DEVELOPMENT OF LIGHT SEEKING ROBOT CAR USING LDR

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ABSTRACT: Nowadays, the development of robot car has become very common and advance in this era. The development of robot car is to help people to solve their daily problems. Thus, light seeking robot car is introduced in this project. A light seeking robot car is a car which move corresponds to the light intensity. The light seeking robot car will move towards the direction of light. Light Dependent Resistor(LDR) is used with another resistor to create a light sensor circuit. This circuit will help to detect light and transmit signal to the car system. FPGA board is used to design the digital circuits of the system. Pulse Width Modulation (PWM) is also used to control the speed of the car. To produce PWM signal, an irregular synchronous counter is designed and used with 4-to-1 multiplexer. This report demonstrates a model car which runs according to the light intensity and the direction of the light. The car is tested using a torchlight to test the sensitivity of the light sensors. Simulation of the system has been made by using Quartus II. Oscilloscope is used to measure the PWM signal. The car is developed and will be used in many applications.

KEYWORDS: *FPGA, Light Dependent Resistor (LDR), Irregular Synchronous Counter, PWM*

1.0 INTRODUCTION

Nowadays, the development of robot car has become very common and advance in this era. The development of robot car is to help people to solve their daily problems. In this project, a light seeking robot car is introduced to solve our problems in daily life. Mahapatra (2008) introduces a light seeking robot car is a car which will detect the light and move towards the direction of the light. The light seeking robot car can be used in many applications such as watch dog robot or moving platform of the potted plants in smart gardening system.

In order to build a light seeking robot car, light sensors are used in this project. Light Dependent Resistors(LDR) and resistors with fixed resistance are used to build a simple light sensing circuit. Besides, in order to control the movement of the robot car, a field-programmable gate array (FPGA) is used to build our digital circuits by using Quartus II. Similar project developed in Garcia (2010). In this project, the FPGA board that we used is Altera DE2 Board. To control the direction of the robot car, a few of programmable logic gates are used so that the car moves towards the direction of the light. Moreover, to control the speed of the DC motor of the car, a technique which is called Pulse Width Modulation (PWM) is used. Moreover, PWM wave will be transmitted to the motor driver to control the speed of the DC motors.

2.0 SYSTEM DESCRIPTION

A. Light Sensor Circuit

In order to build a light sensor circuit, a LDR is connected with a resistor in series. A 5V DC supply from the header of FPGA is connected to the LDR and resistor so that to form a voltage divider which the potential difference of the LDR depends on the light intensity. The potential difference of LDR will be used as the input of the light control logic gate circuit. Three light sensor circuits are used, which represent left light sensor, right light sensor and back light sensor.

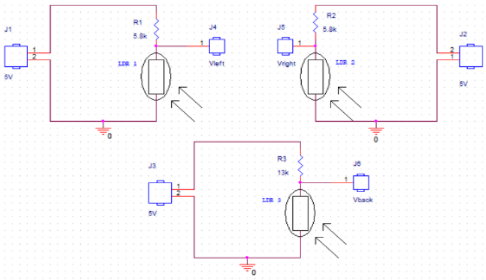

Fig. 1. Circuit diagram of the completed light sensor circuit

B. Light Control Digital Circuit

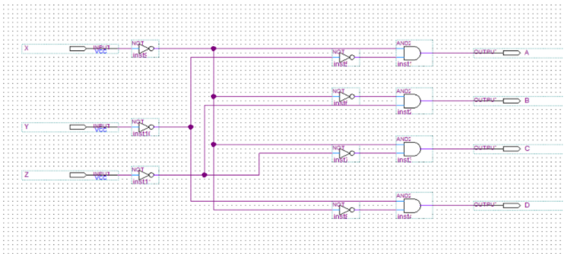

Fig. 2. Block diagram of Light Control Digital Circuit

Digital circuit is programmed by Quartus II in Altera DE2 board in order to control the movement of the car, digital circuit is used to analyze and interpret the input signal from the light sensors and send output signal to the L293D motor driver. In this circuit, logic gates such as NOT gate and AND gate is used. This circuit is an active low digital circuit because as the light intensity increases, the resistance of the LDR decreases, thus the potential difference across it decreases. Therefore, the input signal will be low when the light intensity increases at the surrounding of the light sensors. To allow the car moves towards the direction of the light, the circuit should be in active low so that the car will only responds when there is light around it. Besides, active low signals are used in digital circuitry to reduce errors caused due to interference (noise), the information was mentioned in Shaikh (2018).

