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Design and Implementation of an Automatic Sun Tracking Solar Panel without Light Sensors

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Abstract: Solar energy is one of the most commonly used types of renewable energy in areas that experience a lot of sunlight annually. Most solar panels are installed in a stationary position where they receive solar radiations from the sun. But still, there is a lot of solar energy that escapes as the sun rises and sets. Two stepper motors are used for dual axis movements of the panel, as it seeks for points where sunlight energy is highest. One motor tilts the panel through an angle of 45° on the vertical axis and the second motor will rotate the panel through 360° angle at a point on the horizontal axis. The control circuit which is programmed to give a signal to the stepper motors to rotate after a given time so that the solar panel can track the sun, and then give voltage signals to the controller. The messages are compared and the maximum voltage is the point where the panel will be stationed for a particular period of time.

Keywords: Steeper Motors, Solar Energy, 9-v Battery, Ardunio Software and Microcontroller

1. Introduction

Renewable energy is rapidly gaining significant importance as an energy resource as fossil fuel prices fluctuate. At the educational level, it is therefore necessary for engineering and technology students to have an understanding and appreciation of the technologies associated with this renewable energy. One of the most popular renewable energy sources is solar energy [1].

Many types of research were conducted to develop some methods to increase the efficiency of Photo Voltaic systems (solar panels). One such method is to employ a solar panel tracking system. This system deals with an RTC based solar panel tracking system. Solar tracking enables more energy to be generated because the solar panel is always able to maintain a perpendicular profile to the sun's rays [2]. Development of solar panel tracking systems has been on-going for several years now. As the sun moves across the sky during the day, it is advantageous to have the solar panels to tracks the location and direction of the sun, such that the panels are always perpendicular to the solar energy radiated by the sun. This will tend to maximize the amount of power absorbed by PV systems. [1]

A solar tracker is a device for orienting a solar photovoltaic panel during day lighting reflector or concentrating solar mirror or lens toward the sun. Solar power generation works best when pointed directly at the sun, so a solar tracker can increase the effectiveness of such equipment over any fixed position. [3] The solar panels must be perpendicular to the sun's rays for maximum energy generation. Deviating from this optimum angle will decrease the efficiency of energy generation from the groups. Finding sufficient supplies of clean energy for the future is one of society's most daunting challenges. Alternative renewable energy sources such as sun energy can be substituted for exceeding human energy needs. Covering 0.16% of the land on earth with and the earth and its projection on the equatorial plane is called the solar declination angle (d). This angle is zero at the venal (20/21 march) and autumnal (22/23 September) positions. [4]

The solar altitude angle (a) is defined as the vertical angle between the projections of sun's rays on the horizontal plane to direction of sun's rays passing through the point. [2] As an alternative, the sun's altitude may be described in terms of the solar zenith angle (uz) which is a vertical angle between sun's rays and a line perpendicular to the horizontal plane through the point (uz =90 ? a). Solar azimuth angle (gs) is the horizontal angle measured from south (in the northern hemisphere) to the horizontal projection of the sun's rays [4].

Solar energy systems have emerged as a viable source of renewable energy over the past two or three decades, and are now widely used for a variety of industrial and domestic applications. Such systems are based on a solar collector, designed to collect the sun's energy and to convert it into either electrical power or thermal energy. The literature contains many studies regarding the use of solar collectors to implement such applications as light fixtures, window covering systems, cookers, and so forth [5].

In general, the power developed in such applications depends fundamentally upon the amount of solar radiation energy captured by the collector, and thus the problem of designing tracking schemes capable of following the trajectory of the sun throughout the day on a year-round basis has received significant coverage in the literature. For example, various schemes have been proposed for optimizing the tilt angle and orientation of solar collectors designed for different geographical latitudes or possible utilization periods [5].

With rapid advances in the computer technologies and systems control fields in recent decades, the literature now contains many sophisticated sun tracking device systems designed to maximize the efficiency of solar thermal and photovoltaic systems. These systems can be classified as either closed-loop or open-loop types, depending on their mode of signal operation [5].

