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Design and Development of Bluetooth Base Home Automation System using FPGA

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Key words: Bluetooth HC-05, FPGA, relay, UART receiver, VHDL

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Abstract: Wireless technology is one of the most widely used in Internet of Things (IOT). Wireless system can be use in different ways, i.e., voice communication, remote control, etc. However application with IOT can easily control using mobile app. Bluetooth module can exchanged data wirelessly and control many devices. In this study, Bluetooth module HC05 is used to control home appliances from the smart phone application 'Arduino Bluetooth control app'. Data from the mobile app is passed through Bluetooth HC05. HC05 send data to FPGA board by using UART receiver. UART receiver is designed using VHDL. Relay acts as a switch and it is interfaced with FPGA board to control the home appliances. And the simulation is done on the Artix-7 series FPGA board Target device (XC7A35TCPG236-1) (speed grade-1) using Vivado 2015.2. Also, synthesis results are compared with existing IOT based Home Automation System using FPGA. Using this wireless technology, we can control or convert many home appliances into home automation efficiently. Purposed home automation can be used in short range applications.

INTRODUCTION

Nowadays Home Automation is one of the most popularly trend in this world to control lightning, heating, remote control, voice communication, password lock system etc.[1]. Home Automation can be done in two ways that is wire communication and wireless communication[2]. Wire communication can be done in Home Automation, however, wireless is more convenient to use while operating the system and make us easier to use them. In order to communicate wirelessly Bluetooth Module, WiFi module, etc. are used. Bluetooth is widely used for only short range communication[2]. For long range communication-WiFi module or GSM module can be used, however, they are very costly in the market while comparing with Bluetooth module. Bluetooth is interfaced with FPGA board to design a wireless communication[3]. FPGA offers high processing power and speed, this give better response times and give overall improved performance as compare to other modern microprocessor.

Most of the people use mobile phone and aware about many application in the mobile phone. Using an application to control the home appliances would be very comfortable while using it. This will reduce the risk of shock from the electric that is even a child can operate easily without risk. So, in every field we need to reduce risk and need to improve the easiest and comfortable way while using it.

Literature review: Many author have design different model for wireless transmission in home automation.

Chandrasiri *et al*.[1] design a model using Bluetooth module, DE2-70 FPGA board, mobile app. to control home appliances. Bhoite and Mali[3] design using Bluetooth, spartan 6 LX9 FPGA board and mobile app to switch a LED. Abdul *et al*.[2] design a model using WiFi module, FPGA board and android application to control home appliances. Jothibasu *et al*.[4] design model using Arduino, LCD Display, 5 V Relay Module, Infrared Sensors to monitor the room and count the visitors. Gaurav Waradkar, Hitest Ramina, Vinaj Maitry, Tejasvi Ansurkar, Prof. Mrs. Asha Rawat and Prof. Mr. Parth Das design a model using Two IR sensor, AT89S52 micro-controller and power supply to controlled room light as well as count the number of person entering the room.

MATERIALS AND METHODS

Proposed design for implementing home automation system: The main aim is to design a model of home automation which is controlled from mobile application with low power consumption, low cost and to operate in real time.

Figure 1 is the block diagram for Designing Bluetooth base Home automation system. In this block diagram, transmitter section will transmit the instruction and the receiver section will received the transmitted instruction. Receiver section include Bluetooth and FPGA board and the power of the Bluetooth is given from the Arduino and output from FPGA is connected to the input of relay and the switching of LED bulb is done from relay.

Hardware details

Basys 3 FPGA: Figure 2 represents basys 3 FPGA board diagram.The Basys 3 board can be described as a complete, ready-to-use digital signal development program based on the newest Artix-7 Field Programmable Array (FPGA) from Xilinx. With its high-capacity FPGA (Xilinx part number XC7A35TCPG236-1) (speed grade-1) has low overall expense and number of USB, VIDEO GRAPHICS ARRAY and can easily host models ranging from initial combinational circuit lines to intricate sequential circuit lines like set processors and controllers. It provides enough links, LEDs and also other I/O units to allow numerous designs being completed with no need for any further hardware and enough uncommitted FPGA I/O pins to let designs for being expanded employing Diligent Pmods or various other custom panels and circuit lines[5]. Basys 3 component descriptions are shown in Table 1.

