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An Autonomous Institute Affiliated to Savitribai Phule Pune University
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A PROJECT REPORT ON

Smart Library with Automatic Book Management

SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE IN THE PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE OF

BACHELOR OF

ENGINEERING IN

ELECTRONICS AND TELECOMMUNICATION

BY

Aniket Pattanshetti,
Dnyaneshwar Bhalke,
Prajkta Sarode

UNDER THE GUIDANCE OF

PROF. Chandrakant K Bhange

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION

BY ALL INDIA SHRI SHIVAJI MEMORIAL SOCIETY'S INSTITUTE OF INFORMATION TECHNOLOGY, PUNE -411001

ACADEMIC YEAR: 2022-23

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GOAL 9: Industry, Innovation and Infrastructure

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BY

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Department of Electronics and Telecommunication Engineering

Certificate

This certify that the Project Report entitled

Smart Library with Automatic Book Management
GOAL 9: Industry, Innovation and Infrastructure

Submitted by

Aniket Pattanshetti,
Dnyaneshwar Bhalke,
Prajkta Sarode

is a record of bona-fide work carried out by them, in the partial fulfillment of the requirement for the award of Degree of Bachelor of Engineering in Electronics and Telecommunication Engineering at All India Shri Shivaji Memorial Societies' Institute of Information Technology, Pune under the Savitribai Phule Pune University, Pune. This work is completed during academic year 2022-23, under our guidance.

Prof. Chandrakant K Bhange	**Dr. Mohini Sardey**	**Dr. P.B. Mane**
Project Guide	**Head of the Department**	**Principal**

Acknowledgement

It is our great pleasure in expressing sincere and deep gratitude towards my guide Prof. Chandrakant K Bhange, Professor Electronics & Telecommunication Engineering Department for his valuable guidance and constant support throughout this work and help to pursue additional studies in Internet Of Things by implementing the Embedded System.

We take this opportunity to thank head of the department Dr..M,.P.Sardey and project coordinator Prof. Archana Ubale and all staff members of department of electronics & Telecommunication Engineering AISSMS IOIT,Pune for cooperation provided by them in many ways. The motivation factor for this work was the inspiration given by our honorable principal Dr .P .B. Mane. Lastly we are thankful to those who have directly or indirectly supported for our work.

Sign	Sign	Sign
Aniket Pattanshetti	Dnyaneshwar Bhalke	Prajkta Sarode

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ADDING VALUE TO ENGINEERING

Department of Electronics and Telecommunication Engineering

Vision

To provide quality education in Electronics & Telecommunication Engineering with professional ethics.

Mission

To develop technical competency, ethics for professional growth and a sense of social responsibility among students.

Program Educational Objectives

The Program Educational Objectives (PEOs) are as follows:

1. To provide graduates of the program with pertinent skills to boost employability and all- round development.
2. To empower graduates of the program to exhibit professionalism and adopt lifelong learning in the emerging areas of technology.
3. To prepare graduates of the program to evolve as socially committed entrepreneur's sensitive to the needs of the society.

Program Specific Outcomes

Graduates will be able

1. Apply domain specific knowledge to develop electronics and telecommunication systems/applications.
2. Select different software tools, test and measurement equipment and use them efficiently for system solution.

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Department of Electronics and Telecommunication Engineering

Program Outcomes

Graduates will be able to

1. Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
[**Engineering knowledge]**

2. Identify, formulate, research literature, and analyse complex engineering problem searching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.[**Problem analysis]**

3. Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations. [**Design/development of solutions]**

4. Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. [**Conduct investigations of complex problems]**

5. Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations. [**Modern tool usage]**

6. Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities

relevant to the professional engineering practice. [**The engineer and society]**

7. Understand the impact of theprofessional engineering solutions in societal and environmental contexts,and demonstrate the knowledge of, and need for sustainable development. [**Environment and sustainability]**

8. Apply ethical principles and commit to professional ethics andresponsibilities and norms of the engineering practice. [**Ethics]**

9. Function effectively as an individual, and as amember or leader in diverse teams, and in multidisciplinary settings. [**Individual and team work]**

10. Communicate effectively on complex engineering activitieswith the engineering community and with society at large, such as, being ableto comprehend and write effective reports and design documentation, makeeffective presentations, and give and receive clear instructions. [**Communication]**

11. Demonstrate knowledge andunderstanding of the engineering and management principles and applythese to one's own work, as a member and leader in a team, to manageprojects and in multidisciplinary environments. [**Project management and finance]**

12. Recognize the need for, and have the preparation andability to engage in independent and life-long learning in the broadest contextof technological change. [**Life-long learning]**

ABSTRACT

Libraries are indispensable for books and reading, as well as an abundant source of information. The majority of the current conventional libraries employ labor-intensive, time-consuming processes that result in long lines for borrowing and returning materials. In this paper, we propose a smart library system built on the Internet of Things that addresses these issues. The proposed system involves using books that have RFID tags attached to them and a camera at the borrowing counter. The RFID readers on the bookshelves and at the borrowing counter can read the book information stored electronically on the RFID tags and the camera verifies the user by scanning their face using a face recognition model. As a result of the combination of Face recognition and RFID Technology, the system automates the processes of borrowing, returning, and sorting the books by enabling the self-borrow and self-return process along with the ability to track each book's location on the bookshelf. An e-mail will be sent to the user acknowledging both the transactions. The proposed system remarkably quickens the process of borrowing, returning and sorting thus reducing long queues at the librarian's desk and lesser human intervention for the management.

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CHAPTER 1

INTRODUCTION

1. Introduction

A library management system is designed to monitor all the library activities and maintain a database of all books with their issue, return details as well as the due dates. The main aim of a library management system is to provide accurate data regarding any type of book and easy user interaction with the system therefore saving a lot of time and effort. The major problem faced by the current system is the improper management of books, misplacement and slow check in/check out for the user. The conventional methods use barcode scanning, magnetic stripe reading etc to prevent these problems but they are often error prone and also consume a lot of time. The existing system is semi-automated meaning it requires additional efforts for the librarian for borrowing the books, sorting it and observing the misplacement of the books in the bookshelves. The users often experience long delays while borrowing or returning the books which leads to spending unnecessary time in queue. Hence, there is a need for an automated library management system and a solution for updating the location of the library books in a central database efficiently.

The proposed system is to be deployed in public libraries which currently uses a manual system consisting of bar-code technology for accessing the book and requires a dedicated person to scan the books and place them returned in the designated shelf. It replaces the existing traditional library management system with a combination of RFID and Face Recognition mechanism thus allowing a very effective level of automation in the various processes of the library.

The proposed system is based on the technologies of RFID, Face Recognition and Cloud computing.

RFID stands for Radio Frequency Identification and involves an RFID Reader and an Antenna (Tags). It was invented by Charles Walton as the first patent holder for RFID technology. RFID uses electromagnetic fields radio waves to automatically identify and capture information stored on a RFID tag attached objects, where the RFID tag contains electronically-stored information. RFID tags transmit data through radio waves. They typically do not have a battery instead, they receive energy from the radio waves generated by the reader. When the tag receives the transmission from the reader/antenna, the energy runs through the internal antenna to the tag's chip. The energy activates the chip, which modulates the energy with the desired information, and then transmits a signal back toward the antenna/reader. RFID reader is a device that can receive and transmit a radio signal. It is built to encode the information stored in the tag's microchip.

Face recognition is a way of identification of an individual using their face. Facial recognition systems can be used to identify people in photos, videos, or in real-time. The software reads the geometry of your face. Key factors include the distance between your eyes, the depth of your eye sockets, the distance from forehead to chin, the shape of your cheekbones, and the contour of the lips, ears, and chin. The aim is to identify the facial landmarks that are key to distinguishing your face.

Cloud computing is the process of using the internet to access and use computing resources such as data storage, processing power, and software programs. Cloud computing enables users to store and process data remotely in sizable data centers owned and operated by third-party companies rather than depending on local servers or personal computers. Customers get on-demand access to these resources, typically via a subscription-based approach, and can adjust their usage as necessary. The flexibility and scalability of cloud computing are two of its main advantages. Customers don't need to make expensive hardware updates because they can quickly modify their computing capacity to suit their changing needs. This makes it possible for people and enterprises to be more adaptable and receptive to market needs. The proposed system utilizes Cloud Database based on the Cloud Computing technology to store the necessary library information.

The proposed system will make use of the above key components to automate the library management. The bookshelves which will be equipped with RFID readers will enable the user to return the borrowed book with a single tap before putting it back in the designated shelf. The data will be sent to the central database on the cloud. At the borrowing counter, the registered user will be identified using the camera and face recognition algorithm. The book to be issued will be identified using RFID and the combination of this data will be sent to the central database thus completing the process of issuing the book faster. An e-mail receipt of both these transaction will be sent to the user automatically.

The materials which will be covered consists of hardware sourced from local shops which includes the RFID Readers, RFID Tags, Microcontroller units, Power supply, Camera and the other materials i.e Cloud Database and a Wireless Network.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review

	Research paper	Authors	Name of Journal	Year of Publication	Hyperlink
1.	RFID based Library Management System	Kumar, Nivedita & H C, Sateesh	International Journal of Engineering Science and Technology	2020	https://www.researchgate.net/publication/343442213_RFID_Based_Library_Management_System
2.	An IOT based Secured Smart Library System with NFC based Book Tracking	A Larsan Aro Brian, L Arockiam & P. D. Sheba Kezia Malarchelvi	IJETCSE	2014	https://www.ijetcse.com/admin/uploads/AN%20IOT%20BASED%20SECURED%20SMART%20LIBRARY%20SYSTEM%20WITH%20NFC%20BASED%20BOOK%20TRACKING_1605851121.pdf
3.	Smart Library System using QR Code	A.Singh	Academia	2019	https://www.academia.edu/96961729/Smart_Library_Management_System_using_QR_code
4.	Attendance Monitoring System Using Face Recognition	Amrutha H. B, Anitha C, Channanjamurthy K. N, Raghu R	IJERT	2018	https://www.ijert.org/research/attendance-monitoring-system-using-face-recognition-IJERTCONV6IS13213.pdf
5.	Design of an RFID-Based Manufacturing Data Tracking System in Plant Production	Zhou, Guanghui & Jiang, Pingyu & Zheng, Mei	ICIRA	2008	https://link.springer.com/chapter/10.1007/978-3-540-88518-4_74

6.	IoT Based Water Level Monitoring System Using NodeMCU	Rmsm, Dissanayaka &Wickramaarachchi ,Helani	ASBIRES Conference	2019	https://www.researchgate.net/publication/338002821_IoT_Based_Water_Level_Monitoring_System_Using_NodeMCU
7.	SLMS: A smart library management system based on an RFID technology	Younis, Mohammed	IJRIS	2012	https://www.researchgate.net/publication/235637059_SLMS_A_smart_library_management_system_based_on_an_RFID_technology

Table no. 1

2.2 Literature Summary

The system proposed in [1] includes RFID Based Library Management System. It uses RFID for borrow and return as well as for authentication of the user. Every user is given an Identity Card with RFID tag embedded in it. The system authenticates when the user scans this Identity Card against the RFID Reader to gain access to the library. It follow the same procedure to borrow and return the book by scanning the book which is embedded with RFID tag, against the RFID Reader. The returned books after scanning are placed in a return tray. It also implements a security mechanism which involves the entry/exit gate which is equipped with RFID Reader, detect unborrowed book going out of the library and raises an alarm. The system suggested in [2] makes use of the Near Field Communication technique for book tracking. There is a NFC tag on each book. The user places their NFC-enabled phone on the NFC reader at the entrance. The user is connected to the LAN if their fingerprint and user ID have been recorded in the database. The user uses his phone to send a request to the system for a book search, and the server responds with information about the book rack. The user sends this request to the local positioning system, which then directs him further to the selected rack. A new book is initially registered in a rack by scanning its NFC tag against the monitor of that specific rack. The entry/exit includes NFC scanners to carry out the borrow procedure. In order to return the book, the user has to just drop the book in the designated drop box. Another technology used to enable Smart Library is a QR Code based Library Management System [3]. It involves an android application which carries out the various services in the library such as book borrow, book return, browsing the collection, checking availability of a book and a managing function for the librarian to observe the movement of books and prevent thefts. The user is authenticated by the app using an User ID and password. In order to borrow a book, the user has to click on the borrow button in the application which opens the camera on the phone to scan the QR Code. After scanning the QR Code on the book, the relevant details are gathered, return date is calculated and the process is completed by sending all the details to the database. Similarly, to return a book, the user scans the QR Code on the book and places the book in a designated shelf near the librarian. The system checks whether the book is returned in time and charges a fine if returned after the due date. Face recognition based Attendance Monitoring System [4] identifies the person using a Face Recognition algorithm and marks its attendance record in the database. The algorithm used in this system involves steps; Image acquisition,

Histogram normalization, Noise removal, Skin classification and Face Detection. After the Face detection, the face image is cropped covering the detected face and is compared with the database. This is how the student is verified and then the data is sent to the database to mark the their attendance. The system results into more accurate and faster method of authentication thereby saving time and efforts and enabling convenience for the user. In this paper [5], an RFID-based manufacturing data tracking system is designed to collect all kinds of data and track them in real time. All kinds of users in the plants can guarantee to execute their operations in both time saving and cost effective manner.The Radio Frequency Identification (RFID) technology is utilized to acquire the data derived from the plant in real time. This paper [6] involves using the Firebase cloud real time database to store the measured water level and volume of the water in real-time using an ultrasonic distance sensor and a wireless network. This study [7] suggests an RFID-based smart library management system that makes use of inexpensive passive tags. The duty of both library patrons and employees is made simple, clever, practical, and easy by integrating RFID into the library administration system.

CHAPTER 3

AIM, OBJECTIVE AND METHODOLOGY

3.1 Aim

The aim of this project is to combine RFID, Face Recognition and Cloud Computing integrating them into library management system which results into a highly automated system with minimum human involvement and seamless user interaction. This makes both the library users and staff's task easy, smart, efficient and convenient. The highlight of this proposed system is the registered user picking up the book it wants and borrowing it quickly within few seconds as well returning the book with a single tap.

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3.2 Objectives

1. To provide instant borrowing/returning of books using Face Recognition and RFID eliminating time and labour consuming checkout counters and queues.
2. To provide a useful interface allowing the librarian to observe the automated library functioning.
3. To allow tracking of each book's location in the bookshelves by transforming the book shelves into RFID based and allow efficient sorting.

3.3 Methodology

1. Registration:

The user while registering for the library service will be asked by the librarian to capture their face via the camera on the borrowing device and the face recognition system will store the identification data. The other details about the user such as Name, User ID, Book details will be added to the database. The user will now be ready to use the library service. The information about each book including title, author, publication, etc will be entered into the database. The same information will also be written to the RFID tag which will be embedded into the book.

2. Book Borrow:

The user browses the bookshelves and searches for the required book. If found, the user will take it to the borrowing counter and scan the book by tapping it on the borrowing device. The system will extract the book details using RFID and then ask the user to scan their face. The camera equipped will scan the face of the user and match it to the user`s identity0in the database. Upon successful verification, the system will send all of the obtained data to the database thereby completing the borrowing process. The communication between the borrowing device at the borrowing counter and the database will be carried out wirelessly. All the steps throughout the process will be notified to the user through an OLED display. An email receipt will be sent to the user automatically after the borrow process is finished.

3. Book Return:

The user when returning the book has to make a single tap on the sensor area of the designated sector of the bookshelf according to the category of the book. The return device of the bookshelf will extract the book details through the RFID reader. It will intitate a search query to the database to identify the user who has borrowed the book. Once the identification is done, it will make the necessary changes to the data in the database thereby completing the return procedure. All the steps in this process will be notified to the user through different types of beeps. An email receipt will be sent to the user automatically after the return process is finished.

4. Sorting:

In an event where a user tries to return the in the incorrect place, the return device compares the category of the book obtained by through the RFID reader to the category of the sector and sends an alert beep to notify the user of the incorrect location of the book. It stops the return procedure and the book is not returned to the library thereby avoiding the incorrect placing of the books in the bookshelves.

5. Database:

The cloud database displays all the necessary information about all the library activities in real time which is accessible to the librarian. It establishes a secure connection with the borrow and return counters before carrying out the two way data transfers. The communication is carried out wirelessly using a wireless network connected to the Internet.

CHAPTER 4

PROBLEM STATEMENT

4. Problem Statement

- The major problem faced by the existing system is improper management of books, misplacement and slow check in/check out for the user.
- The existing system is semi-automated meaning it requires additional human effort for placing the returned books in the designated shelf, sorting it and monitor the misplacement of books.
- The users often experience long delays while borrowing/returning the books which ends up spending unnecessary time in queue.

CHAPTER 5

BLOCK DIAGRAM AND EXPLANATION

5.1 Block Diagram

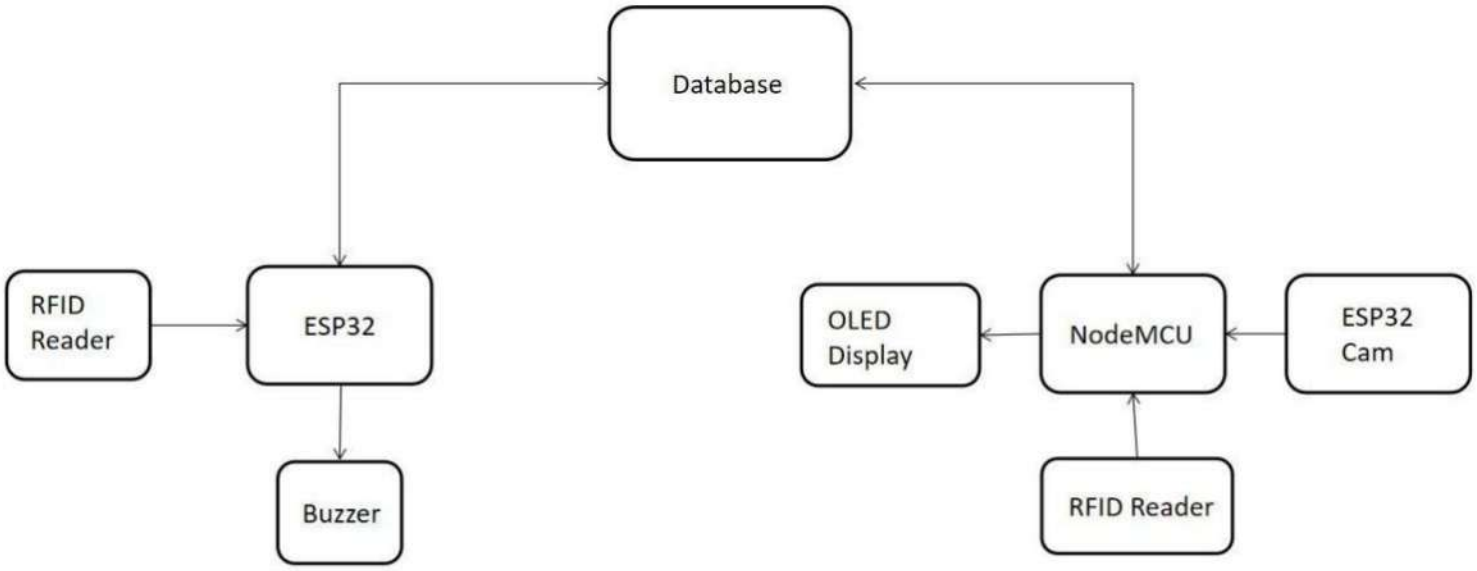

Fig no. 1

5.2 Explanation

The above diagram is a block diagram of the proposed system. It follows the principle of Internet Of Things (IoT) where there is a network of things communicating with each other enabled by sensors and other technologies. The block diagram can be categorised in three units. The first unit has the NodeMCU as the central processing unit which handles the borrow process by controlling and communicating with the RFID reader to obtain RFID tag data and receiving Face recognition data from the ESP32 Cam microcontroller which has a camera attached to it. The details during the borrow process are displayed onto the OLED display. The second unit has the ESP32 as the central processing unit which can handle the return process using multiple RFID readers through SPI interface and produce sound from the buzzer post completion of certain actions. The third unit has the central database which is a realtime database hosted on the cloud by the service provider which records all the library information over the Internet through the microcontrollers.

