SMART HOME SECURITY: AN FPGA-BASED SOLUTION FOR ASSISTED LIVING

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ABSTRACT

A reconfigurable framework to automated reconfigurable secure home system. The proposed system has 3 main features: monitoring controlling of smart home automation through password-protected door lock system, the monitoring controlling of day-to-day electronic devices, fire safety with room temperature monitoring and antitheft system. In this paper, different sensor combinations are to be integrated with the FPGA board. For the Fire safety module, a temperature monitoring sensor has been used that will display the temperature continuously. If the temperature in the room exceeds 60 degrees Celsius, then it will turn on the buzzer or alarm for fire safety. For the Anti-theft system, infrared (IR) sensors are fitted in each window. If any unauthorized person tries to breach through the window, both IR sensor signals will be turned ON and the output of the buzzer goes to high. For the door lock system, a finite state machine (FSM) has been implemented. This work focuses on a scalable smart home automation framework using the FPGA board that can be used for integration of multiple sensors in a cost-effective way. The research in this project is focused on processing multiple analog sensor inputs through the FPGA board.

Keywords: Smart Home Automation, Home Security, Assisted Living; Internet of Things, FPGA, Finite State Machine, Fire and Smoke Detection, Password Protected Door Lock, Anti-Theft System

INTRODUCTION

In this robust proposed model, home automation is proposed with 3 main features such as Fire Safety, Electronic Device monitoring & Antitheft Module, and a Password Protected Door Module. In our thematic diagram figure 1.1, a module of the virtual house has been considered. The outputs are initiated to zero. The inputs of our system include room door IR sensor, room windows IR sensor, room door ultrasonic sensor, Smoke sensor, Temperature sensor, Door lock module which are essential modules for smart home automation [1] and assisted living [2], [3]. All input signals contain data such as a password to turn ON and OFF security, temperature, door, and window are in input to the IR sensor, smoke as an input to the smoke detector sensor, clocks for clock input, and so on. FSM reset is going to be implied to restart the state machines and transition between each module. The output signals include door condition for opening and closing of a door, fire status to find if there is smoke present in the atmosphere, temperature status for checking the environment as well, window status for opening and closing window, output

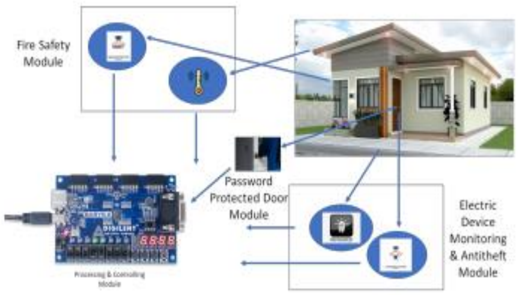

Fig. 1. Thematic picture of the proposed framework

Fig. Thematic picture of the proposed framework

on entering the wrong password. The FPGA is programmed using the hardware description language, Verilog. FPGA has multiple timing domains and there are plenty of asynchronous errors. These kinds of circumstances occur when different kinds of specific data patterns exist. It is difficult to include multiple sensors in a single FPGA platform due to the lower number of input-output ports. Also, Basys 3 FPGA board does not come with an integrated GSM, Wi-Fi module. Having so many limitations, our main challenge is to incorporate multiple sensors like IR, PIR, Ultrasonic, Temperature, and Gas sensors in a single platform which is rarely seen in the FPGA platform. This research will not only be used in home security but can also be installed in offices, schools, medical hospitals, and others.

Implementation and validation of the proposed system

Different sensors have been integrated into a single system with the help of the FPGA board. Under the Fire safety module, the LM35 Temperature sensor has been used. This is a precision integrated-circuit temperature device with an output voltage linearly proportional to the Celsius temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. An infrared sensor (IR sensor) is a radiation-sensitive optoelectronic component with spectral sensitivity in the infrared wavelength range 780 nm to 50 µm. A buzzer has been included as the audio signalling alarm. The FPGA board has been integrated with the sensor and alarm system as shown in figure 4.

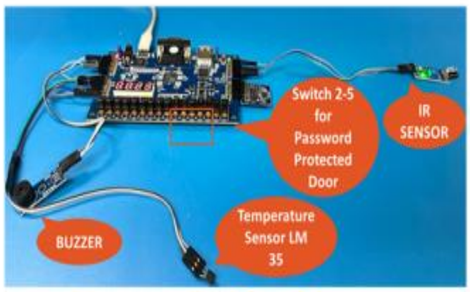

Fig. 4. Prototype of the proposed system

Fig. Prototype of the proposed system

LITERATURE REVIEW

M. Mendez, J. Carrillo, O. Martin, C. Tchata, P. Sundaravadivel, and J. Vasil. EasyYard: An IoT-Based Smart Controller for a Connected Backyard. In IEEE International Symposium on Smart Electronic Systems (ISES) (Formerly iNiS), pages 257–261, 2019.

With many identified applications that can be automated in the smart city paradigm, the number of devices that are connected for each of these applications is increasing multi-fold. It is predicted that the number of connected devices would be in the orders of billions in the next few years. In order to address this scalability issue in the connected smart home, we propose, EasyYard, which allows the user to control lighting, read temperature, access video, and control audio within their home at their convenience using a single controller.

