DEVELOPMENT OF WATERING SYSTEM BY USING FPGA PLATFORM

Tew Jin Chun, Muhammad Akram Idros and Wan Rahiman[1]

School of Electrical and Electronic Engineering
Universiti Sains Malaysia, Engineering Campus
Pulau Pinang, Malaysia.

Corresponding Author's Email: [1]wanrahiman@usm.my

ABSTRACT: The FPGA based watering system by our team is an autonomous watering system. The purposes of our watering system are to ensure the crops will have enough water, to reduce the user's job and reduce the waste of water. Our system measures the moisture of the soil by using sensor and it act as the input of our system, and the stepper motor will turn the faucet on or off. The control signals to the motors are provided by FPGA board through its GPIO (General Purpose Input Output) pins depending on the input. The digital circuit is designed using Altera Quartus II design software and the FPGA (Field Programmable Logic Array) board used is Altera DE2-115. The circuit contains 5 systems which are sensor signal system, frequency divider system, clock pulse generation system, direction selection system and 7-segment display system. The sensor signal gives the input signal. The frequency divider system divides the high frequency while the clock pulse generation system generates clock pulse desired. The direction selection system allows the motor to rotate in either clockwise or anticlockwise direction. Lastly, the 7-segment display system shows the condition of the faucet. The concepts involved in this project are bidirectional shift register, synchronous up down counter, logic gates and flip flops.

KEYWORDS: *FPGA, Watering system, Logic gates*

1.0 INTRODUCTION

Malaysia weather is very unpredictable. Sometimes, it can be sunny day for few days and rainy day for few days. According to Maruthaveeran (2006), irregular watering leads to the mineral loss in the soil and may end up with rotting the plants, we should know if the soil really needs to be watered and when exactly should we have to water the plants. In the age of advanced electronics and technology, the life of human being should be simpler and more convenient, there is a need of many automated systems that are capable to replace or reduce human effort in their daily activities and jobs. Here we introduce one such system, named as FPGA based Watering System, which is a model of controlling irrigation facilities that uses soil moisture sensor to sense soil moisture with FPGA in order to make a switching device. In the form of unique intersection between biological engineering and electronic, the solution requires only a little bit knowledge of electronics as well as that knowledge related to botany and plant physiology (Đuzić (2017)).

In manual Altera (2013) explained Field Programmable Gate Array (FPGA) is a semiconductor device that is based around a matrix of configurable logic blocks connected via programmable interconnects. FPGA is similar in principle to, but have vastly wider potential application than, programmable read-only memory (PROM) chips. By using the prebuilt logic block and programmable routing resources, the custom hardware functionality can be implemented without using a breadboard or soldering iron. Ultimately, FPGA might allow computer users to tailor microprocessors to meet their own individual needs (Serrano (2007)).

For this project, unipolar stepper motors are used. The unipolar stepper motor operates with one winding with a center tap per phase. Each section of the winding is switched on for each direction of the magnetic field. Each winding is made relatively simple with the commutation circuit, this is done since the arrangement has a magnetic pole which can be reversed without switching the direction of the current.

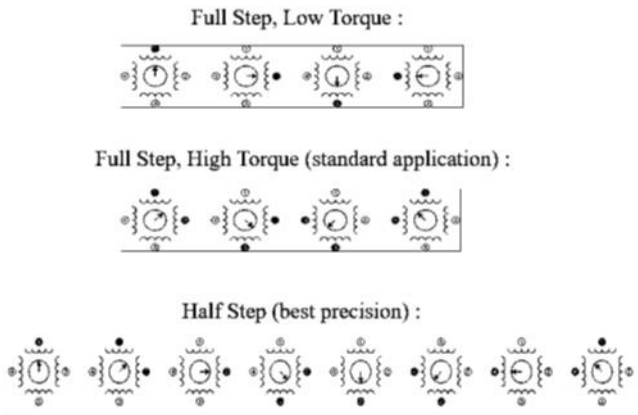

Fig 1. Modes of Stepper Motor

Stepper motor can be driven in several modes as shown in Figure 1. The decision to drive PM4222-09 Unipolar Stepper Motor in Full Step High Torque mode was made instead of Full Step, Low Torque and Half Step modes is following the steps of the process in Williams (2006).

2.0 SYSTEM DESCRIPTION

The watering system consists of 5 main systems, which are Frequency Divider System, Clock Pulse Generation System, Direction Selection System, Rotational Degree Limitation System and 7-Segment Display System.

