GSM-Based Remote Sensing and Control System Using FPGA

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Abstract

Home security today needs to make use of the latest available technological components. In this paper, we present the design and implementation of a remote sensing, control, and home security system based on GSM (Global System for Mobile). This system offers a complete, low cost, powerful and user friendly way of 24 hours real-time monitoring and remote control of a home security. The design has been described using VHDL (VHSIC Hardware Description Language) and implemented in hardware using FPGA (Field Programmable Gate Array).
Keywords: FPGA, GSM, VHDL, home security.

I. INTRODUCTION

Burglar and fire alarms are commonly found in electronic form today. A system of sensors is connected to a control unit, which in turn connects to a means for announcing the alarm, hopefully to elicit some response [1-3]. Some systems are dedicated to one mission; others handle fire, intrusion, and safety alarms simultaneously. Different systems have been introduced in [4-8], some are using microcontrollers, others are using PC, and the rest are using ASICs (Application Specific Integrated Circuits). ASIC is the best choice of these systems for the stand alone system that can give a multi inputs and output, but the problem With ASICs is the high cost for the masking process. We are introducing a low cost and powerful stand alone security and control system. The system has the advantage of large number of inputs and outputs compared to the exciting systems, this large number of I/Os can be used either for sensing or controlling the devices at home. The system is based on designing and implementing an FPGA chip that is interfaced with a GSM MODEM to work together as a remote fire/security and control system at the same time.

The hardware of the chip has been designed using VHDL and has been tested using Xilinx FPGA. First a synthesizable VHDL code has been written and simulated using Xilinx ISE 6.2i tools, and then implemented on a Xilinx Spartan 3 FPGA. The design has been successfully simulated and tested for both sensing and controlling purposes at different frequencies (4800 KHz, 9600 KHz, and 19200 KHz). This section of the article gave an introduction to the presented work, the next section gives some details about the system operation, in section III we are giving some details about the system architecture, section IV will talk about the VHDL top level model and RTL schematic of the design, in section V the simulation results will be discussed; at the end a conclusion about the work done will be given.

II. OPERATION OF THE SYSTEM

In this section we will give some details about the system operation in case of control action or fire/security action. The system works as a remote sensing for the electrical appliances at home to check whether it is on or off, at the same time the user can control the electrical appliances at home by sending SMS (Short Messaging Service) message to the system, for example turning on the AC before returning home. In case of fire/security the chip will receive signals from the different sensors in the monitoring place and acts according to the received signal by sending an SMS message to user's Mobil Phone, it also works as automatic and immediate reporting to the user in case of emergency for home security, as well as immediate and automatic reporting to the fire brigade and police station according to activated sensor to decrease the time required for tacking action.

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III. SYSTEM ARCHITECTURE

The architecture of the system mainly consists of three components as shown in Figure .1, the GSM MODEM, the controller, and the interface circuit that include the different sensors used. The function of the GSM MODEM is the remote communication between the user and the controller through the RS232 serial communication standard. The function of the controller is to continuously check the inputs coming from the different sensor and send message through the GSM network in case of emergency such that it acts as a 24 hours monitoring, and continuously checking for any received message from the user through the GSM MODEM to switch on the AC for example. The advantages of using FPGA as a controller is achieve multi inputs/outputs and low cost, where the used FPGA chip has 256 inputs/outputs that achieve the multi inputs and outputs. Since many components can be integrated into the FPGA chip that has 200 k Logic Gate, a low cost is also achieved. The FPGA is connected to the different type of sensors (smoke detector, motion detector, fire detector, magnetic detector, fluid detector), at the same time the FPGA is connected to the controlled devices like AC, TV, Refrigerator, washing machine, dishwasher, and light bulbs; the GSM connected to the user, police station, and fire brigade through the mobile cellular network.

An interface circuit has been designed which includes sensors as input devices and 220 volt lamp as an output devices which represents the controlled devices. Then the programmed FPGA has been connected to the interface circuit and the GSM MODEM through the serial port of the GSM MODEM. The VHDL code includes a UART, and a communications through the AT commands of the GSM MODEM.

