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FPGA BASED HOME AUTOMATION

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Abstract: Centered on FPGA-based home automation utilizing the Basys 3 board, this project seamlessly integrates a suite of sensors tailored for temperature monitoring, door status detection, and remote-controlled operation of an LCD projector. Leveraging Verilog programming, the system ensures real-time temperature surveillance, with the capability to activate fans for optimal environmental control. Reed sensors are strategically deployed to detect door openings, triggering automated light activation, thus enhancing both convenience and security within the household. Empowered by FPGA control, users can remotely manipulate the lights, fans, and LCD projector, thereby augmenting the flexibility and accessibility of the home entertainment system.

Index Terms – Home automation, FPGA board, Verilog, security

I. Introduction

The modern era witnesses the convergence of advanced technologies, ushering in an era of smart living. Homes equipped with intelligent systems redefine comfort, convenience, and energy efficiency. Among these, Field-Programmable Gate Arrays (FPGAs) offer versatility and adaptability, providing a robust platform for sophisticated automation solutions.

In this paper, we present an FPGA-based home automation system developed using the Basys 3 board, aimed at addressing the diverse needs of contemporary households through innovative sensor integration and intelligent control mechanisms. A fundamental aspect of our FPGA-based home automation system is real-time temperature monitoring. By integrating temperature sensors with the Basys 3 board, our system offers homeowners insights into ambient temperature levels. This enables optimization of indoor comfort and implementation of efficient climate control strategies, contributing to energy savings by ensuring judicious use of heating and cooling systems.

In addition to temperature monitoring, our system integrates intelligent lighting control mechanisms triggered by door activity. Through reed sensors and FPGA logic, the system detects door openings and adjusts lighting accordingly. This proactive lighting automation enhances convenience and energy efficiency, tailoring illumination to household occupancy patterns while minimizing unnecessary energy consumption.

Our FPGA-based solution extends its capabilities to include advanced functionalities such as remote-controlled LCD projection. Utilizing the processing power of the Basys 3 board and wireless communication protocols, users can remotely activate and control an LCD projector, transforming any space into a versatile multimedia environment. This feature adds entertainment value and demonstrates the flexibility and scalability of FPGA-based home automation solutions.

Central to implementing our FPGA-based home automation system is the use of Verilog programming language. Leveraging the flexibility and scalability of Verilog, we developed a robust codebase orchestrating system components with precision and efficiency. This programming paradigm empowers us to harness FPGA technology's full potential, customizing system functionality to suit specific user requirements for seamless integration and optimal performance.

II. System level modelling

The system model utilizes the Basys 3 FPGA board as the central processing unit to manage sensor inputs and control outputs. Sensors, including temperature sensors for climate monitoring and reed sensors for detecting door status, interface directly with the FPGA.

For temperature monitoring, the FPGA continuously reads sensor data and processes it using predefined thresholds to trigger fan activation when temperatures exceed specified limits. Similarly, reed sensors provide input to the FPGA, allowing the system to respond to door openings by controlling connected lighting fixtures.

Additionally, the FPGA manages the interface with an LCD projector for remote-controlled multimedia display. By interpreting wireless commands received from a remote or mobile application, the FPGA activates the LCD projector and coordinates the selection and playback of multimedia content.

The entire system operates through the FPGA's programmed logic, which handles sensor data interpretation, decision-making based on predefined rules, and actuation of connected devices. This approach ensures efficient and responsive home automation tailored to user preferences and environmental conditions.

