Penerbit Akademia Baru

Journal of Advanced Research in Computing and Applications

Journal homepage:
https://akademiabaru.com/submit/index.php/arca/index
ISSN: 2462-1927

Infrared Sensor and PWM Integration Using FPGA Platform for Ground Vehicle Navigation and Speed Control

Wan Rahiman[1,*]

[1] School of Electrical and Electronic Engineering, Universiti Sains Malaysia, Engineering Campus, Pulau Pinang, Malaysia

ARTICLE INFO

Article history:
Received 5 August 2021
Received in revised form 9 October 2021
Accepted 23 November 2021
Available online 4 December 2021

Keywords:
FPGA, Infrared (IR) sensor, Pulse Width Modulation (PWM)

ABSTRACT

In today's modern world, an autonomous driving system where a vehicle or a robot is capable of moving without control is a promising technological con-cept. However, at the same time, manual control system are still playing a significant role in robotic field. The final goal of the work is to create a robot car system that utilizes both manual and auto control through usage of the in-frared (IR) sensor. The infrared sensors enable robot to be controlled through manually or through obstacle while making the prototype low-cost and af-fordable. This paper demonstrates the development of prototype of the IR sen-sor controlled robot car. The main objective of this design is to focus on ver-satility, durability, simplicity and improvised operations.

1. Introduction

An infrared (IR) sensor is an electronic instrument that is used to sense certain characteristics of its surroundings and there are many applications by means of IR device [1]. In general, this type of sensor is either by producing or detecting infrared radiation. Infrared sensors are used for measuring the heat of its surrounding; emitted by an object and detecting motion. As projected, the work optimizes the use of IR transmitter to measure the pulse rate of the drive while driving the vehicle [2].

IR technology is not only found in industry, but also in day-to-day life. Data transfer for wireless application, for example, use an IR detector to understand the signals sent from a remote control [3]. There are two well-known types of short range using remote control automation. N IR sensors are used for motion detection systems, and Light Dependent Resistor (LDR) sensors are used for outdoor lighting systems. The advantages of infrared sensors comprise of low power requirements, simple circuitry and portable features.

Flynn has studied navigation system that utilize IR implementation for motion. Multiple sensors can be used on a controlling mobile robot so that it can perceive its environment with better accuracy than if either sensor were used alone [4].

* *Corresponding author.*
E-mail address: wanrahiman@usm.my (Wan Rahiman)

Infrared sensors can be active or passive and they can be split into two main types:

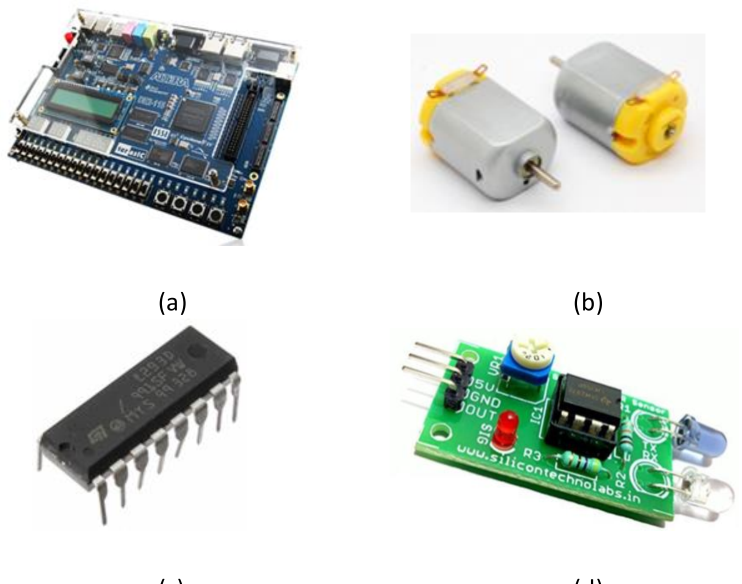
i. Thermal infrared sensors [5] – use infrared energy as heat. Their photo sensitivity is independent of the wavelength being detected. Thermal detectors do not require cooling but do have slow response times and low detection capabilities.
ii. Quantum infrared sensors [6] – provide higher detection performance and faster response speed. Their photo sensitivity is dependent on wavelength. Quantum detectors have to be cooled in order to obtain accurate measurements.