C. 3-bit Irregular Synchronous Counter

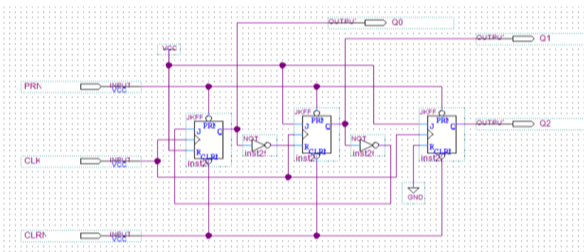

Fig. 3. Block Diagram of Irregular Synchronous Counter

To produce PWM signal, irregular synchronous counter is used. The clock of the counter is connected from the output signal of frequency divider. The state diagram of the counter is shown in Fig 4. The most significant binary bit of the counter is represented by Q_2, whereas the least significant binary bit is represented by Q_0. Thus, it will produce three types of PWM signal which represent 100% duty cycle (Q_2), 66% duty cycle (Q_1) and 33% duty cycle (Q_0).

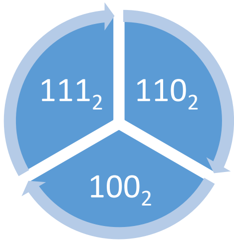

Fig. 4. State Diagram of Irregular Synchronous Counter

D. 4-to-1 Multiplexer

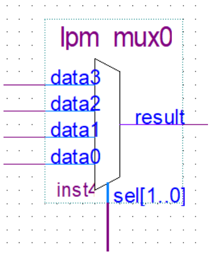

Fig. 5. Block Diagram of 4-to-1 Multiplexer

According in Altera (2013), 4-to-1 multiplexer is used to select the mode of speed of the motors. The selection inputs are connected to two toggle switches, which is SW16 and SW17 on the DE2 Board. Data0 input, D_0 will be connected to the ground, and data1 input, D_1 will be connected to output Q_0 from the irregular synchronous counter. D_2 and D_3 are connected to output Q_1 and Q_2 respectively. Therefore, 4 speed modes of motors can be selected by using the two toggle switches. The output of the multiplexer will be the PWM signal that is selected by the user. The output signal is then sent to the motor driver.

3.0 METHODOLOGY

A. Design of Light Control System

The procedure in this project was following the instruction in Serrano J. (2007) in order to make the car move towards the direction of light, truth table is drawn to design the digital circuit. The input signals are from the light sensors.

1-Dark, 0- Bright (Active Low)

Table I. Truth Table of Light Control Digital Circuit

Input			Output				
Back, X	*Left, Y*	*Right, Z*	*IN1, A*	*IN2, B*	*IN3, C*	*IN4, D*	*Movement*
0	0	0	0	0	0	0	Stop
0	0	1	0	0	1	0	Back to left
0	1	0	1	0	0	0	Back to right
0	1	1	1	0	1	0	Backward
1	0	0	0	1	0	1	Forward
1	0	1	0	0	0	1	Left
1	1	0	0	1	0	0	Right
1	1	1	0	0	0	0	Stop

Then, by using the Karnaugh maps, the results of the design of the circuit are shown in the form of Boolean expressions.

$$A = \bar{X}Y \quad (1)$$

$$B = X\bar{Z} \qquad (2)$$
$$C = \bar{X}Z \qquad (3)$$
$$D = X\bar{Y} \qquad (4)$$

The digital circuit is then built based on the expressions above.

B. Design of PWM Speed Control System

To design the irregular synchronous counter, transition table is drawn.

