DESIGN AND CONSTRUCTION OF DUAL AXIS SOLAR TRACKER WITH TEMPERATURE AND IRRADIATION SENSING CAPABILITY

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A PROJECT REPORT SUMMITED TO THE DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY, MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY YOLA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING.

JANUARY, 2020

DECLARATION

I hereby declare that this project report was written by me and it is a record of my research work. It has not been presented before in any previous application for a bachelor's degree. References made to published literature have been duly acknowledged.

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CERTIFICATION

This project entitled **"DESIGN AND CONSTRUCTION OF DUAL AXIS SOLAR TRACKER WITH TEMPERATURE AND IRRADIATION SENSING CAPABILITY"** by **SAMAILA MOHAMMED (EE/14/0405)** meets the regulation governing the award of the bachelor's degree of the Modibbo Adama University of Technology, Yola and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this project to Almighty Allah for giving me the strength and courage throughout my study, also to my father, mother and siblings for their enormous support, care and finance.

ACKNOWLEDGEMENTS

All thanks and praises be to the Almighty Allah who give me the strength and capability for the completion of this project, overlook my mistakes, pardoned my sins, and took lenient to my disorderly conduct. May the peace and blessing be upon the last prophet (S.A.W) and his house hold. There are many people who have helped me directly and indirectly in the successful completion of my project. I will use this opportunity to thanks those who have contributed to my incapability's toward this project.

My most sincere gratitude goes also, to my supervisor Engr Mathew K. Luka for always being available whenever I require his guidance as well as for motivating me throughout the project work and to the head of the of department of Electrical and Electronics Engineering Engr. Dr. I.M. Visa and the entire lecturers in department for being not just a lecturer but more than a father.

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ABSTRACT

The variation in sun availability occurs daily because of day night cycle and also seasonally because of the earth's orbit around the sun. Population of the world is getting increased rapidly day by day and the demand for energy is increasing appropriately. During the recent decades, the main sources of energy such as the Oil and coal are expected to end up from the world. This ends up in a serious problem for providing the world with the most affordable and reliable source of energy. All the people in the world need the renewable energy resources which is inexhaustible. Solar energy is fast becoming a very important means of renewable energy resource. With solar tracking system, it will become possible to generate more energy since the solar panel can maintain a perpendicular profile to the rays of the sun. A Solar Tracker is a device onto which solar panels are built-in which tracks the motion of the sun ensuring that maximum amount of sunlight strikes the panels all over the day. This project discuss the design and construction of a solar tracking system that has dual axis of freedom with temperature, humidity and solar intensity measurement capability. Light Dependent Resistors (LDRs) are used for sunlight detection. The control circuit is based on an ATMega328P microcontroller. It was programmed to detect sunlight via the LDRs before actuating the servo to position the solar panel.

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ABBREVIATIONS AND SYMBOLS

Abbreviations	Meaning
AC	Alternating Current.
ADC	Analogue to Digital Converter
AREF	Analogue Reference
ASCII	American Standard Code for Information Interchange
AVCC	Analogue Positive Voltage
CdS	Cadmium Sulphide
CPU	Central Processing Unit
DC	Direct Current
GaAS	Gallium Arsenide
GND	Ground
IAP	In-Application Programmable.
IDE	Integrated Development Environment
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
MCU	Microcontroller Unit
OTP	One Time Programmable
PCB	Printed Circuit Board
PSoC	Programmable System on Chip

PV	Photo Voltaic
PWM	Pulse Width Modulation
RAM	Random Access Memory
RISC	Reduced Instruction Set Computer
ROM	Read Only Memory
SMA	Shape Memory Alloy
VCC	Positive Voltage Supply
VLSI	Very Large Scale Integration

Chapter one: Introduction

1.1 Background

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 10% efficient solar conversion systems would provide 20 TW of power, nearly twice the world' s consumption rate of fossil energy [1]. Solar energy is rapidly gaining notoriety as an important means of expanding renewable energy resources [2]. With the alarming rate of depletion of the major energy resources worldwide, it has become an urgent necessity to seek for renewable energy resources that will power the future. According to the worldwide market economy, the increasing demand for energy had forced to put a huge price tag on natural combustible sources of energies. In fact, it has been predicted that in the near future the demand of energy will grow in such a rate that it will be completely impossible to find out or meet the demand with the resources that we had been using for so long, such as – oil, gas, coal, etc. This issue throws a positive challenge to the scientific community as more and more funds are being allocated for the research and development of new alternatives [3].

Solar energy systems have emerged as a possible source of renewable energy over the past two or three decades, and are now utilized for a variety of household and industrial applications. Such systems are based on a solar collectors that are designed to collect the sun's energy and to convert it into either electrical power or thermal energy. Despite the immense energy output of the sun, harvesting solar energy has proved to be a great challenge because of the limited efficiency of solar cells. The efficiency of solar cells has been estimated to be between 10-20 percent. In general, the power gotten from the solar panels depends upon the amount of solar energy captured by the collector. There are many factors affecting the panel efficiency such as tilt angle, shading, dust, solar radiation level, temperature and wiring losses. Among these factors, solar radiation level and temperature are more prominent. The solar radiation level falling on the PV panels varies depending on the location of the panel and the time intervals in a day. Therefore, solar radiation level has a direct effect on the panel power. As a result, a decrease in solar radiation level reduces the panel power. On the other hand, there is an inverse proportion between temperature and panel power. In other words, panel power decreases as the ambient temperature increases [4].

The average annual variation of the extraterrestrial solar radiation level is 1367 W/m^2. On the other hand, the solar radiation level falling on the earth is less than the extraterrestrial solar radiation level and varies depending on the geographic position of the countries. The variation in the solar energy occur daily due to variation in day night cycle and also because of seasonal variations throughout the year [5]. The earth is not static to receive entire energy from sun but dynamic. There are two types of movement of earth one is earth rotation and the other earth revolution. Earth's rotation is the rotation of the planet Earth around its own axis. The Earth rotates towards the East and the west. One rotation completes in 23 hours, 56 minutes and 4 seconds. The other motion of Earth is around the Sun, called as Revolution of the Earth. Earth completes one complete revolution around the Sun in 365 days, 5 hours, 45 minutes and 46 seconds. Sunlight has two components, the "direct beam" that carries about 90% of the solar energy and the "diffuse sunlight" that carries the remaining 10% of the solar energy [6].

This project is based on the concept of improving this efficiency of a solar panel by means of a solar tracking mechanism. The main purpose of a solar tracking system is to track the position of the sun in order to focus the solar panel to a maximum radiation at any given time of the day. This is because the position of the sun with respect to the earth changes in a cyclic manner in the course of the year. The importance of developing tracking schemes capable of following the trajectory of the sun throughout the course of the day and on a year-round basis has received significant coverage in this system [2].

This project ensures maximum power harnessing and efficient utilization of the power by tracking the sun for efficient harnessing of the solar energy and also providing the temperature conditions of the given location and the solar radiation falling on the panel for effective power planning. The project solves the problems being faced in the contemporary solar power stations around the world for efficient harnessing of the energy and effective utilization of the harnessed energy.

1.2 Problem Statement

Due to the dynamic nature of the earth caused by rotation and revolution of the earth around its axis, the solar energy at a particular point varies as the earth rotates and revolves. For an efficient harnessing of the solar energy, the solar panel must be perpendicular to the rays of the sun which yields more power. Most of the solar panels lacks the capability to focus on the sun at all times making it inefficient. The changes in atmospheric conditions such as solar radiation level and temperature throughout the day have a great impact on the panel efficiency. Therefore, it has a great importance to know the solar radiation level and temperature effect on PV panel.

This project design and construction of dual axis solar tracking system with temperature, and sun radiation intensity measurement capability tracks the direction of the sun and turns the solar panel to the direction of the sun for efficient utilization of the solar energy. In addition to this, it provides the temperature and sun radiation status to help in making certain decisions and planning purposes.

1.3Aims and Objective

The aim of the project is to design a system that will track the direction of the sun and turns a solar panel in that direction for an efficient harnessing of the solar power.

The objective off the work are:

1. Secondly the system will be able to measure the temperature, and sun radiation in the given location. In order to achieve the required, the system will make use of sensors to measure the parameters and the microcontroller which is the brain of the project will make the required decisions.

2. The various sensor readings will be displayed to the user using a liquid crystal display.

1.4 Significance

The main significance of this project is that it implements a solar tracking system that ensures the sun rays fall perpendicularly on the solar panel and thus harness the maximum amount of solar energy possible in that location. In doing so, increases the efficiency of solar cells. The system also provides the environmental temperature conditions and the locations solar radiation which will assist in making power management decisions. In addition to this, the system provides a reference materials for future research purposes.

1.5 Scope and Limitation

The project design is limited to the design of the dual axis tracker system that will track the location of the sun and turns the panel to face the location and at the same time displays the weather condition of the given location. The system will not be able to control the load connected the panel or to charge the battery.

Chapter Two: Literature Review

All the solar arrays that are currently being installed in our countries are fixed on the rooftop or in a favorable open space at approximately 23^0 inclination with the surface. Most of the panel installations that are done are all in fixed arrays and can only absorb limited quantity of the solar power per day. As the day passes by, the sun moves away from the facing position of the panel and thus the power output of the panel decreases. A solar tracking system tracks the position of the sun and then turns the panel to face the position of the sun during the day [3].

A solar tracker is a device for orienting solar photovoltaic panel towards the sun. The sun's position in the sky varies both with seasons of the year and time of day as the sun moves across the sky. Solar powered equipment works best when pointed at or near the sun's focus, so the solar tracker can increase the effectiveness of such equipment over any fixed position [3, 5].

2.1 Evolution of Solar Panel

Solar panels are designed so as to convert light energy into electricity. They are called solar after the sun because the sun is the best powerful source of the light energy obtainable for use. They are sometimes called photovoltaic which means "light-electricity". Solar cells or PV cells depend on the photovoltaic effect to absorb the energy of the sun. Each solar cell provides a comparatively small amount of power, a lot of solar cells spread over a large area and can provide enough power to be useful. To develop the most power, solar panels have to be pointed directly next to the Sun. A solar panel physicist Antoine-Cesar Becquerel observed the photovoltaic effect while experimenting with a compact electrode in an electrolyte solution. Subsequently he saw a voltage developed when light fell upon the electrode [7].

According to Encyclopedia Britannica the first honest for solar panel was built around 1883 by Charles Fritts. He used connections formed by coating selenium (a semiconductor) with an extremely thin layer of gold. Crystalline silicon and gallium arsenide are usual varieties of materials for solar panels. Gallium arsenide crystals are grown especially for photovoltaic use, but silicon crystals are obtainable in less-expensive standard ingots, which are produced mostly for intake in the microelectronics industry [8].

2.2 Working Principle of Photovoltaic

Photo voltaic are the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity. A solar cell (also called photovoltaic cell or photoelectric cell) is a solid state electrical device that converts the energy of light directly into electricity by the photovoltaic effect.

A number of solar cells electrically connected to each other and mounted in a support structure or frame are called a photovoltaic module. Modules are designed to supply electricity at a certain voltage level. The current produced is directly dependent on how much light strikes the module and in order to achieve maximum current, the panel has to be inclined perpendicular to the sun rays. [9, 10].

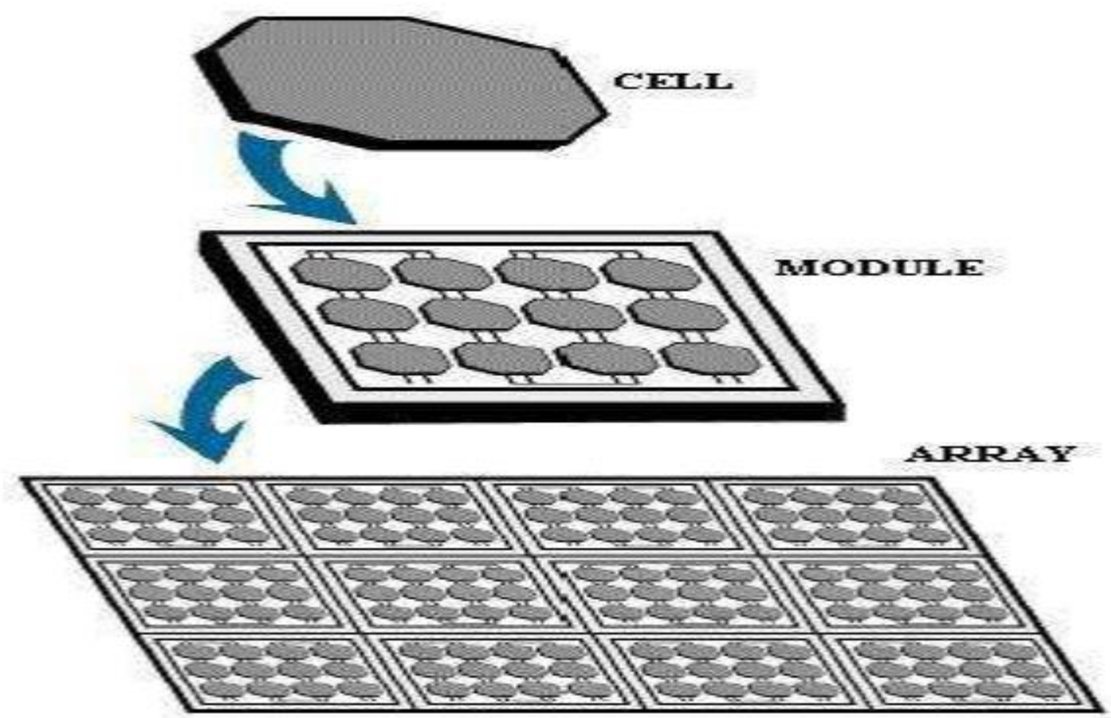

Figure 2.1: Solar Cell, Module and Array

2.3 Solar Radiation

Solar radiation is radiant energy emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy. It's the light and energy that comes from the sun. Solar radiation can be captured and turned into useful forms of energy such as heat and electricity using a variety of technologies. The spectrum of solar radiation is close to that of a black body with a temperature of about 5800 K. About half of the radiation is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum. The units of measure are Watts per square meter.

