

FPGA BASED REAL-TIME WIRELESS HOME CONTROL SOLUTIONS FOR LIGHTING, SECURITY, HVAC AND AV SYSTEMS

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ABSTRACT

Field Programmable Gate Array (FPGA) technology has been a vibrant research area to accelerate complex computational tasks. In this paper, we investigate the state-of-art FPGAs that has been used to implement a rival custom integrated circuit that employs a very flexible user defined functionality that enables high speed interconnects for both analog and digital I/Os. Home Controls comprises the ultimate Bluetooth (BLE) enabled automation solution for many home appliances that we use every day, such as lighting control, music, home theater and several more electric equipment. It creates personalized experiences that enhances life and provide added comfort, savings, convenience, and peace of mind. Furthermore, we lead a powerful and reliable android based application which allows exchanging data wireless via Bluetooth enabled smart phones or tablets.

Key words: Bluetooth, BLE, FPGA, Wireless, Home Control

1. INTRODUCTION

Modern Field Programmable Gate Arrays (FPGAs) have developed to the fact that they include millions of configurable logic gates, embedded memory, and preconfigured logic blocks, such as multipliers and microprocessor cores. Engineers can use FPGAs to implement a variety of complex digital systems that rival Application Specific Integrated Circuits (ASICs) in terms of performance but at a fraction of the development costs. As a result, FPGA designs are expected to dominate the market for high performance digital systems, relegating ASICs to only the most demanding high-volume applications that justify their high development and fabrication costs [1].

Home automation offers the automatic control of products and systems using the Bluetooth enabled solution. This will tolerate house or household activities work together. The proposed system enables centralized control of lightning, heating, ventilation, air conditioning systems, security locks and other audio visual systems to provide smart monitoring, added comfort, savings, convenience and security. Automatic home control systems can benefit for older adults and people with disabilities [2] to remain at home safe and relaxed. The need of the home automation is increases in the recent years because of the growth in the smart devices

market.

The proposed system integrates electrical devices in household with each other. This begins with the Android based operation to control the system unit using wireless Bluetooth technology. The Graphical user interface will make controlling easy and faster. This technique employs controlling your home is at your fingertips. Through this integration it will take care of everything, even if you forgot to switch off the lights or shut down the air conditioner in your room.

2. METHODOLOGY

2.1. Hardware Application Development

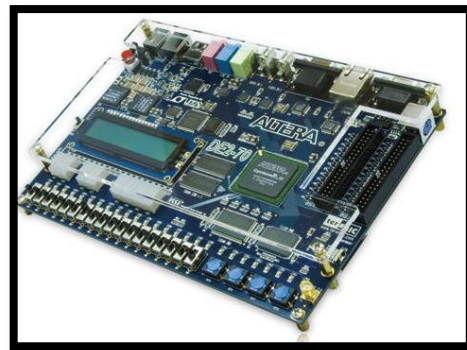


Figure 1: DE2-70 FPGA Development Board

The central implementation was conceded out by a DE2-70 FPGA Development Board to evaluate the concept of the system. The General Purpose Input Output (GPIO) configuration was provided as a simple connection to the FPGA board. Universal Asynchronous Receiver Transmitter (UART) was used to communicate between the FPGA and the Bluetooth Module [3]. To establish a link between the android mobile and the FPGA board a Serial Port Profile (SPP) was used.

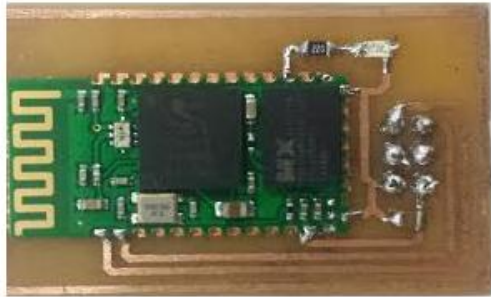


Figure 2: Bluetooth Module

The transmission line comprises of one single wire. While the line is idle, it holds the HIGH state. If it is going to send data, the state changes to the LOW, signaling the start of the transmission [4]. The first bit that we have to send is called the start bit. After the start bit we send our 8 bits of data, where the HIGH state of the transmission line is corresponding to the logic 1 and LOW to 0. After directing 8 bits of data, the transmission is finished by the stop bit, which is logic 1. The line keeps this state until the next communication. So each data packet is 10 bits long: 8 bit of data pulse stop and start bit.