2. Project Development

The purpose of this project is to build and develop a navigation system that takes input from IR sensors, using them to help the vehicle move forward and turn based on the inputs given. Overall process can be divided into 3 parts:

i. Picking up of surrounding signals through sensors
ii. Signals sent to central processor. Processor read the signals, computes the direction for the car, and send out the signals.
iii. Wheels of robot receive the signals and move.

The main objectives are developing of a system that enables auto and manual control, in which auto mode enable detection and passing of obstacles in front, while manual mode ensure the car to follow the direction of motion from user. The project was using Altera Cyclone as a microcontroller and a few other items as referring in Figure 1.



(a) (b) (c) (d)

Fig. 1. Main components (a) Altera Cyclone IV E (ce115f29c7n), (b) DC Motor, (c) Microcontroller L293D IC, (d) IR Sensor

The developing a prototype is taking a concept introduced by Murati *et al.,* [7] to compare the physical and mathematical results conducted in accordance with the properties of radio-controlled car with the results that come out from the simulation in FPGA platform. As it was mentioned, these results will depend on the physical properties of radio-controlled car and the properties of the environment. In order to have successful result, which leads to proper operation (desired movement) of a radio controlled, the model of the car must be chosen the appropriate electrical component and the suitable electrical component for a safe movement. The works were followed set of guidelines introduced by Sedra [8] and Gray [9] on how to analyze and design electronic circuits.

In order to build the IR-based autonomous navigation system for the vehicle, few considerations relate to multiple problems that may occur during project completion. Listed below are risks that need to be taken into consideration.

i. Motor-Control Circuit: Using dc motors, experimentation is needed to figure out how the both motors are controlled to move.
ii. Sensors used are highly sensitive. Infrared sensors are difficult to control and need to test several times for a same reading and were used up to 3 of them. This increased the difficulties in handing them.
iii. Suitable circuit design is required to enable to operate each component of the vehicle system, i.e. IR sensors, direct motors. Integrating all of the software into one operational module will potentially require debugging, testing and redesigning.

3. Procedure and Results

3.1 Components and Functions

A few components are needed for the project. 2 Direct Current (DC) motors are used as wheels, and also L293D IC to act as the motor driver for both of the dc motors. For the computing unit / programmable integrated circuit (IC), in this project uses Field Programmable Gate Array (FPGA) named Altera Cyclone IV E (ce115f29c7n) by Intel [10]. Some components that come with the FPGA are also used, such as toggle switches and LEDs. Software use to program the FPGA is Quartus IV 12.1 edition.

Firstly, the IR sensors will pick up motion or object from 3 different directions (front, left and right). If a signal is detected, IR sensor will send it to FPGA for analysis, and output is given based on mode that's been chosen. For auto mode, the robot car will move to the right if left IR get reading, left if right IR give reading, and stop if straight path is blocked. For manual mode user can control the direction of car by blocking the IR sensor, (left if left sensor has a reading, right if right and so on.) Controlling of both left and right motor are done using the L293D IC that act as motor driver.

3.2 Block Diagram

A diagram showing in schematic from the general arrangement for the L293D IC of a complex system [11] can be found in Figure 2. In Figure 3, flowchart gives a logical flow of the project and the process for the project to show a stage by stage progression.

