AUTOMATED LAUNDRY DRYING SYSTEM

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ABSTRACT: A new era of intelligent systems is fast-approaching, and many industries are focusing in developing automated appliances to make household lives easier. One such simple example is laundry. Hence, this project aims to develop an automated system that can sense the change in weather and reposition the laundry accordingly. Without needing any manual controls or instructions from user, the system is able to operate by itself, hence the keyword 'automated'. The system is designed by understanding the conditions that affect the output, and a prototype is built to demonstrate how the field-programmable gate array (FPGA) can play a huge role in this system, coupled with three different sensors to make the laundry work. The objective of this project is to be able to develop and provide a sustainable appliance that can help to benefit the community. This reliable automated system will help household members in handling laundry perfectly without worrying about retrieving them in a hurry every time the weather turns undesirable.

KEYWORDS: *FPGA, Automated System, Laundry, Weather Sensor*

1.0 INTRODUCTION

As time passed, people are more interested with intelligent products that are automated, especially something that helps them with their daily household chores. A simple and most appropriate example would be the duty of doing laundry, even though it is something common, most people would be grateful for something that can automatically keep the laundry under a dry shelter every time the weather becomes unfavorable (Downey (1998)). Since the change of weather these days seem erratic, automated system needed to help the laundry dried well in any change of weather. Therefore, in Shoewu (2016), the Automated Laundry Drying System is introduced as the product to help with drying laundry after washing. People usually place their laundry out in the open during a sunny day to dry them, but it is difficult to predict when it would rain, and it becomes more of a burden that hinders one's other daily household chores.

So for this project, it will counter the problems above since any change in weather will give a signal to the system to have the laundry carried in. This system is able to detect the difference by its own with the help of the sensors and a circuit with different combinational logic gates through the FPGA. This project uses FPGA to install the design that conduct the system properly and will automatically move out the clothes when it is a sunny day and carry in the clothes when it is a rainy day. In order to achieve the repositioning of laundry, a conveyer system is made consisting of two wheels that are controlled by a DC motor each, which converts electrical power into mechanical power for repositioning. This system will help out with the laundry greatly, and household members need not worry about weather and undried clothes anymore.

2.0 PROJECT DESCRIPTION

This prototype model is built and programmed with a circuit that takes inputs from the surroundings through the FGPA and using those inputs to successfully drive the laundry along the path when the condition.

A. Components

To make this project effective, Serrano (2007) and William (2006) suggested a few components are selected to be included in the prototype. They include:

a. Water sensor: In this project, this sensor will be used as an alternative to the rain sensor, which can detect the presence of raindrops more acutely than the water sensor. The resistance of the water sensor is high when no water is detected.
b. Light Dependent Resistor (LDR) : This is a component that has variable resistance that changes accordingly to the light intensity that falls upon it. For example, the resistance of the component is high when light intensity is low.
c. Infrared sensor (IR): An electronic device that emits in order to sense some aspects of the surroundings. An IR sensor can senses an object by measuring the heat of an object as well as detects motion. For this project, the sensor is used to tell whether the clothes are inside the shelter. The clothes will be detected if it is near its vicinity, and meant the clothes are under a shelter.
d. ULN2003: High voltage, high current arrays each containing seven open collector Darlington pairs with common emitters. In this project, the timer is used as a relay that allows operating only one motor at a time.
e. DC Motor (0.5V to 6V) – an electrical device that converts electrical energy into mechanical energy. This motors will help the system in moving the clothes in or out of the shelter, depending on the weather.

B. Conveyer System

The conveyer system is made by tying the clothesline around two wheels. The wheels have groves on them so that the clothesline would not come off when the wheels are rotating. Clothes will be hanged upon the clothesline near the bottom of the wheels. The left motor moves the clothes out of the shelter, whereas the right motor moves them back in. Only one motor will be running at a time, depending on the input states.