In recent years, the need for energy will increase many fold, while the reserves of conventional energy will get depleted at a rapid pace. To meet this growing demand for energy, harnessing of non-conventional / renewable energy sources becomes a necessity. Solar energy is the most abundant and uniformly distributed from among all the available non-conventional sources. Even though technology for trapping solar energy is already in existence, the process can be further improved to increase its efficiency [6], thereby making it more Cost effective. Solar energy is freely available, needs no fuel and produces no waste or causes any pollution. Moreover solar power is renewable.

The change in sun's position is controlled and the view of the panel is always maintained at normal to the direction of the sun. By doing so, maximum irradiation from the sun takes place. The elevation angle of the sun remains almost invariant during a month and varies little (latitude ± 10°) in a year [6]. The proposed system uses a single axis position control scheme which is sufficient for the collection of solar energy.

The most immediate and technologically attractive use of solar energy is through photovoltaic conversion. The physics of the PV cell (also called solar cell) is very similar to the classical p-n junction diode. The PV cell converts the sunlight directly into direct current (DC) electricity by the photovoltaic effect. [7]

According to [7], A PV panel or module is a packaged interconnected assembly of PV cells. In order to maximize the power output from the PV panels, one needs to keep the panels in an optimum position perpendicular to the solar radiation during the day. As such, it is necessary to have it equipped with a Sun tracker. Compared to a fixed panel, a mobile PV panel driven by a Sun tracker may boost consistently the energy gain of the PV panel.

To take full advantage of the Sun's energy, the solar system surface must be perpendicular to the Sun's rays. For this reason, a wide range of solar tracking systems have been proposed by several authors like [8].

2. Material and Methods

Block Diagram of the System

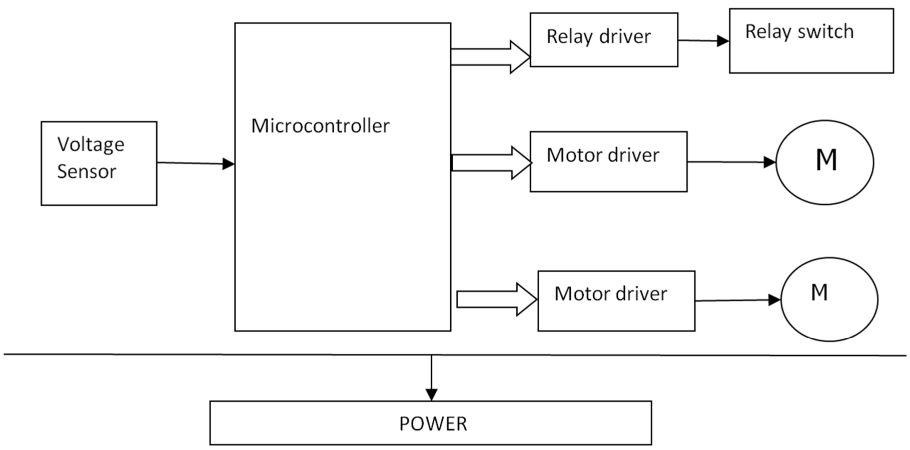

Figure 1. *Block Diagram of the whole System.*

2.1. Components Description

The design and implementation of each of the fundamental circuit units and how the program was implemented to, control the plan and perform the required functionality.

From the above illustration, it can be seen that the significant parts of the system include the following;

1. Main Solar panel
2. the charge controller circuit
3. Voltage sensor

4. Microcontroller
5. Stepper motors
6. 12v rechargeable battery
7. Five v dc power supply circuit

2.1.1. Main Solar Panel and Charge Controller

In this project a 6V, 1.5W industrial grade solar panel is used as the primary solar panel.

The panel ranges from 6 V to 7.411V. The output current is rated at 0.0 A. Depending on the light conditions; the solar panel outputs 2.5 Ah to 4 Ah a day. It measures 10.6 x 10.6 x 1.0 centimetres and weighs 2 pounds. Due to its small dimension and lightweight, it can be adjusted very easily.

