System Design and Circuit Implementation of a solar powered car

A Thesis submitted to the
Dept. of Electrical & Electronic Engineering, BRAC University
in partial fulfillment of the requirements for the
Bachelor of Science degree in Electrical & Electronic Engineering

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Declaration

We do hereby declare that the thesis titled "System Design and Circuit Implementation of a solar powered car" submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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Abstract

The project is about the designing and implementation of the electrical drive system of a solar powered car. The solar panel collects energy from the sun during the day time and stores this in a lead-acid battery through a charge controller that to drive the motor of the car. The charge controller circuit has been used to supply the battery with the maximum amount charge possible, while protecting it from overcharge by the solar panels or the electric source as well as over discharge by the motor. Functionality of both the driver circuit and the charge controller circuit are controlled by the PIC16F876A microcontroller. For the charge controller circuit, the PIC detects the current and voltage of the battery and thereby, according to the state of the battery, it feeds back a Pulse-Width Modulated (PWM) flow of charge from the panel to the battery. As the whole thesis project is based on Direct Current Power System, Direct Current (DC) motors are worthier in this case. DC motor has become familiar as an essential drive configuration or pattern for many applications widely in terms of power and speed. The number of applications implemented by DC motor will continue grow for the predictable future because of the quality of easy controlling and the outstanding performance of the DC motors. The main motive of this thesis project is to design a speed controller system or driver circuit for DC motor in both the theoretical and practical way.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

The sun is a free resource with its unlimited supply of energy. While the supply of natural gas (which provides 89% of total power generation in Bangladesh) are increasingly getting depleted and unreliable for uninterrupted electricity supply, harnessing the energy of the sun efficiently, we believe, can sustain to provide for the electrical demands of the future in an economically viable way.

Solar energy is the most effective energy supply for electric vehicle in comparing with other renewable energy source. Other source of renewable energy cannot be used in electric vehicle. The body frame of the vehicle can be used as solar plate from where the vehicle can get the total power. Bangladesh is situated between 20.30 - 26.38 degrees north and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Here solar radiation varies between 4 to 6.5 kWh per square meter and maximum amount of radiation is available in summer. So for Bangladesh electric vehicle using solar power is most effective

This chapter introduces the project, with an outline of the project, the project objectives and scopes of the project. It also summarizes the organization of this thesis paper.

1.2 Project Outline

The project is about developing the circuits of a solar power car system. The solar panel collects energy from the sun during the day time and stores this in a lead-acid battery through a charge controller that to drive the motor of the car. The charge controller circuit has been used to supply the battery with the maximum amount charge possible, while protecting it from overcharge by the solar panels or the electric source as well as over discharge by the motor. Functionality of both the driver circuit and the charge controller circuit are controlled by the PIC16F876A microcontroller. For the charge controller circuit, the PIC detects the current and voltage of the battery and thereby, according to the state of the battery, it feeds back a Pulse-Width Modulated (PWM) flow of charge from the panel to the battery. The driver circuit for DC motor which will be designed for controlling the speed of the motor is implemented in both theoretical way and practical way. In the theoretical part, an equation will be derived from the relationship of mainly voltage, current, torque of the DC motor which will be used further to control the speed of the DC motor. Practically, for implementing the driver cicruit for DC motor PIC16F876A is used along with Analog to Digital Converter method and Pulse Width Modulation technique to control the speed of the DC motor. In is a rainy day and night the sun is absent then battery will charge from the electric source by a ac to dc conveter. Rectifire circuit convert the AC current to DC current to charge the battery.

