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Prototype Of An RFID-Based Door Lock System Using An ESP32 Microcontroller With Telegram Notifications

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Abstract

Door security is an important aspect of restricting access and protecting assets from unauthorized use. This study aims to design and develop a door lock prototype based on the ESP32 microcontroller by integrating an RFID RC522 module, a 4×4 matrix keypad, a 16×2 I2C LCD, an SG90 servo motor, LEDs, a buzzer, and a Telegram Bot for monitoring and remote control. The system implements RFID card and keypad password authentication, equipped with an automatic blocking feature after three consecutive incorrect password attempts and real-time notifications via Telegram. Testing results showed that the ESP32 Expansion Board received an input voltage of 12.28 VDC and successfully distributed operating voltages to all components, including 3.2 VDC for the RFID RC522, 5 VDC for the 16×2 I2C LCD and SG90 servo motor, and approximately 3 VDC for the LEDs. The RFID module was able to read cards at a maximum distance of 4 cm, while the servo motor successfully opened the door for 5 seconds through RFID and keypad authentication, and 3 seconds through Telegram commands. All components operated according to the design, demonstrating that the system can enhance door access security, support real-time activity monitoring, and provide a practical and reliable Internet of Things (IoT)-based door security solution.

Keywords: ESP32, RFID, Door Lock, Telegram Bot, Internet Of Things (IoT).

INTRODUCTION

The rapid development of information technology and the Internet of Things (IoT) has driven significant innovations in security systems, including door locking systems. However, most door security systems still rely on conventional mechanical locks, which are considered less practical because users must always carry physical keys and these locks are vulnerable to unauthorized access using simple burglary tools. In addition, problems such as lost or forgotten keys frequently occur, increasing the risk of criminal activities. Therefore, there is a growing need for a more modern, secure, and user-friendly door security system.

One of the technologies widely adopted in door security systems is Radio Frequency Identification (RFID). This technology enables fast and contactless user identification, allowing access only to registered RFID cards. Nevertheless, using RFID as a single authentication method still has several limitations, particularly when users lose or forget their RFID cards. This condition highlights the need for a multi-factor authentication system that can enhance security while providing an alternative access method for authorized users.

This research develops a prototype door lock system based on the ESP32 microcontroller, integrating RFID technology, a keypad, a servo motor, and the Telegram application. The ESP32 serves as the main controller, processing input data from both the RFID module and the keypad, controlling the door unlocking mechanism through a servo motor, and utilizing a Wi-Fi connection to send notifications and receive commands via Telegram. The system is designed to allow users to unlock the door either by using an RFID card or by entering a password through the keypad when the RFID card is unavailable.

To improve security, the proposed system implements an automatic lockout mechanism after three consecutive failed authentication attempts. When this condition occurs, access through both the RFID module and the keypad is disabled, and the ESP32 automatically sends a Telegram notification displaying the message "Three failed attempts – Door Locked." Subsequently, unlocking the system and controlling the door can only be performed remotely through the Telegram application via an

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internet connection. In addition to providing real-time notifications, Telegram also functions as a remote control platform, enabling users to lock or unlock the door from different locations.

The integration of RFID, a keypad, an ESP32 microcontroller, a servo motor, an LCD, LEDs, a buzzer, and Telegram is expected to produce a door security system that is more effective, practical, and adaptive than conventional locking systems. Besides enhancing security through dual authentication and an automatic lockout feature, the proposed system also provides real-time monitoring and remote control capabilities, supporting the implementation of IoT technology in residential and office security systems. Therefore, this study aims to design and develop an ESP32-based RFID door lock prototype with Telegram notifications as a modern, efficient, and user-friendly door security solution.

RESEARCH METHODS

This study employed a Research and Development (R&D) method with an experimental approach to design, develop, and evaluate a prototype door lock system based on the ESP32 microcontroller using Radio Frequency Identification (RFID) technology and Telegram notifications. The research stages consisted of system requirements analysis, hardware and software design, prototype development, system integration, and functional testing. The hardware components included an ESP32 microcontroller as the main controller, an RC522 RFID module for user authentication, a 4×4 keypad as an alternative access method, a servo motor as the door lock actuator, a 16×2 I2C LCD for displaying system information, a buzzer and LEDs as status indicators, and a Wi-Fi network for communication with the Telegram application. The software was developed using the Arduino IDE with the C/C++ programming language, while the Telegram Bot API was utilized to provide real-time notifications and remote door control.