Table II. Transition Table of irregular synchronous counter

Present State			**Next State**			**Flip Flop Transition**					
Q_2	Q_1	Q_0	Q_2	Q_1	Q_0	J_2	K_2	J_1	K_1	J_0	K_0
1	1	1	1	1	0	X	0	X	0	X	1
1	1	0	1	0	0	X	0	X	1	0	X
1	0	0	1	1	1	X	0	1	X	1	X

Then, by using Karnaugh maps, the logic expressions of the flip flops are obtained.

$$J_2 = J_1 = K_0 = 1 \qquad (6)$$
$$K_2 = 0 \qquad (7)$$
$$K_1 = \bar{Q}_0 \qquad (8)$$
$$J_0 = \bar{Q}_1 \qquad (9)$$

From the logic expression, the 3-bit irregular synchronous counter is built.

Fortunko C. M. (1991) suggests the output signal from the frequency divider will be used as the clock of the 3-bit irregular synchronous counter. Three period of clock wave will produce one period of PWM wave. Thus, the frequency of the clock is three times of the PWM signal.

$$F_{PWM} = \frac{F_{CLK\_OUT}}{3} = \frac{3295.90}{3} = 1098.63Hz \qquad (10)$$

Next, the PWM output signals will be connected to the data inputs of the 4-to-1 multiplexer.

Table III. Truth Table of The 4-to-1 Multiplexer

S_1	S_0	Output
0	0	0
0	1	Q_0
1	0	Q_1
1	1	Q_2

The output signal of the multiplexer will be controlled by the toggle switches according to the table above.

4.0 RESULTS AND DISCUSSION

A. Simulation

The simulation is done by using the simulator in Quartus II 9.0. The simulation of the light control digital circuit is shown below.

Fig. 6. Timing Diagram of Light Control Digital Circuit from Simulation.

The results from the simulation match the results from the truth table. Thus, the design of the digital circuit is correct. For the 3-bit irregular synchronous counter, the simulation is shown below.

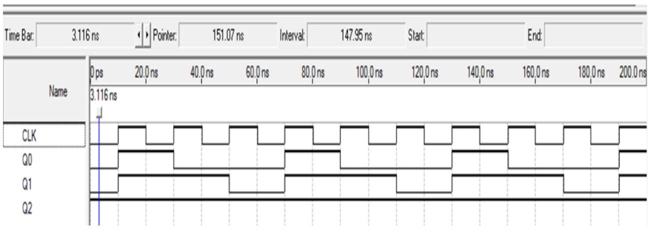

Fig. 7. Timing Diagram of Irregular Synchronous Counter from Simulation.

From the simulation, it is proven that three types of PWM waves which are 100%, 66% and 33% duty cycle square waves are produced. It is also proven that Eq. 10 is correct and accurate. The measurements of PWM waves from oscilloscope prove that the frequency of the PWM wave is almost the same as the calculated frequency.

B. Experiment

Before testing the robot car as in Fig. 8, the resistance of the resistors in the light sensor circuits has been adjusted so that the car will not operate under normal room light. Torchlight is used to test the sensitivity of the light sensors and the DC motors of the car. The car is operated with 33% of the full speed. First, when the bright light is at the left light sensor, only the right DC motor runs clockwise. It means the car moves to the left. Then, when the bright light is at the right light sensor, only the left DC motor runs clockwise, which means the car moves to the right. When the bright light is at left and right sensors, both DC motors run clockwise, which means the car moves forward.

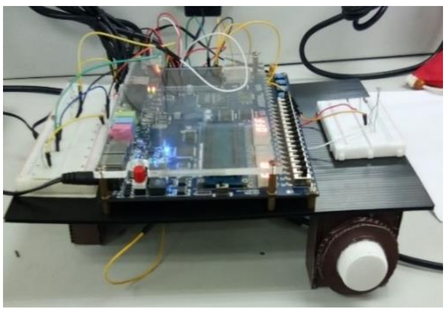

Fig. 8. The model of the light seeking robot car

Next, when the bright light is at the back sensor, both DC motors runs anticlockwise, which means the car moves backward. When the bright light is at left and back sensor, only the right DC motor runs anticlockwise. When the bright light is at right and back sensor, only the left DC motor runs anticlockwise. Lastly, when all of the light sensors are under bright light, the car stops running if the car is running before. Therefore, the light control system of the car is successful as the car moves towards the direction of light. Then, when the two toggles switches are used to change the speed of the motors, the motors run faster when the car operates at 66% or 100% of the full speed. Thus, the PWM speed control system is successful as the speed of the car can be controlled. The extra features such as LEDs and 7-segment displays are functioning well too as shown in Fig. 9.

