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Smart Home Security Access System Using Field Programmable Gate Arrays

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Article Info	ABSTRACT

Nowadays, the rapid growth of burglary and theft cases over the world has been threatening to the vulnerability of traditional home security systems. Therefore the development home security with intelligent control wherein focus to enhance conventional technique to theadvanced digital security systemand to be more interestinginhome or building owner for preventing intruders in smart home implementation. However, using avariety of type conventional lock doors for security purposes and analog intruder sensor with individual function system is not secure enoughin order to protect the person or company properties. That why the emergence of new technology such as integrated circuit network will apply in Smart Home system for abetter security solution to prevent the houses from theintruder and hazardous fire incident. Therefore, this project is done to design and build a smart system with consist of digital security entry for automatic lock doors and also for activating or deactivate all security sensor in houses which is function for detecting the irregular movement and hot temperature (fire incident) in-house for the domestic residential sector. This product includeswith doors automatic lock system using servo motor and detect irregular movement intruder using PIR motion sensor (HC-SR501) and also measure hot temperature using temperature sensor (LM35). The sensor will transmit theanalog signal to Field Programmable Gate Array (FPGA) the Altera DE2-115 board to be processed and which will then display the status entry after key-in password and activation security system on the LED seven segment displays. The entry login controller will use apush button or switchesavailable on FPGA board that are used to login password for automatic door accessand also able maintained for control home smart security system.

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1. INTRODUCTION

A "smart home" technology is one realization of home automation ideals employs integrated digital systems such as FPGAs technology. FPGA's has vastly wider potential for many applications depend on innovation and market demand especially to implement a fully functional or reliable of thesmart home product [1]. Since smart home product such as security system become more popular because dramatically increase of burglary and theft threats last few years and threatening of vulnerability of traditional security system in future [2]. Therefore based on reviews of statistical cases found that a house without asecurity

system, often to be broken into compared to those equipped with security alarm [3]. Thereby vital fact of cases obviously shows security system had proved could reduce the intrusion incident. Hence, it is become compulsory to develop and enhance existing security system with smart technology that can protect people or resident and their properties.

In this project, to make security access system more intelligent and effective, the emergence of digital integrated circuit technologies are implementing for setting security entry system. There are 3 different subsystems that are combined together to form a smart system which known as smart home security access system. It will work with acombination of few input and output components such as servo motor, Passive Infrared (PIR) motion sensor, temperature sensor, led seven segments display, buzzer, push buttons and switches [4]. This project is being implemented using Field Programmable Gate Array (FPGA) Altera DE2-115 board and programmed using Verilog Hardware Description Language (HDL).

The first subsystem is the setting of security access system. This security access system consists of two major parts. There are code entry and memory entry logic. The code entry logic is acombinational logic network which will process all logic function and the memory entry logic while keeping the present security codes define by user. The correct login security access will activate the servo motor gear for unlocking thedoor and deactivate the other additional secure sensor in the house.

Secondly, thesubsystem is the LED seven segment display system. The LED is used to display the status login access through keypad press of user and statuses activate or deactivation functional sensors and alarm during project running.

The third subsystem is the motion detection and temperature sensing setting. The motion setting is used to set the distance radius for intruder detection desired areas in house by PIR motion sensor [5]. Meanwhile for the temperature setting is used to set the range of desired temperature either normal or high temperature (very hot) condition for hazardous fire detection. Therefore theoperation of both device depends on thesetting,or parameter calibration such as user could insert detection range of distance motion start between 1 to 3 meters and also setting hot temperature start when room temperature over 50 degrees Celsius.

The main project system is consisting acombination of the digital security access and another security devices system on detecting any irregular motion, and high temperature incident occurred in the smart home security system. When the login security access correct or the motion and temperature sensor was trigger, it will send thesignal to the Altera DE2-115 board, the program will process the signal and decide the suitable output that will be turned on. In further action when unsecure or emergency condition occurred, then alarm device will activate such as buzzer will functioning when either one or both of sensors are detecting any intrusion,or fire incident occurs in the house. This project is a result of a subject MEE 10203 – Programmable Electronics. The aim of this project experience is to expose and gain anunderstandingof the Verilog programming application using of Quartus II software.

