Future Institute of Engineering and Management Kolkata

HELIANTHUS

THE SOLAR TRACKING SYSTEM

A

PROJECT BY

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ECE, 4TH YEAR

OF

FUTURE INSTITUTE OF ENGINEERING AND MANAGEMENT

DEPT. OF ELECTRONICS AND COMMUNICATION ENGINEERING

ACKNOWLEDGEMENTS

I wish to thank **Prof. Somnath Maiti**, former Head of the Dept. of Electronics and Communication Engineering, for his valuable suggestions and advices throughout the project that helped me a lot to sort out all the problems.

I would like to thank **Prof. Debashis Chakraborty**, Head of the Dept. of Electronics and Communication Engineering.

I am really grateful to my dear friends, **Sounak Sarkar** and **Sayan Das** for helping me throughout the project. Without them this project would not be completed.

I am grateful to other honorable faculty of our college to prop up confidence level and motivating me throughout the process, that help me to move ahead towards the completion of the project.

I also acknowledge with thanks, the event **'Papyrus'** in **Phoenix 2011** for selecting my model for demonstration.

- Arindam Bose.

PREFACE

A **solar tracker** is a generic term used to describe devices that orient various payloads toward the sun. Payloads can be photovoltaic panels, reflectors, lenses or other optical devices.

Solar energy is rapidly advancing as an important means of renewable energy resource. More energy is produced by tracking the solar panel to remain aligned to the sun at a right angle to the rays of light. This paper describes in detail the design and construction of a prototype for solar tracking system with two degrees of freedom, which detects the sunlight using photo censors.

The control circuit for the solar tracker is based on an Atmega16 microcontroller (MCU). This is programmed to detect the sunlight through the photo censors and then actuate the motor to position the solar panel where it can receive maximum sunlight.

In standard photovoltaic (PV) applications trackers are used to minimize the angle of incidence between the incoming light and a photovoltaic panel. This increases the amount of energy produced from a fixed amount of installed power generating capacity. In standard photovoltaic applications, it is estimated that trackers are used in at least 85% of commercial installations greater than 1MW from 2009 to 2012.

In concentrated photovoltaic (CPV) and concentrated solar thermal (CSP) applications trackers are used to enable the optical components in the CPV and CSP systems. The optics in concentrated solar applications accepts the direct component of sunlight light and therefore must be oriented appropriately to collect energy. Tracking systems are found in all concentrator applications because such systems do not produce energy unless oriented closely towards the sun.

CONTENTS

INTRODUCTION

Renewable energy solutions are becoming increasingly popular. Photovoltaic (solar) systems are but one example. Maximizing power output from a solar system is desirable to increase efficiency. In order to maximize power output from the solar panels, one needs to keep the panels aligned with the sun. As such, a means of tracking the sun is required. This is a far more cost effective solution than purchasing additional solar panels. It has been estimated that the yield from solar panels can be increased by 30 to 60 percent by utilizing a tracking system instead of a stationary array. This project develops an automatic tracking system which will keep the solar panels aligned with the sun in order to maximize efficiency.

This paper begins with presenting background theory in light sensors and stepper motors as they apply to the project. The paper continues with specific design methodologies pertaining to photocells, stepper motors and drivers, microcontroller selection, voltage regulation, physical construction, and a software/system operation explanation. The paper concludes with a discussion of design results and future work.

The details description of Solar Trackers is as follows,

Photovoltaic Tracker Classification:

Photovoltaic trackers can be classified into two types: Standard Photovoltaic (PV) Trackers and Concentrated Photovoltaic (CPV) Trackers. Each of these tracker types can be further categorized by the number and orientation of their axes, their actuation architecture and drive type, their intended applications, their vertical supports and foundation type.

Tracker Types:

Photovoltaic trackers can be grouped into classes by the number and orientation of the tracker's axes. Compared to a fixed mount, a single axis tracker increases annual output by approximately 30%, and a dual axis tracker an additional 6% i.e. 36%.

1. Single Axis Trackers: This is of 3 types,
   a. Horizontal Single Axis Tracker (HSAT)
   b. Vertical Single Axis Tracker (VSAT)
   c. Tilted Single Axis Tracker (TSAT)
      i. Polar Aligned Single Axis Trackers (PASAT)
2. Dual Axis Trackers: This is of 2 types,
   a. Tip – Tilt Dual Axis Tracker (TTDAT)
   b. Azimuth-Altitude Dual Axis Tracker (AADAT)

Drive types

Active trackers use motors and gear trains to direct the tracker as commanded by a controller responding to the solar direction.

