iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VI **Month of publication:** June 2021

DOI: https://doi.org/10.22214/ijraset.2021.35942

Design and Implementation of RFID Controller using Verilog HDL

J. Balakrishna
Department of ECE, CBIT(A), Hyderabad, India

Abstract: Manual monitoring consumes more time, man power and shows inaccurate results. So, automation is the solution to cover the problems stated. Barcode and RFID are two different forms of automated technology that are used for reading and collecting data. The RFID (Radio Frequency Identification) technology is a well-known wireless application for traceability, logistics and access control. The RFID controller is constructed in to demonstrate access control through the use of low-frequency RFID tags. These tags contain identification number which is read by the reader, sent to a database where it is compared with stored values. It works on the principle that If the tag's identification number is in the system database, it gives access. If the data is not in the system database, it doesn't give access. To implement these various blocks, include RFID transmitter, RFID receiver, Baud clock generator, Database are designed. The RFID Controller is designed using Verilog HDL in Xilinx ISE tool.

I. INTRODUCTION

RFID stands for Radio Frequency Identification [1]. RFID is a remote sensing and control technology that can be used to identify and track people or objects. Applications of this technology include Industrial, Automotive, Aviation, Defence and in many other applications.

RFID system consists of a Tag and a Reader. The RFID tag contains a memory chip with a unique ID. The RFID tag reader consists of a transceiver, decoder and an antenna to receive data from the Tag. The reader transmits a continuous interrogation electromagnetic signal which is received by a tag when it is within range. Upon receiving and decoding this signal, the tag sends the reader its identification data, which is typically a stream of bits.

Today, transportation has an important role in our society. However, as we notice, the human population is growing bigger along with vehicles are also growing in number. Monitoring today is becoming a big challenge for everyone in securing their own properties.

In many areas that vehicle passes, there are problems encountered when it comes to security. A lot of vehicles that enter and exits in one place to another is one of the realistic circumstances. It has been raised that there is a difficulty in managing the entrance and exits of the vehicles manually.

RFID tags[3] containing 96-bit to 128-bit Electronic Product Codes (EPCs) are attached to products or devices. The tags, which can be battery-powered active tags or battery-less passive tags, can be read automatically by RFID tag readers, which can send the scanned tag information to a host computer system for processing and storage.

II. LITERATURE REVIEW

A. Edward B. Panganiban, Jennifer C. Dela Cruz, "RFID –Based Vehicle Monitoring System", 978-1-5386-0912-5/17 ©2017 IEEE [1]. In this paper author clearly explained about the operation of RFID-based Vehicle monitoring system. It collects, records, maintains, and saves data detected from the vehicles running in road, passing through road gates, monitoring vehicle status, and entering/leaving an area using RFID Tags as well as gathering and sending Tag ID information into a base station.

B. Suresh Chalasani and Rajendra V. Boppana, "Data Architectures for RFID Transactions", IEEE transactions on industrial informatics, Vol. 3, No. 3, August 2007[2]. In this paper the author clearly explained about the data models for storing the data generated by radio frequency identification (RFID) transactions and architectures for processing such data. Different events that produce RFID transactions in the supply chain are presented and data models to store the data generated by these transactions are discussed.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VI June 2021- Available at www.ijraset.com

III. FEATURES OF RFID TECHNOLOGY

1) *RFID Tag:* RFID technology uses digital data in an RFID tag, which is made up of integrated circuits containing a silicon microchip attached to a small antenna and mounted on a substrate and encapsulated in different materials like plastic or glass veil and with an adhesive on the back side to be attached to objects.

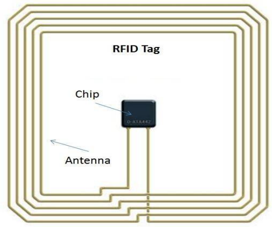

Fig 3.1: RFID Tag

2) *Choice of RFID Tags:* The tags are selected depending on the following factors:
a) Surface of Tag.
b) Read range.
c) Size limitation.
d) Environmental Conditions (Hot or Cold).
e) Method of attachment (Adhesive, Epoxy, Rivets and Screws).