CHAPTER 6

HARDWARE DESIGN

6.1 Hardware

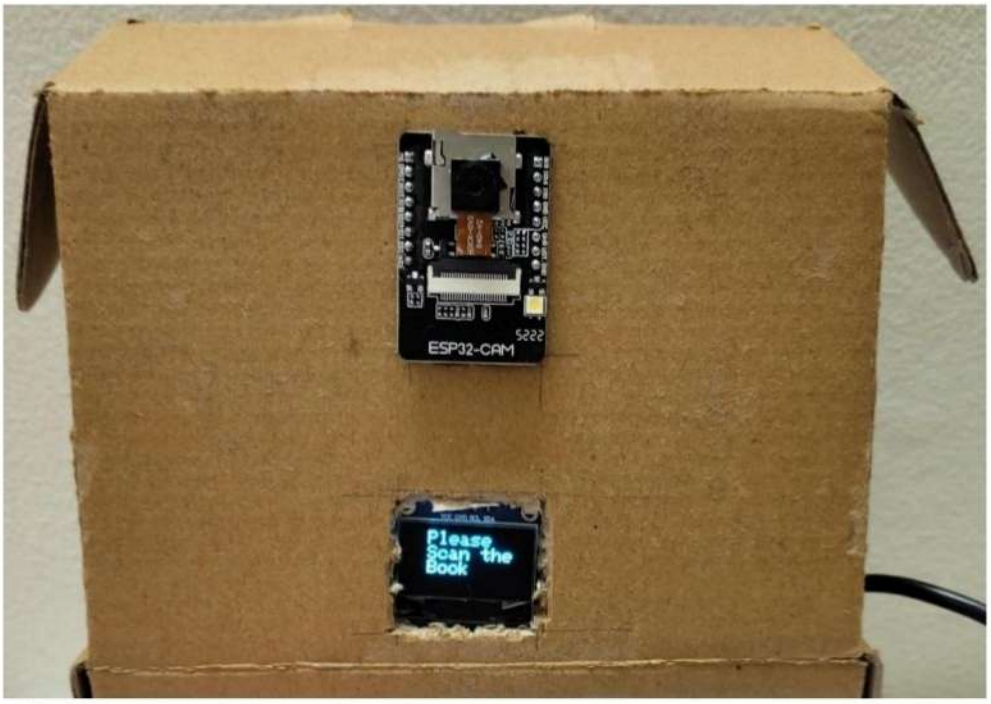

Fig no. 2. Book borrow device

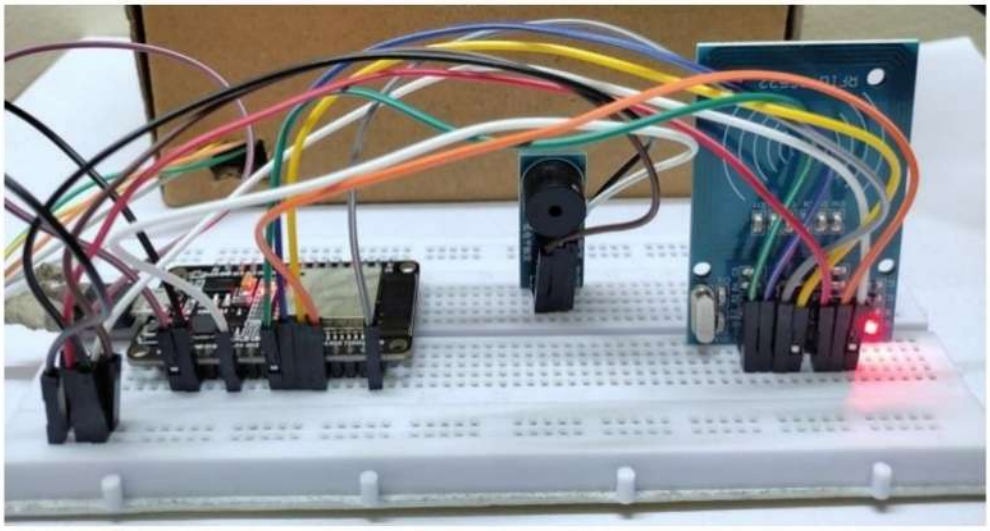

Fig no. 3. Book return device to be mounted on bookshelves

6.2 Hardware Requirement

1. ESP8266 NodeMCU
2. ESP32Cam
3. ESP32
4. OV2640 2MP Camera
5. Active Buzzer Module
6. OLED Display SSD1306
7. MFRC522 RFID Reader
8. RFID Tags
9. FTDI Adapter Module
10. Jumper Wires
11. Breadboard
12. Micro USB cables
13. Soldering Material

6.3 Software Used

1. Arduino IDE
2. Firebase
3. Tinkercad
4. Fritzing

6.4 Circuit Diagram

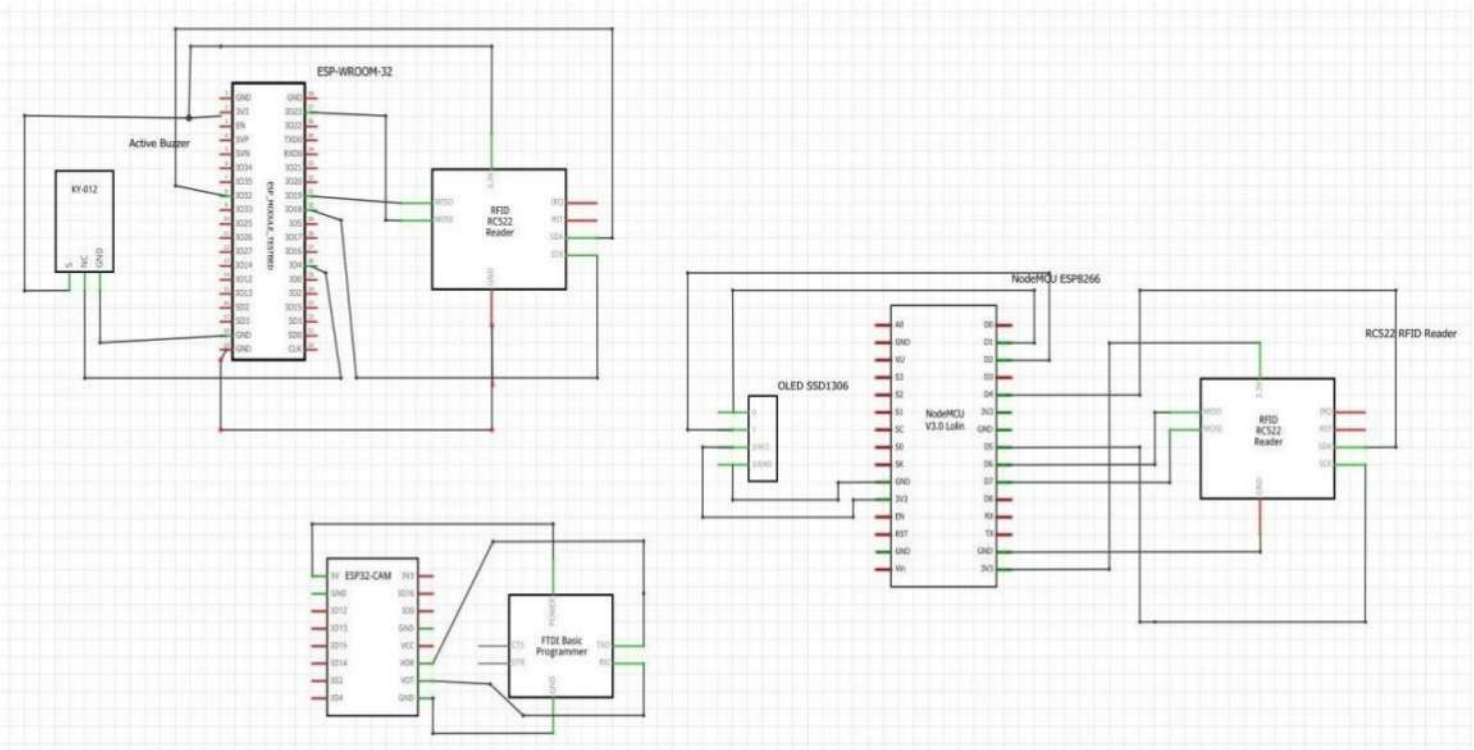

Fig no. 4

The above diagram illustrates the circuit connections of the different components involved in the system. The system design is physically implemented into 2 modules; Borrow device and Return device.

The borrow device has the ESP8266 Node MCU as the main processing unit which is connected to the MFRC522 RFID Reader via SPI Pins and SSD1306 OLED display via the I2C Pins. The ESP32 Cam is connected to the FTDI programmer for the serial interface and power supply.

The Return device is a ESP32 microcontroller which is connected to an Active Buzzer Module with a single data pin and an MFRC522 RFID reader via SPI pins. The device can be connected to upto 6 readers for different rows of the shelves each having a separate data line.

6.5 Component Details

1. ESP8266 NodeMCU:

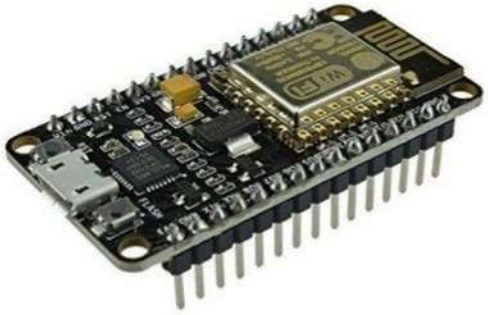

Fig no. 5

Node MCU is a development board and open-source Lua-based firmware that is specifically aimed for Internet of Things (IoT) applications.It has hardware based on the ESP-12 module and firmware that operates on Espressif Systems' ESP8266 Wi-Fi SoC. It supports UART, SPI, and I2C interface. Node MCU can be powered through the USB port in case of 5V supply and the Vin pin for 7-12V input. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. Node MCU has 128 KB RAM and 4MB of Flash memory to store data and programs.

2. ESP32Cam:

Fig no. 6

The ESP32 CAM WiFi Module Bluetooth with OV2640 Camera Module 2MP for Face recognition has a very competitive small-size camera module that can operate independently as a minimum system with a footprint of only

40 x 27 mm; a deep sleep current of up to 6mA and is widely used in various IoT applications. It is equipped with 802.11b/g/n Wi-Fi, Bluetooth 4.2 with BLE, 520 KB SRAM plus 4 MB PSRAM, 9 GPIO ports and Built-in Flash LED.

3. ESP32:

Fig no. 7

ESP32 is a microcontroller developed by Expressif that has inbuilt WiFi and Bluetooth capability. It features a dual core; Xtensa 32-bit LX6 microprocessors that have low power consumption. It has a ROM of 448KB and a 520KB SRAM. It has an operating voltage of 2.5-3.6V and can take an input voltage ranging 4.5-12V. It has 30 available pins which support various interfaces such as UART, I2C and SPI.

4. Active Buzzer Module:

Fig no. 8

Active Buzzer is an audio signalling device that has a built- in oscillating source which meaning it only requires a DC power source to produce sound. The module used in the system has an operating voltage of 3.3-5V.

5. OLED Display SSD1306:

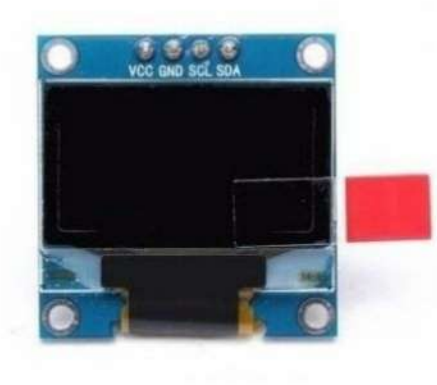

Fig no. 9

It is an OLED (Organic Light Emitting Diode) monochrome display which has a size of 0.96 inches and works on the I2C interface. It is designed to work with any 3.3V-5V microcontroller. It features high brightness, high contrast ratio, wide viewing angles and very low power consumption compared to LCD displays.

6. MFRC522 RFID Reader:

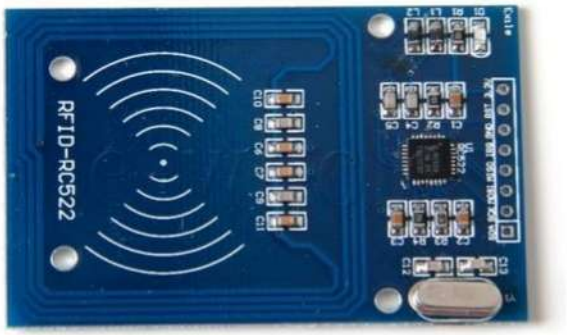

Fig no. 10

The RFID reader that is going to be used is the RC522 model. It requires a power supply of 3.3V and operates on 13.56 MHz frequency.It can communicate0directly with any CPU board by connecting through the SPI protocol, which ensures reliable work and reading distance up to 60mm.

7. RFID Tags:

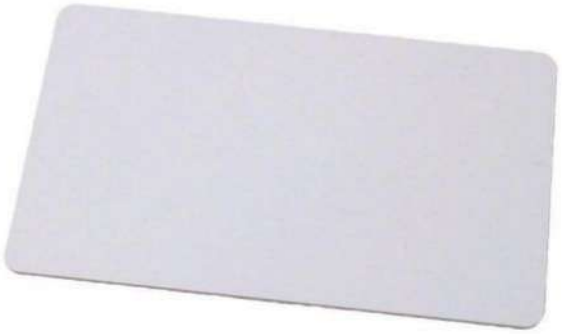

Fig no. 11

RFID Tags or cards that are used are designed for contactless transmission of data and they do not require battery for their operation . Its operating distance is up to 1 Meter depending on antenna geometry. Operating frequency is 13.56MHz and Data transfer speed is 106 kbit/s.

8. FTDI Adapter Module:

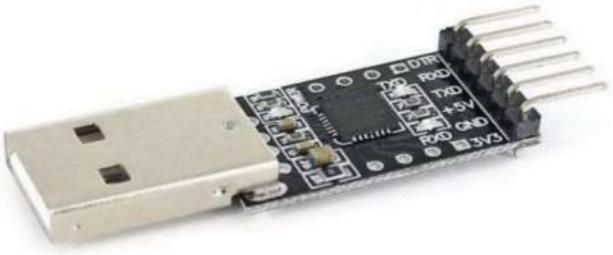

Fig no. 12

The FTDI adapter module is a complete package in which the FTDI chip is integrated with connectors, voltage regulators, Tx/Rx, and other breakout points. The module thus falls under the category of UART board and is mostly used for TTL serial communication. The FTDI chip or ICs as the brain of the FTDI modules and cables. Once the input signal is received and converted to proper channels, the FTDI chip operates the interfacing procedure in the module.

9. Firebase:

Firebase is cloud based data storage service created by Google that offers high speed NoSQL based realtime databases. The data is stored as JSON and is synchronized in real time to all the clients that share a connection to it. The service offers security functions and the database can be accessed by any device like a mobile or a laptop without any need of an application.

10. Arduino IDE:

Fig no. 13

The Arduino Software (IDE), often known as the Arduino Integrated Development Environment (IDE), has a text editor for writing code, a message area, a text console, a toolbar with buttons for basic functions along with a number of menus. To upload programmes and communicate with them, it establishes a connection with the Arduino hardware.

CHAPTER 7

BILL OF MATERIALS

7. Bill of Materials

SR.NO	COMPONENT NAME	QUANTITY	UNIT COST (RS)	TOTAL COST
1	NodeMCU ESP8266	1	Rs 299	Rs 299
2	ESP32Cam	1	Rs 489	Rs 489
3	ESP 32	1	Rs 449	Rs 449
4	MFRC522 RFID and RFID Tags	2	Rs 190	Rs 380
5	0.96 Inch OLEDSSD1306	1	Rs 224	Rs 224
6	GL-12 840 Point Breadboard	1	Rs 59	Rs 59
7	Active Buzzer Module	1	Rs 29	Rs 29
8	FTDI Module	1	Rs 165	Rs 165
9	Soldering Iron	1	Rs 309	Rs 309
10	Solder Wire 50g	1	Rs 110	Rs 110
11	Desolder Pump	1	Rs 75	Rs 75
12	Cleaning Sponge	1	Rs 15	Rs 15
13	Jumper wires F2M 20cm 20 pcs	1	Rs 29	Rs 29
14	Jumper WiresM2M 20cm 20 pcs	1	Rs 29	Rs 29
15	Jumper Wires F2F 20cm 40 pcs	1	Rs 39	Rs 39
			Total	Rs 2510

Table no. 2

CHAPTER 8

RESULT

8. Result

The proposed system results in automation of the library system based on IOT using a network of sensors placed at different locations of the library. It eases the process of sorting and maintaining the bookshelves. The proposed system allows an automatic management of the library where the registered users can experience a fast borrow and return process enabled by facial recognition and RFID embedded into the books and the bookshelves. The need for human intervention in the monitoring of books is largely reduced as the interactions with the books are properly tracked. It successfully reduces long queues at the counter as0compared to the existing systems. All the information about the status of users and every book in the library is precisely stored in the central database. The librarian is able to view all the necessary information in real-time and thus effectively monitor the activities taking place inside the library. The following figures show the database handled by the system and the camera interface for face recognition.

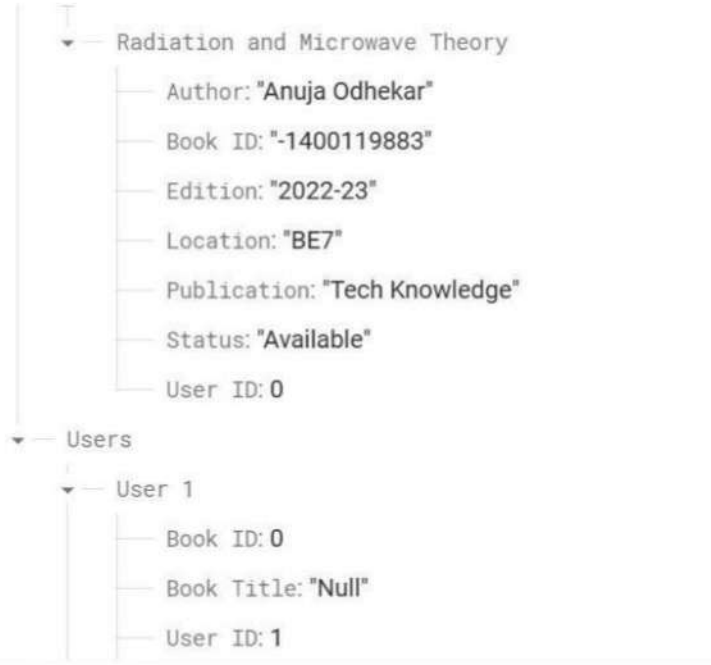

Fig no. 14

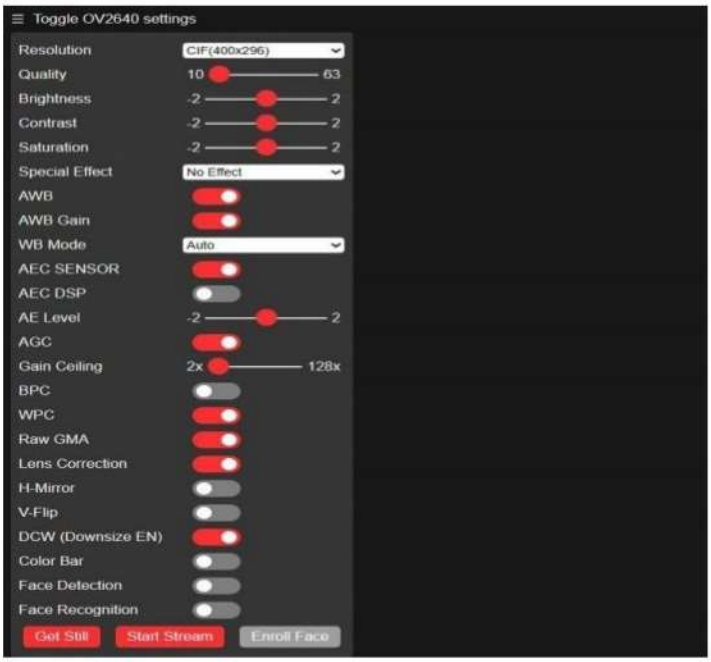

Fig no. 15

CHAPTER 9

SOFTWARE DESIGN

9.1 Software Simulation

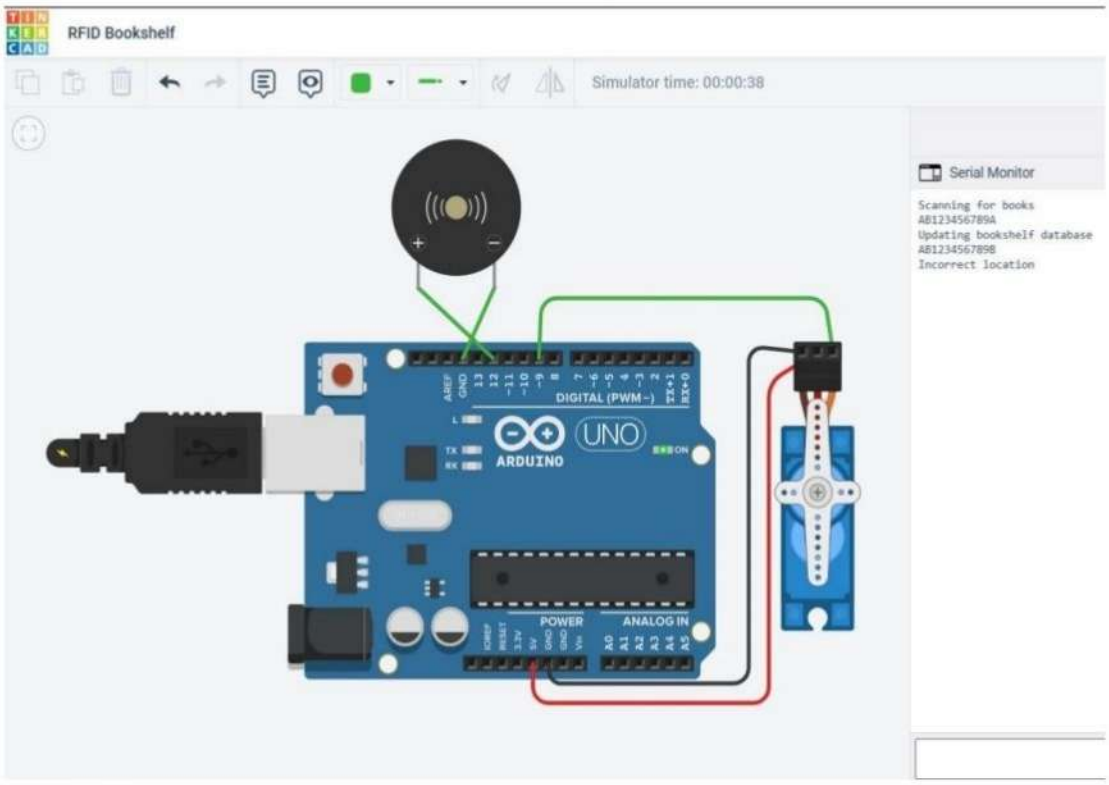

Fig no. 16

The above simulation of the return device has been performed using Tinkercad and briefly demonstrates the working of the RFID Bookshelf module. The DC motor rotates representing the RFID reader placed on one part of the bookshelf which is in reading mode to look for RFID tags in the books. The serial monitor represents the scanning process done by the RFID Reader. Consider 'AB123456789A' as the RFID tag (placed in book) read by the RFID reader and it matches with the correct designated row number. Hence it initiates the return process and updates the database accordingly. The next book containing tag data 'AB123456789B' read by the reader is of the book placed in the wrong location. Hence the buzzer then beeps alerting about the wrongly placed book in the shelf and does not proceed with the return procedure.

9.2 Flowchart

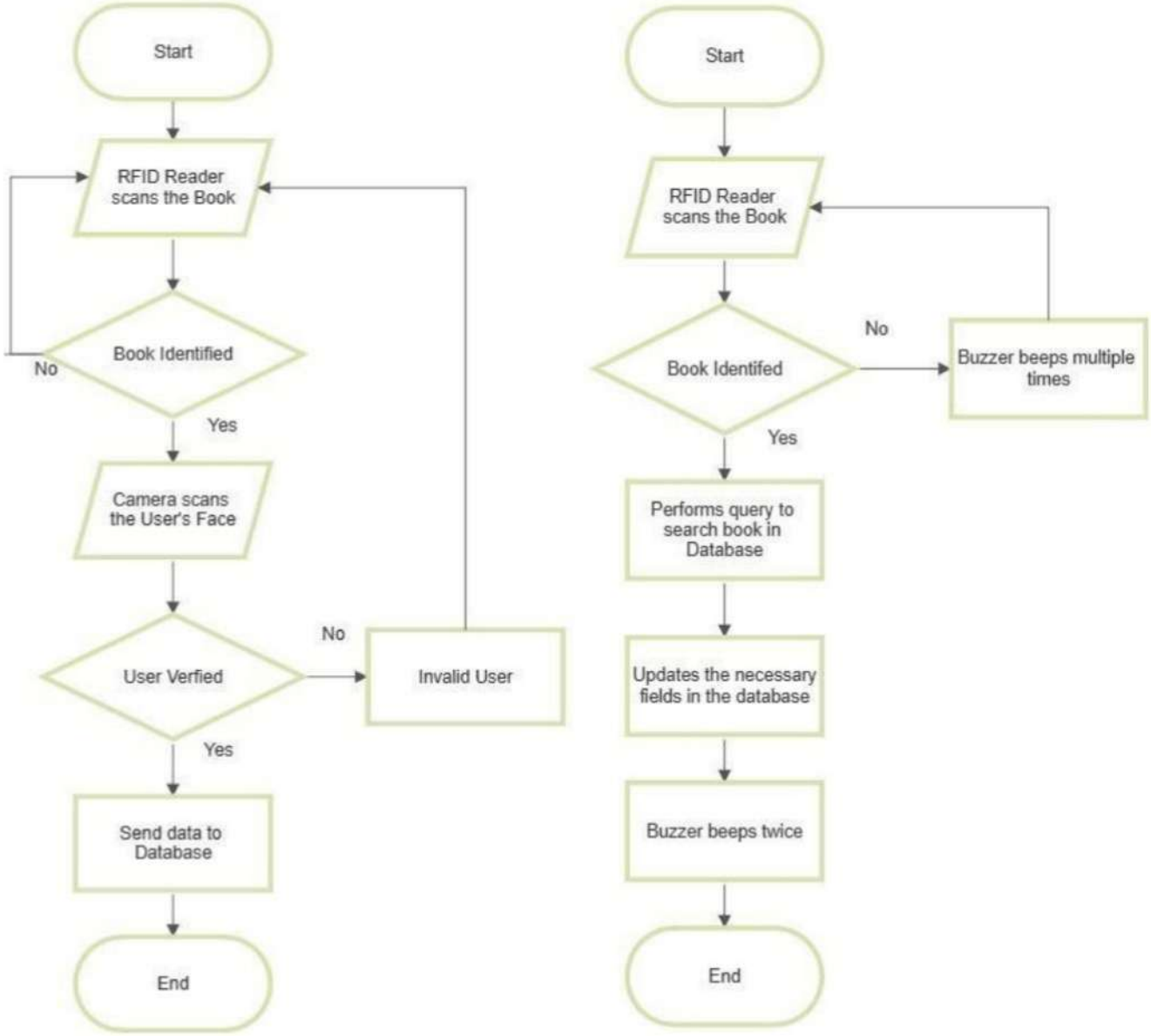

Fig no. 17

CHAPTER 10

ADVANTAGES, DISADVANTAGES AND APPLICATION

10.1 Advantages

- Faster book borrowing process
- Single tap book returning process
- Greatly reduces the need for sorting of bookshelves by the library staff
- Elimninates long queues at the librarian counter
- Simple and convenient experience for the users
- Realtime location tracking of the books in the bookshelves

10.2 Disadvantages

- The proposed system relies on an active internet connection and it cannot work in
- absence of it.
- The system lacks a mechanism to prevent unborrowed book going out of the library.
- The system is designed and implemented for actual physical environment hence it
- does not support online users and those interested in purchasing the books.
- The system fails to notify the users directly, about the due date to return the books.
- The system fails to identify the book in an event of damaged RFID tag.