System testing was conducted to evaluate the functionality of each component, including RFID card detection, password verification through the keypad, servo motor operation, LCD display performance, buzzer and LED indicators, the automatic locking mechanism after three consecutive failed authentication attempts, and notification delivery and remote door control via Telegram. The test results were analyzed descriptively by comparing the designed system functions with the actual performance of the prototype. The success of this study was determined by the prototype's ability to perform all designed functions correctly, provide secure access for authorized users, and deliver fast and accurate notifications through Telegram as an implementation of the Internet of Things (IoT) concept.

RESULTS AND DISCUSSION

Prototype Door Lock System Design Results

The ESP32-based door lock prototype was tested to evaluate the functionality of all integrated components, including the RC522 RFID module, 4×4 keypad, SG90 servo motor, 16×2 LCD, LED indicators, buzzer, and Telegram Bot. The system supports two authentication methods, namely RFID cards and keypad passwords, with an automatic lockout feature activated after three consecutive incorrect password attempts. Once locked, the system can only be unlocked remotely through the Telegram "/unlock" command.

Prototype Door Lock System

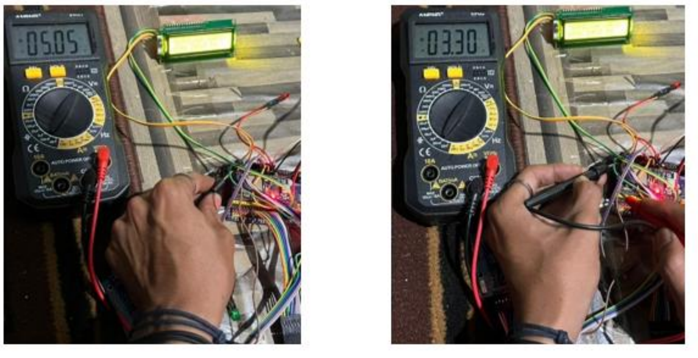
The developed prototype successfully integrated all hardware components with the ESP32 serving as the central controller. The RC522 RFID module performs user authentication, the keypad functions as an alternative input, the LCD displays system status, and the SG90 servo motor controls the door locking and unlocking mechanism.

Figure 1. Prototype of the Door Lock System

ESP32 Testing

The ESP32 was tested to verify its performance as the main controller of the RFID-based door lock system. The test results showed that the ESP32 successfully processed data from all connected components and executed the programmed functions properly. Voltage measurements were also performed to ensure stable operation during system testing.

ESP32 Voltage Measurement Results



(a) (b)

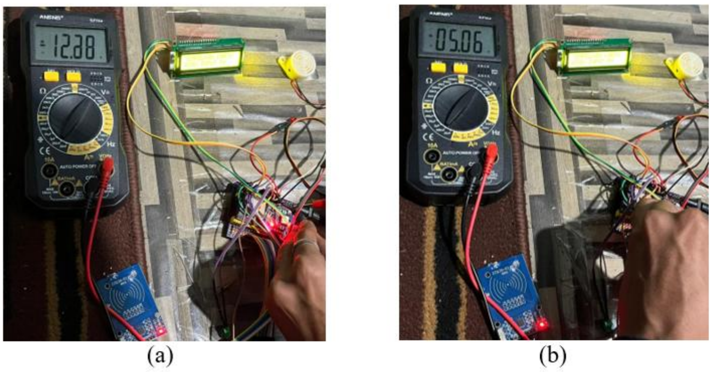
Figure 2. ESP32 Voltage Measurement Results

Voltage measurements were performed using a digital multimeter to verify the operating voltage of the ESP32. The input voltage measured 5.05 VDC, while the output voltage was 3.30 VDC, indicating that the ESP32 operated within its specified voltage range and functioned properly.

ESP32 Expansion Board Testing

The ESP32 Expansion Board was tested to evaluate its ability to distribute power and connect the ESP32 with peripheral devices, including the RFID module, LCD, keypad, buzzer, LEDs, and servo motor. The test results confirmed that the expansion board operated properly, providing stable power distribution and reliable communication for all connected components.

ESP32 Expansion Board Voltage Measurement Results



(a) (b)

Figure 3 ESP32 Expansion Board Voltage Testing

Voltage measurements of the ESP32 Expansion Board were performed using a digital multimeter to verify its power distribution. The input voltage from the power supply was 12.28 VDC, while the output voltage measured 5.06 VDC, indicating that the expansion board provided stable voltage for all connected components.

