SMART SUN TRACKING WITH AUTOMATED CLEANING SYSTEM FOR PV MODULES

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DEDICATION

Specially dedicated to

My beloved family, and those who have guided and inspired me

Throughout my journey of learning

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Throughout the development of this project I have gained chances to learn new skills and knowledge. I wish to express my sincere appreciation and gratitude to my supervisor, En. Wan Ismail Bin Ibrahim for his continuous guidance, concern, encouragement and advices which gave inspiration in accomplishing my final year project.

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ABSTRACT

Solar power is one of environment friendly power source. It is characterized by being highly dependent on the radiation level which is function of sun position at the sky. As it is a single axis tracker, the tracker will follows the Sun's in East-West movement. While, a smart sun tracking is a system develop to make sure that the PV module always perpendicular to the sun for maximum extraction. To control the single axis rotation, the circuit is programmed to fulfill a minimum and maximum requirement value from the PV module. When the amount of radiation on the module is not between the required values, power window motor will rotate until it reaches a point where the produces voltage is acceptable. As for cleaning purposes, a mechanism consists of sliding brushes has been developed. The mechanism works with the help of gravity which when the module inclined, the brushes will slide to the same direction of the module and clean the module surface. The automated cleaning system is implemented to prevent the formation of dust on the module surface. It is to make sure that the module can extract maximum capacity of solar power.

ABSTRAK

Tenaga solar merupakan salah satu sumber tenaga yang mesra alam. Tenaga ini dikategorikan sebagai tenaga yang sangat bergantung kepada kedudukan matahari di langit. Ini adalah kerana ia adalah pengesan paksi tunggal, pengesan akan mengikut matahari dalam pergerakan Timur-Barat. Manakala, pengesan matahari yang pintar adalah satu sistem yang dibangunkan untuk memastikan bahawa modul PV sentiasa berserenjang dengan matahari untuk pengekstrakan maksimum. Untuk mengawal putaran paksi tunggal, litar diprogramkan untuk memenuhi keperluan nilai minimum dan maksimum dari modul PV. Apabila jumlah sinaran pada modul tidak menepati nilai-nilai yang ditetapkan motor kuasa tingkap akan berputar sehingga ia sampai ke satu tempat di mana nilai penghasilkan voltan boleh diterima. Untuk tujuan pembersihan, satu mekanisme terdiri daripada berus gelongsor telah dibangunkan. Mekanisme ini berfungsi dengan bantuan graviti yang apabila modul cenderung, berus akan luncurkan ke arah yang sama modul dan membersihkan permukaan modul. Sistem pembersihan automatik dilaksanakan untuk mencegah pembentukan debu di permukaan modul. Ia adalah untuk memastikan bahawa modul boleh mengekstrak kapasiti maksimum tenaga solar.

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LIST OF ABBREVIATION

ADC	-	Analog Digital Converter
DC	-	Direct Current
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
EMF	-	Electro Motive Force
GND	-	Ground
LCD	-	Liquid Crystal Display
OSC	-	Oscillator
PIC	-	Peripheral Interface Controller
PV	-	Photovoltaic
PWM	-	Pulse Width Modulator
R	-	Resistor
USART	-	Universal Asynchronous Receiver Transmitter
T	-	Transistor
V	-	Volt
Vpp	-	Voltage Peak to Peak
VR	-	Volatge Regulator
ZD	-	Zener Diode

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter will briefly discuss about the background study of the project, the light radiation and solar array. Other than that, main criteria of the project which were discussed are the problem statement, objectives, scope and methodology of the project.

1.1 Background Study

Solar panel or also known as photovoltaic module is a most effective thing of way to produce the electricity. Extracting useable electricity from the sun was made possible by the discovery of the photoelectric mechanism and subsequent development of the solar cell. A photovoltaic cell is usually made of semiconductor material that is able to conduct sunlight and generates it into DC voltage using photovoltaic effect. Sunlight is made of photons, a small particle of energy. These photons are then absorbed by the solar cell. The movement along the path will generates electricity. Nowadays, solar panels are widely used in many application of alternative energy as it is commonly known as harmless to the environment [1].

1.2 Objective of project

Essentially, there are two main objectives to be accomplished by doing this project:

- Tracking system: to extract maximum voltage by keeping the PV module to always perpendicular with the sun.
- Automated cleaning system: to accumulate as much light from the sun by keeping the PV module surface is free from dust.

1.3 Project Scope

This project is focused to design and build the prototype of solar tracking system that would be a starting point to build the realistic solar tracking system. Therefore, this prototype will cover the scope as followed.

- Using microcontroller (16F877A).
- Using 12V Power Window Motor.
- Using LCD to show the generated supply.

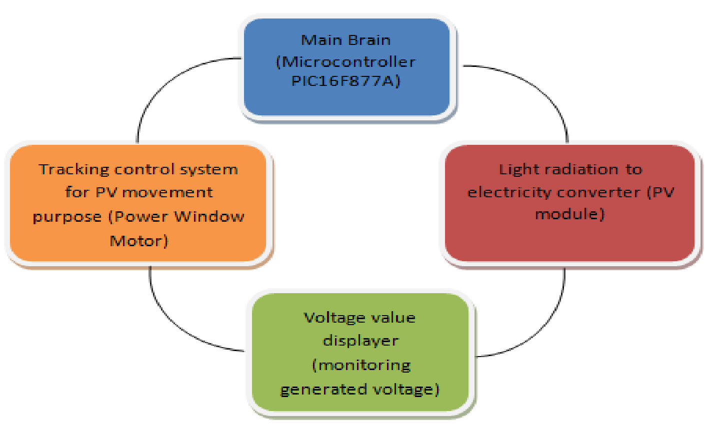

Figure 1.1: Scope of project

1.4 Problem Statement

Everyday, the sun rises in the east, moves across the sky and sets in the west. Each hour, earth rotates about 15° about its axis [2]. This causing the sun position on the sky to always changed. As photovoltaic cell highly dependent on irradiation level, this condition will affect the amount of electricity generates by the photovoltaic cell. The higher the irradiation level, the higher electricity it will produce.

Usually, a photovoltaic module is placed in an open space which is exposed to dust and dirt. The constant exposure will cause the accumulation of dust and dirt at the photovoltaic surface. The formation will blocked the incident light from reaching the module thus causing the output voltage to drop rapidly. It has been observed that the reduction in energy output from a PV module with dust could be as much as 50%, when the modules are not cleaned for 30 days [2].

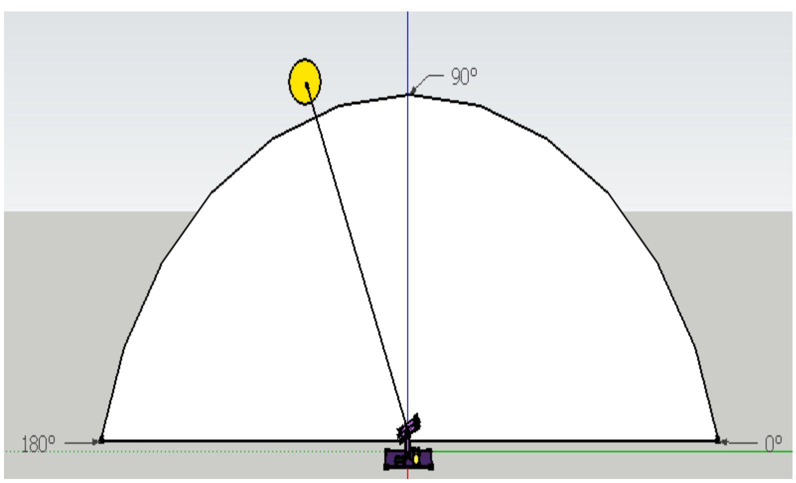

Figure 1: 180° solar azimuth angle

1.5 THESIS ORGANIZATION

This thesis is divided into several chapters. The first chapter concentrate on the surface of the project including the project objective, project scope, problem statement and lastly, thesis organization.

In chapter 2, literature review of the project is discussed. The concept of photovoltaic and cleaning system is explained briefly in order to create a basic understanding of the project.

Chapter 3 will stressed out the project methodology. It explains how the project is organized and the flow of process in completing this project. Certain components used in the project are discussed too including the software that is used to carry out the project.

Chapter 4 contained detailed description about hardware development. The main circuit and program are show in this chapter.

Lastly, for chapter 5 will point out the conclusion and future recommendations of this project.

CHAPTER 2

LITERATURE REVIEW

Before starting on a project, some fundamental steps are really necessary. Among of the steps, the preliminary one is to conduct research based on the chosen title and collect appropriate information from what others had done and achieved. Below are some theories and researches that are related to this project.

2.1 Background

It is necessary to obtain background information of the solar module, method of cleaning and tracking before designing the tracking system. The equally is important to examine the detection system available in the market now. To obtain this information, a study of related literature and journal was conducted.

2.2 Photovoltaic

Photovoltaic (PV) is the technology of direct conversion of light into electrical energy. The conversion process can be explained by using the photovoltaic effect in a PV cell. A PV cell is a semiconductor device comprising a p-n junction that has a built-in Electro-Motive-Force (EMF). As light of suitable quanta of energy reaches the p-n junction, electrons (-) are freed and holes (+) are formed. These are then driven by the EMF to the sides of the p-n junction. When connected to an external conducting path, the circuit is complete; thus providing useful electric energy for powering up an electric load.

The phenomenon of converting light directly into electricity was discovered by Henri Becquerek back in year 1839. Then Albert Einstein explained the principle of photovoltaic in year 1905 using quantum theory.

Significant use of PV power systems has started in space application in the 1905's and its modest use in terrestrial application began in the 1960's. However, at the beginning of 1970's and 80 saw a larger and significant use of PV power system. Today, it is not uncommon to see solar PV farms.

2.2.1 Photovoltaic Effect

The basic physical process through PV cell converts sunlight into electricity is the photovoltaic effect. Sunlight is composed of packets of solar energy. These sunlight radiations contain different amounts of energy that correspond to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. The absorbed photons generate electricity.

The photovoltaic cells generally consist of two thin regions, one above the other, N-type and P-type. This two region structure, called a p-n junction. The collection of light-generated carriers by the p-n junction causes movement of electrons to the n-type side and holes to the p-type side of the junction. When open circuit, carriers are prevented from leaving the solar cell, then the collection of light-generated carriers causes an increase in the number of electrons on the n-type side of the p-n junction and a similar increase in holes in the p-type material. This separation of charge creates an electric field at the junction which is in opposition to that already existing at the junction.

Under short circuit conditions, the minority carrier concentration on either side of the junction is increased and the drift current, which depends on the number of minority carriers, is increased. In equilibrium (in the dark) both the diffusion and drift current are small.

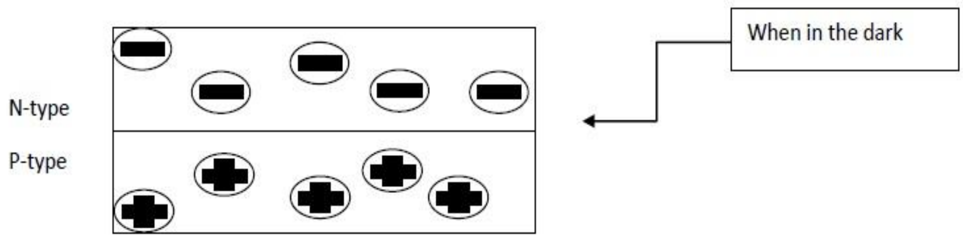

Figure 2.1: The photovoltaic effect in the dark place

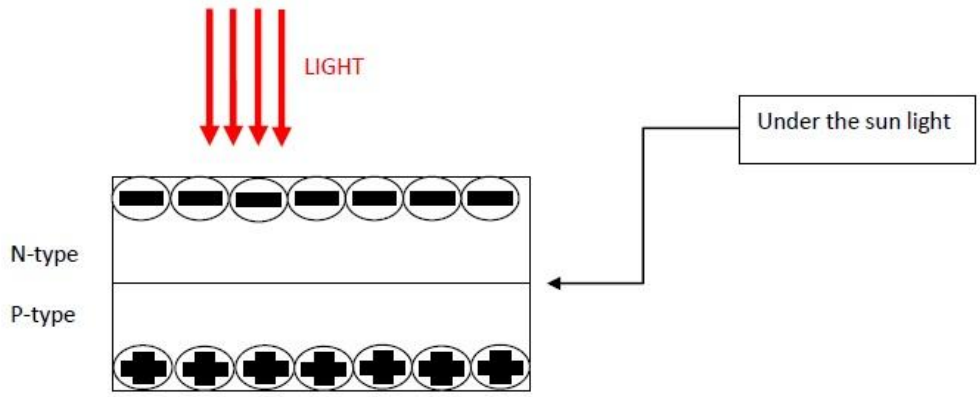

Figure 2.2: The photovoltaic effect under the sunlight

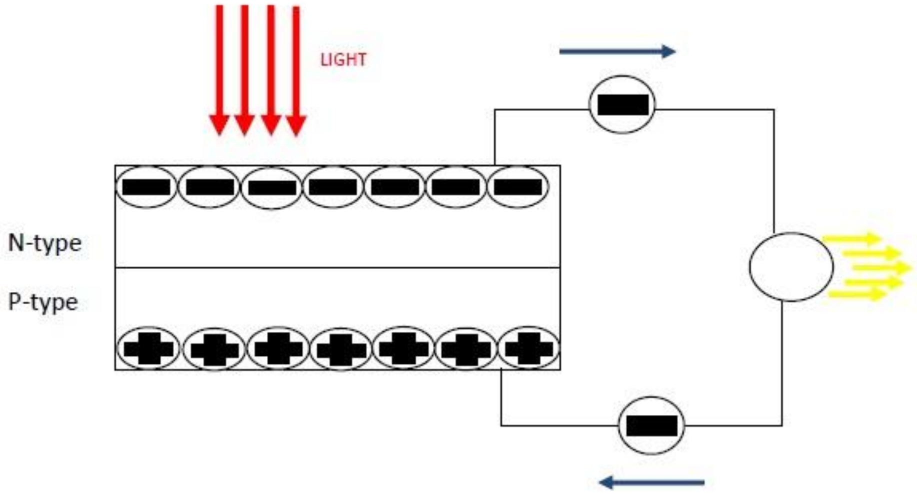

Figure 2.3: The photovoltaic effect in the bright place

2.2.2 Photovoltaic System

Reaction of nuclear fusion on the sun‘s surface have supply earth with enough solar energy. This energy is emitted in the form of electromagnetic radiation primarily in ultraviolet, radio spectral region and infrared. Currently, the most effective means of harnessing this power is a solar cell, which functions to convert solar radiation directly into electricity.