10.3 Application

- The system can be implemented in Public libraries as well as in Educational institutions.
- The system can be used to automate the library services.
- The system can provide fast borrow and return of books.
- The system can be used to increase the correctness of arrangement of books in the bookshelves.

CHAPTER 11

CONCLUSION AND FUTURE SCOPE

11.1 Conclusion

The concept of Internet Of Things is executed with the system having a network of sensors, camera and processing units in system. The system automates the main library activities, makes them faster and easier for the user. The system has shown it does not require the librarian to intervene in the book borrow and return process. The return device reduces the instances of the books placed in wrong part of the bookshelf hence also reducing the need to sort the books manually. If the face recognition accuracy is improved with robust algorithms, the system can be deployed at actual libraries including public libraries and educational institutions.

11.2 Future Scope

1. The system can be enhanced with security by installing a gate with RFID Readers that detect the presence of unborrowed books going out of the library and raising an alarm.
2. A mobile application can be developed for the users to browse the available books in the library along with their location.
3. UHF RFID can be implemented to further optimise the bookshelf operations
4. A higher resolution camera that can recognise faces faster and more accurately.

CHAPTER 12

ACKNOWLEDGEMENT

12. Acknowledgement

It is my great pleasure in expressing sincere and deep gratitude towards my guide **Prof. Mr. Chandrakant K Bhange**, Assistant Professor Electronics & Telecommunication Engineering Department for his valuable guidance and constant support throughout this work and help to pursue additional studies in Internet of Things and Embedded system programming through Arduino IDE.

We take this opportunity to thank Head of the Department **Dr. M. P. Sardey** and Project coordinator **Mrs. A. S. Ubale** and all staff members of department of Electronics & Telecommunication Engineering AISSMS IOIT, Pune, for cooperation provided by them in many ways.

The motivation factor for this work was the inspiration given to me by our honourable principal **Dr. P. B. Mane.**

Lastly, I am thankful to those who have directly or indirectly supported our work.

CHAPTER 13

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APPENDIX 1

DETAILS OF COMPETITION/AWARD/ SPONSORSHIP

Department of ENTC Engineering

Project Group No.	Application of Project	Sponsored Project Company name	Paper publication details Journal name, volume and issue date	Project Exhibition/ Participation Place/national/ inter national	Name of Award Received
D14	Automation of Library	N/A	IEEE Internet of Things Journal (under Review)	1. MIT AOE Technophilia' 23 National Level Project Competition 2. AISSMS IOIT Project Competition 3. AISSMS IOIT Project Poster Competition	N/A

APPENDIX 2

ABSTRACT

Smart Library with Automatic Book Management

GOAL 9: Industry, Innovation and Infrastructure

Division- D | **Group Number-D14**

1. Aniket Pattanshetti (181)
2. Dnyaneshwar Bhalke (157)
3. Prajkta Sarode (202)

Name of Internal Guide – Mr. Chandrakant K Bhange

Problem Statement - The existing system requires manual effort in borrowing, returning and sorting the books in the bookshelves resulting in sluggish experience for the user and increase workload for the librarian.

Project Domain: Internet Of Things

Objectives -

1. **To provide faster borrowing and returning of books using RFID and Face Recognition.**
2. **To provide an automatic system with minimal additional effort required from the librarian.**
3. **To enable easy monitoring and sorting by transforming the bookshelves into RFID based.**

Abstract –

Libraries are indispensable for books and reading, as well as an abundant source of information. The majority of the current conventional libraries employ labor-intensive, time-consuming processes that result in long lines for borrowing and returning materials. Hence we propose a smart library system built on the Internet of Things that addresses these issues. The proposed system involves using books that have RFID tags attached to them and a camera at the borrowing counter. The RFID readers on the bookshelves and at the borrowing counter can read the book information stored electronically on the RFID tags and the camera verifies the user by scanning their face using a face recognition model. As a result of the combination of Face recognition and RFID Technology, the system automates the processes of borrowing, returning, and sorting the books by enabling the self-borrow and self-return process along with the ability to track each book's location on the bookshelf. An e-mail will be sent to the user acknowledging both the transactions. The proposed system remarkably quickens the process of borrowing, returning and sorting thus reducing long queues at the librarian's desk and lesser human intervention in the management.

Project Mapping with Program Outcomes (1 – Slight, 2- Moderate, 3- Substantial)

PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
3	2	2	3	3		3	3	3	3	3	3	3	3

Participation in Competition: MIT AOE Technophilia'23 Project Competition
AISSMS IOIT Project Poster and Project Competition

APPENDIX 3

PROJECT EVALUATION

AISSMS
INSTITUTE OF INFORMATION TECHNOLOGY
ADDING VALUE TO ENGINEERING

Department of Electronics and Telecommunication Engineering
Academic Year 2022-23

Project Title:		**Guide:**	
Project Domain:		**Group No:**	

Roll No.	Name	Email ID	Mobile No.	Sign

Project Phase 1

Presentation 1 Evaluation

Criteria	Student's	Student1	Student2	Student3	Student4
↓	Name				
	Sign				
Literature Review	(4 Marks)				
Formulation of Aim and Objectives	(4 Marks)				
Timely Submission	(2 Marks)				
Total Marks					

TW Submission Checklist

Synopsis (Three different topics)	
Log Book	
Project Phase 1 Report with Plagiarism Report (2 Copies)	
Project Title Mapping with POs and PSOs	
Presentation PPT	
Sponsorship Letter (If any)	

Presentation 2 Evaluation

Criteria	Student's	Student1	Student2	Student3	Student4
↓	Name				
	Sign				
System Design	(4 Marks)				
Simulation using Modern Computer Aided Tools	(4 Marks)				
Timely Submission	(2 Marks)				
Total Marks					

Guide Sign	
HOD Sign	
Evaluator/ External Examiner Sign	

AISSMS
INSTITUTE OF INFORMATION TECHNOLOGY
ADDING VALUE TO ENGINEERING

Department of Electronics and Telecommunication Engineering
Academic Year 2022-23

Project Phase 2

Presentation 3 Evaluation

Criteria ↓	Student's Name	Student1	Student2	Student3	Student4
	Sign				
System Implementation	(4 Marks)				
Working Model	(4 Marks)				
Timely Submission	(2 Marks)				
Total Marks					

Final Project Submission Checklist

Project Abstract	
Plagiarism report (Project Report and Paper)	
Published paper in UGC/WoS/Scopus care journal with DOI	
Two signed copies of report with CD	
Participation Certificate (Project or Paper Presentation Competition)	
Project Hardware	
Project group photo with Guide (Soft and hardcopy)	

Presentation 4 Evaluation

Criteria ↓	Student's Name	Student1	Student2	Student3	Student4
	Sign				
Working Model with Enclosure	(3 Marks)				
Effective Presentation	(3 Marks)				
Project Report	(3 Marks)				
Timely Submission	(1 Marks)				
Total Marks					

Guide Sign	
HOD Sign	
Evaluator / External Examiner Sign	

Paper publication/IPR Details:

Paper Title:		Journal/Conference Name:	
Authors:			
DOI/IPR No.			

APPENDIX 4

SELF EVALUATION OF PROJECT BY STUDENTS

Department of Electronics and Telecommunication Engineering
BE Project/ Academic Year 2022-23
Self-Evaluation Sheet 1

Group Number: **D14**

Project Title: **Smart Library with Automatic Book Management**

Name of Students:
1. Aniket Pattanshetti
2. Dnyaneshwar Bhalke
3. Prajkta Sarode

Literature Survey	Design	Implementation	Test Result	Attendance on the Project day	Working according to plan activity	Maintaining Log Book	Research Paper	Participation in Project/Poster Competition	Award/ Prize if any
(5)	(20)	(20)	(5)	(10)	(5)	(5)	(5)	(5)	(5)
5	15	17	5	10	5	1	3	4	0

Observation and Comments of Guide:

The students have successfully built the project achieving all the planned objectives. It has been observed that the project work is completed fulfilling most of the criterias in the evaluation rubrics with excellent results.

Student Name **Sign**
1. Aniket Pattanshetti
2. Dnyaneshwar Bhalke
3. Prajkta Sarode

Guide Name **Sign**
Mr. Chandrakant K Bhange

Department of Electronics and Telecommunication Engineering
BE Project/ Academic Year 2022-23
Self-Evaluation Sheet 2

Group Number:	**D14**
Project Title:	**Smart Library with Automatic Book Management**
Date:	**05-06-2023**

1. Describe your feelings about working on the project. Did you enjoy working on it?
A. Yes, the overall experience working on the project was very satisfying and sharpened a lot of skills.

2. What was the hardest part about working on your project?
A. The hardest part was to prepare the design that would fit the external environment and work properly.

3. List some of the things you learnt while working on your project?
A. The project taught time management skills, effectively assigning tasks to other members, working with a team and enhanced existing technical skills.

4. Were you satisfied with your final project?
A. Yes, the final project was very satisfying.

5. What did you like the best about your project?
A. The best part of the project is how seamlessly it automates the library functions.

6. What did you like the least about the project?
A. The speed of performance of the project is slower than expected and can be improved.

7. What was the most important thing that you learnt from doing your project that will help you in the future?
A. Efficiently working alongside a team will help in achieving greater heights in the industry.

Student Name **Sign**
1. Aniket Pattanshetti

2. Dnyaneshwar Bhalke

3. Prajkta Sarode

Guide Name **Sign**
Mr. Chandrakant K Bhange

Group Number:	**D14**
Project Title:	**Smart Library with Automatic Book Management**
Date:	**05-06-2023**

Department of Electronics and Telecommunication Engineering
BE Project/ Academic Year 2022-23

Critical Thinking Questionnaire

1. Who benefits from the project?
The libraries along with its staff and users will benefit from the project because of the automation that is offered.

2. Who is this project harmful to?
The project does not pose any harm to individuals or the external environment.

3. What are the strengths and weaknesses of the project?
The strength of the project is that it enables faster and automatic borrow and return of the books and the weakness of the project is the lack of security i.e it cannot prevent the unborrowed books going out of library automatically.

4. Where would we see this project in real world?
The project can be implemented in various libraries especially public libraries.

5. When would this project benefit our society?
The project will benefit the society in current times as it offers automation and saves time and effort.

6. Why is this project a problem/challenge?
The project can be a challenge due to its need of uninterrupted and good quality internet to work.

7. How does this project benefit us/others?
This project benefits us as it greatly simplifies the process of borrowing and returning a book in a library. We are not needed to carry any sort of ID Card or remember any login credentials.

8. Where are the areas for improvement?
The project can be improved with the use of UHF RFID to add much needed security and also further reduce the cases of misplacement of books in the bookshelves.

Student Name **Sign**
1. Aniket Pattanshetti

2. Dnyaneshwar Bhalke

3. Prajkta Sarode

Guide Name **Sign**
Mr. Chandrakant K Bhange

APPENDIX 5

CERTIFICATES

MIT | Academy of Engineering
(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

International Society of Automation
Pune Section

Spark Club, MITAOE

CERTIFICATE
OF PARTICIPATION

SPARK
MIT Academy of Engineering

TechnoPHILIA'2023

6th National Level

Technical Paper Presentation & Project Competition

Modern Emerging Trends in Electronics Technology

Certificate No. SCMT169/2023 Date : 24 March 2023

This is to certify that

Mr. Aniket Pattanshetti has participated in Project Competition in the event **TechnoPHILIA** organized by School of Electrical Engineering, MITAOE **in association with ISA Pune Section.**

Shilpa K Rudrawar	**Dr. Dipti Y Sakhare**	**Dr. Mahesh D Goudar**	**Mr. Gurmeet Anand**
Convener	Dean	Director	ISA President
TechnoPHILIA'23	School of Electrical Engineering	MITAOE, Alandi	Pune Section

MIT | Academy of Engineering
(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

International Society of Automation
Pune Section

Spark Club, MITAOE

CERTIFICATE
OF PARTICIPATION

TechnoPHILIA'2023

6th National Level

Technical Paper Presentation & Project Competition

Modern Emerging Trends in Electronics Technology

Certificate No. SCMT169/2023 Date : 24 March 2023

This is to certify that

Mr. Dnyaneshwar Bhalke has participated in Project Competition in the event **TechnoPHILIA** organized by School of Electrical Engineering, MITAOE **in association with ISA Pune Section.**

SPARK
MIT Academy of Engineering

Shilpa K Rudrawar	Dr. Dipti Y Sakhare	Dr. Mahesh D Goudar	Mr. Gurmeet Anand
Convener	Dean	Director	ISA President
TechnoPHILIA'23	School of Electrical Engineering	MITAOE, Alandi	Pune Section

MIT | Academy of Engineering
(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

International Society of Automation
Pune Section

Spark Club, MITAOE

CERTIFICATE
OF PARTICIPATION

TechnoPHILIA'2023

6th National Level

Technical Paper Presentation & Project Competition

Modern Emerging Trends in Electronics Technology

Certificate No. SCMT169/2023 Date : 24 March 2023

This is to certify that

Ms. Prajkta Sarode has participated in Project Competition in the event **TechnoPHILIA** organized by School of Electrical Engineering, MITAOE **in association with ISA Pune Section.**

SPARK
MIT Academy of Engineering

Shilpa K Rudrawar
Convener
TechnoPHILIA'23

Dr. Dipti Y Sakhare
Dean
School of Electrical Engineering

Dr. Mahesh D Goudar
Director
MITAOE, Alandi

Mr. Gurmeet Anand
ISA President
Pune Section

APPENDIX 6

RESEARCH PAPER

(under review)

IoT-29664-2023

Smart Library with Automatic Book Management

Aniket Pattanshetti[1], Dnyaneshwar Bhalke[2], Prajkta Sarode[3], Chandrakant Bhange[4]
[1,2,3,4]AISSMS Institute of Information Technology, Pune, India
aniketsp0@gmail.com

***Abstract*—Libraries are indispensable for books and reading, as well as an abundant source of information. The majority of the current conventional libraries employ labor-intensive, time-consuming processes that result in long lines for borrowing and returning materials. In this paper, we propose a smart library system built on the Internet of Things that addresses these issues. The proposed system involves using books that have RFID tags attached to them and a camera at the borrowing counter. The RFID readers on the bookshelves and at the borrowing counter can read the book information stored electronically on the RFID tags and the camera verifies the user by scanning their face using a face recognition model. As a result of the combination of Face recognition and RFID Technology, the system automates the processes of borrowing, returning, and sorting the books by enabling the self-borrow and self-return process along with the ability to track each book's location on the bookshelf. An e-mail will be sent to the user acknowledging both the transactions. The proposed system remarkably quickens the process of borrowing, returning and sorting thus reducing long queues at the librarian's desk and lesser human intervention for the management.**

Index Terms—Radio Frequency Identification, Device-to-Device Communication, Cloud Services, User experience

I. INTRODUCTION

A library management system is designed to monitor all the library activities and maintain a database of all books with their issue, return details as well as the due dates. The main aim of a library management system is to provide accurate data regarding any type of book and easy user interaction with the system therefore saving a lot of time and effort. The major problem faced by the current system is the improper management of books, misplacement and slow check in/check out for the user. The conventional methods use bar code scanning, magnetic stripe reading and other methods to prevent these problems but they are often error prone. The existing system is semi-automated meaning it requires additional efforts for the librarian for borrowing the books, sorting it and observing the misplacement of the books in the bookshelves. The users often experience long delays while borrowing or returning the books which leads to spending unnecessary time in queue. Hence, there is a need for an automated library management system and a solution for updating the location of the library books in a central database efficiently.

The proposed system is to be deployed in public libraries which currently uses a manual system consisting of bar-code technology for accessing the book and requires a dedicated person to scan the books and place them returned in the designated shelf. It replaces the existing traditional library management system with a combination of RFID and Face Recognition mechanism thus allowing a very effective level of automation in the various processes of the library. The proposed system is based on the technologies of RFID, Face Recognition and Cloud computing. The bookshelves which will be equipped with RFID readers will enable the user to return the borrowed book with a single tap before putting it back in the designated shelf. The data will be sent to the central database on the cloud. At the borrowing counter, the registered user will be identified using the camera and Face recognition. The book to be issued will be identified using RFID and the combination of this data will be sent to the central database thus completing the process of issuing the book faster. An e-mail receipt of both these transaction will be sent to the user automatically.

The terms RFID Reader and Tags refer to Radio Frequency Identification technology. RFID automatically identifies and collects data from objects by attaching RFID tags to them using electromagnetic fields and radio waves. In this case, the RFID Tag has a microchip that saves data. Radio waves are used by RFID tags to transfer data. They normally don't have batteries; instead, they get their power from the radio waves the reader produces.The energy travels through the internal antenna of the tag to the tag's chip after the transmission is received from the reader/antenna. This chip gets turned on and starts modulating the energy with the information that is stored inside it. The signal is then sent back to the RFID Reader. RFID reader is a device that can receive and transmit a radio signal.

Face recognition is a frequently used biometric technology in access control and authentication. It makes use of automated techniques to confirm or identify the identity of a living individual on the basis of their physiological features. People can be recognized using facial recognition technology in real-time or in still images and videos. The computer reads the person's face's geometry. The separation of the eyes, the depth of eye sockets, the space between forehead and chin, the form of cheekbones and the shape of lips, ears, and chin are all important aspects taken into consideration. The objective is to discover the distinctive facial features that make a person's face unique.

Cloud Computing is a method of accessing and using computing resources like data storage, processing power, and software packages via the internet. Cloud computing enables

users to store and process data remotely in sizable data centers owned and operated by third-party companies rather than depending on local servers or personal computers. Customers get on-demand access to these resources, typically via a subscription-based approach, and can adjust their usage as necessary. It provides tw0o of the key aspects i.e flexibility and scalability which are important for large scale applications. Customers don't need to make expensive hardware updates because they can quickly modify their computing capacity to suit their changing needs. This makes it possible for people and enterprises to be more adaptable and receptive to market needs.The proposed system utilizes Cloud Database based on the Cloud Computing technology to store the necessary library information.

II. RELATED WORK

Some of the related work in this area includes RFID Based Library Management System [1]. It uses RFID for borrow and return as well as for authentication of the user. Every user is given an Identity Card with RFID tag embedded in it. The system authenticates when the user scans this Identity Card against the RFID Reader to gain access to the library. It follow the same procedure to borrow and return the book by scanning the book which is embedded with RFID tag, against the RFID Reader. The returned books after scanning are placed in a return tray. It also implements a security mechanism which involves the entry/exit gate which is equipped with RFID Reader, detect unborrowed book going out of the library and raises an alarm.

Face recognition based Attendance Monitoring System [2] identifies the person using a Face Recognition algorithm and marks its attendance record in the database. The algorithm used in this system involves steps; Image acquisition, Histogram normalization, Noise removal, Skin classification and Face Detection. After the Face detection, the face image is cropped covering the detected face and is compared with the database. This is how the student is verified and then the data is sent to the database to mark the their attendance. The system results into more accurate and faster method of authentication thereby saving time and efforts and enabling convenience for the user.

Face Recognition based on ESP32Cam [3] uses the micro-controller to stream the camera vision on a web server and recognize the person in real-time. The systems consists of a OV2640 camera having 2MP resolution and an Arduino Uno board as a communication interface to upload program to the ESP32Cam micro-controller unit. The ESP32Cam connects to a WiFi network and displays the IP address where the camera interface is setup to activate the camera. A database is created using python script consisting of 100 images each for a person recording the different grimaces. The camera after detecting the person's face, compares it with the database and displays the name of the person in an event of successful verification. The results are saved in an excel file containing the name of the person, date and time of verification.

The system suggested in [4] makes use of the Near Field Communication technique for book tracking. There is a NFC tag on each book. The user places their NFC-enabled phone on the NFC reader at the entrance. The user is connected to the LAN if their fingerprint and user ID have been recorded in the database. The user uses his phone to send a request to the system for a book search, and the server responds with information about the book rack. The user sends this request to the local positioning system, which then directs him further to the selected rack. A new book is initially registered in a rack by scanning its NFC tag against the monitor of that specific rack. The entry/exit includes NFC scanners to carry out the borrow procedure. In order to return the book, the user has to just drop the book in the designated drop box.

Another technology used to enable Smart Library is a QR Code based Library Management System [5]. It involves an android application which carries out the various services in the library such as book borrow, book return, browsing the collection, checking availability of a book and a managing function for the librarian to observe the movement of books and prevent thefts. The user is authenticated by the app using an User ID and password. In order to borrow a book, the user has to click on the borrow button in the application which opens the camera on the phone to scan the QR Code. After scanning the QR Code on the book, the relevant details are gathered, return date is calculated and the process is completed by sending all the details to the database. Similarly, to return a book, the user scans the QR Code on the book and places the book in a designated shelf near the librarian. The system checks whether the book is returned in time and charges a fine if returned after the due date.

III. PROPOSED SYSTEM

The proposed system consists of 3 elements namely the borrow device, return device and Cloud database. The borrow device is placed at the borrowing counter and the return device is placed on a bookshelf each. The database is hosted on Cloud is provided by Google Firebase. Each book is embedded with a RFID Tag containing all the necessary details about the book. The processes involved are explained as follows.

A. Registration

The user while registering for the library service will be asked by the librarian to capture their face via the camera on the borrowing device and the face recognition system will store the identification data. The other details about the user such as User Name, User ID will be added to the database. The user will now be ready to use the library service. The information about each book including Author, Book ID, User ID, Edition, Location, Publication and Availability Status will be entered into the database by the library. The books will be embedded with RFID Tags and the librarian will write the tags with the Name and Book ID of the book using an additional RFID reader/writer module.

B. Book Borrow

The borrow device is built using an RFID Reader and an OLED Display along with two microcontrollers; ESP32Cam and ESP8266 Node MCU which are connected to WiFi and communicate with each other using a cloud platform through MQTT protocol. The RFID reader and OLED Display is connected to the Node MCU whereas the ESP32Cam handles the camera function using an interface on a web server as shown in Fig. 1 In order to borrow the book, the user scans the book by placing it near the scanning area of the borrow device.The device then reads the RFID tag in the book using the RFID reader and captures the book details. The device then scans the user's face using the camera on the ESP32Cam. Upon successful verification, the microcontroller sends the user details to the Node MCU through MQTT protocol. The NodeMCU sends the combination of book and user data to the relevant fields in the cloud database through the internet therefore completing the borrow process. It sends an email to the user acknowledging the borrow process using SMTP. All steps initiated during the process are displayed to the user on the OLED display.

