Management and monitoring of lithium-ion battery recharge with ESP32

Estefany Gomez-Huaylla, Luis Mejía-Cruz, Ernesto Paiva-Peredo
Department of Mechatronic Engineering, Universidad Tecnológica del Perú, Lima, Peru

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ABSTRACT

Air quality is important for human health, the use of clean energy is one way to improve it. And the management and monitoring of the recharge of ion-lithium batteries used in electric vehicles and other devices requires efficient systems. The objective is to develop an intelligent electrical recharging system for lithium-ion batteries using internet of thing (IoT) technology. In this article, an electrical recharging system for lithium-ion batteries was designed and carried out, which is made up of a source, a diode bridge, L298 n driver, current sensor, a voltage divider sensor and the ESP32 microcontroller. The system determines the storage capacity of the battery and monitor it remotely via WIFI. The data is sent to a Shiftr.io server and graphically displayed on a NODE RED platform. The message queuing telemetry transport (MQTT) protocol is used to communicate the devices and decide the best time to recharge the batteries. The results show that the system works correctly and offer useful information that optimizes the charging process, it contributes to improving savings in the payment of electricity consumption and the use of clean energy. The limitations of the study are the small sample size and the lack of comparison with other similar systems.

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Corresponding Author:

Ernesto Paiva-Peredo
Department of Mechatronic Engineering, Universidad Tecnológica del Perú
125 Natalio Sánchez Street, Santa Beatriz Urbanization, Cercado de Lima, Lima, Peru
Email: epaiva@utp.edu.pe

1. INTRODUCTION

According to the World Health Organization (WHO), air quality is considered unsafe for human beings. This is due to the concentration of PM2.5, which is 25 ug/m3 [1], which exceeds the WHO recommendation, which is 10 ug/m^3 [1]. According to a study by the Organization for Economic Cooperation and Development (OECD), by 2060 there will be between 6 and 9 million premature deaths due to air pollution. Which in turn will cause an annual cost of 2.6 trillion dollars to the world economy, equivalent to 1% of GDP. Likewise, said air pollution is the cause of respiratory and cardiovascular diseases [2], [3].

Due to the pollution produced by combustion vehicles [4], the transport of electric vehicles emerges as an alternative. However, the impact that it will cause when integrated into the electrical grid system is unknown [5], which is why various companies in the world have developed electric charging stations using different methods in order to contribute to the consumption of clean or renewable energy to contribute to the consumption of clean energy [6]. Likewise, various investigations can be found in scientific journals, where they share their results, such as electric vehicle battery testing technology located in electric vehicle (EV) charging stations with photovoltaic energy, proposing an online inspection solution, and battery failure detection. EV during the life cycle, using the state of charge (SoC) algorithm, they also present a predictive method based on the EV and battery aging model [7], [8]. Other investigations propose that charging stations

(CS) be synchronized and monitored in real-time in order to efficiently manage charging times for EVs [9], [10], and all the information is stored in a cloud database [11].

Some applications monitor the charging capacity of electric vehicle systems in real-time, based on network information [12], to reduce waiting times and take advantage of fewer demand hours to maximize the time when recharging EVs [13]. We also have articles that evaluate energy efficiency and environmental impact [14]. Internet of things (IoT) technology applied with the ESP32 microcontroller is appropriate because it allows processing, reading, and interpreting the roles of different types of sensors. Moreover, thus, constantly monitor the process [15], [16]. The objective is to design and implement an electrical recharging system for lithium-ion batteries using IoT technology capable of monitoring and managing the recharging of lithium-ion batteries in order to contribute to the scientific community in advancing more efficient ways of consuming clean or renewable energy, in addition to obtaining the lowest cost in paying for energy consumption that varies by country.

This development and innovation project meets two of the seventeen sustainable development goals set by the United Nations or UN. Objective 11 and 13, both aim at the creation of technologies to achieve a sustainable city and to reduce the environmental impact generated by gasoline vehicles. Goal 11 mentions that by 2030 we have to reduce our environmental impact by paying close attention to air quality. Likewise, this project promotes the achievement of objective 13 of the sustainable development goals (SDG) [17], which urges governments to integrate measures for climate change into national policies and plans [18].

