Evolution in Electrical and Electronic Engineering Vol. 2 No. 2 (2021) 224-230
© Universiti Tun Hussein Onn Malaysia Publisher's Office

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Design and Development of Servo Motor Controller for SoC-FPGA

Mohd Zahiruddin Zainon[1], **Hazwaj Mhd Poad**[1]*

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2021.02.02.027
Received 22 July 2021; Accepted 26 August 2021; Available online 30 October 2021

Abstract: An Field-Programmable Gate Array (FPGA) are fully programmable systems on a chip (SoC), capable of handling a wide range of tasks. The key characteristics of current FPGAs are first outlined and compared to those of previous generations. This project aims to develop a servo motor controller that is implemented on the FPGA and evaluate the motor controller system by its efficiency. The Verilog code of the controller will be generated containing the motor controller. The outputs of the controller will be observed by using Terasic DE10-Nano Development Kit. To develop the servo motor controller, firstly develop the Pulse Width Modulation motor for the controller and determine its functionality. Proceed to pin assignment for the inputs and outputs signal using Quartus II software and bump into the DE10-Nano board if no error occurred. The result will be obtained through software and hardware simulation. Motor controller output will be analysed from the waveform and LED test to test the servo motor controller.

Keywords: Servo Motor, FPGA, SoC

1. Introduction

Every year, there is a major event for the Field Programmable Gate Arrays design competition called Field-Programmable Technology (FPT) conference [1]. Therefore, the FPGA design competition is intended to put together the ideas of FPGA researchers to facilitate the study of FPGA technologies required for the autonomous driving of the future at level 5 and accelerate the implementation of autonomous driving level 5 [2].

This project is based on the FPT conference and aims to build a model car with an SoC-FPGA servo motor controller. This project will also follow all contents and conditions for the FPT design contest but not for joining the FPT conference.

To make a model car is the main part of this project. This project will be needed to develop a car motor controller for the steering system and accelerating car. As stated earlier, this project will be based on the FPT conference. So, it will need to do a study about model car design that meets the rules requirements and the model car must be used FPGA and fully automated.

---

*Corresponding author: hazwaj@uthm.edu.my

2. Methodology

For this project, a four-wheel car is selected. This car uses DE10-nano as its main controller, an obstacle avoidance by using an ultrasonic sensor and three Lego NXT servo motors, one motor for steering and two motors for accelerating the car [3].

2.1 Car Control System

There are three servo motors that will be used in NXT Race Car. FPGA module will control the motor direction, speed and movement of the car. The first motor will be used for steering car direction and the other two motors will be used for acceleration and deacceleration of car speed and obstacle avoidance by using an ultrasonic sensor.

For hardware, there are a few main components for this project that will be highlighted. Terasic DE10-Nano will be used for the FPGA module to control the servo motor by using Verilog. Lego NXT Servo Motor will be used for the movement of the model car. 11.1V Lithium Polymer (LiPo) will be built with a motor driver board in the external circuit for power sources to power up the servo motor and DE10-Nano. Ultrasonic sensors will be used for sensor measurement. The block diagram of the car control system is shown in Figure 1.