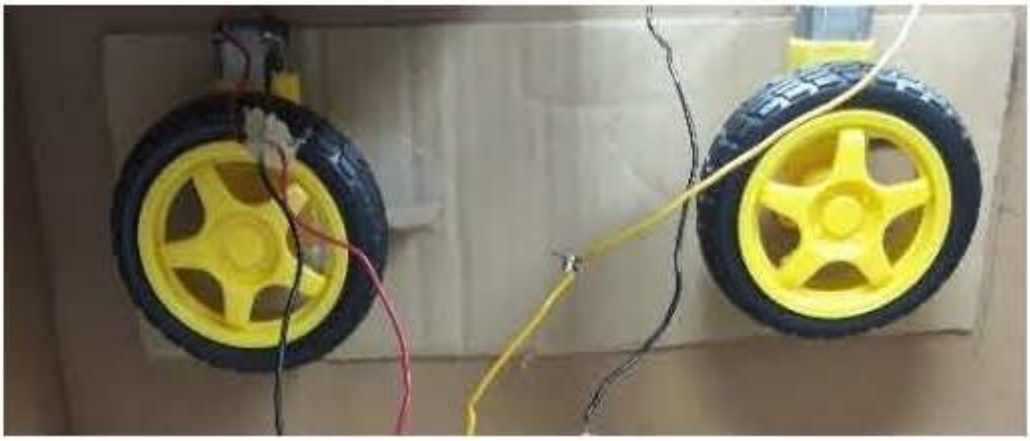

Fig. 1. The conveyer system where the clothesline will be

3.0 CIRCUIT DESIGN AND HARDWARE

This section explains in detail how the circuit for the entire project is designed and drawn using the Quartus II software in order to be programmed onto the FPGA board, and the steps required to verify the usability of the circuit designed before being uploaded into the board.

Mayer-Baese (2007) suggests that the circuit needs to be designed in order to be configured into the FPGA in the form of block diagrams. Before designing the circuit, the following conditions are listed:

i. When it is raining or there is no sunlight, the clothes will be moved into the shelter if the clothes are out to be dried.
ii. When it is raining or there is no sunlight, the clothes will remain within the shelter, if they are already inside the shelter.
iii. When it is not raining and there is sunlight, the clothes will be moved out of the shelter, if they are inside the shelter.
iv. When it is not raining and there is sunlight, the clothes remain out of the shelter if they are already outside of the shelter.

From the conditions listed it is clearly seen that there are two inputs, which is presence of sunlight and the presence of rain. Hence, the light-dependent resistor (LDR) is used to detect the presence of sunlight, and the water level sensor is used to detect the presence of rain.

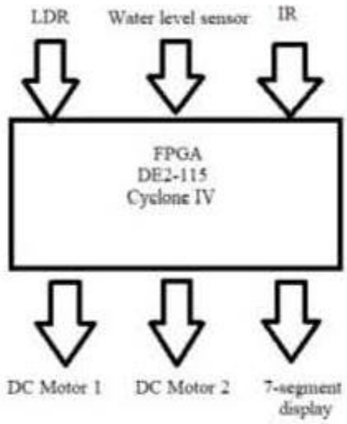

Fig.2. Block architecture diagram of overall system

Table I shows the truth table constructed based on the conditions listed. '1' is HIGH and '0' is LOW.

Table I. Truth Table for Circuit Design

X	Y	Z	Q_1	Q_2
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	1	0
1	0	0	0	1
1	0	1	0	0
1	1	0	0	0
1	1	1	0	0

From the truth table, Karnaugh maps can be drawn for output Q_1 and Q_2 to determine the combinational logic functions needed for the circuit schematic.