Due to the technological advances that society is experiencing, it is necessary to develop an electrical recharging system for lithium-ion batteries [19], [20]. Lithium-Ion batteries are the most suitable for this type of application, since they have advantages such as high energy density, low self-discharge and long useful life. For example, a lithium-ion battery with a density of 128 Wh/kg can provide 16 kW of power, weigh only 140 kg and cost 5,846.19 soles until the year 2022. In addition, the recharging time depends on the power, which is equivalent to 150 km of autonomy for an electric vehicle using different information technologies. Currently the technologies that use IoT are cheap and easily accessible [21], [22] and we find as precedent works developed to monitor and manage intelligent systems in the control of battery charge and discharge through the use of data such as temperature, state and level of charge, current level with the purpose of protecting the useful life of ion-lithium batteries [23].

2. METHOD

The development of the lithium-ion battery recharge monitoring system with the ESP32 module [24] includes several stages. Design stage, as seen in Figure 1, a printed circuit board (PCB) began by designing in the EasyEDA program, with the components mentioned in Table 1. In the power stage, the RS808 diode bridge prevents circuit shorting at the system input. It also has two LM2596 regulators, its purpose is to regulate the input voltage, for the logic system of the project, that is, the ESP32 and the drivers.

The other LM2596 is used to power the current sensor. In the control stage, the ESP32 was used, and it was programmed in the C++ language and applications in NODE RED, likewise, the shiftr.io server was implemented. The L298N driver, which is responsible for sending power to the 3 lithium-ion cells. Finally, in the measurement stage, the DS18b20 temperature sensor was used, which is responsible for measuring the charge and discharge temperature of lithium-ion batteries in series configuration. Additionally, 2 resistors were used to perform voltage division. The operation of the board was evaluated by connecting the discharged lithium batteries resistors were used to perform voltage division. The operation of the board was evaluated by connecting the discharged lithium batteries.

In Figure 1, the components specified in Table 1 are observed. Where the 12 V source is connected to a diode bridge and is connected to two 3.3 V and 5 V voltage regulators as seen in Figure 2. The 3.3 V is connected to the ESP32 and the 5 V voltage regulator is distributed to the L298N driver (its function is to regulate and add current to the range of 10 V to 12.5 V) and to the optocoupler. The temperature sensor whose function is to read the temperature of the plate, also, if the temperature of the plate is not adequate, it will stop the charging process of the ion-lithium battery.

The purpose of charging the battery requires powering the logic system, that is, the 3.3 V powers the temperature sensor, the OLED screen and the ESP32. The 5 V regulator feeds the LM2596 driver, that is, the PWM control, which makes it possible for the voltage of the lithium-ion batteries to be minimal, increase the energy with PWM and PID when it reaches 12 V, which is the maximum, the load is also stop the 5 V that the second voltage regulator that feeds the current sensor and the optocoupler emits. This last device has the function of isolating the circuit and at the same time fulfills the function of reception system. The entire process can be detailed in Figure 3. The calibration of the voltage regulators was carried out as shown in Figure 4, the first one was regulated from 12 V to 3.3 V as shown in Figure 4(a), then the second regulator was regulated from 12 V to 5.0 V as seen in Figure 4(b).