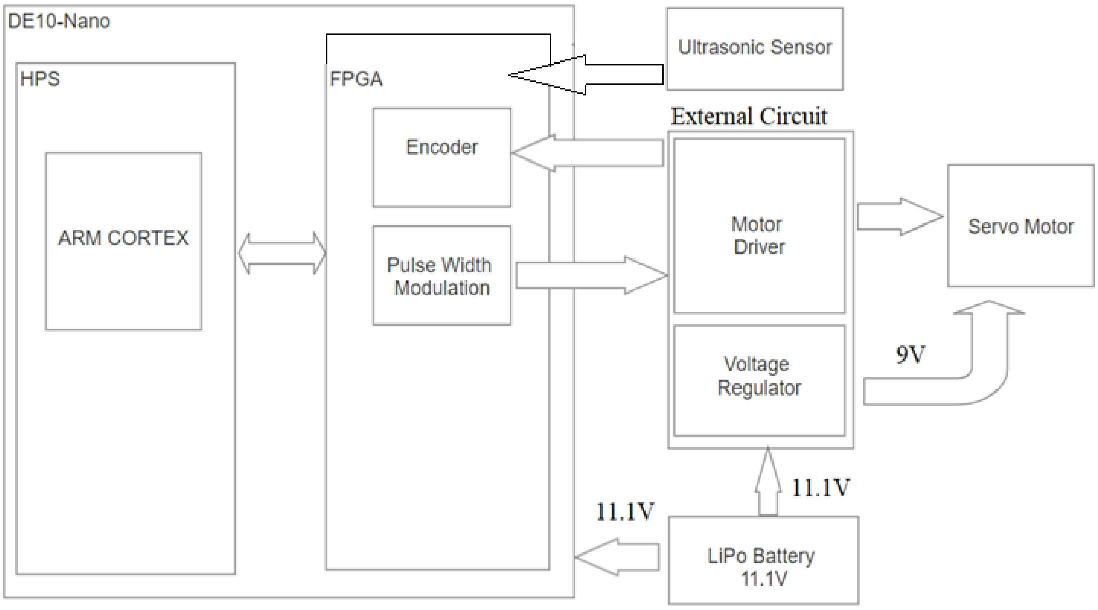


Figure 1: Block Diagram of a car control system

2.2 Servo Motor Controller

When codes are developed in Quartus II, the output waveforms can be viewed on Modelsim and the Register Transfer Level (RTL) schematic, as shown in Figure below, which provides a brief overview of the servo motor controller architecture's function. The RTL design shown in Figure 2 the flow of digital signals between hardware registers and the logical operations performed on those signals [4].

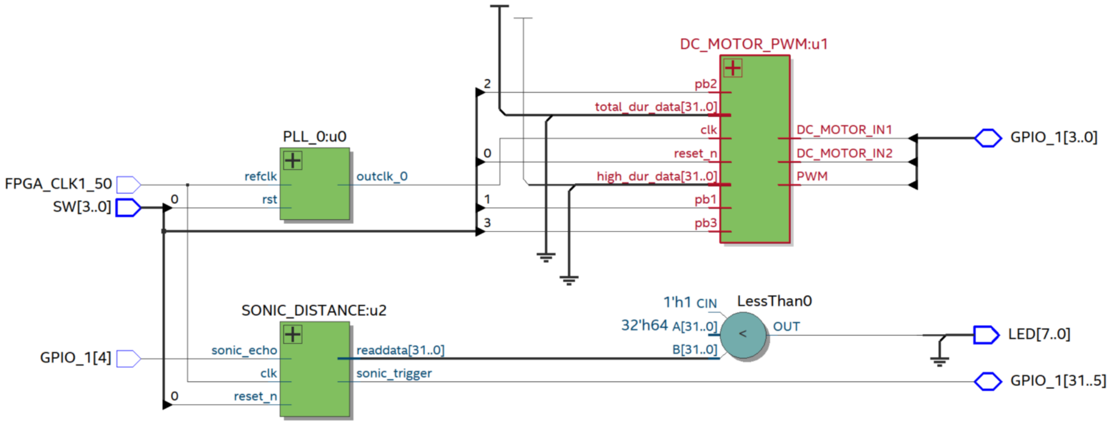


Figure 2: Top Level RTL design for motor controller design

The components are connected to complete the circuit, as shown in Figure 3. The DE10-Nano is connected to the motor driver unit by 5 GPIO pins. The ultrasonic sensor was connected to pin AG28 and AF28 on DE10-Nano GPIO pinout with the correct connection for Trigger and Echo on the ultrasonic sensors. The servo motor was connected to the motor driver via a dedicated pin on DE10-Nano GPIO. It is connected to pin AC24 for PWM for servo motor control, pin AA15 for IN1 and pin AD26 for IN2.