Passive trackers use a low boiling point compressed gas fluid that is driven to one side or the other (by solar heat creating gas pressure) to cause the tracker to move in response to an imbalance.

A chronological tracker counteracts the Earth's rotation by turning at an equal rate as the earth, but in the opposite direction.

PROJECT DESIGN METHODOLOGY

STRUCTURAL DIAGRAM

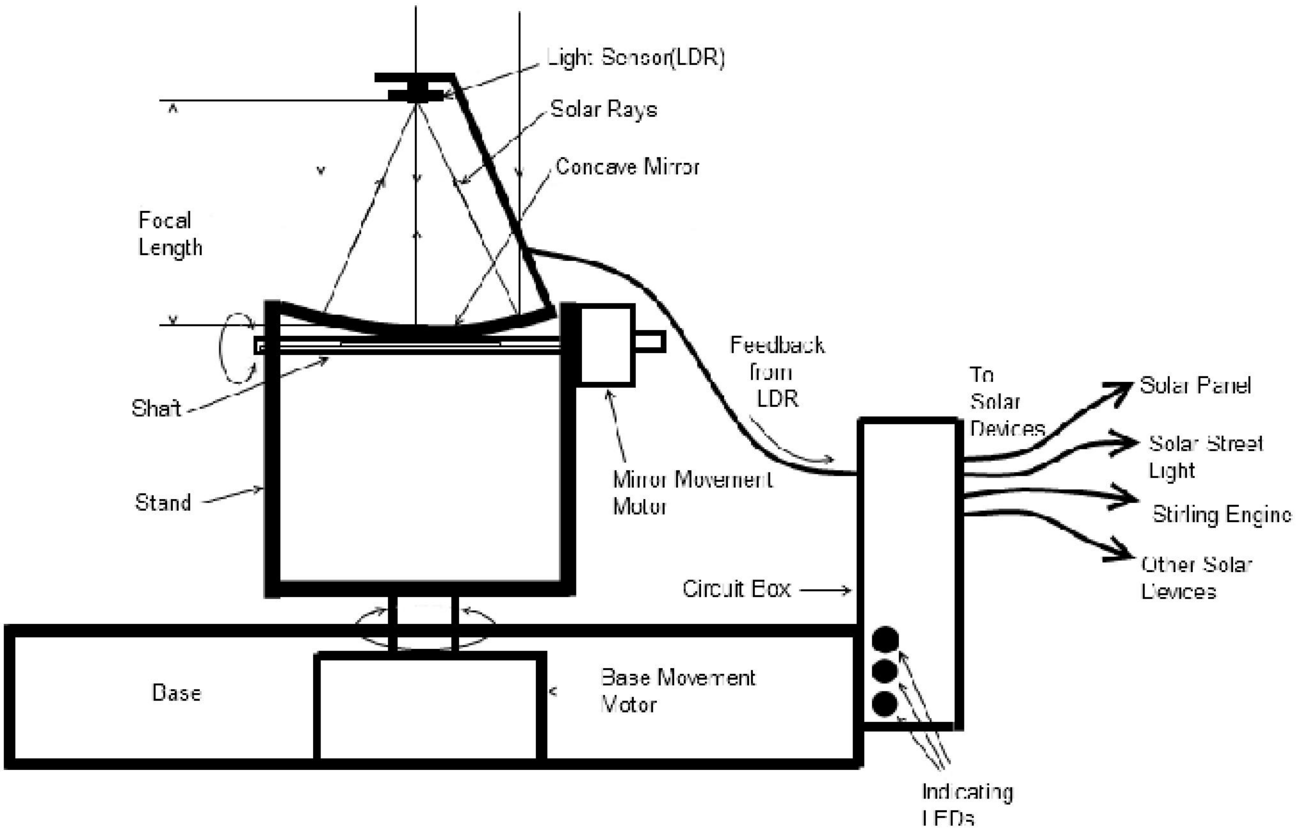

FIG 1: Structural Diagram

This is the complete structure of the solar tracking system. There are 2 stepper motors used for movement for 2 degrees of freedom. The horizontal motor is responsible for movement of the concave mirror. And the vertical motor is used for movement of the stand. A photo sensor (LDR) is used at the focus of the concave mirror. The wire connected to the sensor is giving feedback to the microcontroller in the circuit box where all the calculations and processing is going on according to predefined algorithm. The microcontroller is also giving feedback to all connected solar devices to align towards the sun. 3 different indicating LEDs are also there for indicating the types of processing.