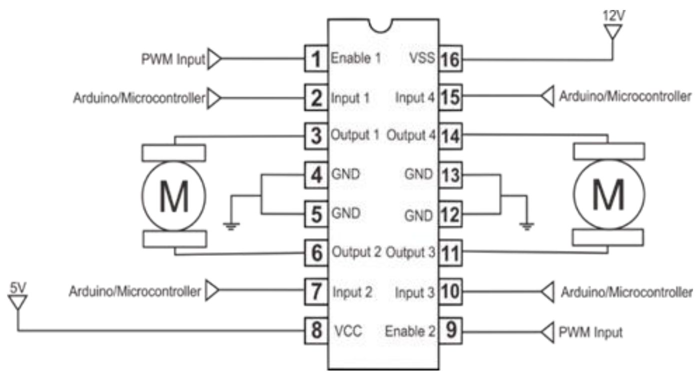


Fig. 2. Pin of IC L293Dc

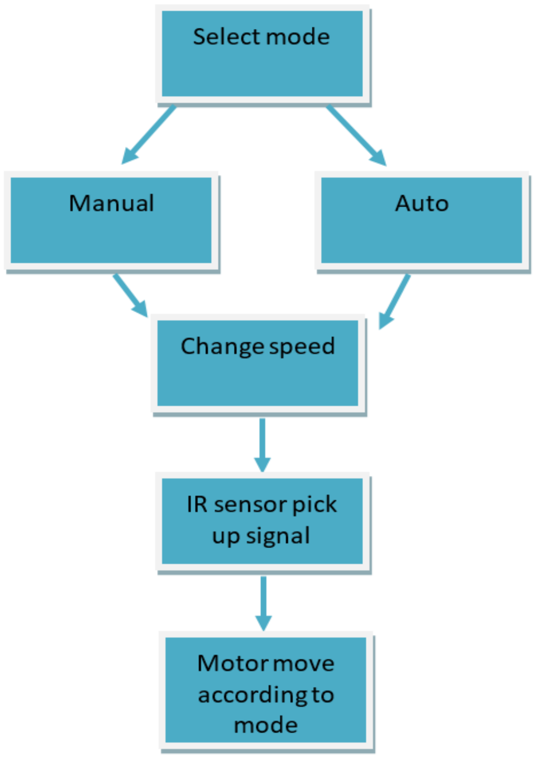


Fig. 3. Flowchart of the process implemented

3.3 Motor Part Design

Manual Mode: There are 2 inputs for each motor. But only connect to 1 input, O1 for left motor and O2 for right. I1, I2 and I3 represent IR straight, left and right.

Table 1
Manual truth table

I1	I2	I3	O1	O2
0	0	0	0	0
0	0	1	1	0
0	1	0	0	1
1	0	0	1	0

Auto Mode

Table 2
Auto truth table

I1	I2	I3	O1	O4
0	0	0	1	1
0	0	1	0	1
0	1	0	1	0
1	0	0	0	0

Logic gates were implemented to build the circuit. K-maps is used to find out which logic gates to be used. Circuit Diagram in Figure 4 shows the circuit for both manual and auto mode.