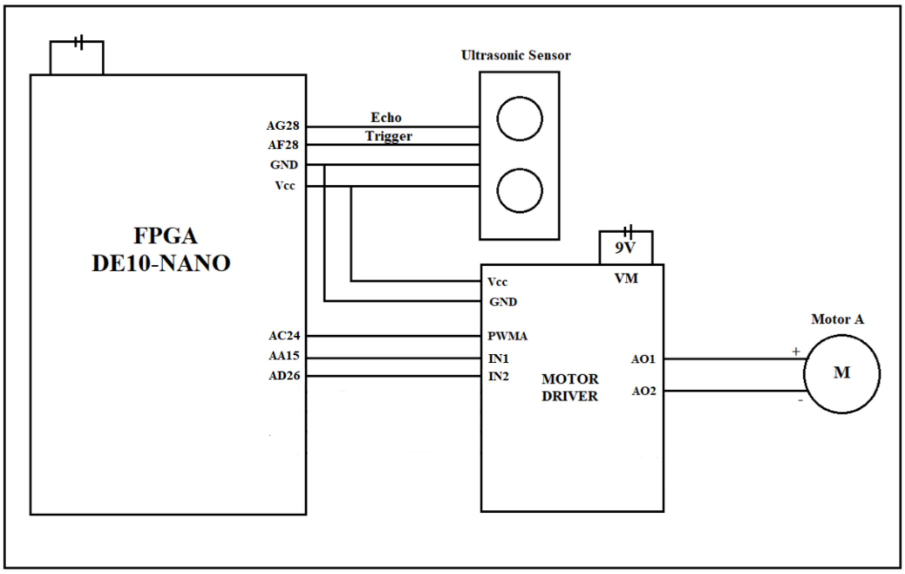
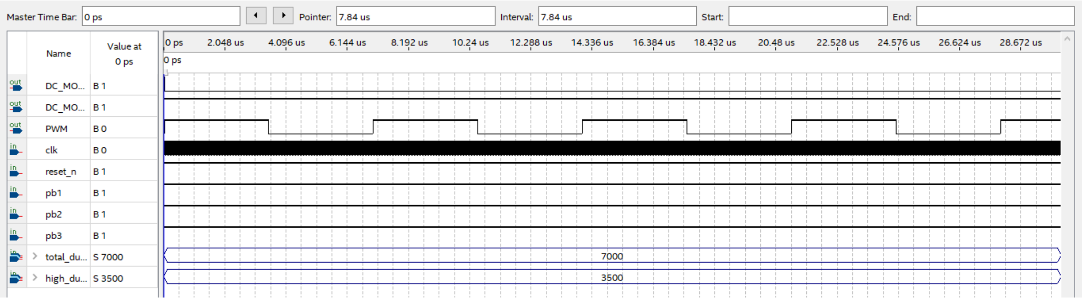


Figure 3: Top Level RTL design for motor controller design

3. Results and Discussion

The results working flow was discussed and the prototype results tested were analysed using a suitable method. The programming was carried out using a Quartus II and the circuitry was designed on the DE10-Nano FPGA board according to the specific programming. The test results from the waveform and LED test will be analysed to test the servo motor controller.

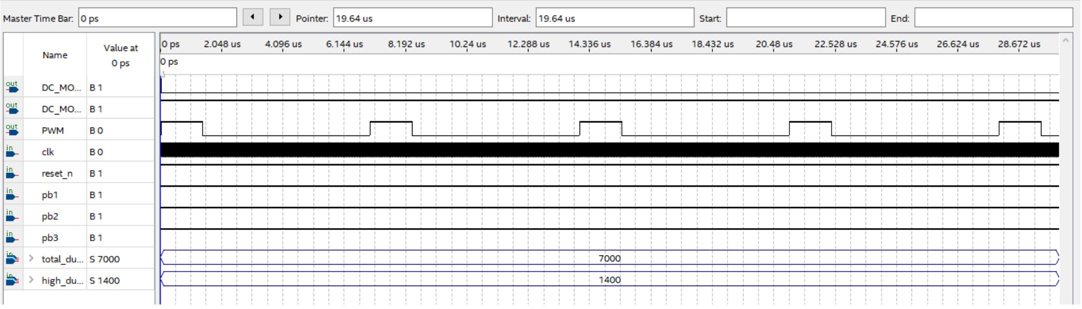
The duty cycle for PWM can be seen by simulating waveform in Modelsim in Figure 4 and Figure 5. Pulse width modulation, or PWM, is a considerably efficient way of controlling servo motors. PWM sends a series of pulses to the motor. Each pulse is the maximum voltage that the motor can handle. For example, a 6-volt motor will receive 6-volt pulses, whereas a 9-volt motor will receive 9-volt pulses. The pulse width is changed to control the motor speed. Pulses with a small width make the motor spin very slowly. As seen below, increasing the pulse width increases the motor's speed.



Master Time Bar: 0 ps Pointer: 7.84 us Interval: 7.84 us Start: End:

Name	Value at 0 ps
DC_MO...	B 1
DC_MO...	B 1
PWM	B 0
clk	B 0
reset_n	B 1
pb1	B 1
pb2	B 1
pb3	B 1
total_du...	S 7000
high_du...	S 3500

Figure 4: Waveform the duty cycle at 50% (Fast)



Master Time Bar: 0 ps Pointer: 19.64 us Interval: 19.64 us Start: End:

Name	Value at 0 ps
DC_MO...	B 1
DC_MO...	B 1
PWM	B 0
clk	B 0
reset_n	B 1
pb1	B 1
pb2	B 1
pb3	B 1
total_du...	S 7000
high_du...	S 1400

Figure 5: Waveform the duty cycle at 20% (Slow)

To validate the Verilog code, the LED in DE10-nano will be used as output. PB1, PB2, PB3 switch is used to set the output LED. LED 0 is used as output for IN1, LED 1 is used as output for IN2 and LED 2 is used as output for PWM.