LCD Testing

The LCD was tested to verify its ability to display system status during operation. The results showed that the LCD successfully displayed all operating conditions, including standby mode, access verification, access granted, access denied, system lockout, and system recovery.

LCD Display Test Results

The LCD displayed the appropriate messages for each system condition, confirming that it functioned properly as a real-time user interface.

Tabel 4. 1 Hasil Pengujian Tampilan LCD

No	Displayed Message	Condition
1		LCD Startup Display
2		RFID Card and Keypad Successfully Verified
3		Unregistered RFID Card
4		Incorrect Password
5		System Locked. Waiting for Telegram Command
6		Access Blocked. RFID and Keypad Disabled
7		System Successfully Unlocked

The test results showed that the LCD successfully displayed the appropriate messages for each operating condition, including standby mode, successful authentication, access denial, system lockout, and system recovery. These messages provide users with real-time information about the door lock status, enabling easy monitoring of system operation. The consistency between the displayed messages and the actual system conditions confirms that the LCD functioned properly throughout the testing process, as summarized in the following table.

Table 2. LCD System Testing Results

No.	System Condition	LCD Display	Description
1	System standby	**"Tap RFID Card or Enter Password"**	Initial display when the system is in standby mode
2	Valid RFID card	**"Access Granted – Door Unlocked"**	RFID card successfully verified
3	Correct password	**"Access Granted – Door Unlocked"**	Keypad password successfully verified
4	Invalid RFID card	**"Access Denied – Invalid Card"**	RFID card not recognized by the system
5	First incorrect password	**"Incorrect Password – Try Again"**	First failed authentication attempt
6	Second incorrect password	**"Incorrect Password – Try Again"**	Second failed authentication attempt
7	Third incorrect password	**"Incorrect Password – Try Again"**	Third failed authentication attempt
8	System lockout activated	**"Access Blocked – Awaiting Telegram Command"**	System is waiting for the **/unlock** command via Telegram
9	System locked	**"Access Blocked"**	RFID and keypad authentication are disabled
10	System unlocked	**"System Unlocked – Access Active"**	System returns to normal operation

LCD Voltage Measurement

The LCD voltage was measured using a digital multimeter to verify its operating power. The measurement showed an input voltage of 4.97 VDC, which is close to the nominal operating voltage of 5 VDC, indicating that the LCD operated normally and displayed system information correctly.

RFID RC522 Testing

The RFID RC522 module was tested to evaluate its ability to recognize registered and unregistered RFID cards. When a registered card was scanned, the ESP32 verified the card UID, unlocked the door using the servo motor, activated the green LED and buzzer, and sent a Telegram notification. Conversely, unregistered cards were rejected, activating the red LED and buzzer while sending an alert with the detected UID via Telegram.

RFID RC522 Test Results

Table 3. RFID RC522 Testing Results

No.	RFID Condition	Expected Result	Actual Result
1	Registered RFID card	Servo unlocks, green LED on	Door unlocked successfully, green LED activated, response time ±5 s
2	Unregistered RFID card	Red LED and buzzer activated	Access denied, red LED activated, buzzer sounded for ±2 s

The results confirmed that the RFID module accurately distinguished between registered and unregistered cards, allowing access only to authorized users while providing real-time security notifications.

RFID Reading Distance Test

The RFID reading distance was evaluated to determine the maximum effective detection range of the RC522 module.

Table 4. RFID Reading Distance Test Results

No.	Distance from Reader	Reading Status
1	1 cm	Detected
2	2 cm	Detected
3	3 cm	Detected
4	4 cm	Detected
5	5 cm	Not Detected
6	6 cm	Not Detected

The RC522 module successfully detected RFID cards at distances of 1–4 cm. At 5 cm and beyond, the card could no longer be detected, indicating that the effective reading range of the module is limited by its electromagnetic induction capability.

RFID Voltage Measurement

The RFID RC522 module was supplied with **3.20 VDC**, which is within its operating range, confirming stable performance during card detection.

Keypad Testing

The keypad was tested using both correct and incorrect passwords. A valid password unlocked the door and triggered a Telegram notification, while invalid passwords activated the red LED and buzzer. After three consecutive failed attempts, the system automatically entered lockout mode.

Keypad Test Results

Table 5. Keypad Testing Results

No.	Password Input	Attempt	Actual Result
1	Correct	1st	Door unlocked, green LED activated
2	Incorrect	1st	Red LED and buzzer activated
3	Incorrect	2nd	System remained active, red LED and buzzer activated
4	Incorrect	3rd	System locked, local access disabled

The keypad correctly authenticated valid passwords and counted failed attempts before activating the security lockout feature.

