

A Design of Low Power Single Axis Solar Tracking System Regardless of Motor Speed

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Abstract: Solar power generation had been used as a renewable energy since years ago. Residential that uses solar power as their alternative power supply will bring benefits to them. The main objective of this paper is to present development of an automatic solar tracking system whereby the system will caused solar panels will keep aligned with the Sunlight in order to maximize in harvesting solar power. The system focuses on the controller design whereby it will caused the system is able to tracks the maximum intensity of Sunlight is hit. When the intensity of Sunlight is decreasing, this system automatically changes its direction to get maximum intensity of Sunlight. LDR light detector acts as a sensor is used to trace the coordinate of the Sunlight by detecting brightness level of Sunlight. While to rotate the appropriate position of the panel, a DC-g geared motor is used. The system is controlled by two relays as a DC-g geared motor driver and a microcontroller as a main processor. This project is covered for a single axis and is designed for low power and residential usage applications. From the hardware testing, the system is able to track and follow the Sunlight intensity in order to get maximum solar power at the output regardless motor speed.

Keywords: Solar tracking, solar tracker, microcontroller, DC motor, LDR.

1. Introduction

In last ten years, many of residential around the world used electric solar system as a sub power at their houses. This is because solar energy is an unlimited energy resource, set to become increasingly important in the longer term, for providing electricity and heat energy to the user. Solar energy also has the potential to be the major energy supply in the future. Solar tracker is an automated solar panel that actually follows the Sun to increase the power [3]. The sun's position in the sky varies both with equipment over any fixed position. One well-known type of solar tracker is the heliostat, a movable mirror that reflects the moving sun to a fixed location, but many other approaches are used as well. Active trackers use motors and gear trains to direct the tracker as commanded by a controller responding to the solar direction. The solar tracker can be used for several application such as solar cells, solar day-lighting system and solar thermal arrays [1]. The solar tracker is very useful for device that needs more sunlight for higher efficiency such as solar cell.

Many of the solar panels had been positioned on a fixed surface such as a roof. As sun is a moving object, this approach is not the best method. One of the solutions is to actively track the sun using a sun tracking device to move the solar panel to follow the Sun. With the Sun always facing the panel, the maximum energy can be absorbed, as the panel is operating at their greatest efficiency [4]. The main reason for this project is to get the maximum efficiency for the solar cells. Although there are many solar trackers in the market, the price is

expensive and unaffordable because the market for solar tracker is still new and only certain countries use the solar tracker such as USA and South Korea. The large scale solar tracker that normally used is not suitable for the residential use. As a result, this project will develop a Sun tracking system specially designed for residential use for a low cost solar cell.

Previous researchers [5, 7] and [6] used LDR and photodiode as sensors respectively. Meanwhile [5] and [6, 7] used DC motor with gear and stepper motor respectively. Those projects have disadvantages and some of the disadvantages are high cost during development, difficult to control motor speed and difficult to design because using microprocessor.

The main objective for this project is to develop the sun tracking solar system model which is a device that follow the movement of the Sun regardless of motor speed. Beside that, it is to improve the overall electricity generation using single axis sun tracking system and also to provide the design for residential use.

LDR or light dependent resistor has been chosen as the sensor because LDR is commonly used in sun tracking system. This is because LDR is sensitive to the light. The resistance of LDR will decreases with increasing incident light intensity [2]. For the controller, PIC16F877A had been chosen. This PIC programming will give the pulse to the driver to move the motor. For the driver, bi-directional DC motor control using relay has been used. The motor controller had been chosen because it can control the motor to rotate clockwise and counter-clockwise easily. DC geared motor also been

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chosen because it has a hold torque up to 24 kg.cm and low rpm. Last but no least, LM7805 is used to convert the input voltage from the source to 5 V output because integrated circuit only need 5 V to operate.

2. Methodology

This project is divided into two parts, hardware development and programming development. Figure 1 shows block diagram of the project.

