Microcontroller-Based Two-Axis Solar Tracking System

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ABSTRACT

The main goal of this project is to develop and implement a prototype of two-axis solar tracking system based on a PIC microcontroller. The parabolic reflector or parabolic dish is constructed around two feed diameter to capture the sun's energy. The focus of the parabolic reflector is theoretically calculated down to an infinitesimally small point to get extremely high temperature. This two axis auto-tracking system has also been constructed using PIC 16F84A microcontroller. The assembly programming language is used to interface the PIC with two-axis solar tracking system. The temperature at the focus of the parabolic reflector is measured with temperature probes. This auto-tracking system is controlled with two 12V, 6W DC gear box motors. The five light sensors (LDR) are used to track the sun and to start the operation (Day/Night operation). Time Delays are used for stepping the motor and reaching the original position of the reflector. The two-axis solar tracking system is constructed with both hardware and software implementations. The designs of the gear and the parabolic reflector are carefully considered and precisely calculated.

Keywords

PIC microcontroller, parabolic reflector, LDR, DC gear box motor,

1. INTRODUCTION

Solar energy is the most democratic of renewable energy resources. It is available everywhere on the earth in qualities that vary only modestly. The role of solar energy is indeed going to be predominant. Because solar energy is available free at any place on the earth. Solar energy is renewable and will not deplete within the next several billion years.

Several applications of solar energy ranging from simple solar water heating to complex megawatt power generation systems are under extensive investigation. The function of the solar collector is to collect the radiation incident from the sun. Solar collectors can be grouped into two general classifications: flat-plate (low to medium temperature) collectors and focusing (high temperature) collectors. Focusing (parabolic dish) collector systems are the most efficient of all solar technologies, at approximately 25% efficient, compared to around 20% for other solar thermal technologies[7].

Therefore the parabolic reflector is constructed about 2 feet diameter.The two-axis solar tracking system is constructed with two DC gear box motors because the maximum temperature at the focus of the parabolic reflector is always required. This control system is controlled by PIC 16F84A and interfaced with assembly language.

2. PROPOSED DESIGN

There are two type of control system, open-loop control system and closed-loop control system.Closed-loop control system is used in this project and PIC16F84A is the main controller and input and output devices are sensors and DC gear box system.The proposed design in this project is as follow:

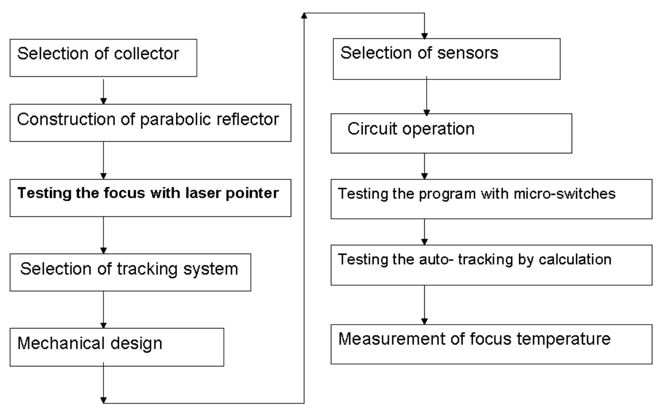

Figure1. Flowchart of the Proposed Design

3. HARDWARE IMPLEMENTATION

The procedure for implementing the whole system includes installing the parabolic reflector, choosing suitable design for gear boxes, and assembling the control circuit for the system.

3.1 Making a Parabolic Reflector out of a Flat Sheet

The parabolic reflector is constructed with glass fiber plate. The easiest way is to cut and fold a flat sheet into a parabolic dish. Then a layer of glass fire is glued on its inner surface, for reflectivity.

The diameter of the parabolic reflector is about 2ft and its radius is about 1ft. So the radii of five concentric circles are drawn with the scales and the circles are divided by 6 uniformly

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spaced diameters (30' apart). Each circle should consist of 12 identical sectors [5]. The photograph of one paddle from 12 segments is shown in Figure(2).

