HOME LIGHTING SYSTEM WITH OCCUPANTS COUNTING AND ALARM

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ABSTRACT: Energy consumption and home security has become major concern around the world. Smart home technologies are proposed to overcome the problem. FPGA based smart home lighting system with occupants counting and alarm is developed. Altera DE2 development board, PIR sensor modules and LDR are the main components. Controlled delay is achieved using frequency divider and up-counter. Two PIR sensors are used to detect walking direction for occupant counting. While LDR sensing light with voltage divider topology, alarm is triggered by motion detected. Limitation of PIR sensors used causes possible occupant counting errors. Future work emphasizing on extra accessibility is needed.

KEYWORDS: *FPGA, Internet of Things (IoT), Smart Home*

1.0 INTRODUCTION

As more electrical products and devices are getting introduced, domestic electricity consumption has increased heaps and bounds over the decades. As a result, energy efficiency has become a major topic to be studied by the world. Many studies have concluded that large amount of domestic electricity is wasted. 10% of citizens regularly leave the lights on when leaving a room at home, 21% of citizens regularly leaving the house, for example when going to work, while 7% of citizens admit that they usually leave at least one light on when going to bed as was discussed in Wei (2011). All these tell us that people are wasting domestic electricity unnecessarily.

Smart home automation system is proposed frequently to save energy. Skeledzija et al. (2014) suggests implementation of modern smart monitoring and control system for building automatization is able to significantly reduce energy consumption by increasing energy efficiency of building under control. Although there are many proposals for the automation of lighting in smart home system, it is obvious that a balance must be made between the cost of electric energy, the costs of smart devices and the particular needs of the owner (Missaoui et al (2014)).

As people are enjoying better quality of life with smart automations, there is an increasing number of people consider that home security is more important than other things. Implementation of home security enhancement appears more frequent on home automation system over recent years. In Hong et al. (2016), Internet of things (IoT) are introduced to smart home security implementation for high accessibility and enhanced security.

This paper proposes an experimental FPGA based smart home lighting system with occupant counting and alarm. The system includes 3 main features, controlled delay, occupants counter and light controlled exterior lighting with alarm. The system is built using low cost components such as PIR sensor module, LED and 5V buzzer. The control system of this proposed system is FPGA Altera DE2 development board.

2.0 SYSTEM AND CIRCUIT DESCRIPTION

The system is a smart lighting system which provides automation to the house. Like other smart lighting products, this system will turn on the lamp with the presence of occupants in the room. Lights will be turned off while the sensor not detecting any occupants' motion after a period. This feature is specially designed to be installed in bedroom which automatically turns off lights as the master fall asleep. To reduce energy consumption, lights will be turned off with enough luminosity in the area. Besides, occupants counter which comes along with the system provides ease of monitoring the number of occupants in specific room. In addition, this system upgrades the security of house by sensing suspicious motion outside the house during nighttime. If motion is detected, outdoor lamps will start to blink and alarm sirens to draw attention and alert the owner. In this project, we are following the instruction given in Altera (2013).

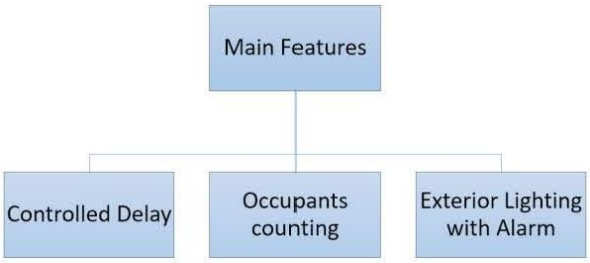


Fig. 1. Features of System

A. Controlled Delay System

Delay is popular in smart home applications as it provides buffer to the system from creating errors. In this system, delay is implemented in indoor lightings. Indoor lightings will be turned off after a delay instead of switching off immediately as no motion is detected by sensors. Although most PIR sensors have their own delays and can be adjusted, a controlled delay is a smarter choice. To create a delay, frequency divider IC 74292 and bidirectional up-down counter IC 74193 are used. IC 74193 is used as up-counter only in this system. Frequency divider divides the internal clock of the FPGA, 50MHz which in turns increases the period. The role of the up-counter is to multiply the period and provides customizability. The final period is the delay time of the system. The formula used to calculate frequency divided by frequency divider is as follow:

$$f_d = \frac{50M}{2^n} \tag{1}$$

where n is the decimal number of the binary code input of the frequency divider. As the system will switch off the lamp after a period, a 4 input AND gate is connected to the output of up-counter. This logic gate resets a SR latch and in turn, switching off the lamp when counter reaches desired output. This output is set by manipulating connections between counter and AND gate. For example, if multiplication of 5 is needed, the expected last output of counter before lamp is switched off will be 0100 as 0000 is also counted, 3 NOT gates are added to the respective binaries. The formula to calculate the delay period, T is as follow:

$$T = f_d(k+1) \tag{2}$$

Apart from switching off, the lamp should be on as long as there is occupant. In the circuit, PIR sensor is connected to CLR pin of up-counter and S pin of SR latch. As the sensor senses motion, up-counter will be cleared and counts again. At the same time, SR latch is set and turns on the lamp. The reason SR latch is deployed instead of JK latch is because the 2 inputs will never be high at the same time as PIR senses motion, it clears the counter, forcing the output of AND gate to be low.