As displayed in Figure 6, the motor will rotate clockwise to go forward in this mode as the IN1 LED is 0 and IN2 LED is 1. The motor control register values are related to DC Motor IN1 and DC Motor IN2, which control the motor rotation direction. To drive the motor forward the PB3. PB2 and PB1 switches must be set to "111". The code will then be executed. DC MOTOR IN1 generates logic 0, and DC MOTOR IN2 generates logic 1.

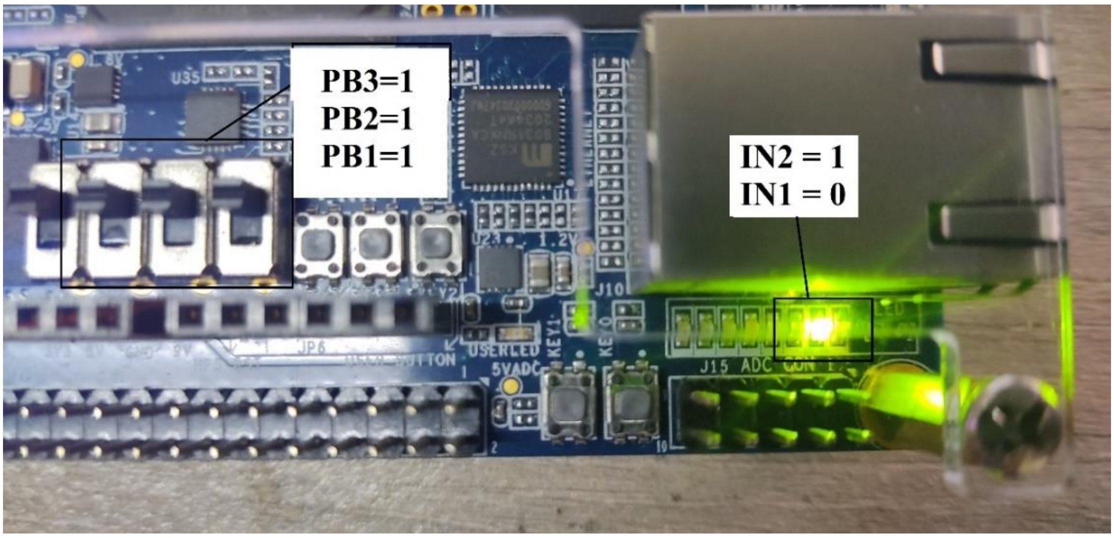


Figure 6: Switch is set to 111 and IN2= 1, IN1=0

As displayed in Figure 7, the motor will rotate counter clockwise to reverse in this mode as the IN1 LED is 1 and IN2 LED is 0. To drive the motor forward the PB3. PB2 and PB1 switches must be set to "101". The code ""DC MOTOR IN2, DC MOTOR IN1, PWM=1'b0, 1'b1, PWM OUT; / reverse" will then be executed. DC MOTOR IN1 generates logic 1, and DC MOTOR IN2 generates logic 0.