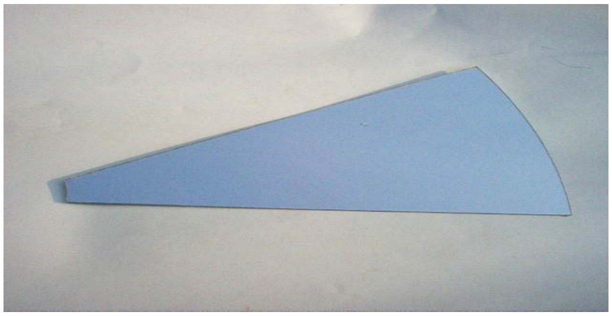

Figure 2.One Paddle from 12 Segments of the parabolic Reflector

3.2 Testing the Focus of the Parabolic Reflector

A laser pointer can be used for checking the real shape accuracy of any "dish" reflector. Some dishes aren't parabolic. So orthogonal (perpendicular) mounting the laser pointer to point directly into the dish and translating the laser along a rigid support, one can simulate parallel rays entering the dish. These can be reflected off the back of the dish and the focus movement observed. By translating the laser pointer from the rim of the dish towards the center (in at least two axes) the real upper limit of useable frequency for a particular dish can be measured. Using the laser gives a visible indication of the focus movement as the laser is translated. Some reflectors (dishes) aren't parabolic and therefore the focus will move as the laser is translated. A true parabolic shape will have no movement of the focus. Most available dishes aren't perfect but they can accurate enough for amateur microwave applications [6].

4. MECHANICAL DESIGN OF GEAR BOX SYSTEM

Gears are used in the two-axis parabolic tracking system. Two DC motors are worm and worm wheel DC gear box motors and the driver is used worm and the driven is used the worm wheel. It is used in the gear box motor because this position is more reduce the speed of the reflector than other gear system. The revolution of 12V, 6W DC motor is about 1908 rpm. It can be measured by revolution counter.

A worm and worm wheel DC motor and two helical gears system are used for the vertical motion of reflector. In the vertical motor, the driver worm wheel has 51 teeth and the gear ratio is 51:1. First helical is 5 teeth helical gear and second helical is 78 teeth and its diameter is 72 mm. This gear's gear ratio is 78:5. The total gear ratio of vertical (altitude) motor is 795.6:1 and the final speed of the vertical motor is about 2.4 rpm.

Two worm and worm wheels are used for horizontal (azimuth) motion of reflector. In horizontal (azimuth) motor, the worm wheel has 53 teeth and the gear ratio is 53:1. In second worm and worm wheel, worm wheel is 86 teeth and the gear ratio is 86:1. The total gear ratio is 1:4558 and the final speed of the horizontal motor is 0.4 rpm. The arrangements of two DC gear box motors on the frame are shown in Figure (3).

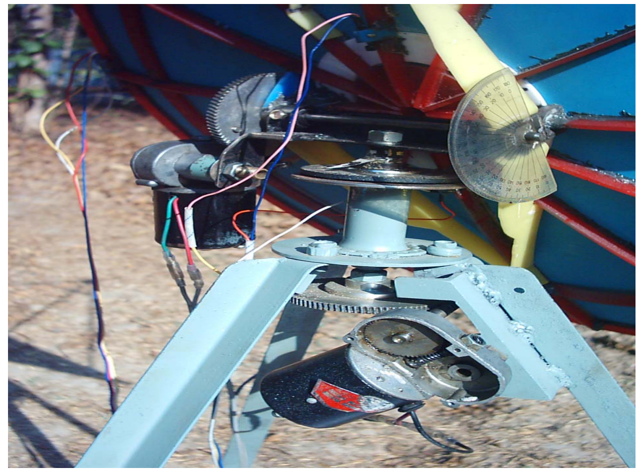

Figure 3. Two DC Gear Box Systems

5. COMPONENTS AND OPERATION OF THE CONTROL SYSTEM

In the control system, the important components are Light dependent resistor (LDR), LM 358 window comparator, TA7291PICs, BP139, TIP32, TIP31 ICs, and PIC16F84A microcontroller.

5.1 Sensors

Light dependent resistors (LDR) are used in the two-axis solar tracking system for detecting the dish position. Four LDRs are used for moving the altitude and azimuth of the reflector. Two sensors (East/West) are used in the altitude motion of the reflector and two sensors (Left/Right) are used in the azimuth motion of the reflector. These sensors are placed on the same plane in two black pipes because sensors are sensitive the ambient light. A concave and convex mirror is placed at the top of the pipe for the light is falling on the centre of four LDR sensors.

One LDR and 5kΩ variable resistors are joined and are connected to the 12Vdc power supply. This circuit is connected to 3rd LM358 and then the output of LM358 is connected to Pin 2 of 16F84A microcontroller. The whole circuit will start in the operation when the output voltage of light falling on this LDR is greater than 2.7V.

5.2 Interface with the Microcontroller

Two LM 358 ICs are used as a window detector (window comparator). In this project, the motor is ON when the output is below the set-point and OFF when the output is above the set-point. ON/OFF action control is controlled with LM 358 window comparator shown in Figure (4).