B. Occupants Counter

The main idea of the counter is to detect the direction of the walking motion in order to calculate the number of occupants. For instance, the counter will perform summation of 1 when a person enters a room and subtraction of 1 when he exits the room. To achieve this, 2 PIR sensors are used. A sensor outside of room named PIR enter and another inside named PIR exit. The sequence of detection indicates the direction of motion. The number of occupants can be viewed from the 7 segments display on FPGA development board.

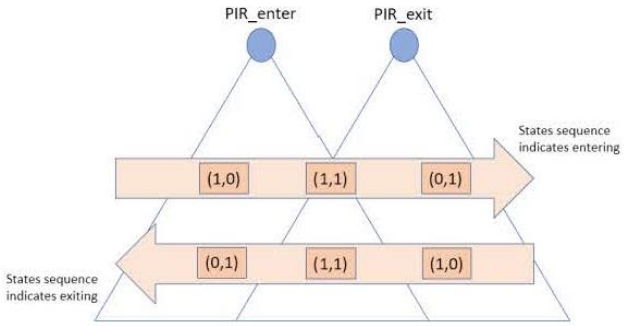


Fig. 2. Working Principle of Direction Detector

To transform the detected direction to mathematical operations for a up-down counter, a logic circuit is designed using combinations of logic gates. The circuit uses shift registers to record the input from PIR sensors and once specific sequence of inputs are detected, the circuit will trigger counter to increase or decrease. Counter will be up for 1 bit when PIR_enter records 110 and PIR_exit records 011. Counter will be down for 1 bit when PIR_enters records 011 and PIR_exit records 110. To record the inputs correctly, the clock of the shift registers is controlled by a circuit. This circuit consists of D-flip flops and XOR gates. This circuit will give a pulse to the clock pin of shift register when state change of either PIR sensors is detected.

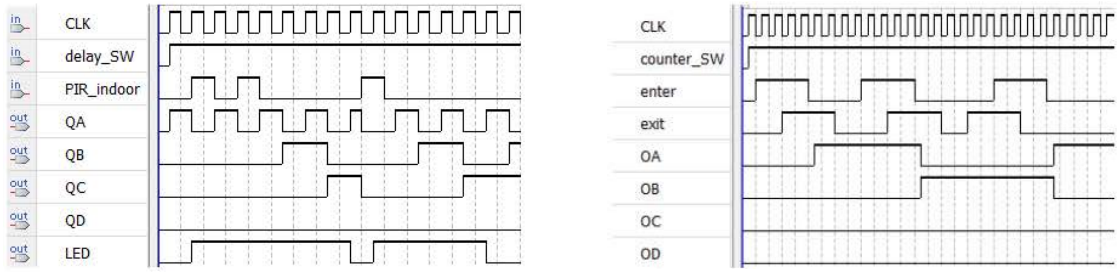
C. Exterior Lighting with Alarm

Exterior lightings cannot be ignored in home lightings. It takes up a large composition of home lamps and energy consumption especially for detached residence. In this system, exterior lightings are controlled by luminosity. As the sunlight scattering off the atmosphere during dusk, luminosity decreases until a threshold to turn on the lamps. Light dependent resistance, LDR is used to detect luminosity. A voltage divider consists of LDR and potentiometer is set up to provide easy adjustment to the sensitivity of LDR.

Alarm system is optional and can be turned on to operate anytime via master control board, FPGA. When alarm mode is on, PIR which are mounted near doors and windows will start to operate. Any suspicious motion detected will trigger the alarm, resulting in blinking lights and sirens to draw attentions from neighborhood and owner. The circuitry on this system is much simple, which only includes logic gates and frequency divider to create blinking lights and siren. The divided frequency is 1.49Hz. In other words, the lamps light up and off 3 times in 2 seconds, which is optimal for drawing attentions.

4.0 SIMULATIONS

Stimulations about few features on the project are done. The involved features are controlled delay system, occupant counter, light sensing and alarm mode. Stimulations are done using ModelSim which creates vector waveform files. All waveform of clock, CLK in these stimulations are assumed to be divided by frequency divider. This is because the division is too large and impossible to display internal clock of 50MHz and divided frequency at the same time.



