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Research Article

Implementing RFID Technology for Hospital Security to Track Infants and Sensitive Psychological Patients

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Abstract

The adoption of advanced security solutions in hospitals is vital for ensuring safe and efficient operations. The integration of Radio Frequency Identification (RFID) technology has become an essential component in enhancing both security and operational effectiveness within healthcare environments. These systems facilitate access control for medical personnel and patients through the use of smart cards or RFID tags, thereby significantly improving security measures.

RFID technology is particularly beneficial in sensitive areas, such as neonatal units, and for tracking patients and high-value medical equipment. By affixing RFID tags to newborn Babies, hospitals can effectively prevent abductions and ensure continuous monitoring throughout the facility. Moreover, labeling medical equipment enhances the process of locating necessary items, thereby reducing the risk of loss or misplacement. Staff management is also improved through the use of smart cards, which serve as effective safeguards against unauthorized access to pharmacies and other critical areas.

This paper explores the design and implementation of an RFID smart lock system specifically developed for hospitals. This system regulates access to various sections by interpreting RFID card data based on predefined permissions. Key advantages of this system include maintaining data integrity during power outages, logging entry and exit times, the ability to easily change access codes, controlling door mechanisms via relay systems, and real-time monitoring of access. Additionally, a tracking system for infants and patients is proposed, utilizing biosensors such as gyroscopes to send immediate alerts in the event of a wristband being removed or if an infant or patient is moved. Such measures are crucial for preventing errors and safeguarding vulnerable populations. Experimental results indicate that the proposed system operates with high speed and accuracy, establishing it as a fundamental solution for intelligent hospital management.

Key Words: smart lock; rfid; microcontroller; newborn tracking; intelligent hospital

1. Introduction

Radio Frequency Identification (RFID) technology and smart cards are essential tools in access management within hospital environments, significantly enhancing security protocols. These systems facilitate precise control over the access of both patients and staff, thereby markedly improving the safety of healthcare facilities[1]. This technology not only protects infants but also enhances responsiveness to patient needs and reduces the likelihood of medical errors. Furthermore, it optimizes the labeling of medical equipment, leading to cost reductions and increased operational efficiency [2]. RFID tags assigned to newborns enable continuous monitoring, empowering healthcare personnel to promptly address any unauthorized movements. This feature is particularly beneficial for patients requiring specialized care, such as infants and individuals with mental health conditions [3, 4].

Additionally, RFID smart locks enhance security by managing access to sensitive areas, ensuring that only authorized personnel can enter critical locations, including the neonatal ward and pharmacies. These systems also play a pivotal role in preventing the theft of medical equipment and medications while effectively identifying counterfeit and substandard products. The RFID smart lock provides a keyless access solution that integrates the precision of RFID technology with the versatile capabilities of microcontrollers, thereby transforming traditional locking mechanisms. By employing electromagnetic fields for identification and tracking, these systems offer a secure, contactless method for access management. AVR microcontrollers serve as the backbone of the system, coordinating the authentication process and activating the locking mechanisms [5]. Such solutions facilitate efficient access management across various areas of a hospital, effectively preventing unauthorized entry into sensitive sections. This ensures that only individuals possessing authorized RFID tags or cards can access specific locations within the facility. This advancement not only eliminates reliance on conventional keys but also significantly enhances security while providing a sophisticated level of complexity and flexibility.

In response to the growing demand for secure and advanced solutions, RFID-based door lock systems utilizing AVR technology emerge as exemplary models of contemporary innovation and reliability. These systems not only fortify security and mitigate risks associated with unauthorized access but also offer functionalities such as tracking access history and time during power outages. This capability enables users to manage and monitor activities with heightened accuracy across various domains, particularly in the healthcare sector [6-8].

Biometric systems, typically designed for identification purposes such as facial recognition, fingerprint scanning, and iris detection, are primarily tailored for adults and may not be suitable for infants. Consequently, an infant tracking system utilizing RFID technology is proposed as an effective solution for safeguarding newborns in healthcare settings [2].

Abkari [9] introduces a medication management system in hospitals that is designed using RFID technology and digital signatures. This system, with ESP8266 modules and RFID readers, enables automatic identification and management of medications, and its goal is to reduce medication errors and increase patient safety. Shi [10] examine the integration of RFID technology in smart healthcare and its security and privacy challenges. After identifying potential threats, they investigate the appropriate security needs for this industry and compare existing technologies to analyze their suitability for the smart healthcare industry.