IV. VHDL TOP LEVEL SYMBOL

The system has been designed to control and sense five zones, each zone includes five sensors (fire, magnet, motion, fluid, smoke), and five devices to be controlled. The controlled and sensing devices in Figure .1 represents only one zone, each zone represents one or two rooms in the house. Figure .2 shows the VHDL Top Level Symbol that clarify the interface of the main controller, where Clk, Rst, GSM_Rx, and Sensors<0:24> are inputs, and GSM_Tx, and Devices<0:24> are outputs. GSM_Rx has to be connected to Tx of Maxon GSM, and GSM_Tx has to be connected to Rx of Maxon GSM without using any flow control. The Sensors input is connected to the different sensors in all zones, and the Devices output is connected to the electric appliance to be controlled with five devices in each zone.

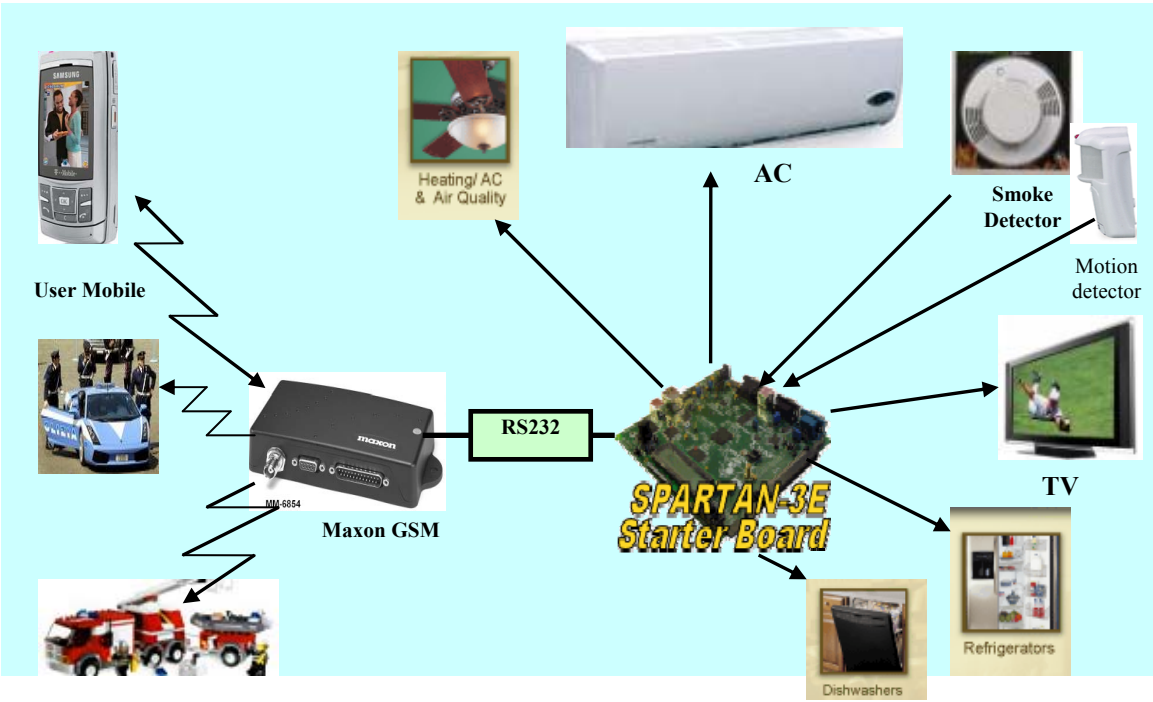

Figure 1. System Architecture

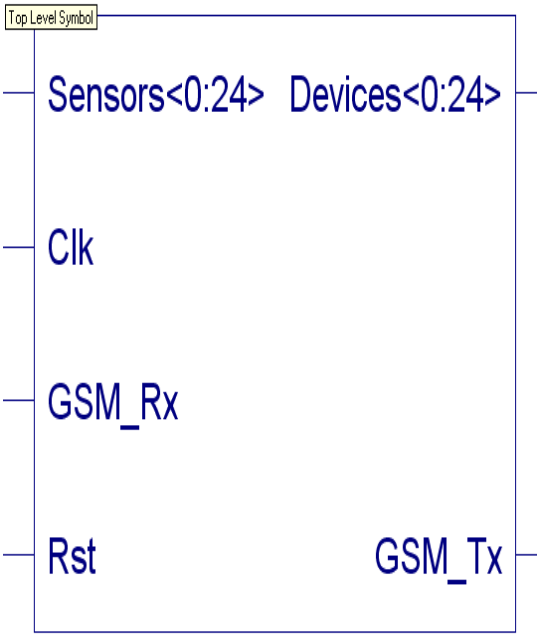

Figure 2. VHDL Top Level Model

The reasons for dividing the home into zones are to easily reach the activated sensor in case of emergency, like the fire alarm. Both of GSM_Rx and GSM_Tx are connected to Maxon GSM through RS232 converter, which converts the RS232 voltage level to TTL voltage level in case receiving data from GSM, and converts the TTL voltage level to RS232 voltage level in case of sending data to GSM MODEM