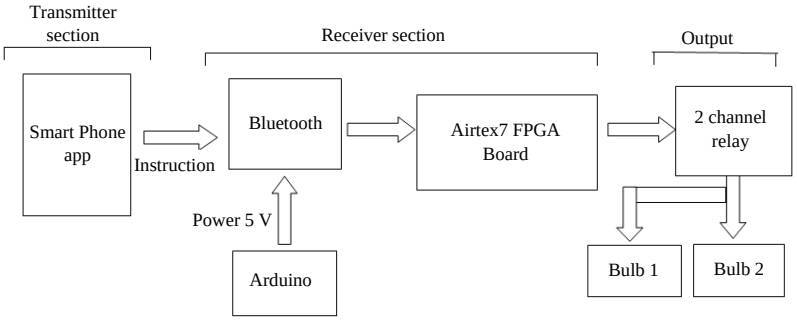

Fig. 1: Block diagram for Designing Bluetooth Base Home Automation system

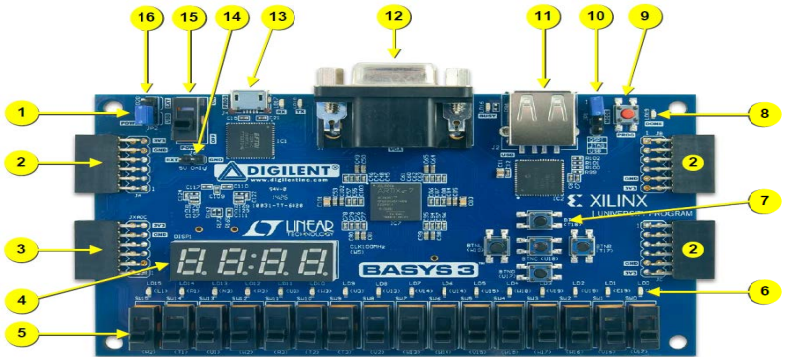

Fig. 2: Basys 3 FPGA board with callouts

Table 1: Basys 3 component descriptions

Callout	Component description	Callout	Component Description
1	Power good LED	9	FPGA configuration reset button
2	PMOD port(s)	10	Programming mode jumper
3	Analog signal Pmod port (XADC)	11	USB host connector
4	Four digit 7-segment display	12	VGA connector
5	Slide switches (16)	13	Shared UART/ JTAG USB port
6	LEDs (16)	14	External power connector
7	Pushbuttons (5)	15	Power Switch
8	FPGA programming done LED	16	Power Select Jumper

Table 2: Pin Description of HC05

Pin	Description
Key (EN)	It is used to bring Bluetooth module in AT commands mode which are used to change setting of HC05
VCC	Connect 5V to this Pin
GND	Ground Pin of module
TXD	Transmit Serial data (wirelessly received data by Bluetooth module transmitted out serially on TXD pin)
RXD	Received data serially (received data will be transmitted wirelessly by Bluetooth module)
State	It tells whether module is connected or not

Bluetooth module HC05: A diagram of Bluetooth module HC-05 is shown in Fig. 3. Bluetooth module HC05 is designed for wireless communication. It can be used in master or slave configuration. It has short range up to <100m which depend on the transmitter and receives. It uses serial communication to communicate with device with microcontroller using serial port[6]. Pin descriptions of HC-05 are shown in Table 2.

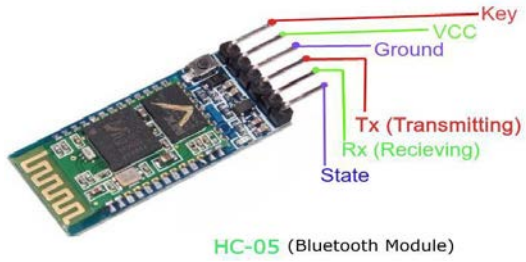

Fig. 3: Diagram of Bluetooth module HC05

Relay: Figure 4 represents 4 channel relay diagram. A relay is a device which is used as an electrically operated switch. Relay can be operated by using electromagnet or solid state relay however most of the relay that found in the market is using electromagnet. Relay used to control many circuit by a separate low power signal or by one signal.