Sundarajoo [11] proposes a remote monitoring system for infants using RFID and GPS. This system identifies the status of the infant and the environment using sensors and sends information to parents through a mobile application. Additionally, location tracking and white noise are used for the safety and comfort of the infant. The aim of this system is to help parents ensure the safety and comfort of infants and prevent misuse. Ulutaş [12] has developed a security system for infants in hospitals that leverages wireless technologies and software. The primary aim of this system is to prevent the theft or swapping of infants. It includes RFID readers and tags that transmit essential information to caregivers. The tags are equipped with temperature and light sensors, relaying data such as the infant's status and access permissions to a centralized database. This information aids healthcare staff in maintaining oversight of the infant's condition.

The article [13] focuses on the design and implementation of a digital security system based on RFID technology for access control in secure areas. This system utilizes passive RFID tags that operate without batteries, rendering them cost-effective. It functions in real-time, automatically unlocking doors as users approach the reader. Additionally, it maintains a comprehensive log of user entries and exits, along with their basic information. Article [14] addresses the security and privacy challenges associated with RFID systems and presents existing solutions. It proposes an advanced approach that employs random numbers and symmetric encryption to effectively protect against tracking, counterfeiting, and various types of attacks. However, significant drawbacks of this method include implementation complexity, the need for additional resources, and limitations in scalability. Study [15] emphasizes the development of a low-cost security system that integrates RFID technology, an electromagnetic lock, and a GSM module. This system utilizes an electromagnetic lock for authorized personnel instead of a traditional key and issues alerts in the event of unauthorized access. Nevertheless, this system has its shortcomings. Firstly, its reliance on electricity renders it inoperable during power outages. Secondly, the RFID reading range may be limited and susceptible to environmental interference. Finally, it requires ongoing maintenance and regular updates. Article [16] explores the development of a security door authentication system based on RFID that incorporates two-factor access control. This system consists of an RFID unit, a microcontroller to manage door operations via a synchronous motor, and integrated circuits. Experimental results demonstrate the system's effectiveness and reliability in preventing unauthorized access. Sobor and et.al [17] have designed and constructed a low-cost security lock aimed at protecting valuable items and assets in public spaces. This RFID-based security lock allows users to secure their belongings within the lock using RFID tags and retrieve them after completing their tasks. While this system can effectively prevent the theft or loss of valuable items in public locations, it also faces challenges such as reliance on electricity, potential vulnerabilities of RFID tags, and the necessity for regular maintenance and updates.

This paper investigates the design and implementation of a smart locking system that employs RFID technology and the ATmega32 microcontroller within hospital environments. The system effectively manages access to sensitive areas by interpreting RFID card data based on predefined permissions. Through the integration of an LCD display and a keypad, users can conveniently view and manage access information. Key benefits of this system include the preservation of data integrity during power outages, the logging of entry and exit times, the capability for administrators to modify passwords, control of the door mechanism via relay systems, and real-time access monitoring. The RFID infant tracking system represents a significant innovation in the healthcare sector, aimed at enhancing infant safety and reducing the risks of loss or theft. With its advanced capabilities and the use of various sensors, this system facilitates the identification and tracking of infants, thereby improving overall care [18, 19]. This paper also proposes a tracking system designed for both infants and psychiatric patients.

Experimental results demonstrate that the proposed system exhibits high speed and accuracy. When implemented correctly, it has the potential to serve as a fundamental solution for access management in sensitive environments.

2. Methods and Materials

2.1 RFID Lock for Smart Access Management in Hospital

This study focuses on the design and implementation of a smart door access control system utilizing RFID technology in conjunction with the ATmega32 microcontroller. The system architecture is delineated into two primary segments: hardware and software.

In the hardware segment, essential components were meticulously selected and designed, including the ATmega32 microcontroller, RFID module, LCD display, and keypad. The software segment involved the development of algorithms for data processing and access management. Following this, the hardware components were integrated, and the software was deployed onto the microcontroller. This phase encompassed rigorous testing and debugging to ensure optimal functionality of all components. Post-implementation, the system underwent a series of evaluations to assess its performance in real-world scenarios. These evaluations included tag recognition, access logging, and performance testing under varying conditions.

As illustrated in Figure 1, the block diagram depicts the interconnections among the various components of the smart electronic door system. The RFID reader functions as the core unit for tag identification, transmitting recognized data to the ATmega32 microcontroller. The keypad facilitates user input for password entry and communicates this information to the microcontroller. The DS1307 module, serving as the system's real-time clock, transmits accurate time and date data to the microcontroller via the I2C protocol.

