cooling system. A Global System for Mobile Communications is utilized to monitor battery parameters to prevent battery damage. The system used a programming-based Arduino to monitor the battery [22]. Currently, each individual spends time on electronic gadgets during charging without ignoring the battery health state. The computer system shows the battery percentage while not monitor the battery health [23]. The purpose of this study is to design a battery management system capable of measuring the resistance and internal parameters used in different communication systems. The lithium-ion battery LifeP04 batter was considered in this study to check the energy density and power parameters to increase the lifespan of the battery. The electronic monitoring system uses an Arduino Uno with a voltage sensor and Wi-Fi module to demonstrate the real-time parameters [24]. Electrical cars integrated with lithium batteries have attracted considerable attention. Vehicles are shifting from conventional to electrical systems to reduce fossil-fuel-based technology. Thus, the efficiency of the battery needs to be improved. To improve efficiency, Internet of Things (IoT)-based technologies must be implemented. This study forecasted battery charging/discharging parameters to estimate battery parameters [25]. This study focused on lithium polymer batteries to monitor and test their stability. This study observed the state of charge and health of the batteries. Different methods are used to inspect the charge for reliable operation with lessen errors [26].

MATERIALS AND METHODS

A. Hardware Components

Microcontroller: The Arduino ATmega2560 was used to design the prototype. All hardware components were integrated with a microcontroller to analyze the health of the batteries. The table shows the Arduino pin configuration.

Table 1 Arduino specification

S.	Pin number	Pin configurations
1	D0 - D53	54 Digital I/ O Pins.
2	A0 - A15	16 Analog I/O Pins.
3	D2 - D13	12 Pulse Width Modulation Pins
4	RX0-RX3	Receiving Serial Communication Ports
5	TX0-TX3	Transmitting Serial Communication Ports

MOSFET: The MOSFET connected with power resistor load to the cell for the discharging of cell linked with Arduino.

Table 2 MOSFET specification

S.	Specifications	Values
1	Voltages	VGS = 0 V VDS = 25 V
2	On state resistance	25 m ohms VGS = 5 V
3	On state resistance	22 m ohms VGS = 10 V
4	Operating temperature	-55 °C to 175 °C

Lithium-ion battery: The lithium-ion cell utilized in this prototype to charge and analyze battery health.

Figure 1 lithium-ion batteries

Power Resistors: The 10 watt, 10 Ω power resistors were installed in the system and utilized as a load resistor connected with a MOSFET for the discharge indication.

Figure 2 Power Resistor

Table 3 Power resistor specification

S.	Specifications	Values
1	Resistance	10 ohms
2	Tolerance	5%
3	Voltage	550 V
4	Temperature	-55^{o} to $+155^{o}$ C

Charging module: The charging module TP-4056 was utilized for lithium battery charging and overcharge protection.

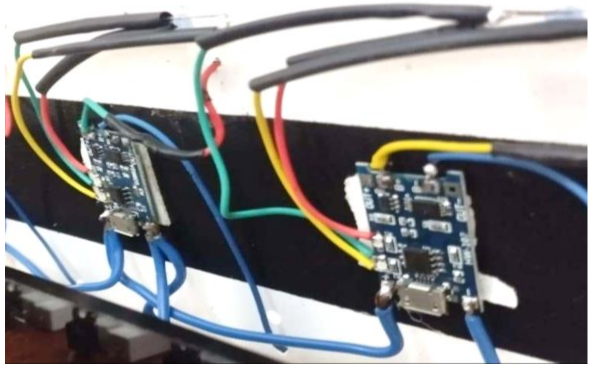

Figure 3 Charging module

Table 4 Charging module LED specification

S.	Charge	RED	Green
1	Charging	ON	OFF
2	Full	OFF	ON

Methods

This prototype key component of the Arduino microcontroller managed and monitored the charging and discharging parameters. Arduino IDE software was utilized for the programming setup. All the instructions were set in the program. There are five charging stations and five discharging stations to test battery health. If any cell is not connected, the LED demonstrates no battery indication; otherwise, it demonstrates the voltage, current, and battery heath condition percentage. The battery analyzes health by the time period for discharging, calculates the time eriod, and indicates the battery life. The power resistors were connected to the MOSFET to discharge the cell. When the cell is completely discharged, it indicates the LED indication to show battery health. The Arduino controls the MOSFET operation and load resistor connected to the battery load. A powerful charger was connected to the system to charge the batteries. Figures 4, 5, and 6 show the hardware flow, schematic diagram of the proteus, and experimental setup of the prototype.