A type of relay that can be handle the high power required to directly control an electric, motor or other load is called a contractor. In solid state relay power circuitis controlled by using a semiconductor device to perform switching. In old relay , multiple operating coils are used to protect a electrical circuit from overload however in modern relay all these function are performed by digital Instrument called Protective relay.

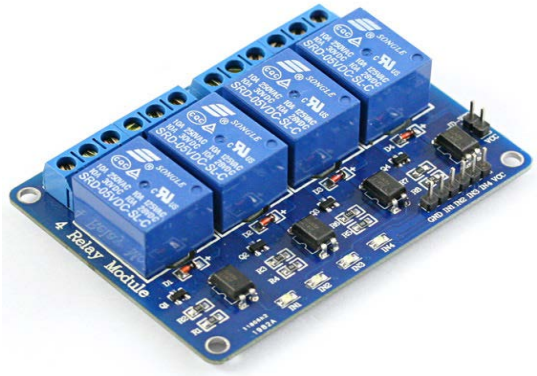

Fig. 4: Channel relay

Arduino: A diagram of an Arudino board is shown in Fig. 5. It is a platform of open source to link computer hardware and software project. It has single board micro-controller and its kits. Its board are design a variety of microprocessor and controllers. This board consist sets of digital and analogue input and output pin they may be interface to various expansion boards or other circuit. It has 14 digital input output pin (of which 6 can be used as pulse wide modulation “PWM” output, another 6 is used as analogue input). Table 3 represents Pin description of an Arduino uno board.

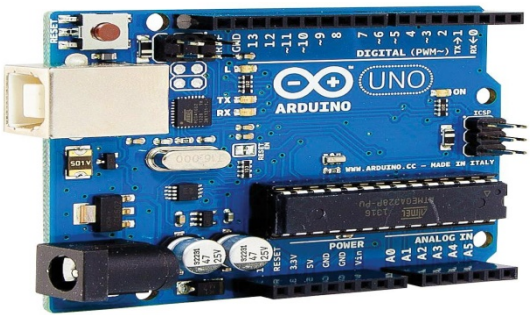

Fig. 5: Arduino board

Table 3: Pin description of Arduino UNO

Pin	Pin name	Description
Power	Vin, 3.3V,5V,GND	Vin: Input voltage to android when using an external power source 5V: Regulated power supply used to power micro-controller and other components on the board 3.3 V:- 3.3 V supply generated by on board voltage regulator. Maximum current draws is 50 mA GND: Ground pin
Reset	Reset	Reset the micro-controller
Analog Pin	A0-A5	Used to provide analog input in the range of 0-5V
Input/output pin	Digital pin 0-13	Used to provide analog input in the range of 0-5V
Inbuilt LED	13	To turn on the inbuilt LED
Serial	0 (Rx), 1(Tx)	Used to receive and transmit TTL Serial data.
External Interrupt	2, 3	To trigger an interrupt
PWM	3, 5, 6, 9, 11	Provide 8-bit PWM
SPI	10 (SS), 11 (MISO) and 13(SCK)	Used for TWI communication
AREF	AREF	To provide the reference voltage for input voltage

