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BLUETOOTH BASED WIRELESS HOME AUTOMATION SYSTEM USING FPGA

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ABSTRACT

With the increasing development of modern technology and Smartphone, smart way of living has turned out to be a major part in the present era of human life. Due to rapid growth in Technology, Bluetooth has brought a revolutionary change. Bluetooth technology, which aims to exchange data wirelessly within a range of short distance by providing a necessary platform to create convenience and controllability. Being wireless, it has wide range of applications. In this paper we presented one of its day to day application i.e.., Home automation, which is controlled by using Android Smart Phone. A Bluetooth module (HC-05) is used to control the home appliances that are connected to FPGA board. The home appliances that we need to control are connected to the Input / Output ports of the FPGA board and communication is established between the FPGA board and Bluetooth device using Serial Communication. Home automation not only helps to reduce human efforts but is also energy efficient and time saving. The main objective of home automation is to help handicapped and old aged people that will enable them to control home appliances and alert them in some immediate situations.

Keywords: *Smartphone, Bluetooth (BT), FPGA, Home automation, Serial Communication*

1. INTRODUCTION

Due to tremendous growth in the present day emerging technology, humans are adapted to these technologies in many ways. Communication is the process of transferring information from one point to other point. It can be done in two ways i.e., either by wireless communication or wired serial communication. Among these two types of communication wireless communication have proved to be more popular among everyone which received huge appreciation from all parts of the world. The main reason behind this is to provide security to the users. Among different wireless technologies, Bluetooth technology stands on the top as it is able to provide a communication between devices and users in a simple and efficient manner. There are many types of Bluetooth devices that are being used in our daily life. In these various types of Bluetooth devices there are several types of Bluetooth modules that are designed to control various appliances [4]. These modules are based on several specifications based on which they perform the operations that are related to it. One of its specifications is that, they work within a range of 45metres and will operate at 2.4GHz frequency. Using this we are designing a home automation system which works with the help of a Bluetooth technology [2]. The Bluetooth module that is used here is HC-05. First of all when designing a home automation [7], [13] system we have to consider about some issues like, the user should be able to connect to that Bluetooth module from any device he would wish to. He should be able to change the host from one device to other device and that module

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should work accordingly. If any fault occurs it should be able to diagnose it and the system should work immediately when an instruction is given to improve the nature of wireless technology. FPGA board is used here as it is able to provide high security [11] to our system.

In the coming chapters we discussed about Xilinx EDK Design Flow in Chapter 2, Chapter 3 deals about our Bluetooth module (HC-05), Chapter 4 discusses about the Design Procedure, Chapter 5 shows us the Simulation Results of our project, Chapter 6 deals with the Physical Implementation.

2. XILINX EDK DESIGN FLOW

XilinxISE(Integrated Software Environ ment), developed by Xilinx to perform Synthesis and the analysis of the HDL designs which enable the developer to compile user designs, examine the RTL schematic diagrams, perform the timing analysis, simulate the developed design and configure the target device with the programmer. Xilinx ISE is primarily used for circuit synthesis and design, other components that are shipped with Xilinx includes various tools, Embedded Development Kit (EDK) [5], [6] and Software Development Kit (SDK).

2.1 Embedded Development Kit (EDK):

It provides a list of design tools that are based on a common framework which enable you to design a complete system for the implementation in a Xilinx FPGA device. It consists of: Xilinx Platform Studio (XPS).

- Embedded System Tools suite.
- SDK (Software Development Kit), can be used to develop your embedded software application.

It has large number of commonly used peripherals where various kinds of systems can be created by using these peripherals. To create our own peripherals EDK uses Intellectual property interface (IPIF) library in order to perform common functionality among various processor peripherals. It also gives us a set of simplified bus protocol called IP Interconnect which is much easier to use instead of operating on PLB bus protocol directly. By using this IPIF module with parameterization matches our needs which reduce our design and test effort by large amount. XPS is used by Base System Builder (BSB) for generating a simple processor system which may use custom peripheral. HDL templates can be generated by using create mode (Create and Import peripheral wizard). To open the .npl file that we generated in create mode project navigator is used. We can add extra generics to the peripheral top template file to implement our custom functionality in user logic.vhd file.