BLOCK DIAGRAM AND DESCRIPTION

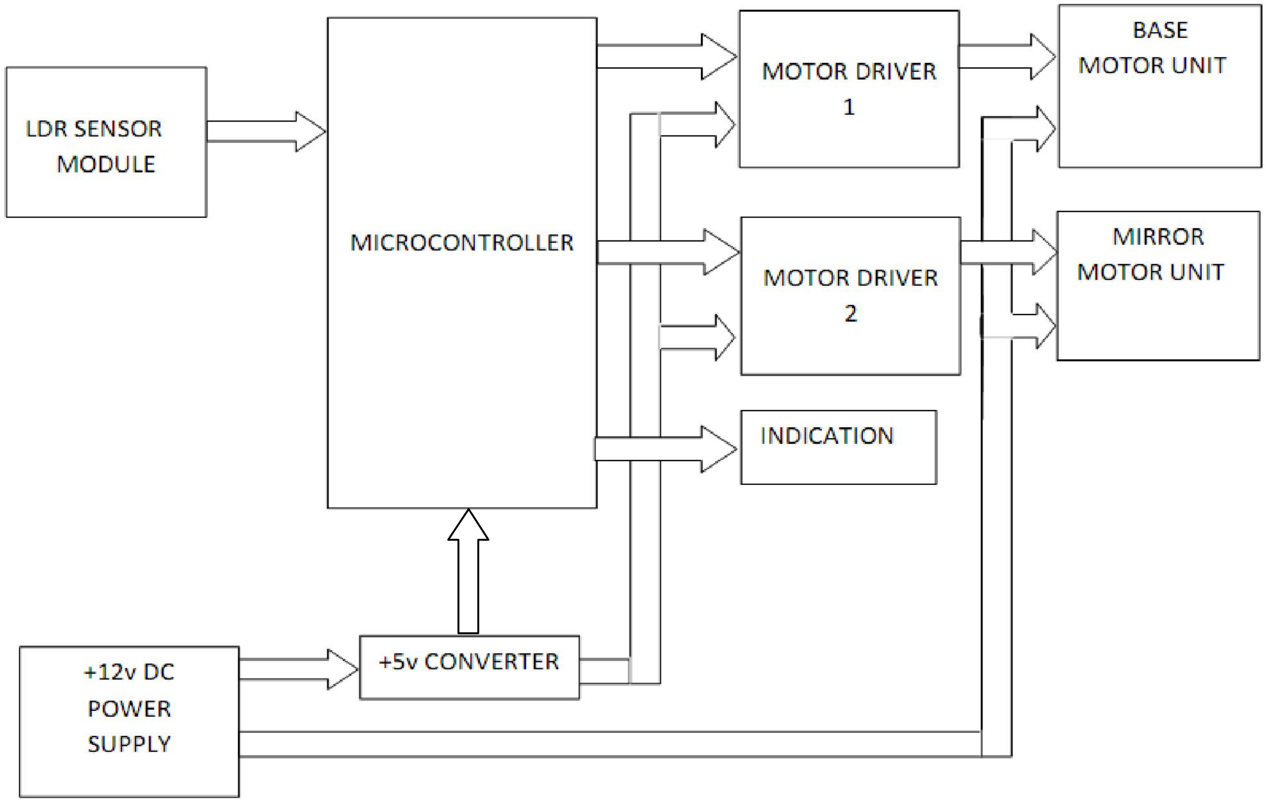

FIG 2: Block Diagram

The description of the each block is given with reference to the circuit diagram of the complete section.

- **POWER SUPPLY:** The AC mains voltage is stepped down by the centre tap transformer, rectified by bridge rectifier and finally filtered out by capacitors to obtain a steady +15 volt DC level. Then it is passed to +5 volt DC regulator (IC7805) to obtain a +5 volt DC output.
- **MICROCONTROLLER:** The Microcontroller we have used here is ATMEGA16 which belongs to AVR family. Detailed description is discussed later.
- **LDR SENSOR MODULE:** This is the main input section. Detailed description is discussed later.
- **MOTOR DRIVER:** Motor driver circuit is used for driving the stepper motors. We have used here IC ULN2803. We have used here 2 separate drivers for driving two separate stepper motors.
- **MOTOR UNIT:** There are two motor units. One for movement of base and one for movement of the concave mirror.
- **INDICATION:** These are simple LEDs. The red LED indicates the power supply. The yellow LED glows when total calculation is being carried on by the MCU. After calculation is over, when the system stabilized in the direction of the Sun, the green LED glows.