Every location receives sunlight at least part of the year. The amount of solar radiation that reaches any spot on earth surface varies according to geographic location, time of the day, season, local landscape and local weather [11].

2.5 Insolation

Insolation is a measure of solar radiation energy received on a given surface area and recorded during a given time. It is also called solar irradiation and expressed as hourly irradiation if recorded during an hour, daily irradiation if recorded during a day. The unit recommended by the World Meteorological Organization is MJ/m^2 (mega joules per square meter) or J/cm^2 (joules per square centimeter). Over the course of a year the average solar radiation arriving at the top of the Earth's atmosphere at any point in time is roughly 1366 watts per square meter. The insolation into a surface is largest when the surface directly faces the Sun. As the angle increases between the direction at a right angle to the surface and the direction of the rays of sunlight, the insolation of the surface is reduced [9].

2.6 The Orbit and Rotation of the Earth

The earth revolves around the sun once per year in an elliptical orbit with the sun at one foci. Due to this, the sun strikes the earth at different angles, ranging from 0^0 just above the horizon to 90^0 directly overhead. When the sun arrays are vertical, the earth surface gets all the energy possible. The more slanted the sun rays are, the longer they travel through the atmosphere, becoming more stressed and diffused [11]. The earth also rotates on its own polar axis per day. The polar axis of the earth is inclined at 23.45 degrees to the plane of the earth's orbit around the sun. This inclination causes the sun to be higher in the sky in the summer than in the winter. It is also the cause of longer summer sunlight hours and shorter winter sunlight hours. The figure below shows the orbit of the earth around the sun, and declination at different times of the year.

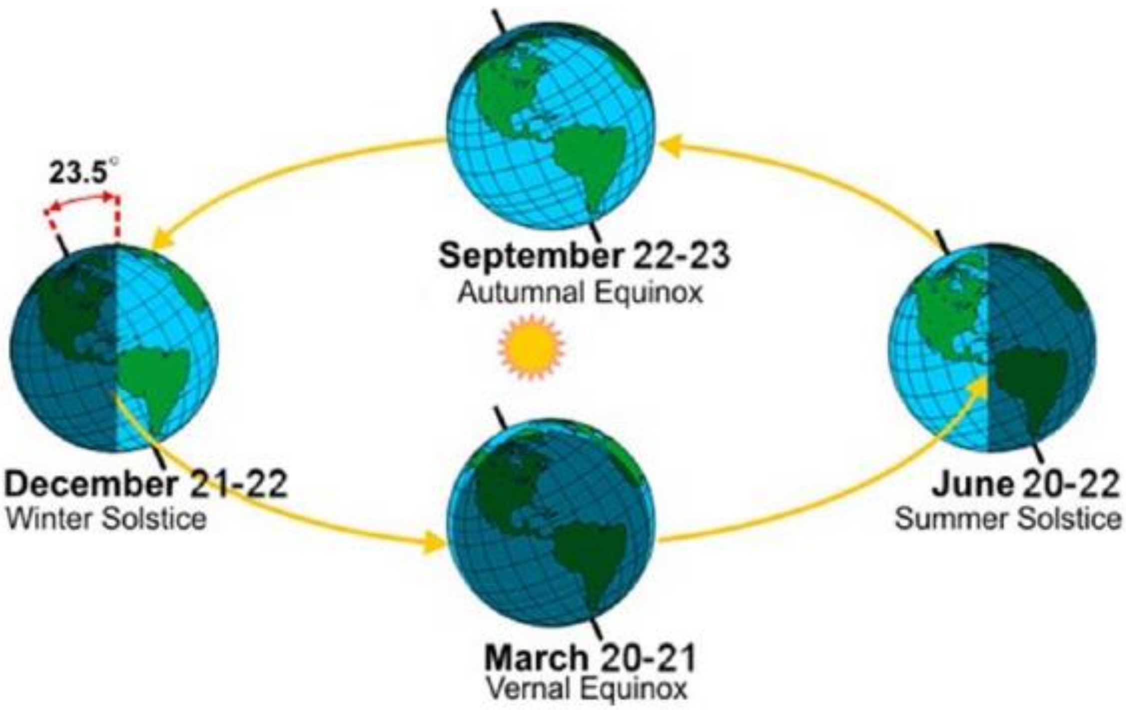

Figure 2.2: Rotation and Revolution of the Earth

2.7 Evolution of Solar Tracker

Solar tracking system can be implemented by using one-axis, and for higher accuracy, two-axis sun-tracking systems. For a two-axis sun-tracking system, two types are known as: polar (equatorial) tracking and azimuth/elevation (altitude‑azimuth) tracking. The solar tracker is a device that keeps PV or photo-thermal panels in an optimum position perpendicular to the solar radiation during daylight hours thereby increasing the collected solar energy. The first tracker was introduced by Finster in 1962 and it was completely mechanical. One year later, Saavedra presented a mechanism with an automatic electronic control, which was used to orient an Eppley pyrheliometer [1].

Trackers need not point directly at the sun to be effective. If the aim is off by 10^0, the output is still 98.5% of that of the full-tracking maximum. In the cloudiest, haziest locations the gain in annual output from trackers can be in the low 20% range. In a generally good area, annual gains between 30 and 40% are typical. The gain in any given day may vary from almost zero to nearly 100%.

Solar tracking uses complex instruments to determine the location of the Sun relative to the object being aligned. These instruments typically include computers, which can process complicated algorithms that enable the system to track the Sun, and sensors, which provide information to a computer about the Sun’s location or, when attached to a solar panel with a simple circuit board, can track the Sun without the need for a computer [12].

Figure 2.3: Solar Tracking System

2.8 Types of Solar Trackers

Solar tracking systems can be divided in to two major categories namely;

- Passive tracking and
- Active tracking

2.8.1 Passive Tracking Systems

The passive tracking system realizes the movement of the system by utilizing a low boiling point liquid. This liquid is vaporized by the added heat of the sun and the center of mass is shifted leading to that the system finds the new equilibrium position [10].

2.8.2 Active Tracking System

The active solar tracking are divided into two categories namely dual axis and single axis tracking system. The single axis tracking system rotates the panel only in one direction usually the vertical rotation. The dual axis tracking system on the other hand is more efficient than the single axis as it turns the panel in both vertical and horizontal directions [10]. Dual axis tracking is extremely important in solar tower applications due to the angle errors resulting from longer distances between the mirror and the central receiver located in the tower structure. Dual axis solar tracker normally uses horizontal and vertical axis. The dual axis tracking system is used for concentrating a solar reflector toward the concentrator on heliostat systems. By tracking the sun, the efficiency of the solar panels can be increased by 30-40%.

Single axis solar trackers can either have a horizontal or a vertical axis. 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. In concentrated solar power applications, single axis trackers are used with parabolic and linear Fresnel mirror designs.

2.9 Temperature Measurement

A temperature based weather station is a facility on land or sea with instruments an equipment for measuring the atmospheric temperature conditions of the location to provide information for weather forecast and to study the weather and the climate. Temperature weather station systems are huge, sensitive, and reliable systems. Hence, the key reason that makes such systems considerably wanted to be available is the planning issues. Stability and average of weather is important because civilization relies on consistent predictable conditions for resources supply [13, 14].

Solar panels are obviously affected by the amount of sunlight that was exposed it, both by the number of hours and the intensity of the sun. Temperature is the measurement of the hotness or the coldness of an environment. Temperature have an effect on the amount of solar radiation being absorbed by a panel in a given area. The performance of a solar panel is inversely proportional to the environmental temperature. [15].

2.10 Review of Related Literatures.

2.10.1 Design of an Automatic Solar Tracking System to Maximize Energy Extraction

The author describes in his paper the design, construction and testing of a cost effective intelligent sun tracking system to extract maximum solar energy. It is designed to be driven by a microchip PIC 18F452 micro controller. The system is based on two mechanisms. The first one is the search mechanism (PILOT) which locates the position of the sun. The second mechanism (intelligent PANELS) aligns itself with the PILOT only if maximum energy possible could be extracted [16].

2.10.2 Automatic Sun Tracking System Using PSoC

The author discusses a system using a Programmable system on chip device to control a small model of solar tracker. Voltage across the solar panel and a photo resistor is fed as an input to the PSoC(Programmable System on Chip) to be processed and the output is fed to the geared DC motor. One microcontroller can be used to control many solar panels; only correct information needs to be sent. Efficiency is increased almost by a factor of two [17].

2.10.3 Design and Construction of an Automatic Solar Tracking System

In this paper, the author have described a microcontroller based design which consists of light dependent resistors as sensor, to be used as a tracking mechanism for PV Panels, of which one prototype is also constructed. The prototype represents a method for tracking the sun in both normal and bad weather condition. Moreover, the tracker can initialize the starting position by itself which reduces the need of any more photo resistor [18].

2.10.4 Design and Construction of a System for Sun Tracking

The author describes design and construction of an electromechanical system to follow the position of the sun. It allows the automatic measurement of direct solar radiation with a pyrhelio meter. It operates automatically and is guided by a closed loop servo system. A four-quadrant photo detector senses the position of the sun and two small DC motors move the instrument platform keeping the sun's image at the center of the four-quadrant photo detectors. Under cloudy conditions, when the sun is not visible, a computing program calculates the position of the sun and takes control of the movement, until the detector can sense the sun again. It is possible to use this type of tracker with larger and heavier systems, like solar panels and concentrators. Other cheaper tracking sensors could be used. Digital control should be used to get higher resolution and better response [19].

2.10.5 Design and Development of a Sun Tracking mechanism using the Direct SMA Actuation

An attempt has been made to develop a simple yet efficient sun tracking mechanism (SSTM) using smart Shape Memory Alloy (SMA). The SMA element incorporated in the SSTM device performs the dual functions of sensing and actuating in such a way as to position the solar receptor tilted appropriately to face the sun directly at all times during the day. The mechanism has been designed such that the thermal stimulus needed to activate the SMA element is provided by the concentration and direct focusing of the incident sun rays on to the SMA element. This paper presents, in detail, the design and construction adopted to develop the functional model that was fabricated and tested for performance [20].

2.11 Review of Major Components

2.11.1 Light Dependent Resistor Theory

The simplest optical sensor is a photon 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 two cadmium sulfide (CdS) photocells for sensing the light. The 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 capacitor. 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. Light intensity is measured in Lux, the illumination of sunlight is approximately 30,000 lux [7] [21].