IP CORE generator accelerates the design time by providing access to highly parameterized IP for FPGA and is included in ISE design suite. These user programmable IP functions range in complexity from commonly used memories and FIFOs. This highly optimized IP allows designers on building designs quicker. We will create HDL to configure FPGA system elements like MGTs, Ethernet and PCI express hard blocks by using the logiCORE GUI-based customizers. After the generation of IP core the top module is synthesized and then we implement the design that has to be done. This design consists the process of Translate, Map, Place and route. After implementing the design bit file is to be generated which will be downloaded to the FPGA board.

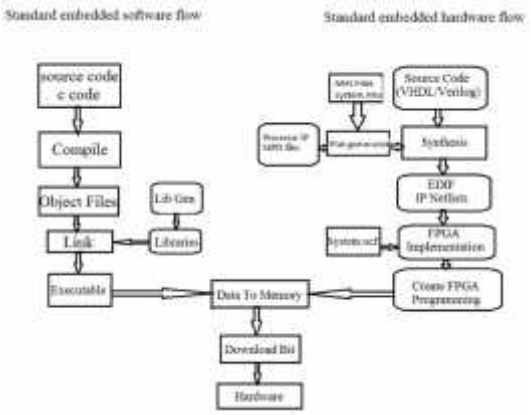

Fig1: Design Flow Of EDK

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2.2 Xilinx Platform Studio (XPS):

It provides an environment for creating both software and hardware specification flows for embedded systems. To create and edit source code XPS provides an editor and a project management interface. It provides customization of tool flow configuration options. XPS also provides a graphical system editor for connection of processors, peripherals, and buses. It has the ability to add and edit core parameters. It has the ability to generate and modify the MSS file. It has an ability to generate and view a system block diagram. It supports multiple-user software applications and project management.

2.3 Software Development Kit (SDK):

SDK is a complementary GUI to (Xilinx Platform Studio) and provides a development to software application projects. It is based on the Eclipse open-source standard. Platform Studio SDK provides rich C/C++ code and compilation environment and project management. It provides Application build configuration and automatic make file generation. Error navigation is its special feature.

3. BLUETOOTH MODULE (HC-05)

HC-05 is a Bluetooth serial interface module which is used at Civil level and not at the industrial level. This level has two types of modules (HC-05, Hc-06) [1].These modules are used for converting serial port to Bluetooth. Generally, these Bluetooth modules have two modes: master and slave device. HC-05 has an advantage where users can set the work mode (master or slave) of the device by AT commands. The main function of Bluetooth serial module is replacing the serial port line. Once the devices are paired connection can be established between them. This Bluetooth connection is equivalent to a serial port line connection which includes Received, Transmitted signals and they can use the Bluetooth serial module to communicate with each other. The communication between two Bluetooth modules requires at least two conditions:

1. The communication must be between master and slave.
2. The password must be correct.

In HC-06, user can't reset the work mode (master or slave) and only a few AT commands and functions can be used, like reset the name of Bluetooth (only the slave), reset the password, reset the baud rate. But the command set of HC-05 is more flexible than HC-06 and so only it is mainly recommended for the user. In this master and slave mode can be switched at a time.

3.1 Role of Master:

Normally, there is no specific function in this to remember the last paired device, even though it can be paired to any slave device. If we want HC-05 to remember the last paired slave device you can set AT+CMODE=0 after pairing with the other device. Pin diagram of HC-05 is shown in fig2:

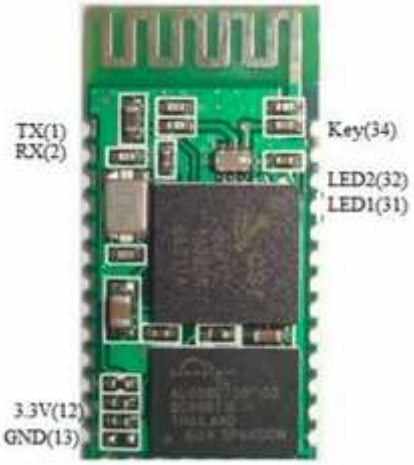

Fig2: HC-05

The Master device can not only pair with specified devices but also can search and make pair with slave device automatically. On some specific conditions master and slave devices can make pair with each other automatically. After power on, first set the PIN34 as high level, the Baud rate used here is of our own requirement. All AT commands can be operated only when the PIN34 is at high level.

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Only part of the AT commands can be used if PIN34 is not set to high level after entering to the AT mode. Using this kind of design, we can set permissions for the module that is left to the user's external control circuit that makes the application of HC-05 much more flexible. During the process of communication, the module can enter to AT mode by setting PIN34 to high level. By releasing PIN34, the module can go back to communication mode in which user can inquire some information dynamically. Default baud rate we can use is 9600.