PIC 16F84A microcontroller is the main controller of the whole circuit and has many electronic circuits built into it, which can decode written instructions and convert them to electrical signals.

The first LM358's Pin 1 and Pin 7 are connected to the RB0 and RB1 of PIC 16F84A and are used as the inputs of the 16F84A IC.

The second LM358's Pin 1 and Pin 7 are connected to the RB4 and RB5 and are also used as the inputs of the 16F84A. These two LM358's Pin 2 and Pin 5 are joined and connected to the outputs of two LDR sensors (East/ West) and two LDR sensors (Right/ Left sensor). The first and second LM358 is used as the window detectors.

The third LM358 is used as a comparator and this comparator is used the start of the two axis solar tracking system. Pin 4 and Pin 14 of PIC are connected to the 5V dc power supply and Pin 5 is ground. Pin 16 and Pin 15 are connected to the two 22pF capacitors and 4MHz crystal for clock frequency to orchestrate the movement of the data around its electronic circuits. RA0, RA1, RA2 and RA3 are the outputs of the 16F84A and these outputs are connected to Pin 5 and Pin 6 of two TA7291Ps. In this project, two TA7291P ICs are used for driving the DC motor. 12V dc power supply didn't really provide enough torque for the gear box motor to run smoothly. Finally, Darlington pair circuits are replaced between TA7291P IC and DC motor and are used for power amplifier. The circuits of two-axis tracking system are shown in figures (4), (5) and (6).