The ATmega32, acting as the central processing unit, processes incoming data from both the RFID reader and keypad, executing decisions to control the relay, buzzer, and LCD display. The relay is utilized to manage loads such as the electronic lock, receiving commands from the ATmega32. The buzzer is integrated to provide audio notifications, including alerts and confirmations, while the LCD displays critical information such as access status and the current time and date. This seamless interaction among components ensures that the system operates efficiently and reliably.

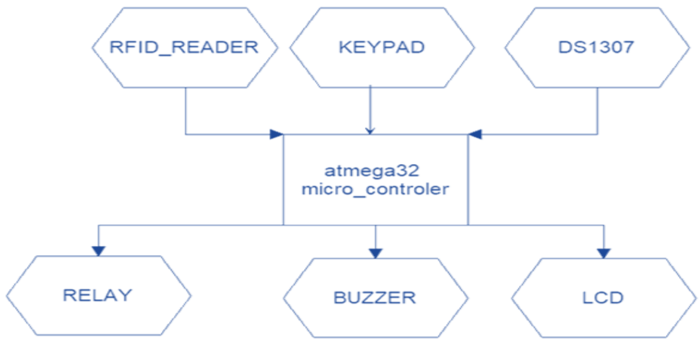


Figure 1: Block Diagram of the Circuit

The subsequent sections will introduce the overall hardware components of the system in greater detail.

RFID Tag: RFID tags represent a fundamental element in wireless identification systems, utilized for the identification and tracking of objects, individuals, and assets. Each tag is equipped with an antenna designed for the transmission and reception of radio frequency signals, while its integrated circuit (IC) is responsible for storing critical information, such as a unique identifier. The RFID tag communicates data regarding the associated object through radio waves to the reader/antenna system.

RFID Reader: The RFID reader is a pivotal device that reads the information encoded within RFID tags and transmits this data to the microcontroller for tag activation. The architecture of an RFID system encompasses both the reader and the tags. The reader itself consists of an antenna, transceiver, and processor, which collectively facilitate the sending and receiving of radio signals. The tags, in turn, comprise an antenna and chip that store data and establish communication via radio frequencies.

Microcontroller: In the context of RFID smart door systems, the ATmega32 microcontroller serves as the central processing unit, tasked with processing input signals from the RFID module, managing security algorithms, and executing decisions regarding door operation. This microcontroller leverages programs stored in flash memory to oversee the overall functionality of the system and to enable communication with other components. Acting as the core of the system, it reads tag information and compares it with pre-stored data to authenticate access.

LCD (Liquid Crystal Display): The LCD functions as a user interface, displaying essential information such as security settings, lock timing, and details pertaining to authorized users. Liquid crystals possess unique properties that allow them to exhibit liquid-like behavior while maintaining a specific molecular arrangement. The LCD facilitates technicians and system administrators in efficiently modifying and managing system settings. Furthermore, it may display battery status or power supply conditions, ensuring the system operates at optimal performance levels.

Transistors: In RFID systems, transistor switching circuits play a crucial role as electronic switches within the circuitry. These switches can rapidly and accurately toggle signals, which is vital for the reliable operation of RFID systems. Additionally, transistors are employed in voltage regulation circuits, where they may be integrated into power circuits to convert input voltage to appropriate levels for various components.

Keypad: The keypad in an RFID smart door system allows users to input security codes for system access. These inputs are relayed to the microcontroller, where they are compared against stored codes. Upon a successful match, the microcontroller generates signals to unlock the door. The keypad also serves as a means for configuring system settings and entering supplementary data, with distinct keys performing specific functions that become active after the entry of an administrator password.

DS1307 Module: The DS1307 module is utilized in RFID smart door systems to log the precise time each time the door is accessed. This temporal data is invaluable for monitoring access patterns and generating comprehensive reports. The module can also be programmed to schedule various operations, such as the timed opening and closing of the door, thereby allowing users to configure the system according to specific timeframes. Additionally, it can facilitate the timing of particular events, such as the duration of user entries or exits, enabling relevant analytical assessments.

Relay: In RFID door systems, relays are integral for controlling electric locks. Upon verification of authorized access by the microcontroller, the relay sends a signal to the lock mechanism to initiate the door opening process. Relays can also be programmed for scheduled operations, enabling the execution of specific functions, such as the timed opening and closing of the door. The components utilized in the construction of the circuit are illustrated in detail in Figure 2.