3) *RFID Tags Frequency Range:* Based on the frequency range, the distance covered by the tags is dependent and usage in various applications[6]. RFID tags generally operate at three distinct frequencies:

Table-3.1: RFID Tags Frequency of operation

	Frequency Range	Distance covered	Applications
Low Frequency (LF)	125-135 KHz	10 cm	Animal tracking
High Frequency (HF)	13.56 MHz	30 cm	NFC in mobile communication
Ultra High Frequency (UHF)	856-960 MHz	12-15 meters	Defense applications

4) *Types of RFID Tags:* Generally the RFID Tags are divided into two major types; Active and Passive RFID Tags.
5) Passive *RFID Tag:* Passive RFID tags have no internal power supply. A small electric current is created in the antenna when an incoming signal reaches it. This current provides enough power to briefly activate the tag, usually just long enough to relay simple information, such as an ID number or product name. Because passive RFID tags do not contain a power supply, they can be very small in size, sometimes thinner than a piece of paper. These tags can be activated from a distance of ten millimeters to over 3 meters away. 128 bytes small read/write data.

Advantages
- Longer lasting, tag life doesn't depend on battery.
- Tags are inexpensive.
- Tags are more resistant to physical damage or harsh environments.

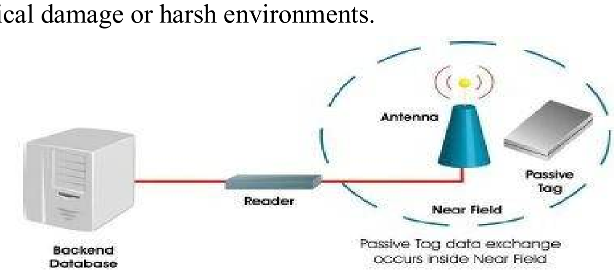

Fig 3.2: RFID Passive Tag

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6) *Active RFID Tag:* Active RFID tags do contain an internal power source, which allows for a longer read-range and for a bigger memory on the tag itself. The power source also makes it possible to store information sent by the transceiver. Active RFID tags are larger than passive tags, usually slightly bigger than a coin. They can be read from many meters away, and generally have a battery life of about ten years.

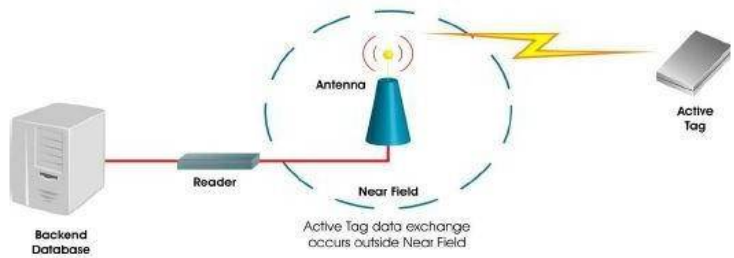

Fig 3.3: RFID Active Tag

Table-3.2: Comparison of different RFID Tags

Type of Tag	EPC Class	Memory type	Radio Frequency used	Bits	Power source	Reading distance(meters)
RFID Passive	0	ROM	138 KHZ-13.95MHZ	64	Reader EMF	0.04-3
RFID Active	4	ROM	13.85MHZ	64	Battery	3-10
RFID Passive Programmable	1	EEPROM	138KHZ-13.95MHZ	96,128	Reader	0.04-3
RFID Active Programmable	2,3,4	EEPROM	138KHZ	>128	Battery	3-10
Data Tag	2,3,4	CMOS RAM	13.85 MHZ-965 MHZ(UHF)	>128	Battery	3-10

7) *Types of Memories in RFID Tag*
a) *Reserved Memory:* It is used to store password when tags are encrypted. It has some instructions like ACCESS or KILL. If KILL command executes then the tag disables permanently. ACCESS command is to lock or unlock the tags read/write capability. Most users don't use this unless their applications contain sensitive data.
b) *EPC Memory:* It stores EPC (Electronic Product Coode) code of 96 to 128 bits wide.
c) *TID Memory:* It is used for storing the unique ID of the chip comes from the manufacturer.
d) *User Memory:* If the user needs extra memory other than EPC memory then extended user memory of 512 bits can be used.