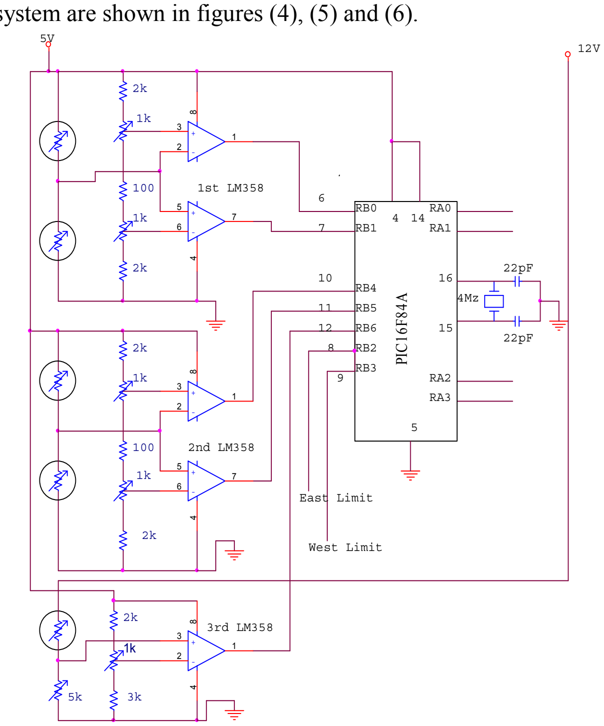

Figure 4. Connecting Three LM358 with PIC16F84A

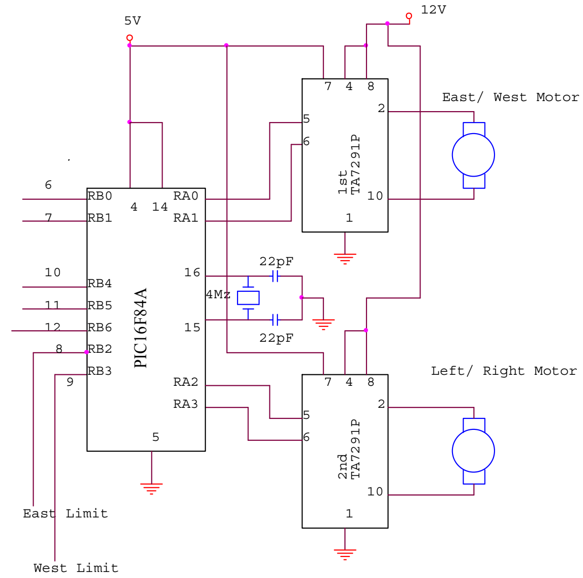

Figure 5. Motor Driver Circuit with PIC16F84A

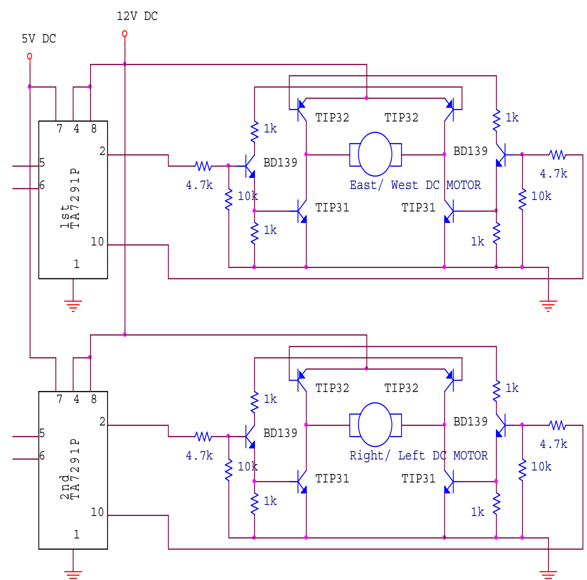

Figure 6. Power Amplifier Circuit of Two Darlington Pairs and DC Driver TA7291P ICs

7. SOFTWARE OPERATION OF CONTROL SYSTEM

The assembly programming language is used to interface with two-axis solar tracking system using PIC16F84A. At first, micro-switches are used to check the program and left/Right motion and East/West motion of the DC motors are tested with program.

At the start of the program is placed delay time. After light level is one, the whole circuit is to start the operation. The software turns the motor on and off, or sets the speed within very short time. Thus, the controller spends an insignificant amount of time on controlling the motor. In this project, Time Delay is always placed between motor driving and motor stopping for stepping DC motor.

7. TRACKING SYSTEM RESULTS

In this project, for the reference voltage of third LM358 one LDR and variable resistoris supplied 5V dc but LDR does not sensitive the cloudy and lighting of the sky in this power supply. The output voltages of this circuit are not clearly difference between cloudy and lighting. So this power supply is changed to 12V dc power supply.

The resistances of 4-LDRs are not the same but are chosen nearly the same resistance. These sensors are placed on the same plane and at the side of the reflector.

The Earth spins on its axis and completes one rotation in 23 hours 56 minutes and 4 seconds; this is a sideral day and is slightly different from the familiar 24 hour day. It takes roughly 365 days for the Earth to go around the Sun once. Sun path is calculated by Javascript Solar Position Calculator for the year of sun position at Yangon city in Myanmar [2].

The objective of PIC16F84A module is to sense from sensors and to control solar parabolic reflector. The parabolic reflector is placed to face the sun by manual before the experiment. And then this reflector to trace the sun the whole day until the reflector is touched the limit switches. Limit switches are placed at 30°in the East/West of the reflector. The parabolic reflector is moved the one time per 5 minutes. This parabolic reflector is to track the sun with two-axis movement until the light is falling to the center of a four LDR sensor and the outputs of the 1st and 2nd LM358 are one. The tracking measurements of this parabolic reflector are shown in Table 1. The graphs are arranged to compare with calculation by Javascript Solar Position Calculator and measurements by parabolic reflector movements. These graphs are shown in figure (7)and (8)and figure (9) shows the focus temperatures of the reflector measured by the temperature probe . These data are measured in January and the position of the reflector is placed to face the south position. The west limit switch is placed to the south and the east limit switch is to the north.

Parabolic reflector can track the sun at missing 15° in the azimuth position and missing 10° in the altitude position from the focus of the reflector. Maximum focus temperature is about 200°C. The reflector is always moving to track the sun at about one rotate per five minute. In this way the reflector is moving to face the sun by auto-tracking system the whole day.

The program is modified by replacing the time delay for returning the original position. The reflector is always to touch the West Limit switch at about 15:00 hour. So the time delay is placed in the program and then the reflector returns to move the morning position. At that time the light level is low and the whole system operation is stopped. The reflector returning the morning position is arranged by the time delay. This time delay is obtained by calculation the motor revolutions and the whole day movement degree. In the next morning time the light level is high and the reflector is searched the sun by the little moving the altitude and azimuth positions of reflector. Returning the morning position and starting the morning movement are arranged in this way.