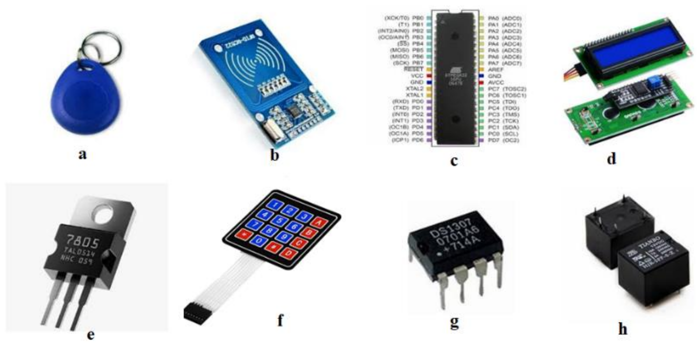


Figure 2: Parts used to make the circuit: a: RFID Tag, b: RFID Reader, c.: Microcontroller, d: LCD, e: Transistors, f: Keypad, g: DS1307 Module, h: Relay

The initial phase of this project involved the simulation of the circuit designed for the RFID smart door system, followed by the programming of the ATmega32 microcontroller. The coding was undertaken using the C++ programming language, which is well-suited for embedded systems development. The circuit design encompasses the interconnections between the RFID reader, microcontroller, LCD, and keypad. Additionally, the integration of the DS1307 real-time clock module and relay enhances the functionality of the system, as illustrated in Figure 3.

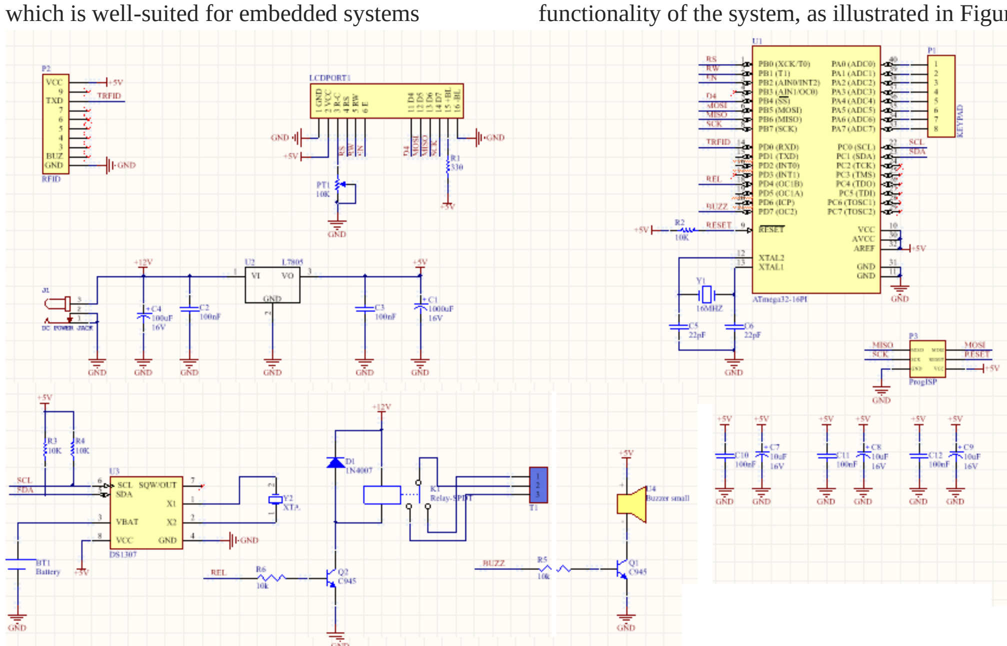


Figure 3: Overall schematic of the circuit.

In the following, some important parts of the circuit will be described.

Noise Filtering Circuit: The noise filtering circuit is designed to mitigate electrical noise and stabilize the power supply. It employs 100 nF capacitors to effectively filter out high-frequency noise, while 100 µF capacitors are utilized for smoothing the input voltage. The 7805-voltage regulator is critical in converting the input voltage to a stable 5V output, thereby ensuring reliable power supply to the digital components of the circuit, as depicted in Figure 4.

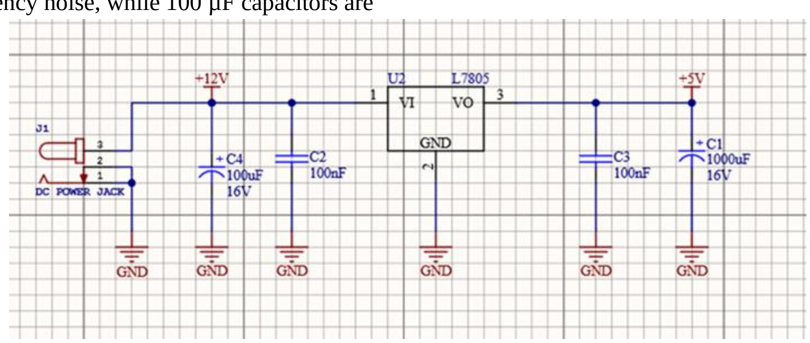


Figure 4: Noise filtering and voltage regulation circuit.