SCHEMATIC DIAGRAM

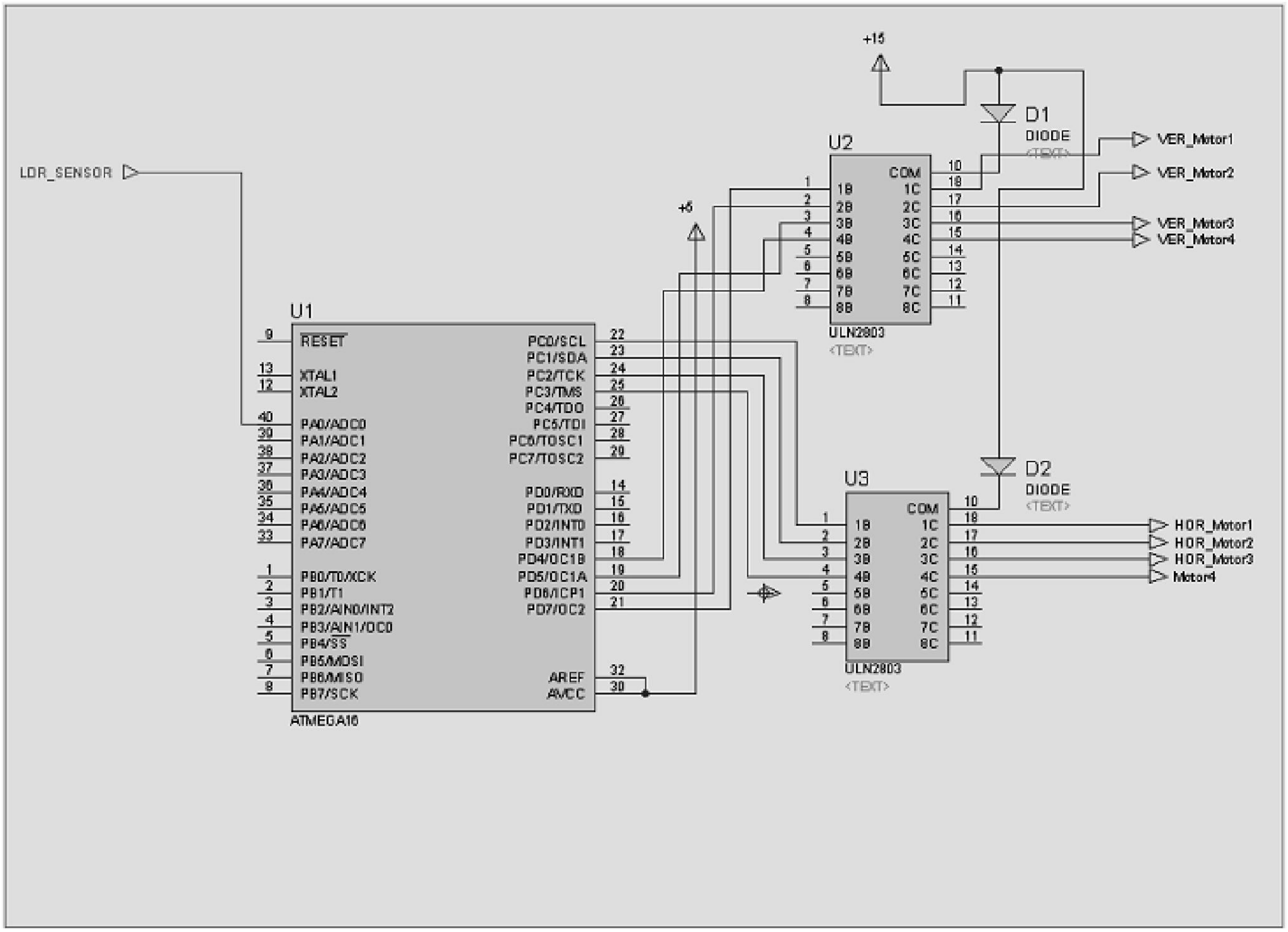

FIG 3: Schematic Diagram

This is the schematic of the solar tracking system. The Microcontroller ATmega16 has been used as the brain of the project. It is connected to the necessary connections as depicted in the figure 3. 2 separate ULN2803 ICs have been used as the stepper motor driver with necessary connections. Motor driver circuit can also be made using Darlington pair transistors instead the IC.