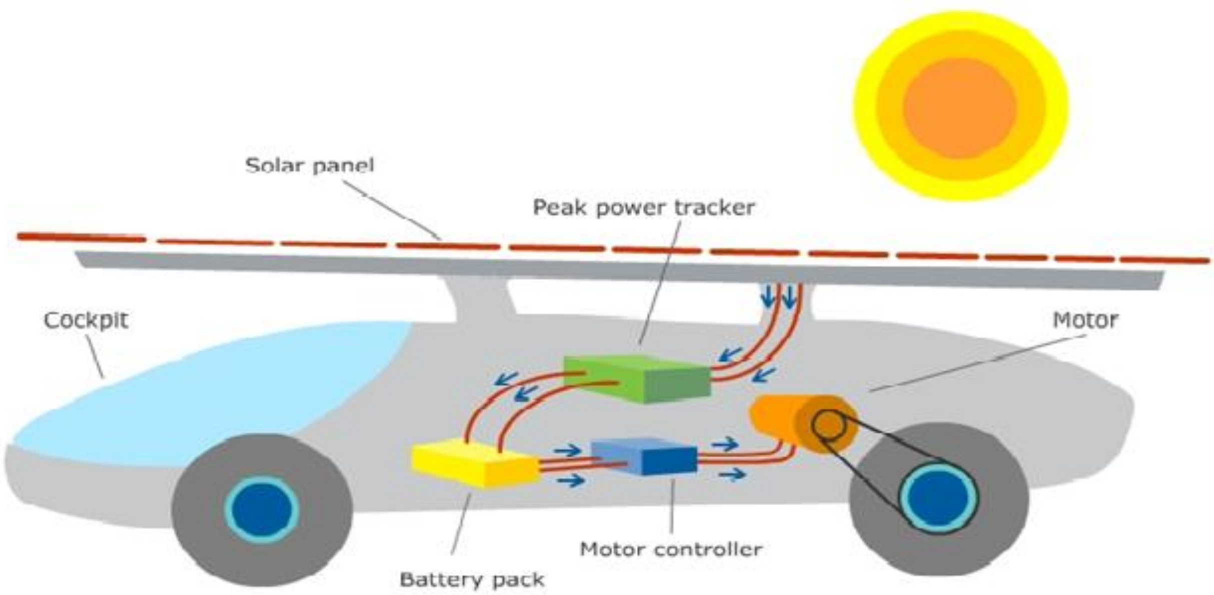


Figure 1.1: System flow

1.3 Project Scope

The scope of this project includes construction of the prototype of driver circuit of a solar powered car. A12 V lead-acid battery supplies energy collected from a solar panel to motor. The different components involved in the designing of this project includes AC to DC converter, a charge controller circuit and a driver circuit, all are controlled by microcontroller programming. The PIC 16F876A microcontroller helps regulate the amount of charge flowing from the panel to the battery and the current across the motor.

1.4 Project Objective

The objective of this project is to develop the driver circuit of a car that are powered by renewable energy and are operated at required intensities such that they are economically viable for the energy sector of Bangladesh. Bangladesh is a developing and over populated country .For this reason the number of private car are increasing day by day in Dhaka city and most of the car in our country were driven by petroleum. Petroleum oil is not a natural resource of Bangladesh, so that each year we have to import it. In international market the demand of petroleum oil is always higher than the supply and that's why it is always expensive. Though Bangladesh government subsidies petroleum oil, but because of increasing the price of petroleum oil in world market, the price of petroleum in our country is increasing day by day. An alternative solution of this problem was found in 2000 and CNG automobiles were launched in Bangladesh which are run in natural gas. But the reserve of natural gas of Bangladesh is not high enough as well as new mine is not discovered and using natural gas in power plants this alternative solution is in danger. Additionally, controlling the speed of DC motor is necessary to drive the solar powered car because if it cannot be possible to control the speed then serious accidents will be occurred in the roads which can result death, injuries and traffic problems in the road. Therefore, it is indispensable to control the speed of the DC motor in desired speed.

1.5 Outline of this thesis

The thesis is organized in an order such as to provide the readers with a general understanding the different components present in the electrical drive systems of a solar power car, before moving on to the details specific to the project. The next chapter introduces the different types of each component, their functions, advantages and disadvantages and their suitability to the project. Chapter 3 provides a block diagram of the complete system along and outlines the different system parameters. It shows the calculations for determining the system size. The last chapter gives a detailed explanation of how the project is implemented. It includes the circuit diagrams and explanation used to build the prototype of the electrical drive system of the solar power car. The paper ends with the future aspects of this project following the results and discussions.