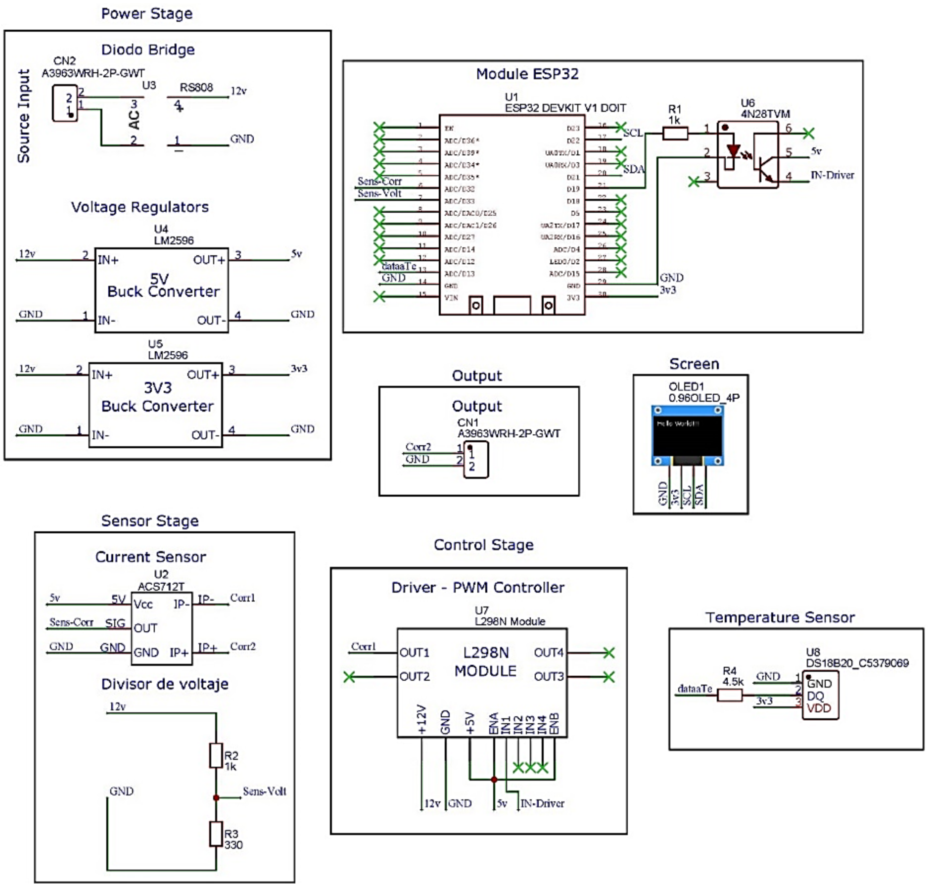


Figure 1. Schematic design of the battery recharge monitoring board with ESP32 in EasyEDA

Table 1. Electronics components

List	Component	Value
1	ESP32	-
2	Resistors	1k and 330 Ω
3	L298n	2 A
4	ACS712T hall effect current sensor	5 A
5	Diode bridge	8 A
6	LM2596	-
7	Ion-Lithium battery	2.5 A
8	DS18b20 temperature sensor	-
9	4n28 Optocoupler	-
10	OLED screen	15.3 in