B. Hardware Flow

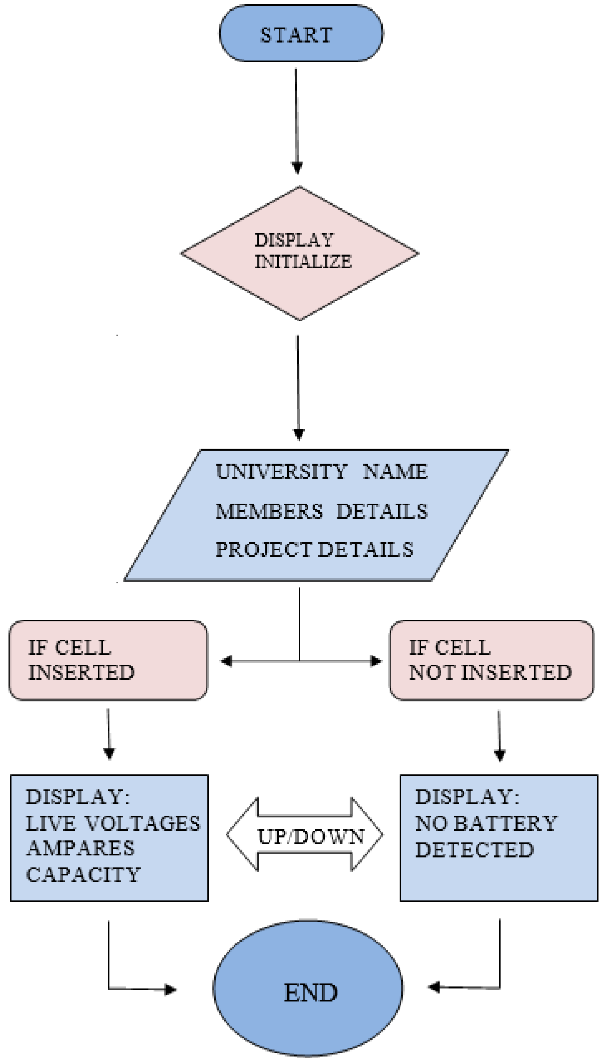

Figure 4 Hardware flow

C. Schematic Diagram

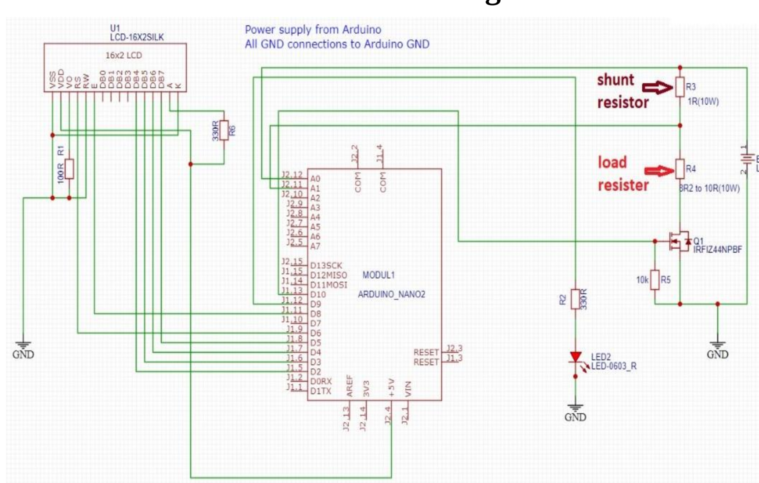

Figure 5 Schematic diagram

D. Experimental setup

Figure 6 Experimental setup

RESULTS AND DISCUSSION

The latest battery-powered systems require efficient operation to enhance the lifespan of lithium batteries. The charge discharge parameters must be monitored to analyze the lifespan. This prototype worked efficiently and was able to detect battery health. The system includes five charging stations to charge the battery and five discharge stations to analyze battery health by calculating the time period. The battery parameters monitored were voltage, power, current, and health capability. All hardware components were integrated with the main controller to monitor the health parameters. The following calculations were used to analyze the health parameters.