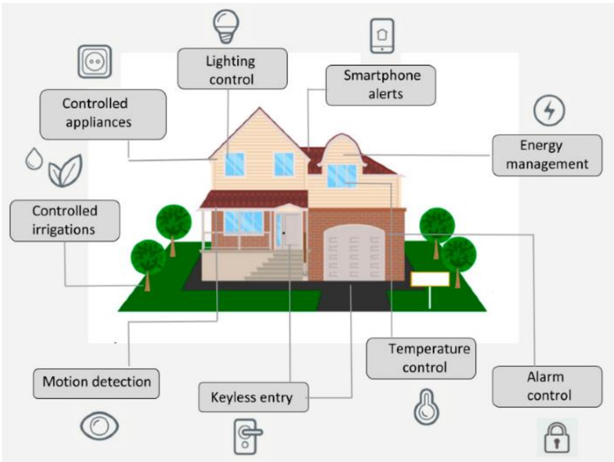

Fig 1: Home automation model

All sensors used in the system, including the IR sensor and the reed sensor, are directly integrated into the FPGA board. The FPGA board serves as the physical support for the development platform, offering seamless integration with standard FPGA synthesis and implementation tools. Specifically, the system utilizes the latest Artix-7 Field Programmable Gate Array (FPGA) from Xilinx, mounted on the Basys 3 board. This FPGA board features 1,800 Kbits of fast block RAM, an on-chip analog-to-digital converter, 16 user switches, 16 user LEDs, and a 4-digit 7-segment display. The signal from the IR sensor is processed through the Pmod JB input port.

III. Literature survey

In this literature survey we embark on an exploration of the burgeoning field of FPGA-based home automation systems, aiming to elucidate the current state-of-the-art and identify key trends and challenges [1]. First paper we reviewed “FPGA—based assistive framework for smart home automation” Md Sharif Ahmed, Ratri Mukherjee. Prosenjit Ghosh, SK Nayemuzzaman Department of Electrical Engineering 2022 IEEE l5th Dallas Circuit and System Conference (DCAS), this study presents a reconfigurable framework for automated home security and monitoring, leveraging FPGA technology and integrating sensors for fire safety and anti-theft measures.

“FPGA-based embedded architecture for IoT home automation application” Chee-Pun. Ooi, Wooi-Haw. Tan, Soon-Nyean. Cheong, Yee-Lien. Lee, V. M. Baskaran, Yeong-Liang. Low Faculty of Engineering, Multimedia University, Malaysia Indonesian Journal of Electrical Engineering and Computer Science ρ 646 Vol. 14, No. 2, May 2019, this project presents an IoT FPGA-based home hub for automating home operations, leveraging FPGA technology and an IoT platform [5]. Through Verilog HDL programming and WIFI extension, it enables sensor integration and user-configurable control rules for diverse home environments.

“Home Automation through FPGA Controller” Madhuri R Mukkawar Student, Dept.of E&TC NBN Sinhghad School Of Engineering Pune, India International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 3 Issue 3, March – 2014, this paper delves into the integration of network-enabled digital technologies for advancing home automation, presenting a design implemented in VHDL on FPGA. Leveraging GSM communication and SMS-based interaction, the system aims to enhance living standards through wireless technology [6].

The paper "An Interactive IoT-based Framework for Resource Management in Assisted Living During Pandemic" presented at ISQED 2021 likely explores an IoT framework tailored for managing resources in assisted living, particularly during pandemics. It may discuss the design and implementation of IoT devices for real-time monitoring and interactive control of resources [2].

The paper titled "Integration of Home Automation and Security System Controller with FPGA Implementation" published in the Annals of Emerging Technologies in Computing, volume 7, issue 5, explores the integration of home automation and security systems using FPGA technology. This study likely demonstrates how FPGA-based controllers enhance the functionality and efficiency of home automation and security systems, potentially offering insights into novel approaches for smart home development [3].

The paper titled "Home automation through FPGA controller" presented at the 2015 Online International Conference on Green Engineering and Technologies (IC-GET) explores the implementation of home automation using FPGA technology [4]. The authors, Sharma et al., discuss the design and development of a system that utilizes FPGA controllers to automate various aspects of home functionality. This study may provide insights into the integration of FPGA technology for enhancing home automation systems, potentially offering efficient and reliable solutions for smart home applications.

IV. Methodology

The methodology for implementing the FPGA-based home automation system involves several key steps. First, the hardware components, including the Basys 3 FPGA board, temperature sensors, reed sensors, and LCD projector, are assembled and connected according to the system design.

Next, the FPGA programming environment, such as Vivado, is utilized to develop the hardware description language (HDL) code, specifically Verilog, for interfacing with the sensors and controlling the output devices. This code defines the behavior of the FPGA in response to sensor inputs and external commands.

Once the Verilog code is developed, it is synthesized, implemented, and verified using simulation tools to ensure correct functionality and performance. This step involves testing the code under various scenarios and conditions to validate its effectiveness in managing sensor data and controlling connected devices.