Keypad Lockout Test Results

Table 6. Keypad Lockout Testing Results

No.	Condition	Actual Result
1	Three incorrect passwords	System entered lockout mode
2	RFID during lockout	Access denied
3	Keypad during lockout	No response
4	LED and buzzer	Red LED and buzzer activated

The lockout mechanism successfully disabled all local authentication until the system was unlocked through Telegram.

Keypad Voltage Measurement

The keypad voltage measured 1.08 VDC when idle and 0.00 VDC when a key was pressed, confirming proper signal transmission to the ESP32.

LED Testing

The LED indicators were tested to verify visual system status. The green LED indicated successful authentication, while the red LED signaled access denial or system lockout.

LED Test Results

Table 7. LED Testing Results

No.	Condition	Green LED	Red LED
1	Valid RFID	On	Off
2	Correct password	On	Off
3	Invalid RFID	Off	On
4	Incorrect password	Off	On
5	System lockout	Off	On

The LED indicators accurately reflected the operating status of the system.

LED Voltage Measurement

The measured voltages were 3.26 VDC for the green LED and 3.25 VDC for the red LED, confirming stable operation.

Buzzer Testing

The buzzer was evaluated as an audible indicator for system events. Different sound durations were assigned to successful authentication, failed authentication, and system lockout.

Buzzer Test Results

Table 8. Buzzer Testing Results

No.	Condition	Duration	Status
1	Valid RFID	0.5 s	Successful
2	Invalid RFID	2 s	Successful
3	Incorrect password	2 s	Successful
4	System lockout	3.5 s	Successful

The buzzer successfully differentiated system conditions through distinct sound durations.

Buzzer Voltage Measurement

The buzzer operated at 3.27 VDC, providing reliable audible notifications during system operation.

SG90 Servo Testing

The SG90 servo motor was tested as the door lock actuator. It successfully unlocked the door after valid authentication and remained inactive when the system was locked.

SG90 Servo Test Results

Table 9. SG90 Servo Testing Results

No.	Condition	Servo Action	Duration
1	Valid RFID	Unlock	5 s
2	Correct password	Unlock	5 s
3	Telegram **/open**	Unlock	3 s
4	System lockout	No movement	—

The servo responded correctly to authentication and remote commands while preventing door access during lockout.

SG90 Servo Voltage Measurement

The servo received **5.05 VDC**, which is consistent with its nominal operating voltage.

Servo Movement Test

The servo rotated 45° to unlock the door after successful authentication and automatically returned to its initial position after the preset opening time.

Telegram Bot Testing

The Telegram Bot was evaluated for real-time monitoring and remote control of the system.

Telegram Bot Command Test

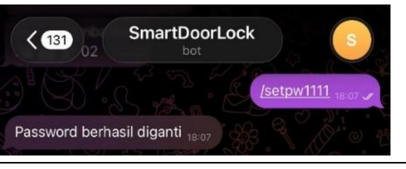
Table 10. Telegram Bot Command Testing Results

No.	Command	Function	Result
1	**/unlock**	Unlock system	Successful
2	**/open**	Unlock door	Successful
3	**/setpw**	Change password	Successful
4	**/addcard**	Register RFID card	Successful
5	**/delcard**	Delete RFID card	Successful
6	**/status**	Display system status	Successful

All Telegram commands were executed successfully, enabling real-time monitoring and remote control of the ESP32-based door lock system.