Photovoltaic panel are made of the natural element which becomes charged electrically when subjected to sunlight. Sunlight is made from photons, which is a small particle of energy. Photovoltaic is the direct conversion of light into electricity at the atomic level. The panel works on the principle of the photovoltaic (PV) effect. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other.

2.2.3 Photovoltaic

When solar energy strikes PV cells attack, electrons from the atoms in semiconductor materials will knocked loose and begin to travel from PV cells, through an electronic circuit to the load. Then, they return to the silicon PV cells in which silicon recaptures the electron, and the process is repeated. Photovoltaic itself is a p-n junction, which electrons passing through the dropping process and is produces current in proportion to the solar radiation. If the electrical conductor are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of electric current and generate electricity. This electricity can then be used to power the load, such as light or devices.

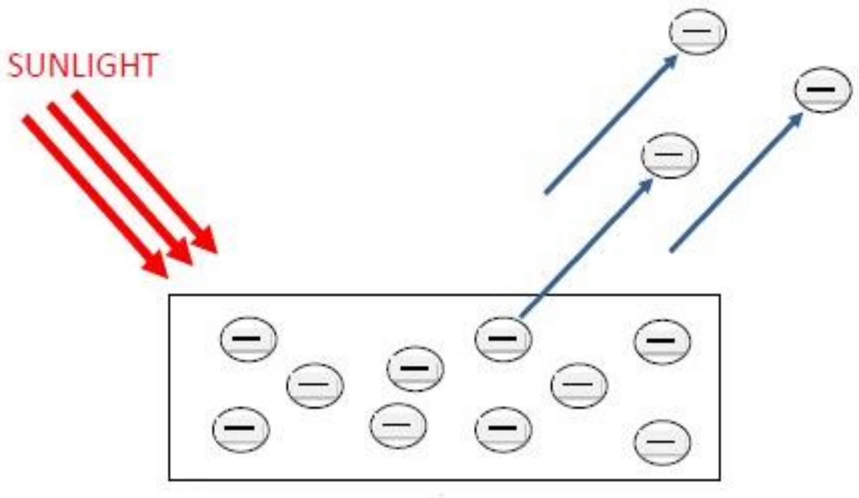

Figure 2.4**:** The emission of electron from metal plate

Figure 2.4 illustrating the emission of electrons from a metal plate, requiring energy gained from absorb sunlight radiation to be more than the work function of the material.

2.3 Solar Tracker

Every day, the sun rises in the East moves across the sun and finally sets in the West. As the sun position on the sky always changed, solar tracker is used in order to keeps photovoltaic module in optimum position which is always perpendicular to the the solar radiation during daylight hour. This can increase the collected energy by up to 40% [3].

Sun tracking system has been studied with different applications to improve the efficiency of the solar system by adding tracking devices to the system through various methods. Detection system must be able to follow the sun with a certain degree of accuracy, to return the collector to its original position at the end of the day and the track during the period covered by clouds [4].

With the intention to improve the efficiency of the solar system, sun tracking system has been studied with different applications by adding tracking devices to the system through various methods. Detection system must be able to follow the sun with a certain degree of accuracy, to return to its original position at the end of the day [5].

2.3.1 Active Solar Tracking

To fully utilise solar power, it require highly efficient solar cells and advanced sun tracking systems. Active solar tracking allows the solar cells to face the strongest sunlight while it is available. The tracker needs to be able to detect the strength of sunlight in different direction to determine the best location for the strongest sunlight [6].

There are two kind of active solar tracking systems,

1. Astronomical or chronologist: the electronic system calculate the current position of the sun location and the tracking motor move the solar modules perpendicular to the sun at pre-set times intervals using precise coordinates.
2. Sensor controlled: Instead of aligning the modules using the astronomical position of the sun, tracking system fitted with light sensor points in the sky. Under a complete overcast sky for example, the modules will be in a horizontal position [7].

Figure 2.5**:** PV panel using active solar tracking system

2.3.2 Passive Solar Tracking

Passive trackers use a compressed gas fluid as a means of tilting the panel. A canister on the sun side of the tracker is heated causing gas pressure to increase and liquid to be pushed from one side of the tracker to the other. This affects the balance of the tracker and caused it to tilt. This system is very reliable and needs little maintenance. Although reliable and almost maintenance free, the passive gas tracker will very rarely point the solar modules directly towards the sun. This is due to the fact that temperature varies from day to day and the system cannot take into account this variable. Overcast days are also a problem when the sun appears and disappears behind clouds causing the gas in the liquid in the holding cylinders to expand and contract resulting in erratic movement of the device.

Passive trackers are however an effective and relatively low cost way of increasing the power output of a solar array. The tracker begins the day facing west. As the sun rises in the east, it heats the unshaded west-side canister, forcing liquid into the shaded east-side canister. The liquid that is forced into the east side canister changes the balance of the tracker and it swings to the east. It can take over an hour to accomplish the move from west to east. The heating of the liquid is controlled by the aluminium shadow plates.

When one canister is exposed to the sun more than the other, its vapour pressure increases, thus forcing liquid to the cooler, shaded side. The shifting weight of the liquid causes the rack to rotate until the canisters are equally shaded. The rack completes its daily cycle facing west.

Figure 2.6**:** PV panel using passive solar tracking system

2.4 Cleaning System

Anything that blocks sunlight from the panel is reducing the effectiveness of the photovoltaic system. Dimming of light through dust or other agents like tree sap, bird droppings, or environmental pollutants, will result in a decrease in energy production. A diffuse layer of dust can reduce solar absorption by 5%. Opaque pollutants like sap, droppings, or leaves which fall and adhere to the panels can reduce absorption by even more. Dirt that blocks all light in segments of the panel could have an even more significant effect [8], [9].

Figure 2.7: PV panel with automatic cleaning system

2.5 Battery charger

Battery charging circuit is used as an input of electrical energy to a rechargeable battery or other electrical cells which have different current levels. In this project, solar module acted as the source of the energy that filling in the form of DC current. A battery charger or a battery charging circuit will conduct an electrical current charging by pushing an electrical current through it. Charging circuit has a assortment of different charge current depending on the type of rechargeable battery [10].

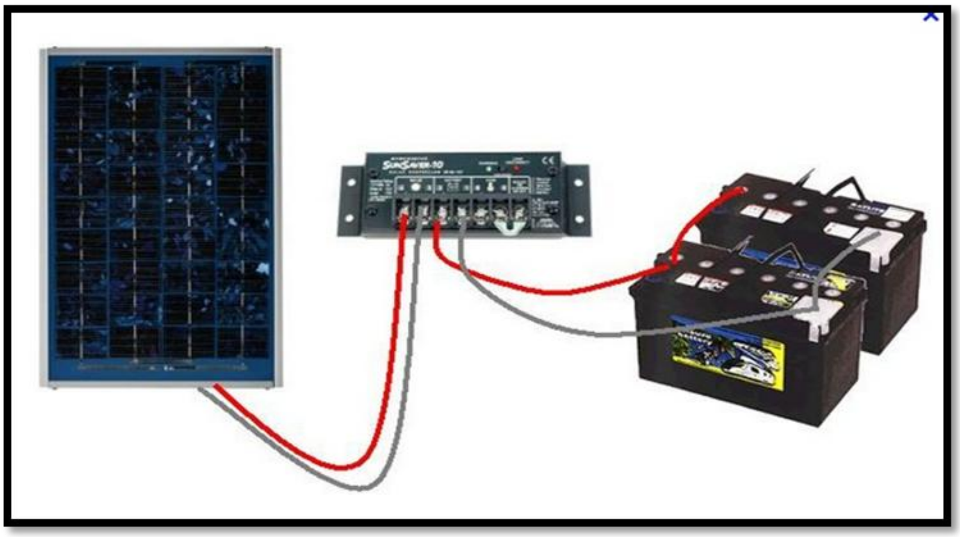

Figure 2.8: Wiring diagram of a battery charging

2.6 DC Motor

DC motors are in many ways the simplest electric motors. All DC "brushed" motors operate in the same way. There is a stator (a larger stationary part) and a rotor (a smaller part spinning on an axis within the stator). There are magnets on the stator and a coil on the rotor which is magnetically charged by supplying current to it. Brushes are responsible for transferring current from the stationary DC voltage source to the spinning rotor. Depending on the position of the rotor its magnetic charge will change and produce motion in the motor. To control speed an in-line variable resistance can be utilized to change the amount of current reaching the coils.

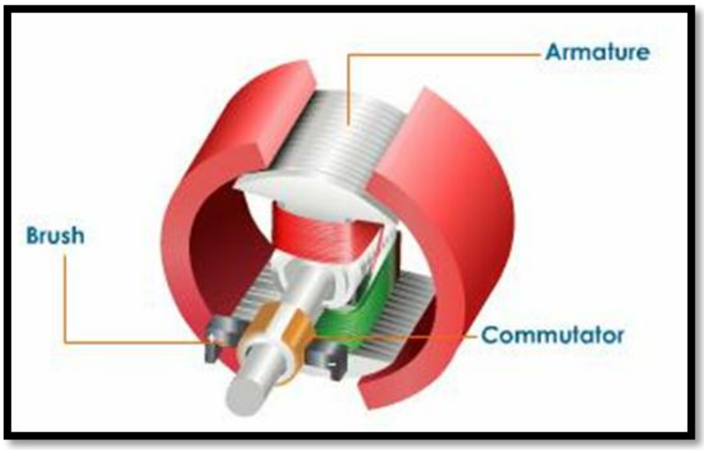

Figure 2.9: Parts of DC Motor

The figure above shows the construction of a DC motor. The motor shown is a simplified "two-pole" motor which uses just two magnets in the stator. In this case the magnets in the stator are permanent magnets for the sake of simplicity. A DC motor can get very complex when more poles are added but a standard "brushed" DC motor of any configuration operates on the same principles illustrated here. The brushes deliver current from a DC voltage source which supplies a magnetic field to that end of the rotor. [4]

The polarity of the field depends on the flow of the current. As the rotor turns the brushes make contact with one side of the DC source, then briefly do not make contact with anything, then continue making contact with the other side of the DC source effectively changing the polarity of the rotor. The timing of this change is determined by the geometrical setup of the brushes and leads to the DC source. The animation helps to illustrate how at the moment of maximum attraction the current will change direction and thus change the polarity of the rotor. At this moment the maximum attraction suddenly shifts to maximum repulsion which puts a torque on the rotor's shaft and causes the motor to spin.

The motor efficiency can be increased by:

i) Increasing the number of turns in the coil
ii) Increasing the strength of the current
iii) Increasing the area of cross-section of the coil
iv) Increasing the strength of the radial magnetic field

2.6.1 Components of DC motor

A DC motor consists of several important components to operates properly and meets the requirement. The components used are as below:

- STATOR: The stator consists of either a permanent magnet or electromagnetic windings. It generates a stationary magnetic field around the rotor which occupies the central part of the motor.
- ARMATURE (Rotor): The armature is made up of one or more electric windings around armature arms. These electric windings generate a magnetic field when energized by the external current. The magnetic poles thus generated by this rotor field are attracted to the opposite poles generated by the stator field and repelled by the similar poles, which causes the armature to rotate.
- COMMUTATOR: The DC motor doesn't use an external current switching device, instead it uses a mechanical connector called the commutator which is a segmented sleeve usually made of copper, mounted on the rotating shaft. The current +/- is supplied to this commutator segments with the help of brushes.
- BRUSHES: As the motor turns the brushes slide over the commutator segments hence creating the variable magnetic field in different arms through the commutator segments attached to the windings. Hence a dynamic magnetic field is generated in the motor when a voltage is applied across the brushes.

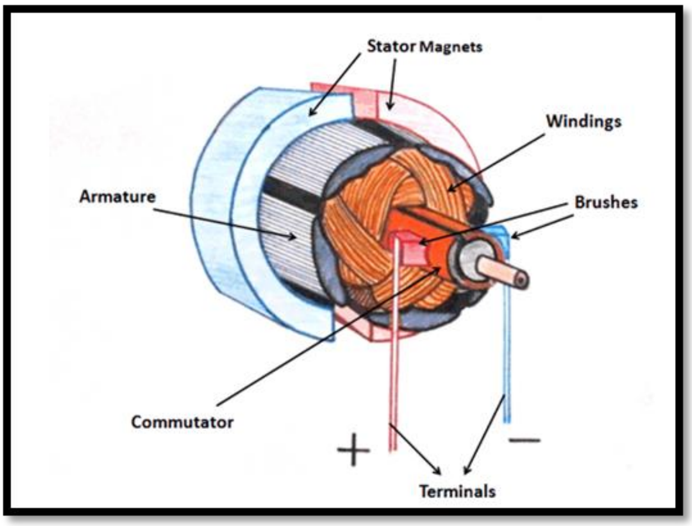

Figure 2.10: Brushed DC Motor

The brushed DC motor a mechanical sliding contact between the brushes and the commutator collar. The brushes and the spring carrying the current need replacing from time to time. The commutator also needs periodic cleaning or replacement.