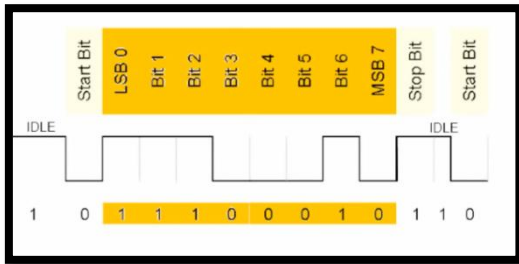


Figure 3: Serial (UART) Protocol

The Figure 4 shows the VHDL code, the codes for receiver and transmitter has been added as COMPONENTs.

```
Code:
ENTITY UART IS
  PORT(
    GPIO_0:OUT STD_LOGIC_VECTOR(30 downto 0); --txd 24
    GPIO_1:IN STD_LOGIC_VECTOR(35 downto 0) --rxd 25
  );
END UART;
```

Figure 4: VHDL code

While implementing the code COMPONENTS we used 50MHz main clock, switches, keys and LEDs to reduce the complexity of the system.

2.2. Android Application Development

The Android application framework design and the implementation of the mobile user interface are discussed below. This application supports the Bluetooth network stack [5], which tolerates a device to wirelessly exchange data with other Bluetooth devices using the Android Bluetooth APIs. The user interfaces are designed using the View and View Group objects [6]. This will enable the ability to store the layout parameters and apply the content in any given area on screen. The following **Figure 5** demonstrations the main layout view that represents the starting point of the application.

In order to initiate a connection with a remote device (a device holding an open server socket), must first obtain a Bluetooth Device object that represents the remote device [7].

We can use the Bluetooth Device to acquire a Bluetooth Socket and initiate the connection [8].

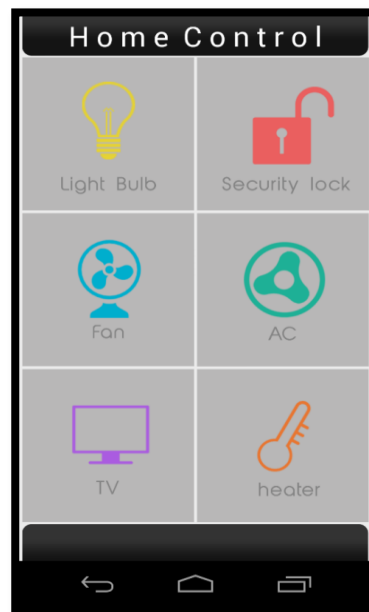


Figure 5: Android Application

3. RESULTS

The results show how easily you can connect to the Home Controlling System using the drop down menu of available Bluetooth enabled devices. This assists the select and touch feature on the connect button and it will direct to the main controlling interface of the application. By simply pressing on the image, we can power on the attached devices. By pressing again on the already powered on device you can make attached device in to switch off mode effortlessly. For this concept we configured some GPIO LED as outputs [9, 10].

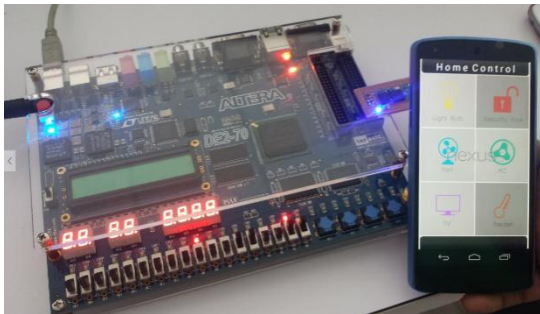


Figure 6: Demo Caption

All the developed VHDL code was tested at block and top levels before downloading the manufactured code for the FPGA. To validate the correct timing and states of the hardware, the waveform was checked for correct operation.

The reception starts if no communication is active (RX_FLG=0) AND RX_LINE is LOW (start bit is detected). If both conditions are true, initialize PRSCL and INDEX, also set RX_FLG and BUSY indicator to '1'.

```

BEGIN
IF(CLK'EVENT AND CLK='1')THEN
  IF(RX_FLG='0' AND RX_LINE='0')THEN
    INDEX<=0;
    PRSCL<=0;
    BUSY<='1';
    RX_FLG<='1'

```

While reception is running, assign the value of RX_LINE to the corresponding bit in DATAFL vector. Each time the PRSCL hits 2600 increase INDEX by 1. If INDEX is equal to 9, then the reception is complete. In this case we have to check if the first bit is equal to '0' and the last bit is to '1'. Then we can make sure that we don't have any frame error. Then pass 8-bit DATA. Also reset BUSY and RX_FLG.