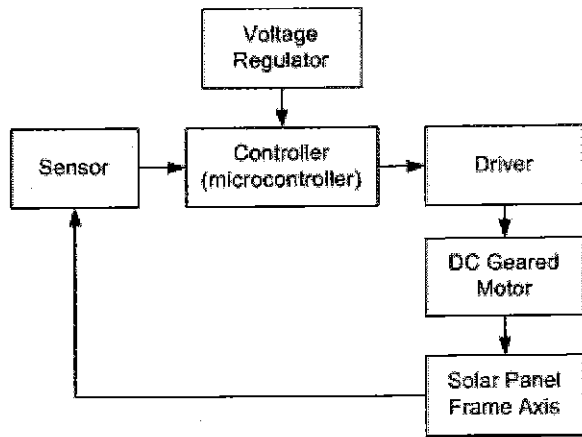


Figure 1: Block diagram of the project

The project is built using a balanced concept which is two signals from the different sensors are compared. Light Dependent Resistor (LDR) as a light sensor has been used. The two light sensor are separated by divider which will create shadow on one side of the light sensor if the solar panel is not perpendicular to the sun. For the controlling circuit, microcontroller PIC16F877A acts as a brain that controls the movement of the motor via relay. Data received from the sensors and processed by the microcontroller. The microcontroller will send a data to the Bi-directional DC-g geared motor via relay to ensure solar panel is perpendicular towards the Sun. Relay controls the rotation of the motor either to rotate clockwise or anticlockwise. The solar panel that attached to the motor will be reacted according to the direction of the motor.

3. Programming

The microcontroller used in this solar tracker system is PIC16F877A and is ready for ADC converter. Figure 2 shows a flowchart of PIC16F877A programming.

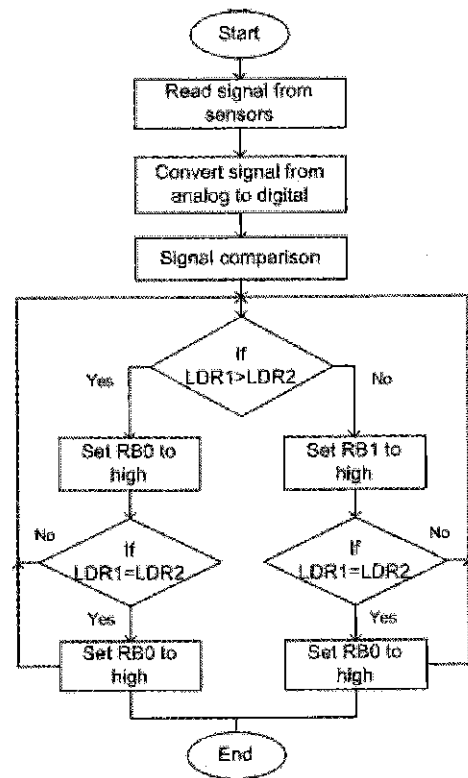


Figure 2: Flowchart of PIC 16F877A programming

4. Results and Analysis

The system is focusing on the controller design. The constructed system has been tested and some data from hardware measurement have been collected and discussed. Typical solar panel has been used and the purpose only to prove the designed system is able to operate accordingly. Therefore the surrounding effects, for instance, weather condition are not seriously considered during hardware testing.

4.1 Sensor

Figure 3 shows sensor circuits for the system.

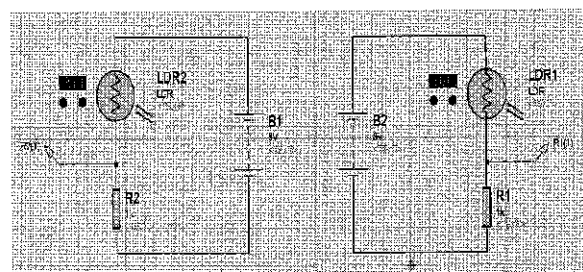


Figure 3: Sensor circuit

Table 1 shows the LDR output voltage from hardware measurement. When LDR is exposed to Sunlight, V_{LDR} is 0.74 V and V_{RLDR} is 1.53 when is not exposed. It shows that the brightness of Sunlight will caused voltage at LDR low.

Table 1: LDR output voltage from solar sensor circuit from hardware measurement

To sunlight	V_{RLDR}	V_{LDR}
Exposed	3.75 V	0.74 V
Not exposed	3.46 V	1.53 V

4.2 Microcontroller

For ADC conversion, the calculation to determine the desired voltage is shown in equation 1 and 2. Using 200_{16} , this condition of sample can be determined. If both inputs for analogue pin in PIC16F877A is less than 0.2 V, the output at pin 33 and 34 will be set low (0). If the difference both input for analogue pin is higher than 0.2 V, the output either at pin 33 and pin 34 will be high (1).

$$V_{step} = \frac{V_{reference}}{ADC\ bit} \tag{1}$$

For this project, $V_{Reference}$ is equal to V_{DD} which is 4.94 V and ADC in PIC16F877A is a 10-bit ADC module. Thus, the calculated V_{Step} is 0.00482 V.

$$ADC\ output = \frac{Desired\ Voltage}{V_{step}} \tag{2}$$

Using calculated V_{Step} , ADC output can be calculated using equation 2. For example, the desired voltage is 3.75 V. So the value for ADC is 777_{10} or 309_{16} .