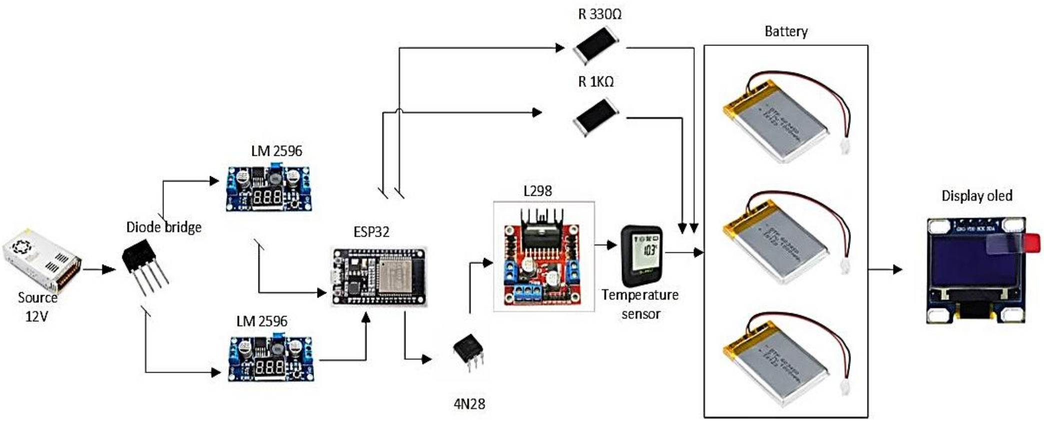


Figure 2. Connection diagram

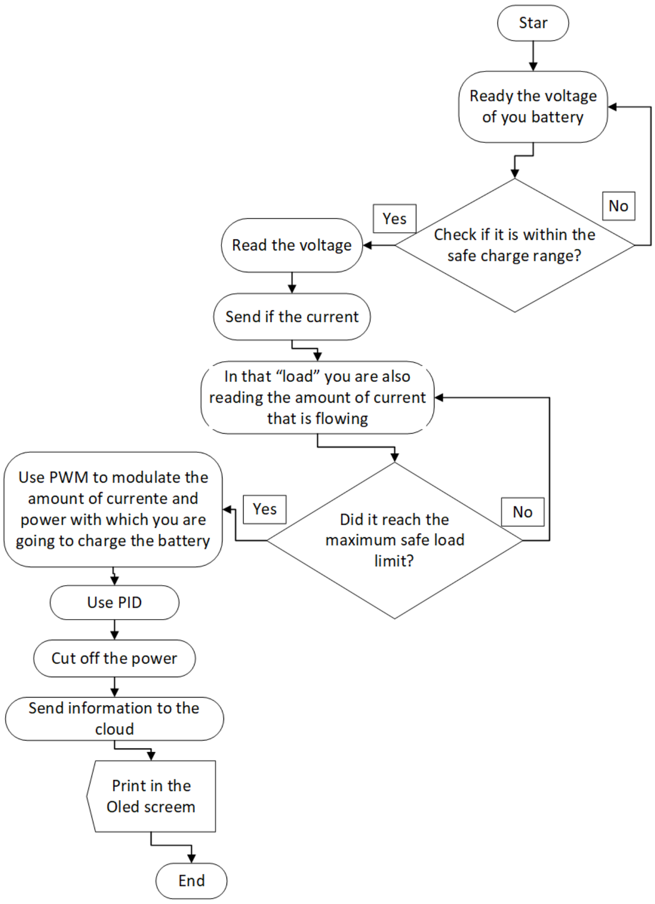
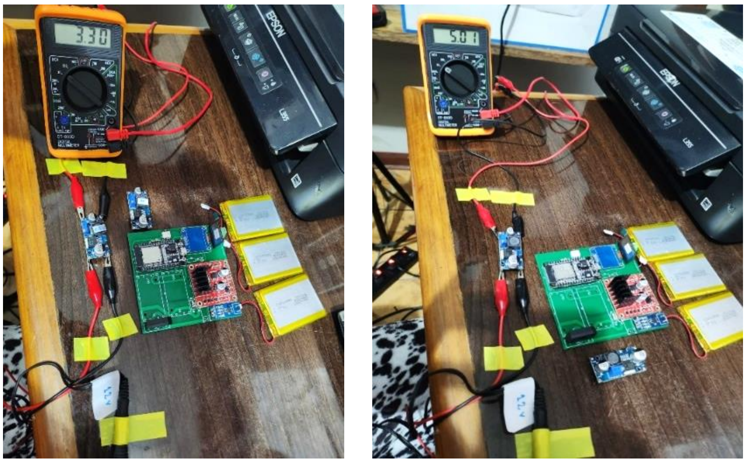


Figure 3. Lithium-ion battery recharge monitoring flowchart



(a) (b)

Figure 4. Calibration of the voltage regulators: (a) Lm2596 from 12 V to 3.3 V and (b) calibrate Lm2596 from 12 V to 5.0 V

Figure 5 shows the board uploading the programming in the flowchart shown in Figure 5(a). This establishes the link directly with the ESP32 with Shiftr.io, which will be the cloud where a server was created on the which the required data was uploaded and then these data are displayed in the NODE RED after making that communication with the message queuing telemetry transport (MQTT) protocol. In part Figure 5(b) a test programming was carried out in the Arduino IDE and thus the ESP32 was linked via WIFI to Shiftr.io

(a) (b)

Figure 5. Board: (a) uploading the code and (b) performing link testing via WIFI

Figure 6 shows the compilation in the Arduino IDE and linked to the server. In Figure 6(a) you can see the compilation that the ESP32 has had to link via WIFI to the network and manage to send data. In part Figure 6(b) the data is observed in the cloud, within which a server was created where data such as the voltage and current of the lithium-ion batteries collected by the card linked to the NODE RED are sent.

In Figure 7, programming in NODE RED in Figure 7(a) and Figure 7(b). The server interacts with data from NODE RED. In part Figure 7(a) it can be seen in NODE RED that it begins by reading the voltage that the battery has, that is, the maximum voltage is 12.5 V and the minimum is 10 V, for correct operation, the measurement must be in that range, otherwise if the reading is lower, the energy is injected through the L298n driver, which makes a change in the load to allow the current to pass until reaching the range of 10 V to 12.5 V, for this the function was created. fluid current, where you can view the charging time it took the battery to reach the ideal values, so that after the process it sends the information on the charge levels and can be viewed on the NODE RED. Upon completion of the charging process, the battery sends the values of the amount of current in amperes in which the battery was charged.