CHAPTER 2

System Description

2.1 Introduction

A electrical drive system of a solar power car is made up the components such as Solar Panel, Battery, Battery Charge Controller, Motor, Motor controller, AC to DC converter and connecting wires. In this chapter, the different components required by the car system for this project will be discussed. The types, advantages, disadvantages, availability and economic value of the Solar Panel, Battery and Motor will be discussed. Charge Controllers and their types, operational stages of charge controllers and their chosen design are outlined in this chapter. DC Motor, their types, chosen DC Motor, operational principle of the chosen DC Motor and its speed control system and finally the specification of DC Motor which will be used for the car system are outlined in this chapter.

Various ways of electricity generation exists. But using solar cells to produce electricity has certain benefits, which are briefly explained below.

- Free Fuel: The main fuel for solar powered systems is the sun, which is available all around the world as a free resource. The environment effect is minimal as there are no harmful by-products.
- Independent Production of Electricity: In this process, electricity is generated independently without the use of fossil fuels and conventional electricity distribution lines.
- Low Maintenance: Since there are no rotating parts such as motors in a photovoltaic system, the maintenance is very simple.
- Added Benefit in determining location of installment: Conventional Power units needs to consider a lot of factors before setting up their centers, such as fuel supply, communication, drawing up electricity lines etc. But to install photovoltaic systems, the chosen location only needs to have abundant supply of sunshine.

- Easy to expand: According to requirements, the capacity of photovoltaic systems can be increased by adding solar modules. This is much less simpler and less costly than conventional power system.
- Maximum Dependability: As long as there is sunlight, the system will keep supplying uninterrupted electricity. Thus the risk of power cut is very low.

2.2 Solar Panels

The sun is a living fireball whose rays reach one side of the spherical earth during day time. Scientists have employed modern tactics to develop the solar cells that can directly convert the energy from sunlight to electrical power. Solar cell is an electronic device that converts energy.

The Greek term ‘Photovoltaic’ refers to the process of electricity generation from light. When a series of Photovoltaic or Solar Cells is put together, they form a Solar Panel. The panels absorb energy from the sun which is converted to electricity by the solar cells.

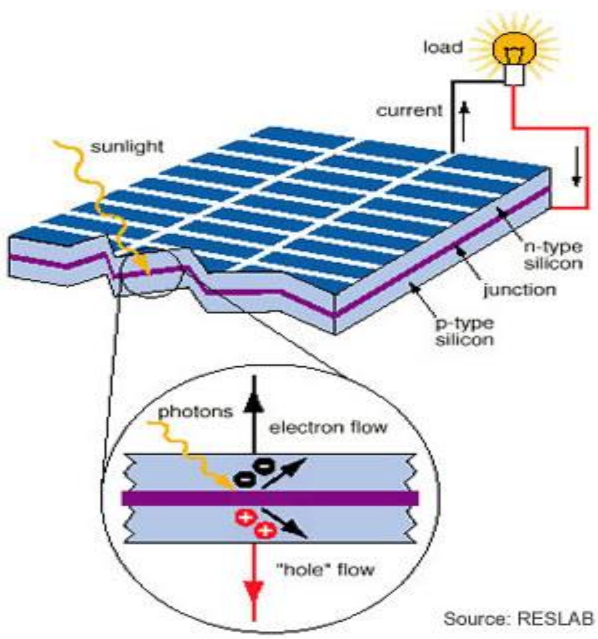


Figure 2.1: Solar panel

The main feature of photovoltaic cells is that we can get direct electricity when light is incident on them. Efficiency of this conversion mostly depends on the type of the solar panel. There are 3 types of commercially available solar panels used in standalone & grids connect systems. All three of them are based on silicon & can be classed into one of the three types. Main 3 types of solar panels are:

1. Polycrystalline Solar Panel

2. Monocrystalline Solar Panel

3. Amorphous Silicon ‘Thin Film’ Modules

Figure 2.2: Solar power car panel

Different country car description

1. Taiwane

It started out as a Taiwanese entry in the Australian World Solar Challenge and was scaled up. "*As [our team] has done quite well in the past 10 years at international solar car races -- this year ranking second out of more than 50 cars at the WSC -- we decided two years ago to broaden our advanced solar technology applications and make a car for the consumer market*," says team leader Ay Herchang. "*At a time when carbon emission reduction and fighting global* *warming are top priorities of governments and people, a wholly solar-powered car would offer a good alternative for the green-minded*."