Battery voltage: 3.7 Volts

Reference voltage 5 Volts

Shunt resistor 0.1 Ohms

Shunt Resistor Voltage Calculation:

$$Shunt\text{ voltage } = \frac{Analog\ Read\ vShunt\ Pin}{1023}\, x\ Vard - - - (i)$$

$$Shunt\text{ voltage } = \frac{512}{1023}\, x\ 5$$

$Shunt$ voltage = 2.5 vdc

Shunt Current Calculation:

$$Shunt\text{ current } = \frac{battery\ voltage - shunt\ voltage}{shunt\ resistance} - - - (ii)$$

$$Shunt\text{ current } = \frac{3.7 - 2.5}{0.1}$$

$Shunt$ current = 1.2 Ampere

CONCLUSION

The current battery system uses lithium-ion batteries, which require serious monitoring for reliable and efficient operation. For the optimum solution, the battery discharging parameters were observed in this prototype to analyze its health. This is a sustainable solution for enhancing the lifespan of the batteries. These lithium-based batteries are utilized in the latest electronic devices. Therefore, there is a need to implement a monitoring system to overcome this problem. The prototype was designed to include five discharging stations to measure the battery health and five charging stations to charge the battery. The key element in this system is the Arduino Mega, which controls hardware components. As in previous projects, this system is a cost-effective and optimal solution.

The experimental results verified the battery efficiency and capacity closely. This system automatically monitored the operation and health of multiple batteries. The prototype observes individual cell parameters to provide real-time data.

The future prospects of this study are to integrate the Internet of Things-based technologies to monitor and observe parameters via cloud servers.

Acknowledgment

We acknowledge the Department of Electrical Engineering, Nazeer Hussain University, for allowing us to conduct this experimental study.

Conflict of Interest

There is no conflict of interest.