8) *RFID Reader:* A RFID system cannot be imagined without the presence of a RFID reader to perform the interrogation and in some cases the power supply of RFID tags. Radio Frequency Identification reader (RFID reader) is a device used to gather information from an RFID tag, which is used to track individual objects[4]. Radio waves are used to transfer data from the tag to a reader. It consists of a scanner with antennas to transmit and receive signals and is responsible for communication with the tag and receives the information from the tag. RFID readers are consisted of three main parts that allow them to function in RF and digital systems.

These main three components are:
- Control section
- High frequency interface
- Antenna.

a) *Control Section:* The control section of the RFID reader is used to perform digital signal processing techniques over the received data from the RFID tags. This section is usually consists of a microprocessor, memory block, analog-to-digital converters and communication block for the software application.

b) *High Frequency Interface:* The high frequency interface of the reader is used to enable RF signal transmission and receiving. The HF interface is one of the most complex sections of the reader for design. Different demodulation techniques are used when decoding the data received from the tags. Most RFID systems operate using BPSK and ASK.

c) *Antenna:* The reader antenna (or aerial) is an electrical device which converts electric power into radio waves, and vice versa. It is used for communication between reader and tags. Antenna determines the reader's interrogation range and the interrogation zone. Depending on the RFID system's application the RFID reader can be designed in different ways where the antenna's resonating frequency, gain, directivity and radiation pattern can vary. Spatial filtering using adaptive smart antennas are a promising technique for implementing into RFID readers

d) *Database:* The database module converts data from the receiver from byte-serial to parallel. Database module is to look up the ID number in a memory to see if the ID number corresponds to a trusted user or not.

9) *Working of RFID System:* In RFID system,

a) When RFID tag comes near the RFID reader module it will reads the information from the RFID tag.

b) Sends the Data in the serial format by using UART communication protocol.

c) UART receiver reads the data in serial form sends Byte format to the FIFO.

d) FIFO means First In First Out[5].

e) After writing data into the FIFO data will be read by using read controller module.

f) UART transmitter module sends the data in the serial form.

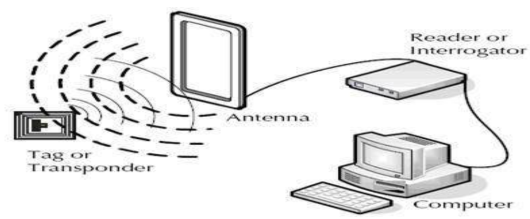

Fig 3.4: Working of RFID System

10) *Communication Protocol:* The singe RFID chip offers either UART or SPI or I2C communication, through which we can connect sensors.

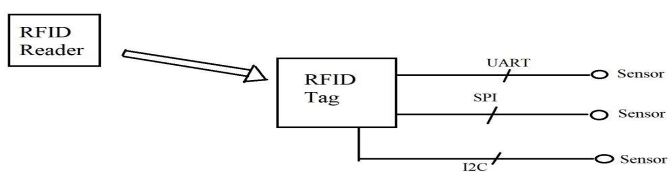

Fig 3.5: Interfacing RFID and communication protocols

11) *UART:* In this paper we use UART serial communication protocol. UART stands for Universal Asynchronous Receiver and Transmitter. In UART communication, two devices communicate directly with each other. The transmitting device converts parallel data from a controlling device like a CPU into serial form, transmits it in serial to the receiving device, which then converts the serial data back into parallel data for the receiving device. Data flows from the Tx pin of the transmitting device to the Rx pin of the receiving device.