1.1. Project Objective
There are three objectives of this project as below:
i.   To design of smart home security access using Verilog (HDL program) to protect thehouse from intruders and hazardous fire incident.
ii. To ensure the design of combination digital automatic door lock with additional sensors security system can help user easy to control and keep better security level in the house.
iii. To activate alarm/buzzer for intrusion and hazardous fire incident in the house by using Field Programmable Gate Array (FPGA) Altera DE2-115 board.

1.2. Project Scope
Our project system was designed to control the door, fire alarm using atemperature sensor and to detect the irregular motion intruder through PIR motion sensor in the houses.

2. OVERVIEW OF PROJECT SYSTEM DESIGN
Programmable Logical Device (PLD) has evolved since its creation in 1984, where at the start of hundreds of logic to ten million logic gates. Latest FPGA technology is one of the major programming tools used in various applications, and the latest FPGAs market has reached nearly $3 billion worldwide. Even FPGA technology today not only has the ocean of millions of logic gates but it also includes a built-in hardwired processor, memory, multiplier-accumulator, standard cell, clock management system, and other features external digital module or gadget for industrial application. In other words, the advantages of FPGA can be configured as a system on the chip (SoC) [6].

Therefore, as the results of these advantages, the project was selected to apply FPGA technology for educational exposure forstudents in Programmable Electronics subject to enhances skill Verilog HDL

programming. The development of smart home security access was done mainly using Verilog (Hardware Description Language). The methodology is the overall process of developing information systems through a multistep process that includes design, analysis, implementation, testing and getting the result. Therefore, the project works are divided into three stages which are design specification, implementation and design testing and verification. This sectiongenerally describes the design methodology of this project. All of the design stages are briefly discussed in the following sections. The purpose of doing methodology is to ensure that the project is in the scope and achieve the objective.

2.1. Design Specification

For this stage, the review of the previous works is needed to determine the design specifications. Thus, the design specifications should able to solve the problem stated in the problem statement and achieve the objective of this project. Therefore, the design specifications for this project are listed as shown below:

(i) Push button and switches as the input interface for the user to give the input. (i.e: keypad)

(ii) Led seven segmentsdisplay as the output interface to display the command status security access and activation status of operation sensors.

(iii) Passive infrared motion sensor (HC-SR501) and temperature sensor (LM35) as the input interface with DE2-115 FPGA board.

(iv) Servo motor and buzzer/siren also as output for doors automatic locking and alarm system interface with DE2-115 FPGA board.

The summarized general methodology and flowchart of the project development is illustrated in the Figure 1 and 2.
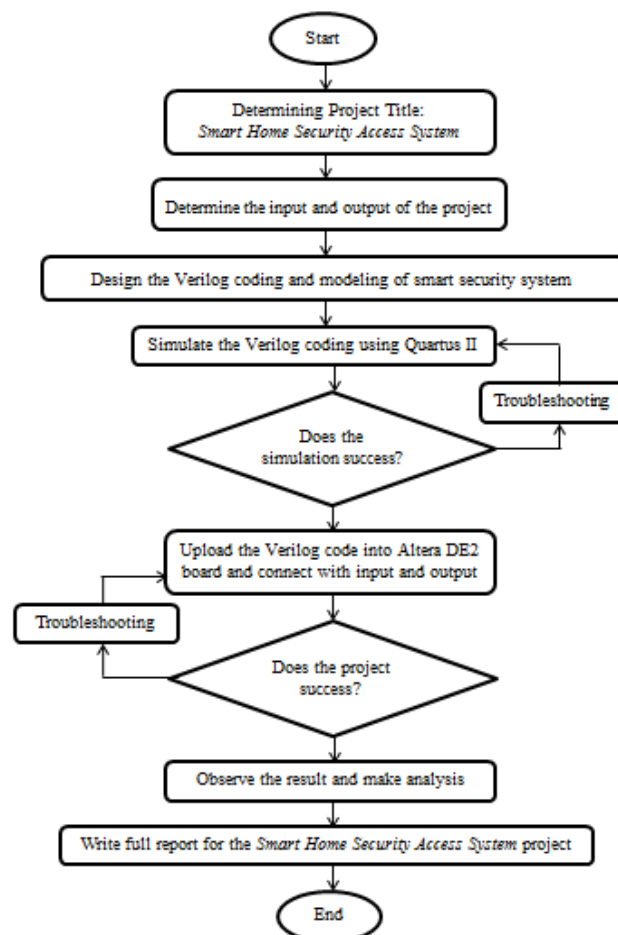