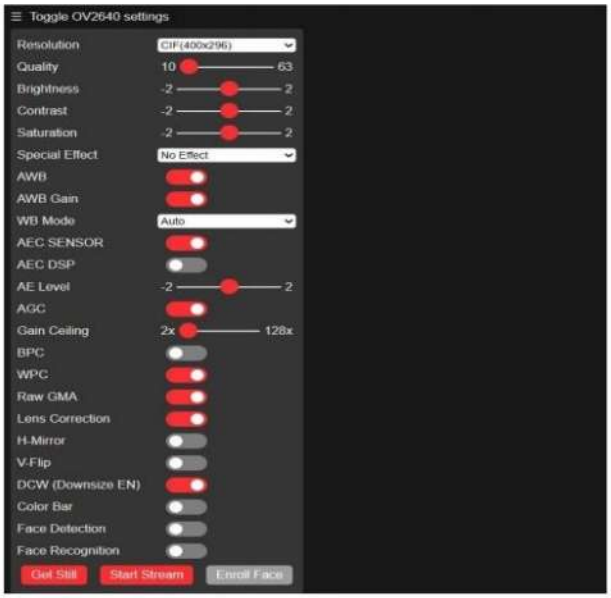

Fig. 1. Camera interface on web server

C. Book Return

The return device as shown in Fig.2 is built using a ESP32 microcontroller as its central processing unit, multiple RFID readers placed at each end of a row and an active buzzer. The user when returning the book has to make a single tap on the sensor area of the designated row of the bookshelf according to the category of the book. The return device of the bookshelf will extract the book details through the RFID reader. It will initiate a search query to the database to identify the user who has borrowed the book. Once the identification is done, it will make the necessary changes to the data in the database thereby completing the return procedure. The user will then place the book in the designated location. All the steps in this process will be notified to the user through different types of beeps by the active buzzer. An email receipt will be sent to the user automatically after the return process is finished.

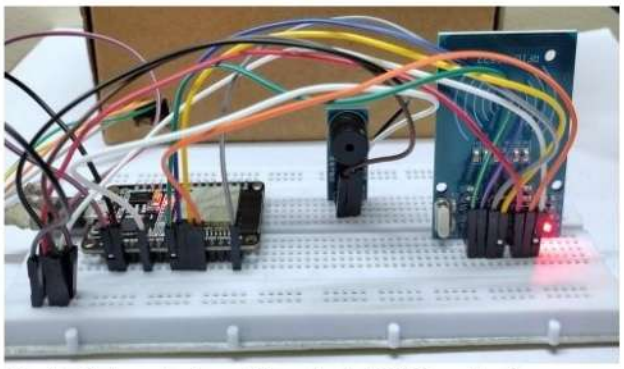

Fig. 2. Return device with a single RFID reader for one row

D. Sorting

In an event where a user tries to return the book and place it in the incorrect location, the return device compares the category of the book obtained by through the RFID reader to the category of the row of the particular bookshelf and sends an alert beep to notify the user of the incorrect location of the book. It stops the return procedure and the book is not returned to the library thereby avoiding the incorrect placing of the books in the bookshelves and reducing the need to sort the books by the librarian.

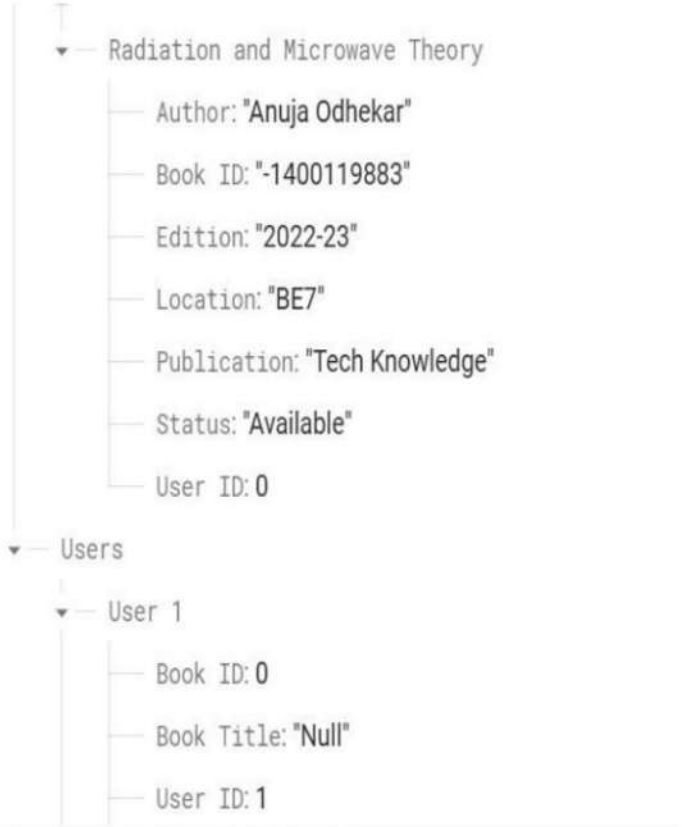

Fig. 3. Two of the fields in the Database

E. Database

The database hosted on cloud by Firebase is a real-time database. It displays all the necessary information about all the library activities in real time which is accessible to the librarian as shown in Fig.3. The database consists of two main sections; books and users. The books section has Author, Book ID, User ID, Edition, Location, Publication and Availability Status of each book in the library. The Users section includes User Name and User ID of each user along with the Book ID and Title of the book it has borrowed. The cloud database establishes a secure connection with the borrow and return devices before carrying out the two way data transfers. The communication with the borrow and return device is carried out wirelessly using a wireless network connected to the Internet.

IV. COMPONENTS USED

A. Node MCU

NodeMCU is a development board and open-source Lua-based firmware designed primarily for Internet of Things (IoT) applications. Espressif Systems has made the firmware to run on the ESP8266 Wi-Fi SoC while the hardware is based on the ESP-12 module. The interfaces UART, SPI, and I2C are supported. In the case of a 5V supply, the USB port can be used to power Node MCU and a Vin pin can be used for input of 7–12V. This microprocessor has an adjustable clock frequency range of 80 MHz to 160 MHz and supports RTOS. To store data and programmes, Node MCU features 4MB of Flash memory and 128 KB of RAM.

B. ESP32Cam

The board is run by a Espressif ESP32-S SoC, a potent, programmable MCU with built-in WiFi and Bluetooth. It has built-in flash LED, Bluetooth 4.2 with BLE, 520 KB SRAM, 4 MB PSRAM, 9 GPIO connectors, and 802.11b/g/n Wi-Fi. The board lacks a standard USB connector, therefore to upload code to it, there is a need to use either an FTDI programmer or an Arduino UNO coupled with the Arduino IDE/ESP-IDF DEV tools. The ESP-32 CAM can do on-device machine learning tasks like picture classification, human detection, etc. using the most recent TinyML models. The ESP32Cam has two input power pins and it takes 3.3V by default. The board becomes unstable with error or images having coloured lines if the OV2640 camera is used under 3.3V supply which is why it is recommended to supply 5V.

C. ESP32

ESP32 is a microcontroller developed by Expressif that has inbuilt WiFi and Bluetooth capability. It features a dual core; Xtensa 32-bit LX6 microprocessors that have low power consumption. It has a ROM of 448KB and a 520KB SRAM. It has an operating voltage of 2.5-3.6V and can take an input voltage ranging 4.5-12V. It has 30 available pins which support various interfaces such as UART, I2C and SPI. The current drawn by each of these pins is a maximum of 40mA according to the ESP32 data sheet. With an operational temperature range of -40°C to +125°C, ESP32 can operate dependably in industrial settings.

D. RC522 RFID Reader

The RFID reader that is going to be used is the RC522 model. It requires a power supply of 3.3V and operates on 13.56 MHz frequency. It uses the SPI protocol to communicate with the CPU board enabling a reading distance upto 60mm.The MFRC522 IC/Chip from NXP Company is the foundation of the RC522 RFID Reader Module. The chip's OSCIN and OSCOUT pins are connected to a quartz crystal with a frequency of 27.12 MHz as the internal oscillator. In the module's PCB is an embedded NFC coil. This antenna produces a high-frequency electromagnetic field with a frequency of 13.56 MHz. This module is also capable of writing to the RFID Tag.

E. SSD1306 OLED Display

It is an OLED (Organic Light Emitting Diode) monochrome display which has a size of 0.96 inches and works on the I2C or SPI interface. It is designed to work with any 3.3V-5V microcontroller. It features high brightness, high contrast ratio, wide viewing angles and very low power consumption compared to LCD displays. This display module has four pins that are Vcc, Ground, SCL and SDA. The VCC and GND pins will power the OLED display whereas the SCL is used to generate clock signal and SDA pins to transmit the data.

F. Active Buzzer Module

Active Buzzer is an audio signaling device that has a built-in oscillating source which meaning it only requires a DC power source to produce sound. The module used in the system has an operating voltage of 3.3-5V.

V. RESULTS

The system was tested on a certain size of sample consisting of students at an educational institution. The Fig. 4 shows the OLED display indicating the borrow device is ready to scan the book. When the user places the in front of the device, the device extracts the book details using RFID in 3-4 seconds time. The OLED display then indicates the user to scan their face. The figure shows the camera interface on the web server displaying the face recognition process. It is observed that the face recognition happens instantly in good lighting conditions however it took more to recognize when there was poor amount of light. Once the face recognition is done, the same is displayed on the OLED and the borrow device starts uploading the data to the cloud database. This process takes around 30-35 seconds to complete and an email is sent to the user automatically immediately after the database is updated thus completing the borrow process. The figure shows a prototype representing a row of a bookshelf which has the RFID reader placed on the side. When the user who wants to return the book places the book near the sensor, an beep sound is made instantly indicating successful return operation and the database is also updates within few seconds.The user then places the book in the bookshelf completing the return process.

Fig. 4. Borrow device asking to scan the book

VI. CONCLUSION

The concept of Internet Of Things is executed with the system having a network of sensors, camera and processing units in system. The system automates the main library activities, makes them faster and easier for the user. The system has shown it does not require the librarian to intervene in the book borrow and return process. The return device reduces the instances of the books placed in wrong part of the bookshelf hence also reducing the need to sort the books manually. If the face recognition accuracy is improved with robust algorithms, the system can be deployed at actual libraries including public libraries and educational institutions. The system can be equipped with security by installing a gate with RFID Readers that detect the presence of unborrowed books going out of the library and raising an alarm. A mobile application can be developed for the users to browse the available books in the library along with their location.

ACKNOWLEDGEMENT

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APPENDIX 7

PLAGIARISM REPORT

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A
PROJECT STAGE-2 REPORT ON
SMART LIBRARY WITH FULLY AUTOMATIC BOOK MANAGEMENT
SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE
IN THE PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE OF
BACHELOR OF ENGINEERING
IN
ELECTRONICS AND TELECOMMUNICATION
BY
ANIKET PATTANSHETTI 72024055H PRAJKTA SARODE 72024102C DNYANESHWAR BHALKE 72162917
C
UNDER
THE GUIDANCE OF
Mr. CHANDRAKANT K BHANGE
ACADEMIC YEAR: 2022-23
CERTIFICATE
This is to certify that Project Report entitled
"
SMART
LIBRARY WITH FULLY AUTOMATIC BOOK MANAGEMENT"
Submitted by
Aniket Pattanshetti (72024055H)
Prajkta Sarode (72024102C)
Dnyaneshwar Bhalke (72162917
C)
is the record of bonafide work carried out by them in
partial fulfillment of the requirement for the award of the Degree of Bachelor of Engineering (Electronics and Telecommunication),
as prescribed by the Savitribai Phule Pune University in the Academic Year 2022-2023.
This project report has not been earlier submitted to any other Institute or University for the award of any degree.
Mr. Chandrakant K Bhange Dr.M.P.Sardey
Internal Guide Head of Department
Department of E&TC Engg. Department of E&TC Engg.
Dr.P.B.Mane

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ABSTRACT
Libraries are indispensable for books and reading, as well as an abundant source of information. The majority of the current conventional libraries employ labor-intensive, time-consuming processes that result in
long lines for borrowing and returning materials. In this paper, we propose a smart library system built on
the Internet of Things that addresses these issues. The proposed system involves using books that have RFID tags attached to them and a camera at the borrowing counter. The RFID readers on the bookshelves and at the borrowing counter can read the book information stored electronically on the RFID tags and
the camera verifies the user by scanning their face using a face recognition
model. As a result of the combination of
Face recognition and RFID Technology, the system automates the processes of borrowing, returning, and sorting the books by enabling the self-borrow and self-return process along with the ability to track each book's location on the bookshelf. An e-mail will be sent to the user acknowledging both the transactions. The proposed system remarkably quickens the process of borrowing, returning and sorting thus reducing
long queues at the librarian's desk and lesser human intervention for the management.

INDEX

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LIST OF ABBREVIATIONS

RFID Radio Frequency Identification

SPI Serial Peripheral Interface I2C Inter-Integrated Circuit SMTP Simple Mail Transfer Protocol OLED Organic Light Emitting Diode

MCU Micro Controller Unit SOC System on Chip FTDI Future Technology Devices International Limited WiFi Wireless Fidelity IDE Integrated Development Environment IOT Internet of Things

1. INTRODUCTION

"A library management system is designed to monitor all the library activities and maintain a database of all books with their issue, return details as well as the due dates. The main aim of a libraryimanagement system is to provide accurate data regarding any type of book and easy user interaction with the system therefore saving a lot of time and effort.

The majoriproblem

faced by the current system is the improper management of books, misplacement and slow check in/check out for the user. The conventionalimethods use barcode scanning, magnetic stripe reading etc to prevent these problems but they are often error prone and also consume a lot of time."The existing system is semi-automated meaning it requires additional efforts for the librarian for borrowing the books, sorting it and observing the misplacement of the books in the bookshelves.

The users often experience long delays while borrowing or returning the books which leads to spending unnecessary time in queue. Hence, there is a need for an automatedilibrary management system and a solution for updating the location of the library books in a central database efficiently.

The proposed system is to beideployed in public libraries which currently uses a manual system consisting of bar-code technology for accessing the book and requires a dedicated person to scan the books and place them returned in the designated shelf. It replaces the"existing traditional library management system with a combination of RFID and Face Recognition mechanism thus allowing a very effective level of automation in the various processes of the library."

The proposed system is based on the technologies of RFID, Face Recognition and Cloud computing.

RFID stands for Radio Frequency Identification and involves an RFID Reader and an Antenna (Tags). It was invented by Charles Walton as the first patent holder for RFID technology."RFID uses electromagnetic fields radioiwaves to automatically identify and capture information stored on a RFID tag attached objects, where the RFID tag contains electronically-stored information."RFID tags transmit data through radio waves.iThey typically do not have a battery instead, theyireceive energy from the radio waves generated by theireader. When the tagireceives the transmission from the reader/antenna, the energy runs through the internaliantenna to the tag's chip. The energyiactivates the chip, whichimodulates the energy with the desired information, and then transmits a signal back toward the antenna/reader. RFID reader is a device that can receive and transmit a radio signal. It is built toiencode the information stored in the tag's microchip.

Face Recognition: Face recognition is a way of identification of an individual using their face. Facial recognition systems can be used to identify people in photos, videos, or in real-time."The software reads the geometry of your face. Key factors include the distance between your eyes, the depth of your eye sockets, the distance from forehead to chin, the shape of youricheekbones, and the contour of the lips, ears, and chin. The aim is to identify the facial landmarks that are key to distinguishing your face."

Cloud Computing: Cloud computing is the process of using the internet to access and use computing resources such as data storage, processing power, and software programs. Cloud computing enables users to store and process data remotely in sizable data centers owned and operated by third-party companies rather than depending on local servers or personal computers. Customers get on-demand access to these resources, typically via a subscription-based approach, and can adjust their usage as necessary. The flexibility and scalability of cloud computing are two of its main advantages. Customers don't need to make expensive hardware updates because they can quickly modify their computing capacity to suit their changing needs. This makes it possible for people and enterprises to be more adaptable and receptive to market needs.The proposed system utilizes Cloud Database based on the Cloud Computing technology to store the necessary library information.

The proposedisystem

will make use of the above key components toiautomate the library management. The bookshelves which will beiequipped with RFID readers will enable the

user to return the borrowed book with a single tap before putting it back in the designated shelf.

The data will be sent to the central database on the cloud. At the borrowing counter,ithe registered user will be identifiediusing the camera and faceirecognition algorithm. The book to be issued will be identified using RFID and the combination of this data will be sent to the central database thusicompleting the process of issuing the book faster.

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An e-mail receipt of both these transaction will be sent to the user automatically.
The materials which will be coverediconsists of hardware sourced from local shops which includes the RFID Readers, RFID Tags, Microcontroller units, Power supply, Camera and the other materials i.e
Cloud Database and a Wireless Network.

2.

LITERATURE REVIEW

1. IJRIS 2012 : "SLMS: A smart library management system based on an RFID technology"
This paper proposes a smartilibrary management system based on an RFID technology using low-costipassive tags. Integrating RFID into library management system makes both the libraryiusers and staff's task easy, smart, convenient, and practical.
2. ICIRA 2008 : "Design of an RFID-Based Manufacturing Data Tracking System in Plant Production"
In this paper, an RFID-based manufacturing data tracking system is designed to collect all kinds of data and track them in real time.iAll kinds of users in the plants can guarantee to execute their operations in both time saving and cost effective manner.The Radio FrequencyiIdentification (RFID) technology is utilized to acquire the data derived from the plant in real time.
3. IEEE 2015 : "An RFID-based System for Library Management and Its Performance Evaluation"
In this paper, it isiproposed that the RFID system enables non-contact communication, various services and applications including the management of a libraryicatalogue are possible. Using electromagneticicoupling, an RFID tag can get power supplier by a reader and communicate with it foridata exchange.
4. UHD Journal of Science and Technology : "Smart University Library Management System Based on Internet of Things"
In this paper, theiperformance of RFID reader motion and tags allows fast transaction flow and easily handling the process likeireferences borrowing from library can be done using RFID technology and users will getinotified using Global System for Mobile.
5. August 2020 International Journal of Engineering Science and Technology: "RFID Based Library Management System"
In thisisystem, the users are identified via the RFID cardsiassigned to them. GSM module has been used in order to provideialert message for the registered user during the return process.
6. March 2015 IJCSMC: "Library access system smartphone application using Android"
This paper proposes aniandroid mobile application which can be used for the Library. The Library Access System Application which allows for an easy interface for the users and which allows to check their due dates ofiborrowed books from the library.
7.
December 2019 ASBIRES Conference: " Rmsm, Dissanayaka & Wickramaarachchi, Helani. (2019). IoT Based Water Level Monitoring System Using NodeMCU."
This paper involves using the Firebase cloud real time database to store the measured water level and volume of the water in real-time using an ultrasonic distance sensor and a wireless network.

3.

AIM AND OBJECTIVES

3.1 Aim:
The aim of this project is to
combine RFID, Face Recognition and Cloud Computing integrating them into library management system which results into a highly automated system with minimum human involvement and seamless user interaction."This makes both the library users and staff's task easy, smart, efficient and convenient. The highlight of this proposed system is the registerediuser picking up the book it wants and borrowing it
quickly within few seconds as well returning the book with a single tap.

3.2
Objectives:
1. To provide instant borrowing/returning of books usingiFace Recognition and RFID eliminating time and labour consuming checkout counters and queues.
2. To provide a useful interface allowing the librarian to observe the automated0library functioning.
3. To allow
tracking of each book's location in the bookshelves
by transforming the book shelves into RFID based.

3.3 Methodology:
Part I : Registration
The user while registering for the library service will be asked by the librarian to capture their face via the camera on the borrowing device and the face recognition system will store the identification data. The other details about the user such as Name, User ID, Book details will be added to the database.

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The user will now be ready to use the library service. The information about each book including title, author, publication, etc will be entered into
the
database. The same information will also be written to the RFID tag which will be embedded into the book.

Part II : Borrowing the Book

The user browses the bookshelves and searches for the required book. If found, the user will take it to the borrowing counter
and scan the book by tapping it on the borrowing device. The system will extract the book details using RFID and then ask the user to scan their face.
The camera equipped will scan the face of the user and match it to the user`s identity0in the database.
Upon successful verification, the system will send all of the obtained data to the database thereby completing the borrowing process.
The communication between the borrowing device at the borrowing counter and the database will be carried out wirelessly. All the
steps throughout the process will be notified to the user through an OLED display. An email receipt will be sent to the user automatically after the borrow process is finished.

Part III : Returning the Book

The user when returning the book has to make a single tap on the sensor area of the designated sector of the bookshelf according to the category of the book. The
return device of the bookshelf will extract the book details through the RFID reader. It will intitate a search query to the database to identify the user who has borrowed the book. Once the identification is done, it will make the necessary changes to the data in the database thereby completing the return procedure. All the steps in this process will be notified to the user through different types of beeps. An email receipt will be sent to the user automatically after
the return process is finished.

Part IV : Sorting

In an event where a user
tries to return the in the incorrect place, the return device
compares the category of the book obtained by through the RFID reader to the category of the sector and sends an alert beep to notify the user of the incorrect location of the book. It stops the return procedure and the book is not returned to the library thereby avoiding the incorrect placing of the books in the bookshelves.

Part V : Database

The cloud database displays all the necessary information about all the library activities in real time which is accessible to the librarian. It establishes a secure connection with the borrow and return counters before carrying out the two way data transfers. The communication is carried out wirelessly using a wireless network connected to the Internet.

3.4 Specifications of the System

Technical Specifications:

1. Node MCU: Node MCU is a development board and open-source Lua-based firmware that is specifically aimed for Internet of Things (IoT) applications.It has hardware based on the ESP-12 module and firmware that operates on Espressif Systems' ESP8266 Wi-Fi SoC.
It supports UART, SPI, and I2C interface. NodeiMCU can be powered through the USB port in case of 5V supply and the Vin pin for 7-12V input. Thisimicroprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. NodeiMCU has 128 KB RAM and 4MB of Flash memory to store data and programs.
2.
ESP32Cam: The ESP32 CAM WiFi Module Bluetooth with OV2640 Camera Module 2MP foriFace recognition has a very competitive small-size camera module that can operate independently as a minimum system with a footprint of only 40 x 27 mm; a deep sleep current of up to 6mA and is widely used in various IoT applications. It isiequipped with 802.11b/g/n Wi-Fi, Bluetooth 4.2 with BLE, 520 KB SRAM plus 4 MB PSRAM, 9 GPIO ports and Built-in Flash LED.
3.
ESP32: ESP32 is a microcontroller developed by Expressif that has inbuilt WiFi and Bluetooth capability. It features a dual core; Xtensa 32-bit LX6 microprocessors that have low power consumption. It has a ROM of 448KB and a 520KB SRAM. It has an operating voltage of 2.5-3.6V and can take an input voltage ranging 4.5-12V. It has 30 available pins which support various interfaces such as UART, I2C and SPI.
4. Active Buzzer Module: Active Buzzer is an audio signalling device that has a built-in oscillating source which meaning it only requires a DC power source to produce sound. The module used in the system has an operating voltage of 3.3-5V.