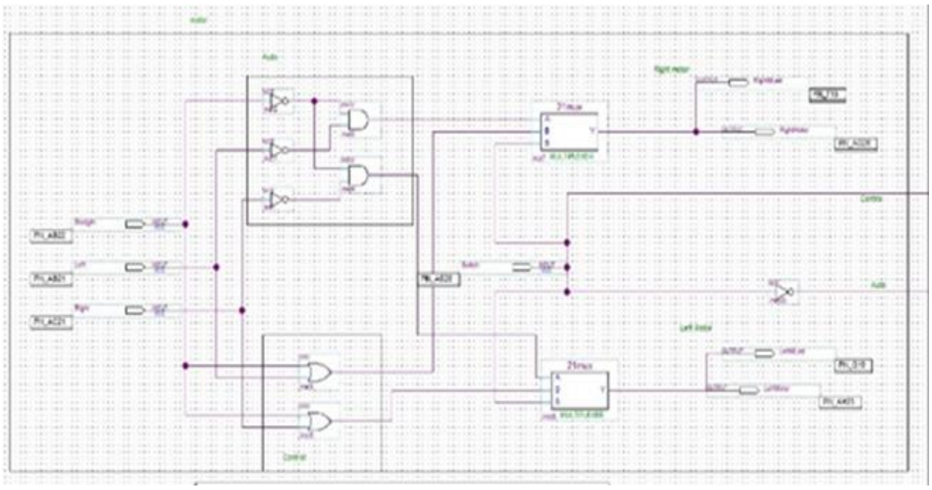


Fig. 4. Motor circuit as in Quartus 12.0

3.4 Pulse Width Modulation (PWM)

The work used PWM, the technique that uses digital input to control output, to modulate the speed of dc motor [12]. Frequency divider is used to decrease the frequency of original clock. 3 different frequency square wave are produced through 3 bit up-counter (Q1, Q2 and Q3) and each is use for 25%, 50% and 75% speed. 100% power is achieved by directly taking the Vcc as input.

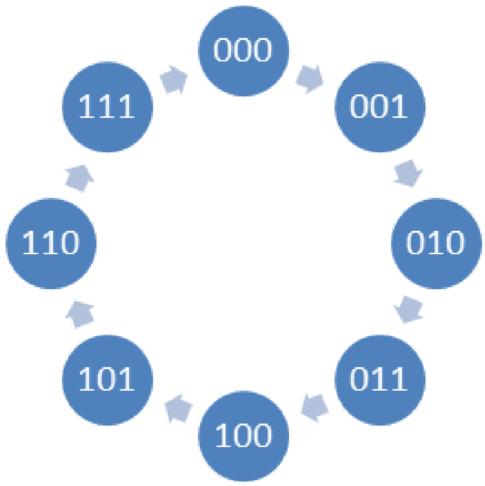


Fig. 5. State Diagram for 3 bit up-counter

Truth table for T flip-flop and Counter with output as follows:

Table 3
Truth table for T flip-flop

Qi	Qi+	T
0	0	0
0	1	1
1	0	1
1	1	0

Table 4
Truth Table for counter

Q2	Q1	Q0	Q2+	Q1+	Q0+	T2	T1	T0
0	0	0	1	0	0	1	0	0
1	0	0	1	1	0	0	1	0
1	1	0	1	1	1	0	0	1
1	1	1	0	0	0	1	1	1

In Figure 6, 4 AND gates and 1 OR gate are used as switch to choose between suitable speed.

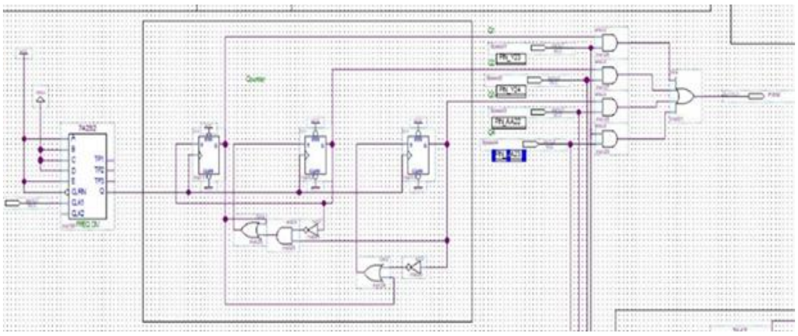


Fig. 6. Counter circuit

3.5 Display

7-segment display on FPGA as display with 2 displays is set, 1 for mode and one for speed.

Mode display: For the displaying mode selection, the truth table and k-maps were used to get all needed output and build the circuit through or gate.