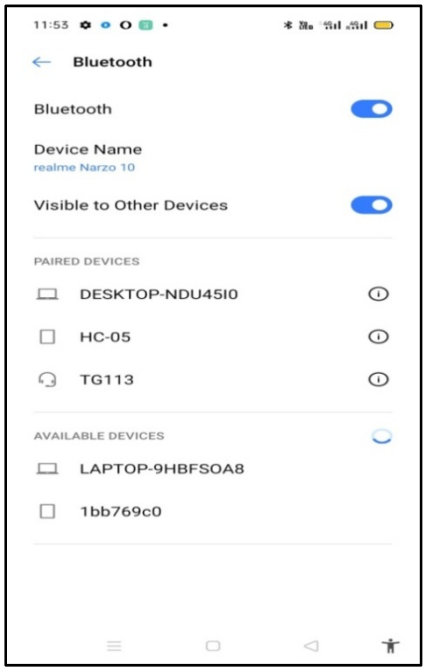

Fig. 6: Bluetooth device HC05 search from mobile phone

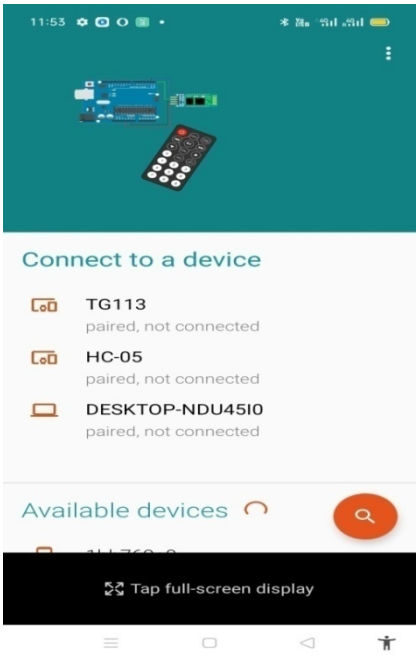

Fig. 7: Bluetooth HC05 connected from Arduino Bluetooth controller app

Implementation: Bluetooth HC05 is checked whether it is in master or slave mode. By default HC05 is in slave mode however we need to check by using AT command in Arduino.

AT+ROLE=? //This will check whether HC05 is in slave or master mode. When we pass this command if the output is 0 then HCO5 is in Slave mode otherwise it is in Master Mode. AT+UART=9600,0,0 // this will set the baud rate of the HC05 module. AT+NAME=HC05//this will set the name of the Bluetooth.

For this project, we have used HC05module in slave mode. Supply Voltage (VCC) required for HC05 is 5V and it is taken from Arduino. As soon as the power is given, LED of HC05 will blink, this indicate that it is in pairing mode that means it is ready to pair with other device, i.e., Arduino Bluetooth control device. And the password of HC05 for pairing is "1234"[3, 6]. In order to pair with Arduino Bluetooth control app, name of the Bluetooth HC05 is search from the mobile phone Bluetooth setting and connected and also paired from the Arduino Bluetooth control app which are shown in Fig. 6 and 7. After paired, LED of HC05 will blink for every 2s, this indicates that the Bluetooth is paired successfully with Arduino Bluetooth control app

After that HC05 is serially connected with Airtex7 FPGA board. UART receiver is designed using VHDL code to switch Bulb 1 and 2. Tx and Rx of HC05 is connected to JB pin A14 and JB pin A16 of FPGA board, respectively. PMODE front view of JB port is shown in Fig. 8. And all the PMODE of FPGA are shown in

Table 4: Basys 3 PMOD pin assignment

PMOD JA	PMOD JB	PMOD JC	PMOD XDAC
JA1: J1	JB1: A14	JC1: K17	JXADC1: J3
JA2: L2	JB2: A16	JC2: M18	JXADC2: L3
JA3: J2	JB3: B15	JC3: N17	JXADC3: M2
JA4: G2	JB4: B16	JC4: P18	JXADC4: N2
JA7: H1	JB7: A15	JC7: L17	JXADC7: K3
JA8: K2	JB8: A17	JC8: M19	JXADC8: M3
JA9: H2	JB9: C15	JC9: P17	JXADC9: M1
JA10: G3	JB10: C16	JC10: R18	JXADC10: N1

Table 5: FPGA Pin description for connecting Bluetooth module HC-05 and 4 Channel Relay to FPGA board

Pin	Details	Input/output	Bluetooth HC-05 Pin	4 channel relay Pin
W5	System clock	Input		
A16	UART transmitter output	Output	Rx	
A14	UART receiver input	Input	Tx	
B15	Relay input 1	Output		In1
B16	Relay input 2	Output		In2