PIN31 refers to LED1, which is the indicator of Bluetooth mode. Slow flicker (1Hz) means entering to the AT mode, while fast flicker (2Hz) represents entering to the pair mode. Double flicker per second represents pairing is finished, the module is communicable. PIN32 refers to LED2, where the state is at low level before pairing, and after the pairing the state is at high level. It is the output terminal. During the pairing, the current is fluctuant in the range of 30-40mA. The mean current is about 25mA. After paring, no matter processing communication or not, the current is 8mA.There is no sleep mode. This parameter is same for all the Bluetooth modules. PIN11 is RESET, it is active when its input is low level. PIN1 is the transmitter pin and PIN2 is the receiver pin. PIN12 is Vcc and PIN13 is GND. PIN34 is Mode switch input. If it's input is at low level, the module is paired or is at communication mode. If it's input is at high level, the module will enter to AT mode. Even though the module is at communication mode, the module can enter to AT mode if PIN34 input is high level. Then it will go back to the communication mode if PIN34 is input low level again. These all features make HC-05 more flexible for use when compared to all other Bluetooth modules.

HC-05 has a better feature when compared to HC-06 as its master and slave mode can be switched whereas they cannot be switched in HC-06. Once the system is disconnected Hc-05 will search for new devices whereas Hc-06 will connect to the last paired device, unless reset button is switched it will not search for new device. During the process of communication the module can enter at AT mode but, it is not possible in HC-06. HC-05 will cover all functions of HC-06, but HC-06 can't perform all the functions of HC-05.

4. DESIGN PROCEDURE

In this paper we present a home automation system which is secured and flexible that is controlled using an android app in a cell phone. FPGA board is used to control the home appliances which are connected through relays via FPGA board. The communication between the Bluetooth module and the cell phone is wireless and then that module is serially connected to the FPGA board through RS-232 for the control of home appliances. The overall architecture of the system is shown in fig3:

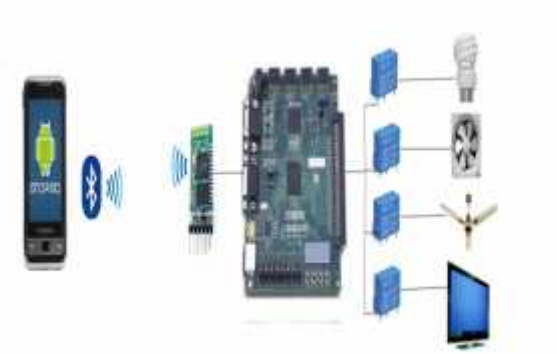

Fig3. Block Diagram

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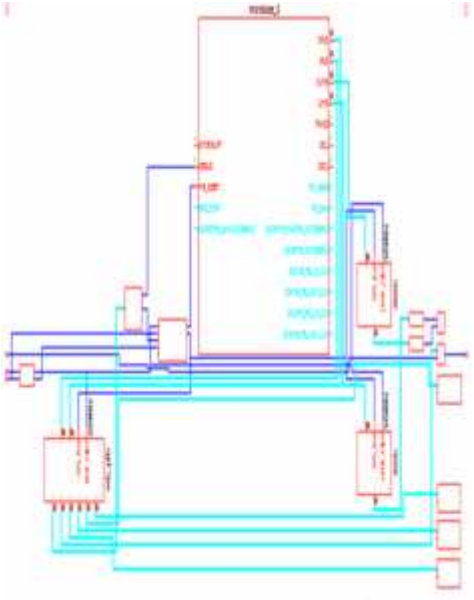

Fig4: Xps Generated Block Diagram

The XPS Generated Block Diagram is shown in above fig4. Android app is developed in JAVA script according to the Bluetooth module specifications. Modifications in app can be made.

Initially the Bluetooth serial module has to pair it with the near Bluetooth devices. The application developed in FPGA to control the appliances and the password is used to authenticate to make the communication can be set by user and once pairing is completed the module receives the commands from the Mobile and then it transmits those commands to RS-232. Based on commands received through HC-05, FPGA controls the appliances through relays. This FPGA board consists of the bit file downloaded into it by the programmer. It consists of all the instructions that are used to control the home appliances.

Algorithm:

The overall procedure is shown in below fig5.