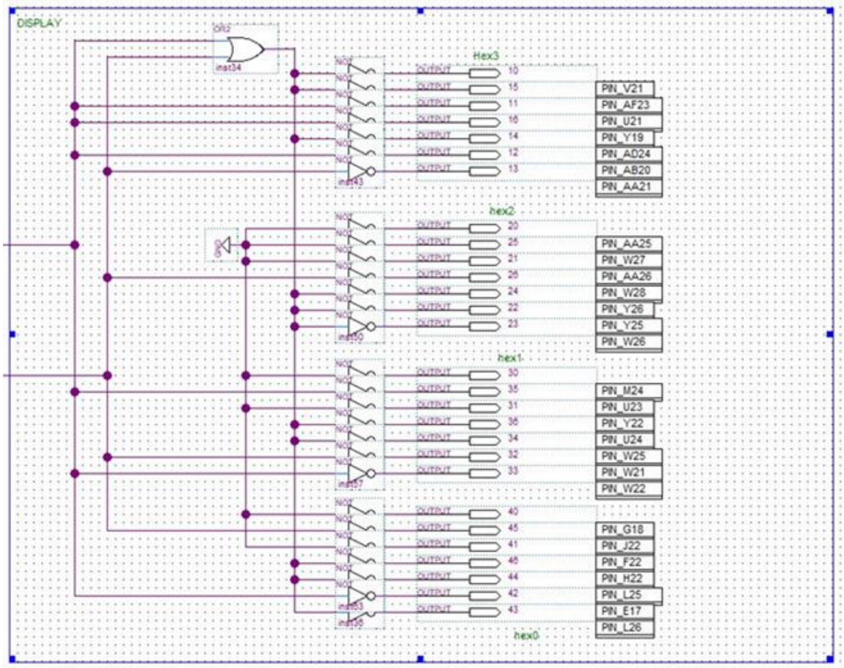


Fig. 7. Circuit for mode display

Speed Display: Then, truth table and K-maps were used to get the needed output from input.

Table 5

Truth table to get binary order of number

I4	I3	I2	I1	C	B	A
0	0	0	0	0	0	0
0	0	0	1	0	0	1
0	0	1	0	0	1	0
0	1	0	0	0	1	1
1	0	0	0	1	0	0

Binary number generated corresponded to the switch pressed. IC 7447 computed to convert binary code to 7-segmented code.

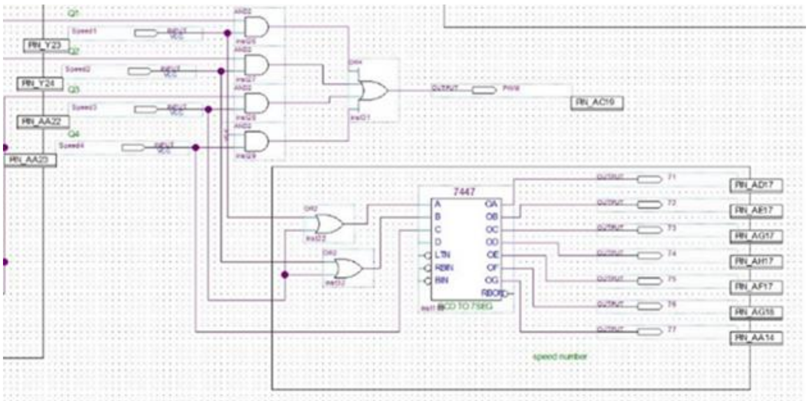
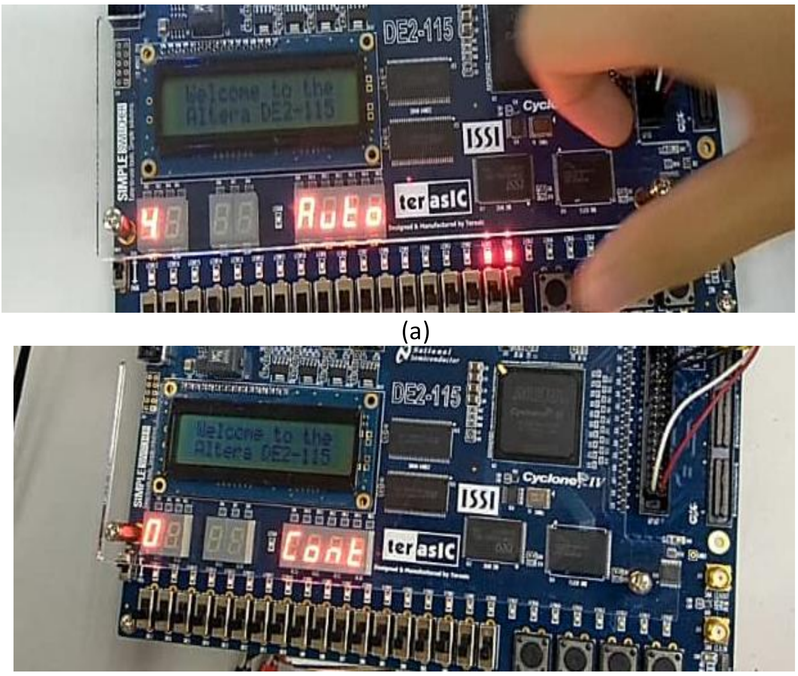