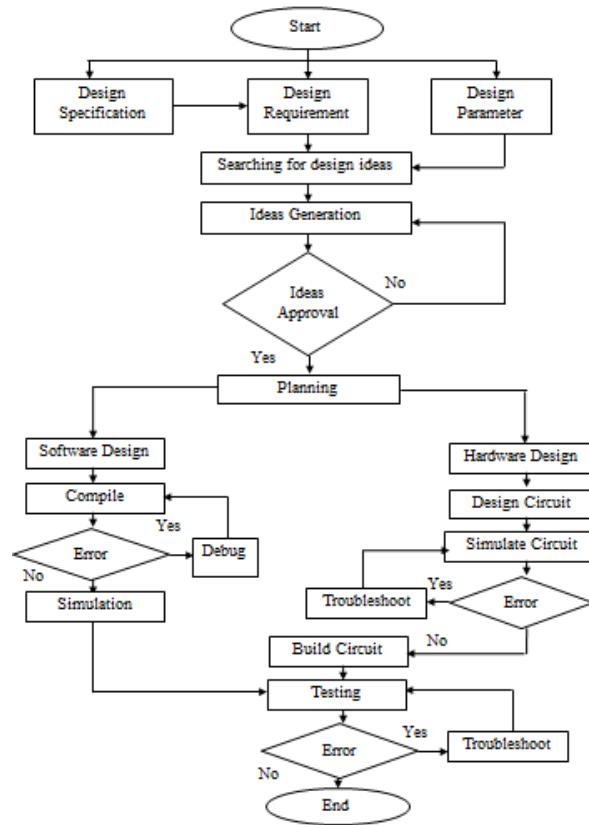Figure 1. General of the Project Methodology

Figure 2. Flowchart Project Development

The block diagram project design also illustrated together in Figure 3. From the block diagram, the push button and switches act input interface (i.e.: keypad) for key-in access security by pressing secret code for open the doors through servo motor. In addition, it also functions forarming or disarming sensors such as PIR motion and temperature sensors. Meanwhile, the led seven segment display will highlight thepresent status of execution task of login access security through push-button/switches interface and output sensor. In this project, the detection system consists of two inputs which arethe temperature sensor and PIR motion sensor. The temperature sensor is used to measure the temperature in a room, and the PIR motion sensor is used to detect any irregular motion which illustrates the connection of FPGA board with input and output hardware. The Altera DE-2 board is being used to interface between input and output components. The FPGA compute and process the signals from the input and sent it to output. The temperature sensor (LM35) senses the range of current temperature in the form of analog signal and sends it to Arduino to convert the analog signal to digital signal before sent to the FPGA [7].
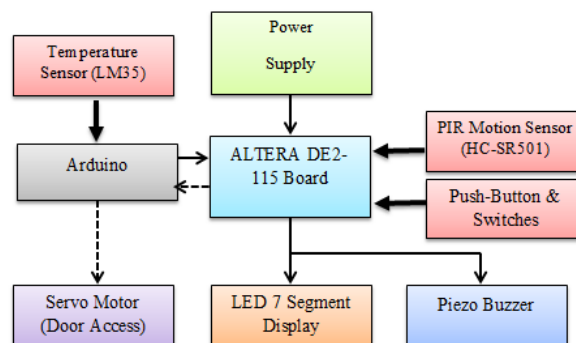

Figure 3. Block Diagram of Smart Home Security Access System

When the room temperature suddenly achieves more than hot temperature limit (over 50 degrees Celsius) the as per design system. Meanwhile, PIR motion sensor is used to detect the irregular movement or motion in specific range distance in selected space area in house depend on user requirement. When the motion sensor suddenly senses or detect irregular movement ina house in time delay 10 seconds in range distance 1 to 3 meters from thedetection area,both sensors will send output to the main security system; then it will trigger 'ON' the alarm system. In this project, we have used buzzer as ademo of analarm device for alerting theuser if any fire incident occurs in the house.