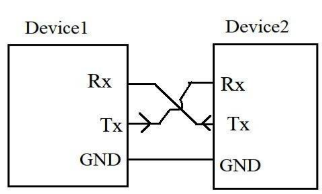

Fig 3.6: UART

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For Asynchronous mode, this protocol makes use of only two wires i.e. Rx and TX. Since no clock is needed here, both the devices have to make use of their independent internal clocks to work. Yet there is a term called baud rate which helps these devices to remain in sync by fixing the speed of data exchange. Baud rate refers to the number of data bits transmitted per second, so both devices should work on same baud rate in order to maintain its proper functioning.

IV. DESIGN METHODOLOGY

1) *Design of RFID Controller:* To design RFID controller the main blocks include Baud clock Generator, First In First Out (FIFO), Receiver, Transmitter and integrate all the blocks.

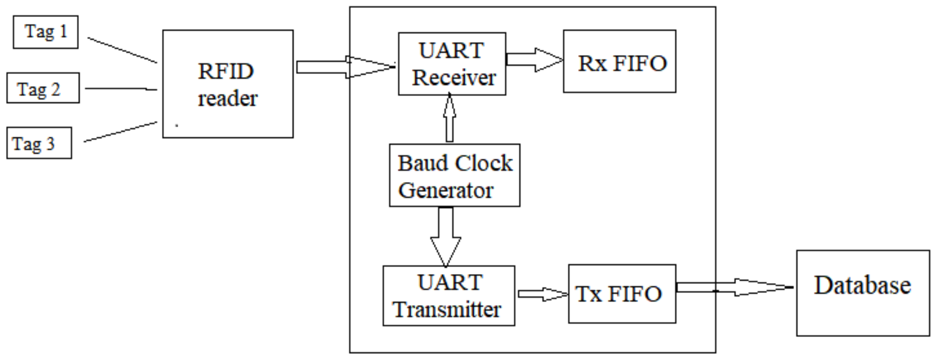

Fig: 4.1 Block diagram of RFID Controller

The tag consists of digital code. When the tag comes into the range of the RFID reader, it retrieves the digital code present in the RFID tag. UART acts as a communication medium between RFID reader and Database.
UART receiver receives the digital code single bit by bit and it is stored in receiver First In First Out (FIFO), after receiving the whole byte of digital code into the FIFO, the UART transmitter transmits the code into database. Baud clock generator is used to maintain synchronization between the transmitter and receiver.

2) *Baud Clock Generator:* Number of signal changes per one second is called Baud rate. Baud rate and Bit rate are not always same. If one bit equal to one symbol then Baud rate is equal to bit rate. Baud Rate Generator defines the clock used for transmitting and receiving data via the UART. Unlike the timer clock, which can be pre-scaled in some rough steps, the UART clock can be divided very precisely, resulting in clean and (to some extent) error-free data transfer. The Fig.4.2 shows the block diagram of baud clock generator. In this paper we assumed eight bits as one symbol, so we choose a counter by taking count value as eight. After every eight counts the baud clock changes level, so the baud rate is divided by 8 before it is fed into the Rx/Tx Shift registers. There's no need to sample data for the Tx/Rx shift register, it is directly clocked by the baud rate. The UART Baud Rate Register (UBRR) is used to set the clock for the UART shift registers. UART Data Register (UDR) is used as buffer in receive direction, so that a completely received byte can be read while the next one is being shifted in.

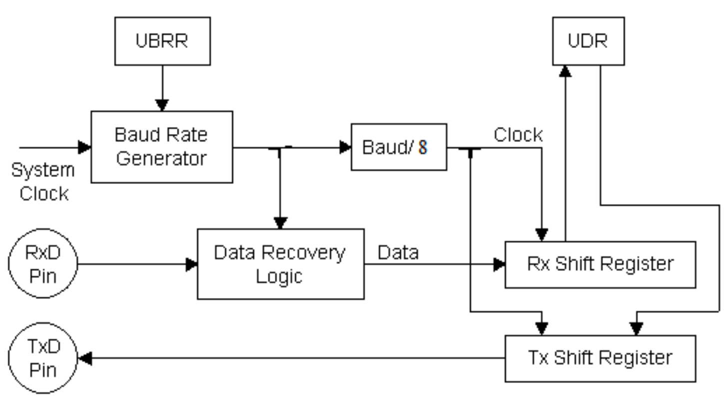

Fig.4.2: Block diagram of Baud clock generator

3) *First In First Out:* First In First Out (FIFO) is used as a buffer between the tag and reader or between the reader and user. It can also be used as a data base for storing the digital code present in the RFID tag. Read or Write operations are done in FIFO. First In First Out (FIFO) is a queue mechanism of first come first served. If FIFO is full then Data is read from FIFO or if FIFO is empty the data is written into the FIFO.