ALGORITHM

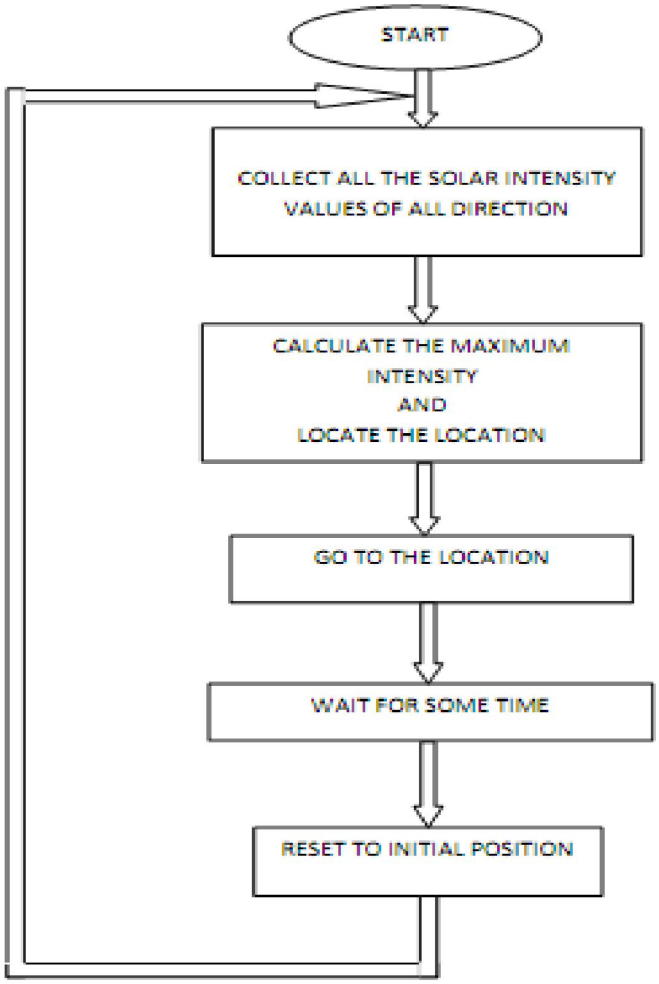

FIG 4: Algorithm

This Solar tracker is basically dual axis tracker. The algorithm of this solar tracking system is very simple and based on 'scan and go'. At first it will scan all the values of light intensity in each point of the upper hemisphere where the sun actually lies. While scanning, when the mirror will be directed towards the sun, parallel sunrays will incident on it, and converge into the focus where the LDR sensor is there. The resistance of LDR will be changed according to the light intensities. So the voltage drop across the LDR will also be changed. This voltage drop is fed to an ADC, and hence a corresponding value is stored in the MCU memory. After scanning it will check all the intensity values and decide which one is maximum and hence the corresponding location is located. Then it will move to the calculated location, as well as it will also send the direction to move according to that position to all the solar devices connected to it where the movement arrangement is also present. It will wait for sometime, until a noticeable change in the position of the sun is there and hence maximum amount of energy is obtained. The waiting time can be changed by the program written in the MCU. After this it will move back to its initial position and start scanning again.

COMPONENTS DESCRIPTION

LIGHT SENSOR (LDR)

A light sensor is the most common electronic component which can be easily found. The simplest optical sensor is a photo resistor or photocell which is a light sensitive resistor these are made of two types, cadmium sulfide (CdS) and gallium arsenide (GaAs).

The sun tracker system designed here uses the cadmium sulfide (CdS) photocell for sensing the light. This photocell is a passive component whose resistance is inversely proportional to the amount of light intensity directed towards it. It is connected in series with resistor. The photocell to be used for the tracker is based on its dark resistance and light saturation resistance. The term light saturation means that further increasing the light intensity to the CdS cells will not decrease its resistance any further. Figure 6 in below shows its Intensity vs. Resistance curve.