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5. SSD1306 OLED: It is an OLED (Organic Light Emitting Diode) monochrome display which has a size of 0.96 inches and works on the I2C interface. It is designed to work with any 3.3V-5V microcontroller. It features high brightness, high contrast ratio, wide viewing angles and very low power consumption compared to LCD displays.
6.
MFRC522 RFID Reader: The RFID reader that is going to be used is the RC522 model. It requires a power supply of 3.3V and operates on 13.56 MHz frequency.It can communicate0directly with any CPU board by connecting through the SPI protocol, which ensures reliable work and reading distance upito 60mm.
7. RFID Transmitting Antenna: RFID Tags or cards that are used are designed for contactlessutransmission of data and they do not require battery for their operation . Its Operating distance islup to 1 Meter depending on antenna geometry. Operating frequency is 13.56MHz and Data transfer speed is 106 kbit/s.
8.
FTDI Adapter Module: The FTDI adapter module is a complete package in which the FTDI chip is integrated with connectors, voltage regulators, Tx/Rx, and other breakout points. The moduleothus falls under the category of UART board and is mostly used for TTL serial communication. The FTDI chip or ICs as the brain of the FTDI modules and cables. Once the input signal is received and converted to proper channels, the FTDI chip operates the interfacing procedure in the module.
9.
Arduino IDE: The Arduino Software (IDE), often known as
the Arduino Integrated Development Environment (IDE), has a text editor for writing code,
a message area, a text console, a toolbar with buttons for basic functions
along with a number of menus. To upload programmes and communicate with them, it establishes a connection with the Arduino hardware.
10. Firebase: Firebase is cloud based data storage service created by Google that offers high speed NoSQL based realtime databases. The data is stored as JSON and is synchronized in real time to all the clients that share a connection to it. The service offers security functions and the database can be accessed by any device like a mobile or a laptop without any need of an application.
Functional Specifications:
1. The systemiidentifies the user and checks his membership status using Face recognition.
2. The system identifies the book to be issued by scanning the
RFID tag embedded in
the book.
3. The user experiences a fast book borrowing process
with less delay.
4. The user is able to return the book with a single tap.
5. The librarianiis able to view all the necessary data on the cloud database.
6. An email receipt is send to the user acknowledging the borrow/return of book.
7. The OLED screen displays the necessary information during the borrow process.
8.
The incorrect position of the books in the books shelves can be avoided and an alert
is ringed to
the user.
4. BLOCK DIAGRAM OF THE SYSTEM AND ITS EXPLANATION
Fig no. 1
The above diagram is a block diagram of the proposed system. It follows the principle of InternetuOf Things (IoT) where there is a network of
things
communicating with each other enabled by sensors and other technologies. The block diagram can be categoriseduin three units. The first unit has the NodeMCU as the central processing unit which
handles the borrow process by controlling and communicating with the RFIDireader to obtain RFID tag data and receiving Face recognition data from the ESP32 Cam microcontroller which has a camera attached to it. The details during the borrow process are displayed onto the OLED display.
The second unit has the ESP32 as the central processing unit which
can handle the return process using multiple RFID readers through SPI interface and produce sound from the buzzer post completion of certain actions. The third unit has the central database which is a realtime database hosted on the cloud by the service provider
which records all the library information over the Internet through the microcontrollers.
5. SYSTEM DESIGN

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5.1 Circuit Diagram:

Fig no. 2

The above diagram illustrates the circuit connections of the different components involved in the system. The system design is physically implemented into 2 modules;

Borrow device and Return device.

The borrow device has the ESP8266 Node MCU as the main processing unit which is connected to the MFRC522 RFID Reader via SPI Pins and SSD1306 OLED display via the I2C Pins. The ESP32 Cam is connected to the FTDI programmer for the serial interface and power supply.

The Return device is a ESP32 microcontroller which is connected to an Active Buzzer Module with a single data pin and an MFRC522 RFID reader via SPI pins. The device can be connected to upto 6 readers for different rows of the shelves each having a separate data line.

5.2

Flow chart

Fig no.3

5.3 Key concepts

5.3.1 Radio Frequency Identification:

Radio waves

are used by RFID to carry out AIDC operations. Automatic Identification and Data Capture, or AIDC, is a technology that identifies objects, collects data, and maps it. In order for the reader and tag to communicate, radio waves must be converted from power via an antenna. RFID tags that are detected and read or written into by RFID readers which then retrieve the data from the tags. One processor, packaging, storage, and transmitter and reception units might be present. There are two types of RFID;

A. Passive RFID:

The power for the passive RF tags in this type is stored instead of being attached by a
power source. When it is transmitted from active antennas and the RF tag
is utilised, a specific frequency is employed, such as 125-134
MHZ low frequency, 13.56 MHZ high frequency and 856 MHZ to 960 MHZ as ultra-high frequency.

B. Active RFID:

In this device, RF tags are equipped with a power supply that emits a signal and there is an antenna for receiving the data. There are a number of RFID frequencies, or RFID frequency bands that systems may use.

Some driver's licences and shipping pallets both feature ultra-high frequency RFID technology. Readers use the 902–928 MHz frequency to transmit signals. By altering how they reflect reader signals, tags can communicate at distances of several metres. The reader can detect these reflections. Backscatter is the name for this method of operation.

HF RFID (High-Frequency RFID); It has a frequency of 13.56 MHz and is commonly found in passports, credit cards, books, and noncontact payment methods. As the physical process relies on induction rather than backscatter, HF RFID has a short range, usually one metre or less. There are many other forms of RFID using other range of frequencies such as the

Low-Frequency RFID.

5.3.2 Internet Of Things:

"Internet of Things (IoT) is the networking of physical objects that contain electronics embedded within their architecture in order to communicate and sense interactions amongst each other or with respect to the external environment. In another words, IoT is network of interconnected computing devices which are embedded in everyday objects, enabling them to send and receive data."The major enabling technologies for IoT include Wireless Sensor Network, Cloud Computing, Big Data Analytics, Communications Protocols and Embedded System. In the proposed system, the books and the bookshelves can be considered as the 'Things' which are the physical objects equipped with sensors to react to external environment and communicate with the database over Internet.

5.3.3 Wireless Fidelity:

"Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access, allowing nearby digital devices to exchange data by radio waves."Wi-Fi uses multiple parts of the IEEE 802 protocol family and is designed to interwork seamlessly with its wired sibling, Ethernet. Compatibleldevices can network through wireless access points to each other as well as to wired devices and the Internet. The differentiversions of Wi-Fi are specified by various IEEE 802.11 protocol standards, with the different radio technologies determiningiradio bands, and the maximum ranges, and speeds that may be achieved. Wi-Fi most commonly uses the 2.4 gigahertz.

5.3.4 Microcontrollers:

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"A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip."A microcontroller is embedded inside of a system to control a singular function in a device. It does this by interpreting data it receives from its I/O peripherals using its central processor. The temporary information that the microcontroller receives is stored in its data memory, where the processor accesses it and uses instructions stored in its program memory to decipher and apply the incoming data. It then uses its I/O peripherals to communicate and enact the appropriate action.

5.3.5

Face recognition:

"

Facial recognition (or face recognition) technology is a method used to map, identity, or verify a person's facial structure."With face recognition technology, it's possible to create a unique numerical code, called a faceprint. These faceprints are stored in a face recognition database. If one enter a photo into the database it will find any matching faceprint it has stored. Facial recognition software detects your face in an image. Facialirecognition algorithms are used to identify your unique facial biometrics and features, such as the space between yourinose and mouth, the size of your eyebrows, the width of your forehead, and numerous other attributes.

These distinctive features are called nodal points, and the average human face contains roughly 80 of them. This analogue information is converted to digital code to form your faceprint. Facialirecognition software can now compare your faceprint to other faceprints in the database to find a match.

5.3.6

Cloud Computing:

Cloud computing is a technology that enables people to connect to and use computing resources such as servers, storage, and software applications via the internet.

As a result, users no longer need to buy and maintain their own hardware and software; instead, they may just pay for the resources they use on a subscription basis and access them from any location with an internet connection. A popular option for both enterprises and people, cloud computing has a number of advantages including scalability, cost savings, and enhanced flexibility. Applications for cloud computing include data storage, backup and recovery, software development, and hosting websites and programmes. There are several sorts of cloud deployment models including public, private, and hybrid clouds, each with its own set of advantages and disadvantages. The various Cloud service models are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).Each of these cloud service models has advantages and disadvantages, and enterprises select the model that best meets their needs. For instance, PaaS is perfect for developers who want to concentrate on building applications without thinking about the underlying infrastructure, but IaaS is perfect for enterprises who need more control over their infrastructure. On the other hand, SaaS is perfect for businesses that wish to use applications without having to buy or maintain the software themselves.

5.4

Limitations:

1. The proposed system relies on an active internet connection and it cannot work in absence of it.
2. The system lacks a mechanism to prevent unborrowedibook going out of the library.
3. The system is designed andiimplemented for actual physical environment hence it does not support online users and those interested in purchasing the books.
4. The system fails to notify the users directly, about the due date to return the books.
5. The system fails to identify the book in an event of damaged RFID tag.

6. SOFTWARE DESIGN

Fig no.4

The aboveisimulation of the return device has been performed using Tinkercad and briefly demonstrates the working of the RFID Bookshelf module. The DC motor rotates representing the
RFID reader placed on one part of the bookshelf which is in reading mode to look for RFID tags in
the books. The serial monitor represents the scanning process done by the RFID Reader. Consider 'AB123456789A' as the RFID tag (placed in book) read by the RFID reader and it matches with the correct designated row number.
Hence it initiates the return process and updates the database accordingly.
The next bookicontaining tag data 'AB123456789B' read by the reader is of the book placed in the wrong location. Hence the buzzer then beepsialerting about the wrongly placed book in the shelf
and does not proceed with the return procedure.

7.

EXPECTED RESULTS

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"The proposed system results in automation of the library system based on IOT using a network of sensors placed at different locations of the library."It eases the process of sorting and maintaining the bookshelves. The proposedisystem allows an automatic management of the library where the registered users can experience a fastuborrow and return process enabled by facial recognition and RFID embedded into the books and the bookshelves. The need for human intervention in the monitoring of books is largely reduced as the interactions0with the books are properly tracked. It successfully reduces long queues at the counter as0compared to the existing systems. All the information about the status of users and every book in the library is precisely stored in the central database. The librarian is able to view all the necessary information in real-time and thus effectively monitor the activities taking place inside the library.

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APPENDIX

A1 Bill of material.

Sr No Component Quantity Type Manufacturer Cost 1. NodeMCU ESP8266 1 Microcontroller Expressif Rs 299 2 . ESP32Cam 1 Microcontroller Expressif Rs 489 3. MFRC522 and Tags 2 RFID Reader and Antenna NXP Semiconductors Rs 190 4. 0.96 Inch OLED 1 Display Robu.in Rs 224 GL-12 840 Point 1 Breadboard C&D Products Rs 59 Active Buzzer 1 Buzzer Module Robu.in Rs 29 FTDI Module 1 USB to Serial Converter Robu.in Rs 165 Soldering Iron 1 Soldering Soldron Rs 309 Solder Wire 50g 1 Soldering Robocraze Rs 110 Desolder Pump 1 Soldering Noel Rs 75 Cleaning Sponge 1 Soldering Robu.in Rs 15 ESP 32 1 Microcontroller Expressif Rs 449 F2M 20cm 20 Jumper Wires Robocraze Rs 29 M2M 20cm 20 Jumper Wires Robocraze Rs 29 F2F 20cm 40 Jumper Wires Robu.in Rs 39 Total Rs 2510

Hit and source - focused comparison, Side by Side

Submitted text	As student entered the text in the submitted document.
Matching text	As the text appears in the source.

APPENDIX 8

CO–PO-PSO MAPPING

DEPARTMENT E&TC ENGINEERING

Project Title Mapping with PO-PSO-MAPPINNG:

Project Mapping with Program Outcomes (1 – Slight, 2- Moderate, 3- Substantial)

PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
3	2	2	2	3	3	3	3	3	3	3	3	3	2

O1: The knowledge we had gained up to now was used to convert a complex Dosing system into a simple and effective Dosing system which can be controlled from anywhere with the help of loT. Basics of math and engineering knowledge, helped us to find solutions to make our system simple, instead of it being complex.

3/3

PO2: We had reviewed many papers and reports and found out the problems they were facing and overcame them with our knowledge. We were able to analyze those complex problems, so that further improvements could be made.

3/3

PO3: The design of our project was very complex at first. But after some research and guidance from experts, we were able to make it simple for users while keeping environmental and safety considerations in check.

3/3

PO4: We went through the experience of many working women and handicap people to understand the problem they faced when they were seeking help in emergency situations so we went through many controllers and sensors suitable for their needs and came up with solutions and conclusions to those problems.

3/3

PO5: Before creating our prototype, first we made an online prototype and simulated it, to know its capacity, predict all the things that could go wrong and its limitations.

3/3

PO6: Our project helps bring technology which is easy to use and understand to people who don't possess technical knowledge, to help them deal with the difficult situation just by pressing the required keys. Thus helping society to help them use technology which is easy to use.

3/3

PO7: Our project helps victims to save themselves without harming anyone's life considering the culprit too. Safety can be ensured with various features according to the victim's need. The goal behind our project was to help everyone, even military people can use it in their field whenever or wherever required.

3/3

PO8: We as engineering students have responsibility to make use of the knowledge we gained to help provide better and easy solutions to ensure security to needy people.

3/3

PO9: While working on our project, tasks were divided equally to reach members and together we were able to develop a prototype. While writing in teams, each member has to understand other member's weaknesses and strengths and help them accordingly to give their best outcome, so that the outcome of our team is best.

3/3

PO10 Before developing our prototype, we had visited an expert to help gain more information on how to proceed with our prototype and make it better. We took this guidance and developed the prototype. To send a word out about our prototype, we even published our paper in a journal. We created PPT and a report to spread information about our project in the engineering community.

3/3

PO11 Along with development of our prototype, project management was very crucial. We had to use our resources and energy very effectively to get the best result while being economical.

PO12 This project has made us realize that technology keeps on advancing and we have to keep on updating knowledge about the technologies. Engineering has taught us that learning is a lifelong process. everyday we get to learn something new and thus help use this knowledge to make the world the greatest place to live.

3/3

PSOI In our project, we have applied the knowledge we learnt about microcontrollers, Internet of things, embedded C language, etc

2/3

PSO2 For our project, first we used Proteus software for simulation, so that we could understand if the system would work properly and then assemble the hardware accordingly while reducing the circuit complexity of our system to run the system efficiently.

3/3

Project Outcome:

The out come of the project is that it has provided a solution to the existing problems in library management by enabling smart and automatic functions.

Declaration: Project is self-sponsored by all the group members.

APPENDIX 9

BILL OF MATERIAL

SR.NO	COMPONENT NAME	QUANTITY	UNIT COST (RS)	TOTAL COST
1	NodeMCU ESP8266	1	Rs 299	Rs 299
2	ESP32Cam	1	Rs 489	Rs 489
3	ESP 32	1	Rs 449	Rs 449
4	MFRC522 RFID and RFID Tags	2	Rs 190	Rs 380
5	0.96 Inch OLEDSSD1306	1	Rs 224	Rs 224
6	GL-12 840 Point Breadboard	1	Rs 59	Rs 59
7	Active Buzzer Module	1	Rs 29	Rs 29
8	FTDI Module	1	Rs 165	Rs 165
9	Soldering Iron	1	Rs 309	Rs 309
10	Solder Wire 50g	1	Rs 110	Rs 110
11	Desolder Pump	1	Rs 75	Rs 75
12	Cleaning Sponge	1	Rs 15	Rs 15
13	Jumper wires F2M 20cm 20 pcs	1	Rs 29	Rs 29
14	Jumper WiresM2M 20cm 20 pcs	1	Rs 29	Rs 29
15	Jumper Wires F2F 20cm 40 pcs	1	Rs 39	Rs 39
			Total	Rs 2510

APPENDIX 10

DATASHEETS

MFRC522

Standard performance MIFARE and NTAG frontend

Rev. 3.9 — 27 April 2016
112139

Product data sheet
COMPANY PUBLIC

1. Introduction

This document describes the functionality and electrical specifications of the contactless reader/writer MFRC522.

Remark: The MFRC522 supports all variants of the MIFARE Mini, MIFARE 1K, MIFARE 4K, MIFARE Ultralight, MIFARE DESFire EV1 and MIFARE Plus RF identification protocols. To aid readability throughout this data sheet, the MIFARE Mini, MIFARE 1K, MIFARE 4K, MIFARE Ultralight, MIFARE DESFire EV1 and MIFARE Plus products and protocols have the generic name MIFARE.

1.1 Differences between version 1.0 and 2.0

The MFRC522 is available in two versions:

- MFRC52201HN1, hereafter referred to version 1.0 and
- MFRC52202HN1, hereafter referred to version 2.0.

The MFRC522 version 2.0 is fully compatible to version 1.0 and offers in addition the following features and improvements:

- Increased stability of the reader IC in rough conditions
- An additional timer prescaler, see Section 8.5.
- A corrected CRC handling when RX Multiple is set to 1

This data sheet version covers both versions of the MFRC522 and describes the differences between the versions if applicable.

2. General description

The MFRC522 is a highly integrated reader/writer IC for contactless communication at 13.56 MHz. The MFRC522 reader supports ISO/IEC 14443 A/MIFARE and NTAG.

The MFRC522's internal transmitter is able to drive a reader/writer antenna designed to communicate with ISO/IEC 14443 A/MIFARE cards and transponders without additional active circuitry. The receiver module provides a robust and efficient implementation for demodulating and decoding signals from ISO/IEC 14443 A/MIFARE compatible cards and transponders. The digital module manages the complete ISO/IEC 14443 A framing and error detection (parity and CRC) functionality.

The MFRC522 supports MF1xxS20, MF1xxS70 and MF1xxS50 products. The MFRC522 supports contactless communication and uses MIFARE higher transfer speeds up to 848 kBd in both directions.

The following host interfaces are provided:

- Serial Peripheral Interface (SPI)
- Serial UART (similar to RS232 with voltage levels dependant on pin voltage supply)
- I^2C-bus interface

3. Features and benefits

- Highly integrated analog circuitry to demodulate and decode responses
- Buffered output drivers for connecting an antenna with the minimum number of external components
- Supports ISO/IEC 14443 A/MIFARE and NTAG
- Typical operating distance in Read/Write mode up to 50 mm depending on the antenna size and tuning
- Supports MF1xxS20, MF1xxS70 and MF1xxS50 encryption in Read/Write mode
- Supports ISO/IEC 14443 A higher transfer speed communication up to 848 kBd
- Supports MFIN/MFOUT
- Additional internal power supply to the smart card IC connected via MFIN/MFOUT
- Supported host interfaces
  - SPI up to 10 Mbit/s
  - I^2C-bus interface up to 400 kBd in Fast mode, up to 3400 kBd in High-speed mode
  - RS232 Serial UART up to 1228.8 kBd, with voltage levels dependant on pin voltage supply
- FIFO buffer handles 64 byte send and receive
- Flexible interrupt modes
- Hard reset with low power function
- Power-down by software mode
- Programmable timer
- Internal oscillator for connection to 27.12 MHz quartz crystal
- 2.5 V to 3.3 V power supply
- CRC coprocessor
- Programmable I/O pins
- Internal self-test

4. Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DDA}	analog supply voltage	$V_{DD(PVDD)} \leq V_{DDA} = V_{DDD} = V_{DD(TVDD)}$; $V_{SSA} = V_{SSD} = V_{SS(PVSS)} = V_{SS(TVSS)} = 0$ V	[1][2]	2.5	3.3	3.6	V
V_{DDD}	digital supply voltage			2.5	3.3	3.6	V
$V_{DD(TVDD)}$	TVDD supply voltage			2.5	3.3	3.6	V
$V_{DD(PVDD)}$	PVDD supply voltage		[3]	1.6	1.8	3.6	V
$V_{DD(SVDD)}$	SVDD supply voltage	$V_{SSA} = V_{SSD} = V_{SS(PVSS)} = V_{SS(TVSS)} = 0$ V		1.6	-	3.6	V

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Table 1. Quick reference data *...continued*

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
I_{pd}	power-down current	$V_{DDA} = V_{DDD} = V_{DD(TVDD)} = V_{DD(PVDD)} = 3$ V					
		hard power-down; pin NRSTPD set LOW	[4]	-	-	5	µA
		soft power-down; RF level detector on	[4]	-	-	10	µA
I_{DDD}	digital supply current	pin DVDD; $V_{DDD} = 3$ V		-	6.5	9	mA
I_{DDA}	analog supply current	pin AVDD; $V_{DDA} = 3$ V, CommandReg register's RcvOff bit = 0		-	7	10	mA
		pin AVDD; receiver switched off; $V_{DDA} = 3$ V, CommandReg register's RcvOff bit = 1		-	3	5	mA
$I_{DD(PVDD)}$	PVDD supply current	pin PVDD	[5]	-	-	40	mA
$I_{DD(TVDD)}$	TVDD supply current	pin TVDD; continuous wave	[6][7][8]	-	60	100	mA
T_{amb}	ambient temperature	HVQFN32		−25	-	+85	°C

[1] Supply voltages below 3 V reduce the performance in, for example, the achievable operating distance.

[2] V_{DDA}, V_{DDD} and $V_{DD(TVDD)}$ must always be the same voltage.

[3] $V_{DD(PVDD)}$ must always be the same or lower voltage than V_{DDD}.

[4] I_{pd} is the total current for all supplies.

[5] $I_{DD(PVDD)}$ depends on the overall load at the digital pins.

[6] $I_{DD(TVDD)}$ depends on $V_{DD(TVDD)}$ and the external circuit connected to pins TX1 and TX2.

[7] During typical circuit operation, the overall current is below 100 mA.

[8] Typical value using a complementary driver configuration and an antenna matched to 40 Ω between pins TX1 and TX2 at 13.56 MHz.

5. Ordering information

Table 2. Ordering information

Type number	Package		
	Name	Description	Version
MFRC52201HN1/TRAYB[1]	HVQFN32	plastic thermal enhanced very thin quad flat package; no leads; 32 terminal; body 5 × 5 × 0.85 mm	SOT617-1
MFRC52201HN1/TRAYBM[2]	HVQFN32	plastic thermal enhanced very thin quad flat package; no leads; 32 terminal; body 5 × 5 × 0.85 mm	SOT617-1
MFRC52202HN1/TRAYB[1]	HVQFN32	plastic thermal enhanced very thin quad flat package; no leads; 32 terminal; body 5 × 5 × 0.85 mm	SOT617-1
MFRC52202HN1/TRAYBM[2]	HVQFN32	plastic thermal enhanced very thin quad flat package; no leads; 32 terminal; body 5 × 5 × 0.85 mm	SOT617-1

[1] Delivered in one tray.

[2] Delivered in five trays.

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6. Block diagram

The analog interface handles the modulation and demodulation of the analog signals.

The contactless UART manages the protocol requirements for the communication protocols in cooperation with the host. The FIFO buffer ensures fast and convenient data transfer to and from the host and the contactless UART and vice versa.

Various host interfaces are implemented to meet different customer requirements.

