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RFID Asset Monitoring Laboratory Environment

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Abstract

This project deals with developing a smart lab equipment management system using RFID and IoT technologies. Presently, various educational institutions use manual logbooks or outdated systems to keep track of valuable tools like multimeters and oscilloscopes, which creates room for potential loss, misuse, or improper resource management. The system, therefore, aims to cater to those inconveniences by automating the borrowing and return of lab equipment through RFID tags and an ESP32 microcontroller. Each event is logged in real time into a cloud database, and Blynk notifications are sent out for overdue alerts and unauthorized activities. The system performed well in test and was proven to be fully accurate and responsive when managing equipment data. It greatly reduces human error and helps maintain responsibility while giving a scalable solution to modern labs. In brief, RFID and IoT technologies found a real-time asset tracking and monitoring soluion in this project .

1. Introduction

Managing lab equipment in schools and universities has become more important than ever, especially since students and staff often rely on valuable tools like laptops, multimeters, and oscilloscopes [1], [2]. Unfortunately, many institutions still depend on old-school methods like physical logbooks or manual check-out systems to track who's using what. These methods may have worked in the past, but they're no longer reliable for today's fast-paced learning environments.

Manual tracking systems can easily lead to mistakes or even intentional misuse. Equipment might not be returned on time or at all because there's no easy way to follow up [1], [3]. Furthermore, data could go missing, records might get edited without anyone noticing, and sometimes people simply forget to write things down [1]. All of this increases the chances of losing expensive items and drives up maintenance or replacement costs unnecessarily.

It also makes life harder for lab managers, which is without a clear view of where the equipment is and who's using it, it becomes tricky to keep everything organized. Some tools might be left unused for long periods or moved to another part of the campus without being tracked properly. When that happens, it becomes nearly impossible to schedule regular maintenance or plan for new stocks leading to poor resource management and, in the long run, a negative impact on student learning and lab productivity [4].

Now, there are some high-end systems out there like those used in hospitals or libraries that help with asset tracking. But those setups often involve complex, expensive technology that's overkill for university lab. They rely on long-range sensors and detailed monitoring systems that aren't necessary for keeping track of a few multimeters and laptops [5]. Plus, not every institution can afford that kind of setup.

That's where this project comes in which is the goal is to create a low cost and easy to use system using RFID technology to track lab equipment automatically. Each item will have an RFID tag that can be scanned by a reader to log its usage [1], [2], [3] to make things even more efficient, IoT system is including that connects to Blynk, so lab staff can receive instant update and notifications when equipment is scanned. In short, the two main objectives are to build an RFID-based system for tracking lab equipment, and to set up an IoT notification system using Blynk [6].

2. Methodology

RFID Asset Monitoring Laboratory Environment is designed to facilitate laboratory assistants to take data about who borrow and return the laboratory item. Every laboratory item receives an RFID tag which contains its own specific identification number. The system uses RFID readers at access points to capture tag information whenever people borrow or return equipment.

The system relies on ESP32 microcontroller which serves as both controller and IoT gateway functions. It collects RFID information then transmits it to a cloud platform through Wi-Fi connections. Real-time equipment status along with usage logs and alerts about overdue or unauthorized activities are maintained on this platform which also notifies lab managers. The system receives an upgrade through the usage of Blynk as its notification system. The notification from Blynk platform will be identified for the item either borrow or return by using student ID.

2.1 System Block Diagram

The diagram offers a picture of the global process flow of the RFID-based lab equipment-monitoring system, which comprises three main components: input, microcontroller, and output. The system begins with the input phase, in which the RFID reader is used to scan the RFID tag as shown in Fig. 1. These tags, attached either to the student ID cards or lab equipment, store an RFID with a unique identifier number that is read by the RC522 module. After scanning a tag, the UID information goes to the microcontroller for further processing.

In the centre of this system lies the microcontroller ESP32 as the central processing unit. It receives input from the RFID reader and uses it to determine if the scanning pertains to the borrowing or returning of an item. It then proceeds with the action appropriate to the scanned data. The ESP32 further establishes an internet connection via Wi-Fi to support cloud-based applications. The output stage contains three components. First, an LCD display presents prompts to scan the student card or item and confirmation messages such as "Item Borrowed" or "Return Successful" to the user. Second, real-time alerts are sent by the system through the Blynk IoT platform, informing notification.