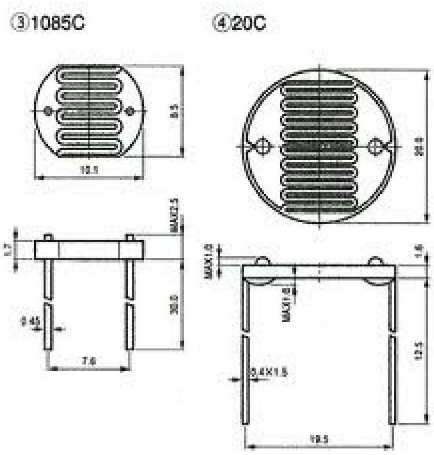

FIG 5: Dimension of LDR

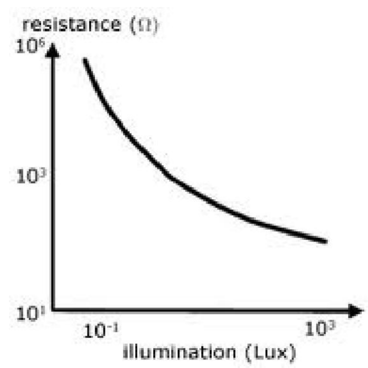

FIG 6: Illumination vs. resistance curve of an LDR

ATMEGA16 (AVR FAMILY) MICROCONTROLLER

The ATmega16 is a 40 pin low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

The Atmega16 has three key features that satisfy our objective. These are as follows:-

- ✓ 512 Bytes EEPROM
- ✓ 32 Programmable I/O Lines
- ✓ 8 bit multi-channel analog-to-digital converter

FIG 7: ATMEGA16

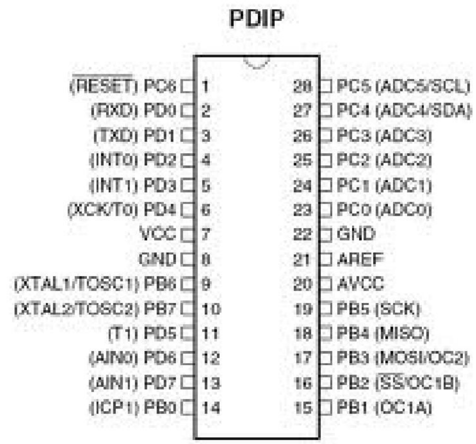

FIG 8: Pin Description of ATMEGA16

ULN2803 MOTOR DRIVER IC

The eight NPN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low logic level digital circuitry (such as TTL, CMOS or PMOS/NMOS) and the higher current/voltage requirements of lamps, relays, printer hammers or other similar loads for a broad range of computer, industrial, and consumer applications. All devices feature open–collector outputs and free wheeling clamp diodes for transient suppression.

The ULN2803 is designed to be compatible with standard TTL families while the ULN2804 is optimized for 6 to 15 volt high level CMOS or PMOS. It is an 18-pin octal high voltage high current Darlington Pair array with voltage rating 50V and current rating 500mA.

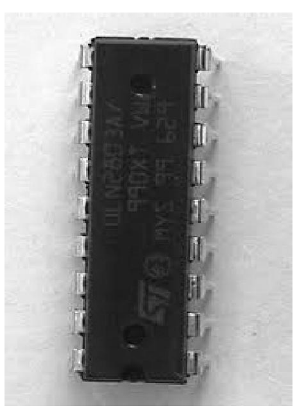

FIG 9: IC ULN2803

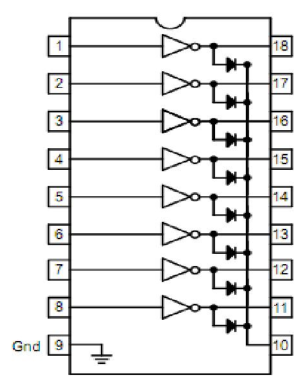

FIG 10: Pin diagram of ULN2803

STEPPER MOTOR AND MOTOR DRIVER CIRCUIT

Stepper motors are commonly used for precision positioning control applications. All stepper motors possess five common characteristics which make them ideal for this application. Namely, they are brushless, load independent; have open loop positioning capability, good holding torque, and excellent response characteristics.

There are three types of stepper motors: permanent magnet, variable reluctance, and hybrid. The arrangement of windings on the stator is the main distinguishing factor between the three types. Permanent magnet motors may be wound either with unipolar or bipolar windings.

The sun tracker uses a unipolar step motor. As such, discussion will be limited to this type of stepper motor. Unipolar motors have two windings with each having a center tap as shown in Figure 11.