Figure 2.3: Two seat solar car

2 Japan

Solar Powered Blue Car Hitting the Streets in 2010 by Jorge Chapa 06/09/09 filed under: Green Transportation, Transportation Tuesday.

Starting this coming spring, a slick new solar-powered electric vehicle will be hitting the streets of Europe. Italian car designer Pininfarina and French battery manufacturer booklore have officially announced that the five door blue car hatchback is now ready for production.

The solar panel on the vehicle's roof provides some power to the vehicle's systems. It comes with regenerative brakes and a Lithium Metal Polymer battery, and has a range of 155 miles per charge. According to the manufacturer, all the materials in the construction have been sourced to be as environmentally friendly as possible.

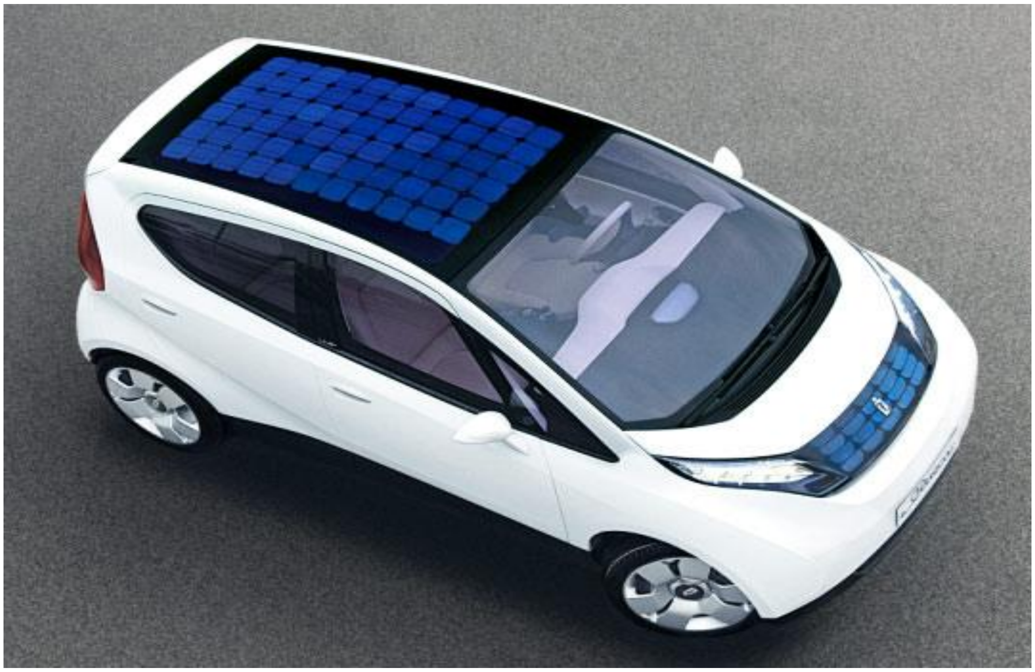


Figure 2.4: Family solar car

Final Design of the solar powered car

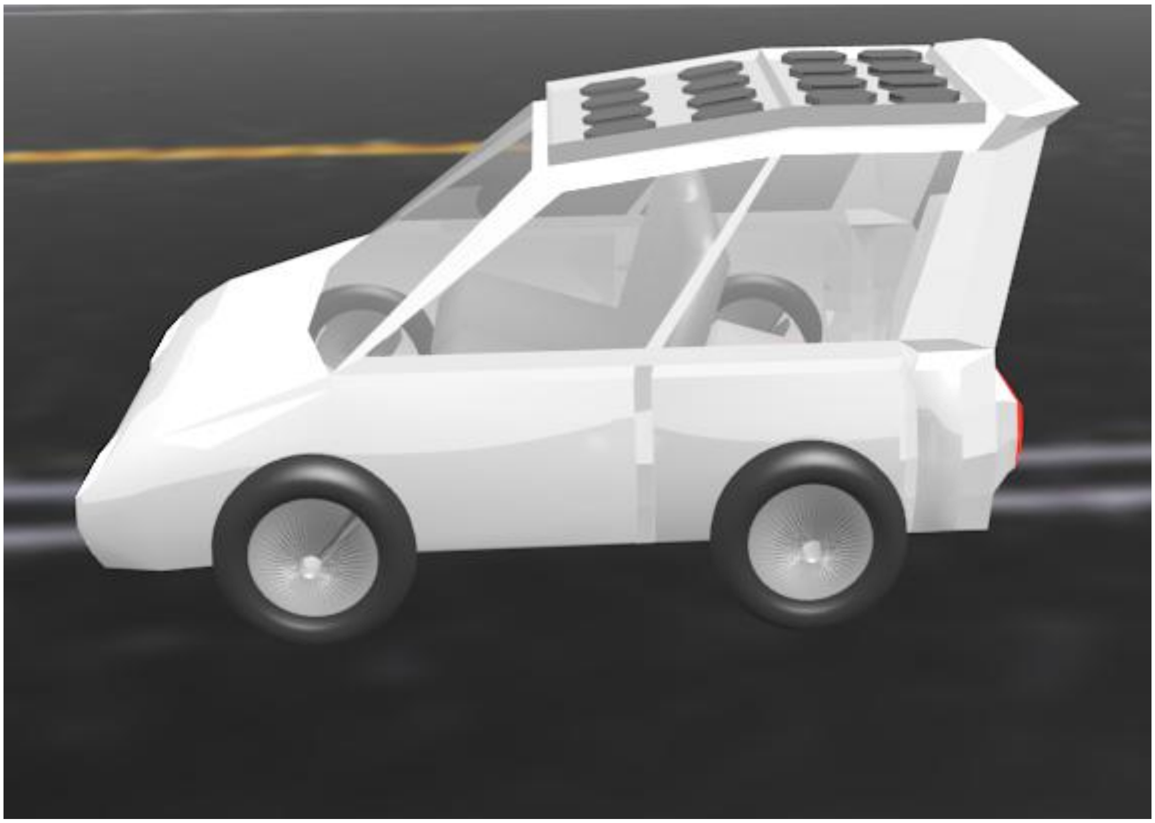


Figure 2.5: Designed solar powered car for this project

2.3 Battery

In stand-alone systems, the power generated by the solar panel is usually used to charge a battery. The electricity produced by PV modules during the day is supplied to the battery and/or the load. The battery does not act only as an auxiliary support; rather it will provide energy to counter the fluctuations of load at any time. These fluctuations may result when the load demand is higher than the energy received from sun, or vice versa. Different types of rechargeable batteries or accumulators are available which can be used. These include the following:

- Lead Acid Battery
- NiCad (Nickel Cadmium) Battery
- NiFe (Nickel Iron) Battery

Most solar and wind powered set-ups have the same basic concept. The sun or the Wind creates power, which is then stored in batteries. That way, even when the sun isn't shining you have power. Also, the batteries act as a kind of power regulator. This article will explain what kind of batteries you need, and how much power that will give you.

Almost all solar installs require Deep Cycle flooded Lead-acid batteries. Deep Cycle technically means that it has been designed to be drained a lot before being recharged. Don't be fooled though, although they are called "Deep Cycle Batteries", if you want them to last for the longest amount of time, you don't want them to discharge more than 30-40% MAX.

Lead acid batteries

These batteries will last much longer if not discharged too deeply. This is known as shallow cycling and greatly extends their life. Considering SOS and Depth of Discharge (DOD), Lead Acid batteries are the best choice for solar energy systems.