2.1.2. Charge Controller

The function of the charge controller is to prevent the battery from overcharge and discharge. The solar panel itself will continue to charge the battery even when the battery has already been thoroughly charged. When the battery reaches a specific voltage, the charge controller will cut off tension to ensure there is no overcharge. When the battery is ata specific voltage, the charge controller will start to charge the battery. Thisprovides that the battery voltage will not fall below the final discharge voltage level. Otherwise, the battery may be severely damaged. Also, the charge controller also provides a regulated output voltage.

2.1.3. Rechargeable Battery

Four Small rechargeable batteries of about 3.7 volts were used. They are connected in series to give a voltage of about 16v dc.

2.1.4. Stepper Motor

The first motor will rotate the panel to track the sun in the horizontal axis. Once it has established the correct direction, it will start following in the vertical axis to get the tilt angle. The working principle of the tracker is based on the short circuit voltage of the solar cell used under correct condition. In the search operation, the system will tack in an arbitrary direction and since the change in the voltage of the solar cell. If a negative feedback is obtained from sensing, the system will turn around and move in the opposite direction until it reaches the maximum point, to prevent the system from oscillating at the maximum region, small minimum charge intensity is required before a step is taken.

The condition for the tracker to search is after a specified period elapses. Since the movement of the sun could be established about 15°/hour, which is appropriate to use a search cycle of 5, 10, 15, 20 minutes can be chosen to start tracking the sun.

The condition while searching is that the system samples the solar intensity for a second every four seconds. The results have analyzed the peak to peak variation is less than a user predefined value of 5mV. If that condition is satisfied, the system starts the search.

2.1.5. Microcontroller

This is the main backbone of the full control system. It gives out a signal to the motor to start the search after 10 minutes delay time elapses.

A microcontroller is a single chip microcomputer made through VLSI fabrication. A microcontroller is also called an embedded controller because the microcontroller and its support circuits are often built into, or integrated in, the devices they control. A microcontroller is available in different word lengths like microprocessors (4bit, 8bit, 16bit, 32bit, 64bit and 128bit microcontrollers are available today).

Construction of the panel moving mechanism

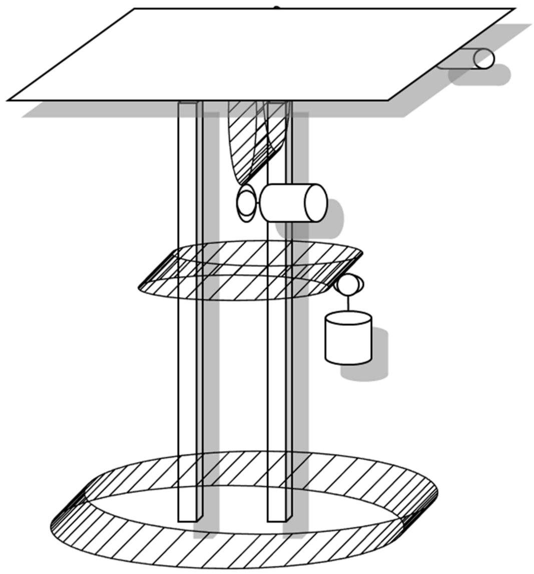

Figure 2. *Showing the assembly of the movement system.*

2.2. Solar Panel

Solar panels are made of many photovoltaic (PV) cells connected in series or parallel. The PV cell is a large area p-n diode with the junction positioned close to the top surface. When the cell is illuminated, electron-hole pairs are generated by the interaction of the incident photons with the atoms of the cell. The electric field created by the cell junction causes the photon-generated electron-hole pairs to separate. The electrons drift into the n-region of the cell and the holes drift into the p-region.

Main advantages of photovoltaic power are: (1) short lead time to design, (2) highly modular, (3) static structure, no moving parts, hence, no noise, (4) high power capability per unit of weight, (5) longer life with little maintenance due to no moving parts, (6) highly mobile and portable because of lightweight.

2.2.1. Single Axis Tracker

Single axis solar trackers can either have a horizontal or a vertical axle. The horizontal type is used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes where the sun does not get very high, but summer days can be very long. The single axis tracking system is the simplest solution and the most common one used.