Z	XY				
		00	01	11	10
	0	0	1	0	0
	1	1	1	0	0

Fig. 3. Karnaugh map of output Q_1

Z	XY				
		00	01	11	10
	0	0	0	0	1
	1	0	0	0	0

Fig. 4. Karnaugh map of output Q_2

From the Karnaugh maps drawn, the sum of products representation for Q_1 and Q_2 respectively are:

$$Q_1 = \bar{X}Z + \bar{X}Z$$
$$Q_2 = X\bar{Y}Z$$

From the sum of products representation, the circuit schematic can be designed using the Quartus II software in the format of block diagrams:

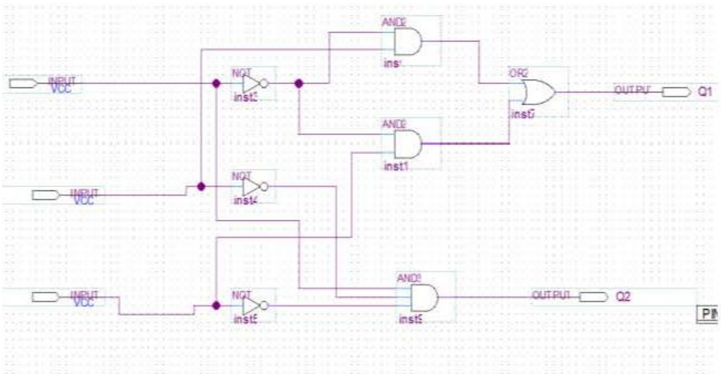

Fig. 5. The circuit schematic drawn from the SOP representation

The sum of products representation for all outputs are as follows:

$$D_0 = D_3 = D_4 = D_5 = \bar{X}\bar{Q}$$
$$D_1 = D_2 = \bar{Q}$$
$$D_6 = Q$$

From the equations, the circuit schematic can be designed using combinational logic blocks. The 7 segment displays on the FPGA DE2-115 board are active low, which means they only light up when the output is 0. Hence, a NOT-gate is added before the output pin to reverse the signals in order to get the desired outcome listed in the truth table. Adding the circuit schematic to the previous circuit design, the overall circuit schematic of the whole project is shown in the Figure 6.

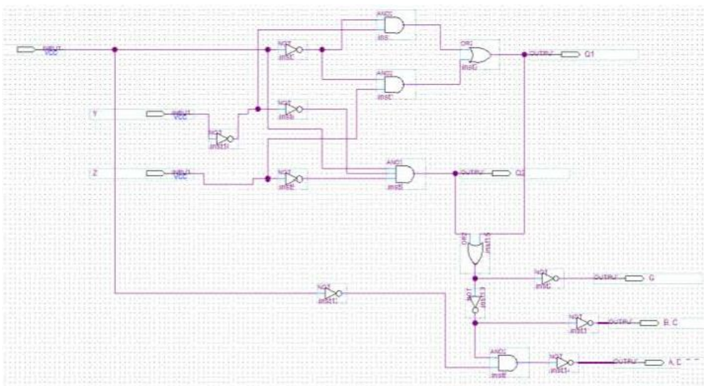

Fig. 6. Overall circuit schematic design

After the circuit is drawn, the block diagram file is compiled and run for synthesis and analysis to check for any errors. All output and input pins listed in the block diagram is assigned to the pins on the general purpose input/output pins (GPIO) of the FPGA, only then the program can be uploaded into the FPGA via the USB Blaster.

4.0 RESULT AND DISCUSSION

The section discusses the results of the experiments with each sensor and motors before integrating them into the circuit. This is to determine any errors or faults found during the experiments and troubleshoot them before being implemented to the FPGA board.

Before uploading the program onto the FPGA board, the schematic designed earlier is compiled to for analysis and synthesis. Successful compilation shows that the schematic has no errors and can be uploaded onto the FPGA board. Before doing so, however, a simulation is run on the circuit schematic to check if the output obtained is the same as the desired output for the project.

Fig. 7. Timing waveform of the simulation

A simulation is a representation of the real process, and includes all flaws and unavoidable errors that are neglected in theory, should there be any. The simulation result shows that the output is same as the one listed in the truth table, however there is an estimated propagation delay of 5ns to 7ns before the output is generated. In digital electronics, propagation delay refers to the amount of time between the input and output of the logic gate to be stable and becomes valid to change states. In this case, the value of the propagation delay time is insignificant and will not affect the output too much in real time since it is in nanoseconds, hence it can be neglected.