2.6.2 Power Window Motor

This motor is a type of DC motor. This type of motor has more power to carry a heavy load like solar panel as it is characterised to be able to handle stall torque not much then 25kg. Other than that, the movement of power window quite slow and it is suitable to be used in this project as the sun trackers need a slow movement in order to follow the sun. The voltage that needed for power window also small, it is only 12V. At the start, the motor current in a no load condition may exceeds to 2.8A and the rated torque is 3Nm.

Figure 2.11: Power window motor

CHAPTER 3

METHODOLOGY

3.1 Introduction

This project requires designing and installing electrical parts. As for that, a flow of methods were used to design and complete the prototype. In the first step, it is important to chart out a process planning. It operates as a guideline so that the final model meets the requirement and time could be managed. The efficiency of the project can be determined by following the parameter. Regulating and analyzing these steps are very important as each of it has its own criteria to be followed.

Designing process is the backbone of the model, therefore using appropriate method is very important to this project. Intense study of the designing phase proved to be essential for the next step. Only with this determination on the designing procedure to be successful, then the circuit installation development of the project can be carried out. The circuit installation process carried out has to be accurate with the design first. Once it is fully established, modification grounds can be made triumph during testing of the solar panel system. During testing, the experiment criteria are validated to suite the performance of the system and understanding. Finally, the analysis of the whole project can be concluded in the next chapter.

3.1.1 Block Diagram

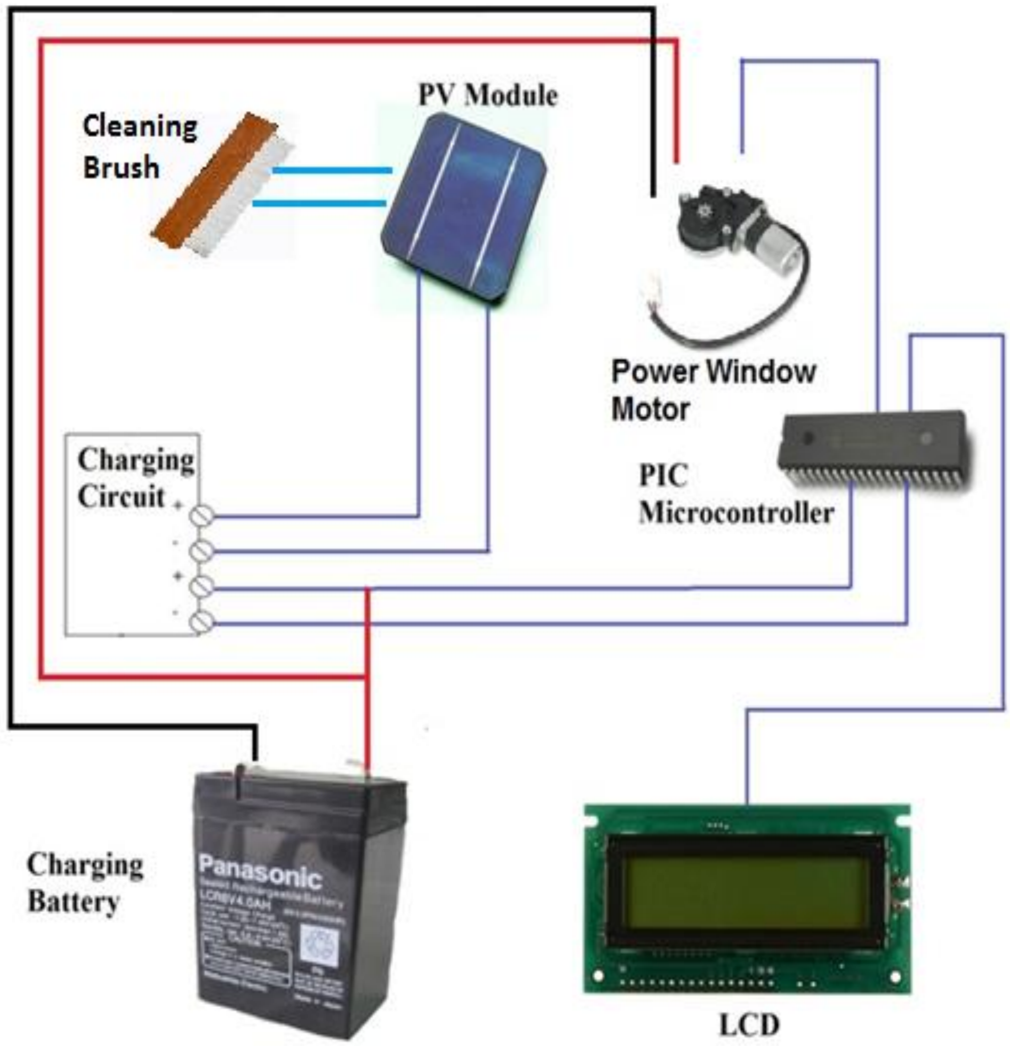

Figure 3.1: Block diagram of the system

3.1.2 Hardware Design

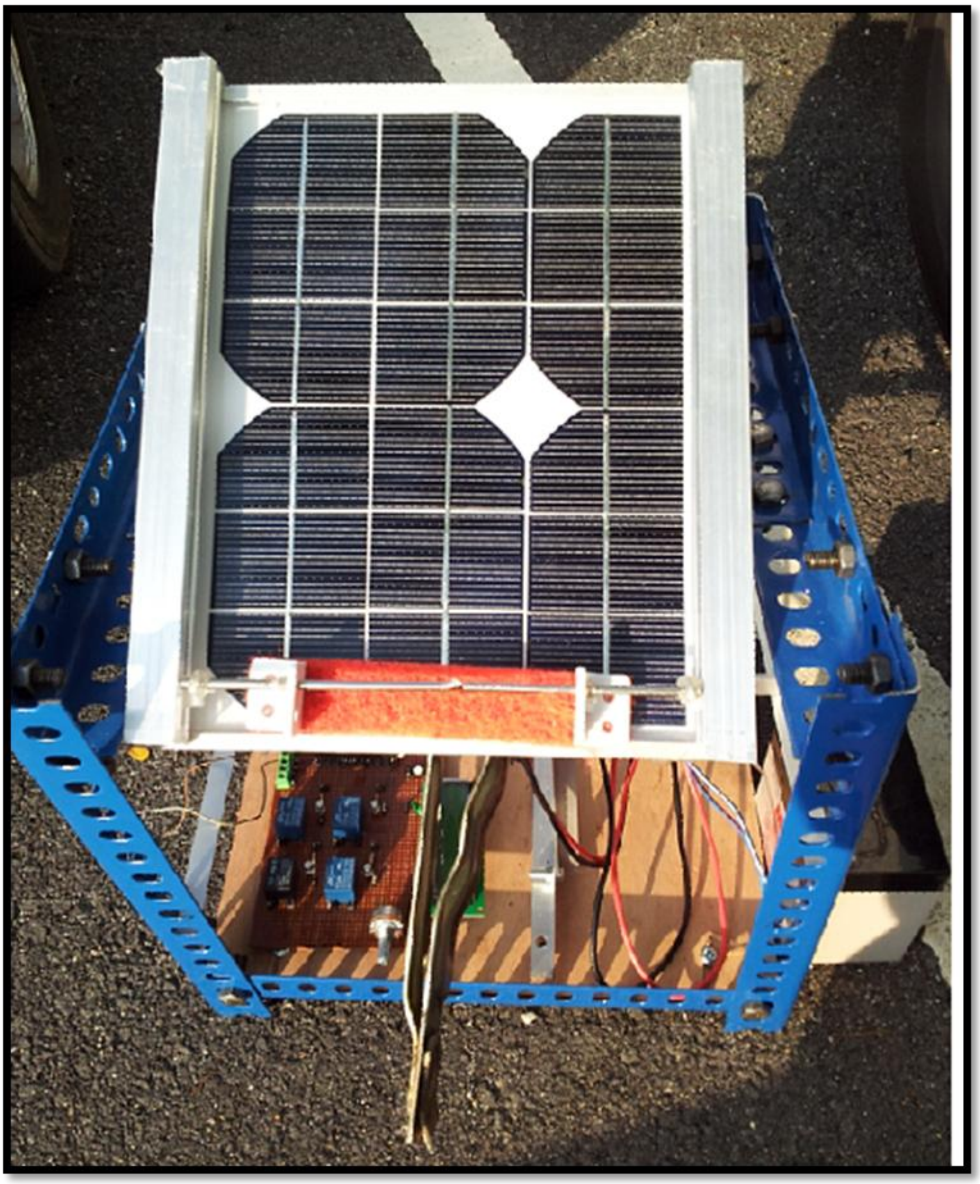

Figure 3.2: Prototype

3.1.3 Flow Chart

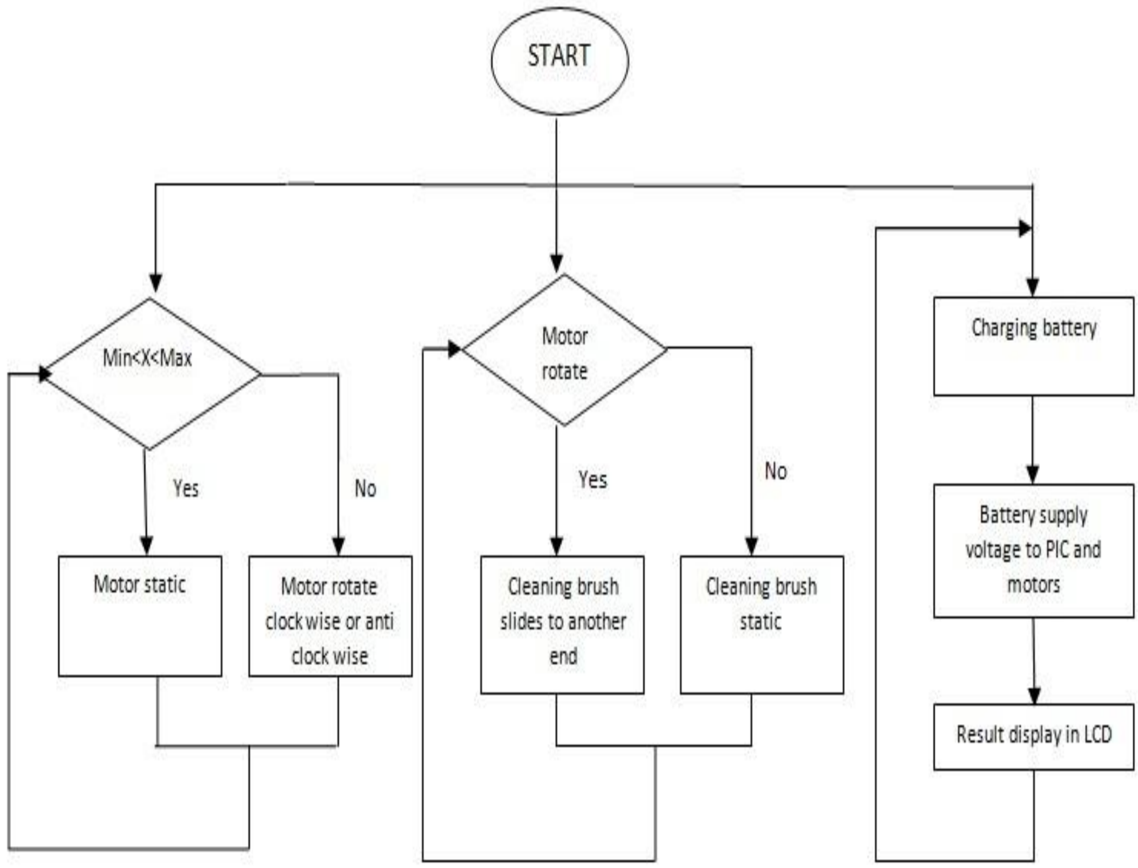

Figure 3.3: System Flow

3.1.4 Description of the System

In this project, all the function runs at the same time. There are 3 main parts in this project, which is the solar module rotation at 180 solar azimuth angles on single axis, cleaning system and charging part. A minimum and maximum value is set from the program to control the rotation of the motor. When the PV module senses the presence of solar radiation, the generated voltage is measured and compare with the sets value. If the generated voltage does not exceed the minimum value sets in the program, the motor will rotate until the minimum value is achieved.

Power window motor will not rotate when the generated voltage is in range between the minimum and maximum value. It will move again when the generated voltage in drop below the minimum value. As for the cleaning mechanism, when the motor rotate and the PV module is inclined, the wheel will slides in the same direction of the PV rotation. This free fall method is energy saving as it does not need supply to move the wheel. The generated voltage is kept in the battery. This battery will supply to power window motor, LCD and PIC Circuit. PIC Circuit will control the movement for motor and LCD will display the amount of voltage generated at the PV module.

3.2 Hardware Implementation

Taking the project as a whole, it involves reading voltages from sensors, then comparing these voltages digitally to determine the direction the array must move to align itself with the sun. To perform this movement a motor circuit is needed to receive output from the controller and step the motors accordingly. The following sections of this chapter outline the methods and designs used to implement this system. Design requirements are:

- Provides a clean surface during its operating time.