4.3 DC-gear Motor Controller

Relay driver has been used to control the direction of the DC geared motor. Figure 4 shows the control circuit of Bi-directional DC-gear motor using relay.

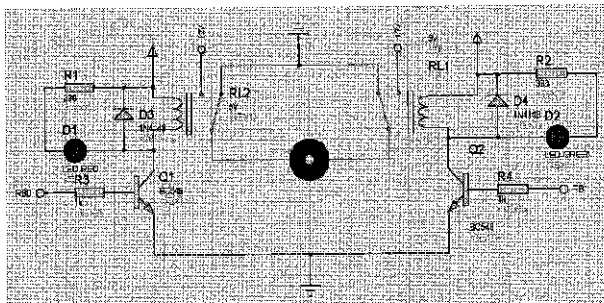
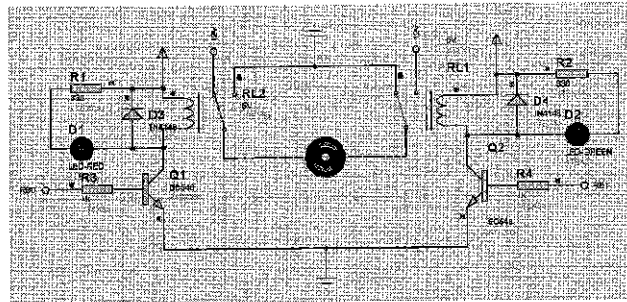


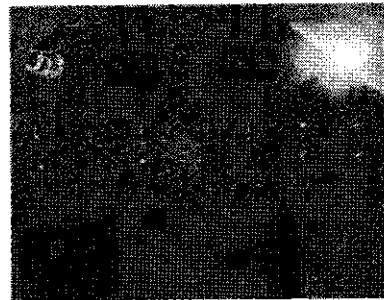
Figure 4: Circuit of Bi-directional DC-gear motor

From hardware observation, when the input RB0 is high (1), relay RL2 will be activated. Therefore 12 V will

be tapped to the DC geared motor. Figure 5 shows the condition when input RB0 is set to high (1), the motor will rotate in clockwise direction.



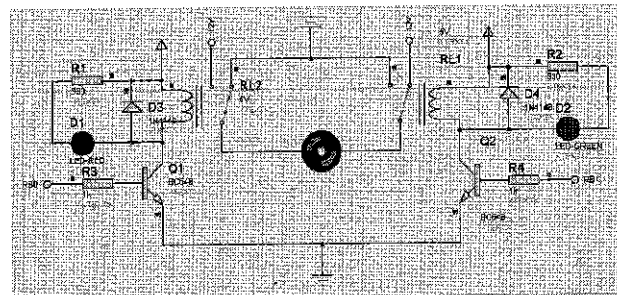
(a)



(b)

Figure 5: Input at RB0 is high (clockwise rotation), (a) designed circuit, (b) hardware circuit (green LED activated)

Hardware observation shows when the input RB1 is high (1), relay RL1 will be activated. Therefore 12 V will be tapped to the DC geared motor. Figure 6 shows the condition when input RB1 is set to high (1), the motor will rotate in counter-clockwise direction.



(a)



(b)

Figure 6: Input at RB1 is high (counter-clockwise rotation), (a) designed circuit, (b) hardware circuit (red LED activated)

Table 2 shows the voltage readings from LDR sensors and this is caused the direction of motor rotation is effected, clockwise or counter-clockwise. Meanwhile, Table 3 shows the motor operating condition.

Table 2: Motor operating condition

Clockwise	Counter-clockwise
LDR1 = 1.06 V LDR2 = 0.25 V	LDR1 = 0.15 V LDR2 = 1.11 V

Table 3: Motor operating condition

RB0	RB1	Direction
0	0	Stop
1	0	Clockwise
0	1	Counter-Clockwise
1	1	Stop

From the hardware testing result, the designed system is able to operate accordingly whereby the DC-g geared motor is able to rotate either clockwise or counter-clockwise directions based on data from the sensors (LDRs) and the sensors are able to detect the brightness level of Sunlight that hit to them. The unique of the

designed system is the speed of DC-g geared motor is neglected because the motor offers low output rated speed, 17 rpm and high output rated torque, 1960 mN.m. Therefore, speed of the motor is not critical consideration during design process. The main consideration of the designed system is direction of motor rotation and this matter has been tackle by considering relay driver circuit.