(a)

(b)

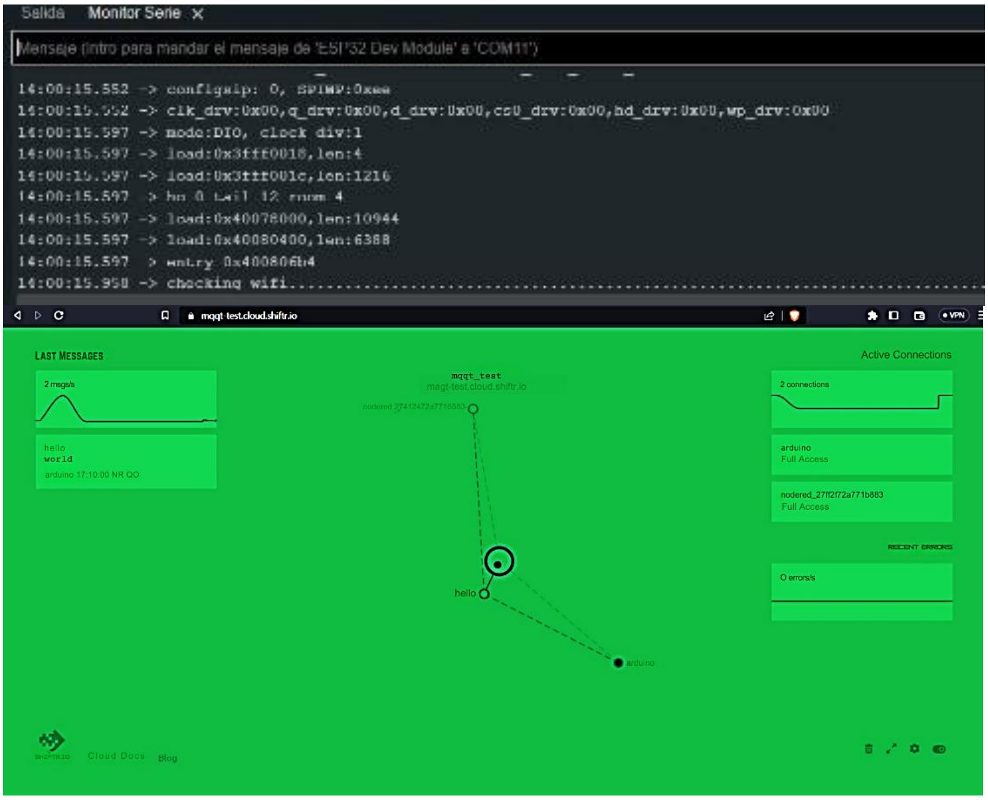


Figure 6. Build: (a) build in Arduino IDE with the ESP32 and (b) cloud created and linked to the server

To protect the created card, a variable called temperature was created to receive the data marked by the temperature sensor in the event of overheating of the card, the load stops the data from the temperature sensor and in case of overheating. At the end of all the process crosses information with the established charging schedule where the energy consumed is of renewable origin, for example from solar or hydroelectric panels, depending on the country where the card is located. This is possible thanks to NODE RED, since it automatically recognizes the date and the time of the region thanks to the network. In part of Figure 7(a) the cloud that was created is observed and within the cloud a server was created where the data such as the voltage and current of the ion-lithium batteries are sent and the monitoring of said data in real time.

(a)

(b)