2.2. Hardware Design
2.2.1. Interfacing of Arduino UNO with Temperature Sensor (LM35)

Thefirst input sensor for *Smart Home Security Access system*, as shown in Figure 4, thetemperature sensor is used to detect unwanted fire incident in house. This temperature sensor produces analog input. Therefore, in order to convert analog to digital for thetemperature sensor, Arduino microcontroller has been used. Then program Arduino code to set up the heat sensor form range of the temperature is between 20 degrees Celsius to 50 degrees Celsius. The Arduino microcontroller codingwillproduce output '1' if the temperature sensor detects the temperature more than 50 degree Celsius. For the simulation part yellow LED is used to represent the digital signal '1'. If the output '1', the yellow LED will light up as shown in Figure 5. The switch is used to manipulate the desired temperature by the user [8].
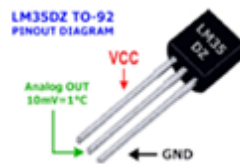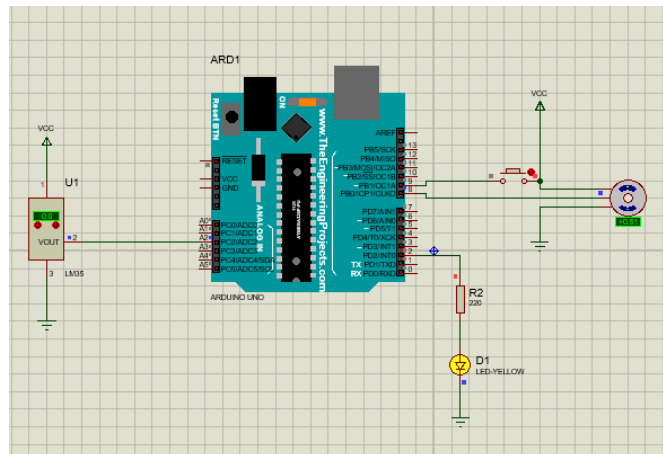

Figure 4. Temperature Sensor (LM35)

Figure 5. Schematic Diagram for Input Temperature Sensor Using Arduino UNO Microcontroller

From Figure 5 above, theservo motoris used as the output system for the Arduino microcontroller. This servo motor functioned as the door lock mechanism for this project which is the smart home security system. The input from FPGA board is connected to input pin 9 of the Arduino microcontroller to trigger the movement of the servo motor for opening door application.In addition, the Arduino microcontroller is used for deciding the direction of the servo motor whether 180º clockwise or anti-clockwise. For the simulation in Proteus software as shown above, the button is representing the digital signal from the FPGA board [9]. When FPGA board send the digital signal to Arduino, the movement direction of theservo motor is 180º clockwise and vice versa.

2.2.2. Interfacing of PIR Motion Sensor (HC-SR501)

The second input sensor for *Smart Home Security Accesssystem* is PIR sensor is used to detect irregular movement. This PIR sensor produces digital output and direct connect into GPIO connection of FPGA board. In order toachieve the detection aim of theproject, the setting of sensor sensitivity needs to adjust for range distance 3 meters and time delay within 10 seconds for aproject requirement. Figure 6 shows the PIR motion sensor and switch is used to manipulate the desired output by the user.

Figure 6. Passive Infrared (PIR) Motion Sensor

2.2.3. Interfacing of Servo Motor, Buzzer, Push Button, Switches and LED Seven Segment Display

In this stage, the push button or switches available on FPGA board become input chums as keypad for key-in access security bypressing push-button for open the doors through servo motorwhile buzzer act as fire/intruder alarmas output devices. The LED seven segment will display thedesired status of activation/deactivation related sensor involved in the project. Figure 7 shows the servo motor and push-button/switchesare used to manipulate the desired input and output into FPGA board by the user.