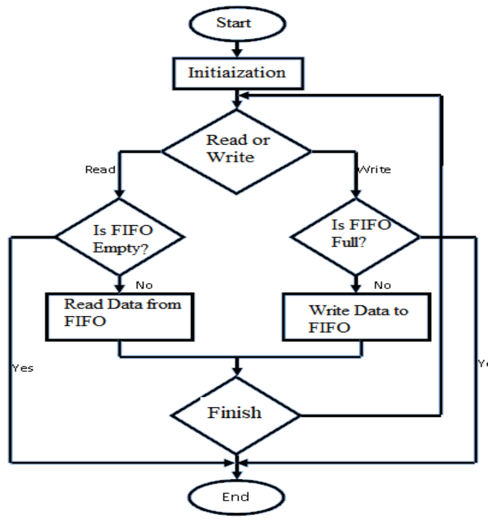

Fig.4.3 Block diagram of First In First Out

The transmitting and receiving process takes place based on the FIFO status whether it is full or empty. Once the FIFO is full the transmission of digital code is taken place.

4) *RFID Receiver:* RFID receiver module receives data in the serial form and output in parallel form, the received data is transferred to the receive FIFO buffer, if it is empty. In this module, we use simple shift registers for getting parallel data. Data was taken at the middle of samples in the data frame. This module is active when serial data is the active low position.
5) *RFID Transmitter:* RFID Transmitter module works same as the shift register. RFID transmitter module design follows same as the RFID receiver module. The transmitter has its own FIFO which is used to transmit the whole digital code to database. In database the received digital unique code is compared with the existing storage of the digital codes.

A. RTL Schematic Of RFID System

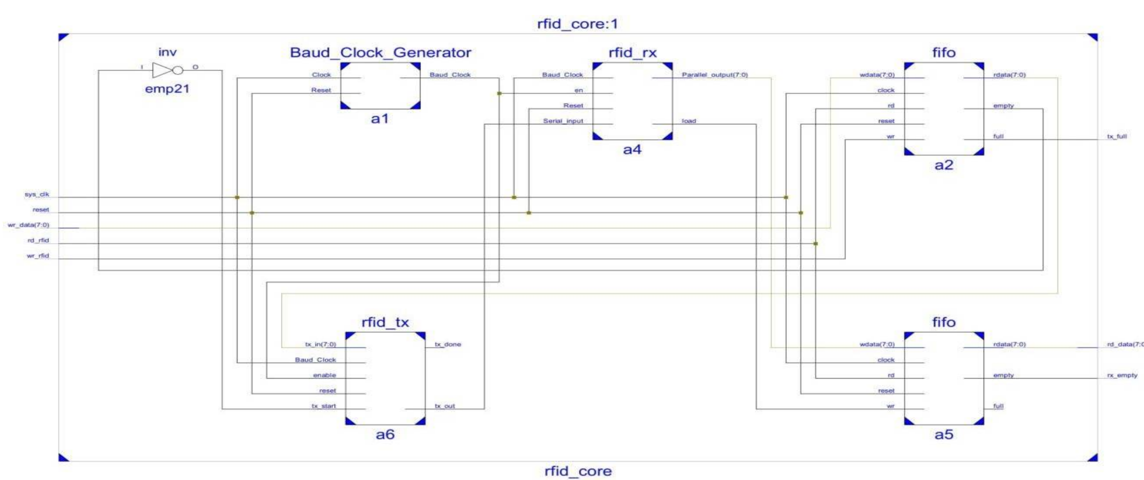

Fig.4.4 RTL Schematic of RFID System

The above figure shows the RTL Schematic of the RFID System consists of Baud clock generator, RFID Receiver, RFID Transmitter, FIFO and integrated all the blocks to form RFID controller.