Telegram Bot Command Test Results

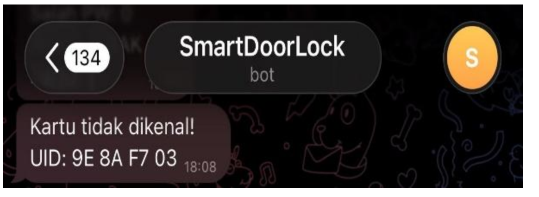
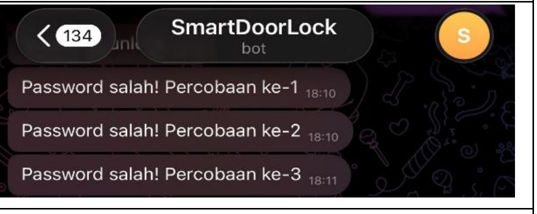
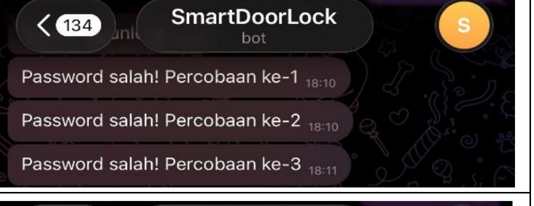
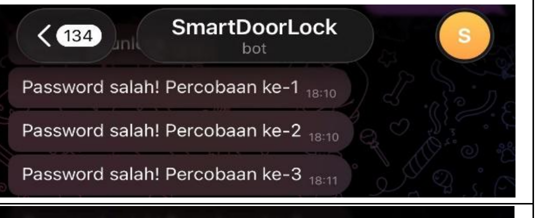
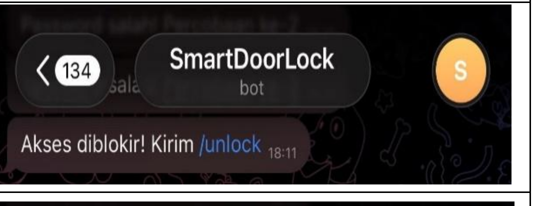
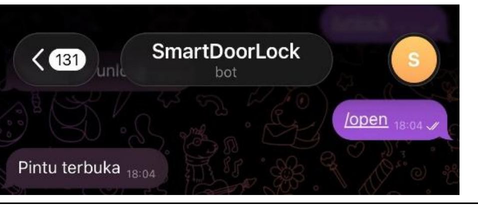
Table 11. Telegram Bot Command Test Results

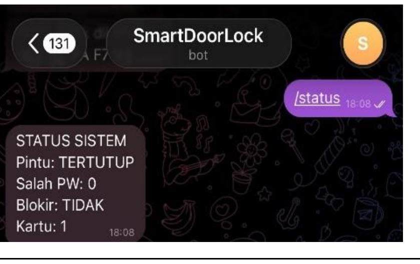
No.	Command	Result
1	/unlock	
2	/open	
3	/setpw	
4	/addcard	
5	/delcard	
6	/status	

Based on the results presented in Table 11, all Telegram Bot commands operated as intended. The /unlock, /open, /setpw, /addcard, /delcard, and /status commands were successfully executed, enabling remote system control and real-time monitoring. These results confirm reliable communication between the Telegram Bot and the ESP32-based door lock system.

Telegram Bot Notification Test Results

Table 13. Telegram Bot Notification Test Results

No	System Condition	Telegram Notification
1	Valid RFID Card or Password	
2	Invalid RFID Card	
3	First Incorrect Password	
4	Second Incorrect Password	
5	Third Incorrect Password	
6	System in Lockout Mode	
7	System Successfully Unlocked	
8	Perintah /open	

9	Perintah /setpw 1234	
10	Perintah /addcard	
11	RFID Card Successfully Registere	
12	Perintah /delcard	
13	RFID Card Successfully Deleted	
14	Perintah /status	

All Telegram notifications were successfully transmitted and received according to the system status. The bot provided real-time notifications for successful authentication, unrecognized RFID cards, incorrect password attempts, system lockout, and system recovery after unlocking. It also responded correctly to user commands, including opening the door, changing the password, registering or deleting RFID cards, and displaying the system status. These results confirm reliable real-time communication between the ESP32-based door lock system and the Telegram Bot for remote monitoring and control.

CONCLUSIONS

This study successfully developed an ESP32-based smart door lock prototype integrating RFID, a 4×4 keypad, a servo motor, LCD, LEDs, buzzer, and a Telegram Bot. The dual-authentication mechanism using RFID and keypad enhanced system security, with the RFID reader accurately detecting registered cards at distances up to 4 cm. Valid authentication unlocked the door for 5 seconds, while invalid access activated the red LED and buzzer and, after three consecutive failed password attempts, automatically locked the system. The ESP32 effectively processed all inputs in real time, controlled the connected devices, displayed system status on the LCD, and transmitted notifications through Telegram. Overall, the hardware and software components operated reliably and performed according to the system design.

The integration of the Telegram Bot successfully enabled real-time remote monitoring and control. Users could unlock the system, operate the door, manage RFID cards and passwords, and monitor system status through Telegram commands. Real-time notifications were generated for successful and failed authentication attempts, unrecognized RFID cards, and system lockout events, improving security and user awareness. These findings demonstrate that the proposed prototype provides an effective, practical, and IoT-based solution for modern door security systems.

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