- During the time sun is up, the system must always perpendicular to the sun's position in the sky.
- The process should be in an active control system as timed movements are wasteful. As the operation are automatic and simple, operator interference have to be minimal and only when it is actually required.

3.2.1 Solar Charging System

There are 3 main components in this project. The first one is the solar module, solar charger (controller) and the third one is the sealed lead battery. The circuit of the 3 components is as below.

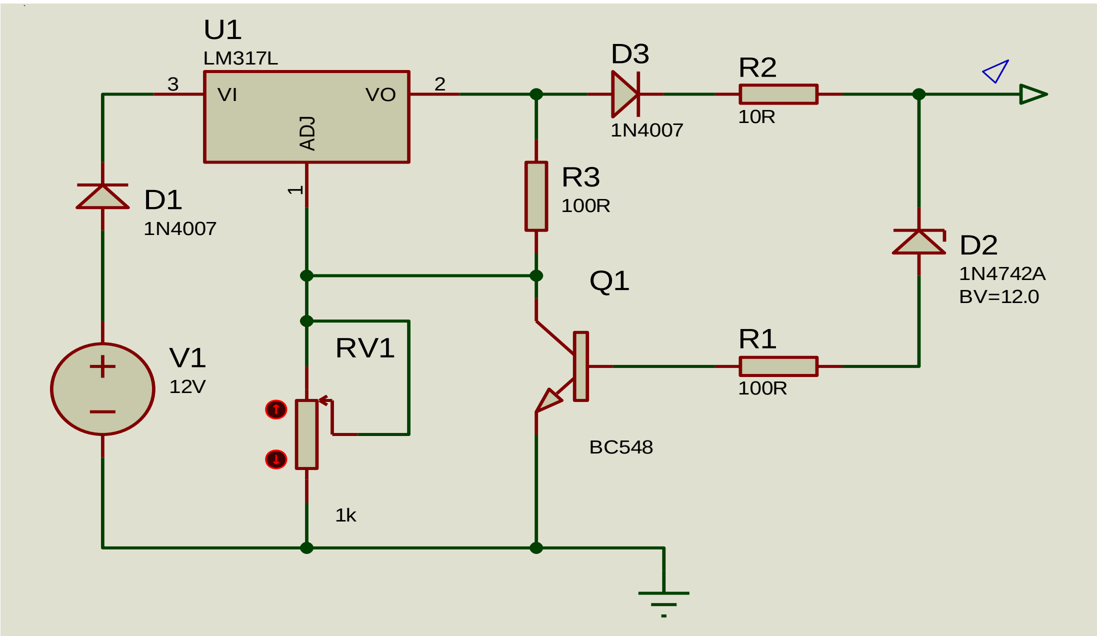

Figure 3.4: Charging Circuit

The battery used in this project is a 12V 4Ah sealed lead battery. The battery is used to supply electricity to power window motor, PIC circuit and LCD. Solar charger will charge the battery automatically, where it will automatically ON when the sun rises and shut down at down. The circuit uses a 12 volt solar module and variable voltage regulator IC LM317. Charged current will pass through D1 to the voltage regulator, IC LM317.

By adjusting its ADJ pin, output voltage and current can be regulated. Voltage regulator is placed between the adjust pin and ground to provide an output voltage of 12V to the battery. Resistor (R3) restricts the charging current and diode D2 prevents discharge of current from the battery. Transistor (T1) and Zener diode (ZD) act as cut off switch when the battery is full. Normally T1 is Off and battery gets charging current.

3.2.2 Microcontroller

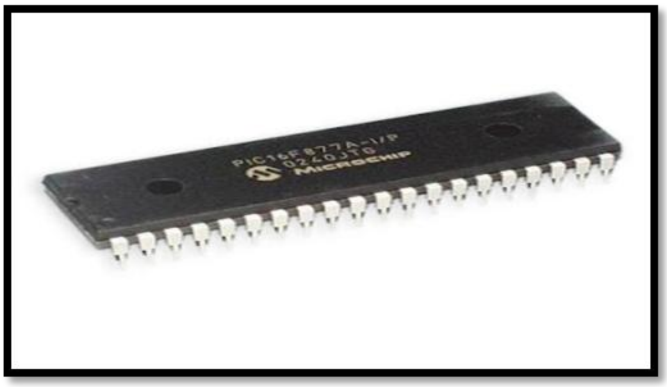

Figure 3.5: PIC16F877A

In this project, the type of controller used is Peripheral Interface Controller (PIC). Almost all type of PIC microcontroller is includes in an 8-bit microcontroller of RISC architecture. Most of the time, PIC architecture is minimized to be simpler item. But it is still operates at the same function.

Microcontroller used in this project is PIC16F877A. This PIC has a total amount of 40 pins. The PIC16F877A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART).

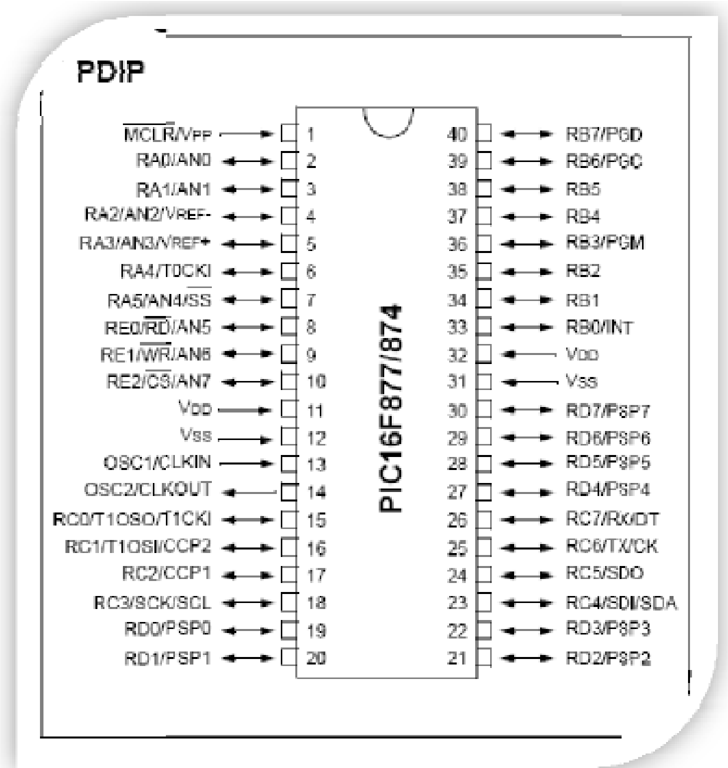

Figure 3.6: Pin Diagram

By referring to above figure, each of the pin is assigned to certain function. It is important to understand the common pins function. For pin no.1 (V_{PP}), pin no.11 (V_{DD}) and pin no.32 (V_{DD}), these three pins are connected to the 5V voltage supply. As for pin no.12 (V_{SS}) and pin no 31(V_{SS}), there pins are connected to the ground (GND). Next is pin no. 13(OSC1) and pin no. 14 (OSC2), will be connected to the oscillator. For other pins, they are used as input or output port depends on the function assigned form the programming.

PIC is the best choice as it is low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability.

3.2.3 PV Module

Photovoltaic or solar cell is a solid state device that converts the energy of sunlight directly into electricity by the photovoltaic effect. Assemblies of cells are used to make solar modules, also known as solar panels. The energy generated from these solar modules, referred to as solar power, is an example or renewable energy.

Photovoltaic is the field of technology and research related to the practical application of photovoltaic cells in producing electricity from light, though it is often used specifically to refer to the generation of electricity from sunlight.

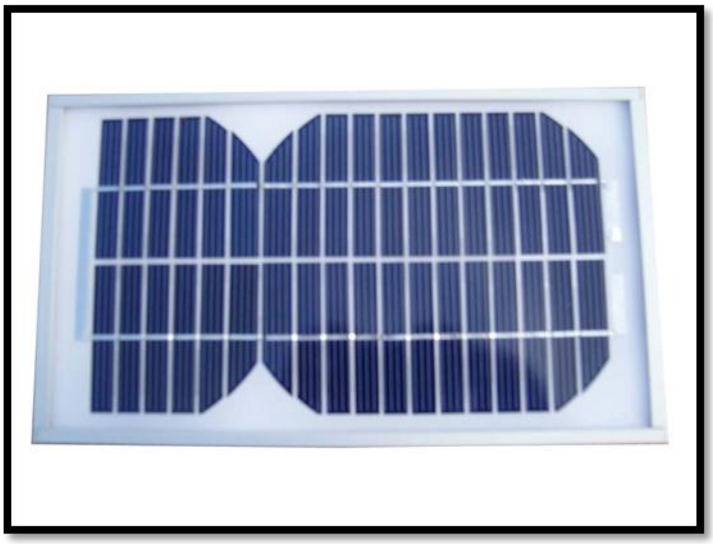

Figure 3.7: Solar cell

Cells are described as photovoltaic cells when the light source is not necessarily sunlight. These are used for detecting light or other electromagnetic radiation near the visible range, for example infrared detectors or measurement of light intensity:

1. Photons in sunlight hit the solar panel and absorbed by semiconductor material such as silicon.
2. Electrons are knocked loose from their atoms, allowing them to flow through the material in order to produce electricity. Due to special

composition of solar cells, the electrons are only allowed to move in a single direction.

3. An array of solar cells converts solar energy into usable amount of direct current (DC) electricity.

3.2.4 Voltage Regulator

Voltage Regulator is a small device or circuit that regulates the voltage fed to the microprocessor. The power supply of most PCs generates power at 5 volts but most microprocessors require a voltage below 3.5 volts. The voltage regulator's job is to reduce the 5 volt signal to the lower voltage required by the microprocessor. Typically, voltage regulators are surrounded by heat sinks because they generate significant heat.

Voltage Regulator (regulator), usually having three legs, converts varying input voltage and produces a constant regulated output voltage. They are available in a variety of outputs.

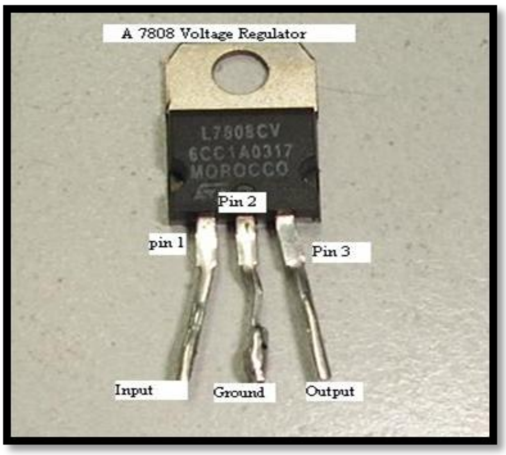

Figure 3.8: Voltage Regulator

3.2.5 Power Window Motor

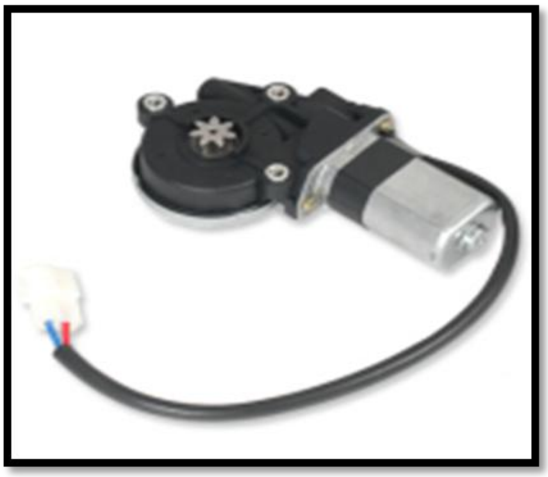

Figure 3.9: Power Window Motor

This motor is used for tracking propose as it is has a stable torque to keep planes fixed when there is no supply voltage. In this project, the power window motor is able to carry a heavy load like solar panel. Other than that, the movement of power window quite slow and it is suitable with the project purpose, as the sun tracker need a slow movement to follow the sun. The voltage that needed for power window also small, it is only 12V.

STEP	WIRE 1	WIRE 2
STOP	LOW	LOW
CLOCKWISE	LOW	HIGH
ANTI CLOCKWISE	HIGH	LOW

Table 1: Motor Sequence

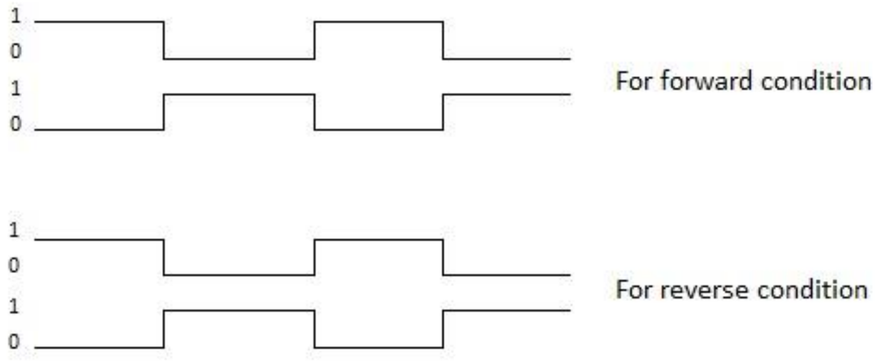

Figure 3.10: Motor Input Graph

3.2.6 LCD

Liquid crystal display used in this project is an electronic visual display which uses light modulating properties of liquid crystal. The liquid crystal does not emit light directly. LCD is choose as it can display small information content needs to be displayed, it is the lowest power consumption displayer as it has no backlight and the cost is cheaper than any other display. In this project, LCD is needed to displayed the voltage generates by the PV module from time to time. To operate, the LCD will need a 5V power supply.