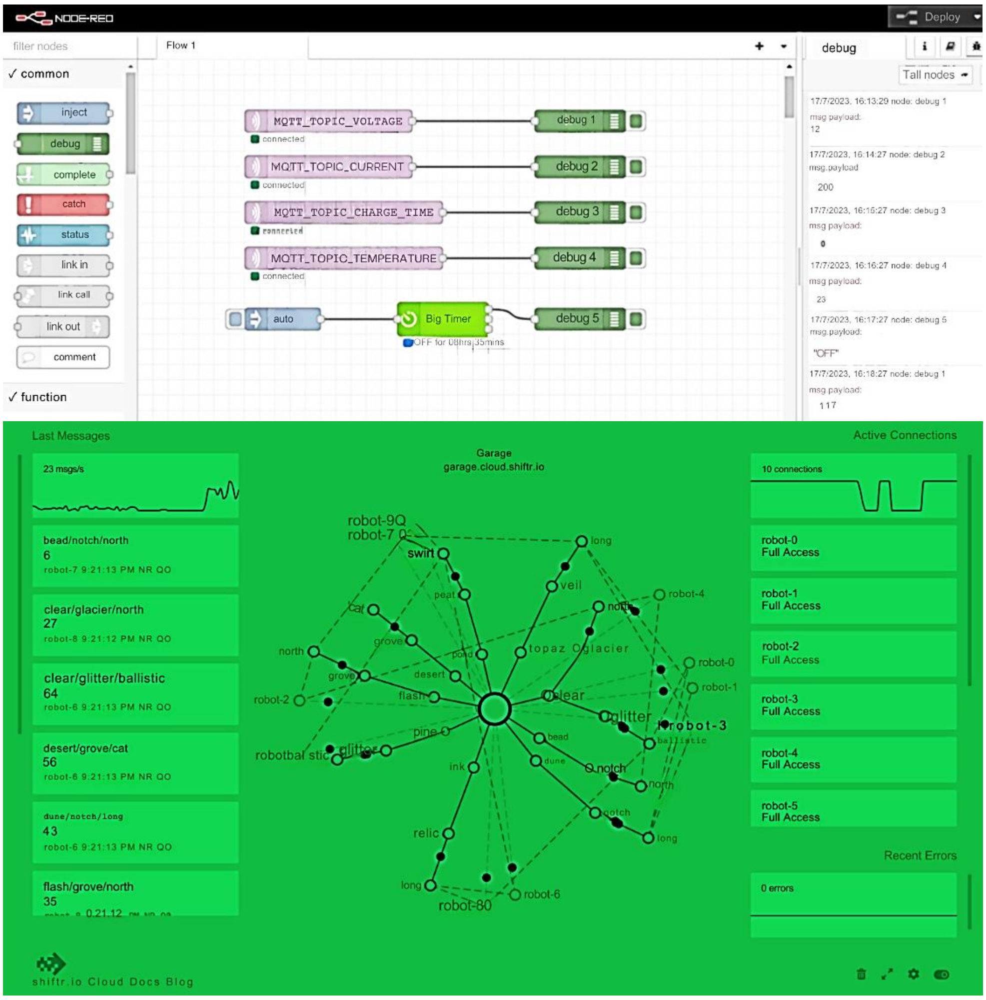


Figure 7. Link programming with NODE RED and shift.io: (a) NODE RED and (b) server interacting with NODE RED data

3. RESULTS AND DISCUSSION

The design and implementation of the ESP32 lithium-ion battery charging management and monitoring system was analyzed about the use of electricity from renewable or clean sources. Energy consumption data was collected over a more than 50 hours sample period. In the following, the results obtained are presented and discussed in comparison to the study by [15].

3.1. Design and implement an electrical recharging system for ion-lithium batteries with IoT

Figure 8 shows the implementation and installation of all the components mentioned in Table 1, which work according to the block diagram explained in Figure 2 and are compared with the implementation by [15]. Figure 9 shows the OLED display that presents real-time parameters, such as voltage, current, and temperature. Notably, in contrast to [15], our study displays the same set of parameters within a more compact space, utilizing an OLED display instead of a 16×2 LCD, as demonstrated in Nguyen T.'s [15] study.

3.2. Remote monitoring via WIFI

The monitoring stage of the study is compared to the study in [25]. It is compared in Figure 10, where real-time current versus voltage data is shown in NODE RED and on the OLED display. In Figure 11, the load per minute is monitored, and in Figure 12, the temperature sensor data is observed, while in Figure 13, the temperature versus current graph is presented. This study is more detailed than the one mentioned above.

Table 2 shows the energy savings between 1:00 a.m. and 4:00 a.m. when the lithium-ion battery recharging system is activated. Since this is when the energy comes from renewable or clean sources, it is compared to the study of [25], whose system makes the user aware of the transparency of energy metering. In contrast, our system acts directly by automating this process.