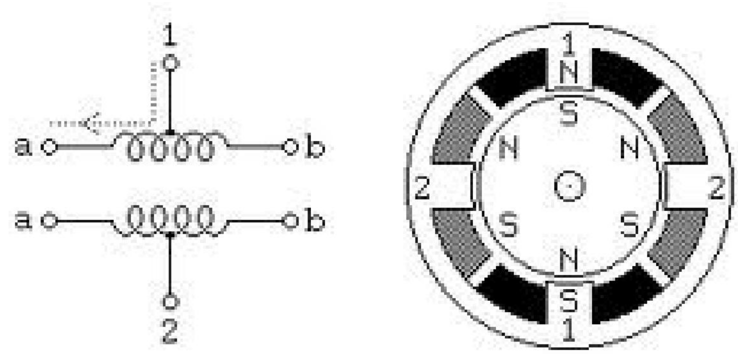

FIG 11: Winding of a Unipolar Stepper Motor

The center taps are connected to a positive voltage while the coil ends are alternately grounded to cause a reversal of the field direction in that winding. Figure 9 shows a 4-phase motor. The number of phases is equal to two times the number of coils. The motor is rotated by applying power to the windings in a sequence as shown in table.

No of Sequence	Coil 1a	Coil 2a	Coil 1b	Coil 2b
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1

TABLE 1: Energizing sequence of unipolar stepper motor

The two stepper motors are driven using a ULN2803APG .The ULN2803APG Series are high−voltage, high−current Darlington drivers comprised of eight NPN Darlington pairs.
Figure 10 shows a schematic of the motor control design. ULN2803APG provides the proper drive sequence to rotate the motor either clockwise or counterclockwise.

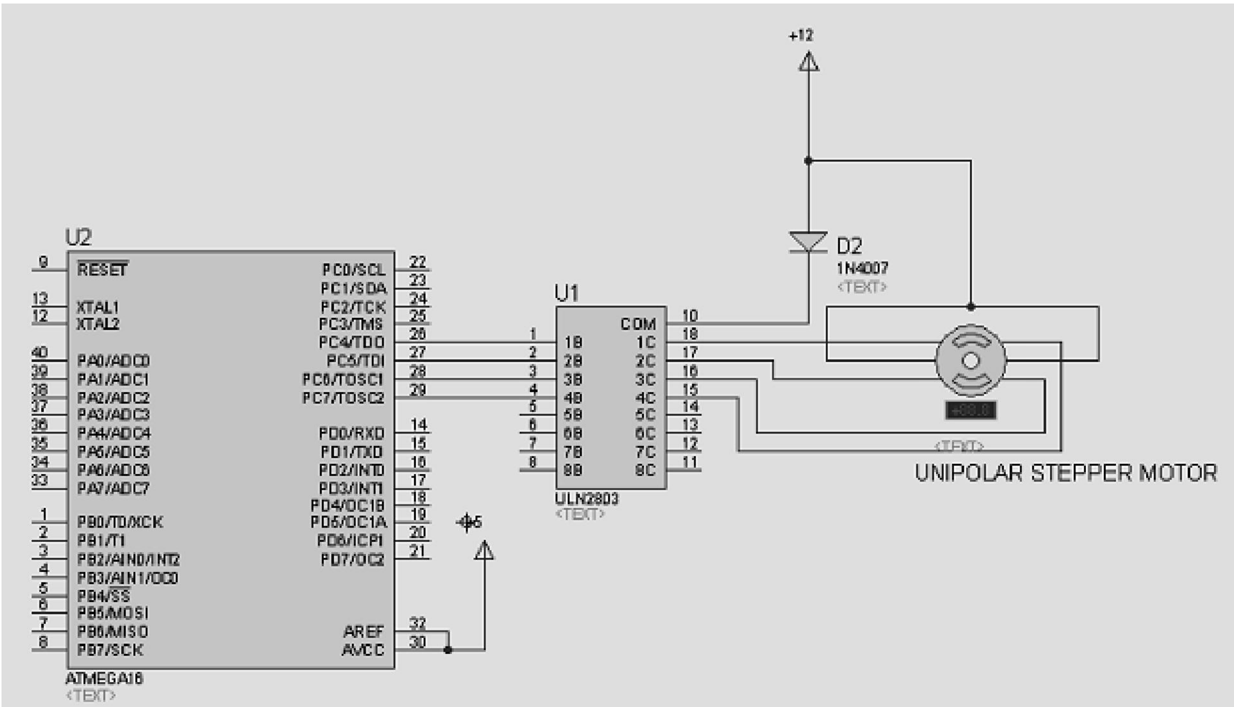

FIG 12: Motor Driver Circuit

CONCAVE MIRROR

A Concave mirror is a mirror with a curved reflective surface, which may be either convex (bulging outward) or concave (bulging inward). Most curved mirrors have surfaces that are shaped like part of a sphere, but other shapes are sometimes used in optical devices. The most common non-spherical type are parabolic reflectors, found in optical devices such as reflecting telescopes that need to image distant objects, since spherical mirror systems suffer from spherical aberration. The solar tracker uses a Concave mirror of focal length of 15cm.