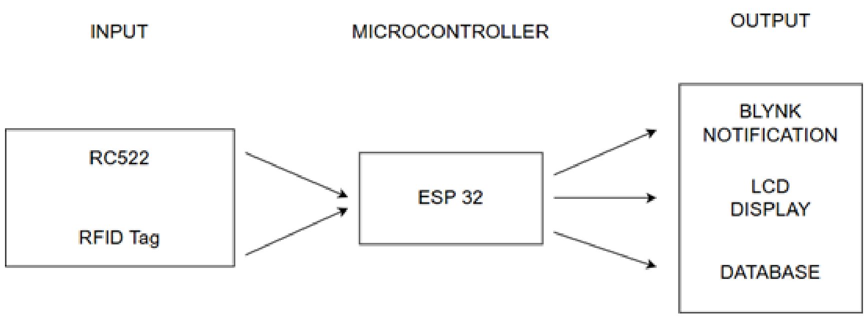


Fig. 1 *System block diagram*

The system in operation functions based on data derived from RFID cards, which are read by RFID sensors for the identification of both students and items. The flowchart in Fig. 2 presents the clear sequence of operations involved in the activities of item borrowing and returning. The borrowing and returning sequence of operations starts from scanning the student card for identification. After successful identification, the student's information is saved into the database. Following this, the item card is also scanned, and the borrow or return status is saved. After this, the information travels to the system server and gets stored on the system database. A notification is sent out to the Blynk Application installed on the mobile device of the party concerned, containing the details of the transaction. A smooth flow of functionalities can be seen in the flowchart, showing how integrated RFID and IoT technologies make item management much more efficient and traceable.

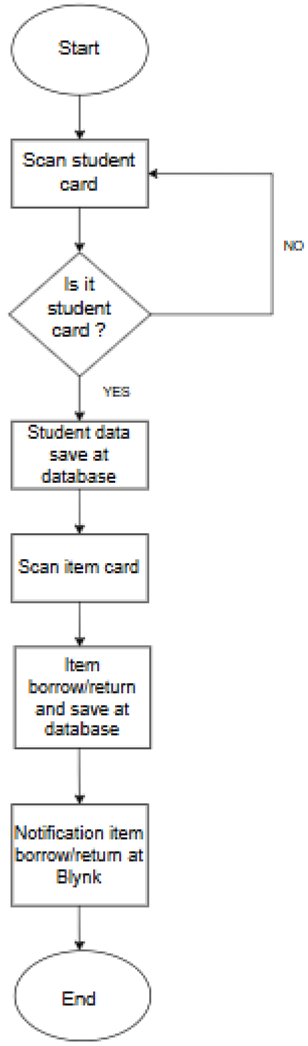


Fig. 2 *Flowchart of RFID asset monitoring laboratory environment*

2.2 Schematic Circuit

The circuit gets power from the VIN pin of the ESP32, which usually gets a 5V input from USB or from external supply. This voltage both powers the ESP32 and supplies 3.3V to other peripherals like the RFID reader. A common GND connection is made for all modules to keep them working stably and consistently throughout. The ESP32 microcontroller is at the heart of the circuit. It is the central controller for all connected components. It handles data communication, processing of logic, and even provides Wi-Fi connectivity for IoT integration. It also communicates with the RFID module across SPI, wherein such pins as GPIO5 (SDA), GPIO18 (SCK), GPIO23 (MOSI), GPIO19 (MISO), and GPIO22 (RST) are assigned for this purpose. The RFID reader (RC522) sends out signals to grab the unique ID of RFID cards, which are student or item IDs in this case.

Then, one more device connected to the ESP32 is the LCD display working on the I2C protocol, which requires just two data lines: GPIO21 (SDA) and GPIO22 (SCL). These lines make the wiring simple. This LCD shows system prompts or feedback in real time; for example, it might ask the user to scan their card. The schematic circuit diagram is shown in Fig. 3.

