MOTION FOLLOWING SMART FAN USING INFRARED SENSOR

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ABSTRACT: With the continuity of home automation, the project is to design an automatic fan system which will track the person in the living room or hall by using infrared sensor with field programmable gate arrays (FPGA) board as a platform . The main components were used dc motor, stepper motor, and IR sensors. The dc motor used to apply the rotation of propeller of the fan. The IR sensor is used to sense a human in the surrounding of the fan. The mechanism is focusing on the object detection that is when an objects or person be in front of it, the fan will be on. The stepper motor is used to control the direction of airflow. The stepper motor will rotate the upper body of fan to the left or to the right depends on the position of the human that is sensed by the IR sensor.

KEYWORDS: *IR sensor, stepper motor, FPGA and DC motor.*

1.0 INTRODUCTION

Most of the living rooms are not well arranged with air conditioning. Therefore, the fan is the main idea of cooling down the surrounding and is used in most of the houses and so on. But when it is desired to change the direction of air flow, the fan does not have any automatic or efficient feature. Conventional fans have usually two options for directing air flow. Laximi (2017) elaborates that fan is static and physically redirect it to change the direction of the airflow. This option is not user friendly because when one wants to change the location of the in the room, he has to redirect the fan's air flow. Secondly fan can rotate clockwise and anticlockwise normally within a set of angle that is less than 180 degrees (Lim (2004)). This might be unnecessary as the fan may direct air at empty space for a large portion of the rotation cycle. In addition, the normal design of the fan is it can only be turned off by using the switch. In this condition, somebody needs to turn off the switch when the fan is not used and it might cause the waste of energy when somebody forgets to turn off the switch of the fan. Hence, we have designed a FPGA based motion following smart fan system using infrared sensor which will solve the above problems and make the use of fan more eco-friendly.

A. Field Programmable Gate Arrays(FPGA)

The fan that had been designed based on automatic system by using FPGA board, which is Altera's DE2-115 Development and Education Board. Altera (2013) has giving the procedure on how the FPGA board can be used to load configuration data into internal memory. The FPGA contains of programmable logic blocks and hierarchy of reconfigurable interconnects that allow the block to be wired together like many logic gates that can be inter-wired in the different configurations. Logic blocks can be configured to perform complex combinational function or merely simple logic gate like AND gate and XOR gate. In FPGA, logic blocks also include memory elements, which may be simple flip-flops or more complete blocks of memory. FPGA can be programmed to implement different logic functions, allowing flexible reconfigurable computing as performed in computer software (Quartus II Software).

B. Infrared Sensor

An active infrared sensor (IR sensor) consists of two elements, which are infrared source and

infrared detector. An infrared laser diode is used as the infrared source whereas infrared detectors can be photodiodes or phototransistors. The infrared radiation emitted by the infrared source is reflected by an object and falls on the infrared detector. Thus, the object can be detected. A LOW digital signal will be sent by the IR sensor as it is an active LOW component.

C. DC Motor

The DC motor is the motor that used to apply the energy from electrical energy to mechanical energy. In this project, a 12-Volt DC motor is used to spin the propeller of the smart fan. Due to the low voltage and current output from the FPGA board, the DC motor cannot be connected directly to the output pin of the FPGA board. Therefore, external motor driver IC and external power source are required.

2.0 PROJECT DESCIPTION

The purpose of the project is to build a FPGA based motion following smart fan that can detect the presence of user and follow the motion of the user in order to track the moving object. This idea was translated into a working prototype in Gotmare (2012). Besides, the fan is also eco-friendly and energy saving as it will turn off automatically when there is no person in front of it. The project is done by using a DC motor, three Infrared sensors (IR sensor) and a stepper motor. One of the IR sensor is used for the detection of the presence of user in front of the fan, while the another two IR sensors are used to sense the position of the user whether is at the right side or left side of the fan. For example, the fan will turn left if there is a user standing at its left side. Hence, the fan will always face to the user.