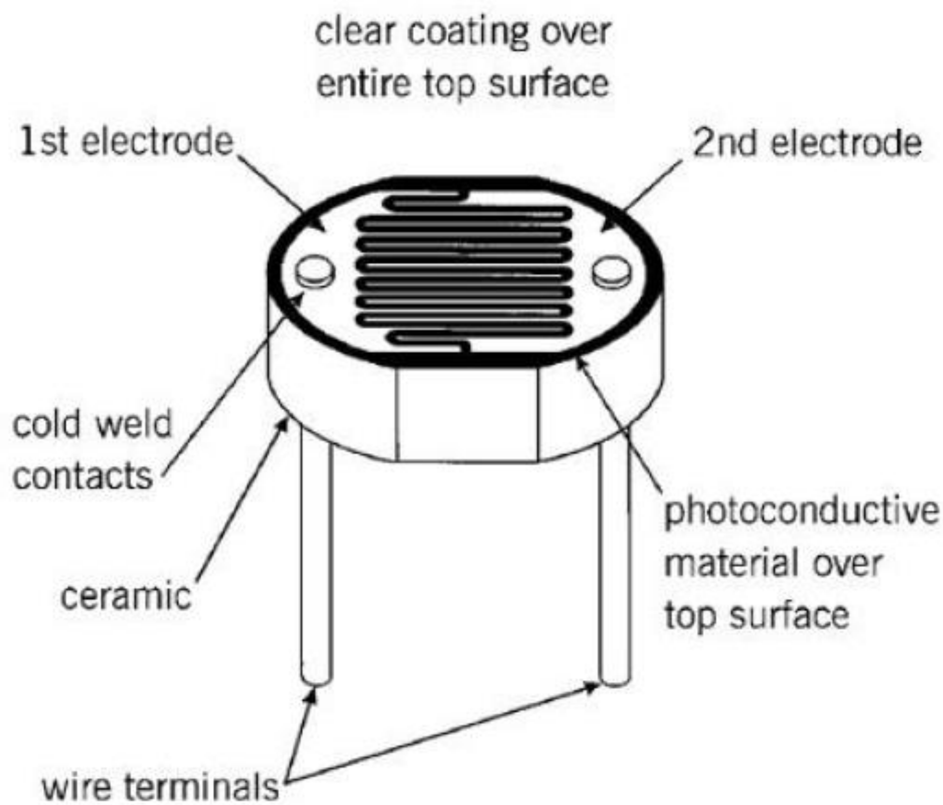

Figure 2.4: LDR Structure

The stable position is when the two LDRs having the same light intensity. When the light source moves, i.e. the sun moves from west to east, the level of intensity falling on both the LDRs changes and this change is calibrated into voltage using voltage dividers.

The changes in voltage are compared using built-in comparator of microcontroller and motor is used to rotate the solar panel in a way so as to track the light source [7].

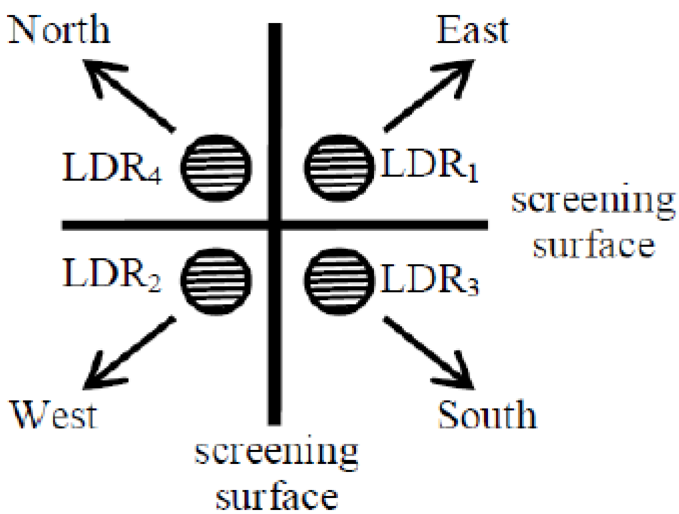

Figure 2.5: LDR Positioning for Solar Tracking.

2.11.2 Servo Motor

Servo motor is a device which rotates in a specific angle usually turns at an angle of 90 degrees in either direction for a total of 180 degree movement, there is a minimum pulse and a maximum pulse for repetition rate. The motor's neutral position is defined as the position where the servo has the same amount of potential rotation in both the clockwise or counter-clockwise direction. They are small in size but unlike normal motor, due to these features, they can be used to operate radio controlled toy cars, robots and airplanes. Example of such application are; numerically controlled machinery, robotics, automation and other mechanism where the staring and the stopping functions are quickly and accurate. Special ability of the servo motor is that the rotor construction is made of special material with less weight to decrease inertia of armature but at the same time, it is capable of producing the necessary magnetic flux. The capability of immediately starting and stopping during the on-off conditions increases due to low rotor inertia [22, 7].

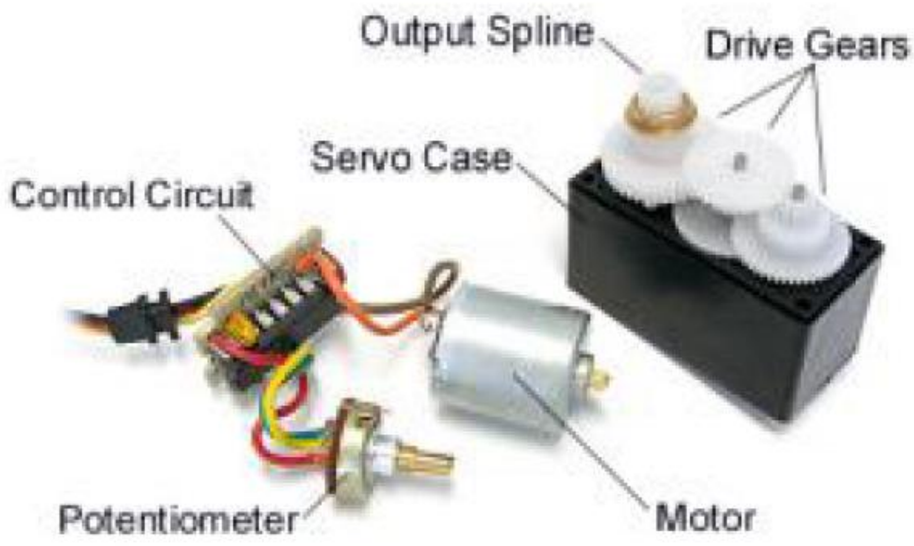

Figure 2.6: Servo Motor Structure

2.11.3 Microcontroller

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

- Central processing unit (CPU)
- Random Access Memory (RAM)

- Read Only Memory (ROM)
- Input/Output ports
- Timers and Counters
- Interrupt controls
- Analog to digital converters
- Digital analog converters
- Serial interfacing ports
- Oscillatory circuits

Microcontrollers need to be programmed to be capable of performing anything useful. It then executes the program loaded in its flash memory – the code comprised of a sequence of zero’s and ones. It is organized in 12-, 14- or 16-bit wide words, depending on the microcontroller’s architecture. Every word is considered by the CPU as a command being executed during the operation of the microcontroller [23, 7].

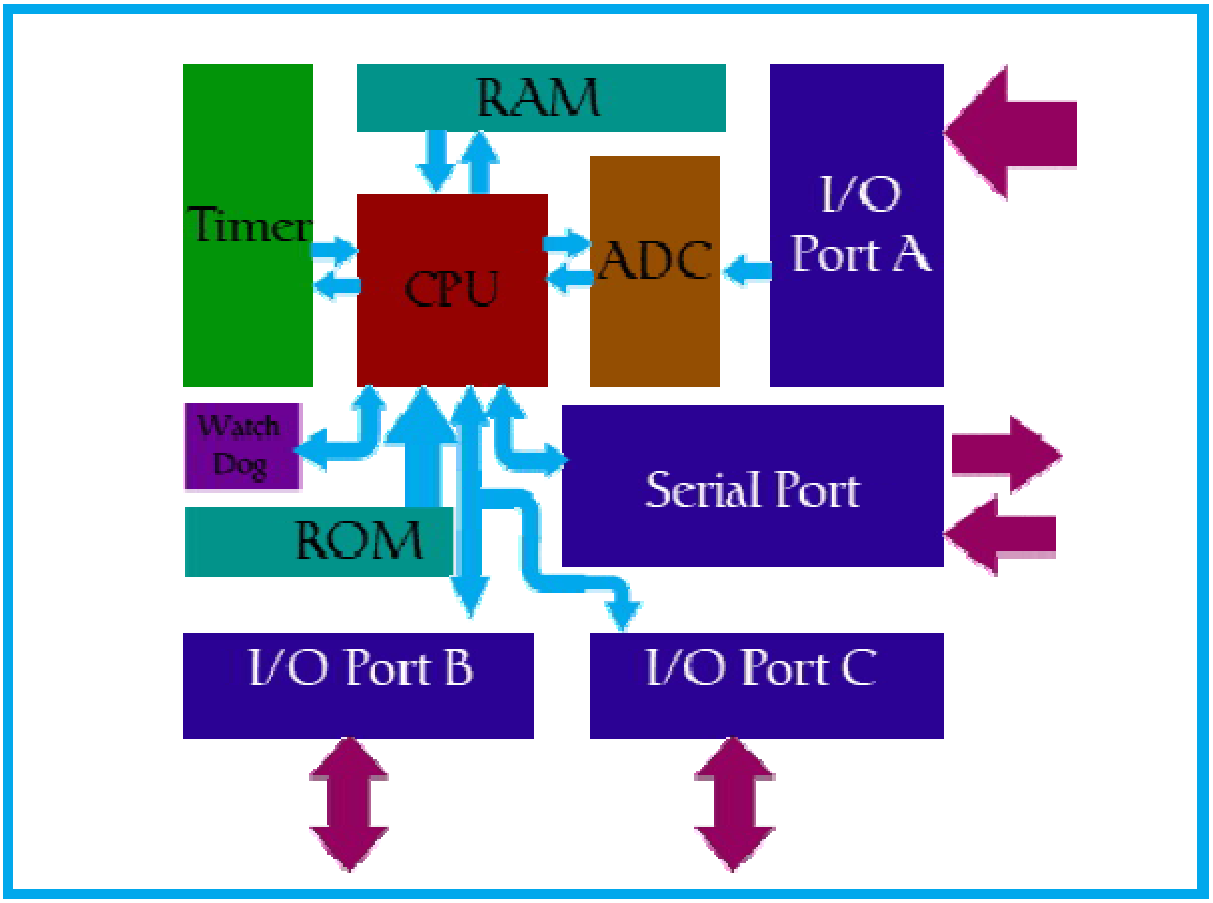

Figure 2.7: Microcontroller Block Diagram

2.11.4 Liquid Crystal Display (LCD) Screen

LCD (Liquid Crystal Display) screen is an electronic display module and has a wide variety of applications. The very basic module is 16x2 LCD display module and it is the very commonly module in various devices and circuits. These LCD modules are preferred over other multi segment LEDs and seven segment display. The 16x2 LCD can display 16 characters per line and there are 2 such lines. This LCD has two registers namely the Command and the Data. Each character is displayed in 5x7 pixel matrix. Such type of LCDs is economical, easily programmable, and reliable and has no limitations of displaying special and even custom characters unlike the seven segment display and so on. Figure bellow shows the LCD which displays the desired input value. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. the data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

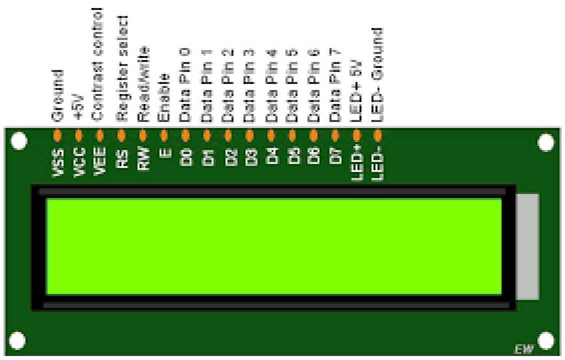

Figure 2.8: 16X2 LCD Module

Table 2.1: pin description of LCD module

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor (10 kΩ)	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0

8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

2.11.5 Voltage Regulation

Voltage regulators are designed to automatically maintain voltages at a constant level. The LM7805 voltage regulator is used. It is a member of the 78xx series of fixed linear voltage regulator ICs. Voltage sources in circuits could be having fluctuations and thus not be able to give fixed voltage output. The voltage regulator IC maintains the output voltage at a value that is constant. The LM7805 provides +5V regulated power supply. Capacitors are connected at the input and output depending on respective levels of voltage [7].

Figure 2.9: Voltage Regulator

2.11.6 Temperature / Humidity Sensor (DHT)

Temperature / Humidity sensor (DHT) measures the values of (T) and (H) periodically based on the update period with adjusted digital signal output. The sensor is considered reliable and stable due to the exclusive digital signal and data realization based Temperature / Humidity sensing module. DHT sensor is constructed of resistive type element that reads Humidity and a negative temperature coefficient NTC element that reads temperature. The sensor deals with 8 – bit microcontroller which demonstrate reliability, sensitivity, stability, high response, no interference, and finally can be found in a low cost. The employed Temperature / Humidity sensor (DHT) is given by 3 pins identified as VCC connected to the 5V of Arduino, GND connected to Arduino GND, and DATA pin connected to the digital pin of Arduino board [24].

The DHT11 sensor is comprised of 3 parts, a capacitive humidity sensor, a thermistor and a chip that performs analog to digital conversion and outputs a digital signal with the temperature and humidity. The digital signal can be read using any microcontroller. Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as programs in the One-Time Programmable (OTP) memory, which are used by the sensor’s internal signal detecting process [25].