P. Wilmoth and P. Sundaravadivel. An Interactive IoT-based framework for Resource Management in Assisted living during pandemic. In 22nd International Symposium on Quality Electronic Design (ISQED), pages 571–575, 2021.
With a steady rise in the aging population, researchers predict that one out of every six people will be over the age of 65 by 2020. Seniors need to monitor their health consistently as chronic diseases such as diabetes, arthritis, dementia, are highly prevalent among them. This has lead to an increase in the use of devices such as sensors, cameras, and robots, with technologies such as artificial intelligence and the internet of medical things. These can help in designing innovative solutions for improving the daily life of seniors and helping them to be more independent.

A. Sallah and P. Sundaravadivel. Tot-mon: A real-time internet of things based affective framework for monitoring infants. In 2020 IEEE Computer Society Annual Symposium on VLSI (ISVLSI), pages 600–601, 2020

An increase in the number of working parents has led to a higher demand for remotely monitoring activities of babies through baby monitors. The baby monitors vary from simple audio and video monitoring frameworks to advance applications where we can integrate sensors for tracking vital signs such as heart rate, respiratory rate monitoring. Internet of Things based frameworks consists of sensors or nodes that can wirelessly transmit the acquired data to the cloud.

PROJECT OBJECTIVE

The primary objective of this project is to design and implement a smart home automation frame work using Field Programmable Gate Array (FPGA) technology. The goal is to create a reliable, reconfigurable, and real-time control system that automates various home functions such as lighting, fan, air conditioning, washing machine, and enhances security and safety features like password-protected door lock**,** fire alarms, and smoke detection. By leveraging the parallel processing capabilities of FPGAs, the system ensures rapid response to sensor inputs, enabling quick and precise control over connected devices.

One of the key objectives of the project is to enhance home security through a door lock system based on password authentication. The system compares a user-input password with a pre-stored value. Only when a match is found, the door is unlocked, and access is granted. This approach avoids the vulnerabilities associated with traditional lock-and-key mechanisms and introduces a programmable, scalable method for user authentication.

Appliance Automation and Energy Efficiency

Another major goal is to improve comfort and energy efficiency by automating common home appliances. Switches are provided for each appliance—light, fan, AC, and washing machine—which the FPGA monitors continuously. Based on the input state, the corresponding device is either activated or deactivated. The FPGA's synchronous logic ensures accurate timing and control, allowing for efficient use of power and improved user convenience.

Fire and Smoke Safety Monitoring

The system also addresses home safety by integrating real-time monitoring of fire and smoke sensors. If any of these sensors detect dangerous levels of smoke or heat, the FPGA immediately triggers outputs like the alarm and smoke_detector, alerting occupants to evacuate or take necessary precautions. The primary aim here is to minimize property damage and ensure the safety of individuals through immediate system response.

Real-Time, Reconfigurable, and Scalable Design

The use of FPGA as the core platform offers the added advantage of re-configurability and parallelism. This project aims to demonstrate how multiple home functions can be executed concurrently without the need for a microcontroller or processor. The design is modular, allowing for future scalability, meaning more sensors or control blocks can be integrated as required. The real-time processing and hardware-level implementation reduce latency and increase the system's responsiveness compared to software-based automation systems.

PHYSICAL MODEL DESCRIPTION

The FPGA_Smart_Home system is a smart home automation framework designed using an FPGA. It integrates three major control modules—Door Lock Control, Appliance Control, and Fire Alarm—within a single programmable hardware platform. The system takes several sensor and switch inputs to monitor and control home functionalities such as lighting, security, appliances, and safety mechanisms in real time.

The system receives a set of input signals from various sources, representing user interactions and environmental conditions. These inputs include a clock (clk) and reset signal to initialize and synchronize the operation. User inputs such as door password and password are used for secure access control. Additional user-operated inputs include switches for light, fan, AC, and washing machine control. Environmental inputs include fire sensor and smoke sensor, which detect hazardous conditions inside the home. These inputs are processed in parallel within their respective modules

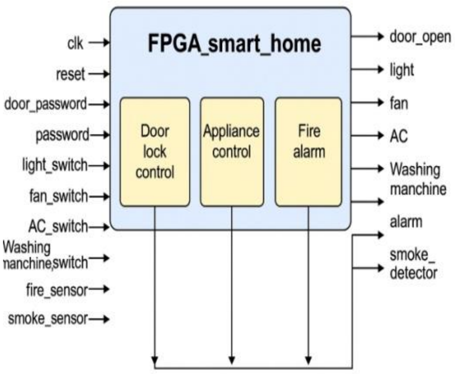

Fig: Block Diagram

Key Functional Blocks Inside FPGA_smart_home:

Door Lock Control

The Door Lock Control block handles the authentication mechanism for home entry. It compares the input password entered by the user (door password) with the stored system password (password). If the passwords match, the module sets the output signal door_open to high, simulating the unlocking of the door. This module enhances the security of the home by allowing only verified users to gain access.