Relay Output Mechanism: Upon activation of the output connected to the base pin of the transistor by the microcontroller, the transistor enters saturation, allowing current to flow from the collector to the emitter. This process activates the relay, thereby altering its state. A fly back diode (model 1N4007) is integrated into the circuit to safeguard the transistor from voltage spikes generated by the collapsing magnetic field in the relay coil, as illustrated in Figure 5.

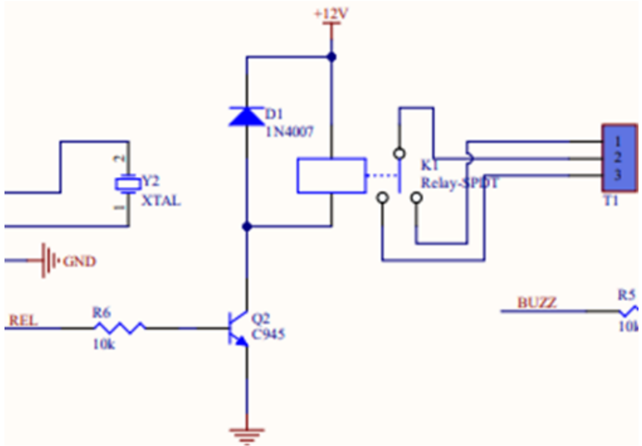


Figure 5: Relay and transistor circuit configuration

DS1307 Circuit: To ensure continuous operation of the DS1307 IC during power outages and to retain accurate time and date information, a coin cell battery is employed. The DS1307 communicates with the microcontroller utilizing the I2C protocol, which facilitates efficient data transfer. Resistors R3 and R4 serve as pull-up resistors for the I2C bus, ensuring proper signal levels. For precise timekeeping, the DS1307 requires a 32 kHz crystal oscillator, as shown in Figure 6.

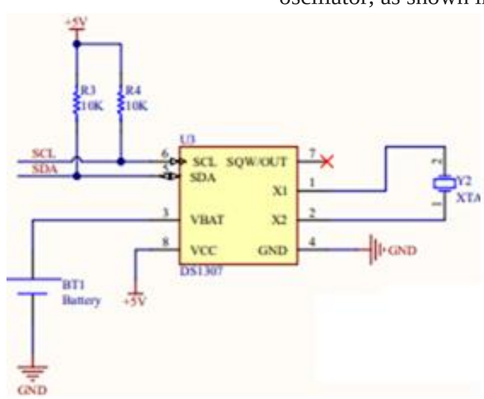


Figure 6: DS1307 circuit schematic.

LCD Interface Circuit: The LCD module features an integrated controller that displays information on a segmented screen, typically organized into multiple rows and columns. For instance, transmitting the character 'M' to the LCD results in its visual representation on the display. The system can also execute various commands, including clearing the display, shifting content, and toggling the display state. Resistor R1 is employed to limit the current supplied to the backlight, while potentiometer PT1 adjusts the display contrast, as illustrated in Figure 7.

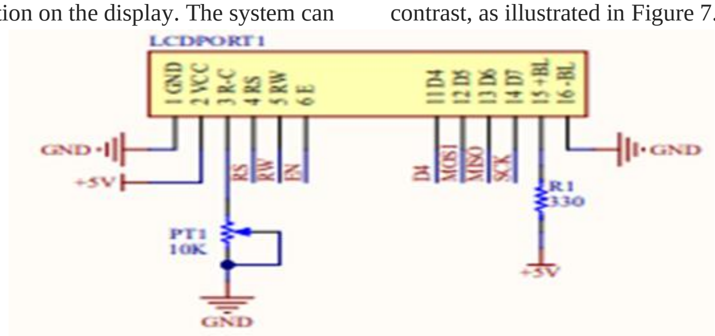


Figure 7: Components of the LCD and control lines.

The software architecture is designed to issue commands for opening or closing the door upon detection of an RFID tag, simultaneously displaying relevant information on the LCD. Furthermore, the software manages date and time functionalities via the DS1307 module and controls the relay mechanism for door operation. The PCB layout of the circuit is presented in Figure 8.

