Journal of Manufacturing Engineering, March 2026, Vol. 21, Issue. 1, pp 006-010
DOI: https://doi.org/10.37255/jme.v21i1pp006-010

LOW-COST ESP32-BASED SMART 18650 LI-ION BATTERY CHARGER WITH IOT MONITORING

W.J. Gayan Gomes[1], Dushan Dinushka[2]

[1] Department of Physics, University of Colombo, Colombo 00300, Sri Lanka.
[2] Department of Electrical Technology, University College of Rathmalana, Rathmalana, Sri Lanka.

Abstract

Lithium-ion batteries, particularly 18650 cells, are widely used in portable electronics, laboratory equipment, and energy storage applications. Safe charging, effective monitoring, and accurate capacity estimation are critical to ensure battery performance and longevity. This paper presents the design and implementation of a low-cost smart battery charger for 18650 lithium-ion cells using an ESP32 microcontroller. The proposed system supports controlled charging and discharging, real-time measurement of voltage, current, temperature, humidity, and battery capacity, and local visualization using an OLED display. In addition, the charger integrates Internet of Things (IoT) functionality through the MQTT protocol, enabling real-time data transmission and cloud-based logging using Google Sheets. Experimental results demonstrate stable charging performance, reliable data acquisition, and effective battery capacity estimation. The developed system is suitable for educational laboratories, battery testing, and low-cost IoT-based energy monitoring applications.

Keywords: *18650 battery, lithium-ion charger, ESP32, IoT, MQTT, battery monitoring, Arduino*

1. Introduction

Lithium-ion batteries have become the preferred energy storage solution for modern electronic devices due to their high energy density, low self-discharge rate, and long cycle life. Among various formats, the 18650 cylindrical lithium-ion cell is one of the most widely used battery types in laptops, power tools, electric vehicles, and laboratory applications. However, improper charging and discharging can significantly shorten battery lifespan and pose safety hazards. Traditional battery chargers often lack intelligent monitoring, data logging, and battery health evaluation capabilities.

Recent research highlights the importance of smart charging techniques, IoT-based monitoring, and cloud data analysis for improving battery management systems [1], [2]. With the rapid development of low-cost microcontrollers such as the ESP32, it is now feasible to design intelligent battery chargers with wireless connectivity and real-time monitoring. This paper presents an ESP32-based low-cost smart 18650 lithium-ion battery charger with IoT-based monitoring. The proposed system measures critical battery parameters, estimates battery capacity via controlled discharge, and uploads real-time data to a cloud platform via MQTT. The design focuses on low cost, simplicity, and suitability for educational and experimental use.

2. System Overview

The smart battery charger consists of a single independent charging slot for an 18650 lithium-ion cell, an ESP32 microcontroller, sensing units, an OLED display, and wireless communication modules. The system is powered by a 5V, 2A external power supply. Figure 01-based representation (block diagram) includes the battery interface, sensing circuits, ESP32 controller, display unit, and IoT communication block.

The main objectives of the system are:

i. Safe charging and controlled discharging of 18650 lithium-ion batteries
ii. Real-time monitoring of voltage, current, temperature, humidity, and capacity
iii. Local visualization of battery parameters
iv. Wireless data transmission and cloud-based storage for analysis

3. Hardware Design

3.1 ESP32 Microcontroller

The ESP32 microcontroller serves as the system's core processing unit. It provides integrated Wi-Fi connectivity, sufficient processing capability, and

**Corresponding Author -E-mail: gayan2664@gmail.com*

Journal of Manufacturing Engineering, March 2026, Vol. 21, Issue. 1, pp 006-010
DOI: https://doi.org/10.37255/jme.v21i1pp006-010

compatibility with the Arduino IDE, making it suitable for IoT-based embedded applications [3], [7]. The ESP32 controls charging and discharging, reads sensor data, updates the OLED display, and handles MQTT communication.