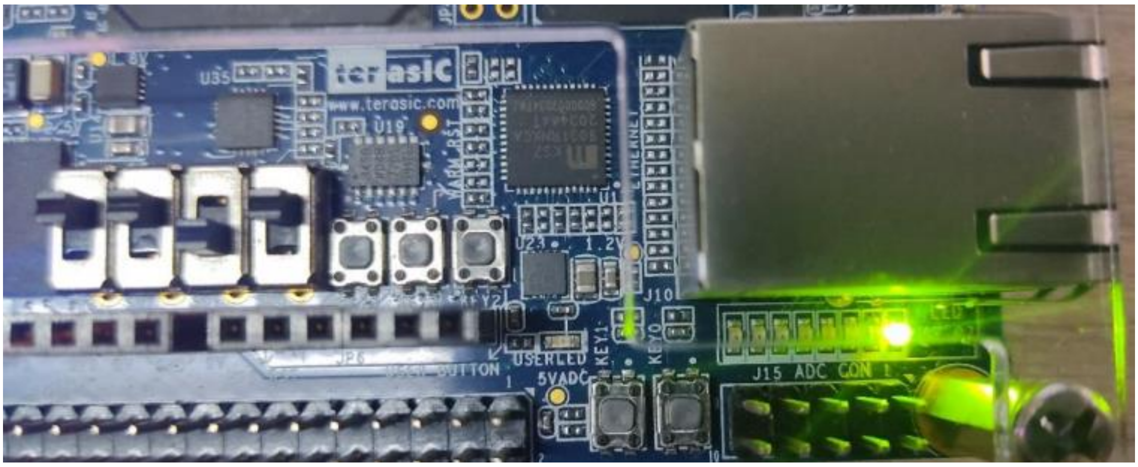


Figure 7: Switch is set to 101 and IN2= 0, IN1=1

As displayed in Figure 8, the motor will stop rotating in this mode as the IN1 LED is 1 and IN2 LED is 1. To drive the motor forward the PB3. PB2 and PB1 switches must be set to "100". The code ""DC MOTOR IN2, DC MOTOR IN1, PWM=1'b, 1'b1, 1'b0; / stop" will then be executed. DC MOTOR IN1 generates logic 1, and DC MOTOR IN2 generates logic 1. The truth table for the motor controller is shown in Table 1.

Figure 8: Switch is set to 100 and IN2= 1, IN1=1

Table 1: Truth table of motor controller

	Input		Output			
PB3 Fast Decay = 1 Slow Decay = 0	PB2 Forward=1 Reverse=0	PB1 Motor Go = 1 Motor Stop = 0	PWM	IN2	IN1	
1	1	1	Out	1	0	Forward
1	0	1	Out	0	1	Reverse
1	0	0	0	1	1	Stop
0	1	1	Out	1	0	Forward
0	0	1	Out	0	1	Reverse
0	0	0	0	1	1	Stop

Figure 9 and 10 show a complete prototype of a model car equipped with an ultrasonic sensor and servo motor. The robot's length was 26 cm, and its width was 15 cm. The ultrasonic sensor was attached to the top of the box using a glue gun to ensure it remained in place. The picture of this model car is the prototype only because the motor controller system in FPGA is not functioning. It is hard to determine the cause of prototype failure due cannot access the laboratory to check the motor controller signal by using an oscilloscope to decide whether the problem is from FPGA implementation of the external circuit.

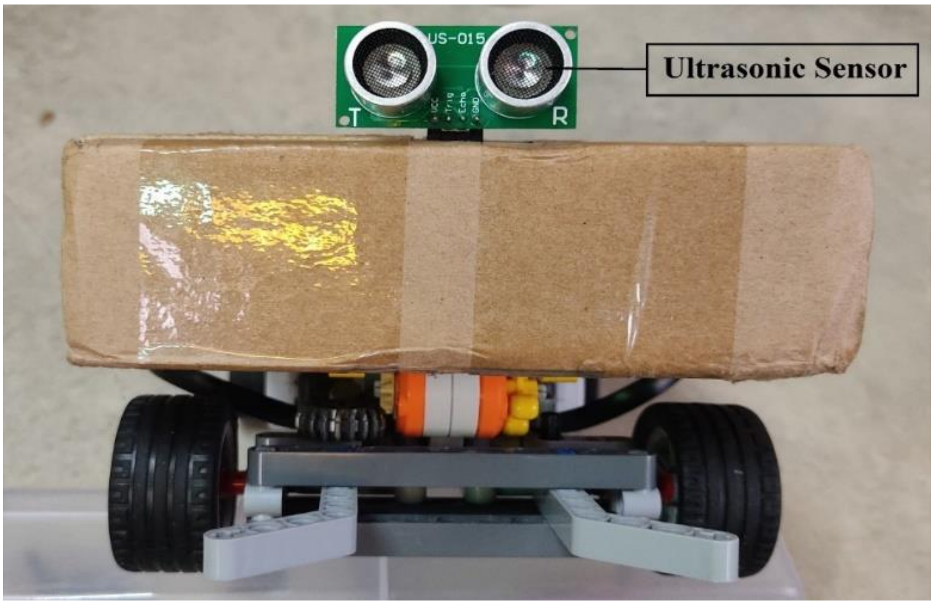


Figure 9: Front View

Figure 10: Back View

Figure 11 shows the circuit connection in the prototype. The motor driver and DE10-Nano are connected and powered up by an 11.1V Li-Po battery, regulated to 9V. The motor driver allowed a separated power supply for the servo motor to use an external power supply. The servo motor can operate between 5V to 9V power source, and their speed can be controlled via DE10-Nano. The prototype car used an 11.1V Li-Po battery to supply power for the servo motor. The sensors operate on a 5V power supply from the DE10-Nano board, while the servo motor has its own external power supply.