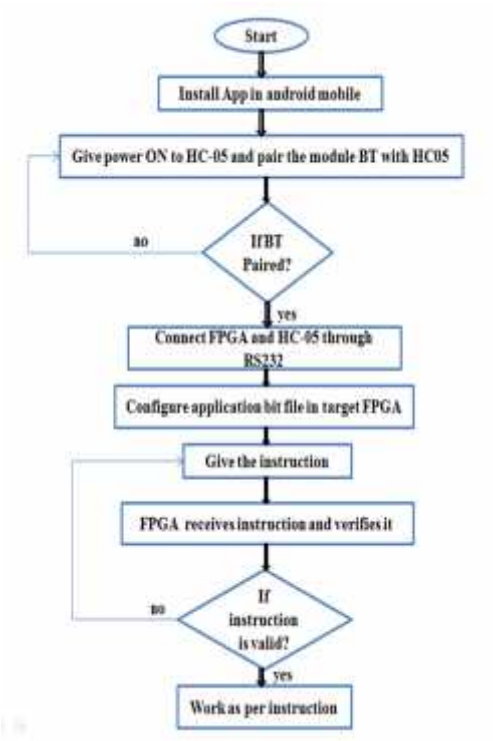

Fig5: Flowchart

Initially to start our process we need to install the application that we developed in our android mobile and then switch ON the Bluetooth in our mobile, make sure that the Bluetooth is in ON condition or not. If it is not ON then turn it ON. Once the Bluetooth is turned ON give power supply to the HC-05 Bluetooth module and pair it with the android mobile via Bluetooth. Pairing between these devices is done by typing the secured password which is set by us. Make sure that the module is in given range as all the controls works only if the Bluetooth module is in our range This Bluetooth module has another option of connecting to the last paired device directly i.e, if the device is already paired and got disconnected it can get paired automatically as it is already stored in phone memory. This is the flexibility that is available with this Bluetooth module.

If the Bluetooth module is paired then connect the FPGA and HC-05 through RS 232. This RS 232 is a serial port device that transfers all the instructions given to it in serial manner. Now, configure application bit file in target FPGA and then give the instruction. This instruction given

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to control the appliances that are to be controlled. The software supports any type of instruction i.e, they can either be Upper characters or Lower character or numbers or symbols. Once, if an instruction is given in the application, FPGA receives the instruction via serial port and then it checks whether the given instruction has valid address or not. If the instruction is valid then the corresponding appliance works and if it is not valid, the system will repeat the process until a valid instruction is given.