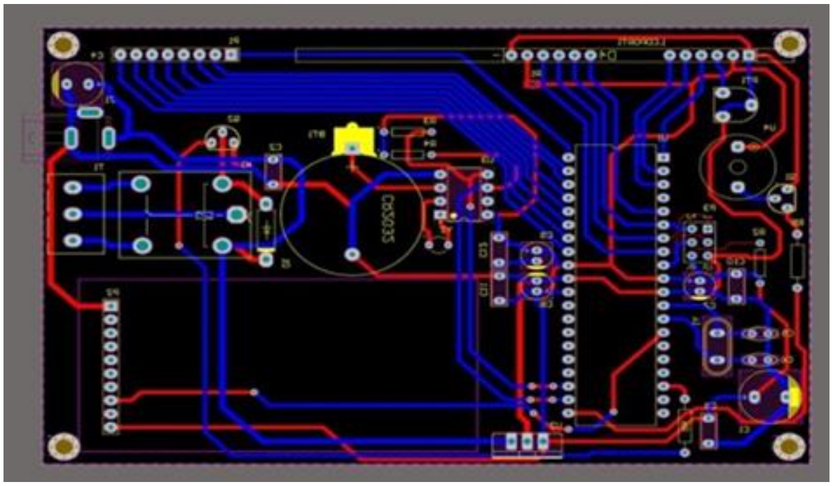


Figure 8: The schematic of PCB layout

2.2 Infants tracking System Based on RFID

The RFID infant tracking system comprises four essential components, each playing a vital role in its functionality. RFID tags, attached to infants or their clothing, can be classified as passive, semi-passive, or active. Generally, passive or semi-passive tags are preferred for infant tracking due to their lower energy consumption and cost-effectiveness.

RFID readers emit radio waves and receive reflected signals from the tags, with these devices being either stationary or portable, efficiently collecting information. Antennas, integral to the reader system, are responsible for transmitting and receiving radio waves. The software used to manage and interpret the collected data must be capable of displaying information in a centralized system and sending security alerts as necessary.

RFID tags store unique identifiers, such as the infant's identification code. The readers transmit signals to the tags via radio waves, which the tags receive and reflect back. The gathered information is then sent to a central database for real-time monitoring.

A key feature of this system is the inclusion of a gyroscope, designed to detect any attempts to tamper with or remove the tags. If a tag is unintentionally or intentionally removed from the infant, the gyroscope promptly identifies this change and activates the alarm system. This feature is particularly crucial during emergencies, helping to prevent unfortunate incidents**.** Figure 9 shows the block diagram of the proposed system based on RFID for infant tracking**.**