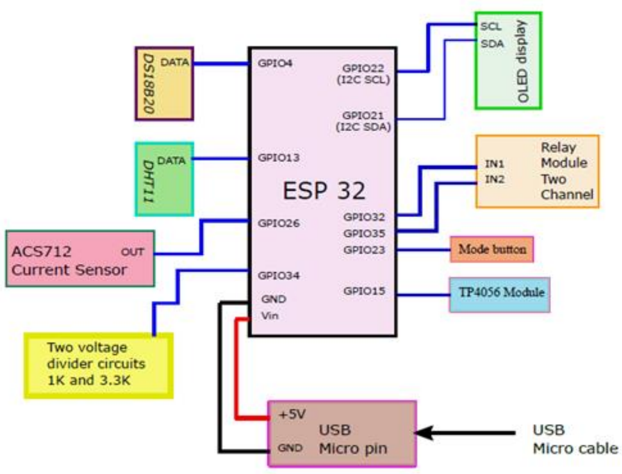

Fig. 1. Block diagram of the proposed ESP32-based smart 18650 Li-ion battery charger system.

3.2 Charging and Discharging Circuit

The charger operates primarily in constant current (CC) mode with a nominal charging current of approximately 1000 mA. The maximum charging voltage is limited to 4.2 V, which is the recommended upper voltage for standard 18650 lithium-ion cells [1]. Discharging is terminated at a minimum voltage of 3.0 V to prevent deep discharge damage.

3.3 Sensors

Battery and environmental parameters are measured using the following sensors:

i. **DS18B20 Temperature Sensor:** Measures battery temperature accurately over a wide range and is suitable for harsh environments.

ii. **DHT11 Sensor:** Measures ambient temperature and humidity to observe environmental conditions during charging and discharging.

These measurements help improve operational safety and provide additional data for analysis.

3.4 Display Unit

A 128 × 64 OLED display shows real-time information, including battery voltage, charging or discharging current, accumulated capacity (mAh), battery temperature, ambient temperature, humidity, and operating time.

4. Software Design

The firmware is developed using the Arduino IDE. The software architecture includes sensor data acquisition, charging and discharging control logic, display management, and IoT communication modules.

4.1 Operating Modes

i. **Charging Mode:** Automatically activated when a battery is inserted. Charging continues until the battery voltage reaches 4.2 V.

ii. **Discharging Mode:** Activated using a mode button when the battery voltage is above 3.0 V. This mode is used to calculate battery capacity.

4.2 IoT and MQTT Communication

The ESP32 connects to a Wi-Fi network and publishes real-time battery data to an MQTT broker (broker.hivemq.com). MQTT is selected for its lightweight communication and reliability in IoT applications [5], [9]. The data are forwarded to Google Sheets using a Google Script ID, enabling cloud-based storage and visualization for further analysis [4], [11].

5. Battery Capacity Measurement

Battery capacity is estimated during the controlled discharge process. After the battery is fully charged, the system discharges the cell while continuously measuring the current over time. The accumulated discharged current is integrated to calculate the battery capacity in milliampere-hours (mAh). This method provides a practical estimate of the battery's usable capacity, which is useful for identifying degraded or faulty cells.

Journal of Manufacturing Engineering, March 2026, Vol. 21, Issue. 1, pp 006-010
DOI: https://doi.org/10.37255/jme.v21i1pp006-010