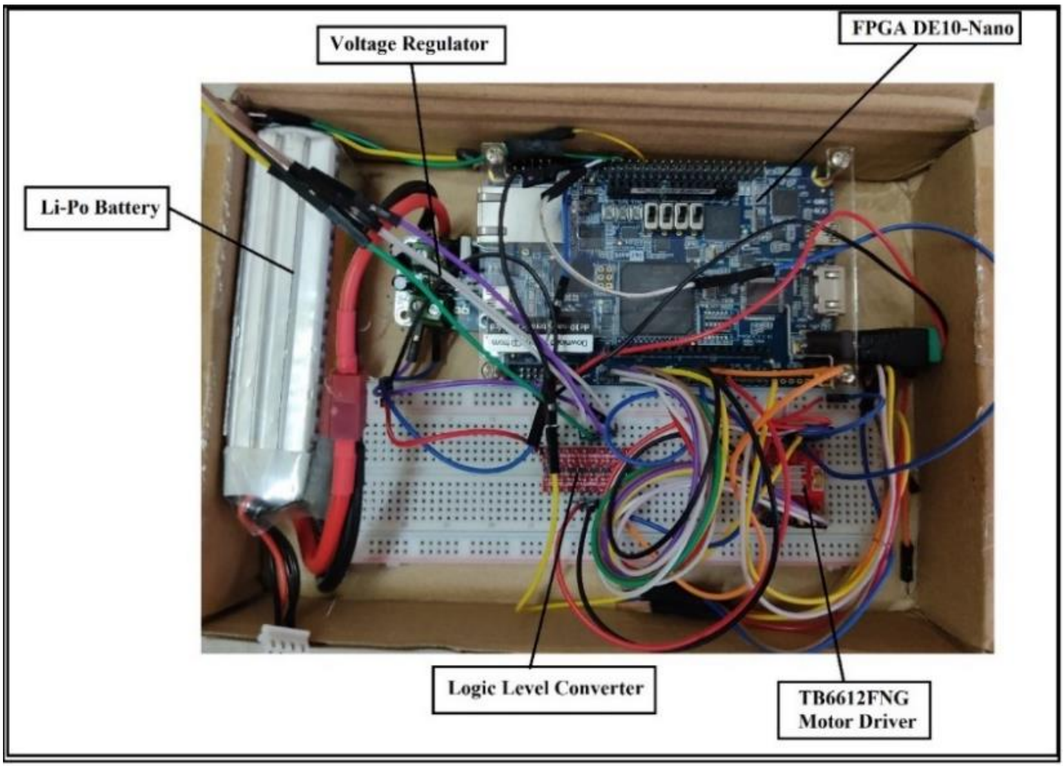


Figure 11: Circuit connection

4. Conclusion

This project concluded by presenting a proposed Verilog FPGA controller design for the variable speed and smooth motion control of the servo motor on the system by referring to the previous chapter. The development of the servo motor is partially successful using an FPGA controller. Literally, the research material found in the references serves as a guide for completing this project to shows the output waveforms of the servo motor controller. As can be seen, validation by displaying the waveform is not achieved for all the purposes since the goal is to construct a prototype car with a servo motor controlled with an FPGA servo motor controller. This FPGA controller development can also be implemented and used in another system by developing image processing, a traffic lighting system, etc.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] “Contents and Conditions.” http://fpt19.tju.edu.cn/Contest/FPT2019 FPGA Design Competition/Contents and Conditions.htm

[2] Y. Nitta, S. Tamura and H. Takase, "ZytleBot: FPGA Integrated Development Platform for ROS Based Autonomous Mobile Robot," 2019 29th International Conference on Field Programmable Logic and Applications (FPL), Barcelona, Spain, 2019, pp. 422-423, doi: 10.1109/FPL.2019.00077.

[3] Y. Kim, Control Systems Lab Using a LEGO Mindstorms NXT Motor System. IEEE Trans. on Education, vol. 54, No. 3, pp. 452-461, 2011.

[4] K. Wei, K. Honda, and H. Amano, “FPGA design for autonomous vehicle driving using binarized neural networks,” in Proc. International Conference