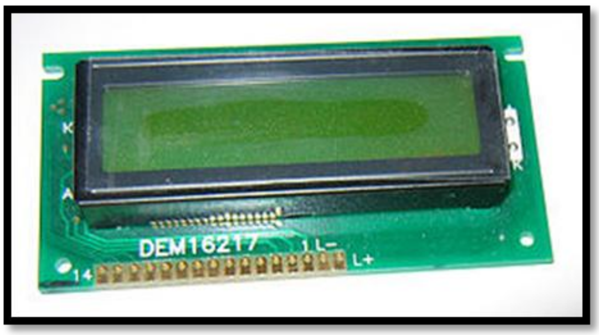

Figure 3.11: LCD

3.2.7 NPN Transistor

Figure 3.12: BC107 Transistor

Transistor is an electrical component made of a semiconductor device used to amplify and switch electronic signals and power. It is composed of a semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals thus changes the current flowing through to another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal.

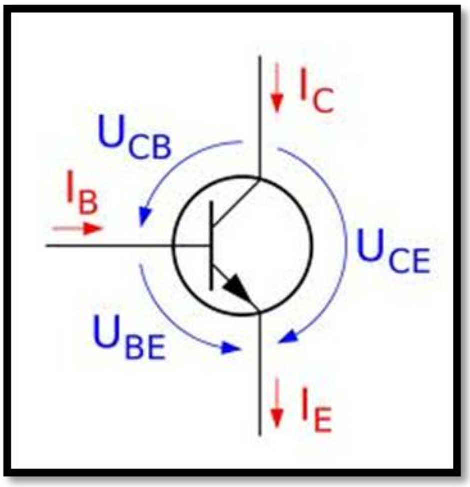

Figure 3.13: The forward-biased junction in an npn transistor

Just as in the case of the pn- junction diode, the n- material comprising the two end sections of the npn transistor contains a number of free electrons, while the center p section contains an excess number of holes. The action at each junction between these sections is the same as that previously described for the diode; that is, depletion regions develop and the junction barrier appears. To use the transistor as an amplifier, each of these junctions must be modified by some external bias voltage. For the transistor to function in this capacity, the first pn- junction (emitter-base junction) is biased in the forward, or low-resistance, direction. At the same time the second pn- junction (base-collector junction) is biased in the reverse, or high-resistance, direction. The letters of these elements indicate what polarity voltage to use for correct bias.

However, since the second pn- junction is required to be reverse biased for proper transistor operation, the collector must be connected to an opposite polarity voltage (positive) than that indicated by its letter designation (npn). The voltage on the collector must also be more positive than the base. In summary, the base of the npn transistor must be positive with respect to the emitter, and the collector must be more positive than the base.

3.2.8 Relay

A relay is an electrically operated switch. In this project, relay is used to give supply to power window motor. The pin B6 and B7 being triggered, current flows through the coil of the +5V relay creating a magnetic field which attracts a lever and changes the switch contacts. At the initial position, the relay contact is in normally open condition. When the coil is energized, the contact is close. This allows +12V or 0V to flow into the circuit and move the motor. [1]

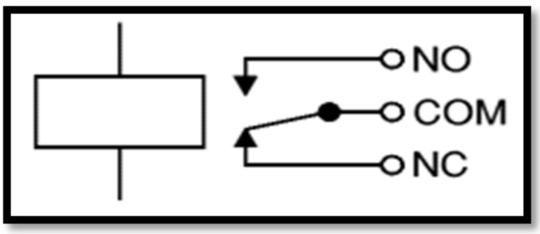

Figure 3.14: Relay contact

3.2.9 Diode

Transistors and ICs used in this project must be protected from the brief high voltage produced when a relay coil is switched off. The diagram shows how a signal diode, 1N4001 is connected 'backwards' across the relay coil to provide a protection. Current flow is through a relay coil creates a magnetic field which collapses suddenly when the current is switched off. The sudden collapse of the magnetic field induces a brief high voltage across the relay coil which is very likely to damage transistors and ICs. The protection diode allows the induced voltage to drive a brief current through the coil (and diode) so the magnetic field dies away quickly rather than instantly. This prevents the induced voltage becoming high enough to cause damage to transistors and ICs.

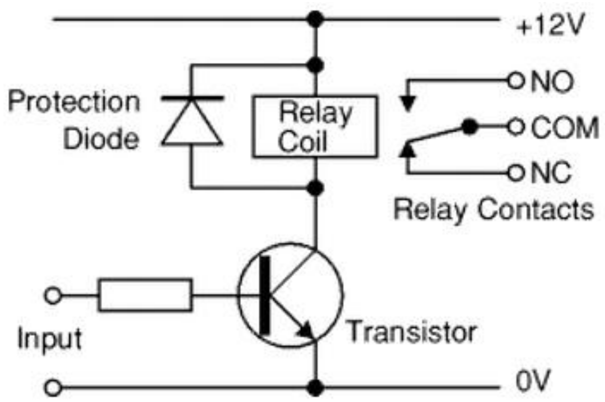

Figure 3.15: Connection of relay and diode

3.3 Software

Without software development, there is no use of establishing any system. In software development of any project, there is a need in programming the microcontroller. In other words, programming the microcontroller is the brain of the system.

3.3.1 Proteus 7 Professional

Proteus 7 Professional is used for simulation purpose before the circuit is implemented on the board. It gives earlier idea of how the circuit going to look like and function. All the function of the components used in the project can be learn by using this software.

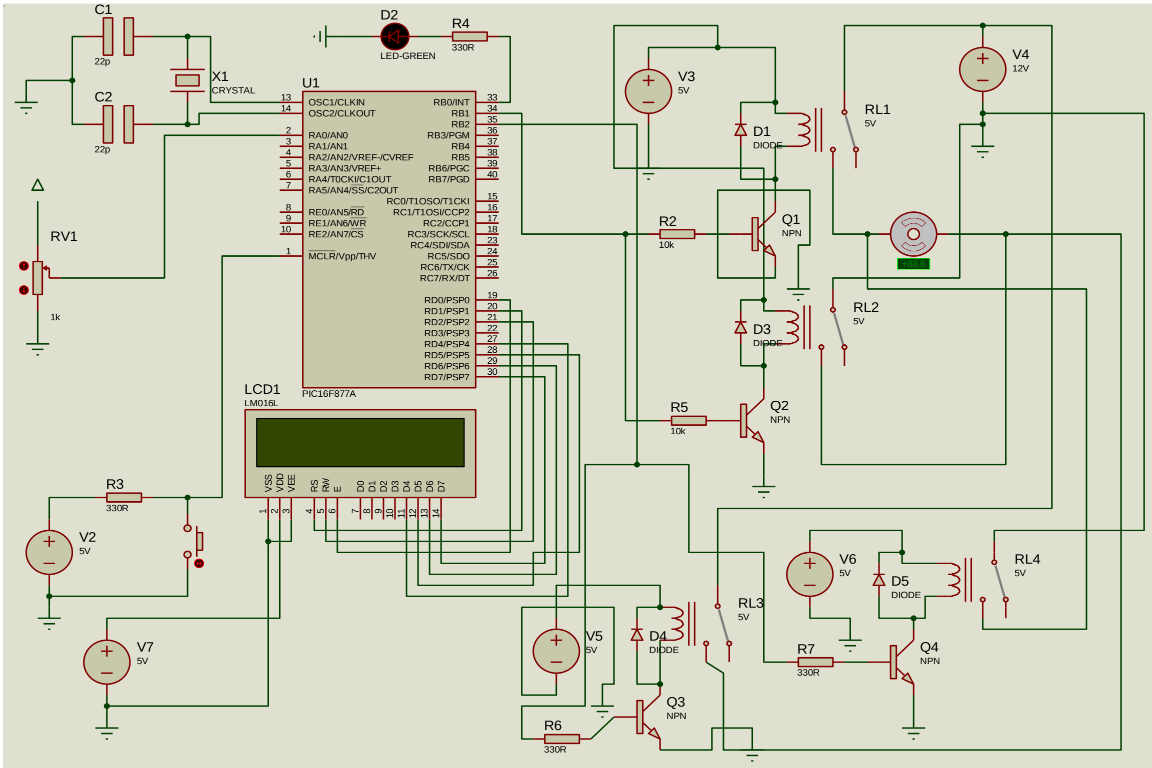

Figure 3.16: Proteus 7 Professional

3.3.2 PIC-C Compiler

PIC-C Compiler is a computer program (or set of programs) that transforms source code written in a computer language (the source language) into another computer language (the target language, often having a binary form known as object code). The most common reason for wanting to transform source code is to create an executable program.

It provides a complete integrated tool suite for developing and debugging embedded applications running on Microchip PIC® MCUs and dsPIC® DSCs. The heart of this development tools suite is the CCS intelligent code optimizing C compiler which frees developers to concentrate on design functionality instead of having to become an MCU architecture expert,

- Maximize code reuse by easily porting from one MCU to another. Device Support.
- Minimize lines of new code with CCS provided peripheral drivers, built-in functions andstandard C operators.
- Built-in functions are specific to PIC® MCU registers, allowing access to hardware features directly from C.

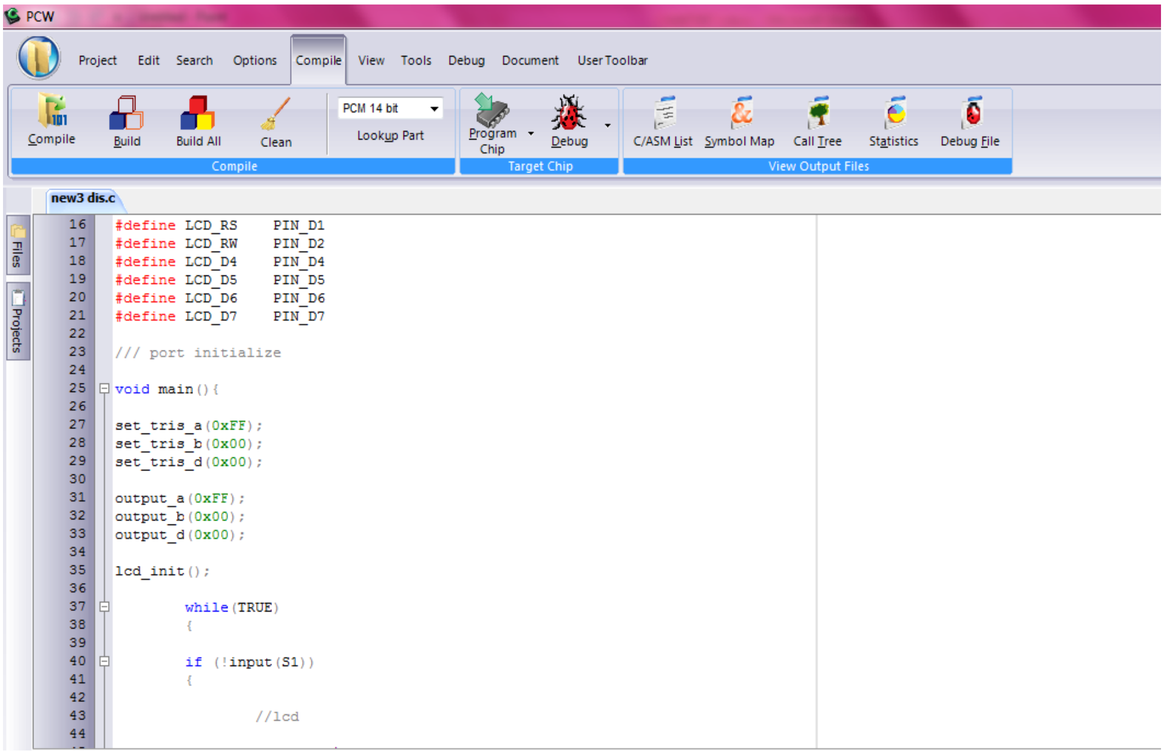

Figure 3.17: PIC C-Compiler

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, it will be focusing on the comparison of the single axis solar panel with the fixed solar panel and also comparing the prototype with the unclean solar panel. Result from simulation of the circuit to be implemented. There are several circuit used in the project. Details are as below.

4.2 Circuitry

This section will show result of all the circuit used in this project. It includes the result from the Proteus and also hardware.

4.2.1 Voltage Regulator Circuit

The PIC used in this project in supply from the 12V Lead Sealed Battery. Normally, PIC only needs 5V to function. As for this, voltage regulator with 5V output is used.

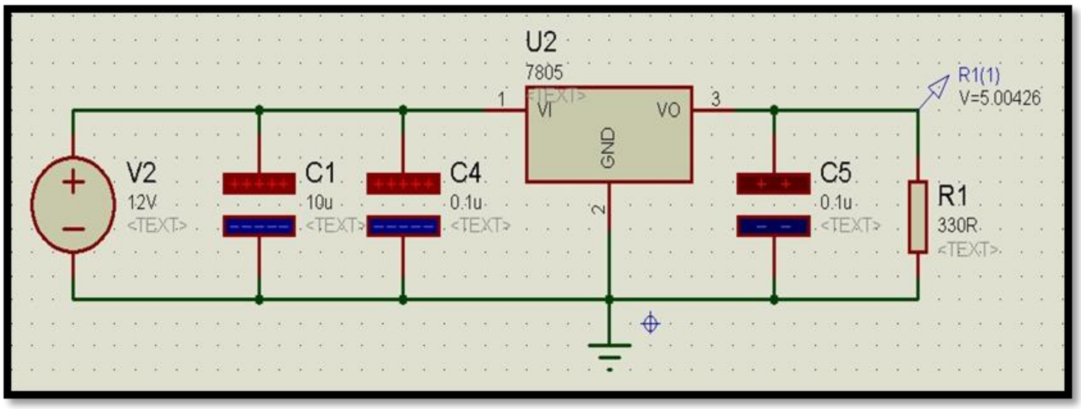

Figure 4.1: Voltage regulator circuit

4.2.2 Charging Circuit

When having a charging unit like battery, it is important to have a charging circuit. It is important to make sure that the battery does not get overcharge as the output from the PV module is not constant and the generated voltage value is too high for the battery.