V. REGISTER TRANSFERE LEVEL SCHEMATIC

Figure .4 shows the Register Transfer Level Schematic generated from the VHDL code. The VHDL program has many components and functions, the most important components are the UART Receiver (U0), Memory Unit (U1), Sensing Unit (U2), Control Unit (U3), and UART Transmitter (U4). The main function of the UART Receiver is to convert the serial data received from the GSM MODEM into parallel data to be processed, normally the received data are coming from the user as SMS message either to control a device or to check for a situation of the device, it may also be a setting of a pass word or resetting the system. The Memory Unit holds the telephone numbers of the user, police station, and fire brigade. The Sensing Unit connected directly to the input sensors and the UART Transmitter through a multiplexer. The Control Unit is the most important component in the system, it generate the AT commands, process the received SMS messages and acts according to the contents of the messages, it also sends SMS message to the user in case of emergency or report to the police station and fire brigade. The main function of the UART transmitter is converting the processed data from parallel to serial, and then sending the serial data to GSM modem, the transmitted data could be an AT command, SMS message to the user, phone call to the Police station, or phone call to the fire brigade.

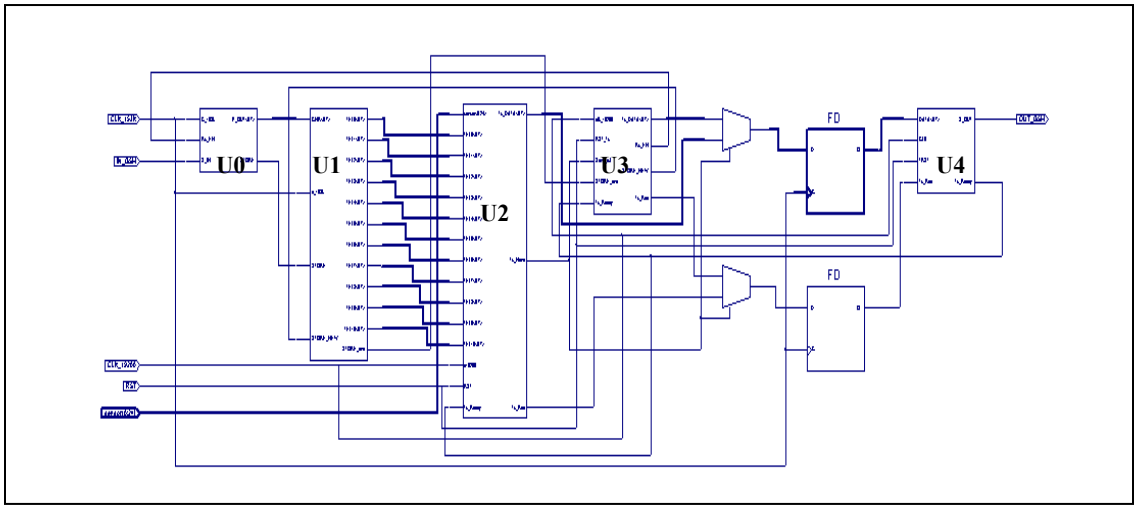

Figure 3. Register Transfer Level Schematic

VI. SIMULATION RESULTS

The system has been experimentally tested for both sensing and controlling purposes first with serial port of the PC, then in a real time using Maxon GSM. Figures (4-6) show the simulation results for the control Unit, the UART Transmitter, and UART Receiver. Figure .4 shows the simulation for the Control Unit which sends parallel data to UART Transmitter; the parallel data represents the ASII code for the characters; the character could be a message or an AT commands. The example given in figure .4 is for sending the AT commands for reading message in location 1 "AT+CMGD=1", '$' and '#' are used for the start and end of the transmitted data.