Figure 7. Servo Motor, Buzzer, Led 7 Segment Display and Push-button/Switches of FPGA board

2.3. Software Design
2.3.1. Verilog HDL

Recently for the electronic application especially in thesemiconductor industry, Verilog is a descriptive hardware language commonly used for design, verification, and implementation of digital logic chips. It is also used in the verification of analog and mixed-signal circuit which contains ahierarchy of modules [10] which are work as acomplete system. In our project, the main program design consistsof several subprogramsin complete the overall design project.

2.3.2. Simulation RTL

RTL Viewer: Based on simulation RTL of theproject in Figure 8 shows that the complete block logic circuit is working as per design. There are several inputs such as aclock, password bits, arming/disarming switch, state sensor and reset in standby mode. Meanwhile for the output project referred

to execution inputs and state process of thelogic circuit before transfer output to external devices (buzzer, servo motor, and seven segment display). Therefore, overall operation and function of theproject areontrack as per design.
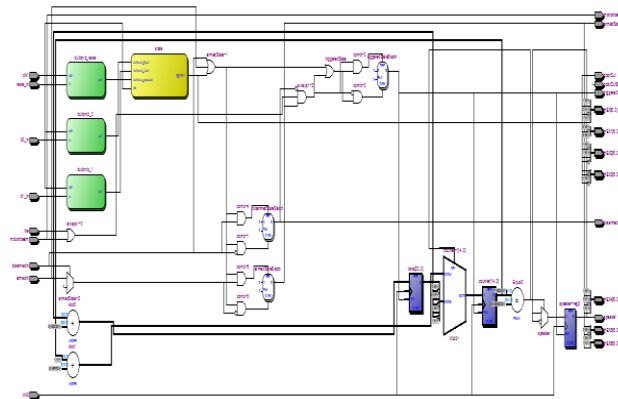

Figure 8. RTL Logic Circuit

3. RESULT

Theoverall result simulation of project design will demonstrate in this section for find out the simulation RTL similar to thedesired physical outcome at FPGA board. The operation of design project will be investigatedto justify the right output of project toachieves the main objective of adevelopment project as below.

Referring to waveform simulation as shown in Figure 9, the logic state starts with theinput of bit '0' and '1' from push button withsecret setup password ('01011') in 3-bit state condition. When the correct password is entering to FPGA, the servo motor will activate to open the door. At the same time all sensors are in disarming condition and to arming back the sensor devices, need to press 'ARM' switch (SW0) for thetrigger in 'HIGH (1)' condition. Therefore, any sensor; PIR motion detect any irregular movement or temperature sensor measure hot temperature (>50 degree Celsius), thealarm system will activate (buzzer =ON). Conversely, if the 'DISARM' switch (SW1) is press by theuser, all sensor is deactivated condition and overallsystem back to initial condition which is the door locking still working as usual when theuserenters the password for close the door. The operational of home sensors can control by the user independently after user get access from door security lock system. The design system provides user opportunity to decide whether to 'ON' or 'OFF' sensor function during themin house or leaving the building for outstation. In this project, the selection of operational of smart home security system depends on user requirement. The important is user feel safe with the full protection of asecurity system; then easy to control and maintain in future.
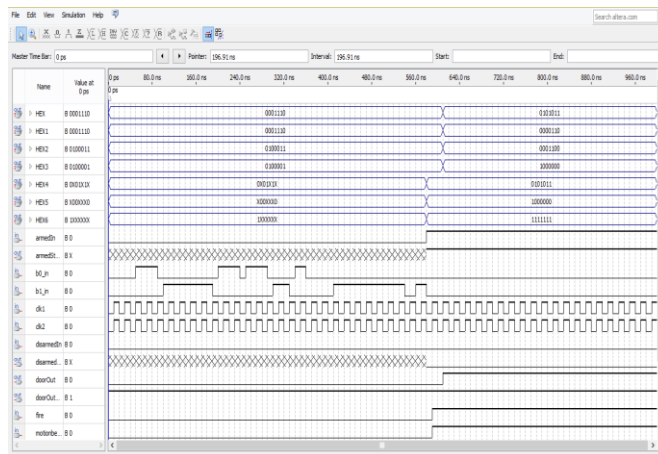