V. SIMULATION RESULTS

The RFID UID (Unique ID) is read by the reader as shown in the Fig.4.5.

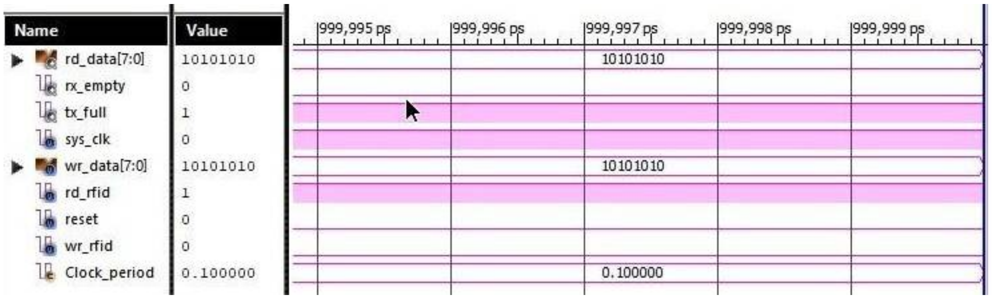

Fig.4.5 Data Read From RFID Tag

The UID is given as input to the RFID controller through test bench in the program as wr_data. The controller reads the data send by the input as rd_data. The reading operations starts once the transmitter FIFO is full.

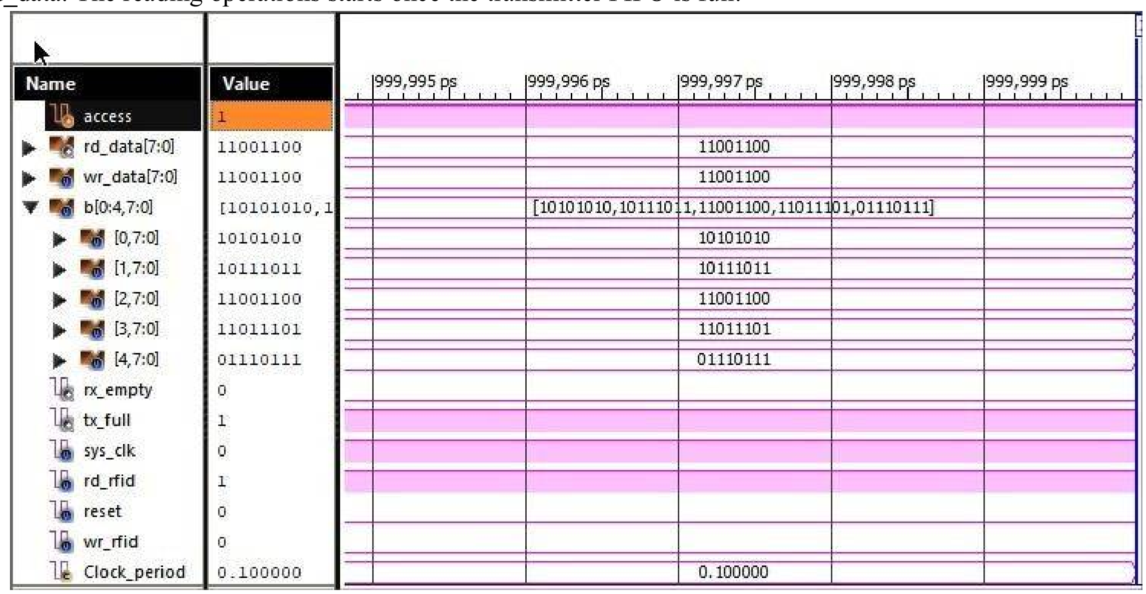

Fig.4.6 Access for Valid ID

The simulation result of Valid ID is shown in Fig.4.6. The Database of Valid RFID Tag ID is developed. The comparison of the RFID tag ID and Tag ID present in the database. If ID present in the database then the controller validate as a Valid ID and it gives access.