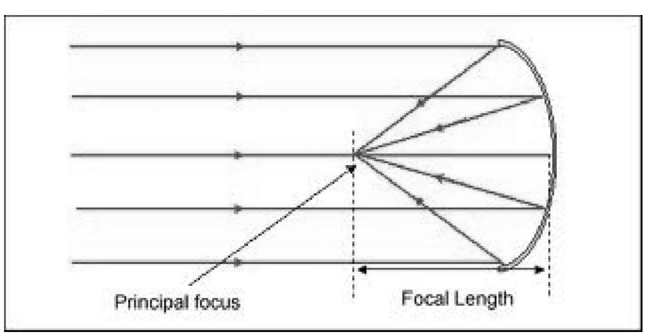

FIG 13: Parallel rays incident on Concave mirror

PRICE LIST

The estimated product cost is given below.

1. Diodes: (1N4007) – 6 pcs	- ₹6
2. Capacitors: 1000 µF/25V	- ₹5
10 µF/63V	- ₹1
3. Voltage Regulator IC: 7805	- ₹8
4. Transformer: 15V/750 mA in secondary	- ₹60
5. ATMEGA16 – 1 pc	- ₹150
6. ULN2803 – 2 pcs	- ₹30
7. Stepper motors – 2 pcs	- ₹400
8. Resistance: 150Ω, 10kΩ	- ₹0.50
9. LDR sensor – 1 pc	- ₹3
10. Concave mirror (Focal length 20 cm) – 1 pc	- ₹75
11. LEDs (Red, Yellow, Green)	- ₹3
12. Connecting wires	- ₹10
13. Vero Board	- ₹10
14. Ply wood	- ₹80
15. Others	- ₹50
Total – around	- ₹850 - ₹900 only.

APPLICATIONS

The Solar Tracking System has the following applications:-

- The Solar Tracking system can be utilized for tracking the sun and thus pointing the solar panel at the point of maximum solar intensity.
- It can also be utilized for automatic switching ON/OFF the street lights by mounting it over a street lights and switch ON whenever the solar intensity goes below a threshold value as dictated by the program.
- It can also be employed with Stirling engine.
- We can use this in some home appliance like solar water heater or something like that.

FUTURE SCOPE

The goals of this project were purposely kept within what was believed to be attainable within the allotted timeline. As such, many improvements can be made upon this initial design. That being said, it is felt that this design represents a functioning miniature scale model which could be replicated to a much larger scale. The following recommendations are provided as ideas for future expansion of this project:

- Remedy the motor binding problems due to the photo sensor leads. This could be done with some sort of slip ring mechanism, smaller gauge wire, a larger motor with more torque, or a combination of some or all of these ideas.
- Increase the sensitivity and accuracy of tracking by using a different light sensor. A photodiode with an amplification circuit would provide improved resolution and better tracking accuracy/precision.
- Different algorithm can be followed for more efficient tracking. This device can be given more intelligence, such as after tracking once, it will able to predict the line of movement of the sun across the sky.
- User-handling can be more sophisticated, i.e. user can select the waiting time.
- A digital display can be configured along with this.

CONCLUSION

A solar tracker is designed employing the new principle of using small solar cells to function as self-adjusting light sensors, providing a variable indication of their relative angle to the sun by detecting their voltage output. By using this method, the solar tracker was successful in maintaining a solar array at a sufficiently perpendicular angle to the sun. The power increase gained over a fixed horizontal array was in excess of 30%.

This project has presented a means of controlling a sun tracking array with an embedded microprocessor system. Specifically, it demonstrates a working software solution for maximizing solar cell output by positioning a solar array at the point of maximum light intensity. This project utilizes a dual-axis design versus a single-axis to increase tracking accuracy.

The electronics needed to activate the motors are simple and the system can be applied to any electromechanical configuration. With minor adjustments it can be used with various types of collectors including flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors.

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