2.2.2. Double Axis Solar Tracker

Double axis solar trackers have both a horizontal and a vertical axle and so can track the Sun's apparent motion exactly anywhere in the World. This type of system is used to control astronomical telescopes, and so there is plenty of software available to automatically predict and track the motion of the sun across the sky. By tracking the sun, the efficiency of the solar panels can be increased by 30-40%. The dual axis tracking system is also used for concentrating a solar reflector toward the concentrator on heliostat systems.

3. Working Principle

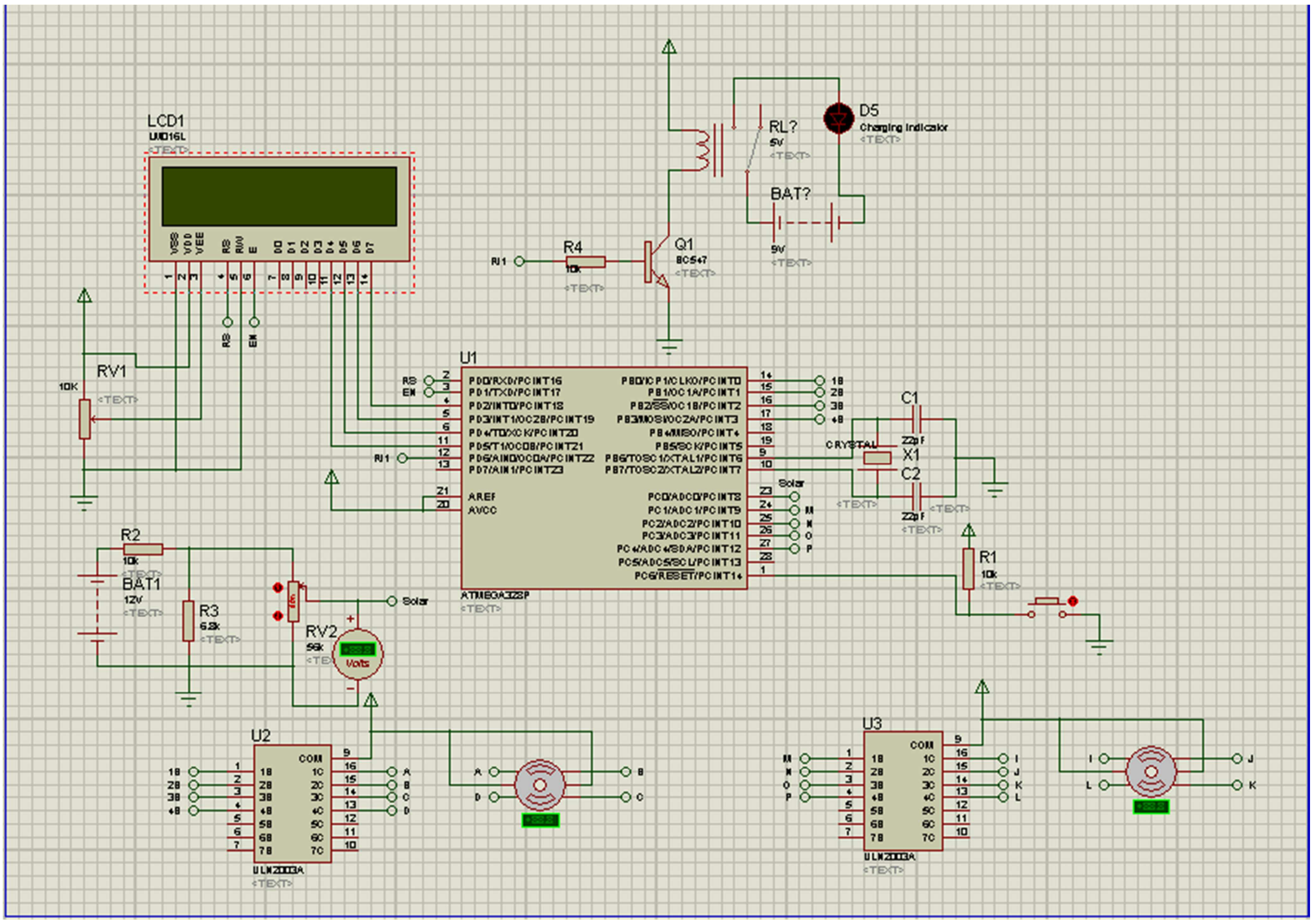

Figure 3. *Showing the simulated Circuit.*

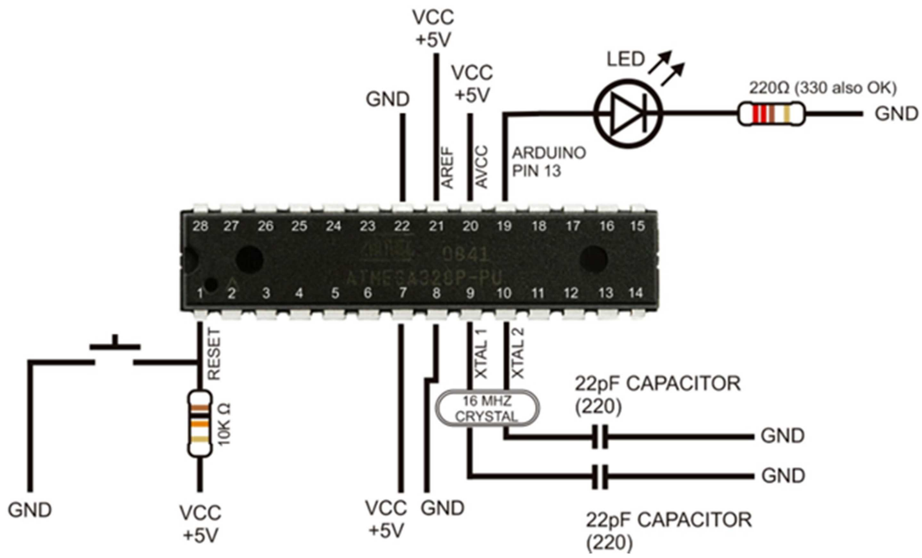

Figure 4. *Showing Snapshot microcontroller circuit connection.*