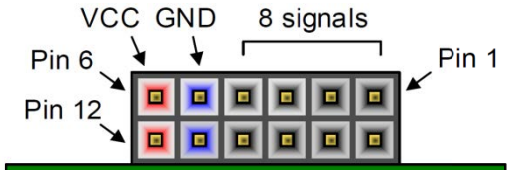

Fig. 8: PMOD ports; front view

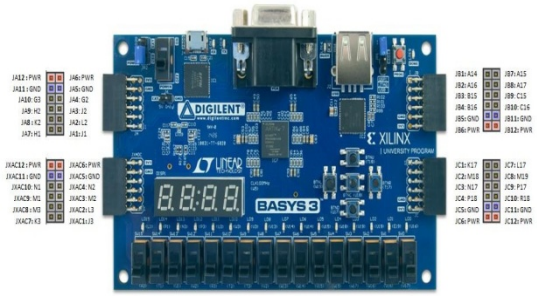

Fig. 9: Basys 3 PMOD Pin-out diagram

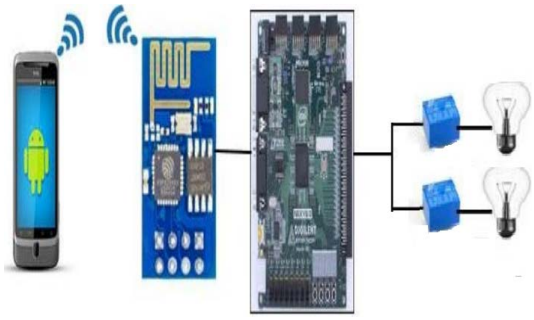

Fig. 10: Block diagram for the purposed design

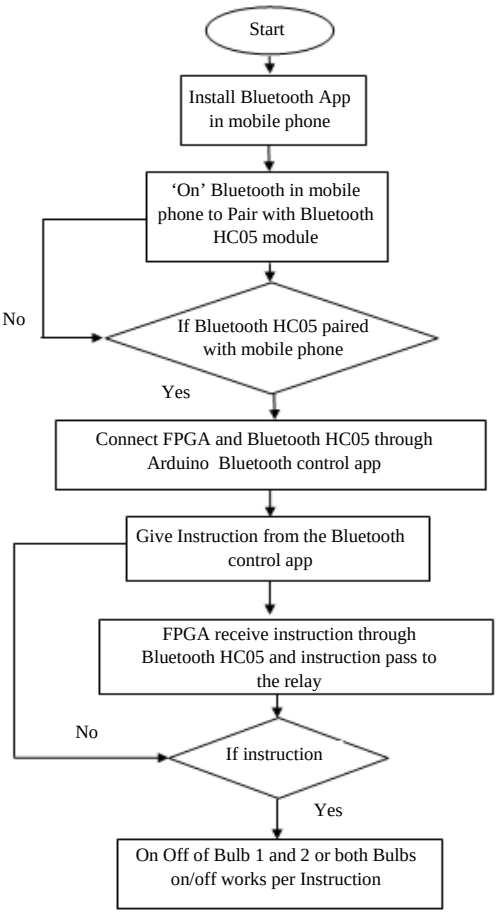

Fig. 11: Flow chart of the proposed design

Table 4 and Fig. 9. Output is taken from pin mode 3 and this output is connected to the input of 4 channel relay however only two channel is used. Bulb 1 and 2 are connected to the K1 and K2 of relay. Supply voltage for relay is taken form Arduino board. The output from the FPGA board is 3.3 V which will control 220 V of the BULBS and this relay will act as a switch. Block diagram and flow chart of the implementation is also given in Fig. 10 and 11, respectively. And the complete experimental set-up diagram is shown in Fig. 12. Table 5 represents FPGA pin details for connecting Bluetooth module HC-05 and 4 Channel Relay to Artix7 FPGA board.