5. SIMULATION RESULTS

Fig6: RTL Schematic

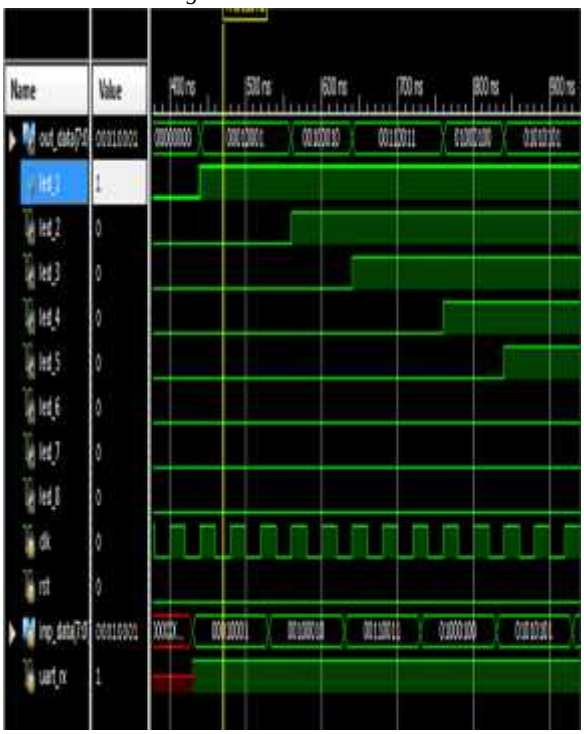

Fig7: Uart Receiver Results

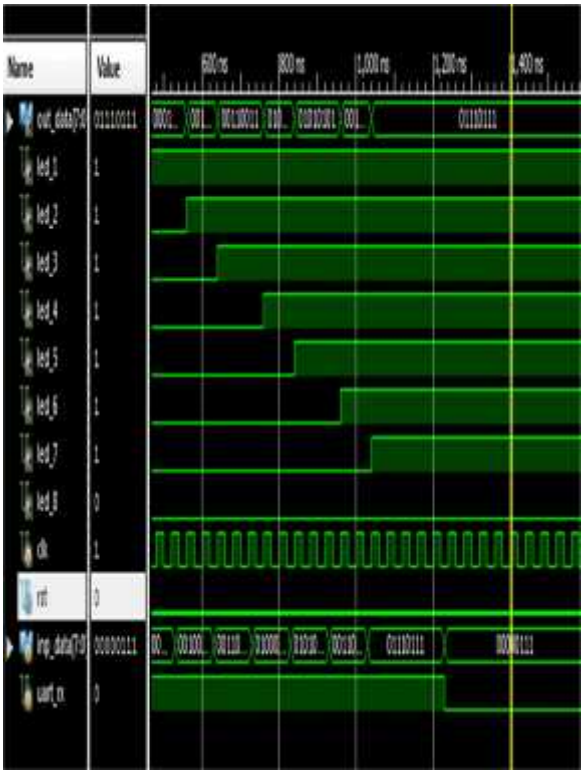

Fig8: Uart Receiver Results

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Fig9: Internal View Of RTL Schematic

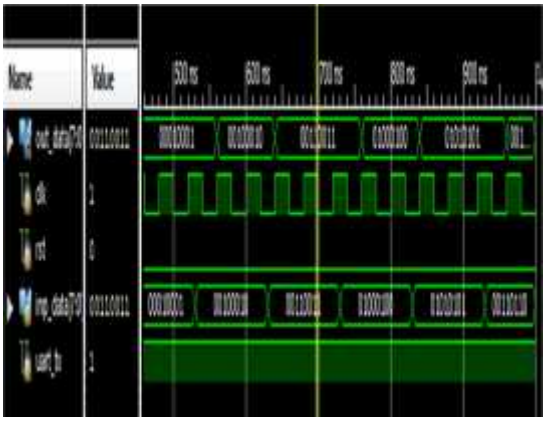

Fig10: Uart Transmitter Results

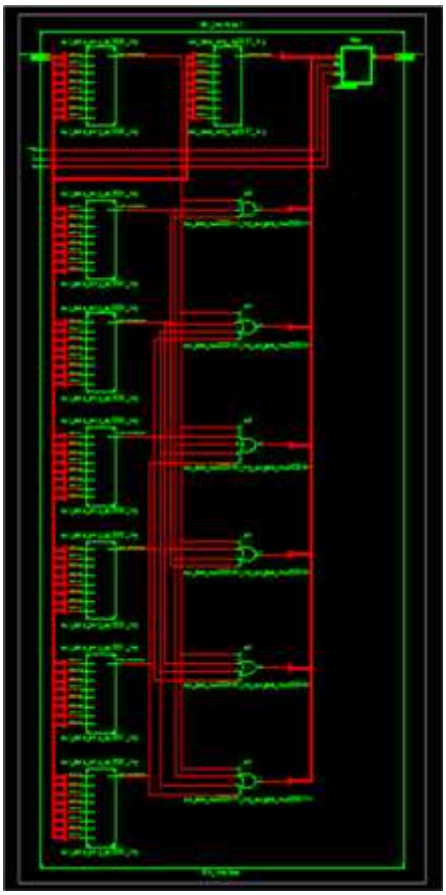

Fig11: RTL Schematic Of Transmitter

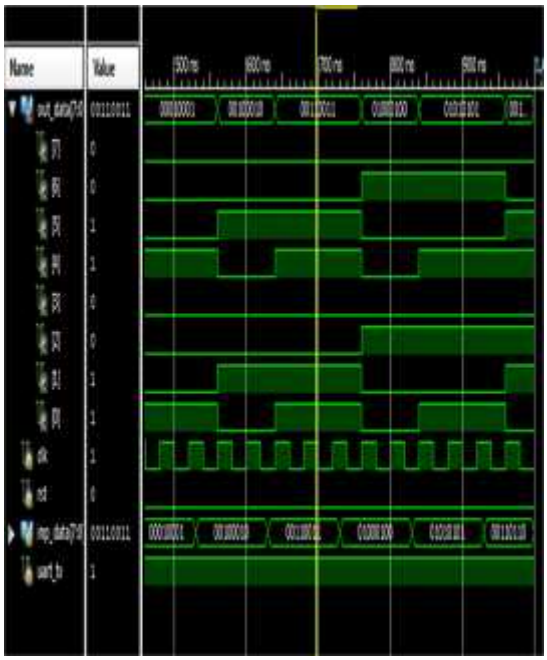

Fig12: Uart Transmitter Results

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Table1: Device Utilization Summary (Dut):