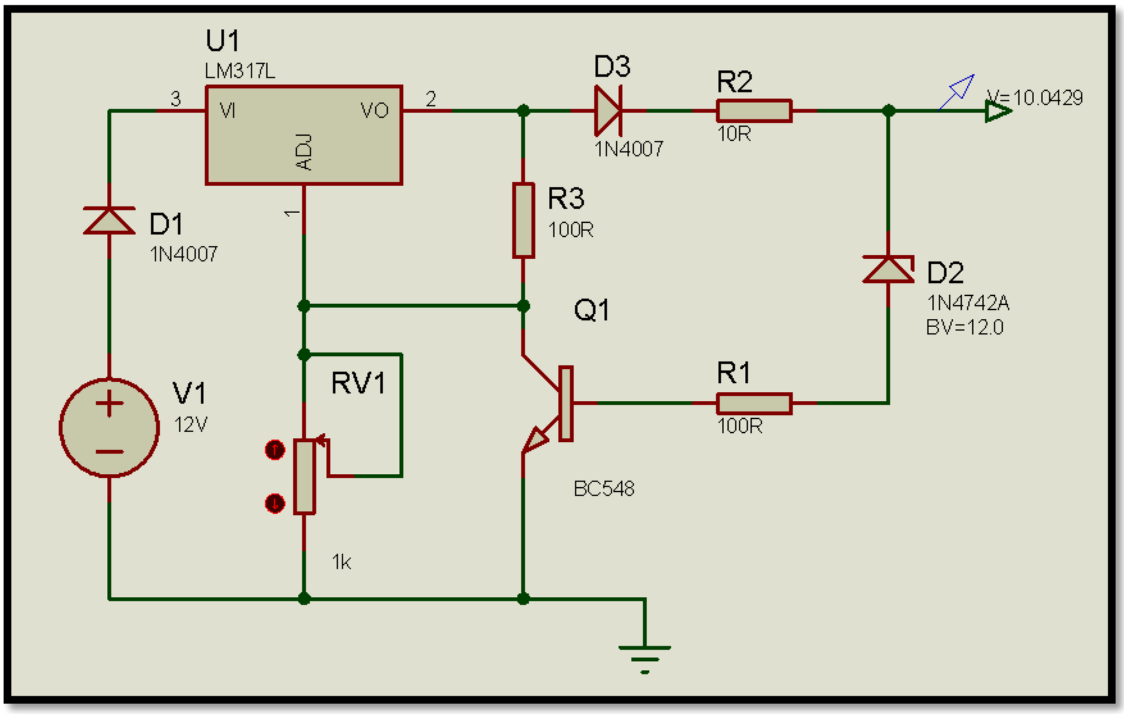

Figure 4.2: Charging circuit

4.2.3 H-Bridge Circuit

The four transistors are connected together in a “H-bridge” configuration with the motor connected in the middle. To make the motor rotate in the forward direction, a high (logic “1″ or +5V) signal is applied to the forward input, while no signal is applied to the reverse input. Transistors Q1 and Q2 conduct current and flow from terminal A through to terminal B (left-to-right direction) of the motor.

To reverse the motor’s direction a high signal is applied to the reverse input and transistors TR3 and TR2 conduct, allowing current to pass through the motor in the opposite direction from terminal B through to terminal A (right-to-left direction). The flywheel diodes, D1 to D4 across relay of the H-bridge motor control circuit help to protect the transistors from any induced back emf generated by the motor during braking.

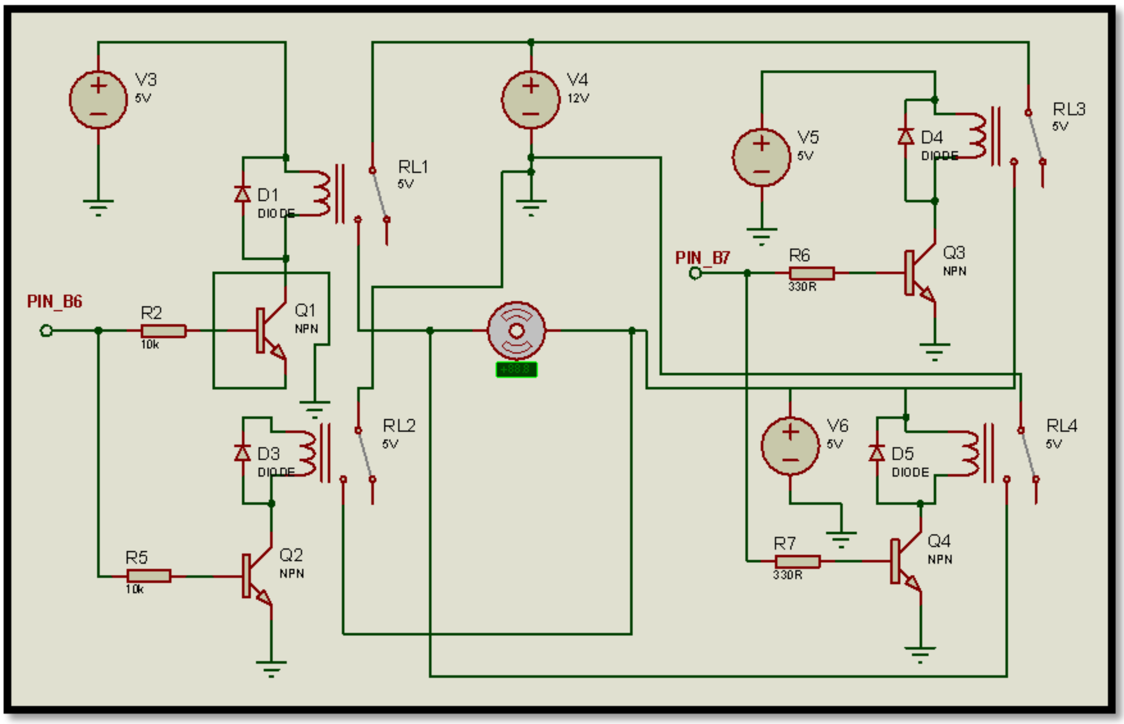

Figure 4.3: H-Bridge circuit

4.2.4 Complete Hardware

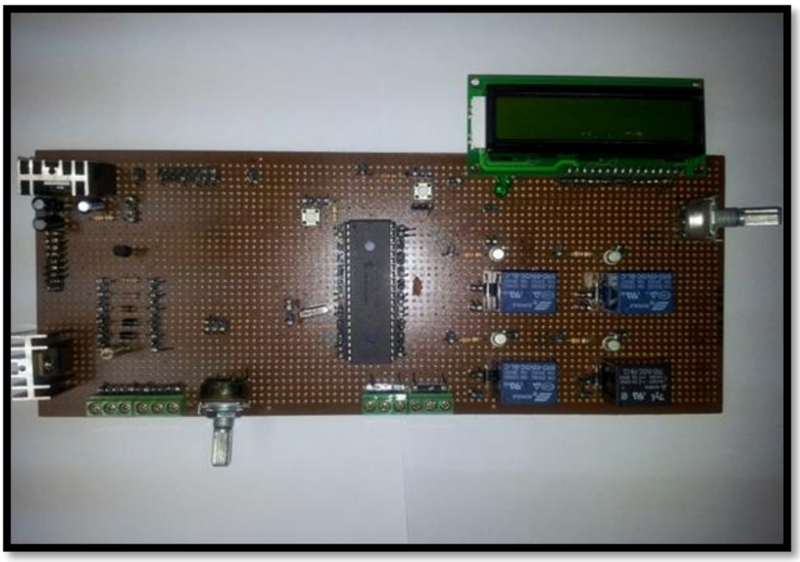

Figure 4.4: Complete Circuit

The above figure shows the complete circuit in this project. It shows the hardware of the voltage regulator circuit, charging circuit and motor driver circuit.

4.3 The Implementation of Hardware

Figure 4.5: Implemented Hardware

Picture in figure 4.5 shows the implemented hardware of single axis sun tracker. The power window motor used to move the solar panel and the solar panel will charge the 12V battery where this battery used as a supply to the circuit and also to the motor.

4.4 Construction of the Solar Tracker Prototype

Figure 4.6: Solar Tracker Prototype

Figure 4.3 below is the model of a single solar tracker prototype. As illustrated the solar tracker prototype accommodates in one degree of freedom which is vertical. The motor will move or rotate when the PIC indicates that the generated voltage did not meet the system requirement. The power window motor will only stop rotating if the PIC implies that the generated voltage from the PV module meet up the requirement range. As long as the produced voltage is within the minimum and maximum range, the PIC will analyze the data and thus will not generate any signal to actuate the motor.

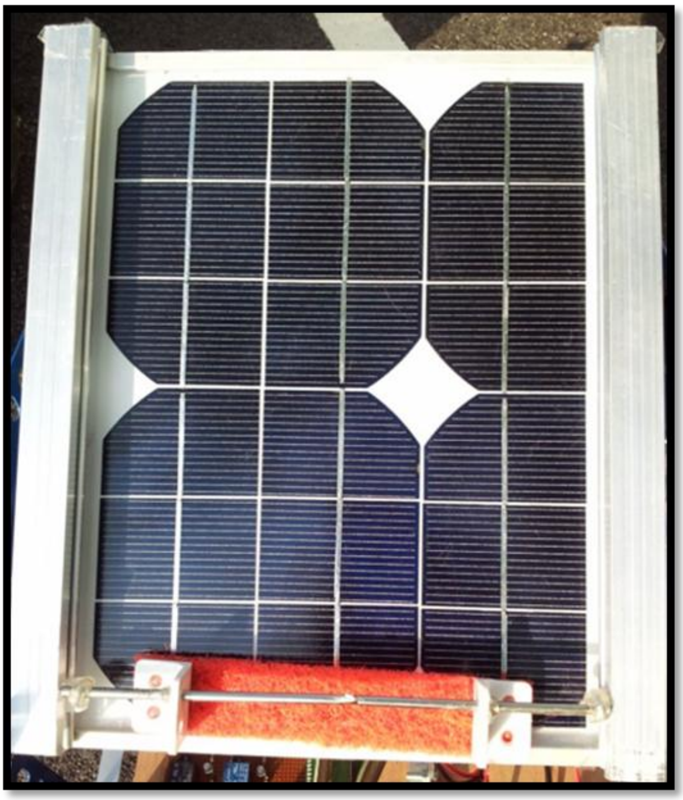

Figure: 4.7: Cleaning mechanism

As for cleaning part, a simple mechanism has been implemented on the PV module surface. The system depends on the movement of the motor in order to slides to left or to right. This PV module will clean twice a day and help PV module from reduce voltage causing by dust.

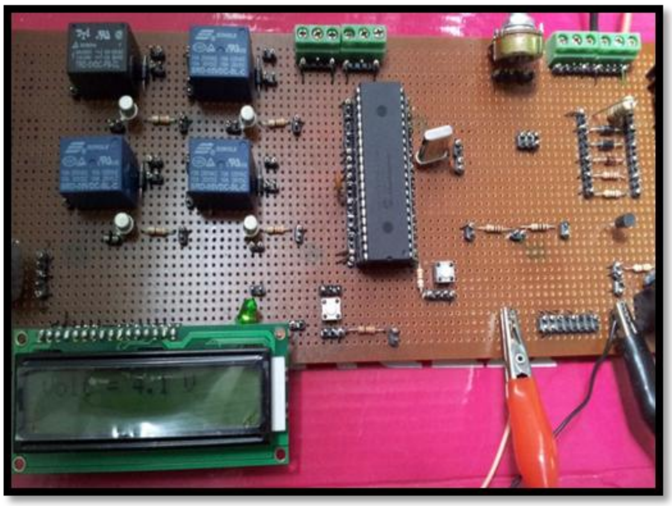

Figure 4.8: LCD at average voltage

When the LCD display 4.1V generated voltage, motor will be in forward condition. It will continue to rotate until the LCD displayed the acceptable value as programmed in the PIC. At the time generated voltage is between the minimum and maximum value, motor will stop rotating.

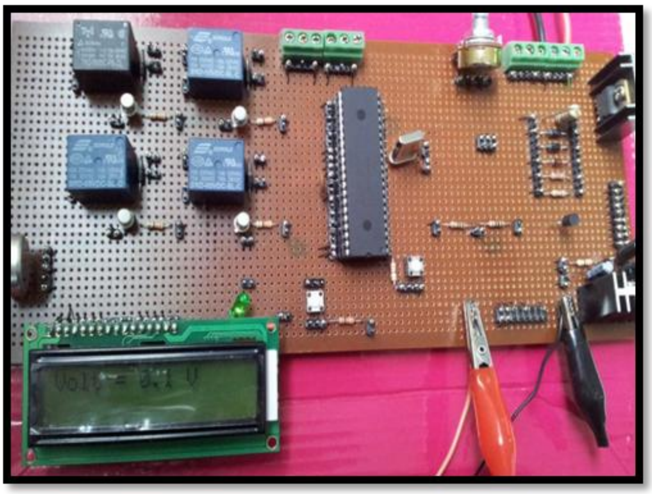

Figure 4.9: LCD at minimum voltage

When the generated voltage has dropped below 1V, motor will move reverse until it reaches a point where the condition meets the terms. As the motor rotates, it will reach a point where the generated voltage is between the minimum and maximum value. At this point the motor will stop from rotating.
[Refer **APPENDIX A]**

4.5 Producing Maximum Output Voltage

From the table 4.0 below, the 2-axis solar tracker produce more output then fixed solar panel. The voltages are measure every one hour from 7.30a.m until 6.30p.m. That is from the sun rise until the sun set.