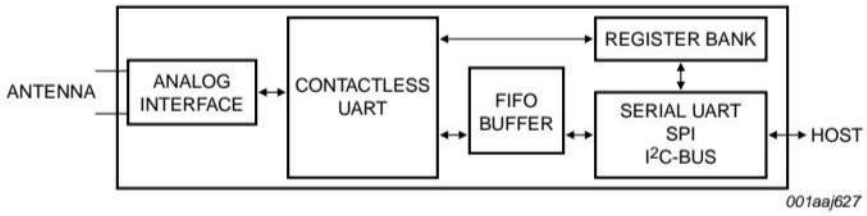

Fig 1. Simplified block diagram of the MFRC522

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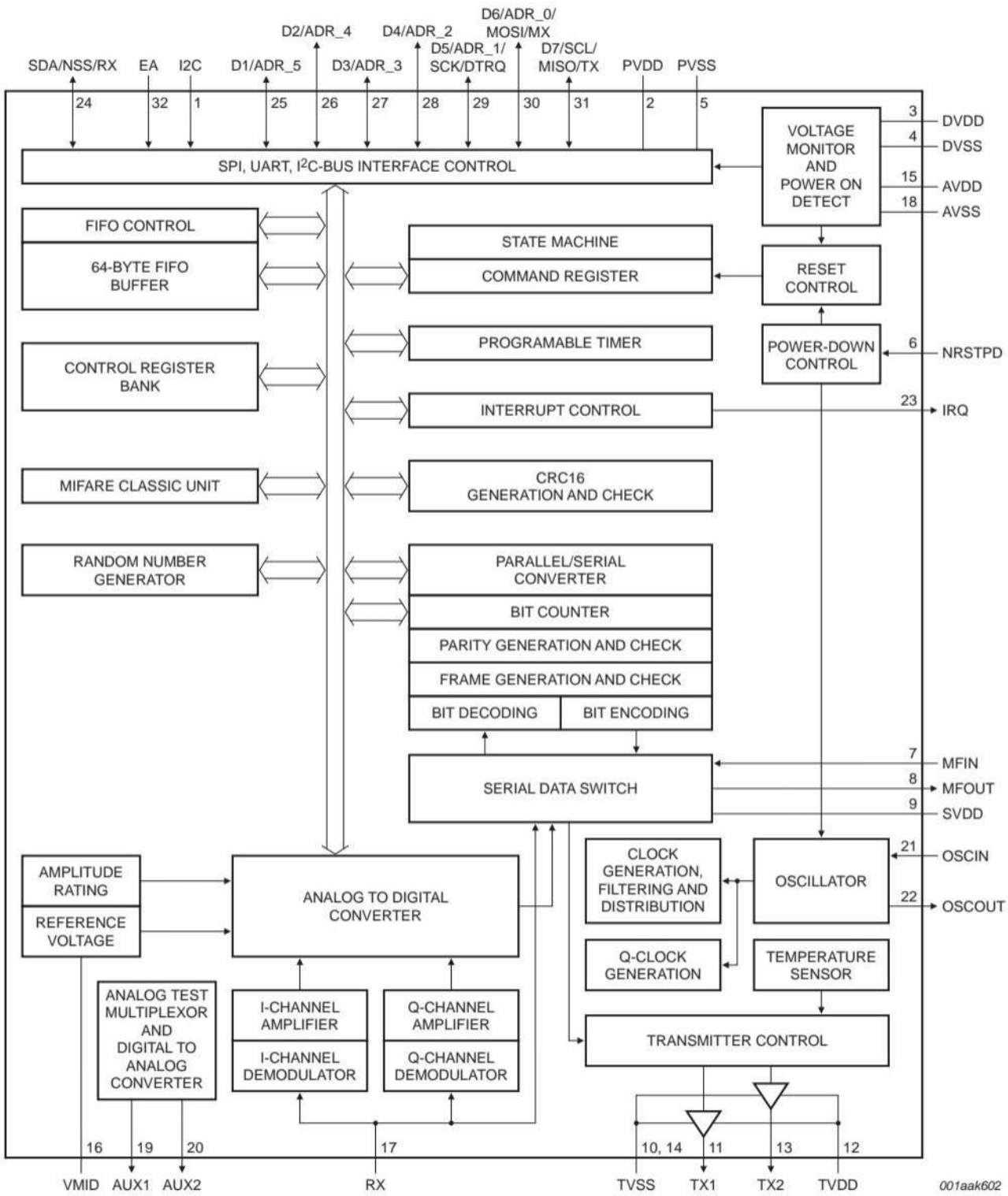

Fig 2. Detailed block diagram of the MFRC522

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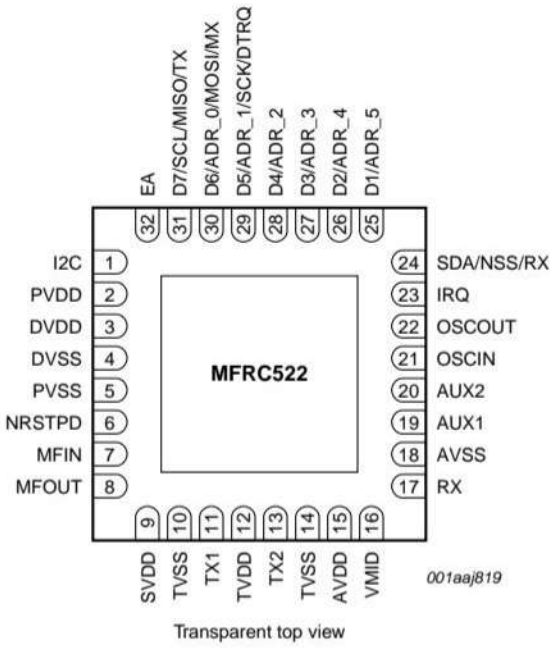
7. Pinning information



Transparent top view

Fig 3. Pinning configuration HVQFN32 (SOT617-1)

7.1 Pin description

Table 3. Pin description

Pin	Symbol	Type[1]	Description
1	I2C	I	I^2C-bus enable input[2]
2	PVDD	P	pin power supply
3	DVDD	P	digital power supply
4	DVSS	G	digital ground[3]
5	PVSS	G	pin power supply ground
6	NRSTPD	I	reset and power-down input: power-down: enabled when LOW; internal current sinks are switched off, the oscillator is inhibited and the input pins are disconnected from the outside world reset: enabled by a positive edge
7	MFIN	I	MIFARE signal input
8	MFOUT	O	MIFARE signal output
9	SVDD	P	MFIN and MFOUT pin power supply
10	TVSS	G	transmitter output stage 1 ground
11	TX1	O	transmitter 1 modulated 13.56 MHz energy carrier output
12	TVDD	P	transmitter power supply: supplies the output stage of transmitters 1 and 2
13	TX2	O	transmitter 2 modulated 13.56 MHz energy carrier output
14	TVSS	G	transmitter output stage 2 ground
15	AVDD	P	analog power supply

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Table 3. Pin description *...continued*

Pin	Symbol	Type[1]	Description
16	VMID	P	internal reference voltage
17	RX	I	RF signal input
18	AVSS	G	analog ground
19	AUX1	O	auxiliary outputs for test purposes
20	AUX2	O	auxiliary outputs for test purposes
21	OSCIN	I	crystal oscillator inverting amplifier input; also the input for an externally generated clock (f_{clk} = 27.12 MHz)
22	OSCOUT	O	crystal oscillator inverting amplifier output
23	IRQ	O	interrupt request output: indicates an interrupt event
24	SDA	I/O	I^2C-bus serial data line input/output[2]
	NSS	I	SPI signal input[2]
	RX	I	UART address input[2]
25	D1	I/O	test port[2]
	ADR_5	I/O	I^2C-bus address 5 input[2]
26	D2	I/O	test port
	ADR_4	I	I^2C-bus address 4 input[2]
27	D3	I/O	test port
	ADR_3	I	I^2C-bus address 3 input[2]
28	D4	I/O	test port
	ADR_2	I	I^2C-bus address 2 input[2]
29	D5	I/O	test port
	ADR_1	I	I^2C-bus address 1 input[2]
	SCK	I	SPI serial clock input[2]
	DTRQ	O	UART request to send output to microcontroller[2]
30	D6	I/O	test port
	ADR_0	I	I^2C-bus address 0 input[2]
	MOSI	I/O	SPI master out, slave in[2]
	MX	O	UART output to microcontroller[2]
31	D7	I/O	test port
	SCL	I/O	I^2C-bus clock input/output[2]
	MISO	I/O	SPI master in, slave out[2]
	TX	O	UART data output to microcontroller[2]
32	EA	I	external address input for coding I^2C-bus address[2]

[1] Pin types: I = Input, O = Output, I/O = Input/Output, P = Power and G = Ground.

[2] The pin functionality of these pins is explained in Section 8.1 "Digital interfaces".

[3] Connection of heatsink pad on package bottom side is not necessary. Optional connection to pin DVSS is possible.

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8. Functional description

The MFRC522 transmission module supports the Read/Write mode for ISO/IEC 14443 A/MIFARE using various transfer speeds and modulation protocols.

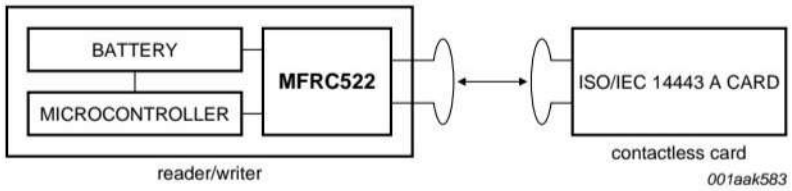
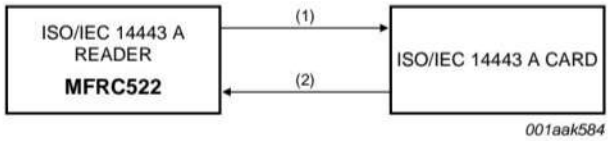


Fig 4. MFRC522 Read/Write mode

The physical level communication is shown in Figure 5.



(1) Reader to card 100 % ASK, Miller encoded, transfer speed 106 kBd to 848 kBd.

(2) Card to reader subcarrier load modulation, Manchester encoded or BPSK, transfer speed 106 kBd to 848 kBd.

Fig 5. ISO/IEC 14443 A/MIFARE Read/Write mode communication diagram

The physical parameters are described in Table 4.

Table 4. Communication overview for ISO/IEC 14443 A/MIFARE reader/writer

Communication direction	Signal type	Transfer speed			
		106 kBd	212 kBd	424 kBd	848 kBd
Reader to card (send data from the MFRC522 to a card)	reader side modulation	100 % ASK	100 % ASK	100 % ASK	100 % ASK
	bit encoding	modified Miller encoding	modified Miller encoding	modified Miller encoding	modified Miller encoding
	bit length	128 (13.56 μs)	64 (13.56 μs)	32 (13.56 μs)	16 (13.56 μs)
Card to reader (MFRC522 receives data from a card)	card side modulation	subcarrier load modulation	subcarrier load modulation	subcarrier load modulation	subcarrier load modulation
	subcarrier frequency	13.56 MHz / 16	13.56 MHz / 16	13.56 MHz / 16	13.56 MHz / 16
	bit encoding	Manchester encoding	BPSK	BPSK	BPSK

The MFRC522's contactless UART and dedicated external host must manage the complete ISO/IEC 14443 A/MIFARE protocol. Figure 6 shows the data coding and framing according to ISO/IEC 14443 A/MIFARE.

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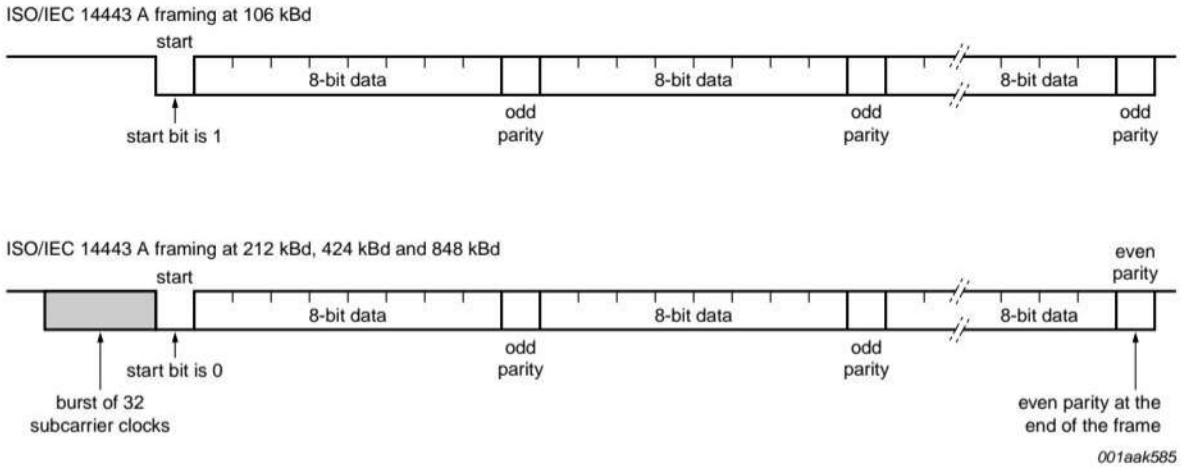

Fig 6. Data coding and framing according to ISO/IEC 14443 A

The internal CRC coprocessor calculates the CRC value based on ISO/IEC 14443 A part 3 and handles parity generation internally according to the transfer speed. Automatic parity generation can be switched off using the MfRxReg register's ParityDisable bit.

8.1 Digital interfaces

8.1.1 Automatic microcontroller interface detection

The MFRC522 supports direct interfacing of hosts using SPI, I^2C-bus or serial UART interfaces. The MFRC522 resets its interface and checks the current host interface type automatically after performing a power-on or hard reset. The MFRC522 identifies the host interface by sensing the logic levels on the control pins after the reset phase. This is done using a combination of fixed pin connections. Table 5 shows the different connection configurations.

Table 5. Connection protocol for detecting different interface types

Pin	Interface type		
	UART (input)	SPI (output)	I^2C-bus (I/O)
SDA	RX	NSS	SDA
I2C	0	0	1
EA	0	1	EA
D7	TX	MISO	SCL
D6	MX	MOSI	ADR_0
D5	DTRQ	SCK	ADR_1
D4	-	-	ADR_2
D3	-	-	ADR_3
D2	-	-	ADR_4
D1	-	-	ADR_5

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8.1.2 Serial Peripheral Interface

A serial peripheral interface (SPI compatible) is supported to enable high-speed communication to the host. The interface can handle data speeds up to 10 Mbit/s. When communicating with a host, the MFRC522 acts as a slave, receiving data from the external host for register settings, sending and receiving data relevant for RF interface communication.

An interface compatible with SPI enables high-speed serial communication between the MFRC522 and a microcontroller. The implemented interface is in accordance with the SPI standard.

The timing specification is given in Section 14.1 on page 78.

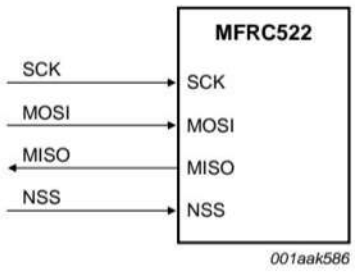

Fig 7. SPI connection to host

The MFRC522 acts as a slave during SPI communication. The SPI clock signal SCK must be generated by the master. Data communication from the master to the slave uses the MOSI line. The MISO line is used to send data from the MFRC522 to the master.

Data bytes on both MOSI and MISO lines are sent with the MSB first. Data on both MOSI and MISO lines must be stable on the rising edge of the clock and can be changed on the falling edge. Data is provided by the MFRC522 on the falling clock edge and is stable during the rising clock edge.

8.1.2.1 SPI read data

Reading data using SPI requires the byte order shown in Table 6 to be used. It is possible to read out up to n-data bytes.

The first byte sent defines both the mode and the address.

Table 6. MOSI and MISO byte order

Line	Byte 0	Byte 1	Byte 2	To	Byte n	Byte n + 1
MOSI	address 0	address 1	address 2	...	address n	00
MISO	X[1]	data 0	data 1	...	data n − 1	data n

[1] X = Do not care.

Remark: The MSB must be sent first.

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8.1.2.2 SPI write data

To write data to the MFRC522 using SPI requires the byte order shown in Table 7. It is possible to write up to n data bytes by only sending one address byte.

The first send byte defines both the mode and the address byte.

Table 7. MOSI and MISO byte order

Line	Byte 0	Byte 1	Byte 2	To	Byte n	Byte n + 1
MOSI	address 0	data 0	data 1	...	data n − 1	data n
MISO	X[1]	X[1]	X[1]	...	X[1]	X[1]

[1] X = Do not care.

Remark: The MSB must be sent first.

8.1.2.3 SPI address byte

The address byte must meet the following format.

The MSB of the first byte defines the mode used. To read data from the MFRC522 the MSB is set to logic 1. To write data to the MFRC522 the MSB must be set to logic 0. Bits 6 to 1 define the address and the LSB is set to logic 0.

Table 8. Address byte 0 register; address MOSI

7 (MSB)	6	5	4	3	2	1	0 (LSB)
1 = read 0 = write	address						0

8.1.3 UART interface

8.1.3.1 Connection to a host

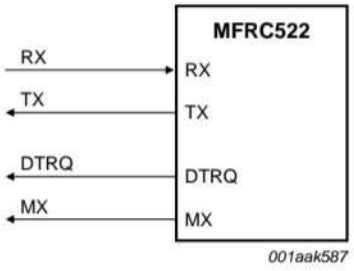

Fig 8. UART connection to microcontrollers

Remark: Signals DTRQ and MX can be disabled by clearing TestPinEnReg register's RS232LineEn bit.

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8.1.3.2 Selectable UART transfer speeds

The internal UART interface is compatible with an RS232 serial interface.

The default transfer speed is 9.6 kBd. To change the transfer speed, the host controller must write a value for the new transfer speed to the SerialSpeedReg register. Bits BR_T0[2:0] and BR_T1[4:0] define the factors for setting the transfer speed in the SerialSpeedReg register.

The BR_T0[2:0] and BR_T1[4:0] settings are described in Table 9. Examples of different transfer speeds and the relevant register settings are given in Table 10.

Table 9. BR_T0 and BR_T1 settings

BR_Tn	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
BR_T0 factor	1	1	2	4	8	16	32	64
BR_T1 range	1 to 32	33 to 64	33 to 64	33 to 64	33 to 64	33 to 64	33 to 64	33 to 64

Table 10. Selectable UART transfer speeds

Transfer speed (kBd)	SerialSpeedReg value		Transfer speed accuracy (%)[1]
	Decimal	Hexadecimal	
7.2	250	FAh	−0.25
9.6	235	EBh	0.32
14.4	218	DAh	−0.25
19.2	203	CBh	0.32
38.4	171	ABh	0.32
57.6	154	9Ah	−0.25
115.2	122	7Ah	−0.25
128	116	74h	−0.06
230.4	90	5Ah	−0.25
460.8	58	3Ah	−0.25
921.6	28	1Ch	1.45
1228.8	21	15h	0.32

[1] The resulting transfer speed error is less than 1.5 % for all described transfer speeds.

The selectable transfer speeds shown in Table 10 are calculated according to the following equations:

If BR_T0[2:0] = 0:

$$transfer\ speed = \frac{27.12 \times 10^6}{(BR\_T0 + 1)} \quad (1)$$

If BR_T0[2:0] > 0:

$$transfer\ speed = \left(\frac{27.12 \times 10^6}{\frac{(BR\_T1 + 33)}{2^{(BR\_T0 - 1)}}} \right) \quad (2)$$

Remark: Transfer speeds above 1228.8 kBd are not supported.

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8.1.3.3 UART framing

Table 11. UART framing

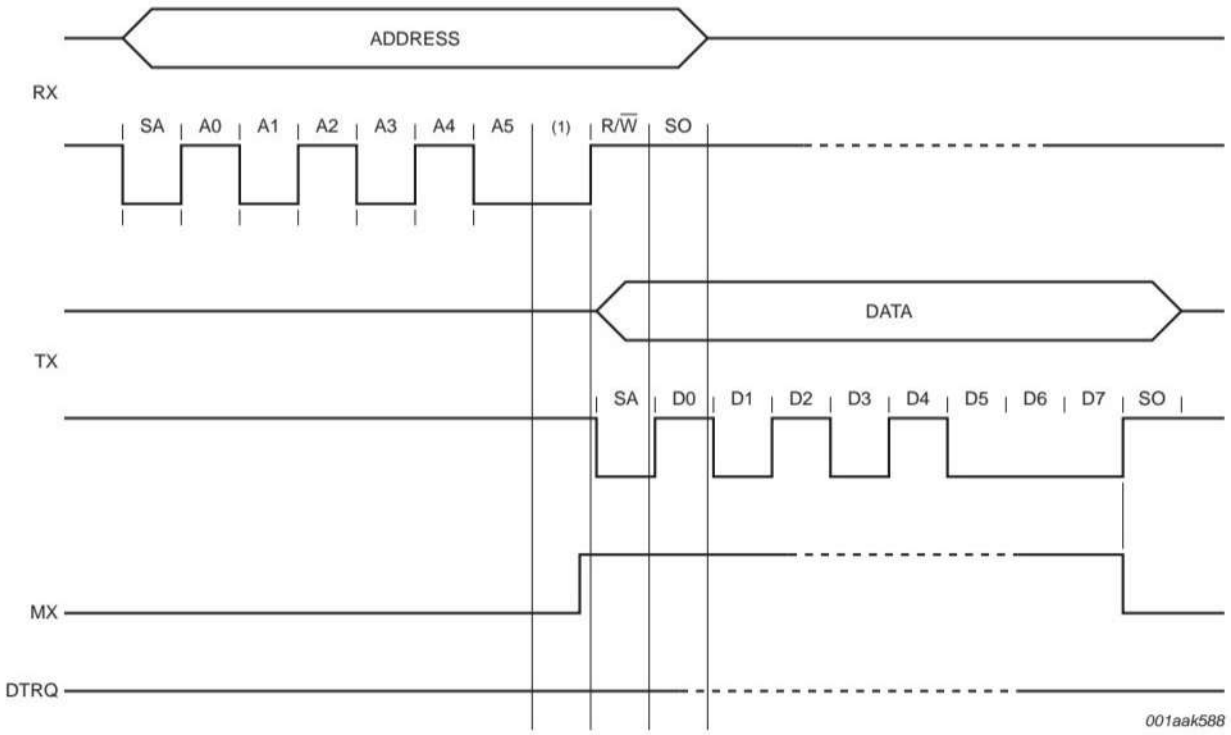
Bit	Length	Value
Start	1-bit	0
Data	8 bits	data
Stop	1-bit	1

Remark: The LSB for data and address bytes must be sent first. No parity bit is used during transmission.

Read data: To read data using the UART interface, the flow shown in Table 12 must be used. The first byte sent defines both the mode and the address.

Table 12. Read data byte order

Pin	Byte 0	Byte 1
RX (pin 24)	address	-
TX (pin 31)	-	data 0



(1) Reserved.

Fig 9. UART read data timing diagram

Write data: To write data to the MFRC522 using the UART interface, the structure shown in Table 13 must be used.

The first byte sent defines both the mode and the address.