Table 1. Sun Position of Yangon and Focus Temperature of Parabolic Reflector

Hour(hr)	Solar Altitude		Solar Azimuth		Focus
	Calculation(°)	Measurement Data(°)	Calculation(°)	Measurement Data(°)	Temperature(°C)
10:00	39.65	36	139.38	139	98
10:15	41.91	38	142.83	144	100
10:30	44	42	146.61	149	103
10:45	45.87	42	150.71	154	107
11:00	47.51	44	155.15	159	115
11:15	48.89	46	159.92	164	122
11:30	49.98	46	164.97	169	123
11:45	50.76	47	170.25	174	116
12:00	51.2	48	175.71	179	112
12:15	51.29	48	-178.77	-175	117
12:30	51.04	48	-173.27	-170	134
12:45	50.45	47	-167.88	-165	143
13:00	49.53	44	-162.69	159	145
13:15	48.31	44	-157.76	-155	126
13:30	46.82	43	-153.14	-149	116
13:45	45.07	41	-148.84	-145	121
14:00	43.09	38	-144.89	-142	108
14:15	40.93	36	-141.25	-139	126
14:30	38.59	33	-137.94	-135	112

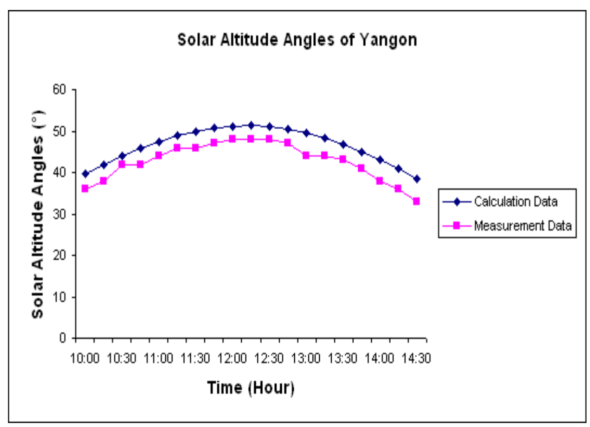

Figure 7. Solar Altitude Angles of Yangon between Calculation Data and Measurement Data

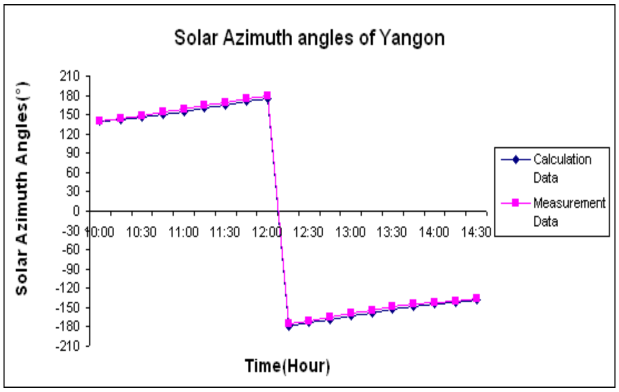

Figure 8. Solar Azimuth Angles of Yangon between Calculation Data and Measurement Data

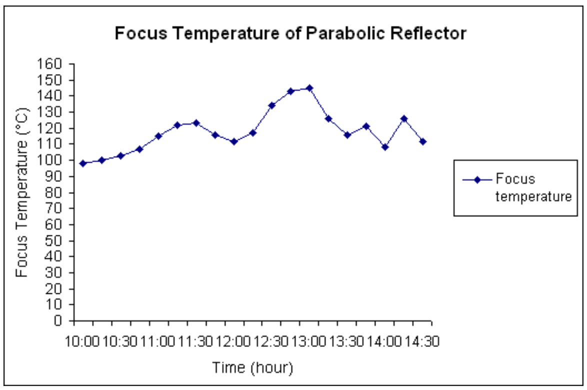

Figure 9. Focus Temperatures of Parabolic Reflector with Auto-Tracking System

8. CONCLUSION AND FUTURE WORK

PIC (Peripheral Interface Controller) based system has various advantages; the electronic circuit components are less and cheaper than PC, portable hardware components, low power consumption rate, simple installation and operation. Besides PIC is used that is cost effective and easy to maintain. So two axis auto solar tracking system is constructed based on PIC and it can be used in generating of electricity and domestic use.

This system may be used for receiving always maximum temperature at the focus of the reflector. The parabolic reflector is arranged with five LDR sensors for moving and changing place to face the reflector and the sun. Therefore the reflector is moving to face the sun to trace with two DC motors. These two DC motors are controlled with PIC16F84A under the programming of assembly language. The control of DC motor is more complex than the stepper motor but the stepping of DC motor is arranged with the gear system. This control is very simple, easier to design and less expensive to build. PIC 16F84A is used to control two DC motors accurately with minimum hardware at a very low cost.

This project is also a trial and the mirror should be used the surface layer of the reflector because it has the best reflectivity. Gear system can also be used other high quality motors and a small Stirling engine can be mounted at the focus of the reflector to produce the electricity to pump water.

9. REFERENCES

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