Atmel ATmega328 8-bit microcontrollers are high-performance RISC-based devices that combine 32KB ISP Flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, serial programmable USART, and more. Atmel ATmega328 MCUs execute powerful instructions in a single clock cycle, allowing the device to achieve throughputs approaching 1 MIPS per MHz while balancing power consumption and processing speed. These Atmel MCUs are developed for use in industrial automation and home and building automation.

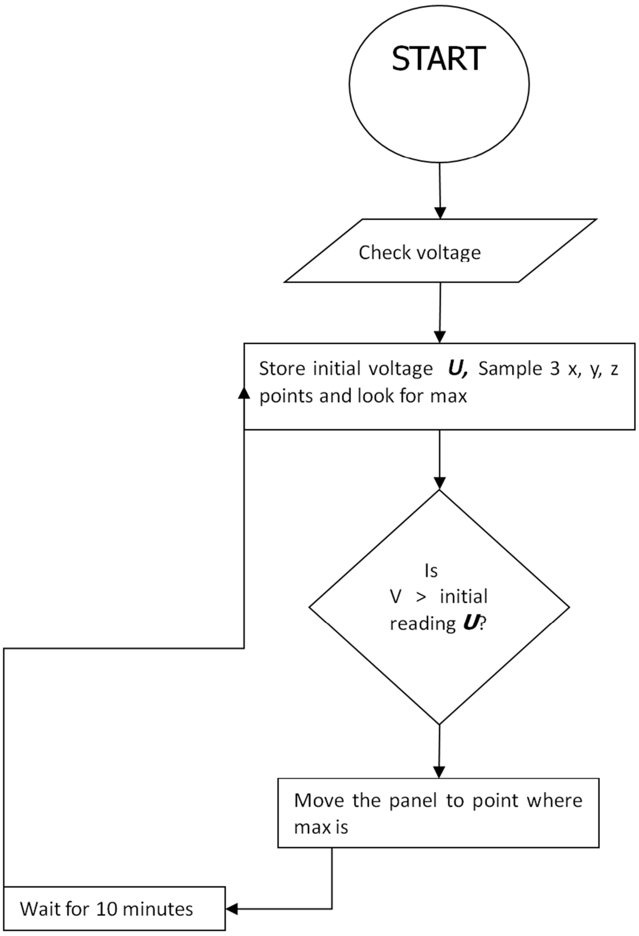

Figure 5. *Flow Chart of the System.*

This allows current to flow in only one direction. By convention, current can only flow from the anode (positive) to the cathode (negative). Current is what determines how bright a LED is More current means more light LED current should typically be between 10 to 20mA. Therefore a current limiting resistor is used to keep the bias current in the above range.