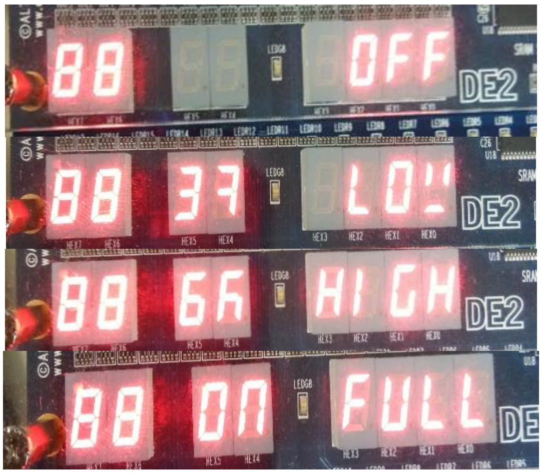

Fig. 9. The 7-segment displays at 4 speed modes

C. Discussion

In practical, the car can move towards the light by using the systems in this project. However, there are some weaknesses in this system. For example, the car cannot move more precisely based on the condition and the light intensity of the surrounding.

Hence, to improve the car system, more light sensors should be used in the system so that the car moves more precisely according to the light intensity of the surrounding. The resistors in the light sensor circuits should be replaced with potentiometers so that the sensitivity of the light sensors can be adjusted. The toggle switches should be replaced bylight sensors so that the speed of the car changes according to the light intensity. The PWM speed control system should be modified too by using light sensors as the inputs so that the car can become an autonomous car. Furthermore, other sensors such as IR sensor or ultrasonic sensor should be added in front and at the back of the car so that to avoid the obstacle in front or at the back of the car.

5.0 CONCLUSION

In this project, the car is successfully run according to the direction of the light. The speed of the car can be controlled by the toggle switches too. The objectives of this project have been achieved.However, the limitation of this system is that the car system cannot analyze the other condition of the surrounding such as obstacle in front of the car. Thus, other sensors such as IR sensor or ultrasonic sensor can be added. Moreover, to make the movement to be more precisely, more light sensors can be added. Toggle switches can be replaced with sensors so that the car can be operated autonomously.

6.0 ACKNWLEDGEMENT

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7.0 REFERENCES

Altera (2013). DE2-115. *User Manual. World Leading FPGA Based Product and Design Services.* Terasic Technologies Inc.

Garcia G. T., Griselda S. G., Cortes J. I., Marin C. N. L., Mariano L. G. & Villafuerte-Herrera F. (2010), Controlled System For Distance Sensing Using FPGA, *International Conference On Instrumentation Applied Science*

Fortunko C. M. (1991). Generation and reception of ultrasonic signal—Ultrasonic testing equipment. In *Nondestructive Testing Handbook, 2nd ed. Vol. 7, Amer. Soc. Nondestructive Testing,* Columbus, OH

Serrano J. (2007). Introduction to FPGA design. In *CAS-CERN Accelerator School Course on Digiatl Signal Processing*. Pages 231-247

Shaikh U., Bawangade S., Tahseen A., Anjum S. & Nasiruddin M. (2018). Design of an FPGA based Control System for Robot, *International Research Journal of Engineering and Technology*, 5(3), 2675-2680

Mahapatra R. P., Kumar K. V., Khurana G. & Mahajan R. (2008) . Ultra Sonic Sensor Based Blind Spot Accident Prevention System, *International Conference on Advanced Computer Theory and Engineering*