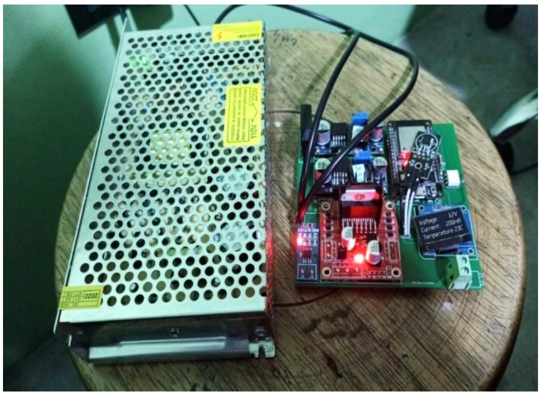


Figure 8. Implementation and installation of the components on the board designed for the management and monitoring of lithium-ion battery recharging

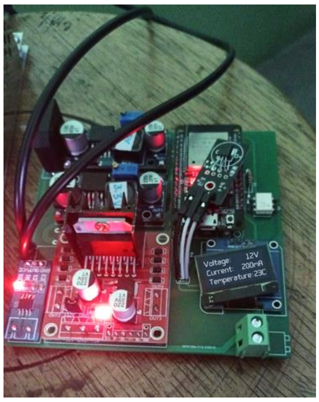


Figure 9. The OLED screen shows the essential parameters for recharging the ion-lithium battery