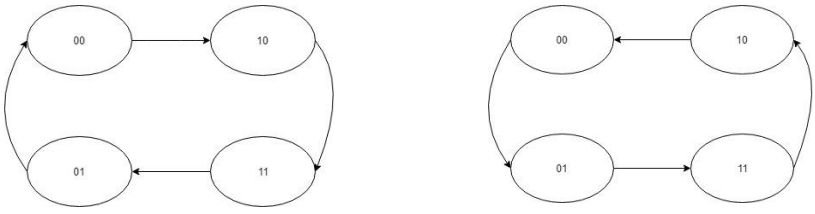
The fan is programmed by using Altera's DE2-115 Development and Education Board. The motion of the upper body of the fan is done by using a stepper motor. The direction of the rotation of the stepper motor is controlled by the FPGA board depends on the signals sent from the IR sensors. If the person is detected by left IR sensor, the stepper motor will rotate in clockwise direction. If the person is detected by right IR sensor, the stepper motor will rotate in anticlockwise direction. The external stepper motor driver IC used is ULN 2003a motor driver IC, because FPGA board cannot provide enough voltage and current to the stepper motor, so external power source is needed.

DC motor is used to spin the propeller of the fan when IR sensor senses a person near the fan.

3.0 METHODOLOGY

A. Digital circuit used to control the direction of stepper motor

A bidirectional asynchronous 2-bit counter is designed to control the stepper motor whether to rotate in clockwise or anticlockwise, this technique was discussed in Shaikh U. (2018). An input X is added to control the direction of the rotation of the stepper motor. When X is HIGH, the motor rotates in clockwise, and when X is LOW, vice versa. The phase sequence for the stepper motor is applied to obtain a full step (7.5 degrees per step) and high torque effect as shown in the Figure 1. The counter is done by using 2 toggle flip-flops, and all the outputs, $\boldsymbol{Q_1}$, $\boldsymbol{Q_0}$, $\overline{\boldsymbol{Q_1}}$ and $\overline{\boldsymbol{Q_0}}$ are used for the stepper motor. Its state diagram is shown as below and is followed by excitation Table 1:



(a) (b)

Figure 1: (a) State diagram when X is HIGH. (b) State diagram when X is LOW.

Table 1: Excitation table for the bidirectional asynchronous 2-bit counter.

Direction	**Present state**		**Next state**		**Toggle flip-flops**	
X	Q_1	Q_0	Q_1**+1**	Q_0**+1**	T_1	T_0
0	0	0	0	1	0	1
0	0	1	1	1	1	0
0	1	1	1	0	0	1
0	1	0	0	0	1	0
1	0	0	1	0	1	0
1	1	0	1	1	0	1
1	1	1	0	1	1	0
1	0	1	0	0	0	1

B. Digital circuit design for the detection of the presence of user

The truth table for the detection of the presence of user is shown in the Table 2:

Table 2: Truth table for the detection of the presence of user.

IR sensor, IR_1	Switch	Enable, En_1
0	0	0
0	1	1
1	0	0
1	1	0

Follow the approached made in Nicula D. (2011), the En_1 output is used to enable the DC motor to spin. The DC motor of the fan will be started to spin if and only if the output of the IR sensor is LOW and the Switch is on (HIGH). If the IR sensor does not sense anything, the fan is off.
The circuit is drawn as below:

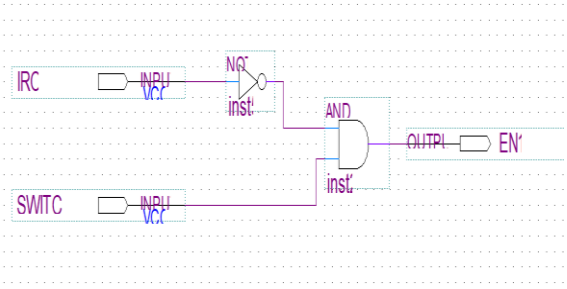


Figure 2: The digital circuit for the detection of the presence of person in front of the fan.

C. Digital circuit used to make the fan to follow the motion of user

This part of circuit will be enable when the DC motor is begun to spin (Enable 1 is HIGH). There are two IR sensors placed at the left and right hand sides respectively of the fan to detect and follow the motion of user. The Enable 2 output, En_2 is used to control the stepper motor when to start spinning. The stepper motor will start to rotate when En_2 is HIGH. The circuit is shown in the Figure 3.

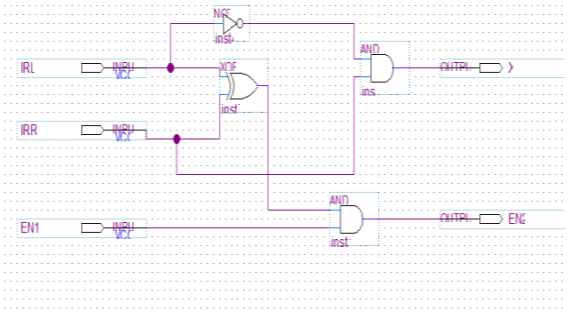


Figure 3: The digital circuit for the motion following purpose.