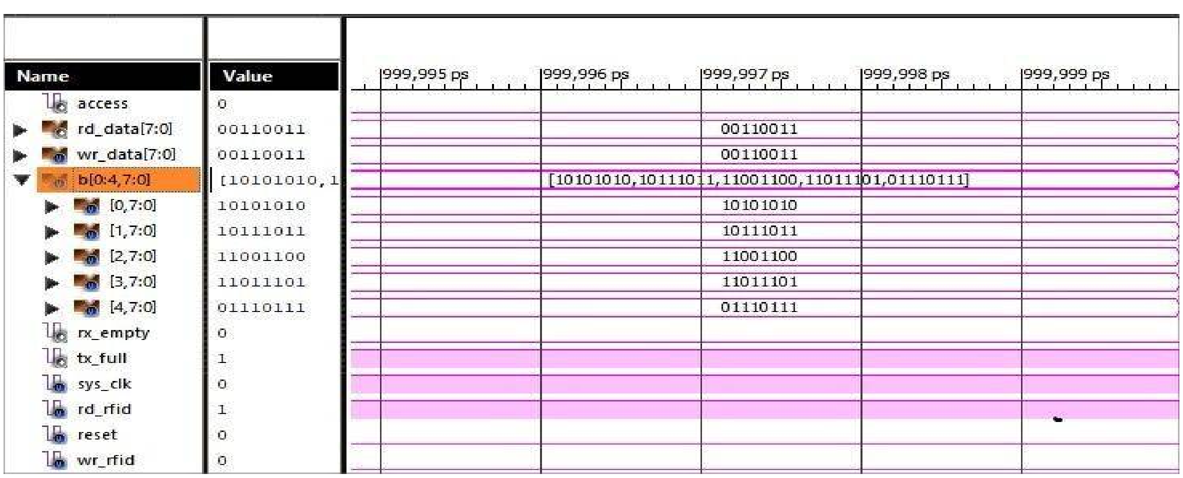

Fig.4.7 No Access for Invalid ID

The simulation result of Invalid ID is shown in Fig.4.7. If the Unique ID is not present in database then it is considered as the Invalid ID and it doesn't give access to it. In the above simulation the input is not present in the database then it doesn't give access to it.

Table.4.1: Simulation Results of the design

Device Utilization Summary (estimated values)			[-]
Logic Utilization	**Used**	**Available**	**Utilization**
Number of Slice Registers	52	4800	1%
Number of Slice LUTs	53	2400	2%
Number of fully used LUT-FF pairs	34	71	47%
Number of bonded IOBs	22	102	21%
Number of BUFG/BUFGCTRL/BUFHCEs	2	16	12%

The utilization of various registers, Look Up Tables (LUT's), IO pins by the RFID controller program is shown in the above table.

Table.4.2: Simulation Results without FIFO.

Device Utilization Summary (estimated values)			[-]
Logic Utilization	**Used**	**Available**	**Utilization**
Number of Slice Registers	20	54576	0%
Number of Slice LUTs	24	27288	0%
Number of fully used LUT-FF pairs	12	32	37%
Number of bonded IOBs	18	218	8%
Number of BUFG/BUFGCTRL/BUFHCEs	2	16	12%

The above table shows the simulation results of the design without FIFO. The FIFO is needed to maintain the database of valid ID arrival timings. If we remove the FIFO the consumption gets reduced and speed improves.

VI. CONCLUSIONS

1) *Conclusion:* RFID Controller is designed by integrating the blocks like RFID transmitter, RFID receiver, Baud clock generator, FIFO. RFID tags data is stored by using FIFO. This provides a database for all Unique ID's. RFID Controller is designed with and without FIFO and compared the parameters affected. This paper differentiates the valid and invalid RFID tags by comparing the Unique Identification number associated with each tag and the UID's present in the database.
2) *Future Scope:* Design of the tag typical RFID system in FPGA improves various parameters of the overall system like performance, power optimization and security. Various protocol was developed and security issue was also be added with the protocol. Various cryptographic techniques will be developed which provides security to the communication between the tag and the reader.