Figure 9. Waveform Simulation of Smart Home Security Access System

3.1. Implemented Servo Motor for Automatic Door Locking Operation

The LED display result ofduring simulation on project subprogram of smart home security access system in thelaboratory. Status 'OFF' shows all sensors in disarming mode before 'ARM' switch not been press or in areset condition while status 'ON' highlight the all sensor smart security had been press to activate the sensor system as shown in Figure 10, 11 and 12.
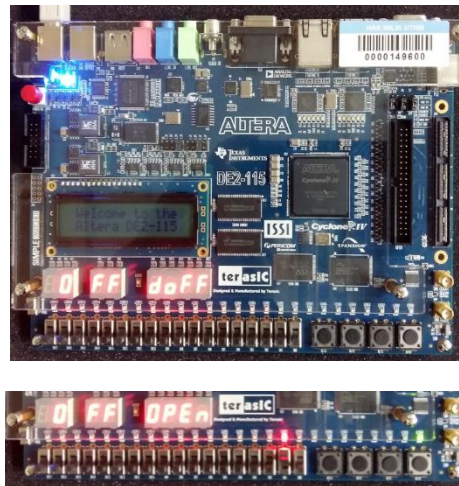

Figure 10. Overall view of Altera DE2-115 board with'd-oFFand 'OPEn' state condition Using Servo Motor as OutputDoor Controller

No.	Sign Display	Description Operation
1.	doFF	Door in close condition
2.	OPEn	Door in open condition

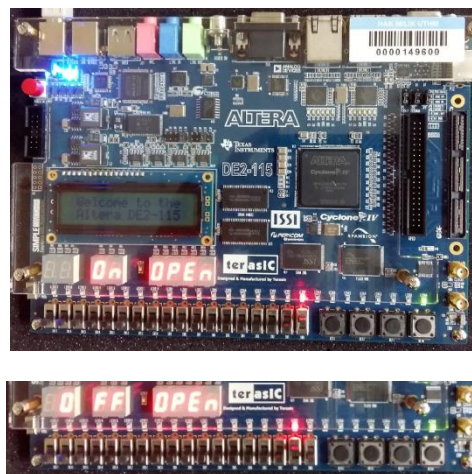### 3.2. Implemented LED Seven Segment Display of Status Operational (arm/disarming) Sensor

Figure 11. Overall view of Altera DE2-115 board with 'OFF'and 'On' state condition Using PIR Motion and Temperature Sensor Detection

No.	Sign Display	Description Operation
1.	OFF	All sensors in deactivate condition.
2.	On	All sensors in anactive condition.

3.3. Implemented Complete Hardware of Smart HomeSecurity Access System
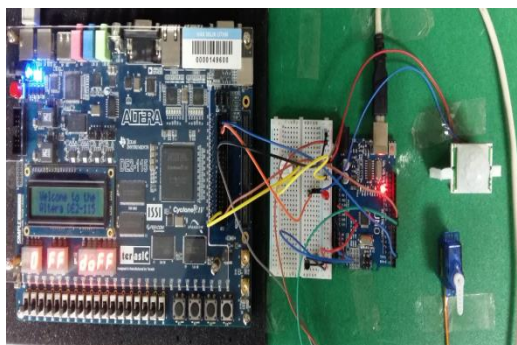

Figure 12. Hardware Simulation of Mart Home SecurityAccess System Project Based on DE2-115 Board

4.   CONCLUSION

In this project, the development of a smart home security system based on FPGA technology is work well in progress. The system is designed and implemented on DE2-115 FPGA board and it also suitable for real-time home security monitoring. Therefore, enhances home safety can preventfromunexpected incidentssuch as fire damage or property loss done by intruders. Instead of applyingdigital lock control; the systems also integrate withadditional fire and intruder sensor to create the home security system verysmart, secure reliable and robust than conventional systems. The system can be implemented in any commercial, residential and industrial buildings. Since the FPGA technologies very robust withextending large capacity, the features of thesystem can be upgradedfor remote control using Wi-Fi, GSM or IoT application for further project development in future.

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