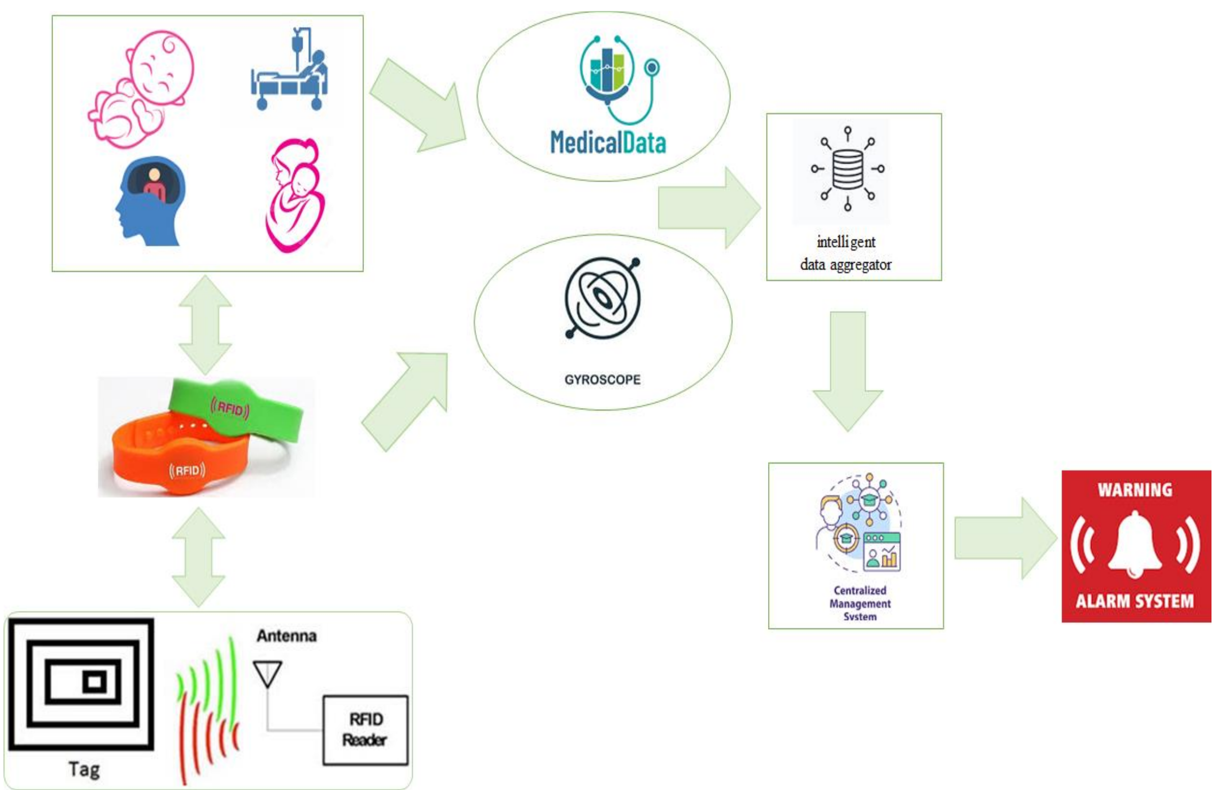


Figure 9: The Block diagram of the proposed system

3. Results

The developed system successfully fulfilled its intended purpose, facilitating the opening and closing of the door through the detection of RFID tags by the reader, which subsequently transmits the data to the ATmega32 microcontroller. Comprehensive testing under various conditions demonstrated satisfactory performance outcomes. Additionally, the incorporation of an LCD and keypad significantly augmented the system's usability and operational efficiency (Figure10).

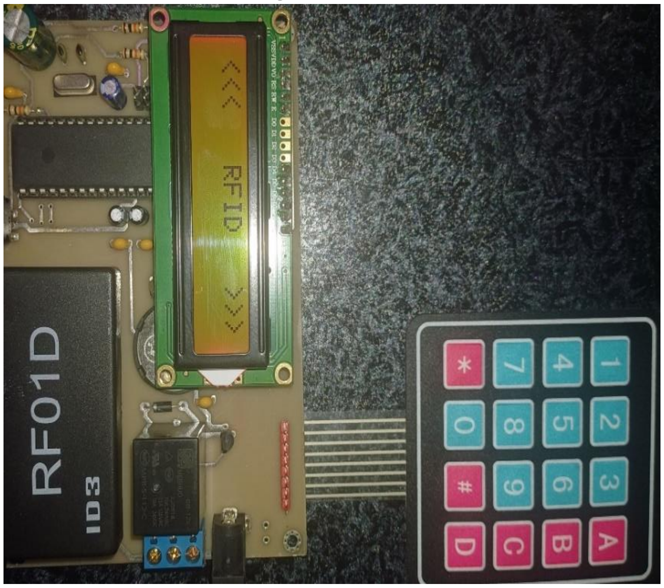


Figure 10: The real view of smart RFID Lock.

The RFID infant tracking system not only enhances safety but also minimizes human errors in infant identification. It facilitates rapid and accurate identification of infants during emergencies, prevents infant theft, and ensures that newborns are monitored in a secure environment. Furthermore, due to its advanced capabilities, the system can also serve as a tracking platform for psychiatric patients, aiding in data collection within hospitals and ensuring that patients receive appropriate support based on their location. Patient data is securely stored in a dedicated database, allowing for easy access to critical information. This system is utilized for tracking both infants and psychiatric patients, preventing them from going missing. Even if individuals inadvertently remove their RFID tags, the system, equipped with a gyroscope, retains the information and triggers an alert. Figure 11 shows the designed circuit.