The Enable 2 is connected with the clock input by using an AND gate to make the motor whether to stop or start spinning.

4.0 SIMULATION

The digital circuit design is drawn and simulated using the Quartus II software. The result of the simulation is shown in the Figure 4. The inputs and outputs of the system are represented by the parameters respectively, which are S = switch, CLK = clock input, IRL = IR sensor at the left hand side, IRR = IR sensor at the right hand side, dc_motor = DC motor and the 'Q's are the outputs for the stepper motor. The frequency of the clock input in the simulation is set to be lower to make the simulation clear.

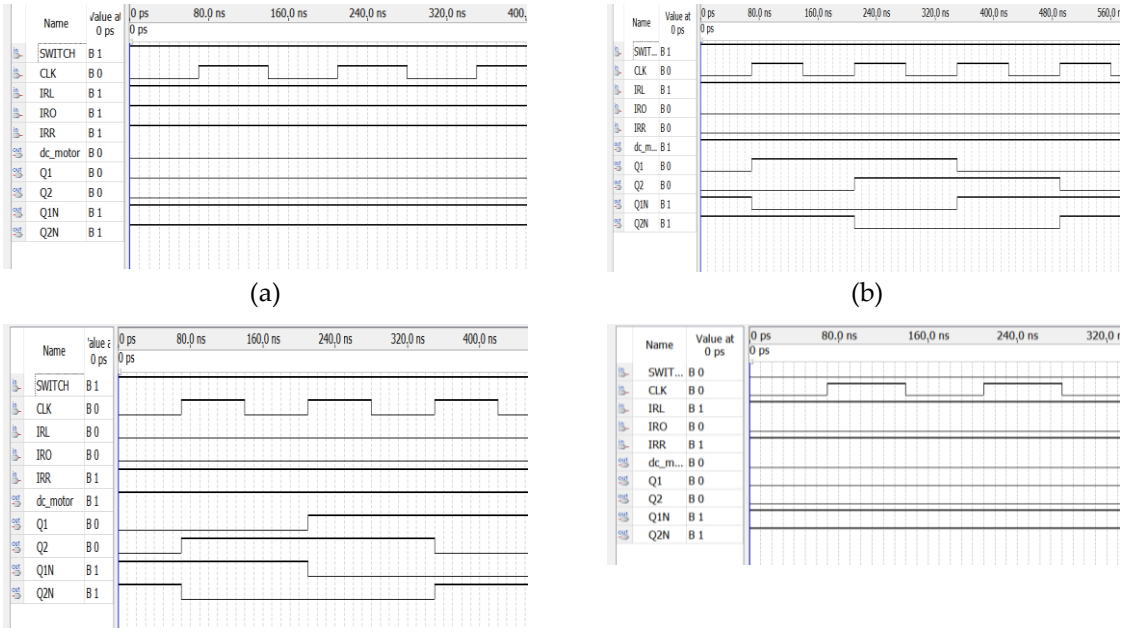


Figure 4: Simulation result (a) first result (b) second result (c) third resutl (d) forth result

In the Figure 4(a), the switch is on and the outputs of the IR sensors are HIGH as there is no person in front of it. Thus, the dc motor is off and the stepper motor does not move. In the second Figure 4(b), IRO and IRR are LOW so it means that there is a person at the right side. The DC motor starts rotating and the stepper motor rotates to the right. The rotation of the stepper motor is controlled by the sequence of the outputs Q. For third condition as in Figure 4(c), the person moves from right to left, so IRL is LOW and IRR is HIGH, the DC motor keeps rotating, and the stepper motor rotates to the left. The Figure 4(d) shows that the stepper motor and DC motor are stopped rotating when the switch is off, even there is a person in front of it. The results of the simulation are summarized in the Table 3.

Table 3: Simulation result.