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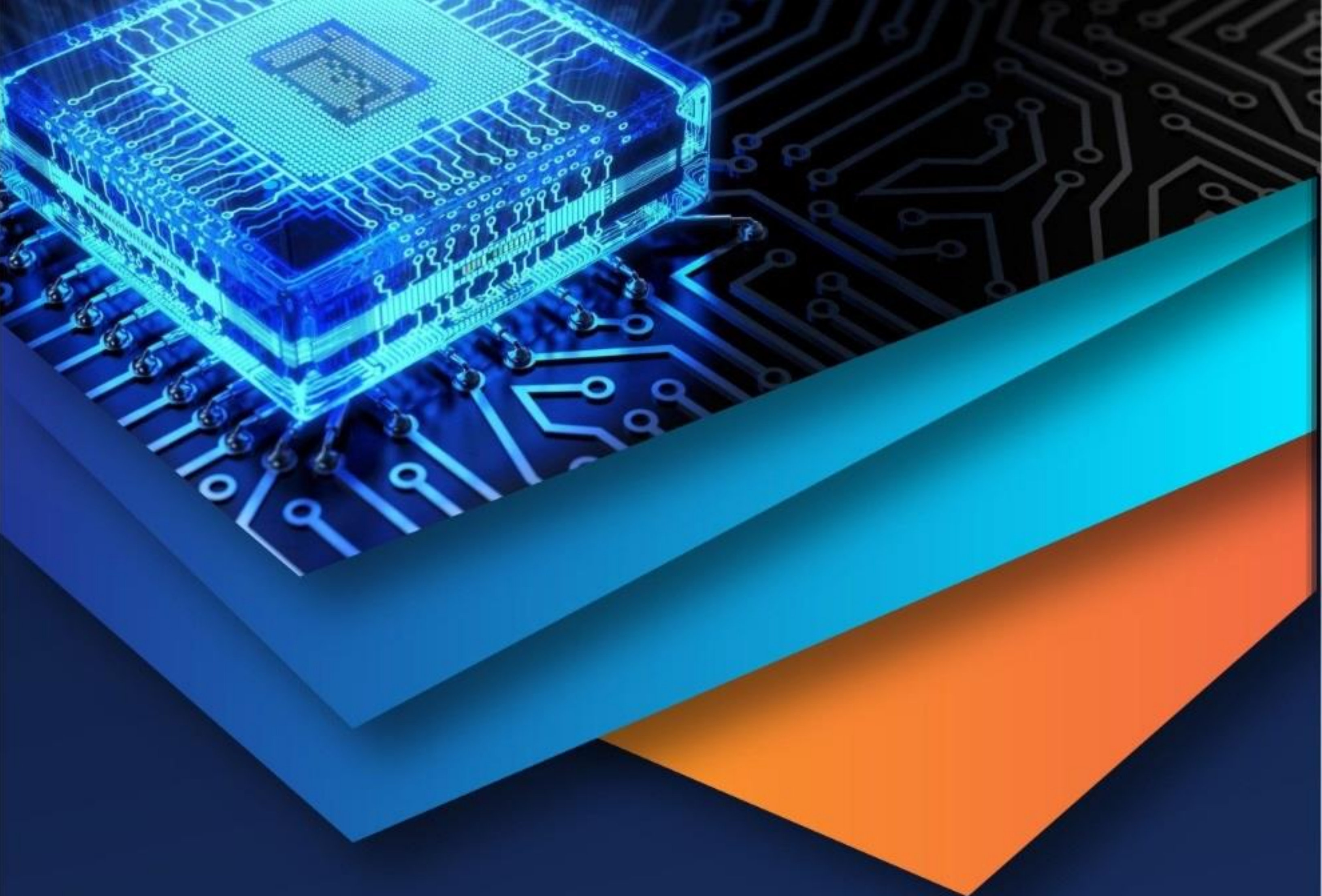

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