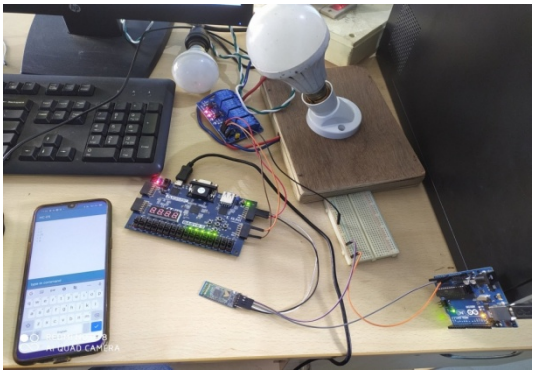

Fig. 12: Complete experimental set-up diagram for the proposed design

Fig. 13: Diagram for passing "1" from Arduino Bluetooth control app to the FPGA board

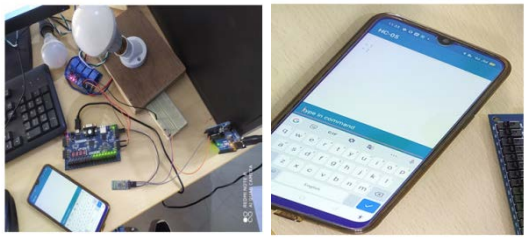

Fig. 14: Diagram for passing "2" from the Arduino Bluetooth control app to the FPGA board

RESULTS AND DISCUSSION

Implemented design After complete setup the result is tasted according to VHDL code. The result will be the switching of Bulb 1 and 2. In order to pass the command we have to write the instruction on the Arduino Bluetooth control app. When, we pass 1 from the Arduino Bluetooth control app, the Bulb1 is on, shown in Fig. 13 and when we pass 2 the bulb 1 is off shown in Fig. 14, again when we pass 28 from the Arduino Bluetooth control app Bulb 2 is on shown in Fig. 15 and when 9 is passed the Bulb 2 is off shown in Fig. 16. Similarly, when "turn on all" is passed all the Bulb 1 and 2 are on shown in Fig. 17 and "turn off all" is passed all the Bulbs will off shown in Fig. 18. RTL diagram of the purpose architecture is shown in Fig. 19. Speed and power results for the

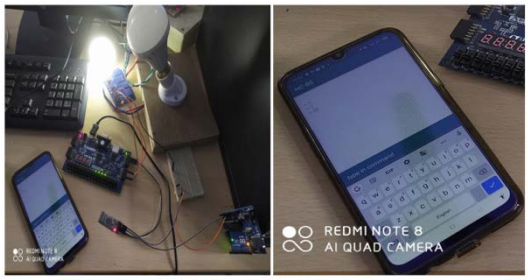

Fig. 15: Diagram for passing "28" from the Arduino Bluetooth control app to the FPGA

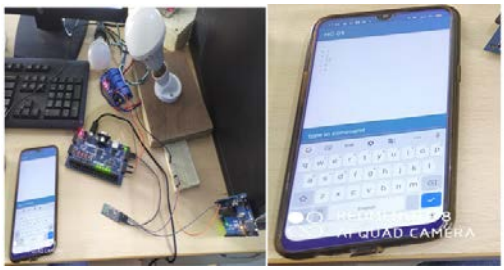

Fig. 16: Diagram for passing "9" from the Arduino Bluetooth control app to the FPGA

Fig. 17: Diagram for passing "turn on all" from the Arduino Bluetooth control app to the FPGA

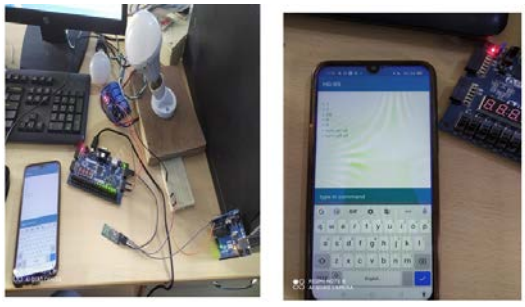

Fig. 18: Diagram for passing "turn off all" from the Arduino Bluetooth control app to the FPGA

purposed design are shown in Table 6. Synthesis results comparison between proposed design and existing IOT module[2] is shown in Table 7.