Next, each of the sensors are tested to make sure they run according to the input of the truth table mentioned. After this step and building the circuit on the breadboard, the complete prototype can be built.

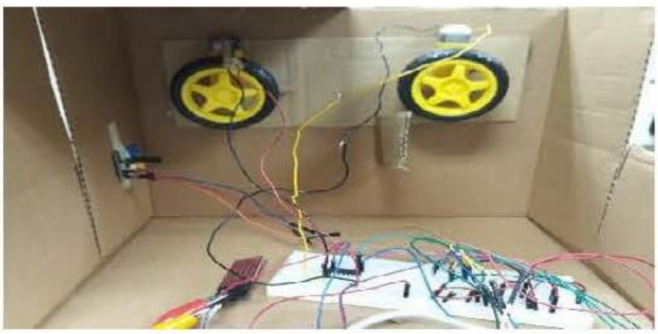

Fig. 8. Building the complete prototype

A. Light Dependent Resistor

An LDR has very high resistance when no light is detected, this meant the LDR becomes a cut-off to the circuit and current will not be able to flow through. However, the conditions from the previous section mentioned that the input from the LDR is '1' if and only if there is no sunlight. Therefore, a NOT gate is placed after the input pin of the LDR from the overall circuit schematic in order to reverse the input. Figure 9 shows the circuit schematic for the LDR that will be built on the breadboard for the prototype.

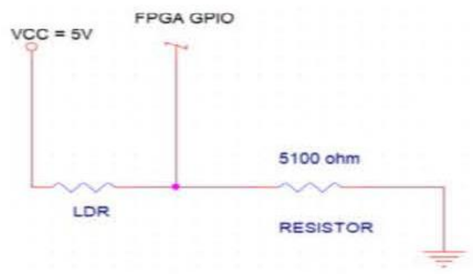

Fig. 9. A schematic of the connections of the LDR

A resistor of 5100Ω is connected to the LDR to reduce the power going through the LDR, as the component is easily damaged if too much current flows through it. The 5V and ground of the schematic as shown are actually connections to the GPIO pins on the FPGA. Another connection to GPIO is the input from the LDR to the FPGA.

B. Water Sensor

The difference between a rain sensor and a water sensor is that the former can detect tiny drops of water, whereas the water sensor needs to be immersed in the water in order to sense water. Similar to the LDR, the water sensor module is connected to the 5V and GND pin of the GPIO. The 'signal' pin on the module is to be connected to the GPIO pin as an input for the integrated circuit. The table shows how different immersion heights of the sensor affect the input to the FPGA, by measuring the voltage output from the sensor with a digital multimeter and an LED which will light up if the signal is HIGH.

Table II. Testing The Immersion Height of Water Sensor

Immersion height (mm)	Voltage (V)	LED output
10.0	0.02	No output
20.0	2.52	Flickers dimly
30.0	4.79	Lights up

From the results in the table, it is shown that the water sensor needs to be immersed to a height of at least 30mm in order to send a HIGH input to the FPGA. A resistor is used to limit the current flowing through the component to avoid damaging it.

5.0 CONCLUSION

The FPGA board help this project achieve the objectives with the help of the sensors which are IR sensor, water sensor and LDR sensor, thus making the project fully automated by detecting the changes in the surrounding and reacting to these changes. The combination of gates (AND, OR, NOT) evaluates the input taken and generates the output as intended by the user.

Thus, one advantage of this automated laundry drying system is it does not need any intervention from the user to move the clothes in or out of shelter. This project is advantageous towards the environment and towards the community. It is also low cost, as the sensors are easily obtainable. The only downside is that if one were to use the rain sensor module, a large space is needed in order to detect rainfall easily.

6.0 ACKNOWLEDGEMENT
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