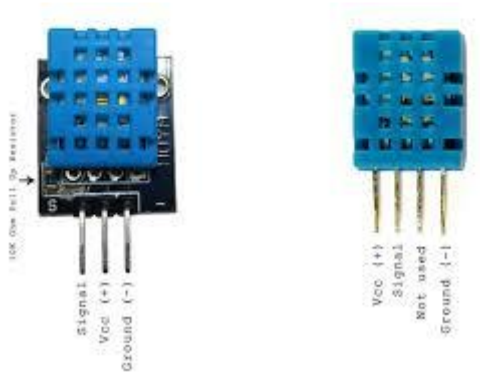

Figure 2.10: Temperature Sensor Module

2.11.7 Solar Panel

Photovoltaic solar panels absorbs sunlight as a source of energy to generate electricity. A photovoltaic (PV) module is a packaged, connected assembly of a number of photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity. Solar energy is the photovoltaic cell which convert light energy received from sun into electrical energy. The name behind “solar” panel is they grab high powerful energy emitted from the sun. The solar panel finds its applications in street lights, domestic and industrial areas. In this project, a solar panel will be used to absorb the energy from the sun and converts it to electricity.

Figure 2.11: Solar panel array

2.11.8 Switches

A switch is an electrical component that can make or break an electrical circuit, interrupting the current or diverting it from one conductor to another. The mechanism of a switch removes or restores the conducting path in a circuit when it is operated. It may be operated manually or automatically by sensing a signals. A switch will have one or more sets of contacts which may operate simultaneously, sequentially, or alternately. Mostly switches are manually operated electromechanical devices with one or more sets of electrical contacts which are connected to external circuits. Each set of contacts can be in one of two states: either “closed” meaning the contacts are touching and electricity can flow between them, or “open” meaning the contacts are separated and the switch is no conducting [26].

Figure 2.12: Push Button Switch

2.11.9 Battery

A battery is an electrical device that produces electrical current with collection of cells. Battery, also called electric cell, is a device that converts chemical energy into electricity. Strictly speaking, a battery consists of two or more cells connected in series or parallel, but the term is also used for single cells. All cells consist of a liquid, paste, or solid electrolyte and a positive electrode, and a negative electrode. The electrolyte is an ionic conductor; one of the electrodes will react, producing electrons, while the other will accept electrons. When the electrodes are connected to a device to be powered, called a load, an electrical current flows. Batteries in which the chemicals cannot be reconstituted into their original form once the energy has been converted (that is, batteries that have been discharged) are called primary cells or voltaic cells. Batteries in which the chemicals can be reconstituted by passing an electric current through them in the direction opposite that of normal cell operation are called secondary cells, rechargeable cells, storage cells, or accumulators [27].

Figure 2.13: Battery and the symbol

Chapter Three: Design and Construction Procedure

3.0 Systems Description

This chapter deals with the design and construction of a dual axis solar tracking system with temperature and solar radiation measurement capability. A solar tracking system is a device that tracks the position of the sun during the day and throughout the year for a maximum and efficient absorption of the solar energy. A solar panel is a device that converts solar energy to electrical energy. The solar tracker rotates the solar panel so that is will be facing the sun at right angle at all time of the day and the year. The system also determines the solar intensity or radiation of the given area and also the temperature of the surrounding environment. The temperature and solar radiation being measured are displayed on a liquid crystal display (LCD) which serves as the user interface. This chapter deals with the design of the hardware and the software of the system and as well the actual construction of the various parts of the system.

3.1 Block Diagram

The systems block diagram consists of the different sections which works together to produce the whole system. Figure 3.1 below shows the system's block diagram. The direction of the arrow shows the flow of signal or command from one part of the circuit to another. The various parts of the block diagram includes the power supply, the microcontroller unit, the display unit, the temperature measurement unit, the solar radiation measurement unit, the solar tracking unit and the solar panel positioning unit.

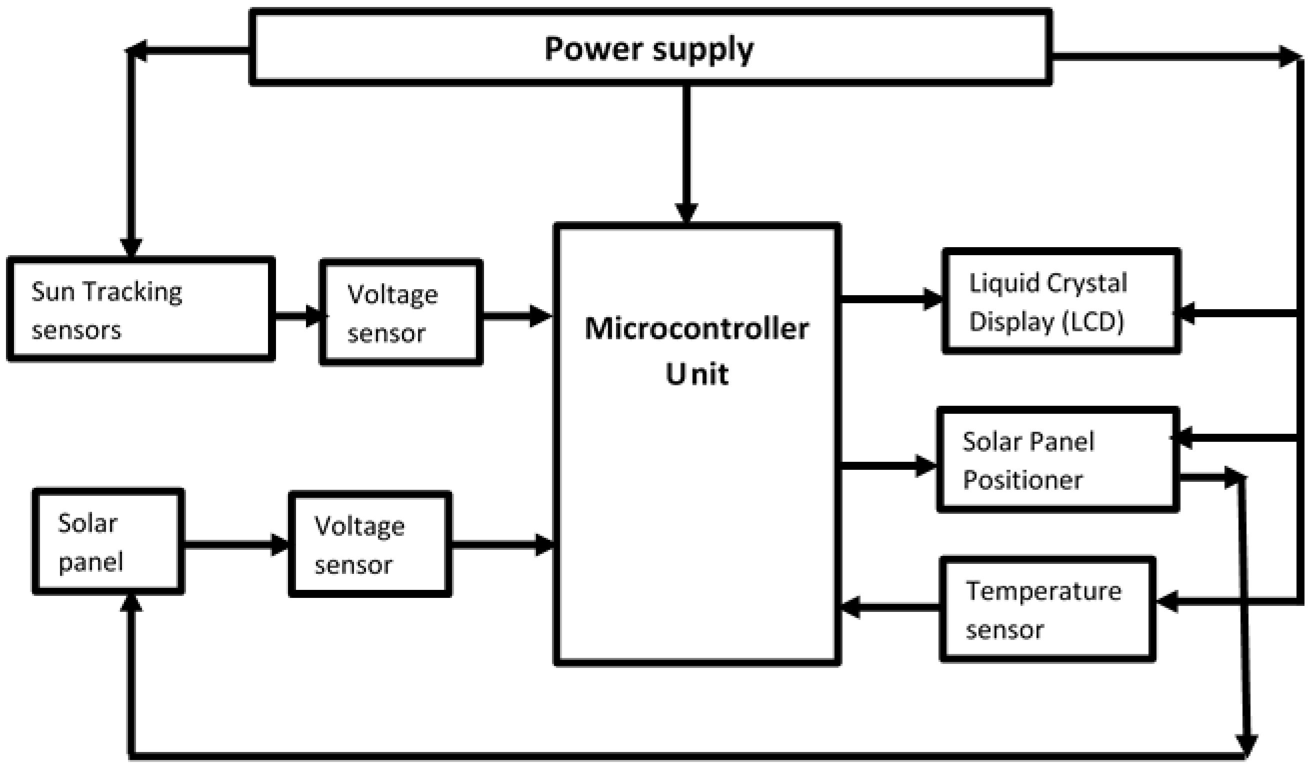

Figure 3.1: The Systems Block Diagram

The summary of the systems block diagrams are as explained below.

3.1.1 The Power Supply: the power supply unit provides the necessary power required for the smooth operation of the system. The power supply unit comprises of the voltage and current source and also the various power control equipment which include the regulators, indicators etc. the power source is from a battery power source.

3.1.2 The Microcontroller Unit: the microcontroller is the brain of the system. It is responsible for coordinating the activities of other units and also processing the information gotten from the sensors. The microcontroller receives data from the temperature sensor, solar sensors and the radiation sensor and then sends command to the solar panel positioner and the display unit.

3.1.3 The Display Unit: the display unit serves as the human interface for obtaining information from the system. The 16X2 liquid crystal display, displays the temperature and solar radiation values all the time.

3.1.4 Temperature Measurement Unit; temperature measurement deals with the determination of how hot or cold an object or environment is. This unit is made up of a temperature measuring device, which determines the environmental temperature and sends it to the microcontroller for proper documentation and processing.

3.1.5 Solar Radiation Measurement: the solar radiation measurement unit measures the solar intensity of the given location. This unit uses the solar panel and a current sensor to obtain the solar power and then measures the solar radiation.

3.1.6 Solar Tracking Unit: the solar tracking units comprises of light dependent resistors which were used to sense the solar intensity and then a voltage sensor to obtain the reading. There are four sensors which are placed in the X and Y directions. The sensors compares the intensity of the sun and the system rotates the solar panel according to the sensor with the highest intensity for a maximum solar tracking.

3.1.7 Solar Panel Positioning Unit: the solar panel positioning unit are responsible for placing the panel in a manner for maximum solar tracking. This nit comprises of metal geared servo motors and some mechanical systems put in place for support and movement of the panel.

3.2 Hardware Design

The hardware design deals with the design and calculations analysis of the various units of the system and the interactions between each part of the circuit and the other. Necessary calculations, equations, plates and diagrams were included in the system designs for a better understanding. The design of each section of the system are as described in the following subsections.

3.2.1 The Power Supply

As stated earlier, the power supply supplies all the required power to the circuit. The system functions on a minimum voltage level of 5V dc which are required by the microcontroller, the temperature sensor, the LCD and the other parts of the circuit. The power supply of the circuit can also be obtained from the solar panel if a proper charge controller is designed for charging of the battery. The power requirement for the system was obtain by summing up all individual power requirement of the subsystem components as stated in table 3.1 below. The voltage given to a device from the power supply depends on its recommended rating, but as for the current the power supply is designed to source; it will be equal to or greater than the sum of the maximum current that each load can sink. The table 3.1 below shows the current each component can consume according to their datasheet ratings and also measurement.

Table 3.1: Summary of the Systems Power Consumption

S/N	UNIT	CURRENT
1	Servo motors	500mA
2	Temperature sensor	2.5mA
3	Microcontroller	250mA
4	Liquid Crystal Display	160mA
5	Total	915mA

The power supply is based on a 7.4V 3A dc battery source. A voltage regulator L7805 regulates the power source to a voltage level of 5V dc required by the circuit to functions.

L7805C Voltage regulator

The regulator used in this project is L7805 for regulated 5V dc power supply. The L78XX series according to the datasheet has a maximum output current of 1.5A but can still be adjusted to produce a variable output current. It has a maximum voltage drop of 2.5V at 25^0C and a resistance of 17mΩ at 1 KHz. The special features of L7805 voltage regulator includes the following as captured from the datasheet [28].

- Output current up to 1.5 A.
- Output voltage of 5V.
- Thermal overload protection.
- Short circuit protection.
- Output transition with SOA protection.
- 2 % output voltage tolerance.
- Guaranteed in extended temperature range.

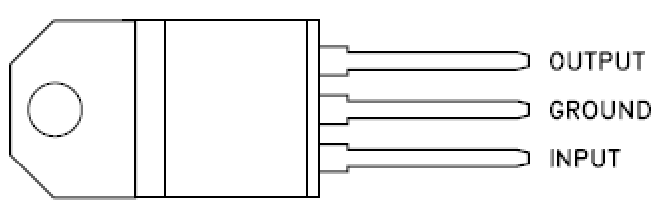

Figure 3.2 L78XXX Voltage Regulator

Two capacitors were connected before and after the voltage regulator as specified in the datasheet of the regulator. The connection of the voltage regulator and other components of the power supply to the system is as shown in the diagram below.

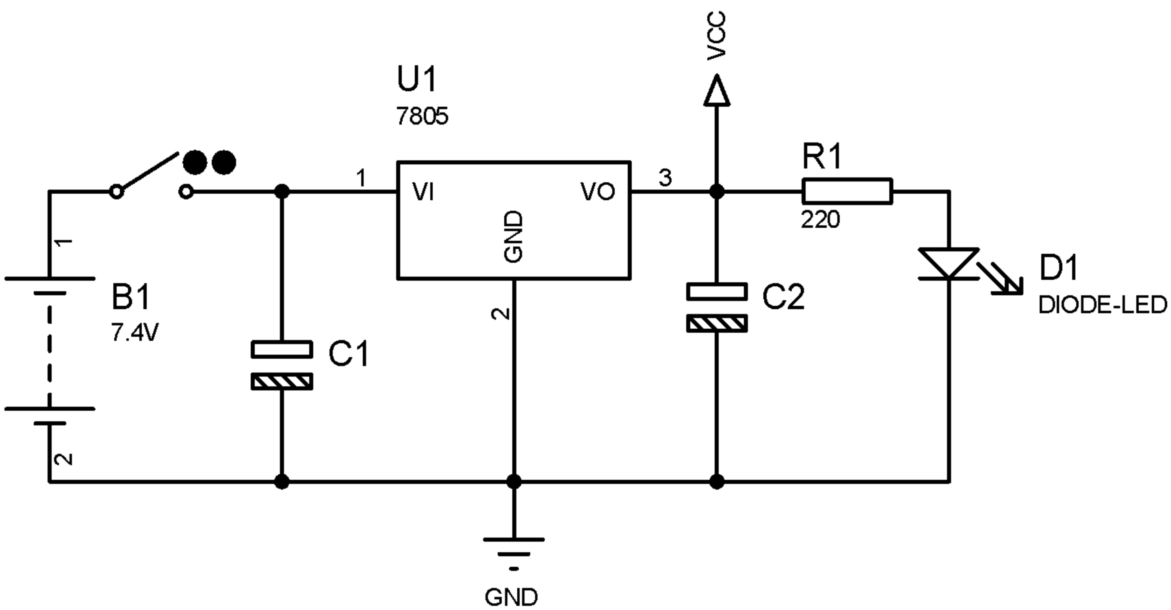

Figure 3.3; Systems Power Supply

3.2.2 The Microcontroller Unit

The microcontroller is the brain of the system. The microcontroller is responsible for coordinating the activities of the whole system. The microcontroller process the input data and gives command to the output peripherals. In the choice of a microcontroller, a microcontroller with at least six analog input pins and eight or more digital input/output pins is required. The microcontroller should be able to store the programs internally and fetch them when needed. Also the microcontroller should have a minimum power consumption hence the choice of ATMEGA328P.