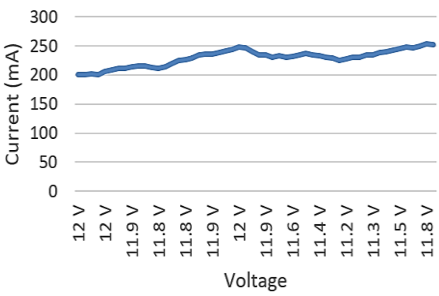


Figure 10. Current (mA) versus voltage

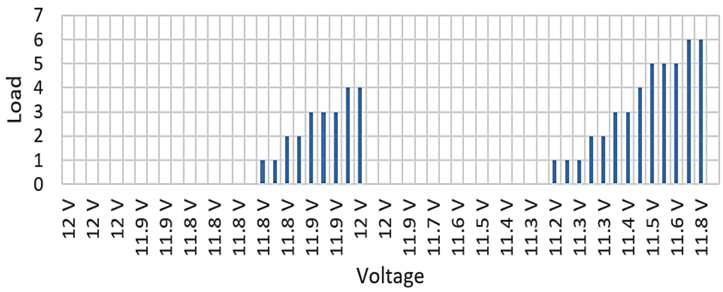


Figure 11. Load per minute

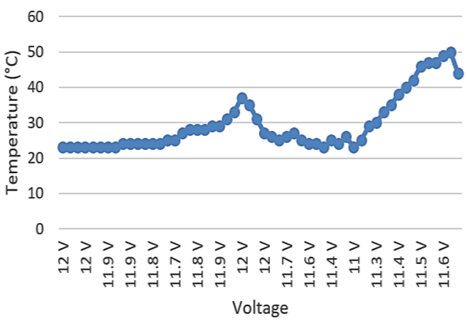


Figure 12. Real-time temperature sensor data

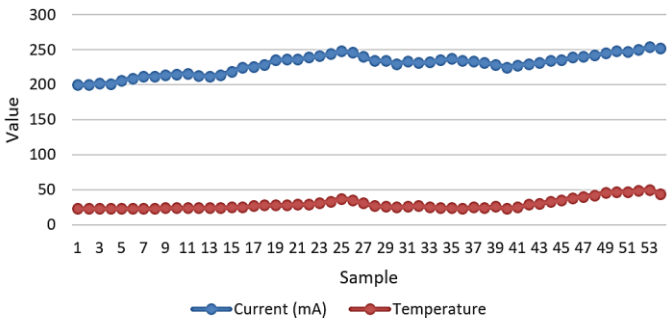


Figure 13. Current vs. temperature data table

Table 2. Green hours

Voltage (V)	Current (mA)	Green hours (save money)	Temperature	Charge state
12 V	200	0	23	OFF
12 V	200	0	23	OFF
12 V	202	0	23	OFF
12 V	201	0	23	OFF
12 V	206	0	23	OFF
12 V	209	0	23	OFF
11.9 V	212	0	23	OFF
11.9 V	212	0	23	OFF
11.9 V	214	0	24	OFF
11.9 V	215	0	24	OFF
11.8 V	216	0	24	OFF
11.8 V	213	0	24	OFF
11.8 V	212	0	24	OFF
11.8 V	214	0	24	OFF
11.8 V	219	0	25	OFF
11.7 V	225	0	25	OFF
11.8 V	226	1	27	ON
11.8 V	229	1	28	ON
11.8 V	235	2	28	ON
11.8 V	236	2	28	ON
11.9 V	236	3	29	ON
11.9 V	239	3	29	ON
11.9 V	241	3	31	ON
11.9 V	244	4	33	ON
12 V	248	4	37	ON
12 V	246	0	35	OFF
12 V	240	0	31	OFF
12 V	234	0	27	OFF
11.9 V	234	0	26	OFF
11.9 V	230	0	25	OFF
11.7 V	233	0	26	OFF
11.6 V	231	0	27	OFF
11.6 V	232	0	25	OFF
11.6 V	235	0	24	OFF
11.5 V	237	0	24	OFF
11.4 V	234	0	23	OFF
11.4 V	233	0	25	OFF
11.3 V	231	0	24	OFF
11.3 V	229	0	26	OFF
11 V	225	0	23	OFF
11.2 V	228	1	25	ON
11.2 V	230	1	29	ON
11.3 V	231	1	30	ON
11.3 V	234	2	33	ON
11.3 V	235	2	35	ON
11.4 V	239	3	38	ON
11.4 V	240	3	40	ON
11.5 V	242	4	42	ON
11.5 V	245	5	46	ON
11.5 V	248	5	47	ON
11.6 V	247	5	47	ON
11.6 V	250	6	49	ON
11.8 V	254	6	50	ON
11.8 V	252	0	44	OFF

4. CONCLUSION

Implementing the ion-lithium battery recharging system integrating IoT technology with the ESP32 microcontroller represents a significant stride in managing and monitoring clean energy consumption. The system optimizes charging processes during "green hours," contributing to energy savings and advocating for renewable sources. Real-time monitoring capabilities through WIFI provide valuable insights into charging parameters such as current, temperature, and charge states, enhancing the efficiency of the recharging system.

This development aligns with sustainable development goals, particularly goals 11 and 13, by promoting technologies for sustainable cities and mitigating the environmental impact of traditional gasoline vehicles. The successful integration of IoT technology with lithium-ion battery recharging demonstrates technical robustness and efficiency. The system's responsiveness to green hour pricing information optimizes energy consumption and positions it as a viable solution for widespread adoption in electric vehicle charging infrastructure.

While the study presents promising results, acknowledging limitations such as a small sample size and the absence of comparisons with similar systems sets the stage for future research. Future endeavors should address these limitations and explore the system's applicability across diverse geographical contexts. Additionally, replicating the study in regions with publicly available green hour pricing information could offer more precise insights into electricity consumption savings.

In conclusion, the successful implementation of this technology underscores its promise in advancing smart and sustainable energy solutions. The integration of IoT technology with the ESP32 microcontroller for ion-lithium battery recharging has proven technically robust and efficient. Further refinements could enhance scalability, interoperability, and integration with emerging IoT standards, contributing to the evolution of intelligent and eco-friendly charging systems.

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BIOGRAPHIES OF AUTHORS

Estefany Gómez Huaylla is a mechatronic engineering student at the Technological University of Peru. She has held various management positions in Technology Companies such as (DENDRO S.A.C), from 2015 to 2019. She was also coordinator of hack space UTP (Technological University of Peru), from 2016 to February 2020. She is currently a professor of the Department of Technology of the International Baccalaureate at Casuarinas International College. She has supervised more than 10 international baccalaureate students at the personal project. Her research interests include IoT, neural networks, and AI. She can be contacted at email: 1412373@utp.edu.pe.

Luis Mejia Cruz is a student of the mechatronics engineering career at the Technological University of Peru. He worked in export and textile manufacturing companies, as a mechanical technician (2009-2014) and currently in telecommunications companies (2014 -2023), as an electronic analyst. He can be contacted at email: 1110672@utp.edu.pe.

Ernesto Paiva-Peredo graduated as an electrical mechanical engineer from the Universidad de Piura in Peru in 2013. He pursued further studies and obtained a master's degree in Electrical Mechanical Engineering with a specialization in Automation and Optimization, which was supported by CONCYTEC and awarded by the Universidad de Piura in 2016. During his academic journey, he served as a research assistant at the Department of Technology and Innovation (DTI) at SUPSI. Presently, he holds the position of a professor-researcher at the Universidad Tecnológica del Perú. He can be contacted at email: C22395@utp.edu.pe.