(a) (b)

Fig. 3. Waveform Signal (a) Controlled Delay System (b) Occupant Counter

Waveform graph in Fig. 3(a) shows that motion detected by PIR sensor will force switch on the LED and clear the values of counter. The values of counter increases by 1 bit every clock cycle. When values of counter reach 0100, LED is switched off, noted that QD is MSB while QA is LSB. After this, any motion detected by PIR sensor will retrigger the LED to high logic level. While, in Fig. 3(b) simulates Logic level of PIR enter is indicated as 'enter' and PIR exit is indicated as 'exit' on waveform graph. As (1,0), (1,1), (0,1) states sequence of PIR sensors are detected, the values of counter increases by 1. As (0,1), (1,0), (1,1) states sequence of PIR sensors are detected, counter subtracts its values by 1. Noted that (state of PIR enter, state of PIR exit).

5.0 EXPERIMENTAL RESULS AND DISCUSSION

All the systems are integrated into a prototype of smart home lighting system. The prototype is connected to FPGA development board while operating. To test and analyze the prototype, switches to turning on and off the features are added.

Fig. 4. Prototype of Project

During the testing phase, PIR sensor is not working as expectation, that is, output is high when motion is detected, output is low when motion is not detected immediately. PIR sensors used in this project are low cost PIR sensor module which are popular in Arduino projects. In practical, the sensor will have high output for a period when motion is detected and low output for a same period afterwards. At the same time, PIR sensors are not able to detect any motion until the sensor finishes giving low output for the period. This gives vulnerability to the system as there is a duration where PIR sensors are not working. The period is controlled by rotating pin on the sensor. The shortest period is 2 seconds approximately as period is not exactly same every time. This behavior of PIR sensor module has less impact on controlled delay system and alarm system as PIR sensors are only used to trigger the system. Impact of this behavior towards occupant counter is heavy as this system operates depending on the states of two PIR sensors. The first case of error is when a person walks in and out of the room short time. Ideally, the PIR sensors are unable to detect for 4 seconds after the first detection. Therefore, the system is unable to detect a person

walking out from the room if he left the room within 4 seconds after entering. Another case of error occurs when a person walks too fast. In practical, PIR sensors will not maintain high output for exactly 2 seconds. The period is different every time but closed to 2 seconds. Take the event that a person walks fast into room as an example, if PIR enter maintains high output longer than PIR exit, the event will be ignored by the system. The error will only occur as the person walks fast, a normal walking speed is always able to be identified by the occupant counter.

A PIR sensor module without delay is better than module with it. PIR sensor module without delay will be high output when detection is detected and immediately low output when detection is not detected. This behavior is more suitable to do the job of occupant counter. With this, 2 cases of error can be overcome. Future research on smart home lightings should focus on quality and type of components. Type of lamps has great impact on power saving. For instance, LEDs have proven to be extremely effective compared to other lightings due to their long lifespan and increased efficiency. PIR sensors should be fast and responsive at the same time without false detection. Access and control of the system should be upgraded also in future research. Internet of things which is popular in recent years can be implemented into the system for extra accessibility. The owner can monitor and access condition of home via webs and apps.

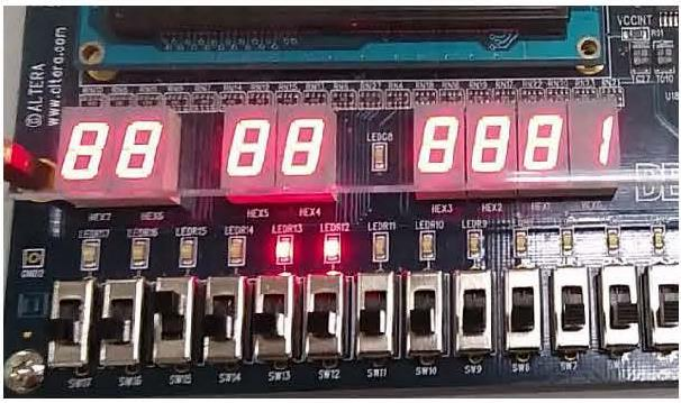


Fig. 5. 7-Segment display of Occupant Counter

6.0 CONCLUSION

In conclusion, smart home lighting system is designed and operates based on Quartus II and FPGA Altera DE2 development board. Block schematic diagram method is used throughout the designation of smart home lighting system in Quartus II.

The system offers remote control via the FPGA board. Features of the system can be controlled by switches on the development board. States of LEDs can be monitored on the board. The system shows high accessibility according to Karmakar (2016). LEDs can be controlled by luminosity and occupancy. LDR which is under shade has low resistance, thus high voltage and it is being considered as high input to the system turns on the LED. Motion detected by PIR sensors also successfully turns on LED. Occupant counter is capable to count people in a room by identifying walking direction. 2 PIR sensors are used to accomplish this task. At the same time, it displays the number through 7-segment display on FPGA board. For alarm mode, LED blinks and alarm sirens only when alarm mode is switched on and PIR sensor senses motion. The warning from system will only stop by switching off the alarm mode through FPGA board.

The limitation of this system can be overcome by replacing suitable sensors such as responsive PIR sensor module without delay. Suggestion on upgrading accessibility of the smart system is implementing internet of things, IoT.

7.0 ACKNOWLEDGEMENT

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