References

- Yang, B., Qian, Y., Li, Q., Chen, Q., Wu, J., Luo, E., ... & Wang, J. (2024). Critical summary and perspectives on state-of-health of lithium-ion battery. Renewable and Sustainable Energy Reviews, 190, 114077.
- Tian, J., Fan, Y., Pan, T., Zhang, X., Yin, J., & Zhang, Q. (2024). A critical review on inconsistency mechanism, evaluation methods and improvement measures for lithium-ion battery energy storage systems. Renewable and Sustainable Energy Reviews, 189, 113978.
- Zheng, Y., Che, Y., Hu, X., Sui, X., Stroe, D. I., & Teodorescu, R. (2024). Thermal state monitoring of lithium-ion batteries: Progress, challenges, and opportunities. Progress in Energy and Combustion Science, 100, 101120.
- Merrouche, W., Harrou, F., Taghezouit, B., & Sun, Y. (2024). Improved lithium-ion battery health prediction with data-based approach. e-Prime-Advances in Electrical Engineering, Electronics and Energy, 7, 100457.
- Massaoudi, M., Abu-Rub, H., & Ghrayeb, A. (2024). Advancing lithium-ion battery health prognostics with deep learning: A review and case study. IEEE Open Journal of Industry Applications.
- Zaheer, S., Krishna, A., Surendran, A., & Sreedeepam, D. (2024). Design and Implementation of a Dashboard for Battery Health Monitoring in Context to Industry 4.0.
- Kalyani, G., Sindhu, V., Kalyani, G., & Sindhu, V. (2024). Design and Analysis of IoT-Based Battery Management and Monitoring System for Electric Vehicle. vol, 11, 42-54.
- Gozuoglu, A. Iot-Enhanced Battery Management System for Real-Time SOC and Soh Monitoring Using Stm32-Based Programmable Electronic Loa. Available at SSRN 4981426.
- Krishna, G., Singh, R., Gehlot, A., Shaik, V. A., Twala, B., & Priyadarshi, N. (2024). IoT-based real-time analysis of battery management system with long range communication and FLoRa. Results in Engineering, 23, 102770.
- Winoko, Y. A. (2024). ESP 8266-BASED CAR BATTERY CURRENT And VOLTAGE MONITORING DESIGN. Evrimata: Journal of Mechanical Engineering, 51-56.
- OLAYINKA, O. M., IBUKUN, A. J., & DAYO, E. T. (2024). THE FORM AND TECHNIQUE OF 12V 75 Ah BATTERY CHARGER. International Journal of Applied and Advanced Engineering Research.
- Sathe, G. N., Devakate, P., Bhure, S., & Koti, S. A. (2024). Optimization Techniques for Battery Health Monitoring and Management.
- Tariq, N. U. S. A., Zeb, K., Kamal, M., Amin, S., & Ali, M. U. Improving Charging Time of Li-Ion Batteries Using Non-Linear Controller.
- Reddy, P. J. K., Kumar, S. P., Rohith, R. S., Satya, B., Uma, T., Nikitha, P., & Niranjan, V. (2024). EV battery soH, soC monitor on the edge of speed control and fire protection. International Journal of Science and Research Archive, 12(2), 1846-1856.
- Sattar, S., Statheros, T., Rahman, S., Gardner, C., Kellner, Q., Bhagat, R., ... & Guo, Y. (2024). Instrumentation of novel optical sensor technology to detect the real-time electrolyte colour change in Li-on pouch cells. Measurement: Energy, 3, 100014.
- PC, S. C. (2024). Enhancement on IoT Based Battery Management System For Electric Vehicles.
- Sithole, T., Veerdhi, V. R., & Sithebe, T.

(2024). The BMS Tool Monitoring Vertiv UPS and Vision Lithium-Ion Battery System. International Journal of Electrical, Energy and Power System Engineering, 7(1), 55-66.

- Ali, S., Che, Y., Abro, G. E. M., & Zafar, A. (2024). Design Analysis of Seven-Level Active Neutral Point Clamped Inverter Based on Diode and Switched Technique. Arabian Journal for Science and Engineering, 1-19.
- Ali, S. S., Ali, S., Khan, J., Khan, Z., Saleem, M., Munawwar, S., & Khawer, H. (2024). Design and Implementation of a Sustainable Microcontroller-based Solar Power Automatic Water Irrigation Control and Monitoring System. Pakistan Journal of Engineering Technology and Science (PJETS), 12(01), 78-90.
- Ali, S., Ali, S. S., Khan, M. A., Hussain, M. A., Khan, M., & Karim, H. F. (2024). IoT enabled implementation of a smart energy management system for real-time monitoring and controlling. VAWKUM Transactions on Computer Sciences, 12(2), 81-98.
- Zhang M, Winata, H., & Surantha, N. (2023). Online Voltage and Degradation Value Prediction of Lead Acid Battery Using Gaussian Process Regression. Applied Sciences, 13(21), 12059.
- Kavitha, K., Logeshwar, R., Kavinkumar, R., Manojkumar, A. R., & Sachin, R. M. (2023). EV Battery Monitoring System using GSM.
- Rana, S. O. H. A. I. L., Ansari, N. M., Rehman, M. U., Iqbal, R. I. Z. W. A. N., Ismail, M. U. H. A. M. M. A. D., AYUB, S., & SHAIKH, M. A. (2023). Design and implementation of laptop battery analysis tool. Journal of Jilin University (Engineering and Technology Edition), 42(2), 219-231.
- Man, M., Aziz, M. F. A. B., Zaki, F. A. M., Bakar, W. A. W. A., Yusof, M. K., Chew, C. S., ... & Josdi, N. L. N. B. (2022). Battery Monitoring System with Internal Impedance Reading (BMS-IIR) Using IoT. Journal of Hunan University Natural Sciences, 49(7)