Table 4.0 Comparison between single axis tracker and fixed panel

Average	**Single-axis Solar Tracker Voltage(V)**	**Fixed Solar Panel Voltage(V)**
7.30a.m	3.0	2.0
8.30a.m	5.0	2.9
9.30a.m	7.6	5.4
10.30a.m	9.0	6.9
11.30a.m	9.5	7.9
12.30p.m	9.6	9.0
1.30p.m	9.9	9.6
2.30p.m	9.8	8.6
3.30p.m	9.6	7.7
4.30p.m	9.2	6.3
5.30p.m	8.6	4.6
6.30p.m	3.3	1.2

Table 4.0 is the average value from May 16, 19 and 20 June 2012. It proves that the single axis solar tracker produce more output voltage than fixed solar panel. The tracker will always make sure that solar panel has maximum concentrated sunlight. Hence, the voltage output is much higher than fixed solar panel and it shows that solar tracker is more reliable than fixed solar panel. Single axis solar tracker has low output voltage in the morning and evening because of the low capacity of sunlight from the sun. But it has maximum concentrated sunlight around 12p.m to 2p.m because of high capacity of sunlight.

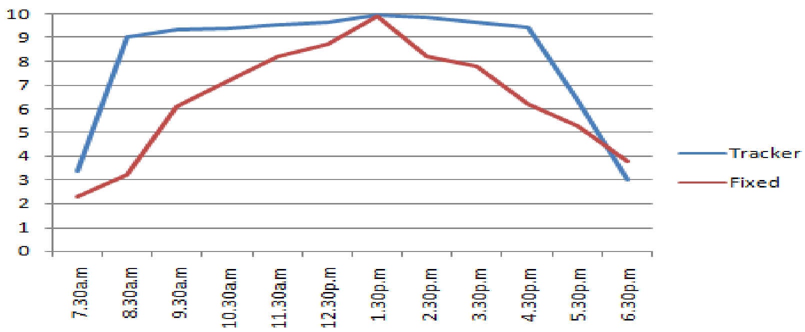

Figure 4.10: Single axis tracker versus fixed panel graph

Table 4.1 Comparison between cleaned single axis tracker and unclean single axis tracker

Time	Cleaned Single Axis Solar Panel Voltage(V)	Unclean Single Axis Solar Panel Voltage(V)
7.30a.m	1.4	0.8
8.30a.m	2.7	1.5
9.30a.m	6.8	2.5
10.30a.m	7.9	3.8
11.30a.m	9.4	4.6
12.30p.m	9.5	5.7
1.30p.m	9.9	5.4
2.30p.m	9.5	5.2
3.30p.m	9.1	4.8
4.30p.m	8.7	3.9
5.30p.m	5.9	3.2
6.30p.m	2.4	1.5

The data above is the average value from May 23, 24 and 26 2012. When the cleaned single axis sun tracking is compared with unclean solar module, a big difference can be seen. The generated voltage of the unclean PV module has been dropped rapidly as the sunlight beam has been blocked from reaching the module surface. This shows that the clean surface of the PV module does affect the outcome voltage and reduce the effectiveness of PV module.

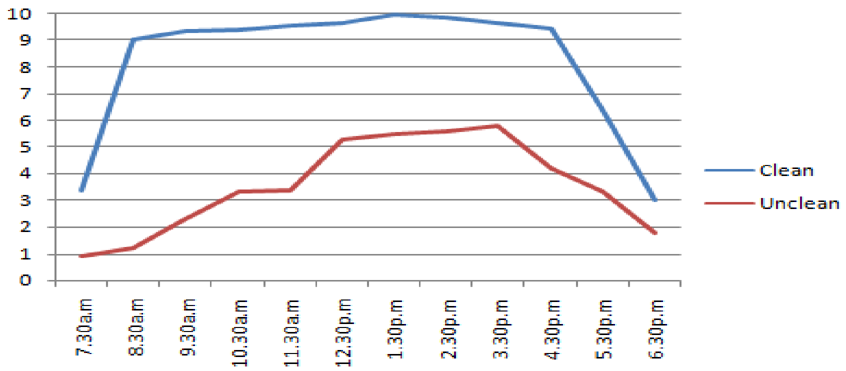

Figure 4.11: Cleaned single axis tracker versus unclean single axis tracker graph.

CHAPTER 5

CONCLUSION

5.1 Conclusion

This project is a solid evidence to prove how a single axis solar tracking system with cleaning system can improve the amount of collected sun light during daytime. This tracking system is able to increase the output voltage by more than 30%, which is higher than basic photovoltaic module without cleaning system. PV module does not only used to generate electricity but also as an input to ADC for rotation purpose. The amount of received voltage is then displayed on the LCD. Motor movement is controlled by the minimum and maximum value programmed in the PIC16F877A.

During the design implementation from Proteus to actual board, there are many problem encounters. The problem is due to different connection and configuration of the Proteus itself. As for that, lots of time is used to solve the problem. The tracking system implementation is almost succeeded when the motor problem is solved.

Future Recommendation

This project is focused on increasing the generated voltage from the PV module by developing a single axis system that is equipped with an automatic cleaning. It is important to make sure the PV module is able to generate a maximum voltage during its operating time so that the purpose of using PV Module as alternative power energy is achieved. This system can be improves in the future by make it to two axes tracking system with automatic cleaning system.

The 2-axes tracking system should be able to operate in two axes which are in altitude and azimuth axes. The system can be programmed not only following the sun movement in the sky but also to rotate whenever clouds blocking the sunlight from reaching the module surface. As for the cleaning mechanism, for more accurate and schedule cleaning, a small dc motor can be used with the help from the PIC program.

As the load increases as three motors needs to be operate in the same time, bigger PV module scale should be use. The battery Amp should be increases too as the motors will produce a high torque current at the start. This 2-axis solar panel will produce maximum voltage or power as the effectiveness of the system is also increased.

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[10]. Mohamad A. S. Masoum, Seyed Mahdi Mousavi Badejani, Ewald FF. Fuchs, *"Microprocessor-Controlled New Class of Optimal Battery Chargers for Photovoltaic Applications"* – IEEE Transactions on Energy Conversion, September 2004.

APPENDIX A - Program development

```
#include <16f877a.h>
#fuses HS, NOWDT, NOLVP, NOPROTECT,PUT
#device adc=10
#use delay(CLOCK = 20M)
#include <lcd.c>

/****************************************************************/

#define LCD_ENABLE_PIN  PIN_D0
#define LCD_RS_PIN      PIN_D1
#define LCD_RW_PIN      PIN_D2
#define LCD_DATA4       PIN_D4
#define LCD_DATA5       PIN_D5
#define LCD_DATA6       PIN_D6
#define LCD_DATA7       PIN_D7

/****************************************************************/
void main()
{
  int32 reading, value, minvalue, maxvalue, night;
  minvalue=7,
  maxvalue=10,
  night=1;

  lcd_init();

  //Setup ADC Ports
  setup_adc_ports(ALL_ANALOG);
  setup_adc(ADC_CLOCK_INTERNAL);
```

```
//Initialize Port
set_tris_a(0xFF);
set_tris_d(0x00);

while(true)
  {

   set_adc_channel(0);
   reading=read_adc();
   delay_ms(100);

   value = reading*10/1023;
   lcd_gotoxy(1,1);
   printf(lcd_putc,"Volt = %u.1 V ",(int)value);

if ((value<minvalue) && (value>night))
{
 delay_ms(1000);
 output_high(PIN_B7); //motor forward
 output_low(PIN_B6);
 output_high(PIN_B0);

}
 else if ((value>minvalue) && (value<maxvalue))

          {
            delay_ms(1000);
            output_low(PIN_B7); // motor stop
            output_low(PIN_B6);
            output_high(PIN_B0);
           }
```

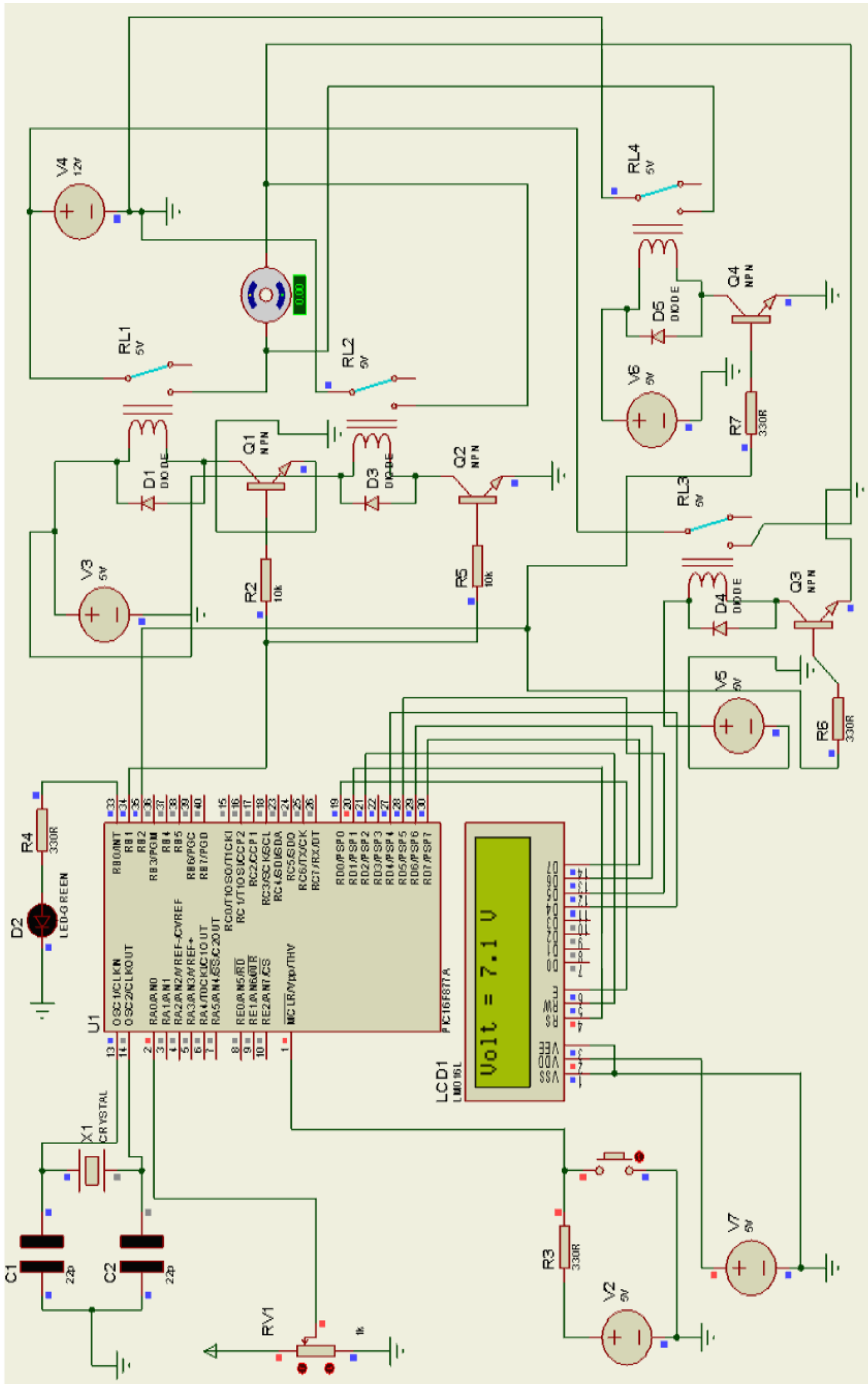
```
    else if (value<night)
          {
            delay_ms(1000);
            output_low(PIN_B7);  // motor reverse
            output_high(PIN_B6);
            output_high(PIN_B0);

         delay_ms(1000);
          output_low(PIN_B7); //motor stop
         output_low(PIN_B6);
          output_low(PIN_B0); //led OFF

          }

    }
  }
```

APPENDIX B - Simulation Circuit



APPENDIX C – Collected data

- Comparison between single axis tracker and fixed panel

May 16, 2012

Time	Single-axis Solar Tracker Voltage(V)	Fixed Solar Panel Voltage(V)
7.30a.m	3.4	2.3
8.30a.m	6.0	3.2
9.30a.m	8.3	6.1
10.30a.m	9.5	7.2
11.30a.m	9.6	8.2
12.30p.m	9.6	8.7
1.30p.m	9.9	9.6
2.30p.m	9.9	8.2
3.30p.m	9.6	7.8
4.30p.m	9.4	6.2
5.30p.m	8.9	5.3
6.30p.m	3.2	0.8