Appliance Control

The Appliance Control block manages home appliances such as the light, fan, AC, and washing machine. It monitors the respective switch inputs (light_switch, fan_switch,AC_switch,andWashing_machine_switch) and produces corresponding output signals (light, fan, AC, Washing_manchine). This design ensures efficient and independent control of each appliance, enabling the user to automate or manually toggle devices within the smart home environment.

Fire Alarm System

The Fire Alarm module is responsible for emergency detection and alert generation. It receives signals from the fire_sensor and smoke_sensor, which detect hazardous conditions like heat and smoke. If either sensor is triggered, the system immediately activates the alarm and smoke_detector outputs. This module plays a critical role in ensuring safety and providing early warning in case of fire-related incidents

Outputs of the System

The outputs of the FPGA_Smart_Home system are control signals that drive external devices. These include:

- door_open (door access)
- light, fan, AC, Washing_manchine (appliances)
- alarm, smoke_detector (safety indicators)

These outputs are driven based on the internal logic of their respective modules and the current state of the input signals. All outputs are synchronized using the system clock to ensure stable and predictable operation.

System Integration and Advantages

The entire system is integrated within an FPGA, leveraging its capability for parallel processing, real-time control, and low-latency response. Each module operates independently but simultaneously, offering high performance and energy-efficient automation. The design is modular and scalable, meaning additional features or sensors can be added with minimal changes to the hardware design

SIMULATION RESULTS

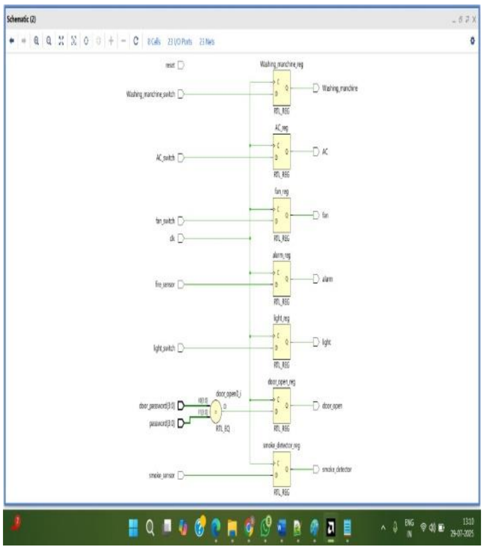

Fig: RTL schematic Diagram

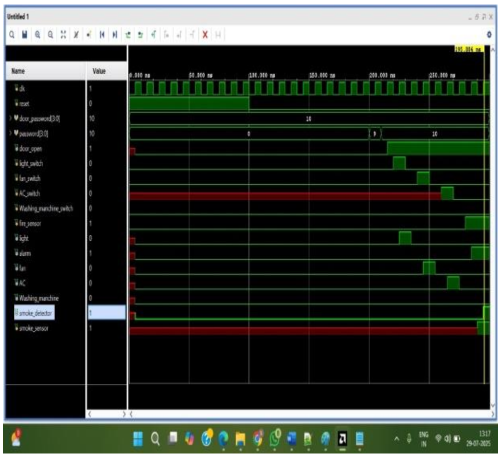

Fig: Simulation Waveform

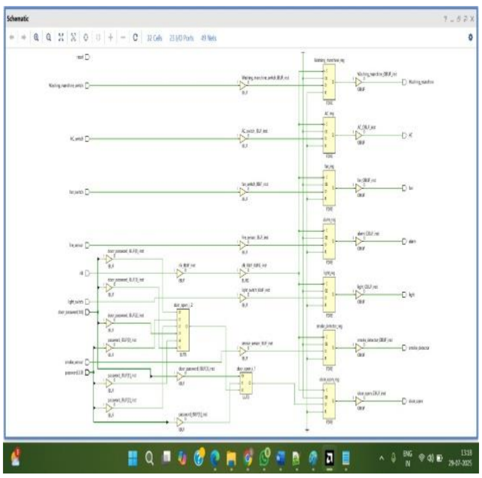

Fig: post-synthesis gate-level view

CONCLUSION

In this paper, we have developed a structure incorporating a highly efficient cost-effective smart home automation security system which can be integrated in any mobility assistive frameworks. Integrating sensors interfaced with an FPGA provides elevated efficiency.

FUTURE SCOPE

Looking forward, the smart home automation framework can be extended and improved in several ways to meet evolving user needs and technology trends. First, integration with wireless communication modules like Zigbee, Wi-Fi, or Bluetooth could enable remote monitoring and control via smartphones or cloud platforms, making the system accessible from anywhere.

Advanced AI and machine learning algorithms could be incorporated to enable predictive control, adapting appliance usage patterns based on user behavior, weather forecasts, or energy tariffs, further optimizing energy consumption and user comfort. Enhanced security measures, including biometric authentication or multi-factor verification, could be added to improve access control and privacy.

Additionally, expanding sensor coverage to include environmental monitoring (humidity, temperature, air quality) and health-related metrics could transform the system into a comprehensive smart living assistant. Lastly, miniaturization and cost optimization through newer FPGA or SoC technologies could make the solution more affordable and scalable for mass-market adoption.

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