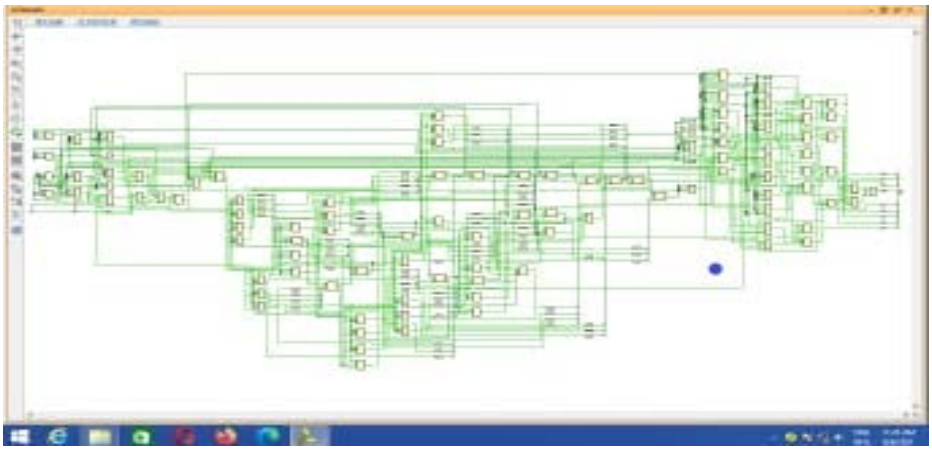

Fig. 19: RTL diagram for the proposed design

Table 6: Speed and power consumption results for the proposed design

Variables	Values
Speed (ns)	7.125
Total on chip power consumption (W)	0.075

Table 7: Synthesis results comparison between proposed design and existing IOT module

Logic utilization	Proposed design	Existing design[2]
LUT	113	2447
Slice flip-flop	42	1475
LUT used on logic	113	2506
RAM	0	256
RAMB 16s	0	16
No. of bonded IOBs	11	35
IOB flip flop	0	22

CONCLUSION

In this study, we have designed and developed home automation system with Bluetooth and FPGA using UART. Synthesis and simulation are being carried out on Artix-7 series FPGA board. Target device (XC7A35TCPG236-1) (speed grade-1) using Vivado 2015.2. There is no loose of data while passing the data from mobile application to the designed system. Our design uses less number LUT and Slice flip-flop compared with the existing IOT module. And this designed system can be used in many applications like in classroom, office, etc. By changing the command, we can control many appliances using number of relay according to the number of appliances going to used.

ACKNOWLEDGMENT

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REFERENCES

01. Chandrasiri, L.H.R. and L.H.S. Chandrasiri, 2016. FPGA based real time wireless home control solutions for lightning, security, HVAC and Av systems. Proceedings of the International Research Symposium on Engineering Advancements (IRSEA'16), June 4, 2016, SAITM, Malabe, Sri Lanka, pp: 131-134.
02. Abdul, A.M., B.M. Krishna, K.S.N Murthy, H. Khan, M. Yaswanth, G. Meghana and G.L. Madhumati, 2016. IOT based home automation using FPGA. J. Eng. Applied Sci., 11: 1931-1937.
03. Bhoite, P.S. and M.B. Mali, 2016. Wireless signal transmission using an android mobile and FPGA. Int. J. Adv. Res. Comput. Commun. Eng., 5: 605-607.
04. Jothibasu, M., B. Aakash, K.S. Ebanesh and G.L. Vinayak, 2019. Automatic Room Monitoring with Visitor Counter (ARM-VC). Int. J. Innovative Technol. Exploring Eng.(IJITEE.), 8: 1379-1383.
05. Anonymous, 2019. Basys 3 FPGA board reference manual revised. Digilent, Inc., Washington, USA.
06. Anonymous, 2021. HC serial bluetooth products, user instructional manual. Wikimedia, USA.