ATMEGA328P

ATMEGA328P is a high performance, low power microcontroller from Microchip. ATMEGA328P is an 8-bit microcontroller based on AVR RISC architecture. It is the most popular of all AVR controllers as it is used in ARDUINO boards. It is an Atmel microcontroller with an In-Application Programmable (IAP), allowing the Flash program memory to be reconfigured even while the application is running. ATMEGA328p is a 28 pin microcontroller. It is powered through the 5v dc power supply. It has an absolute power consumption of 400mA and normal power consumption of 250mA at a clock frequency of 16MHz and dc voltage of 5V. The pins are subdivided into ports from port B to port D and also into analog and digital pins. Each digital pin can sink a maximum current of 40mA and the analog pins can sunk a total current of 100mA.

ATMega328 Pin Configuration

ATMEGA328P is a 28 pin chip as shown in pin diagram above. Many pins of the chip here have more than one function.

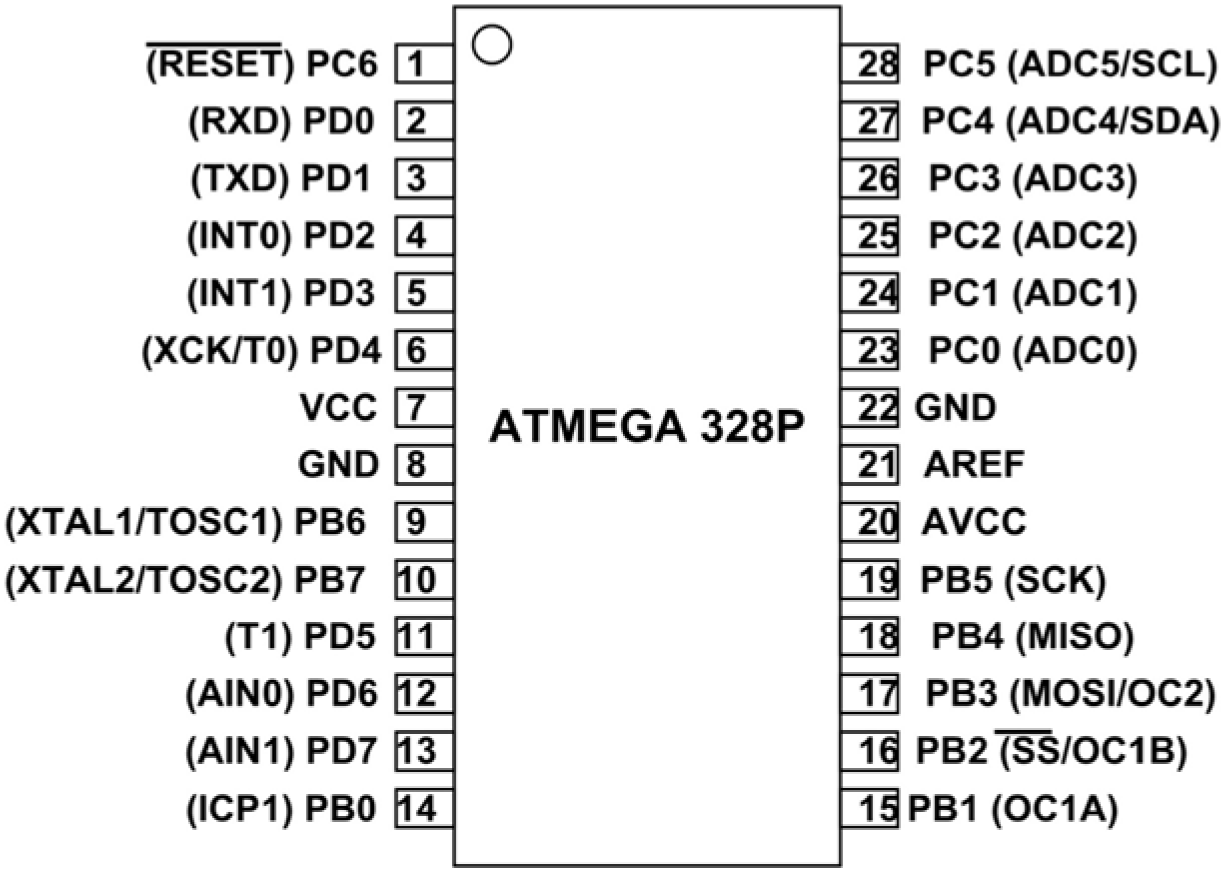

Figure 3.4; ATMEGA328P Pin Configuration.

The table below gives a description for each of the pins of the microcontroller, along with their function.

Table: 3.2 ATMEGA328P Microcontroller Pins Description.

Pin Number	Description	Function
1	PC6	Reset
2	PD0	Digital Pin (RX)
3	PD1	Digital Pin (TX)

4	PD2	Digital Pin
5	PD3	Digital Pin (PWM)
6	PD4	Digital Pin
7	Vcc	Positive Voltage (Power)
8	GND	Ground
9	XTAL 1	Crystal Oscillator
10	XTAL 2	Crystal Oscillator
11	PD5	Digital Pin (PWM)
12	PD6	Digital Pin (PWM)
13	PD7	Digital Pin
14	PB0	Digital Pin
15	PB1	Digital Pin (PWM)
16	PB2	Digital Pin (PWM)
17	PB3	Digital Pin (PWM)
18	PB4	Digital Pin
19	PB5	Digital Pin
20	AVCC	Positive voltage for ADC (power)
21	AREF	Reference Voltage
22	GND	Ground

23	PC0	Analog Input
24	PC1	Analog Input
25	PC2	Analog Input
26	PC3	Analog Input
27	PC4	Analog Input
28	PC5	Analog Input

20 of the pins function serves as input/output ports. This means they can function as an input to the circuit or as output from the microcontroller. Whether they are input or output, the function is set in the software during the programing of the microcontroller. 14 of the pins are digital pins, of which 6 of the digital pins can function to give Pulse Width Modulation (PWM) output. 6 of the pins are for analog input/output i.e. they can accept analog signals or give out analog outputs.

Also 2 of the pins are for the crystal oscillator. This is to provide a clock pulse for the Atmega chip. A clock pulse is needed for synchronization so that communication can occur in synchrony between the Atmega chip and a device that it is connected to. The chip needs power so 2 of the pins, VCC and GND, provides it power so that it can operate. The Atmega328 is a low-power chip, so it only needs between 1.8-5.5V of power to operate.

The Atmega328 chip has an analog-to-digital converter (ADC) inside of it. This must be or else the Atmega328 wouldn't be capable of interpreting analog signals. Because there is an ADC, the chip can interpret analog input, which is why the chip has 6 pins for analog input. The ADC has 3 pins set aside for it to function- AVCC, AREF, and GND. AVCC is the power supply, positive voltage, that for the ADC. The ADC needs its own power supply in order to work. GND is the power supply ground. AREF is the reference voltage that the ADC uses to convert an analog signal to its corresponding digital value. Analog voltages higher than the reference voltage will be assigned to a digital value of 1, while analog voltages below the reference voltage will be assigned the digital value of 0. Since the ADC for the Atmega328 is a 10-bit ADC, meaning it produces a 10-bit digital value, it converts an analog signal to its digital value, with the AREF value being a reference for which digital values are high or low. Thus, a portrait of an analog signal is shown by this digital value; thus, it is its digital correspondent value.

The last pin is the RESET pin. This allows a program to be rerun and start over.

Features of ATMEGA328P

- Atmega328 has 28 pins in total.
- It has 3 Ports in total which are named as Port B, Port C and Port D.
- Port C is an analogue Port and it has six pins in total. So, in simple words, ATmega328 has 6 analogue pins.
- Port B and Port D are digital ports and have 7 pins each.
- So, in total ATmega328 has 14 digital pins.
- It also supports Serial Communications, we can perform serial communication via Pin # 2 (RX) and Pin # 3 (TX).
- It also supports SPI Protocol.
- It needs a crystal oscillator for generating the frequency. You can use crystal oscillator ranging from 4MHz to 40 MHz
- The project uses a 16MHz crystal oscillator to provide the clock frequency.

Microcontroller’s oscillator unit

An oscillator is an electronic device used for the purpose of generating a signal. It is a circuit which generates an a.c output signal without requiring any externally applied input signal. In this circuit, a crystal based oscillator of 16MHz provides the required oscillation circuit for the microcontroller externally. This Crystal Oscillator is a low power oscillator, with reduced voltage swing on the output.

Pins XTAL1 and XTAL2 of the microcontroller which corresponds to pin 9 and 10 of ATMEGA328P respectively are the oscillator’s input and output respectively, of an inverting amplifier. It is configured for use as an On-chip Oscillator, as shown in the Figure 3.11 below. A ceramic resonator in parallel with two 22pF capacitor connected to the ground as specified on the datasheet of the microcontroller provides the circuit’s oscillation [29]. The crystal oscillator is responsible for producing the clock signal required by the circuit (microcontroller). To know the actual value of the crystal oscillator we have to look into some calculation. Using the relation below:

$$f_{int} \quad = \quad \frac{f_{quartz}}{4}$$

Where:

f_{int} = is the internal frequency of microcontroller

f_{quartz} = is the frequency of crystal oscillator

From the data sheet of ATMEGA 328P f_{int} = 4MHZ (i.e. the internal frequency of the microcontroller).

$$f_{quartz} = f_{int} \times 4$$

$$f_{quartz} = (4 \times 10^6) \times 4$$

$$f_{quartz} = 16 \times 10^6 H_Z$$

The capacitor used with the oscillator is 22pf (from data sheet of 16MH_Z crystal).

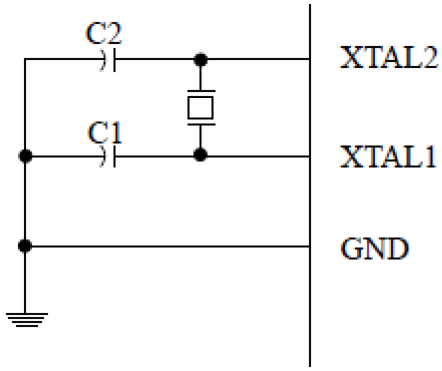

Figure 3.5; Systems Oscillator Circuit

3.2.3 The Display Unit

The display unit is the user interface to the system. The display unit displays values of the environment's temperature and the solar intensity of the given area at specific intervals. The type of display used in the project is a 16X2 Liquid Crystal Display (LCD). An **LCD** is an electronic display module which uses liquid crystal to produce a visible image. The 16×2 **LCD** display is a very basic module commonly used in DIYs and circuits. The 16×2 translates to a display 16 characters per line in 2 such lines.