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Table 13. Write data byte order

Pin	Byte 0	Byte 1
RX (pin 24)	address 0	data 0
TX (pin 31)	-	address 0

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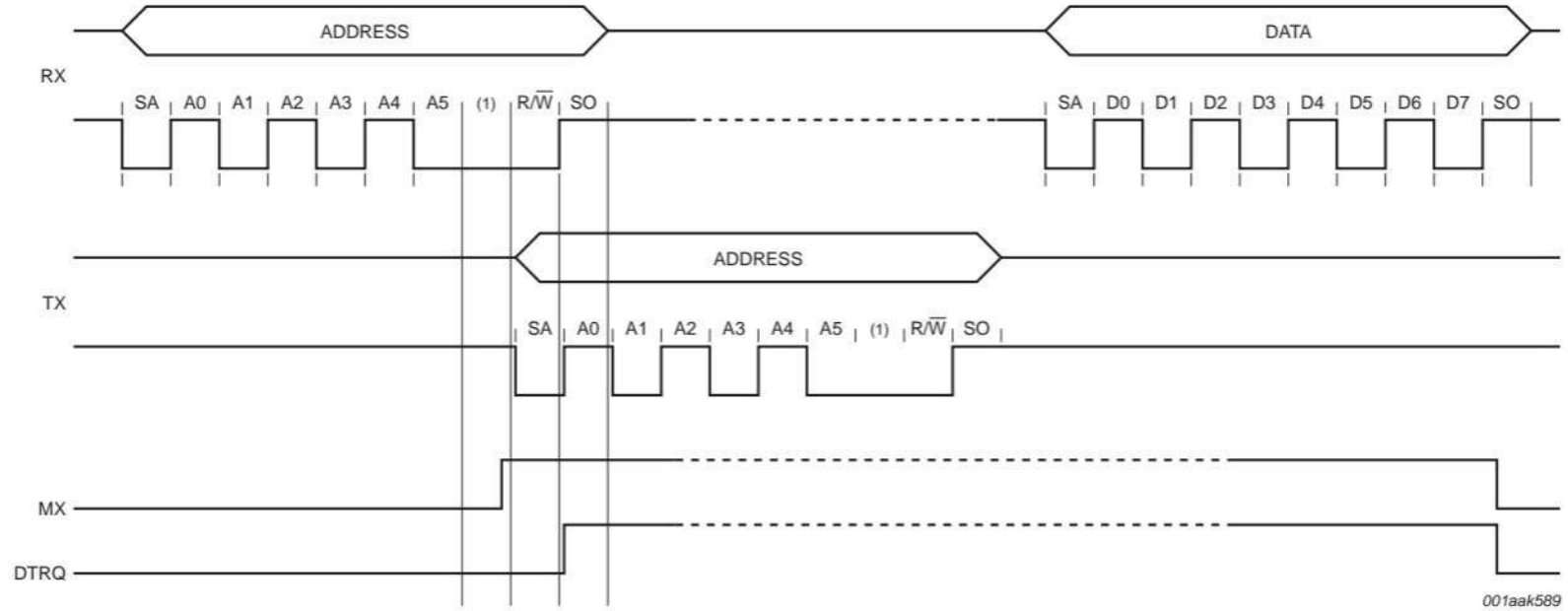

(1) Reserved.

Fig 10. UART write data timing diagram

Remark: The data byte can be sent directly after the address byte on pin RX.

Address byte: The address byte has to meet the following format:

The MSB of the first byte sets the mode used. To read data from the MFRC522, the MSB is set to logic 1. To write data to the MFRC522 the MSB is set to logic 0. Bit 6 is reserved for future use, and bits 5 to 0 define the address; see Table 14.

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Table 14. Address byte 0 register; address MOSI

7 (MSB)	6	5	4	3	2	1	0 (LSB)
1 = read 0 = write	reserved	address					

8.1.4 I²C-bus interface

An I²C-bus (Inter-IC) interface is supported to enable a low-cost, low pin count serial bus interface to the host. The I²C-bus interface is implemented according to NXP Semiconductors' *I²C-bus interface specification, rev. 2.1, January 2000*. The interface can only act in Slave mode. Therefore the MFRC522 does not implement clock generation or access arbitration.

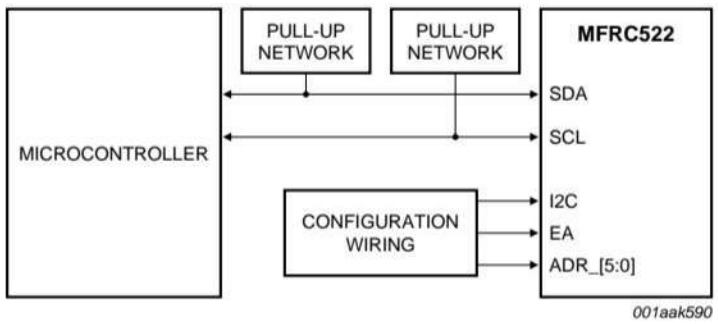

Fig 11. I²C-bus interface

The MFRC522 can act either as a slave receiver or slave transmitter in Standard mode, Fast mode and High-speed mode.

SDA is a bidirectional line connected to a positive supply voltage using a current source or a pull-up resistor. Both SDA and SCL lines are set HIGH when data is not transmitted. The MFRC522 has a 3-state output stage to perform the wired-AND function. Data on the I²C-bus can be transferred at data rates of up to 100 kBd in Standard mode, up to 400 kBd in Fast mode or up to 3.4 Mbit/s in High-speed mode.

If the I²C-bus interface is selected, spike suppression is activated on lines SCL and SDA as defined in the I²C-bus interface specification.

See Table 155 on page 79 for timing requirements.

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8.1.4.1 Data validity

Data on the SDA line must be stable during the HIGH clock period. The HIGH or LOW state of the data line must only change when the clock signal on SCL is LOW.

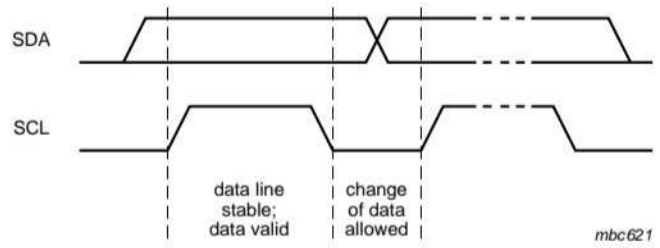

Fig 12. Bit transfer on the I²C-bus

8.1.4.2 START and STOP conditions

To manage the data transfer on the I²C-bus, unique START (S) and STOP (P) conditions are defined.

- A START condition is defined with a HIGH-to-LOW transition on the SDA line while SCL is HIGH.
- A STOP condition is defined with a LOW-to-HIGH transition on the SDA line while SCL is HIGH.

The I²C-bus master always generates the START and STOP conditions. The bus is busy after the START condition. The bus is free again a certain time after the STOP condition.

The bus stays busy if a repeated START (Sr) is generated instead of a STOP condition. The START (S) and repeated START (Sr) conditions are functionally identical. Therefore, S is used as a generic term to represent both the START (S) and repeated START (Sr) conditions.

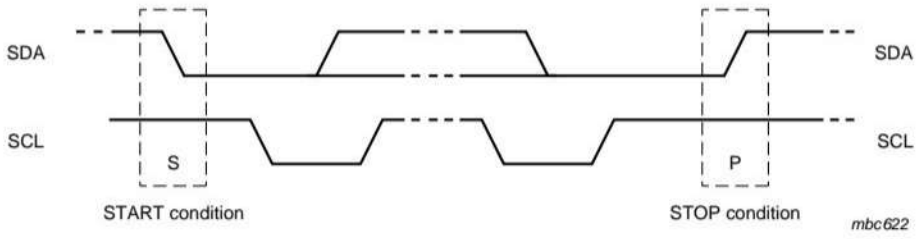

Fig 13. START and STOP conditions

8.1.4.3 Byte format

Each byte must be followed by an acknowledge bit. Data is transferred with the MSB first; see Figure 16. The number of transmitted bytes during one data transfer is unrestricted but must meet the read/write cycle format.

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8.1.4.4 Acknowledge

An acknowledge must be sent at the end of one data byte. The acknowledge-related clock pulse is generated by the master. The transmitter of data, either master or slave, releases the SDA line (HIGH) during the acknowledge clock pulse. The receiver pulls down the SDA line during the acknowledge clock pulse so that it remains stable LOW during the HIGH period of this clock pulse.

The master can then generate either a STOP (P) condition to stop the transfer or a repeated START (Sr) condition to start a new transfer.

A master-receiver indicates the end of data to the slave-transmitter by not generating an acknowledge on the last byte that was clocked out by the slave. The slave-transmitter releases the data line to allow the master to generate a STOP (P) or repeated START (Sr) condition.

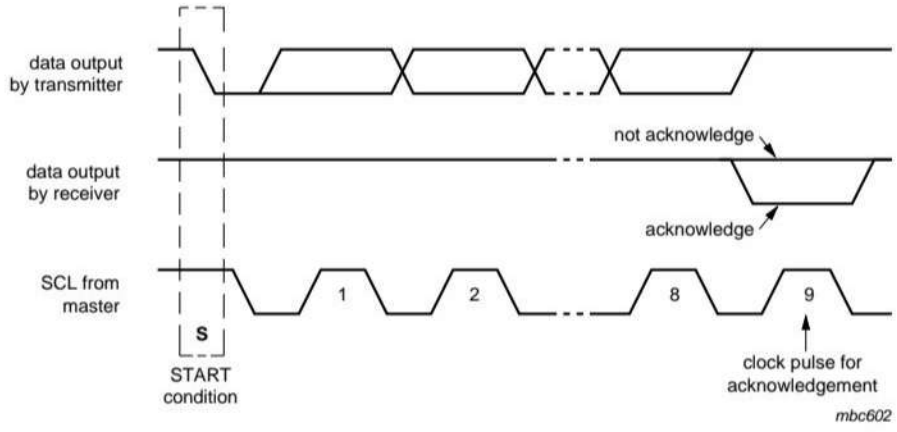

Fig 14. Acknowledge on the I²C-bus

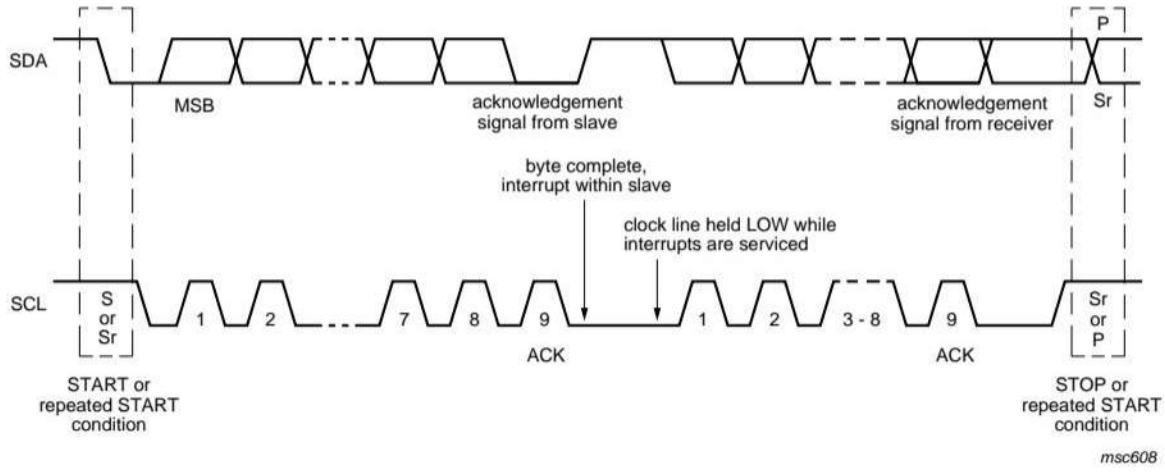

Fig 15. Data transfer on the I²C-bus

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8.1.4.5 7-Bit addressing

During the I²C-bus address procedure, the first byte after the START condition is used to determine which slave will be selected by the master.

Several address numbers are reserved. During device configuration, the designer must ensure that collisions with these reserved addresses cannot occur. Check the *I²C-bus specification* for a complete list of reserved addresses.

The I²C-bus address specification is dependent on the definition of pin EA. Immediately after releasing pin NRSTPD or after a power-on reset, the device defines the I²C-bus address according to pin EA.

If pin EA is set LOW, the upper 4 bits of the device bus address are reserved by NXP Semiconductors and set to 0101b for all MFRC522 devices. The remaining 3 bits (ADR_0, ADR_1, ADR_2) of the slave address can be freely configured by the customer to prevent collisions with other I²C-bus devices.

If pin EA is set HIGH, ADR_0 to ADR_5 can be completely specified at the external pins according to Table 5 on page 9. ADR_6 is always set to logic 0.

In both modes, the external address coding is latched immediately after releasing the reset condition. Further changes at the used pins are not taken into consideration. Depending on the external wiring, the I²C-bus address pins can be used for test signal outputs.

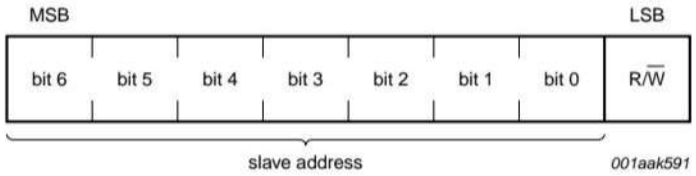

Fig 16. First byte following the START procedure

8.1.4.6 Register write access

To write data from the host controller using the I²C-bus to a specific register in the MFRC522 the following frame format must be used.

- The first byte of a frame indicates the device address according to the I²C-bus rules.
- The second byte indicates the register address followed by up to n-data bytes.

In one frame all data bytes are written to the same register address. This enables fast FIFO buffer access. The Read/Write (R/$\overline{W}$) bit is set to logic 0.

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8.1.4.7 Register read access

To read out data from a specific register address in the MFRC522, the host controller must use the following procedure:

- Firstly, a write access to the specific register address must be performed as indicated in the frame that follows
- The first byte of a frame indicates the device address according to the I²C-bus rules
- The second byte indicates the register address. No data bytes are added
- The Read/Write bit is 0

After the write access, read access can start. The host sends the device address of the MFRC522. In response, the MFRC522 sends the content of the read access register. In one frame all data bytes can be read from the same register address. This enables fast FIFO buffer access or register polling.

The Read/Write (R/W) bit is set to logic 1.

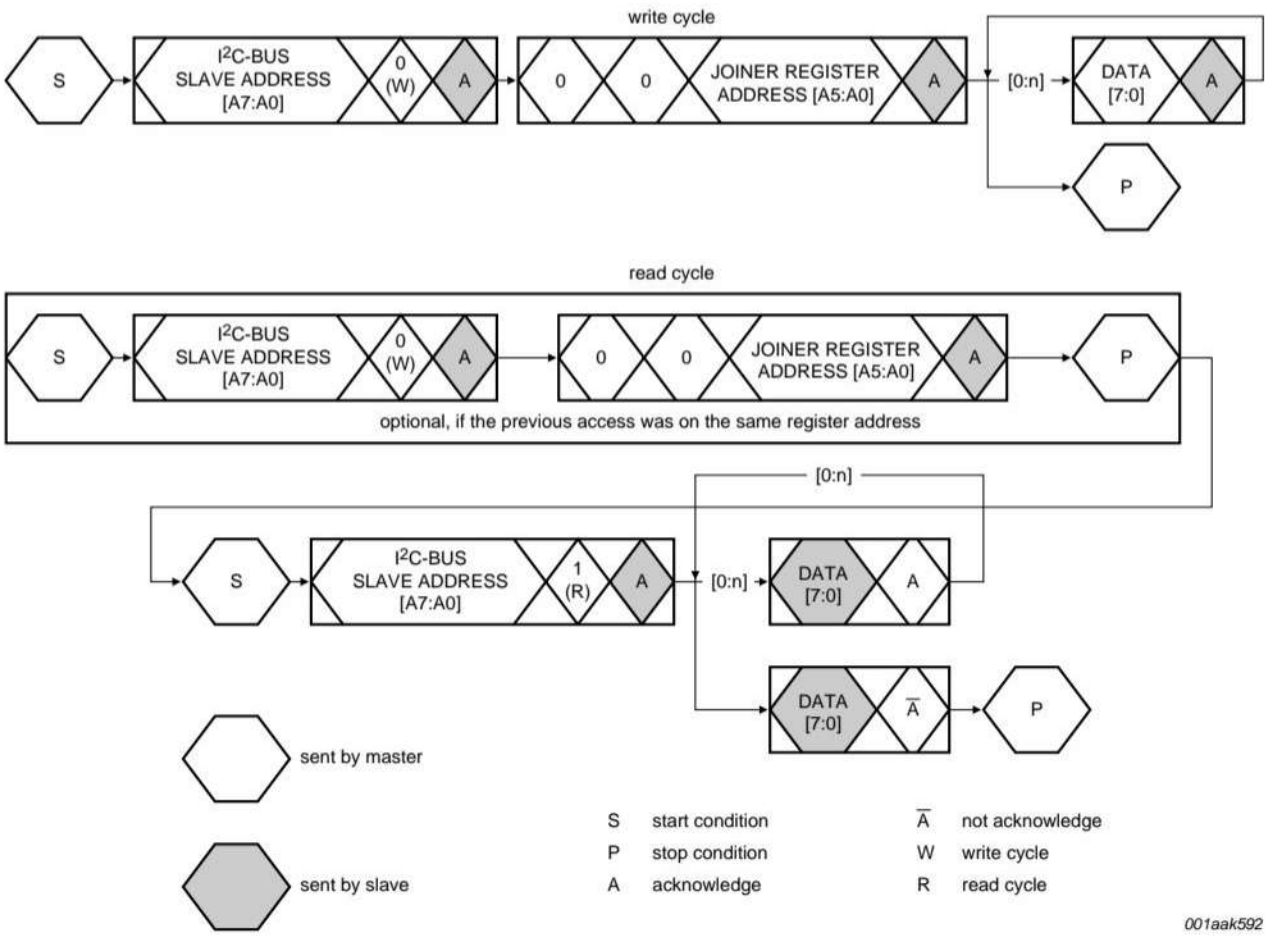

Fig 17. Register read and write access

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8.1.4.8 High-speed mode

In High-speed mode (HS mode), the device can transfer information at data rates of up to 3.4 Mbit/s, while remaining fully downward-compatible with Fast or Standard mode (F/S mode) for bidirectional communication in a mixed-speed bus system.

8.1.4.9 High-speed transfer

To achieve data rates of up to 3.4 Mbit/s the following improvements have been made to I^2C-bus operation.

- The inputs of the device in HS mode incorporate spike suppression, a Schmitt trigger on the SDA and SCL inputs and different timing constants when compared to F/S mode
- The output buffers of the device in HS mode incorporate slope control of the falling edges of the SDA and SCL signals with different fall times compared to F/S mode

8.1.4.10 Serial data transfer format in HS mode

The HS mode serial data transfer format meets the Standard mode I^2C-bus specification. HS mode can only start after all of the following conditions (all of which are in F/S mode):

1. START condition (S)
2. 8-bit master code (00001XXXb)
3. Not-acknowledge bit ($\overline{A}$)

When HS mode starts, the active master sends a repeated START condition (Sr) followed by a 7-bit slave address with a R/W bit address and receives an acknowledge bit (A) from the selected MFRC522.

Data transfer continues in HS mode after the next repeated START (Sr), only switching back to F/S mode after a STOP condition (P). To reduce the overhead of the master code, a master links a number of HS mode transfers, separated by repeated START conditions (Sr).

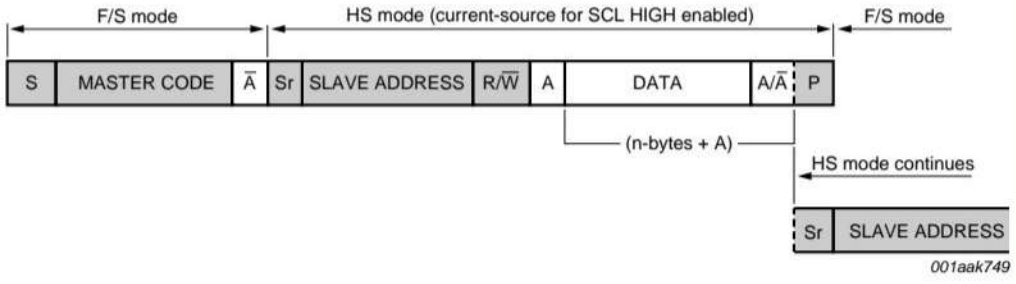

Fig 18. I^2C-bus HS mode protocol switch

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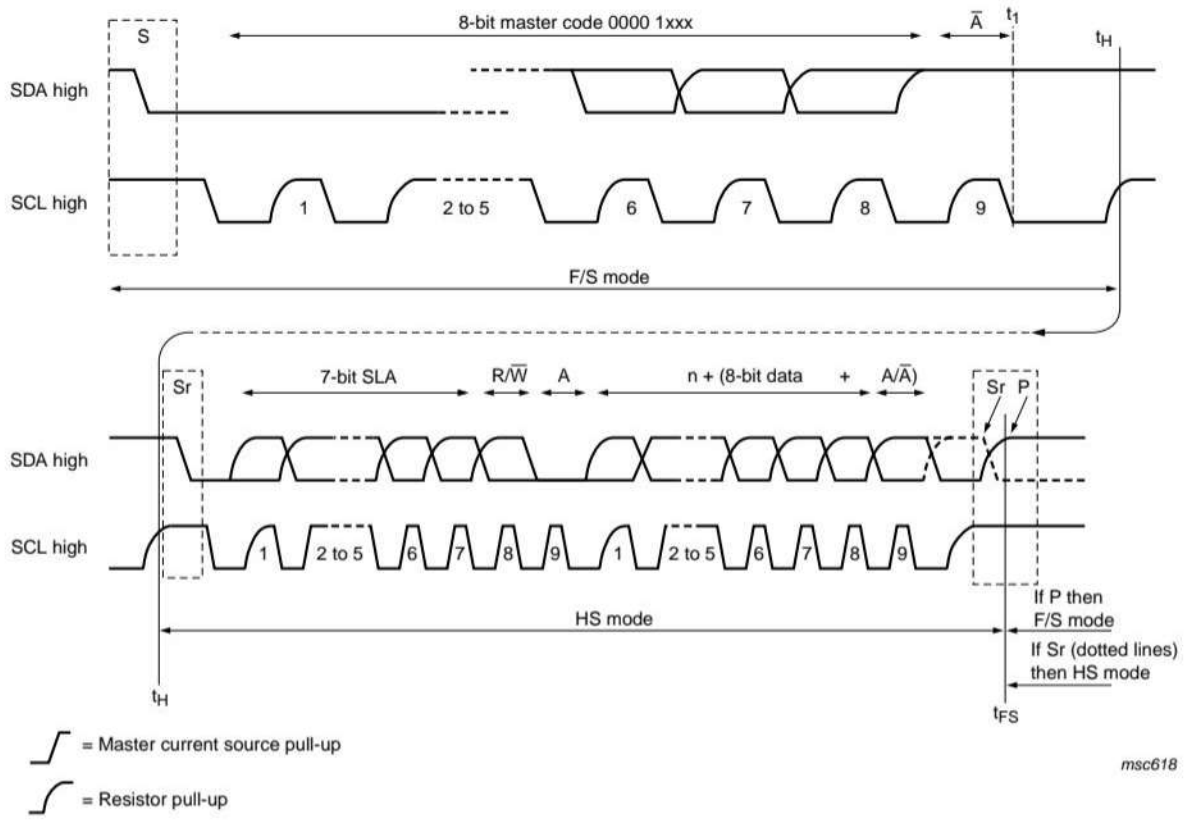

Fig 19. I²C-bus HS mode protocol frame

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8.1.4.11 Switching between F/S mode and HS mode

After reset and initialization, the MFRC522 is in Fast mode (which is in effect F/S mode as Fast mode is downward-compatible with Standard mode). The connected MFRC522 recognizes the “S 00001XXX A” sequence and switches its internal circuitry from the Fast mode setting to the HS mode setting.

The following actions are taken:

1. Adapt the SDA and SCL input filters according to the spike suppression requirement in HS mode.
2. Adapt the slope control of the SDA output stages.

It is possible for system configurations that do not have other I^2C-bus devices involved in the communication to switch to HS mode permanently. This is implemented by setting Status2Reg register’s I^2CForceHS bit to logic 1. In permanent HS mode, the master code is not required to be sent. This is not defined in the specification and must only be used when no other devices are connected on the bus. In addition, spikes on the I^2C-bus lines must be avoided because of the reduced spike suppression.

8.1.4.12 MFRC522 at lower speed modes

MFRC522 is fully downward-compatible and can be connected to an F/S mode I^2C-bus system. The device stays in F/S mode and communicates at F/S mode speeds because a master code is not transmitted in this configuration.