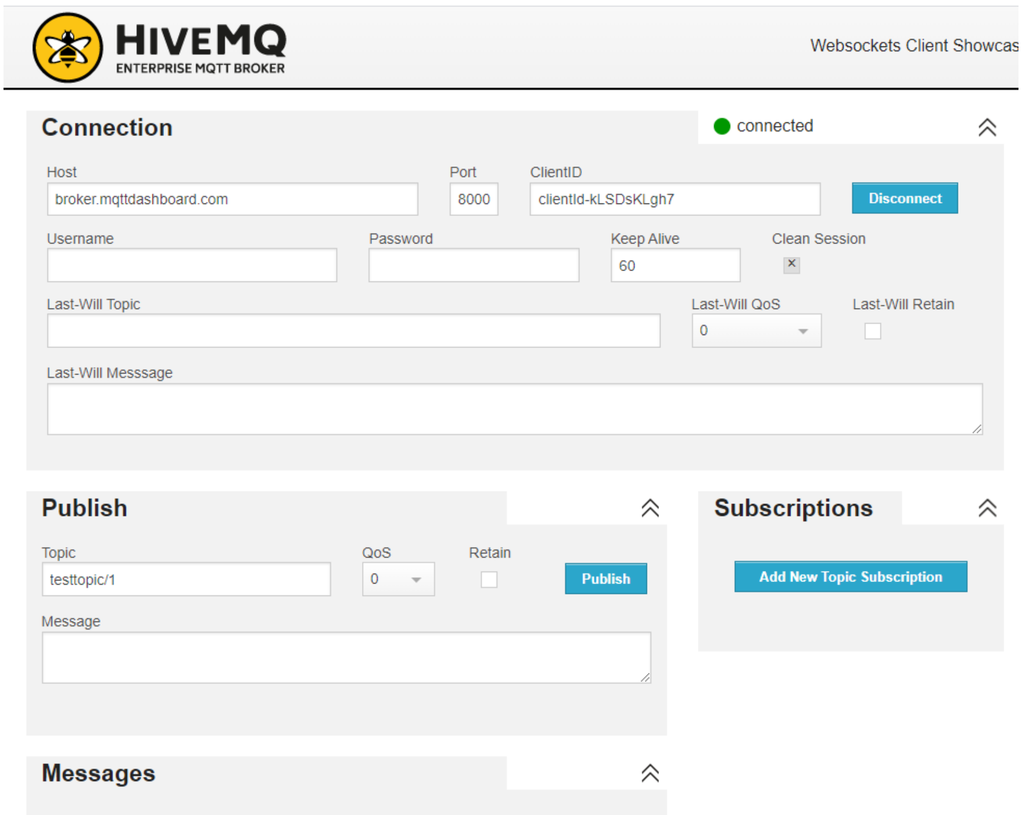

Fig. 2. MQTT broker (broker.hivemq.com) communication.


```
void mqtt ()
{

  WiFi.begin(ssid, password);
  int delaytime = 500;

  sprintf(mqtt_msg, "%2.4f", temp_DHT);
  client.connect("Gayan_40"); //
  client.publish("Gayan_40/2018AE40/Temprature", mqtt_msg);  //
  Serial.println(mqtt_msg);
  delay(delaytime);

  sprintf(mqtt_msg, "%2.4f", Humidity);
  client.connect("Gayan_40"); // change here
  client.publish("Gayan_40/2018AE40/Humidity", mqtt_msg);  //
  Serial.println(mqtt_msg);
  delay(delaytime);

  float Bat_Temp = sensors.getTempCByIndex(0);
  sprintf(mqtt_msg, "%4.2f", Bat_Temp);
  client.connect("Gayan_40"); // change here
  client.publish("Gayan_40/2018AE40/Battery Temprature", mqtt_msg);  //
  delay(delaytime);

  float volt = 0;
  volt = analogRead(34);//gpio 34
```

Fig. 3. The Arduino IDE communication.

Journal of Manufacturing Engineering, March 2026, Vol. 21, Issue. 1, pp 006-010
DOI: https://doi.org/10.37255/jme.v21i1pp006-010

6. Experimental Results

Experimental tests were conducted using standard 18650 lithium-ion cells. The charger successfully monitored voltage, current, temperature, and humidity in real time. The observed charging current ranged from 0.98 A to 1.02 A, while the charging voltage stabilized at 4.2 V. Charging time varied from 1 to 3 hours depending on the battery condition.

6.1 Charging Performance

A partially discharged 18650 battery with an initial voltage of 3.12 V was inserted into the charger. The system automatically initiated charging in constant current (CC) mode. Table 1 summarizes the observed charging parameters.

Table 1. Charging performance of the 18650 battery

Parameter	Measured Value
Initial Battery Voltage	3.12 V
Final Charging Voltage	4.19–4.21 V
Average Charging Current	0.99 A
Charging Duration	2 hours 35 minutes
Battery Temperature (Max)	38.4 °C

The charging current remained stable around 1 A throughout the charging process. The battery voltage gradually increased and stabilized near 4.2 V, indicating correct charging behavior.

6.2 Discharging and Capacity Measurement

After full charging, the battery was discharged using the built-in discharging mode to estimate its capacity. Discharging was terminated automatically when the battery voltage reached 3.0 V. The accumulated discharge current was used to calculate the battery capacity.

Table 2. Battery discharge and capacity estimation results

Parameter	Measured Value
Discharge Current	0.98 A
Discharge Start Voltage	4.20 V
Discharge Cut-off Voltage	3.00 V
Discharge Time	2 hours 10 minutes
Calculated Capacity	2125 mAh

The measured capacity is within the expected range for a used 18650 lithium-ion cell, confirming the effectiveness of the capacity estimation method.