After verification, the FPGA design is synthesized onto the Basys 3 board, and the hardware components are integrated into the home environment. This includes installing temperature sensors in strategic locations, such as living spaces and bedrooms, and mounting reed sensors on doors to detect openings.

Finally, the system is tested and evaluated in real-world conditions to assess its reliability, responsiveness, and overall performance. Any necessary adjustments or optimizations to the FPGA code or hardware configuration are made based on the test results to ensure optimal functionality of the home automation system.

4.1 Block diagram

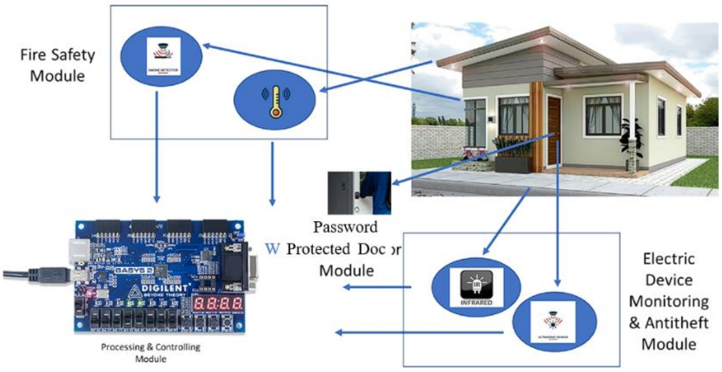

Fig 2. Block diagram of the proposed framework

In this block diagram, home automation is proposed with 2 main features such as Electronic Device monitoring & Antitheft Module, and a Password Protected Door Module. In our block diagram figure 2, 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, Door lock module which are essential modules for smart home automation and assisted living. All input signals contain data such as a password to turn ON and OFF security, door, and window are in input to the IR 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, window status for opening and closing window, output 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.

V. RESULTS AND DISCUSSION

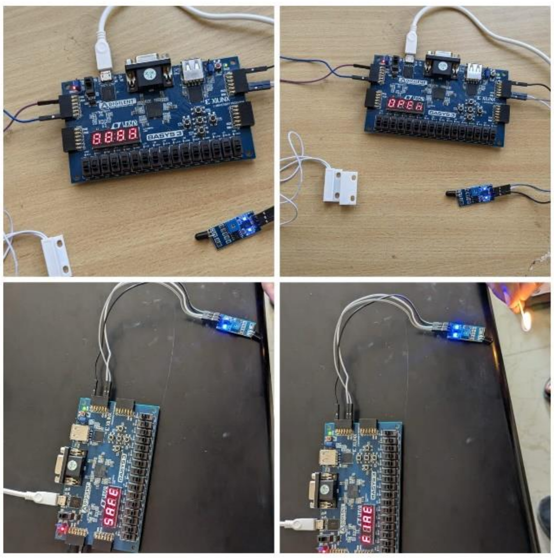

Fig 3: Result for home automation using FPGA

The culmination of the home automation project yields a multifaceted array of results aimed at enhancing the overall living experience. Through meticulous integration of sensors and components, the system achieves a sophisticated level of automation. Temperature sensors detect the temperature and shows fire detection which can further be used in fire alarm by integrating alarm interface, environmental comfort by activating fans remotely. Door status detection can trigger lights to illuminate spaces upon entry by interfacing more sensors, enhancing convenience and safety. Additionally, remote control functionality extends to an LCD projector, facilitating effortless management of multimedia systems. An interface, accessible via Wi-Fi-enabled USB, empowers occupants to monitor and control home devices remotely from any part of the home. Ultimately, the project's outcome embodies a seamless blend of technology and automation, fostering heightened efficiency, comfort, and convenience within the home environment.

VI. Conclusion

In conclusion, the FPGA-based home automation project represents a significant leap forward in residential living, offering a comprehensive suite of features designed to enhance comfort, convenience, and energy efficiency. Through seamless integration of sensor technologies, intelligent control algorithms, and user-friendly interfaces, the system provides users with unprecedented levels of control and accessibility, ultimately redefining the modern domestic experience. As smart automation continues to evolve, this project serves as a testament to the transformative potential of technology in shaping the homes of tomorrow.

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