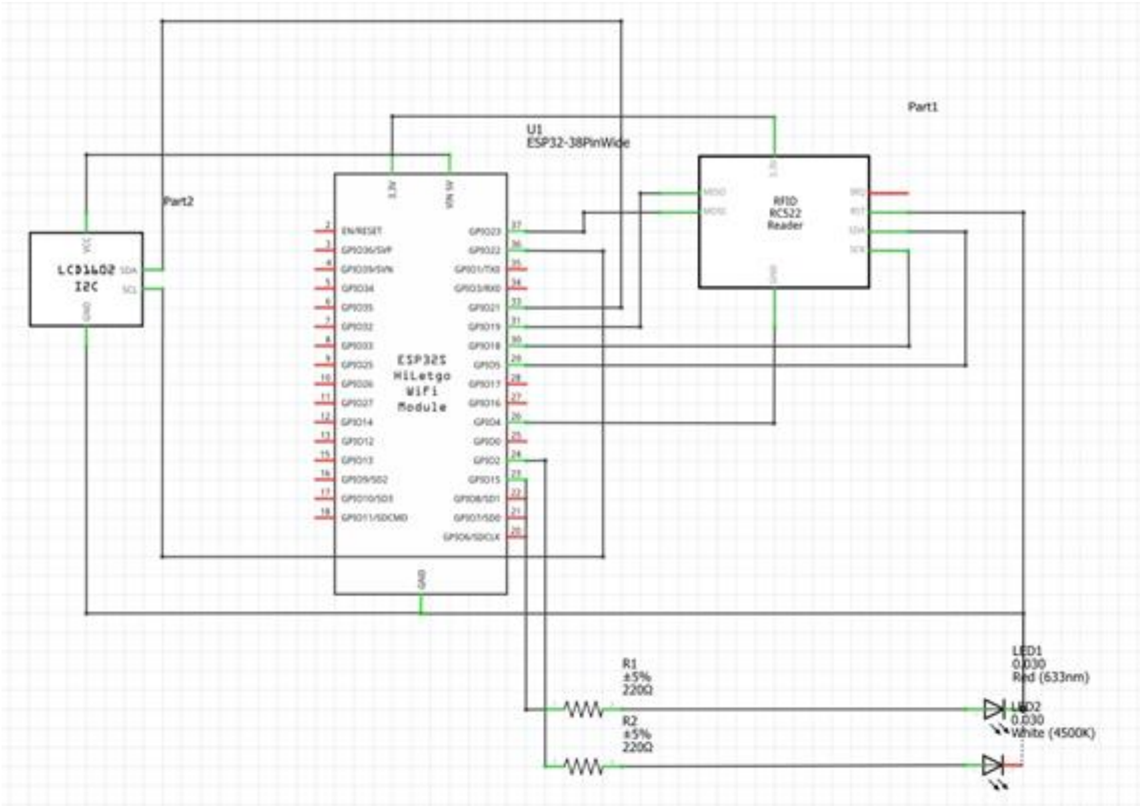
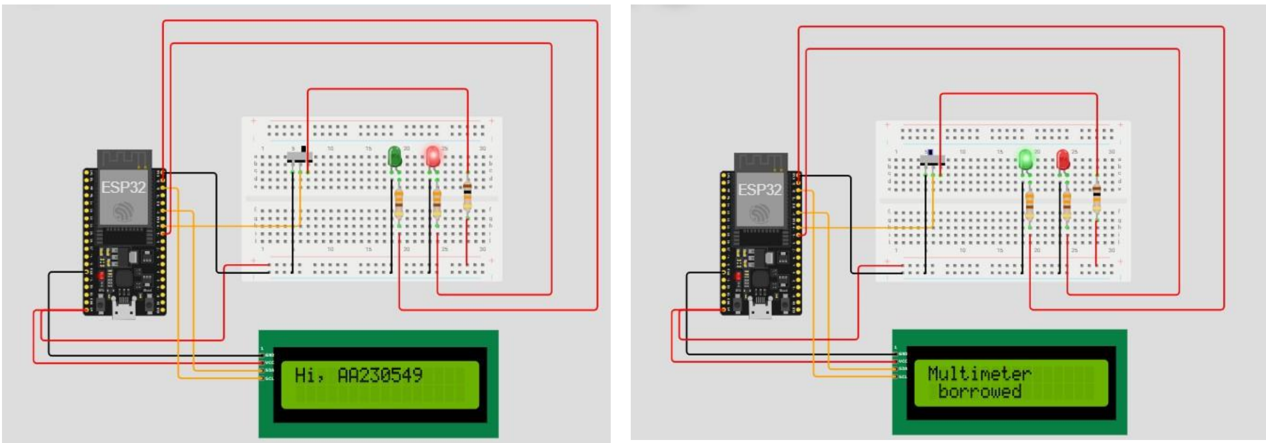


Fig. 3 *Schematic diagram*

2.3 Simulation

Fig. 4 shows the simulation for the project using Wokwi software. In this software, it doesn't have an RFID module, so I replaced it with a push button. When we push the button once, it acts like scanning the student card, and the LCD will display as shown in Fig. 4 (a). The second time the button is pushed, it simulates scanning the item card, and the LCD will display as shown in Fig.4 (b).