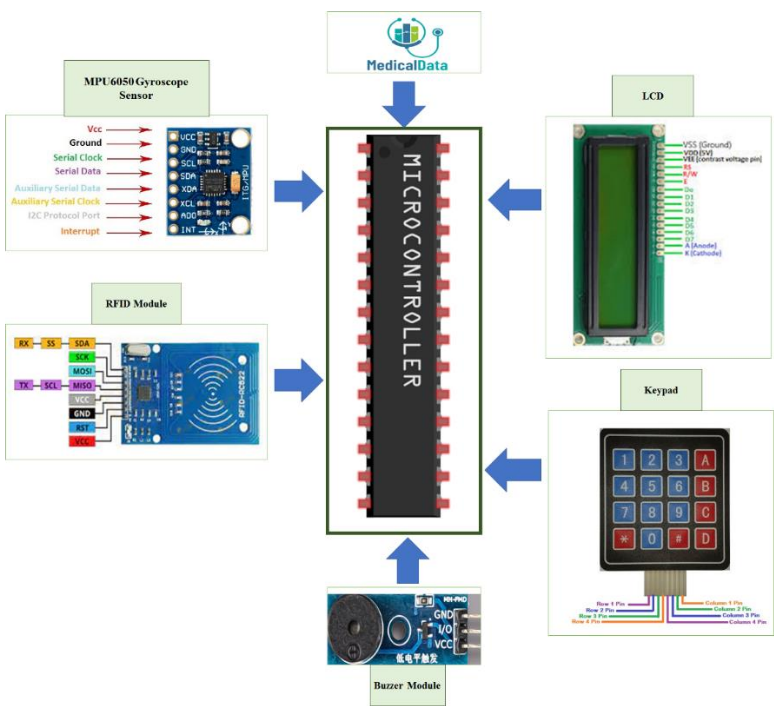
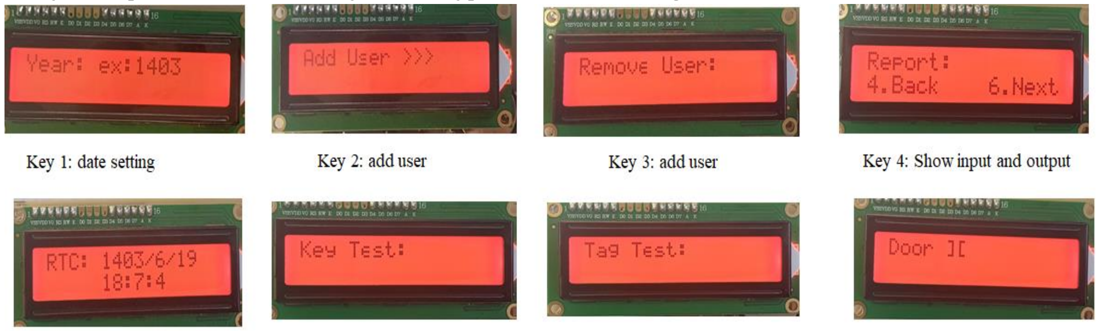


Figure 11: Infants and sensitive patients tracking System Based on RFID

Unlike many existing systems that rely solely on either RFID or keypad technology, this innovative design integrates both modalities, thereby enhancing security and functionality. The specific roles of each key on the keypad are detailed in Figure 12.



Key 1: date setting | Key 2: add user | Key 3: add user | Key 4: Show input and output

Key 5: display date and time | Key 6: keypad test | Key 7: RFID test | Key 8: Relay test

Figure 12: Keypad Functionality.

The system is capable of displaying the last 20 input and output transactions, which facilitates meticulous monitoring and tracking of access events. Users can navigate through previous and subsequent entries using keys 4 and 6, as illustrated in Figure 12 (key4).

Moreover, the capability to modify the admin and RFID Password via the keypad significantly strengthens the system's security and simplifies management and also the implementation of a relay for controlling the door mechanism ensures the system operates effectively and reliably.

4. Conclusion

The integration of RFID technology into hospital management systems has significantly transformed security and operational efficiency in healthcare environments. This study illustrates how RFID-based smart lock systems, utilizing the ATmega32 microcontroller, effectively regulate access to sensitive areas, considerably mitigating the risks of unauthorized entry. By implementing predefined access permissions, the system ensures that only authorized personnel can enter critical zones, thereby protecting patients and valuable medical assets.

Moreover, the use of RFID tags enables hospitals to prevent infant abductions and provides a tracking mechanism for psychiatric patients, facilitating continuous monitoring of their conditions. Patient data is securely stored in a dedicated database, allowing for easy retrieval of essential information. The RFID-based infant tracking system, known for its speed and precision, serves as a fundamental solution for managing access and safeguarding vulnerable populations in hospital settings. The innovative features of this system including real-time access monitoring, preservation of data integrity during power outages, and accurate logging of entry and exit times highlight its reliability and effectiveness in hospital environments. Furthermore, the inclusion of user-friendly interfaces, such as LCD displays and keyboards, enhances usability, enabling administrators to efficiently manage access and monitor system performance. By embracing these technological advancements, healthcare facilities can substantially bolster their security protocols, creating a safer environment for both patients and staff.

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