Advantages

Technology progresses in the mid-1970s when researchers developed a maintenance-free lead acid battery that was able to operate in any position. The liquid electrolyte was transformed into moistened separator and the enclosure was sealed. In addition, safety valves were added to allow venting of gas during charge and discharge. Nowadays, life without lead acid batteries seems implausible. They have myriad uses and are one of the most useful batteries with the longest life cycle, the greatest energy density per pound, and the most mature recycling infrastructure of similarly price batteries. The lead acid battery is simple and inexpensive to manufacture. There are many lead acid batteries manufacturers, OEM, such as Leoch Battery. Having been used over more than 140 years, lead acid batteries are reliable, mature secondary batteries, globally manufactured and therefore a widely understood technology. When used correctly, they are very durable and dependable. Their self-discharge rate is among the lowest of rechargeable battery systems. Capable of high discharge rates, the lead acid battery are able to deliver the bursts of energy required to start an engine. Lead acid batteries are environmentally sound in that they are recycled at an incredibly high rate. Today, 98% of lead acid batteries are recycled. With low maintenance requirements, the lead acid battery includes no memory and no electrolyte to fill on the sealed version.

In terms of these advantages of the lead acid battery, they are widely used by many different industries, such as, telecommunication, power systems, radio, and television systems, solar, UPS, electric vehicles, automobile, forklifts, emergency lights, etc.

Why we use lead acid Battery

As your electrical power usually needs to be available when the sun is not shining, its usually necessary to store electricity. The normal storage is the Lead-Acid battery. This is a good point for some warnings:

1. Lead Acid Batteries can contain a large amount of electrical energy which they are capable of discharging very quickly if any form of conductor is placed across their terminals.
2. Lead acid batteries contain Sulfuric Acid which is corrosive.
3. Lead Acid batteries give off hydrogen when they are being charged, which when mixed with air is explosive, and can be ignited by a small spark.

2.4 AC plug in charger circuit

A rectifier is an electrical device that converting alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Physically, rectifiers take a number of forms, including vacuum tube, diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motors have been used. Early radio receivers, called crystal rodeos, used a "cat’s whisker" of fine wire pressing on a crystal of galena (lead sulfide) to serve as a point-contact rectifier or "crystal detector".

Full-wave rectification

A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. Full-wave rectification converts both polarities of the input waveform to pulsating DC (direct current), and yields a higher average output voltage. Two diodes and a center tapped transformer, or four diodes in a bridge configuration and any AC source (including a transformer without center tap), are needed. Single semiconductor diodes, double diodes with common cathode or common anode, and four-diode bridges, are manufactured as single components.

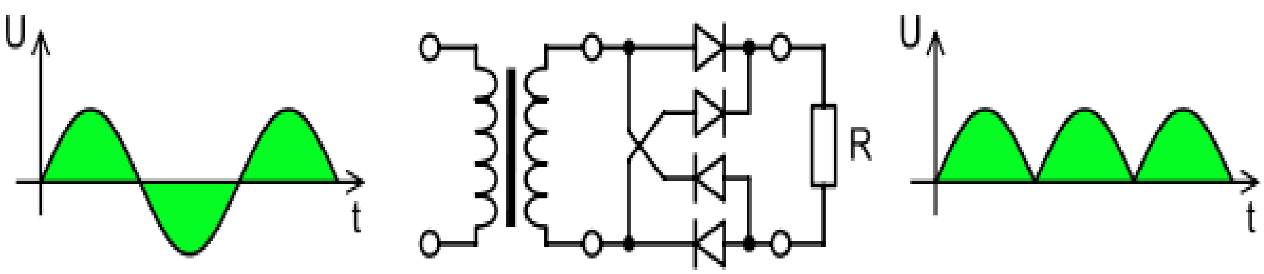


Figure 2.6: Graetz bridge rectifier: a full-wave rectifier using 4 diodes.