When current flows through the LED; a forward voltage drop of about 1.6V will develop between its pins, depending on the current.

Forward voltage drop is not just a function of current, but also LED color and temperature (because of the different LED chemistries) as shown in the table below

Table 1. *Showing LED Color PD Definition.*

LED colour PD definition

LED colour	Potential difference/V
Infrared	1.6 V
Red	1.8 V to 2.1
Orange	2.2 V
Yellow	2.4 V
Green	2.6 V
Blue	3.0 V to 3.5 V
White	3.0 V to 3.5 V
Ultraviolet	3.5 V

To keep the bias current in between 10 and 20mA, the following applies.

5V Supply generated by LM7805 chip has been used in this system.

Using Ohm's Law (V=IR);

(Voltage applied - Forward voltage drop) / Forward current = Resistor value (5V - vdV) / Ida = Rd ohms

Where 5V is the applied voltage and Ida is the forward bias current in amperes of the LED, vdV is the drop across the LED dependent on colour and Rd is the current limiting resistor of the diode.

FLOW CHART OF THE SYSTEM

4. Results and Discussions

The results for the project were obtained from the output voltage from the solar tracking system and the panel that has a fixed position. The results obtained were recorded for four days, recorded and tabulated.

Result from a sunny day

Experiment condition

Weather	Sunny time
Starting time	8th/9/17 2:42:14 PM
Ending time	8th/9/17 6:09:17 PM
Duration	2 hours:42 minutes

Experiment results

Types	Dynamic tracking system	Non-tracking systems
Load	6.8k ohms	6.8k ohms
Average voltage	0.8899V	0.5938V
Average current	0.1679A	0.1120A
Improvement	49.87%	NA
Average power	0.14944W	0.066529W
Av power Impropment	124.6%	NA

Results from Cloudy condition

Experiment condition

Weather	Cloudy time
Starting Time	11th /9/17 3:46:28 PM
Ending Time	11th /9/17 6:13:26 PM
Duration	2hrs 27mins

Experiment results

Type	Dynamic Tracking System	Non-Tracking System
Load	6.8k ohms	6.8k ohms
Average voltage	0.03482v	0.01935v
Average current	0.00695A	0.003686A
Improvement	88.54%	NA
Average power	0.000256%W	0.000072W
Av power improvement	255.5%	NA

5. Results

The objective of the project was to design a system that tracks the sun for a solar panel. This was achieved through using an electrical characteristic of the panel which he opens circuit voltage that can detect the amount of sunlight that reaches the solar panel. This was achieved through moving some steps every after the specified time elapsed. The values obtained by the PV cell are a sample at different points then compared to look for the maximum voltage value and then the panel using a stepper motor moves to that point where it is almost perpendicular to the rays of the sun.

Analysis

This will analyze the power generated by the solar cell with and without a dynamic tracking system.

Effectiveness of tracking system

The effectiveness and reliability of the dynamic sun tracking system employing solar panel characteristics as a sensor are verified by experimental results. For a comparison, a static PV cell and a PV cell with a dynamic tracking system are tested together under the same conditions. Both the PV cells are the same electrical characteristics, i.e. max Voc 2.2V and max Isc 0.1.

From both experimental results show that the tracking system is doing a great job in tracking the sun during afternoon and morning time when the offset from vertical direction is greater. The effectiveness of the tracking system is less during the noon because both the PV cells are facing the same direction.