Fig. 8. Circuit for switch display



(a)

(b)

Fig. 9. Speed display mode (a) Auto mode with Speed 4, (b) Manual (Control) mode with Speed 0

There is a total of 4 speed available -25%, 50%, 75%, and 100%.

4. Conclusion

The utilization of the IR sensors in the robot car is suitable to be used for object/motion detection when navigating around an environment. Provided that users properly control the IR sensors, the robot car will successfully conduct its course of driving without any difficulty. This solution is economically viable, due to the simple construction method and the use of affordable materials and components. Several further improvements can be done, including implementation of PMW system that enable speed changing of wheels into turning mechanism to increase its mobility and flexibility. Further modification can be done so that the robot not only can sense the obstacles, while also can avoid them and even move them from the path. This may help in the development of low-cost household robot or life-saving robots during disaster.

Acknowledgement
This work was supported by the Collaborative Research in Engineering, Science and Technology (CREST) undergrant304/PELECT/6050423/C121.

References

[1] Debnath, Suman. 270 Mini Electronics Project With Circuit Diagram; April 2015.
[2] Buldu, Ali, and Kazim Yildiz. "A Circuit Design by Using an Infrared Sensor Transmitter and Pic16f628 to Measure the Pulse Rate of the Driver." *Measurement and Control* 49, no. 6 (2016): 191-196. https://doi.org/10.1177/0020294016646804
[3] Palmer, John Michael. "Wireless LAN based infrared remote control." (2012).
[4] Flynn, Anita M. "Combining sonar and infrared sensors for mobile robot navigation." *The International Journal of Robotics Research* 7, no. 6 (1988): 5-14. https://doi.org/10.1177/027836498800700602
[5] Budzier, Helmut, and Gerald Gerlach. *Thermal infrared sensors: theory, optimisation and practice*. John Wiley & Sons, 2011. https://doi.org/10.1002/9780470976913
[6] Chilton, Alexander. "The working principle and key applications of infrared sensors." *Infrared Radiation Theory*. (2014).
[7] Murati, Ardit J., Nikolaos A. Fountas, Nikolaos M. Vaxevanidis, and Ersila Shabani. "Design and Study Of Special Radio Controlled Car." (2014).
[8] Sedra, Adel S., and Kenneth Carless Smith. *Microelectronic circuits: theory and applications*. Oxford University Press, 2013.
[9] Gray, Paul R., Paul J. Hurst, Stephen H. Lewis, and Robert G. Meyer. *Analysis and design of analog integrated circuits*. John Wiley & Sons, 2009.
[10] Altera. DE2-115. User Manual. World Leading FPGA Based Product and Design Services. Terasic Technologies Inc., 2013.
[11] Necula, Dan. "Digital electronics: a modern lab approach." *Bulletin of the Transilvania University of Brasov. Series I-Engineering Sciences* (2011): 135-142.