May 19, 2012

Time	Single-axis Solar Tracker Voltage(V)	Fixed Solar Panel Voltage(V)
7.30a.m	2.4	1.6
8.30a.m	3.7	2.5
9.30a.m	6.5	5.1
10.30a.m	8.4	6.6
11.30a.m	9.5	7.5
12.30p.m	9.6	9.3
1.30p.m	9.9	9.6
2.30p.m	9.8	9.0
3.30p.m	9.5	8.5
4.30p.m	9.0	6.9
5.30p.m	8.5	4.7
6.30p.m	2.9	1.0

May 20, 2012

Time	Single-axis Solar Tracker Voltage(V)	Fixed Solar Panel Voltage(V)
7.30a.m	3.1	2.0
8.30a.m	5.4	2.9
9.30a.m	7.9	4.9
10.30a.m	9.0	6.9
11.30a.m	9.3	8.0
12.30p.m	9.5	8.9
1.30p.m	9.9	9.7
2.30p.m	9.8	8.6
3.30p.m	9.6	6.8
4.30p.m	9.3	5.9
5.30p.m	8.3	3.9
6.30p.m	3.7	1.8

Comparison between cleaned single axis tracker and unclean single axis tracker

May 23, 2012

Time	Cleaned Single Axis Solar Panel Voltage(V)	Unclean Single Axis Solar Panel Voltage(V)
7.30a.m	1.3	1.2
8.30a.m	3.0	1.9
9.30a.m	7.3	3.3
10.30a.m	8.3	4.8
11.30a.m	9.5	6.9
12.30p.m	9.6	7.7
1.30p.m	9.9	4.9
2.30p.m	9.8	4.5
3.30p.m	9.6	3.9
4.30p.m	9.4	3.4
5.30p.m	6.3	3.3
6.30p.m	2.8	1.8

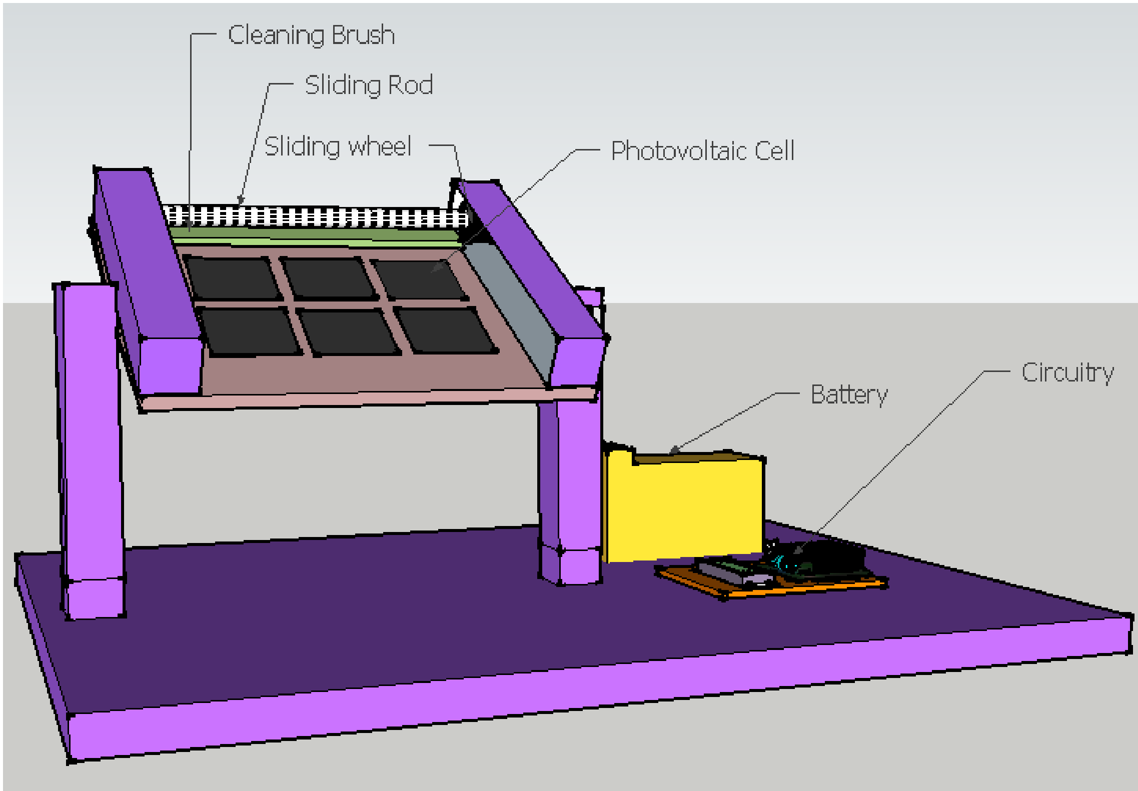
May 24, 2012

Time	Cleaned Single Axis Solar Panel Voltage(V)	Unclean Single Axis Solar Panel Voltage(V)
7.30a.m	1.1	0.5
8.30a.m	2.8	0.9
9.30a.m	6.5	1.7
10.30a.m	7.2	2.9
11.30a.m	8.9	3.1
12.30p.m	9.3	4.9
1.30p.m	9.8	5.5
2.30p.m	9.6	5.6
3.30p.m	9.3	5.8
4.30p.m	8.9	4.2
5.30p.m	5.7	2.7
6.30p.m	1.9	1.6

May 26, 2012

Time	Cleaned Single Axis Solar Panel Voltage(V)	Unclean Single Axis Solar Panel Voltage(V)
7.30a.m	1.7	0.8
8.30a.m	2.5	1.6
9.30a.m	6.7	2.6
10.30a.m	8.2	3.7
11.30a.m	9.7	3.9
12.30p.m	9.7	4.4
1.30p.m	9.9	5.8
2.30p.m	9.1	5.6
3.30p.m	8.4	4.8
4.30p.m	7.8	4.1
5.30p.m	5.8	3.7
6.30p.m	2.4	1.1

APPENDIX D - Prototype Sketch



APPENDIX E – PIC16F877A

MICROCHIP

PIC16F87XA
Data Sheet

28/40/44-Pin Enhanced Flash Microcontrollers

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:

- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input
  DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM),
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) – 8 bits wide with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (VREF) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

CMOS Technology:

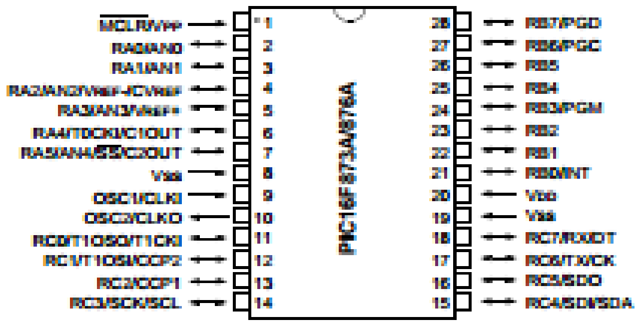
- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I^2C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

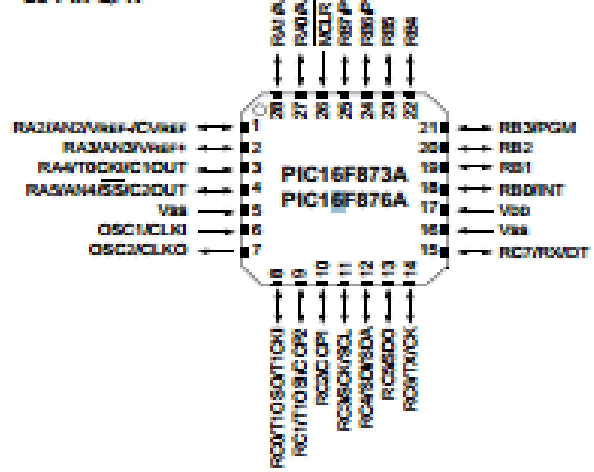
PIC16F87XA

Pin Diagrams

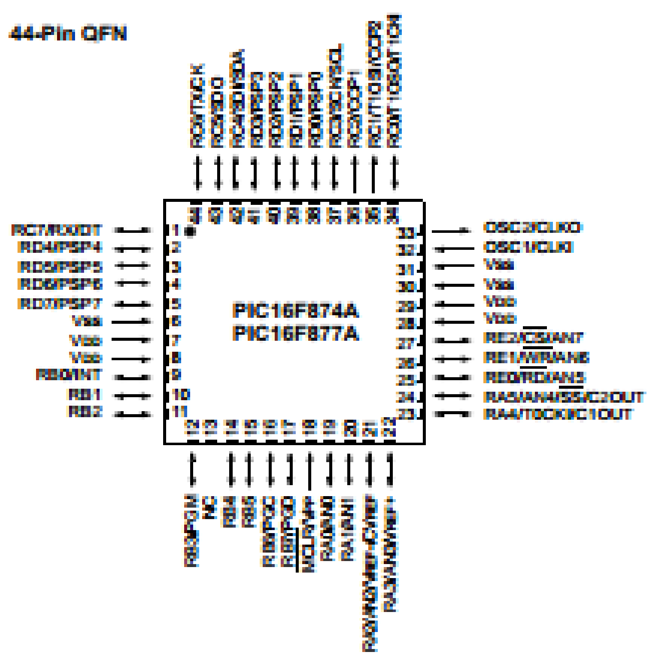
28-Pin PDIP, SOIC, SSOP



28-Pin QFN



44-Pin QFN



APPENDIX F – BC107

NPN general purpose transistors BC107; BC108; BC109

FEATURES

- Low current (max. 100 mA)
- Low voltage (max. 45 V).

APPLICATIONS

- General purpose switching and amplification.

DESCRIPTION

NPN transistor in a TO-18; SOT18 metal package.
PNP complement: BC177.

PINNING

PIN	DESCRIPTION
1	emitter
2	base
3	collector, connected to the case

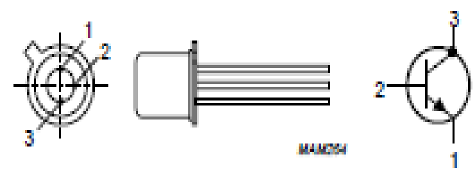


Fig.1 Simplified outline (TO-18; SOT18) and symbol.

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter			
	BC107		–	50	V
	BC108; BC109		–	30	V
V_{CEO}	collector-emitter voltage	open base			
	BC107		–	45	V
	BC108; BC109		–	20	V
I_{CM}	peak collector current		–	200	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25\ ^{\circ}C$	–	300	mW
h_{FE}	DC current gain	$I_C = 2$ mA; $V_{CE} = 5$ V			
	BC107		110	450	
	BC108		110	800	
	BC109		200	800	
f_T	transition frequency	$I_C = 10$ mA; $V_{CE} = 5$ V; f = 100 MHz	100	–	MHz

APPENDIX G – 1N4001

DIODES INCORPORATED

1N4001 - 1N4007

1.0A RECTIFIER

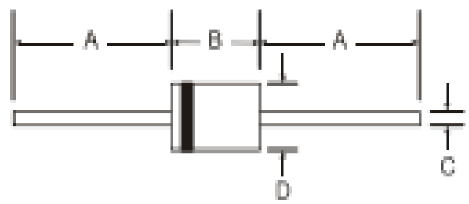
Please click here to visit our online spice models database.

Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- Lead Free Finish, RoHS Compliant (Note 3)

Mechanical Data

- Case: DO-41
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020D
- Terminals: Finish - Bright Tin. Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Mounting Position: Any
- Ordering Information: See Page 2
- Marking: Type Number
- Weight: 0.30 grams (approximate)



Dim	DO-41 Plastic	
	Min	Max
A	25.40	—
B	4.06	5.21
C	0.71	0.864
D	2.00	2.72
All Dimensions in mm		

Maximum Ratings and Electrical Characteristics @T_A = 25°C unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ T_A = 75°C	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load	I_{FSM}	30							A
Forward Voltage @ I_F = 1.0A	V_{FM}	1.0							V
Peak Reverse Current @T_A = 25°C at Rated DC Blocking Voltage @ T_A = 100°C	I_{RM}	5.0 50							µA
Typical Junction Capacitance (Note 2)	C_j	15				8			pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Maximum DC Blocking Voltage Temperature	T_A	+150							°C
Operating and Storage Temperature Range	T_J, T_{STG}	-65 to +150							°C

Notes:
1. Leads maintained at ambient temperature at a distance of 9.5mm from the case.
2. Measured at 1.0 MHz and applied reverse voltage of 4.0V DC.
3. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied, see EU Directive 2002/95/EC Annex Notes.

APPENDIX H – Relay 5V

SONGLE RELAY

松乐继电器 SONGLE RELAY	RELAY ISO9002	**SRD**

1. MAIN FEATURES

- Switching capacity available by 10A in spite of small size design for highdensity P.C. board mounting technique.
- UL,CUL,TUV recognized.
- Selection of plastic material for high temperature and better chemical solution performance.
- Sealed types available.
- Simple relay magnetic circuit to meet low cost of mass production.

2. APPLICATIONS

- Domestic appliance, office machine, audio, equipment, automobile, etc.
  (Remote control TV receiver, monitor display, audio equipment high rushing current use application.

3. ORDERING INFORMATION

SRD	XX VDC	S	L	C
Model of relay	Nominal coil voltage	Structure	Coil sensitivity	Contact form
SRD	03、05、06、09、12、24、48VDC	S:Sealed type	L:0.36W	A:1 form A
				B:1 form B
		F:Flux free type	D:0.45W	C:1 form C

4. RATING

CCC	FILE NUMBER:	CQC03001003731	10A/250VDC
UL /CUL	FILE NUMBER:	E167996	10A/125VAC 28VDC
TUV	FILE NUMBER:	R 50056114	10A/250VAC 30VDC

5. DIMENSION(unit:mm) DRILLING(unit:mm) WIRING DIAGRAM