In the simulation we show the transmitted data in the form of characters but in hardware implementation it is stream of bits that represent the ASCII codes of the characters. In Figure .5, the UART Transmitter is shown in which there are two state, the first one is for preparing data in a frame of 10-bits including the start and stop bits, and the next state is for sending the frame to the serial output S_out, where k is a counter for the number of bits to be send in the second state, and Tx_req and Tx_ready for handshaking. In Figure .6, the UART Receiver is shown, where reg_GSM is a shift register, the input serial data from S_in is shifted in reg_GSM after receiving the start bit, and when rx_en is high, after shifting the 8-bits of the received character and the stop bit, the ASCII character in reg_GSM has to be assigned to P_out. .

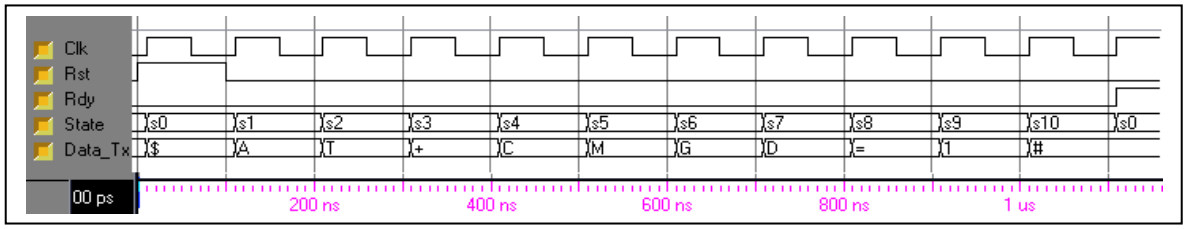

Figure 4. Simulation Results for the Control Unit when sending AT Commands

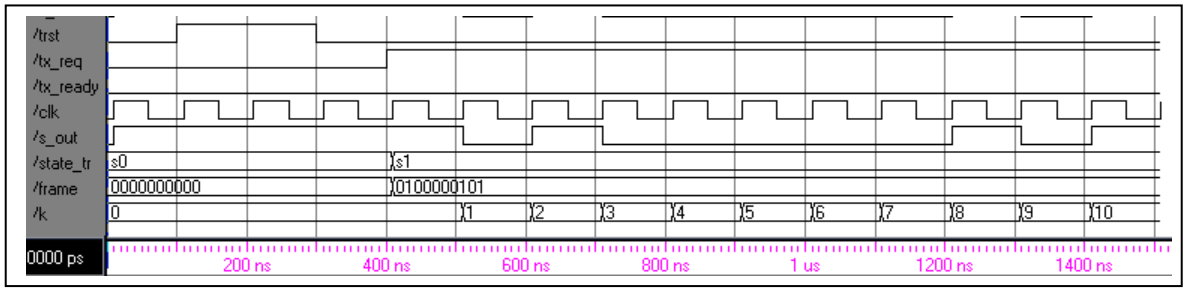

Figure 5. Simulation Results for URAT Transmitter

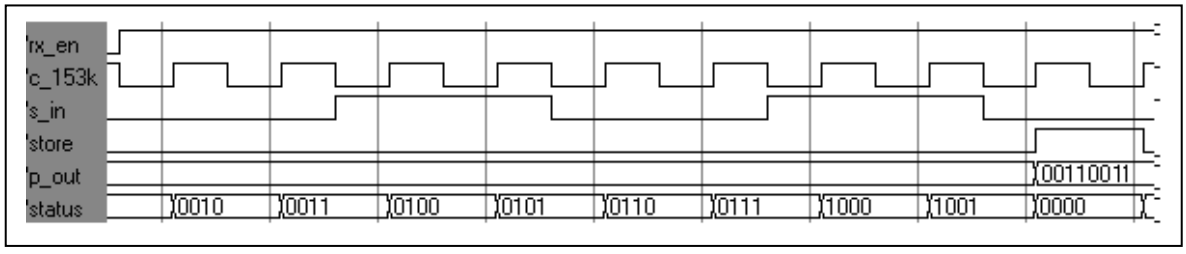

Figure 6. Simulation Results for UART Receiver

VII. CONCLUSION

In this paper we introduced a remote sensing and control system based on using Global System for Mobil (GSM) and FPGA. The system is suitable for a real time monitoring in home security as well as controlling and sensing in home automation with large number of controlled devices. The system has been design and implemented in hardware using VHDL language and Xilinx Spartan 2E FPGA. Maxon GSM has been used for testing the circuit either for the sensing part of the circuit or the control part. The design was simulated and tested in a hardware level and verified the correctness and working operation of the whole system.

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