Now the receive COMPONENT is done and we have to add it into the top entity. We have to declare the component in the declaration part of the ARCHITECTURE (between IS and BEGIN). Then we wrote COMPONENT<NAME> and then list its ports, as they declared in its description.

```

COMPONENT RX
  PORT(
    CLK:IN STD_LOGIC;
    RX_LINE:IN STD_LOGIC;
    DATA:OUT STD_LOGIC_VECTOR
    (7 downto 0);
    BUSY:OUT STD_LOGIC
  );
END COMPONENT RX;

```

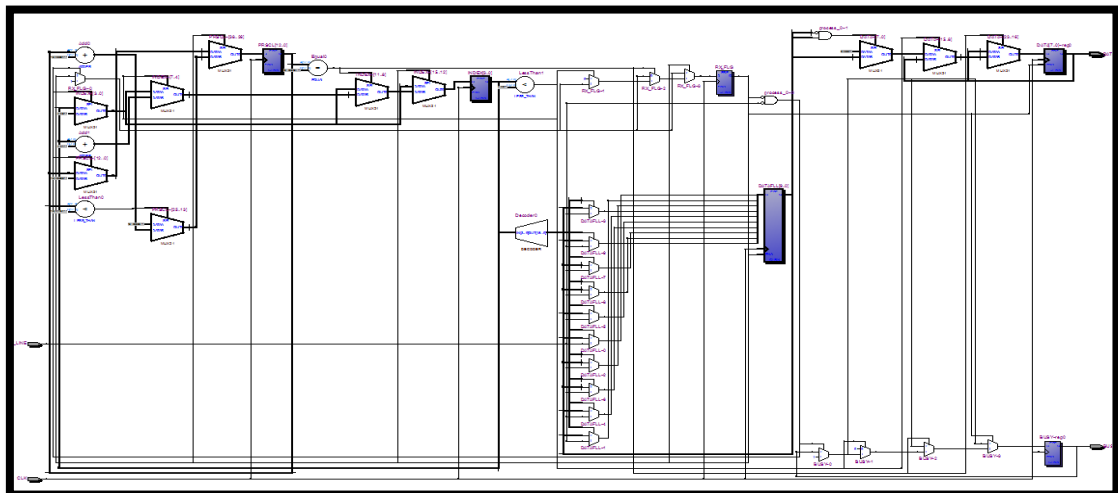


Figure 7: RTL View of the Receiver

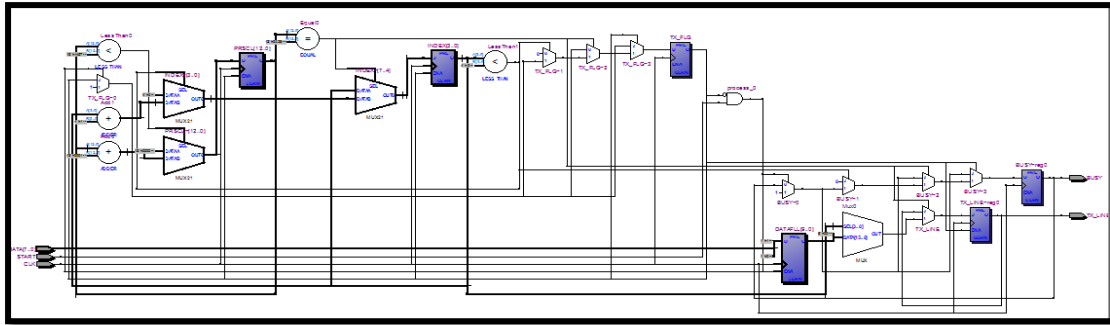


Figure 8: RTL View of the Transmitter

Next the COMPONENT has to be connected to the main entity. This is done by PORTMAP. Then we label the component 'C2', and write RX PORTMAP. In brackets specify which signal of our main entity connects to which port on our component.

C2: RX PORT MAP (CLOCK_50, GPIO_1 (25), RX_DATA, RX_BUSY);

Then received data can be assigned to the first eight red LEDs. The assignment is executed on the falling edge of the BUSY signal.

4. CONCLUSION

The application of Home Automation using FPGA is presented. The FPGA technology was selected as it offers more processing power and faster response time at the hardware level for controlling input and output. The proposed system is more scalable because it is expanded by connecting multiple devices and transferring data using FPGA wirelessly. This leads to a solution where the interface can be easily interchanged by any other wireless solution. Maybe we can use Wi-Fi for more data speed.

In this paper, home automation systems encompass constructing homes to a smarter level. Homes on modern world are compromised with multiple sensors, including motion, light and temperature to provide automated toggling of devices. The energy that is being used to maintain and control all of these devices can be preserved. In the future this can be integrated with home security solutions to allow countless control over safety and comfort for many people. Also, this can be used to control large scale environments such as offices and work stations and will allow digitized households everywhere.

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