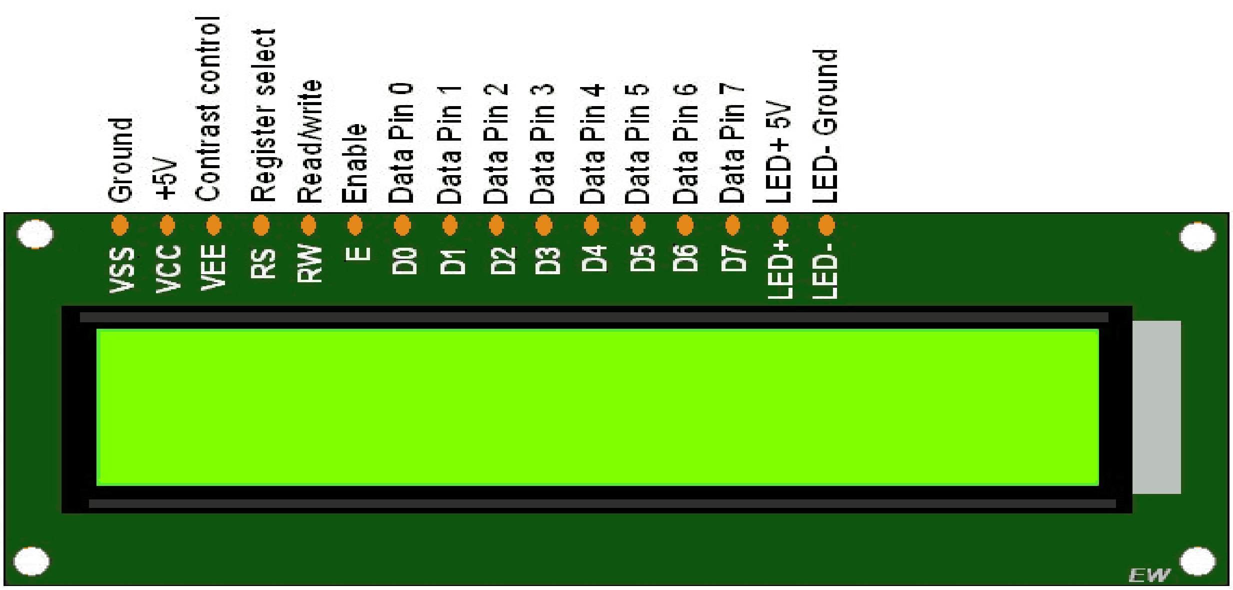

Figure 3.6; LCD 16X2 Module

Table 3.3; LCD Pin Configuration

Pin No:	**Pin Name:**	**Description**
1	Vss (Ground)	Ground pin connected to system ground
2	Vdd (+5 Volt)	Powers the LCD with +5V (4.7V – 5.3V)
3	VE (Contrast V)	Decides the contrast level of display. Grounded to get maxim contrast.
4	Register Select	Connected to Microcontroller to shit between command/data register
5	Read/Write	Used to read or write data. Normally grounded to write data to LCD
6	Enable	Connected to Microcontroller Pin and toggled between 1 and 0 for d acknowledgement
7	Data Pin 0	Data pins 0 to 7 forms 8-bit data line. They can be connected Microcontroller to send 8-bit data. These LCD's can also operate on 4-bit mode in such case Data pin 4,
8	Data Pin 1	
9	Data Pin 2	
10	Data Pin 3	

11	Data Pin 4	and 7 will be left free.
12	Data Pin 5	
13	Data Pin 6	
14	Data Pin 7	
15	LED Positive	Backlight LED pin positive terminal
16	LED Negative	Backlight LED pin negative terminal

Features of 16×2 LCD Module

- Operating Voltage is from 4.7V to 5.3V
- Current consumption is 1mA without backlight
- Alphanumeric LCD display module, meaning it can display alphabets and numbers
- Consists of two rows and each row can print 16 characters.
- Each character is built by a 5×8 pixel box
- Can work on both 8-bit and 4-bit mode
- It can also display any custom generated characters
- Available in Green and Blue Backlight

LCD 16X2 Interface to the Microcontroller

The LCD was connected to the PORTB of the microcontroller. The interface of the module to the microcontroller is as shown in the diagram below. A 10KΩ variable resistor was connected contrast control pin (VEE) which controls the contrast level of the module. A 5 volt power supply was used to power the system. The summary of the modules interface was as summarized in the table below.

Table 3.4; LCD Interface to the Microcontroller

No.	Symbol	Function	Connection
1	VSS	Ground (0V)	Ground
2	VDD	Supply voltage	5V
3	V0	Control adjustment	10K pot
4	RS	Data instruction select	8
5	E	Enable signal	9
6	R/W	Read/Write select	Ground
7	DB4	Data bus	10
8	DB5	Data bus	11
9	DB6	Data bus	12
10	DB7	Data bus	13
11	LED_K	Led power supply (0V)	Ground
12	LED_A	Led power supply (5V)	5V

The LCD was connected to the board through connectors. The interface of the display unit to the microcontroller is as shown below.

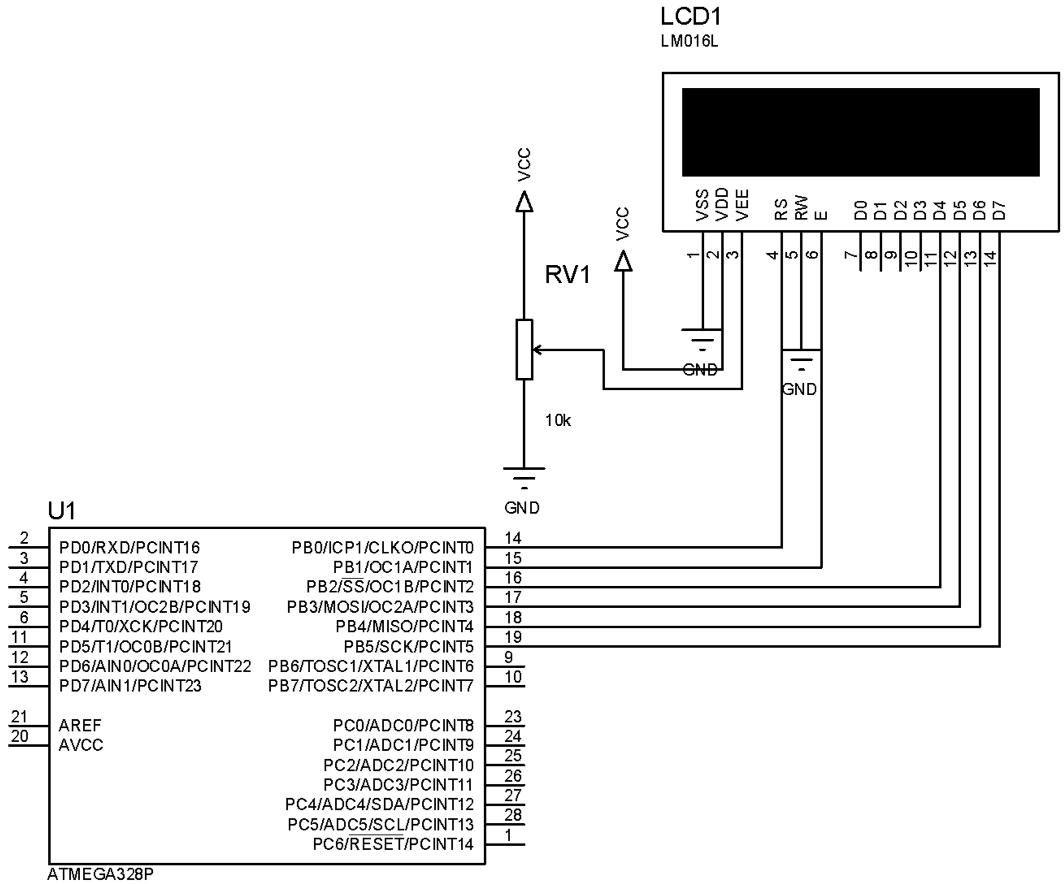

Figure 3.7; LCD Interface to the Microcontroller

3.2.4 The Temperature Measurement

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is that it can only get new data from it once every 2 seconds, so when using the library, sensor readings can be up to 2 seconds old.

Figure 3.8; DHT11 Temperature Sensor Module

Table 3.5; DHT11 Pin Configurations

DHT11 pin configurations		
1	VCC	Power supply 3.5V to 5.5V
2	Data	Outputs both Temperature and Humidity through serial Data
3	Ground	Connected to the ground of the circuit

DHT11 Specifications:

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0°C to 50°C
- Humidity Range: 20% to 90%
- Resolution: Temperature and Humidity both are 16-bit
- Accuracy: ±1°C and ±1%

Interfacing DHT11 to the Microcontroller

The temperature gives out a digital output at a specific intervals. The sensor is connected to the analogue ports of the microcontroller. The power pins which includes the VCC and GND were connected to the systems +5V and ground terminal of the power supply respectively. The signal pin of the sensor was connected to the pin 27 of the microcontroller which is analogue pin A4. The sensors senses the environmental temperatures and constantly sends it to the microcontroller through the data pin. The interface of the sensor to the microcontroller is as shown in the diagram below.

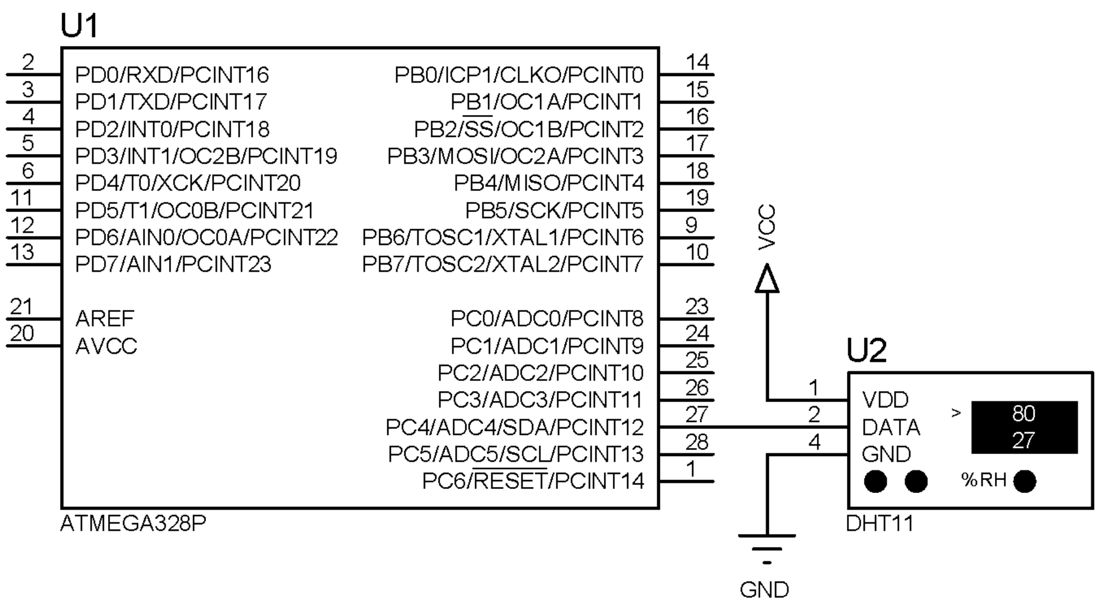

Figure 3.9; DHT11 Interface to the Microcontroller

3.2.5 Sun Tracking Unit

A sensor is a device which detects or measures a physical property and records, indicates, or otherwise responds to it. LDR photo-resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called as photo conductors, photo conductive cells or simply photocells. They are made up of semiconductor materials having high resistance. LDR works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the material's conductivity is increased when light is absorbed by the material.

The most common type of LDR has a resistance that falls with an increase in the light intensity falling upon the device. The system makes use of four LDRs which are positioned at the four cardinal points of the earth namely; East, West, North and the South. The system compares the resistance of the East to the West and North to the South and moves the panel to the direction of the sensor with the lowest resistance. When the sun is towards the east, a barrier casts a shadow on the western LDR hence increasing its resistance. The system responds by turning the panel until both LDRs receives equal amount of light. Similarly when the sun is towards the north, it casts a shadow on the southern LDR there by increasing its resistance. The system responds by rotating the panel until the sensors receives equal amount of light.

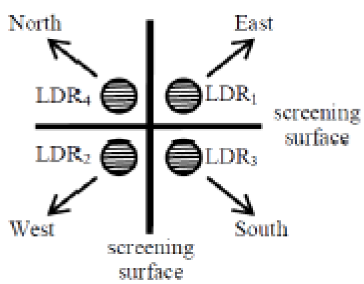

Figure 3.10; LDR's Positioning for Sun Tracking

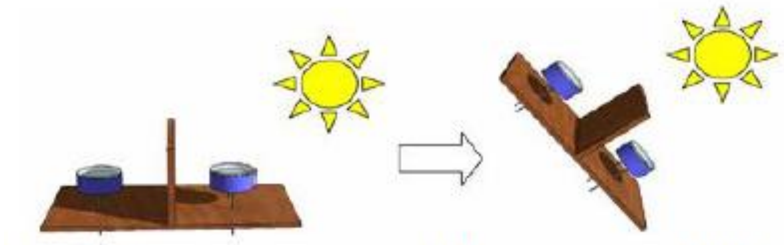

Figure 3.11; Sun Tracker Positioning

Interfacing of LDR to The Microcontroller

The sensors are interfaced to the A0 –A3 pins of the microcontroller which are the analog pins. A0 corresponds to the East sensor, A1-A3 corresponds to West, North and South sensors respectively. The microcontroller compares the voltage level of each sensor to the other. The voltage level corresponds to the light intensity on the sensor. The higher the light, the higher the voltage values of the analog pin. A 10KΩ resistor is used together with the LDR to create a voltage divider and the output is fed to the microcontroller. The interface of the LDR to the microcontroller is as shown in the figure 3.12 below.

The Atmega 328P has 1024 analogue voltage steps and digital 5volts. When analogue signals are converted into digital values, the values will be in the range of 0-1023. In this project, the LDR sensors senses the analogue signals of the sun intensity and the microcontroller converts the signal into a digital value to operate on it. The conversion is done using the relation below.

LDR Output = $\frac{equivalent\ Digital\ Output \times 5}{1023}\ Volts$

$$\therefore\ equivalent\ Digital\ Output = \frac{LDR\ Output\ X\ 1023}{5} Volts$$

The LDR output is the value obtained from the solar sensors and it depends on the intensity of the sun. The system compares the various sensors and uses the differences to control the rotation and revolution of the panel.