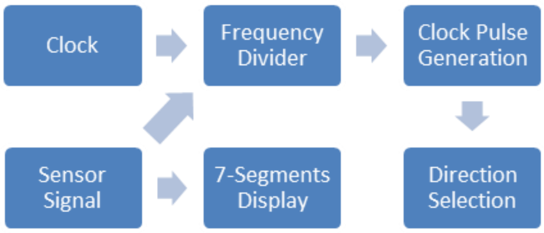

Fig 2. Flowchart of Designed Circuit

The first system is the Frequency Divider System. It is a crucial part to generate a signal with an optimum frequency to act as a clock for the other systems. It consists of an integrated circuit (IC) which can act as a frequency divider.

By referring in Proakis (2006), the next system is the Clock Pulse Generation System. The system is responsible to generate a signal with 12 clock pulse to send to the subsequent system to allow the stepper motor to move for 12 steps which is 90˚. This system consists few D-Flip Flops and some simple logic gates.

The subsequent system is the Direction Selection System. This system is responsible in deciding the moving direction of the state in the system depends on the sensor signal and the number of times of changing the state depends on the number of clock pulse supplied (Chan (1994)). Every output of every bit of the state will be send to the stepper motors through FPGA board.

Sensor Signal System was used in order to determine an appropriate frequency where this system uses voltage divider to get the signal. It will only HIGH when the signal is changing state. The system will consist a moisture sensor, a resistor, some D-flip flops and some logic gates.

For the last system of digital part of the circuit is the 7-Segments Display System. This system will show the current state of the faucet whether it is ON or OFF.

A. Clock Pulse Generation System

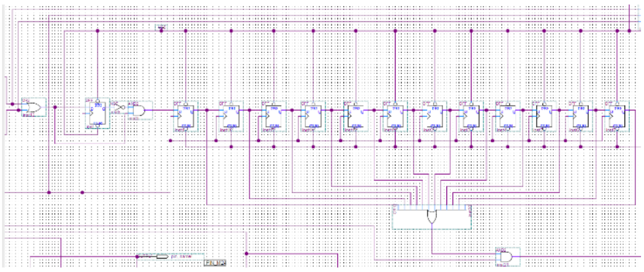

Fig 3. Clock Pulse Generation System Circuit

Since one step of stepper motor is just 7.5˚, the motor need 12 steps to achieve 90˚ which means it needs 12 signals in one time of user input. Therefore, this system needs to generate 12 pulses which can act as clock pulses and send it to the system which control the rotation of stepper motor.

Constructed circuit as shown in Fig 3. to generate the signal with 12 pulses. When the input signal triggers from LOW to HIGH, it will generate a HIGH state at the AND gate. It will change back to LOW after one clock duration because of the NOT gate. Then, the High state will be transferred from one D-Flip Flop to another D-Flip Flop until the 12th D-Flip Flop.

The outputs of all D-Flip Flops are connected to a 12-inputs OR gate. Thus, the OR output will be HIGH for 12 clocks duration. The OR output is then connected to an AND gate with the CLK(Output Q)

Table 1. Truth Table Of Clock Pulse Generation Circuit

Input	AND	1	2	3	4	5	6	7	8	9	10	11	12	OR
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1	0	0	0	0	1	0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	1	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	1	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
1	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

B. Direction Selection System

This circuit is constructed using the concept of Bidirectional Shift Register. The modified of Bidirectional Shift Register circuit into our Direction Selector Circuit as shown in Fig 4.

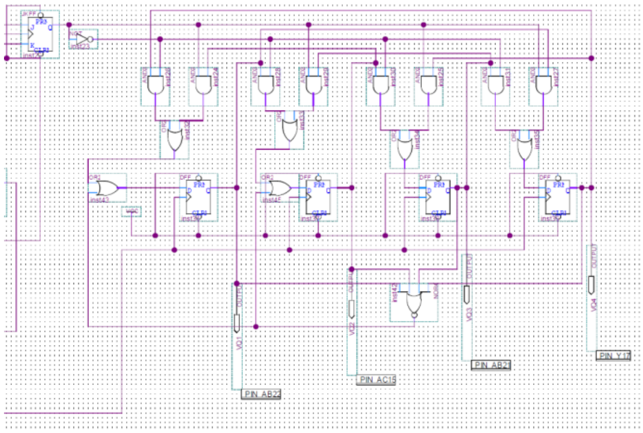

Fig 4. Direction Selection Circuit

The first modification is to set the first two D-Flip Flops to HIGH initially. This can be easily done by connecting a NOR gate. When the board is switched on, the 4 output will be LOW. When all NOR inputs are LOW, the NOR output will be HIGH. This HIGH state will be passed to first two D-Flip Flops by connecting an OR gate. The NOR output will be always LOW after that because the there is always 2 HIGH NOR inputs. This modification is needed because the stepper motors we are using are in the Full Step, High Torque mode, hence it needs to input two High state into this system at the beginning so that the two High state will shift to either left or right one step at every subsequent clock edge depending on the sensor signal input.