Device Utilization Summary (actual values)				
Logic Utilization	Used	Available	Utilization	N
Number of Slice Flip Flops	1,475	9,312	15%	
Number of 4 input LUTs	2,447	9,312	26%	
Number of occupied Slices	1,761	4,656	37%	
Number of Slices containing only related logic	1,761	1,761	100%	
Number of Slices containing unrelated logic	0	1,761	0%	
Total Number of 4 input LUTs	2,506	9,312	26%	
Number used as logic	2,032			
Number used as a route-thru	59			
Number used for Dual Port RAMs	256			
Number used as Shift registers	159			
Number of bonded IOBs	35	232	15%	
IOB Flip Flops	22			
Number of RAMB16s	16	20	80%	
Number of BUFGMUXs	2	24	8%	
Number of DCMs	1	4	25%	
Number of BSCANs	1	1	100%	
Number of MULT18X18SIOs	3	20	15%	
Average Fanout of Non-Clock Nets	3.62			

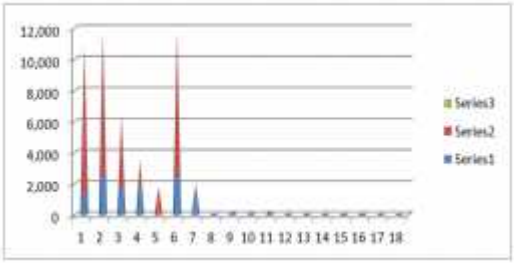

Fig13: Graphical Representation Of DUT

6. PHYSICAL IMPLEMENTATION ON FPGA

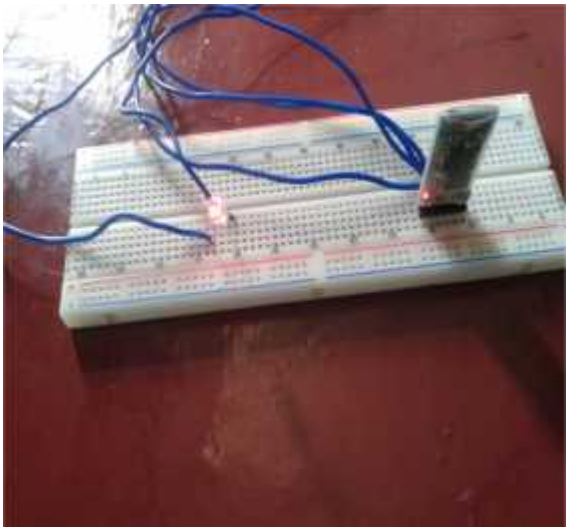

Fig 14: Bluetooth Module Interface Pairing

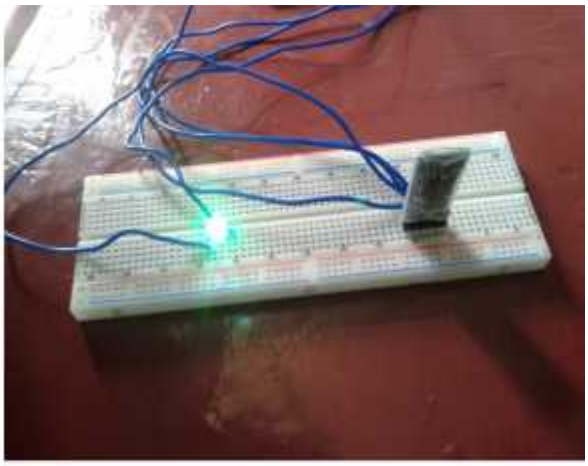

Fig15: Bluetooth Module Interface Paired

Fig16: Commands From Android Smart Phone To Bluetooth Module Through RS232 Interface

6.1 FPGA outputs:

Fig17: When One Appliance Is ON

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Fig18: When 4 Appliances Are ON

Fig19: When All Appliances Are ON

Fig20: When All Appliances Are OFF

6. CONCLUSION

Due to tremendous growth in technology and advancements in wireless communication, smart way of living has turned out to be a major part in the present era of human life. We have proposed a smart home automation system which is operated with the help of android smart phone by using Bluetooth Technology and home appliances will be controlled through FPGA using relays. Work is implemented in real time and appliances are controlled according to the commands from android mobile.

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