For single-phase AC, if the transformer is center-tapped, then two diodes back-to-back (cathode-to-cathode or anode-to-anode, depending upon output polarity required) can form a full-wave rectifier. Twice as many turns are required on the transformer secondary to obtain the same output voltage than for a bridge rectifier, but the power rating is unchanged.

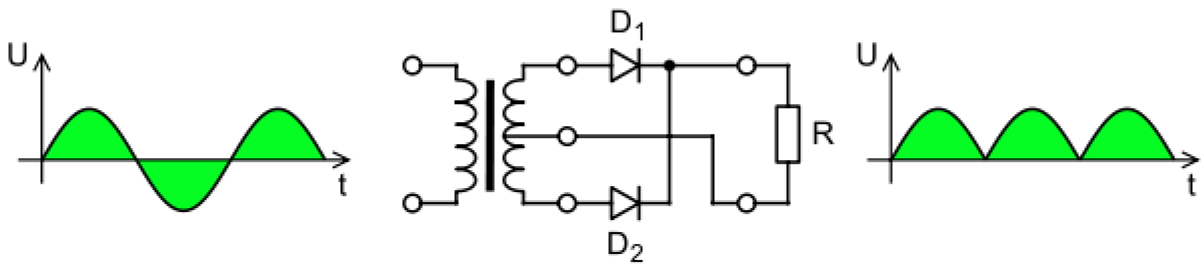


Figure 2.7: Full-wave rectifier using a center tap transformer and 2 diodes.

2.5 Charge Controller

Charge Controllers come into functionality since solar panels do not output a constant stream of voltage. The output from the panels are variable and needs adjustments before they are stored to the battery or supplied to the load. Charge Controllers work by mointoring the battery voltage. In other words, they fetch the variable voltage from the photovoltaic panels, condition to suit the safety of the storage lead-acid battery, and once full charge is reached, the controller can short the solar panel leads together to prevent further accumulation of charge in the battery. Charge Controllers, are therefore, mainly ‘Choppers’ or DC-DC Converters. The main functions of charge controllers are to prevent overcharging of battery from solar panels, overdischarging of battery to the load, and to control the functionalities of load.

2.5.1 Operational principles of charge controllers

Switches are used to operate Charge Controllers. The switch can be either a Relay or a solid state switch such as a MOSFET or power transistor. Relays contribute to less power loss due to their smaller resistence, but they have a limited life span. On the other hand, MOSFETS have a higher longivity, but also a higher rate of power loss in times of high current flow.

Control circuits are used to regulate the switching on-off of controller switches. One of the most popular techniques, and the scheme preferred for this system, is the Pulse Width Modulation

(PWM). In this scheme, the switching time is determined by the percentege of the signal at high voltage. Loss is very less in this system, but the switch used has to be a MOSFET in order to use PWM.

Most controllers measure the amount of voltage in the battery and accordingly supplies current to the battery or stops current flow completely. This is done by measuring the Ah(Ampere Hour) of the battery, rather than looking at the State of Charge (SOC) of the battery. The maximum battery voltage allowed to reach is known as the 'Charge Set Point'. Factors such as prevention of Deep Discharge, Battery Sulfation, over current and short circuit current are also prevented through the controller. Deep discharge can be detected by the microcontroller and it will run an auto boost charge to keep the battery activated.

2.5.2 Charge Controller Designs

Depending on connections, charge controllers can be of two types:

- Parallel/Shunt Controller: the charge controller is connected in paraller with the battery and load.
- Series Controller: the charge controller is placed in series between solar, and battery and load.

The series controller has to handle the work at a lesser voltage than the shunt controller, and it also has less switching noise. Therefore, to sum it up, our preferred method of operation would be using a series controller and employing the Pulse Width Modulation (PWM) scheme as the switching technique. The temperature of the battery will also be maintained within a range of 15°C and 35°C, using a temperature compensator. The current rating of the charge controller will be kept 1.2 times higher than that of the panel for safety purposes. In our system, panel current has been calculatd to be 5 A, thus controller current will be 5*1.2=5.10A.

2.5.3 Types of Charge Controllers

Charge controller come in three general types which are discussed below.