4.4 Solar Model

Table 4 shows the specification of single axis solar tracking system model. Figure 7 shows hardware constructed of the designed system.

Table 4: Specification of Solar Tracking System

Design Aspect	Specification
Weight	2.4 Kg (including the panel)
Size	38cm x 40cm x 32 cm
Material	Bases- PVC pipe (20MM 3/4") Panel chassis - aluminum bar - (.55inch x .55inch)

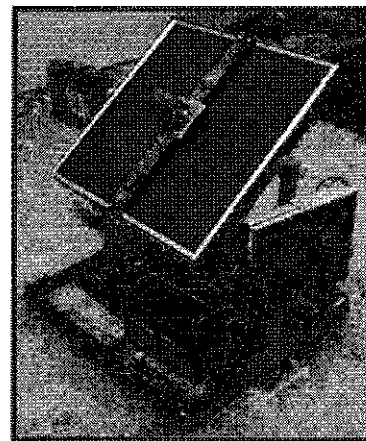


Figure 7: Hardware constructed of the designed system

4.5 Reading Data From Solar Panel During Hardware Testing

Table 5 shows the data of voltage, current and power received from static solar panel and solar tracking system for a day. From static solar panel, maximum voltage, current and power is 21.1 V, 5.94 mA and 125.334 mW respectively. Meanwhile, from solar tracking system, maximum voltage, current and power is 21.6 V, 6.35 mA and 137.160 mW respectively. Figure 8 shows the comparison of electric power characteristic curves from static solar panel and solar tracking system. It shows that solar tracking system is able to receive more Sunlight and consequently generate more power as compared to static solar panel.

Table 5: Reading data from solar panel during hardware testing

Hours	From static solar panel			From solar tracking system		
	V	mA	mW	V	mA	mW
8:00 AM	16.8	1.23	20.664	18.3	3.41	62.403
9:00 AM	17.0	2.34	39.780	18.9	3.57	67.473
10:00 AM	17.6	2.51	44.176	19.4	3.98	77.212
11:00 AM	19.4	3.64	70.616	19.7	4.76	93.772
12:00 PM	19.8	4.45	88.110	20.4	5.40	110.430
1:00 PM	20.5	5.12	104.960	21.6	6.35	137.160
2:00 PM	21.1	5.94	125.334	21.4	6.11	130.754
3:00 PM	19.4	5.43	105.342	20.5	5.87	120.335
4:00 PM	17.2	5.01	86.172	19.6	5.26	103.096
5:00 PM	16.5	4.28	70.620	18.5	4.86	89.910
6:00 PM	16.2	2.87	46.494	17.5	3.75	65.625

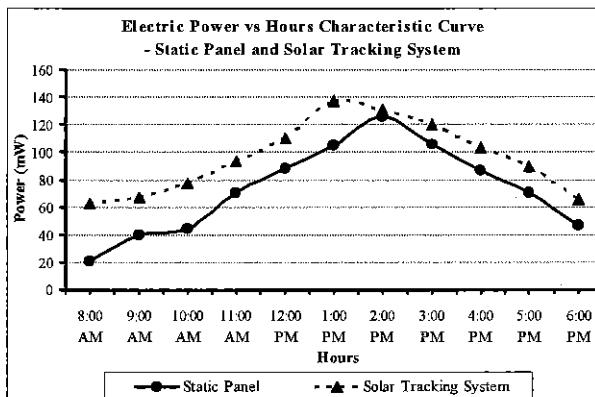


Figure 8: Electric Power vs Hours characteristic curve – comparison between static solar panel and solar tracking system

5. Conclusion

Single Axis Solar Tracking System prototype model is successfully developed. The designed system is focuses on designing controller part and the main concern is to design appropriate circuits and the circuits suppose to be able to control DC-gear motor rotation direction without considering motor speed.

The system is able to track and follow Sunlight intensity in order to collect maximum solar power regardless of motor speed. The unique of developed system, motor speed is not critical consideration because the DC-gear motor offers low output rated speed and high output rated torque. Therefore any types of DC-gear motor can be used for this system regardless of motor speed controller unit as long as the speed and torque of the motor are following the given specification.

The constructed system model can be applied in the residential area for alternative electricity generation especially for non-critical and low power appliances.

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