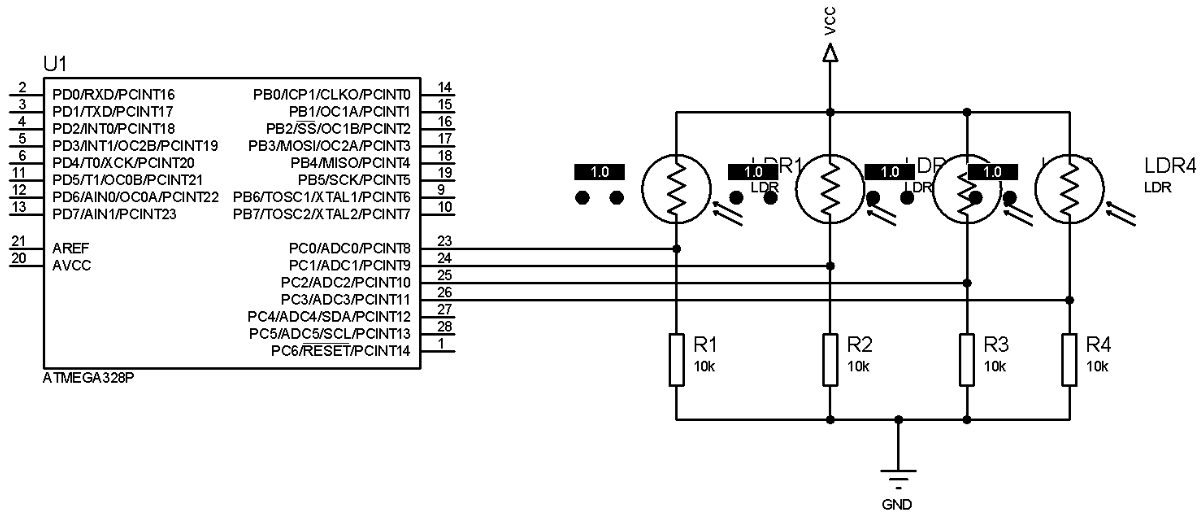

Figure 3.12; LDR Interface to the Microcontroller

3.2.6 Solar Panel Positioning Unit

This unit rotates the panel to be facing the sun rays at right angle. It comprises of two servomotors which corresponds to the vertical and the horizontal movements. The servo motor controls the panel rotation from 30 degrees to 150 degrees in the vertical direction and from 0 degrees to 180 degrees in the horizontal direction. The servomotors were attached to a mechanical arms which supports the solar panel board.

Servo Motor

A **servomotor** is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servomotor Wire Configuration

Wire Number	Wire Colour	Description
1	Brown	Ground wire connected to the ground of system
2	Red	Powers the motor typically +5V is used
3	Orange	PWM signal is given in through this wire to drive the motor

TowerPro SG-90 Features

- Operating Voltage is +5V typically
- Torque: 2.5kg/cm
- Operating speed is 0.1s/60°
- Gear Type: metal
- Rotation : 0°-180°
- Weight of motor : 9gm

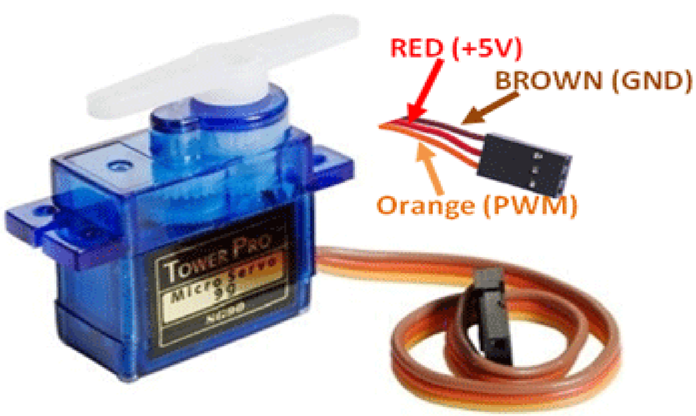

Figure 3.13 SG-90 servo motor

Servo Motor Interface to the Microcontroller

In this project, the servomotors were interfaced to the microcontroller's digital pin – and – for the vertical and the horizontal movements respectively. The VCC pins were connected to a +5V power supply, the GND pins were connected to the common circuit GND while the PWM pins wire connected to the digital pins – and – for the vertical and horizontal servos respectively. The connections of the servomotor to the microcontroller were as shown in the figure below.

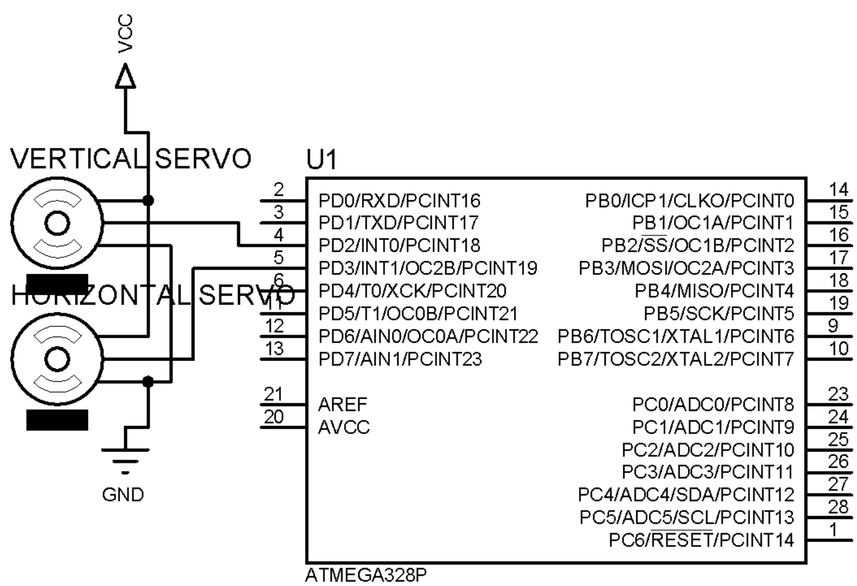

Figure 3.14 servo motor interface to microcontroller

3.2.7 Solar Radiation Measurement

Solar radiation is often defined as the solar energy reaching the earth from the sun per unit area. A large part of this is visible sunlight, but the solar spectrum extends into the UV as well as the near infra-red.

It reaches us in different ways: directly from the sun (direct solar radiation), through scattering through the atmosphere (diffuse solar radiation) or via reflections. The solar radiance is an instantaneous power density in units of kW/m^2. The solar radiance varies throughout the day from 0 kW/m^2 at night to a maximum of about 1 kW/m^2. The solar radiance is strongly dependent on location and local weather. The solar radiation was measured with the help of a solar sensor with determines the actual power being supplied by the sun within the given area. A 5V solar panel was connected to the microcontroller through a 5W 1Ω which converts the solar voltage to current. The microcontroller detects the variation in the current and multiplies it by the voltage of the panel which is constant to obtain the solar power. The solar power is further divided by the surface area to obtain the solar intensity of the given area. The connection of the panel to the microcontroller for solar intensity measurement is as shown below.

The features of the solar panel used is as stated below.

- Output voltage 5V
- Maximum power 0.22W
- Output current 40mA
- Dimensions 57X28mm
- Material polycrystalline silicon

3.3 Software Design

The software is the set of instructions or programs instructing a computer to do a specific task. The software was written with an Arduino IDE and uploaded into the memory of the microcontroller using Arduino uno board. The software design comprises of the systems flow chart and the writing of the program.

3.3.1 The Flowchart

A **flowchart** is a type of diagram that represents a workflow or process. A **flowchart** can also be defined as a diagrammatic representation of an algorithm, a step-by-step approach to solving a task. The **flowchart** shows the steps as boxes of various kinds, and their order by connecting the boxes with arrows. The flowchart for the system is as shown in figure 3.23, it represents the program flow of the dual axis solar tracking system with temperature and solar intensity measurement capability. Refer to Appendix A for the C code that implements the flowchart.

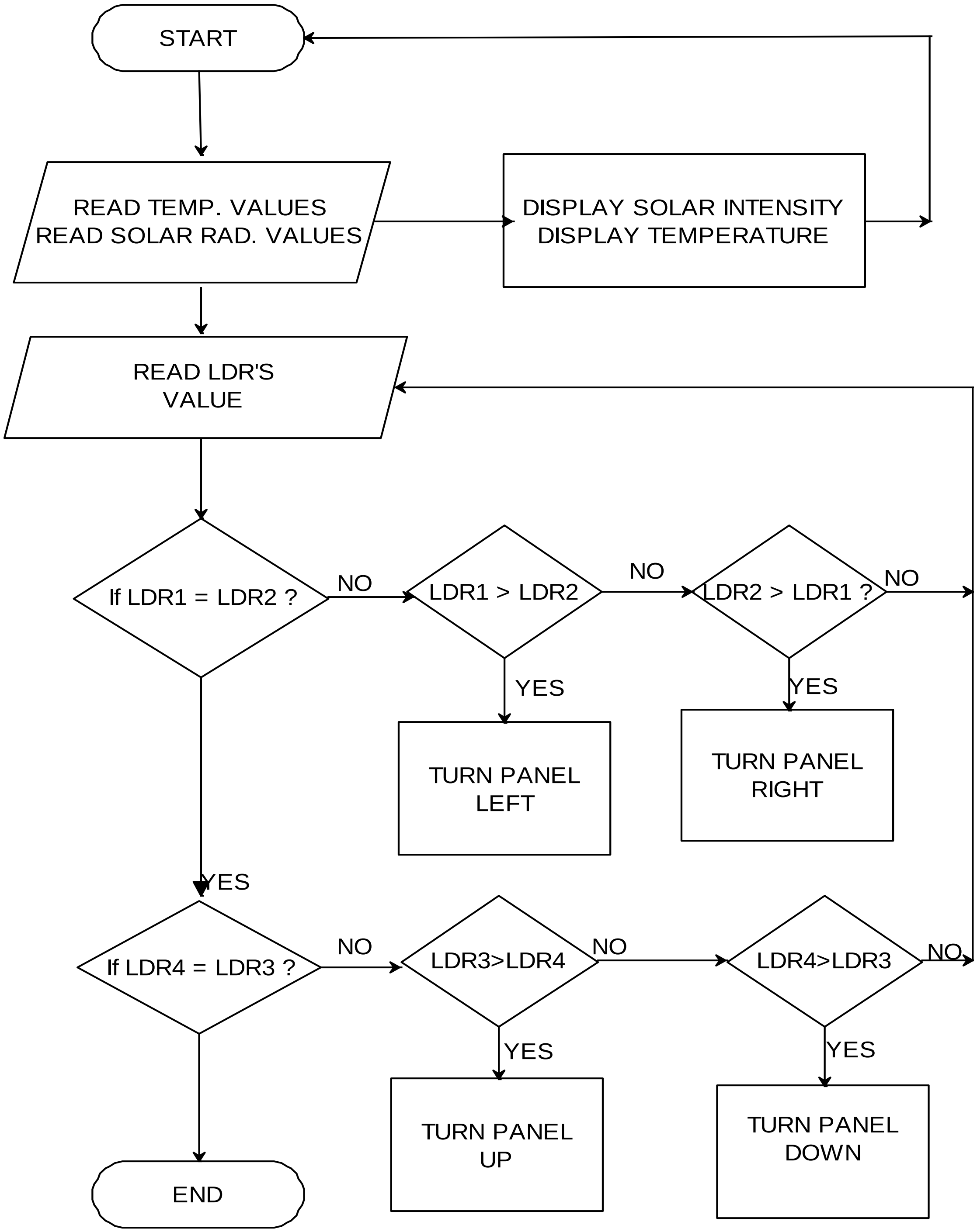

Figure 3.17 systems flowchart

3.3.2 The Arduino IDE

The **Arduino integrated development environment (IDE)** is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino compatible boards. Arduino IDE is an open source software that is mainly used for writing and compiling the code into the Arduino Module. The main code, also known as a sketch, created on the IDE platform will ultimately generate a Hex File which is then transferred and uploaded in the controller on the board. The IDE environment mainly contains two basic parts: Editor and Compiler where former is used for writing the required code and later is used for compiling and uploading the code into the given Arduino Module. This environment supports both C and C++ languages.