The next modification is the input of serial data entry. As shown in Figure 1, 3, 4 and 5, the output of last D-Flip Flop is connected to the serial data entry of the circuit. This is because to drive the stepper motor in Full Step, High Torque mode, the need of only two High state in the system. The pre-set two High state at the beginning, hence the recycle of state in the system as there is no need to input any new data into the system. Therefore, the output of last D-Flip Flop act as the serial data input in the circuit.

The last modification is to add a J-K Flip Flop in front of the circuit. When the soil is dried up (0→1), the J input will be HIGH. When the soil is wet (1→0), the K input will be HIGH. The output will act as Mode Control which are Shift Left Mode and Shift Right Mode for the circuit. When the soil moisture is not changing, both inputs will be LOW. The J-K Flip Flop can let the output remain the same with the previous output to prevent wrong mode is being send into the circuit.

Table 2. Truth Table Of Direction Selection Circuit

J	K	Q(JK)	Q1(D)	Q2(D)	Q3(D)	Q4(D)
0	0	0	1	1	0	0
1	0	1	1	0	0	1
0	0	1	0	0	1	1
0	0	1	0	1	1	0
0	0	1	1	1	0	0
0	0	1	1	0	0	1
0	0	1	0	0	1	1
0	0	1	0	1	1	0
0	0	1	1	1	0	0
0	0	1	1	0	0	1
0	0	1	0	0	1	1
0	0	1	0	1	1	0
0	0	1	1	1	0	0
0	1	0	0	1	1	0

0	0	0	0	0	1	1
0	0	0	1	0	0	1
0	0	0	1	1	0	0
0	0	0	0	1	1	0
0	0	0	0	0	1	1
0	0	0	1	0	0	1
0	0	0	1	1	0	0
0	0	0	0	1	1	0
0	0	0	0	0	1	1
0	0	0	1	0	0	1
0	0	0	1	1	0	0
0	0	0	0	1	1	0

The direction of shifting depends on Q, the output of J-K Flip Flop while the number of times of shifting depends on the number of clock pulse send to all the D-Flip Flop. The direction of shifting decides the rotation direction of the stepper motor to be either clockwise or anticlockwise.

3.0 RESULTS

A. Results Simulation Waveform

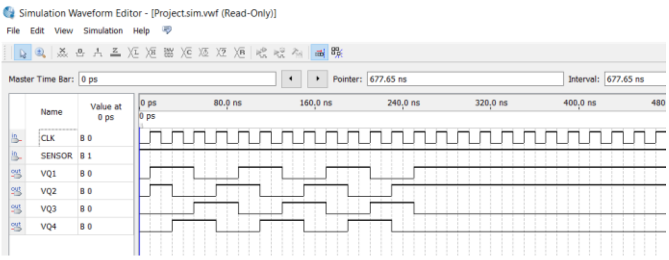

Fig 5. Simulation Waveform for input is HIGH

The waveform shows the output shifts from right to left. This means the stepper motor will rotate anti-clockwise. It only moves 12 steps due to the 12 clock pulses from clock pulse generation system.

B. Observation on the Performance of Prototype

Apart from the data and reading from multimeter, after integrating the whole circuit with the built prototype, a test run of the prototype as shown in Fig. 6. is conducted.

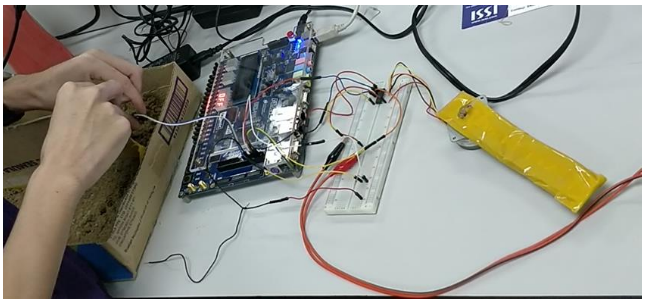

Fig 6. Prototype

After test running, the results were same with as expected. When the soil is moist, the stepper motor rotates anti-clockwise with 90˚. The 7-Segments Display shows OFF. However, when the soil is dry, the stepper motor rotates clockwise with 90˚. The 7-Segments Display shows ON.

4.0 CONCLUSION

In this project, the watering system is successfully built and able to rotate the faucet. This system is based on FPGA. The system consists of Frequency Divider System, Clock Pulse Generation System, Direction Selection System, Sensor Signal System and 7-Segments Display System. However, the limitation of the system is it cannot get the degree of moisture of soil. This is because we can only build digital circuit in FPGA board but it needs analogue value to measure degree of moisture. Thus, if someone splash the water at the sensor area, the system may get confused and stop watering.

5.0 ACKNOWLEDGEMENT

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