(a) **(b)**

Fig. 4 *(a) Simulation when scan student card; (b) Second simulation when scan the item card*

3. Results and Discussions

3.1 Results

Fig. 5 shows where student UID is stored to detect how many times and when they scan their card. Before students borrow or return items, we document their unique ID along with the date and time to establish a precise transaction record which supports responsibility and item usage monitoring.

Student UID	Date	Time
AA230549	23/06/2025	10:36:02
AA230549	23/06/2025	10:36:58
AA230549	23/06/2025	10:56:05
AA230820	23/06/2025	11:10:58
AA230549	23/06/2025	11:30:19
AA230549	23/06/2025	11:31:02
AA230820	23/06/2025	12:56:54
AA230820	23/06/2025	13:01:17
AA230820	23/06/2025	13:01:25

Fig. 5 *Data save at database when they scan their student card*

Fig. 6 shows that students first present their student cards for identification before using the RFID tag scanner to scan the item they want to borrow or return. The system automatically analyzes the scanned information to identify whether the transaction involves borrowing or returning an item because it evaluates the present status of the item. The LCD screen presents the transaction outcome by displaying "Item Borrowed" or "Item Returned" with the exact time stamp. The system creates clear records for every transaction while providing instant confirmation to users. Following the notification via Blynk in Fig.7 will be showing up when someone is borrowing and returning the item.

Item	Date	Time	Status	Student UID
Oscilloscope	23/06/2025	10:36:13	Borrow	AA230549
Oscilloscope	23/06/2025	10:37:23	Return	AA230549
SolderingIron	23/06/2025	11:11:03	Borrow	AA230820

Fig. 6 *Data item is saved at database*

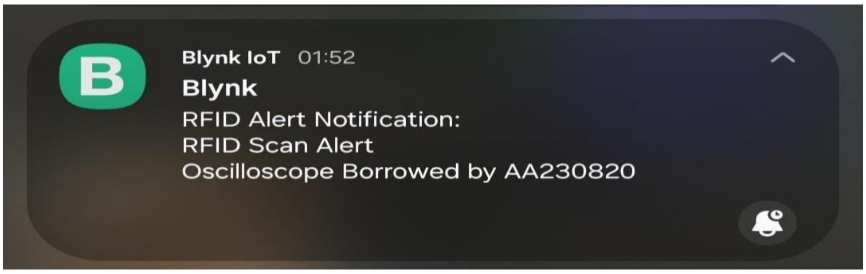


Fig. 7 *Blynk Notification*

3.2 Discussion

The project results indicate that the RFID-based lab equipment monitoring system operates correctly and delivers its expected performance in most testing environments. The system successfully reads both student and item RFID tags and logs the data accurately into the cloud-based database. The LED and buzzer provide immediate confirmation of successful scans, while the LCD screen clearly displays the transaction status. The integration with the Blynk platform also enables real-time notifications to be sent to lab administrators and users, enhancing visibility and traceability.

The project was majorly characterized by peaceful process endeavors with slight challenges in the initial setup and testing phases. One of the central difficulties was the order of scanning: the student card must be scanned before the item card, or else false or incomplete data would be recorded. Hence, instructions in clear terms were displayed on the LCD, and the code was designed to confirm such checks. The system works well when the latter conditions are met; for some reasons, cloud logging or Telegram notifications dependent on Wi-Fi were delayed slightly, and this could be another point of improvement in a future release by optimizing its network handling. Meanwhile, those few drawbacks apart, this project stands to be a good one proving that RFID and IoT can be used effectively for secure and efficient lab equipment tracking.

4. Conclusion

The project successfully accomplished its goal to develop an RFID and IoT-based system which monitors laboratory equipment. The project reached its primary objectives through developing an automated system which uses RFID tags and readers to control borrowing and returning while Telegram notifications provide real-time alerts through IoT integration. The system successfully solved the primary issue of inefficient manual tracking methods which produce human errors and equipment losses while lacking accountability.

The system delivers immediate data recording alongside user authentication and alert systems which substantially enhance both visibility and management of laboratory assets. The system continues to have areas where its operational capabilities could be improved. The system would benefit from three improvements including a late return penalty system and unauthorized equipment removal detection sensors and an advanced dashboard for real-time inventory analytics. Making the user interface better and enabling multiple user access levels would improve the system adaptability and security features.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nur Alya Maisarah Jamaludin;* ***data collection:*** *Nur Alya Maisarah Jamaludin;* ***analysis and interpretation of results:*** *Nur Alya Maisarah Jamaludin;* ***draft manuscript preparation:*** *Nur Alya Maisarah Jamaludin. All authors reviewed the results and approved the final version of the manuscript.*

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