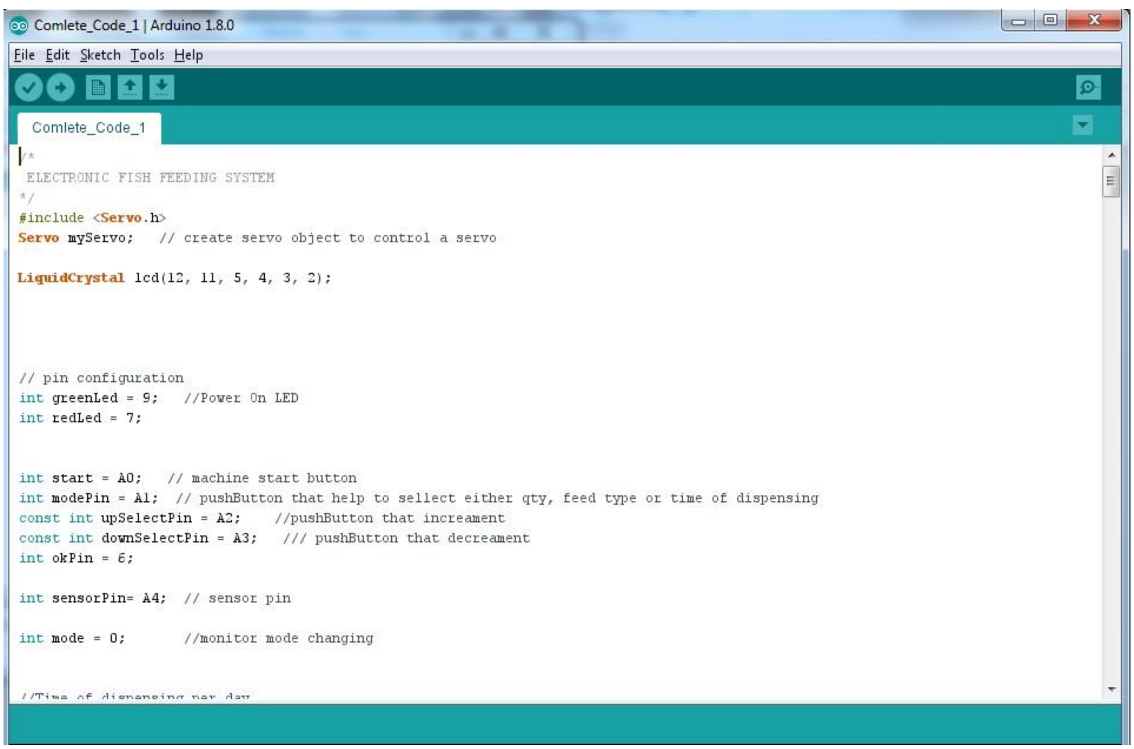

Figure 3.17 Arduino IDE

The program consist of two parts namely the setup and the loop functions. The viod setup part calls a function only once while the loop part calls a function repeatedly.

1. VOID setup ():

This feature of the Arduino IDE is only called once at the beginning of the program. One of the example found in the void setup () is: pinMode(Ledpin, OUTPUT);. This statement declares the Ledpin as the output in the program.

2. VOID loop ():

This feature is called repetitively as long as the development board has power supply. DigitalWrite(Ledpin, HIGH);.this is an example of the statement used in the VOID loop. The statement implies that the led pin which is the output is high at that instance.

3.4 Construction Procedure

The construction procedure refers to the actual arranging of the various parts of the system to form a single system. This involves designing and printing of the printed circuit board, testing and soldering of the components, construction of the mechanical parts and the casing of the project.

3.4.1 Testing and Soldering of Components.

Component testing involves determining whether the components possess the actual electrical properties expected of it. Components testing was done prior to soldering of the components into the circuit board. The testing of the components was done with the help of the multimiter and the modules and sensors were tested with an arduino uno board. The actual values of the components were tested and their stated functional characteristics.

After testing for the workability of each individual component, the circuit was wired on a vero-board. Both short circuit and open circuit tests were carried out using a digital

Multimeters. Also the system was tested to ensure its capability of performing the stated function.

Components soldering involves placing the components in their actual position on the circuit board and securing it with a soldering lead. The components were arranged on the board according to the PCB design. The soldering iron was heated to the required temperature and the soldering lead was applied to the tip of the iron placed on the base of the component at the copper plaited side of the board. This was done to all the remaining components of the circuit. Delicate component and sensors were attached to the board through connectors to avoid destruction by heat.

3.4.2 Construction of the Mechanical Parts

The mechanical parts of the system provides support to the solar panel and also ensures the rotation and movement of the panel. Two mechanical arms were provided which corresponds for the vertical and the horizontal movement.

3.3.4 Casing and Packaging.

A prototype of a dual axis solar tracking system with temperature and solar intensity measurement capability. The main circuit was mounted on a rectangular plastic box which houses the major electrical part of the circuit. The solar panel was supported with a metal arm which allows for its free rotation in both axis. At the top of the box, a space was carved out to accommodate the LCD module.

Chapter Four: Performance and Cost Evaluation

This section of the report deals with analysis of the performance of the system after construction and as well the cost of production of the unit quantity of dual axis solar tracking system with temperature, humidity and radiation measurement capability. The test analysis of the project was also fully discussed.

4.1 Performance evaluation

The system dual axis solar tracking system with temperature, humidity and solar radiation measurement capability is a microcontroller based solar tracking system. The system enhances solar energy harnessing hereby making it more efficient to harness solar energy during the day. The system makes use light sensors to determine the position of the sun at any point in time. The system compares the values of the solar intensity received from the east, west, north and south. The system uses servo motors to rotate the solar panel to face the direction with the highest solar intensity. When the sun moves from east towards the west and the other directions of the globe the system senses the changes in the solar intensity and turns the panel accordingly.

Similarly, the system makes use of a temperature and humidity sensors to measure the value of the surrounding temperature and humidity. Also the system uses a solar radiation sensor to measure the solar intensity value. The measured value are displayed on the LCD screen.

The performance of the system was tested during the day. The system was placed at an open place and the reactions of the system to the direction of the sun were noted. Similarly, the changes in the temperature, humidity and solar intensity were noted.

4.2 Discussion of Results

During the morning period, the surrounding temperature was very low at about 27 degree centigrade. The temperature gradually increases as the day progresses with little variations. The temperature was at its peak when the sun is at the equator. Also towards the evening time, the temperature gradually decreases.

The humidity is measured in % and the value of the humidity was high during the early hours of the day. It gradually decreases as the day gets hotter. The solar radiation is directly proportional to the intensity of the sun.

The tracking system gradually rotates and revolves as the position of the sun changes.

Plate 4.1 system booting.

Plate 4.2 constructed solar tracking system

Plate 4.3 temperature, humidity and solar intensity display.

Plate 4.4 sun’s position tracking

4.3 Cost Evaluation

The cost estimate of this project is summarized in Table 4.2. The analysis mainly considers the physical cost of implementing this project, such as components/materials costs and transportation cost. However, other labour such as programming, construction, consultancy and miscellaneous expenses, are not included.

The cost estimate here assumes a unit production cost of this system. However, producing the same system at large scale may reduce cost of production, as transport cost per unit item, design cost, labour cost, consultancy cost, etc., might have reduced for each unit. This will provide a cost-effective production, thus, making the system affordable. The project also offers a reduced cost for institutions that may intend to implement this system for various research purposes.

Table 4.1: System Cost evaluation

COMPONENT	**TYPE**	**QTY**	**Unit Price (N)**	**AMOUNT (N)**
Microcontroller	Atmega328P	1	2000	2000
Solar panel	Solar panel	1	4000	4000
Resistors	10K	7	30	210
	220R	1	30	30
Capacitor	1000uf/50V	1	200	200
	22pF	2	50	100
Voltage reg.	7805	1	200	100
LDR	resistor	4	200	800
LCD	Display	1	2000	2000
DHT11	Sensor	1	1500	1500
Motor	Servo	2	3000	6000
Battery	4.2V	2	1000	2000

Crystal Oscillator	16MHz	1	150	150
LED	Red	1	30	30
Miscellaneous	Jumper	-	500	500
	Wiring cable	-	700	700
	Gum	5	100	500
	IC Adapter	1	200	200
	Lead	1	400	400
	labour	-	5000	5000
	Casing	-	5000	5000
	Transportation	-	4000	4000
Total				N37,200

Chapter Five: Conclusions

5.0 Summary

The system dual axis solar tracking system with temperature, humidity and solar intensity measurement capability constantly tracks the position of the sun at any point it in time. The system also measures and displays the surrounding temperature, humidity and solar intensity.

This report covers the details analysis of the construction and the operation of the system as well as any other relevant information as pertaining to the system. Chapter one introduces the topic and it covers the problem statement, the aims, objective, significant and the scope of the project. Chapter two is the literature review. It covers some of the related works done by other researchers in relation to the stated topic. Some of the major components used in the construction were also reviewed in the chapter. Chapter three is the construction procedure. It deals with the procedures involved in the construction of the system. Some of the discussed procedures includes the choice of components and as well the system mode of operation. Chapter four is the performance and cost evaluation while chapter five is the conclusions and recommendations.

5.1 Conclusions

The aim of the project to design and construct dual axis solar tracking system with temperature, humidity and solar intensity measurement capability. The system tracks the location of the sun and turns the panel to face the position of the sun. The system utilizes the horizontal and the vertical direction to track the position of the sun making it dual axis tracking system. The system also measures and the displays the temperature, humidity and solar radiation values.

The system provides an efficient means of solar power harnessing and as well a low cost weather measuring instrument.

5.2 Recommendations

In electronic work, its perfection depends on time, working tools and availability of plans and skills. Dual axis solar tracking system is not an exception. In order to improve the functionality of the system, the following recommendations were made;

- The circuit should be protected from harsh weathers such as rainfalls or very high temperatures as it will affect its performance or leads to deterioration.
- Also it can be recommended that further research should be carried on the project to integrate a means of extracting the weather information and transmitting it wirelessly to the user.

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APPENDIX

```
#include <dht.h>

#include <LiquidCrystal.h>

#include <Servo.h>

//defining Servos

LiquidCrystal lcd(8, 7, 6, 5, 4, 3);

Servo servohori;

int servoh = 0;

int servohLimitHigh = 160;

int servohLimitLow = 20;

Servo servoverti;

int servov = 0;

int servovLimitHigh = 160;

int servovLimitLow = 20;

//Ass igning LDRs

int ldrtopl = A2; //top left LDR green

int ldrtopr = A1; //top right LDR yellow

int ldrbotl = A3; // bottom left LDR blue

int ldrbotr = A0; // bottom right LDR orange

#define dataPin 2

dht DHT;

float area = 0.001596;

float voltage = 0.000;

float vole = A4;

void setup ()
```

```
{
  pinMode (vole, INPUT);
  lcd.begin(16, 2);
  lcd.print(" DUAL AXIS SOLAR");
  lcd.setCursor(0, 1);
  lcd.print(" TRACKING SYSTEM");
  delay (9000);
  lcd.clear();
  lcd.print("BY: ISMAIL MOHD");
  lcd.setCursor(0, 1);
  lcd.print("EE/14/0405");
  servohori.attach(9);
  servohori.write(70);
  servoverti.attach(10);
  servoverti.write(70);
  delay(5000);
}
void tempt()
{
  float val = analogRead(vole);
  float voltage = (5 * val) / 1023;
  float power = pow(voltage, 2) / 1000;
  float rad = (power / area) * 64;
  int readData = DHT.read11(dataPin);
```

```
  float t = DHT.temperature;
  float h = DHT.humidity;
  lcd.clear();
  lcd.print(" T");
  lcd.print(t);
  lcd.print("C");
  lcd.print(" H");
  lcd.print(h);
  lcd.print("%");
  lcd.setCursor(0, 1);
  lcd.print(" RAD=");
  lcd.print(rad, 2);
  lcd.print("W/M2");
  delay(3000);
}
void loop()
{
  tempt();
  servoh = servohori.read();
  servov = servoverti.read();
  //capturing analog values of each LDR
  int topl = analogRead(ldrtopl);
  int topr = analogRead(ldrtopr);
  int botl = analogRead(ldrbotl);
```

```
int botr = analogRead(ldrbotr);
// calculating average
int avgtop = (topl + topr) / 2; //average of top LDRs
int avgbot = (botl + botr) / 2; //average of bottom LDRs
int avgleft = (topl + botl) / 2; //average of left LDRs
int avgright = (topr + botr) / 2; //average of right LDRs


if (avgtop < avgbot)
{
  servoverti.write(servov + 1);
  if (servov > servovLimitHigh)
  {
    servov = servovLimitHigh;
  }
  delay(10);
}
else if (avgbot < avgtop)
{
  servoverti.write(servov - 1);
  if (servov < servovLimitLow)
  {
    servov = servovLimitLow;
  }
  delay(10);
```

```
}
else
{
  servoverti.write(servov);
}

if (avgleft > avgright)
{
  servohori.write(servoh + 1);
  if (servoh > servohLimitHigh)
  {
    servoh = servohLimitHigh;
  }
  delay(10);
}
else if (avgright > avgleft)
{
  servohori.write(servoh - 1);
  if (servoh < servohLimitLow)
  {
    servoh = servohLimitLow;
  }
  delay(10);
}
```

```
  else
  {
    servohori.write(servoh);
  }
  delay(50);
}
```

Plate 1: The casing of Dual Axis Solar tracker