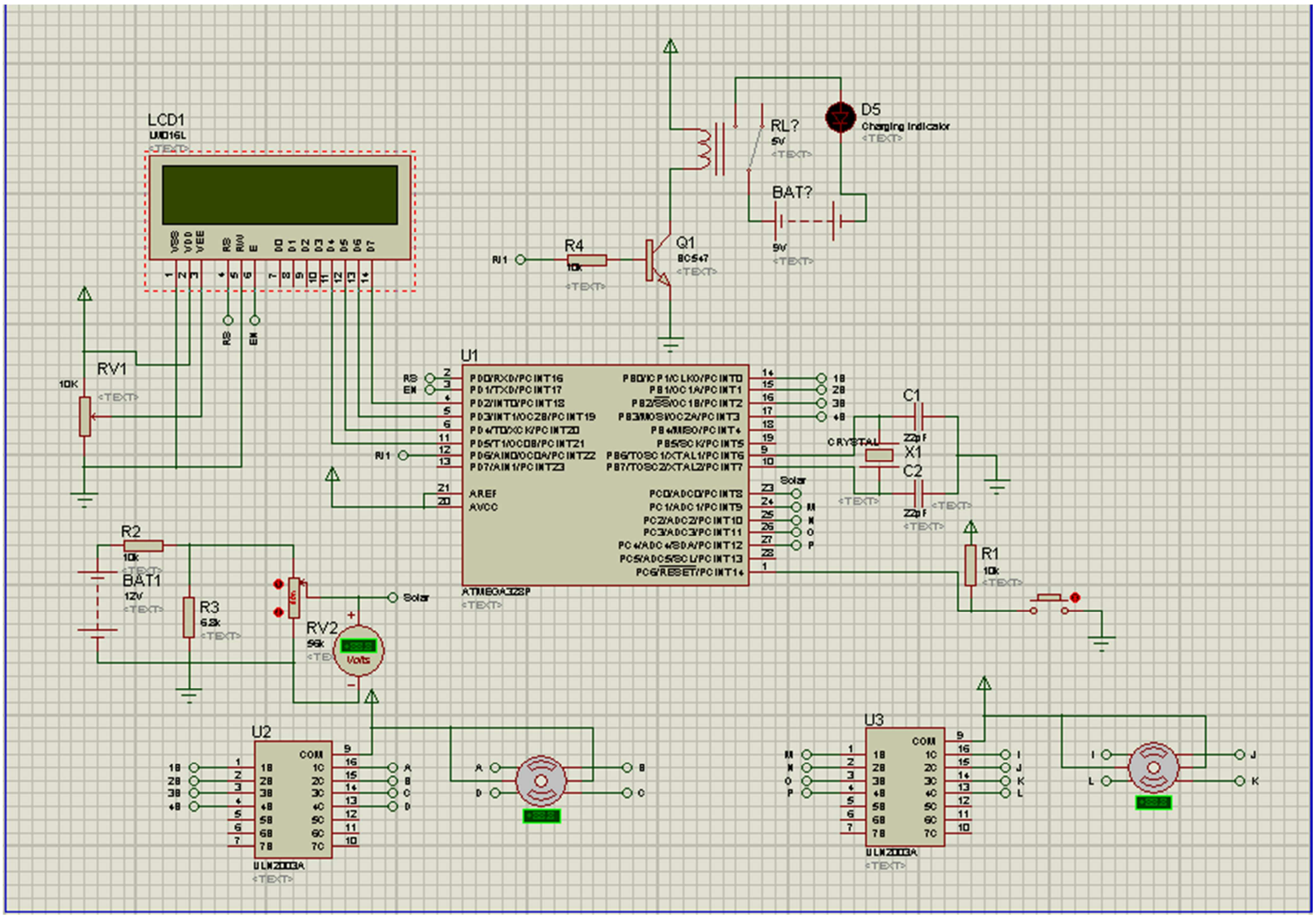

Figure 6. *Shows Complete Circuit diagram using Microcontroller.*

6. Conclusion

The objective of the project was to design a system that tracks the sun for a solar panel. This was achieved through using an electrical characteristic of the panel which he opens circuit voltage that is able to detect the amount of sunlight that reaches the solar panel.

Based on the experimental results, it can be concluded that the automatic sun-tracking panel is not only capable of maintaining optimal tilt angle for the PV cells but also capable of giving actuator signals to prevent unnecessary moves and logging data with real-time performance monitoring.

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