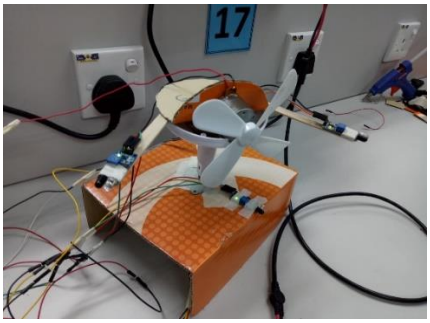
SWITCH	IRO	IRL	IRR	dc_motor
0	X	X	X	0
1	0	X	X	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	0

**X = do not care

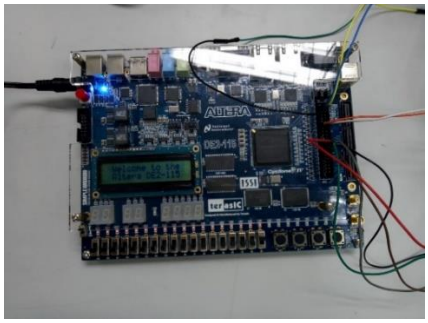
5.0 HARDWARE AND CIRCUIT CONSTRUCTION

Smart fan consists of some major components which are stepper motor, ULN2003a stepper motor driver IC, IR sensors and DC motor. The automatic fan system is controlled by Altera's DE2-115 Development and Education Board. The digital circuit that have been designed is compiled and uploaded to the FPGA board.

The prototype of the project is made of some reused materials such as cardboard, propeller from another old broken fan and so on. The prototype is shown in Figure 5(a) with the coding made in Figure 5(b).



(a)



(b)

Figure 5: (a) The prototype of the smart fan. (b) The connection of the GPIO pins of the FPGA board.

6.0 RESULT AND DISCUSSION

Expected results are obtained and while testing the automatic fan. The results are summarized in Table 4.

Table 4: Result of testing the smart fan.

Switch	Presence of person in front of the middle IR sensor	Position of person	DC motor starts to rotate	The direction of rotation of stepper motor
Off	No	No person	No	No
Off	Yes	No person	No	No
Off	Yes	Either middle, left, right, or both	No	No
On	No	No person	No	No
On	No	Either middle, left, right or both	No	No
On	Yes	Middle	Yes	No
On	Yes	Left	Yes	Clockwise
On	Yes	Right	Yes	Anticlockwise
On	Yes	Both left and right	Yes	No

It shows the similar result as compared to the simulation that has been done before. The limitation of the project is the person cannot be detected when he is standing behind the fan with similar case happened in Kanchanasatian (2017). This is because the IR sensor is placed at the front of the fan. Besides, the sensing range of the IR sensor used is also narrow. The IR sensor can only sense the person who is not only standing exactly in front of the fan, but also standing close to the fan. Next, the rotation of the stepper motor is also not that stable due to its low torque. Inserting an IR sensor at the back of the fan is one of the ways to overcome the weakness that the fan cannot sense the person who stands behind it. Another circuit design might have to be added in the automatic fan system to achieve this purpose. Then, the IR sensor can also be replaced with a wide range higher quality IR sensor. Last but not least, the stepper motor should be replaced by a high torque, low voltage and high current stepper motor to achieve a more stable rotation for the fan when it follows the motion of the user.

7.0 CONCLUSION

In the paper, problems arising during implementation of detection algorithms in FPGA were presented. The proposed solution is to apply object tracking approach with semi-automatic procedure of implementation of hardware and software design with simulation analysis of controlling motion of the fan. The procedure was successfully applied to the prototype development of implementation by using IR sensor and stepper motor.

8.0 ACKNOWLEDGEMENT

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9.0 REFERENCES

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

Gotmare A. D., Sambath M. & Ravi S. (2012). Tracking and Recognizing the Moving Object In Real Time Using Frame Difference Method. *International Conference on Advanced Engineering & Technology*

Kanchanasatian K. (2017). Automatic Speed Control and Turning ON/OFF for Smart Fan by Temperature and Ultrasonic Sensor. *IOP Conf. Series: Materials Science and Engineering 325*

Laximi K. (2017) . Automatic Speed Control and Human Tracking Fan using Image Processing using Matlab. *International Journal for Innovative Research in Science & Technology, 3(10), 98-105*

Lim J. & Kriegman D. (2004).Tracking Humans using prior and Learned Representations of Shape and Appearance. *International Conference on Automatic Face and Gesture Recognition*

Nicula D. (2011). Digital Electronics: A Modern Lab Approach. Bulletin of *the Transilvania University of Braşov Series I: Engineering Sciences, 4 (53) No. 1*

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