6.3 Temperature and Environmental Monitoring

Battery temperature and ambient conditions were monitored continuously during operation. The DS18B20 sensor recorded battery temperature variations, while the DHT11 sensor measured ambient temperature and humidity.

Table 3. Environmental and battery temperature monitoring results

Parameter	Measured Range
Ambient Temperature	29–31 °C
Ambient Humidity	62–68 %
Battery Temperature (Charging)	32–38 °C
Battery Temperature (Discharging)	30–36 °C

All temperature values remained within safe operating limits, indicating stable and safe system operation.

6.4 IoT Data Logging Performance

Real-time data, including voltage, current, temperature, humidity, and capacity, were transmitted to the MQTT broker (broker.hivemq.com) and logged into Google Sheets. Data updates occurred approximately every 2 seconds. No packet loss or communication interruptions were observed during continuous operation exceeding 3 hours.The logged data enabled graphical visualization and long-term storage, demonstrating the reliability of the IoT-based monitoring system.

Example of Logged Google Sheets Data

Table 4 shows a sample of real-time data recorded in Google Sheets during the charging process.

7. Safety and Maintenance Considerations

Proper polarity must be observed when inserting batteries. Non-rechargeable batteries and incompatible battery types must not be used, as they may cause safety hazards. The device is designed for indoor use in a dry environment. Periodic cleaning and proper battery disposal practices are recommended to ensure safe operation and environmental protection.

Table 4. Sample IoT data logged in Google Sheets

Time (hh:mm:s	Battery Voltage	Current (A)	Battery Temp (°C)	Ambient Temp (°C)	Humidity (%)	Capacity (mAh)
10:15:02	3.18	0.99	32.1	30.0	65	120
10:20:02	3.45	1.00	33.4	30.2	66	350
10:30:02	3.78	0.98	35.2	30.5	64	820
10:45:02	4.05	0.99	37.1	30.8	63	1450
11:00:02	4.20	0.97	38.4	31.0	62	2100

8. Conclusion

This paper presents the design and implementation of a low-cost, ESP32-based smart charger for 18650 lithium-ion batteries with IoT-based monitoring. The system provides real-time measurement of key battery parameters, accurate capacity estimation, and cloud-based data logging using MQTT and Google Sheets. The proposed design is low-cost, easy to implement, and suitable for educational laboratories and experimental battery testing. Future work may include multi-slot charging, constant current–constant voltage (CC–CV) charging control, and advanced battery health diagnostics using data analytics.

References

1. *M. A. Hannan, F. A. S. Sharif, and A. Mohamed, "A review of lithium-ion battery charger topologies, charging techniques, and future developments," Renewable and Sustainable Energy Reviews, vol. 82, pp. 150–162, 2018.*
2. *N. Saxena and S. Bansal, "IoT-based real-time monitoring of battery charging station using MQTT," International Journal of Computer Applications, vol. 176, no. 42, pp. 7–12, 2020.*
3. *Khaligh and Z. Li, "Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric hybrid electric vehicles," IEEE Transactions on Vehicular Technology, vol. 59, no. 6, pp. 2806–2814, 2010.*
4. *J. Wang, W. Dong, and X. Li, "Design and implementation of a smart charger for lithium-ion batteries in electric vehicles," IEEE Access, vol. 6, pp. 47283–47293, 2018.*
5. *Espressif Systems, ESP32 Technical Reference Manual, Espressif Systems Inc., 2020.*
6. *H. Rafique, M. Yasin, and M. W. Akram, "Arduino and MQTT-based IoT system for battery monitoring and alerting," International Journal of Scientific & Engineering Research, vol. 11, no. 4, pp. 123–129, 2020.*
7. *OASIS, MQTT Version 3.1.1 Specification, 2014.*
8. *G. B. Gharehpetian, M. Sabahi, and M. A. Ramezani, "An efficient IoT-based battery health prediction system for renewable energy storage," International Journal of Energy Research, vol. 44, no. 3, pp. 1945–1958, 2020.*
9. *D. P. Kubinec and M. S. Alam, "Application of ESP32 Wi-Fi module for remote sensing systems," International Journal of Wireless & Mobile Networks, vol. 12, no. 2, pp. 23–34, 2020.*
10. *S. L. Chung, C. S. Chee, and M. A. F. Ghazali, "IoT-based cloud platform architecture for battery health diagnostics," Journal of Sensors, vol. 2021, Article ID 6674281, 2021.*