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8.2 Analog interface and contactless UART

8.2.1 General

The integrated contactless UART supports the external host online with framing and error checking of the protocol requirements up to 848 kBd. An external circuit can be connected to the communication interface pins MFIN and MFOUT to modulate and demodulate the data.

The contactless UART handles the protocol requirements for the communication protocols in cooperation with the host. Protocol handling generates bit and byte-oriented framing. In addition, it handles error detection such as parity and CRC, based on the various supported contactless communication protocols.

Remark: The size and tuning of the antenna and the power supply voltage have an important impact on the achievable operating distance.

8.2.2 TX p-driver

The signal on pins TX1 and TX2 is the 13.56 MHz energy carrier modulated by an envelope signal. It can be used to drive an antenna directly using a few passive components for matching and filtering; see Section 15 on page 81. The signal on pins TX1 and TX2 can be configured using the TxControlReg register; see Section 9.3.2.5 on page 50.

The modulation index can be set by adjusting the impedance of the drivers. The impedance of the p-driver can be configured using registers CWGsPReg and ModGsPReg. The impedance of the n-driver can be configured using the GsNReg register. The modulation index also depends on the antenna design and tuning.

The TxModeReg and TxSelReg registers control the data rate and framing during transmission and the antenna driver setting to support the different requirements at the different modes and transfer speeds.

Table 15. Register and bit settings controlling the signal on pin TX1

Bit Tx1RFEn	Bit Force 100ASK	Bit InvTx1RFOn	Bit InvTx1RFOff	Envelope	Pin TX1	GSPMos	GSNMos	Remarks
0	X[1]	X[1]	X[1]	X[1]	X[1]	X[1]	X[1]	not specified if RF is switched off
1	0	0	X[1]	0	RF	pMod	nMod	100 % ASK: pin TX1 pulled to logic 0, independent of the InvTx1RFOff bit
				1	RF	pCW	nCW	
	0	1	X[1]	0	RF	pMod	nMod	
				1	RF	pCW	nCW	
	1	1	X[1]	0	0	pMod	nMod	
				1	RF_n	pCW	nCW	

[1] X = Do not care.

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Table 16. Register and bit settings controlling the signal on pin TX2

Bit Tx1RFEn	Bit Force 100ASK	Bit Tx2CW	Bit InvTx2RFOn	Bit InvTx2RFOff	Envelope	Pin TX2	GSPMos	GSNMos	Remarks
0	X[1]	X[1]	X[1]	X[1]	X[1]	X[1]	X[1]	X[1]	not specified if RF is switched off
1	0	0	0	X[1]	0	RF	pMod	nMod	-
					1	RF	pCW	nCW	
			1	X[1]	0	RF_n	pMod	nMod	
					1	RF_n	pCW	nCW	
		1	0	X[1]	X[1]	RF	pCW	nCW	conductance always CW for the Tx2CW bit
			1	X[1]	X[1]	RF_n	pCW	nCW	
	1	0	0	X[1]	0	0	pMod	nMod	100 % ASK: pin TX2 pulled to logic 0 (independent of the InvTx2RFOn/InvTx2RFOff bits)
					1	RF	pCW	nCW	
			1	X[1]	0	0	pMod	nMod	
					1	RF_n	pCW	nCW	
		1	0	X[1]	X[1]	RF	pCW	nCW	
			1	X[1]	X[1]	RF_n	pCW	nCW	

[1] X = Do not care.

The following abbreviations have been used in Table 15 and Table 16:

- RF: 13.56 MHz clock derived from 27.12 MHz quartz crystal oscillator divided by 2
- RF_n: inverted 13.56 MHz clock
- GSPMos: conductance, configuration of the PMOS array
- GSNMos: conductance, configuration of the NMOS array
- pCW: PMOS conductance value for continuous wave defined by the CWGsPReg register
- pMod: PMOS conductance value for modulation defined by the ModGsPReg register
- nCW: NMOS conductance value for continuous wave defined by the GsNReg register's CWGsN[3:0] bits
- nMod: NMOS conductance value for modulation defined by the GsNReg register's ModGsN[3:0] bits
- X = do not care.

Remark: If only one driver is switched on, the values for CWGsPReg, ModGsPReg and GsNReg registers are used for both drivers.

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8.2.3 Serial data switch

Two main blocks are implemented in the MFRC522. The digital block comprises the state machines, encoder/decoder logic. The analog block comprises the modulator and antenna drivers, the receiver and amplifiers. It is possible for the interface between these two blocks to be configured so that the interfacing signals are routed to pins MFIN and MFOUT.

This topology allows the analog block of the MFRC522 to be connected to the digital block of another device.

The serial signal switch is controlled by the TxSelReg and RxSelReg registers.

Figure 20 shows the serial data switch for p-driver TX1 and TX2.

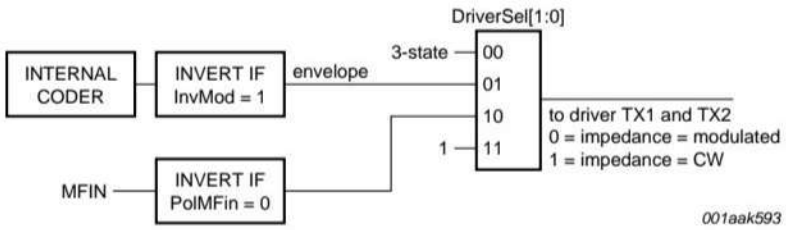

Fig 20. Serial data switch for p-driver TX1 and TX2

8.2.4 MFIN and MFOUT interface support

The MFRC522 is divided into a digital circuit block and an analog circuit block. The digital block contains state machines, encoder and decoder logic and so on. The analog block contains the modulator and antenna drivers, receiver and amplifiers. The interface between these two blocks can be configured so that the interfacing signals can be routed to pins MFIN and MFOUT; see Figure 21 on page 28. This configuration is implemented using TxSelReg register's MFOutSel[3:0] and DriverSel[1:0] bits and RxSelReg register's UARTSel[1:0] bits.

This topology allows some parts of the analog block to be connected to the digital block of another device.

Switch MFOutSel in the TxSelReg register can be used to measure MIFARE and ISO/IEC14443 A related signals. This is especially important during the design-in phase or for test purposes as it enables checking of the transmitted and received data.

The most important use of pins MFIN and MFOUT is found in the active antenna concept. An external active antenna circuit can be connected to the MFRC522's digital block. Switch MFOutSel must be configured so that the internal Miller encoded signal is sent to pin MFOUT (MFOutSel = 100b). UARTSel[1:0] must be configured to receive a Manchester signal with subcarrier from pin MFIN (UARTSel[1:0] = 01).

It is possible to connect a passive antenna to pins TX1, TX2 and RX (using the appropriate filter and matching circuit) and an active antenna to pins MFOUT and MFIN at the same time. In this configuration, two RF circuits can be driven (one after another) by a single host processor.

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Remark: Pins MFIN and MFOUT have a dedicated supply on pin SVDD with the ground on pin PVSS. If pin MFIN is not used it must be connected to either pin SVDD or pin PVSS. If pin SVDD is not used it must be connected to either pin DVDD, pin PVDD or any other voltage supply pin.

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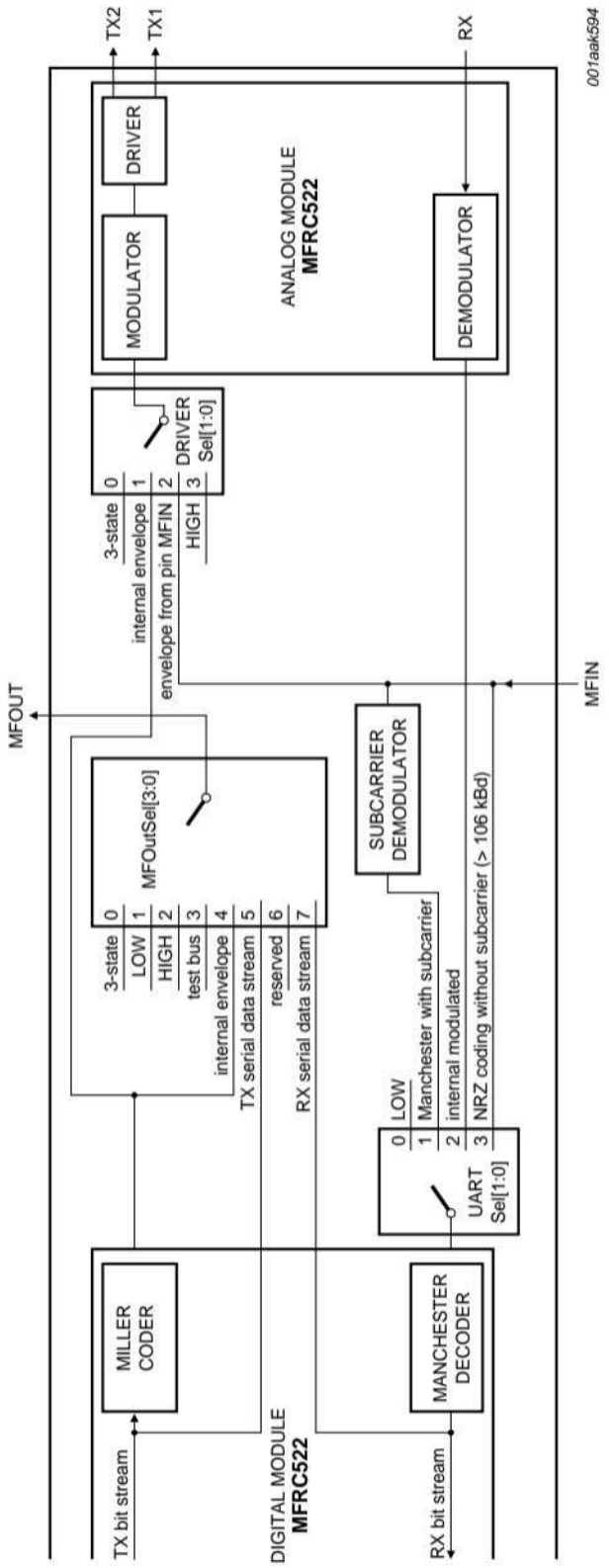

Fig 21. Overview of MFIN and MFOUT signal routing

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8.2.5 CRC coprocessor

The following CRC coprocessor parameters can be configured:

- The CRC preset value can be either 0000h, 6363h, A671h or FFFFh depending on the ModeReg register's CRCPreset[1:0] bits setting
- The CRC polynomial for the 16-bit CRC is fixed to $x^{16} + x^{12} + x^5 + 1$
- The CRCResultReg register indicates the result of the CRC calculation. This register is split into two 8-bit registers representing the higher and lower bytes.
- The ModeReg register's MSBFirst bit indicates that data will be loaded with the MSB first.

Table 17. CRC coprocessor parameters

Parameter	Value
CRC register length	16-bit CRC
CRC algorithm	algorithm according to ISO/IEC 14443 A and ITU-T
CRC preset value	0000h, 6363h, A671h or FFFFh depending on the setting of the ModeReg register's CRCPreset[1:0] bits

8.3 FIFO buffer

An 8 × 64 bit FIFO buffer is used in the MFRC522. It buffers the input and output data stream between the host and the MFRC522's internal state machine. This makes it possible to manage data streams up to 64 bytes long without the need to take timing constraints into account.

8.3.1 Accessing the FIFO buffer

The FIFO buffer input and output data bus is connected to the FIFODataReg register. Writing to this register stores one byte in the FIFO buffer and increments the internal FIFO buffer write pointer. Reading from this register shows the FIFO buffer contents stored in the FIFO buffer read pointer and decrements the FIFO buffer read pointer. The distance between the write and read pointer can be obtained by reading the FIFOLevelReg register.

When the microcontroller starts a command, the MFRC522 can, while the command is in progress, access the FIFO buffer according to that command. Only one FIFO buffer has been implemented which can be used for input and output. The microcontroller must ensure that there are not any unintentional FIFO buffer accesses.

8.3.2 Controlling the FIFO buffer

The FIFO buffer pointers can be reset by setting FIFOLevelReg register's FlushBuffer bit to logic 1. Consequently, the FIFOLevel[6:0] bits are all set to logic 0 and the ErrorReg register's BufferOvfl bit is cleared. The bytes stored in the FIFO buffer are no longer accessible allowing the FIFO buffer to be filled with another 64 bytes.

8.3.3 FIFO buffer status information

The host can get the following FIFO buffer status information:

- Number of bytes stored in the FIFO buffer: FIFOLevelReg register's FIFOLevel[6:0]
- FIFO buffer almost full warning: Status1Reg register's HiAlert bit

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- FIFO buffer almost empty warning: Status1Reg register's LoAlert bit
- FIFO buffer overflow warning: ErrorReg register's BufferOvfl bit. The BufferOvfl bit can only be cleared by setting the FIFOLevelReg register's FlushBuffer bit.

The MFRC522 can generate an interrupt signal when:

- ComIEnReg register's LoAlertIEn bit is set to logic 1. It activates pin IRQ when Status1Reg register's LoAlert bit changes to logic 1.
- ComIEnReg register's HiAlertIEn bit is set to logic 1. It activates pin IRQ when Status1Reg register's HiAlert bit changes to logic 1.

If the maximum number of WaterLevel bytes (as set in the WaterLevelReg register) or less are stored in the FIFO buffer, the HiAlert bit is set to logic 1. It is generated according to Equation 3:

$$HiAlert = (64 - FIFOLength) \leq WaterLevel \quad (3)$$

If the number of WaterLevel bytes (as set in the WaterLevelReg register) or less are stored in the FIFO buffer, the LoAlert bit is set to logic 1. It is generated according to Equation 4:

$$LoAlert = FIFOLength \leq WaterLevel \quad (4)$$

8.4 Interrupt request system

The MFRC522 indicates certain events by setting the Status1Reg register's IRq bit and, if activated, by pin IRQ. The signal on pin IRQ can be used to interrupt the host using its interrupt handling capabilities. This allows the implementation of efficient host software.

8.4.1 Interrupt sources overview

Table 18 shows the available interrupt bits, the corresponding source and the condition for its activation. The ComIrqReg register's TimerIRq interrupt bit indicates an interrupt set by the timer unit which is set when the timer decrements from 1 to 0.

The ComIrqReg register's TxIRq bit indicates that the transmitter has finished. If the state changes from sending data to transmitting the end of the frame pattern, the transmitter unit automatically sets the interrupt bit. The CRC coprocessor sets the DivIrqReg register's CRCIRq bit after processing all the FIFO buffer data which is indicated by CRCReady bit = 1.

The ComIrqReg register's RxIRq bit indicates an interrupt when the end of the received data is detected. The ComIrqReg register's IdleIRq bit is set if a command finishes and the Command[3:0] value in the CommandReg register changes to idle (see Table 149 on page 70).

The ComIrqReg register's HiAlertIRq bit is set to logic 1 when the Status1Reg register's HiAlert bit is set to logic 1 which means that the FIFO buffer has reached the level indicated by the WaterLevel[5:0] bits.

The ComIrqReg register's LoAlertIRq bit is set to logic 1 when the Status1Reg register's LoAlert bit is set to logic 1 which means that the FIFO buffer has reached the level indicated by the WaterLevel[5:0] bits.

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The ComIrqReg register's ErrIRq bit indicates an error detected by the contactless UART during send or receive. This is indicated when any bit is set to logic 1 in register ErrorReg.

Table 18. Interrupt sources

Interrupt flag	Interrupt source	Trigger action
IRq	timer unit	the timer counts from 1 to 0
TxIRq	transmitter	a transmitted data stream ends
CRCIRq	CRC coprocessor	all data from the FIFO buffer has been processed
RxIRq	receiver	a received data stream ends
IdleIRq	ComIrqReg register	command execution finishes
HiAlertIRq	FIFO buffer	the FIFO buffer is almost full
LoAlertIRq	FIFO buffer	the FIFO buffer is almost empty
ErrIRq	contactless UART	an error is detected

8.5 Timer unit

The MFRC522A has a timer unit which the external host can use to manage timing tasks. The timer unit can be used in one of the following timer/counter configurations:

- Timeout counter
- Watchdog counter
- Stop watch
- Programmable one shot
- Periodical trigger

The timer unit can be used to measure the time interval between two events or to indicate that a specific event occurred after a specific time. The timer can be triggered by events explained in the paragraphs below. The timer does not influence any internal events, for example, a time-out during data reception does not automatically influence the reception process. Furthermore, several timer-related bits can be used to generate an interrupt.

The timer has an input clock of 13.56 MHz derived from the 27.12 MHz quartz crystal oscillator. The timer consists of two stages: prescaler and counter.

The prescaler (TPrescaler) is a 12-bit counter. The reload values (TReloadVal_Hi[7:0] and TReloadVal_Lo[7:0]) for TPrescaler can be set between 0 and 4095 in the TModeReg register's TPrescaler_Hi[3:0] bits and TPrescalerReg register's TPrescaler_Lo[7:0] bits.

The reload value for the counter is defined by 16 bits between 0 and 65535 in the TReloadReg register.

The current value of the timer is indicated in the TCounterValReg register.

When the counter reaches 0, an interrupt is automatically generated, indicated by the ComIrqReg register's TimerIRq bit setting. If enabled, this event can be indicated on pin IRQ. The TimerIRq bit can be set and reset by the host. Depending on the configuration, the timer will stop at 0 or restart with the value set in the TReloadReg register.

The timer status is indicated by the Status1Reg register's TRunning bit.

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The timer can be started manually using the ControlReg register's TStartNow bit and stopped using the ControlReg register's TStopNow bit.

The timer can also be activated automatically to meet any dedicated protocol requirements by setting the TModeReg register's TAuto bit to logic 1.

The delay time of a timer stage is set by the reload value + 1. The total delay time (t_{d1}) is calculated using Equation 5:

$$t_{d1} = \frac{(TPrescaler \times 2 + 1) \times (TReloadVal + 1)}{13.56\ MHz} \quad (5)$$

An example of calculating total delay time (t_d) is shown in Equation 6, where the TPrescaler value = 4095 and TReloadVal = 65535:

$$39.59\ s = \frac{(4095 \times 2 + 1) \times (65535 + 1)}{13.56\ MHz} \quad (6)$$

Example: To give a delay time of 25 μs requires 339 clock cycles to be counted and a TPrescaler value of 169. This configures the timer to count up to 65535 time-slots for every 25 μs period.

The MFRC522 version 2.0 offers in addition a second prescaler timer. Due to the fact that the prescaler counts down to 0 the prescaler period always count an odd number of clocks (1, 3, 5, ..). This may lead to inaccuracy. The second available prescaler timer implements the possibility to change the prescaler reload value to odd numbers, which results in an even prescaler period. This new prescaler can be enabled only in version 2.0 using the register bit DemodeReg, see Table 72. Within this option, the total delay time (t_{d2}) is calculated using Equation 5:

$$t_{d2} = \frac{(TPrescaler \times 2 + 2) \times (TReloadVal + 1)}{13.56\ MHz} \quad (7)$$

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8.6 Power reduction modes

8.6.1 Hard power-down

Hard power-down is enabled when pin NRSTPD is LOW. This turns off all internal current sinks including the oscillator. All digital input buffers are separated from the input pins and clamped internally (except pin NRSTPD). The output pins are frozen at either a HIGH or LOW level.

8.6.2 Soft power-down mode

Soft Power-down mode is entered immediately after the CommandReg register's PowerDown bit is set to logic 1. All internal current sinks are switched off, including the oscillator buffer. However, the digital input buffers are not separated from the input pins and keep their functionality. The digital output pins do not change their state.

During soft power-down, all register values, the FIFO buffer content and the configuration keep their current contents.

After setting the PowerDown bit to logic 0, it takes 1024 clocks until the Soft power-down mode is exited indicated by the PowerDown bit. Setting it to logic 0 does not immediately clear it. It is cleared automatically by the MFRC522 when Soft power-down mode is exited.

Remark: If the internal oscillator is used, you must take into account that it is supplied by pin AVDD and it will take a certain time (t_{osc}) until the oscillator is stable and the clock cycles can be detected by the internal logic. It is recommended for the serial UART, to first send the value 55h to the MFRC522. The oscillator must be stable for further access to the registers. To ensure this, perform a read access to address 0 until the MFRC522 answers to the last read command with the register content of address 0. This indicates that the MFRC522 is ready.

8.6.3 Transmitter power-down mode

The Transmitter Power-down mode switches off the internal antenna drivers thereby, turning off the RF field. Transmitter power-down mode is entered by setting either the TxControlReg register's Tx1RFEn bit or Tx2RFEn bit to logic 0.

8.7 Oscillator circuit

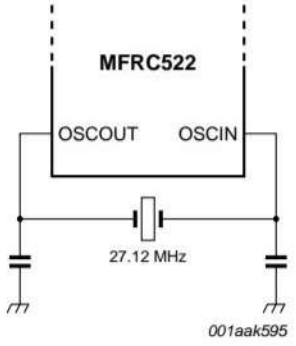

Fig 22. Quartz crystal connection

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The clock applied to the MFRC522 provides a time basis for the synchronous system's encoder and decoder. The stability of the clock frequency, therefore, is an important factor for correct operation. To obtain optimum performance, clock jitter must be reduced as much as possible. This is best achieved using the internal oscillator buffer with the recommended circuitry.

If an external clock source is used, the clock signal must be applied to pin OSCIN. In this case, special care must be taken with the clock duty cycle and clock jitter and the clock quality must be verified.

8.8 Reset and oscillator start-up time

8.8.1 Reset timing requirements

The reset signal is filtered by a hysteresis circuit and a spike filter before it enters the digital circuit. The spike filter rejects signals shorter than 10 ns. In order to perform a reset, the signal must be LOW for at least 100 ns.

8.8.2 Oscillator start-up time

If the MFRC522 has been set to a Power-down mode or is powered by a V_{DDX} supply, the start-up time for the MFRC522 depends on the oscillator used and is shown in Figure 23.

The time ($t_{startup}$) is the start-up time of the crystal oscillator circuit. The crystal oscillator start-up time is defined by the crystal.

The time (t_d) is the internal delay time of the MFRC522 when the clock signal is stable before the MFRC522 can be addressed.

The delay time is calculated by:

$$t_d = \frac{1024}{27\ \mu s} = 37.74\ \mu s \tag{8}$$

The time (t_{osc}) is the sum of t_d and $t_{startup}$.

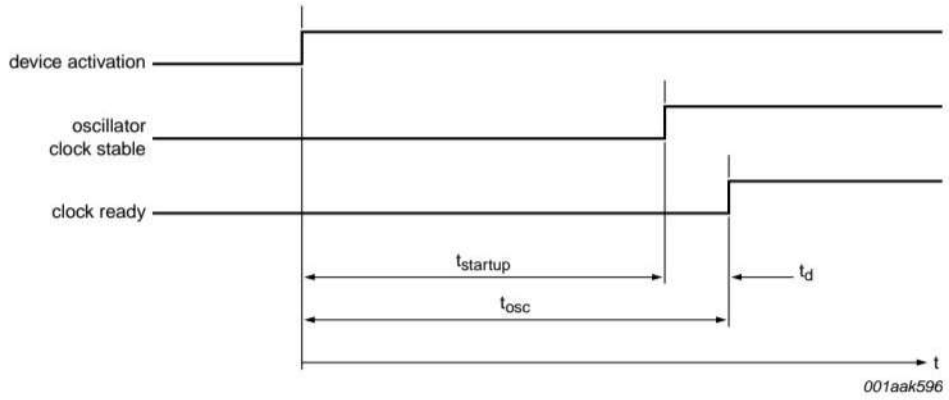

Fig 23. Oscillator start-up time

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