1. Simple ON/OFF Controllers: These are simple controllers which use basic transistors and relays to control the voltage by either disconnecting or shorting the panel to the battery.

2. Maximum Power Point Tracking (MPPT): These types of controllers are highly efficient and provide the battery with 15-30% more power. MPPT Controllers track the voltage of the battery and match the panel output with this. This ensures maximum charge by converting the high output from solar panels to a lower voltage needed to charge the batteries.

3. Pulse Width Modulated Design (PWM): In this type, the controller continuously checks the battery voltage to alter the time and the width of the pulses of voltage it send to the battery. The name itself suggests that the width of the pulses is varied from a few microseconds to several seconds. It operates like a rapid on-off switch which breaks the panel current into pulses of constant frequency and sends a series of width-modulated pulse to the battery. This regulates the amount of charge flowing in the battery. In a discharged the battery, the width of the pulses will be on for almost 100% of the time, whereas in a fully charged battery, PWM as low as 10% may be provided. PWM offers inexpensive, yet more effective ways to control how the battery reaches full voltages without overheating.

2.5.4 3 Stage Charge Cycle

Most Charge Controllers can operate at more than three stages to complete the charging cycle of the battery. These stages vary according to different times and battery voltages. PWM can be employed to control the battery at these stages.

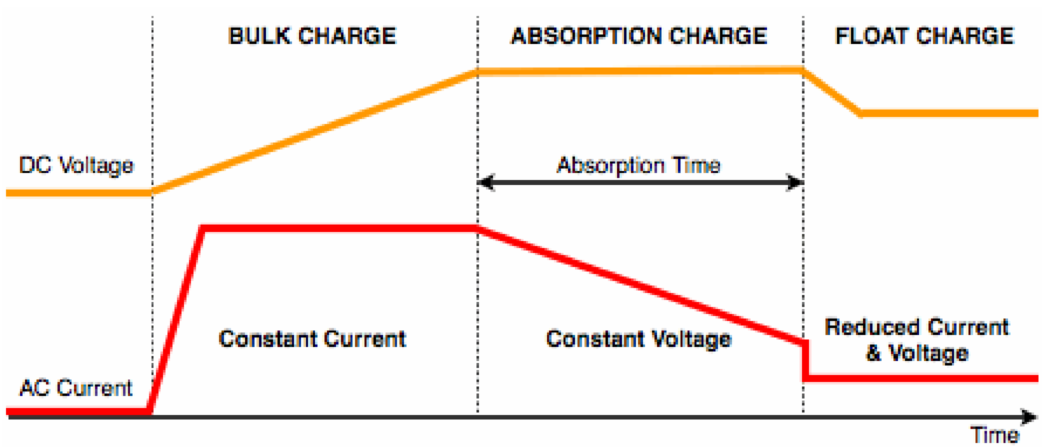


Figure 2.8: Three stages of a charge controller

BULK Stage: This is the first stage of the cycle which takes place when the battery voltage is low. Usually when power is drawn by the load from the battery, charge controllers begin bulk charging. In this stage, the maximum safe current is provided to the battery while voltage gradually rises to bulk level(14.4-14.6), which is 80-90% of fully charge level.

ABSORPTION: When bulk voltage is reached, absorption stage begins. During this, voltage is maintained at bulk for a specified time, for instance 1 hour, in order to safely charge the battery to 100%. As voltage remains constant, internal resistance rises and the current tapers off as the batteries charge up.

FLOAT: The voltage is lowered at float level (usually 12.6 to 13.2). Batteries draw small maintenance current untill next cycle at this stage. This level is important to keep a charged battery from being discharged, and as a result of this maintenance, the battery is likely to have a prolonged life.

2.6 DC Motor

Motors are those electric machines which convert the electrical energy to the mechanical energy. There are two types of motor such as AC motors and DC motors. Basically, for electric cars DC motors are mostly preferable. That is why DC motor is chosen for this thesis project.

Direct Current (DC) motors are preferable expansively in variable speed drives because of having changeable characteristics. There are several reasons for the continued popularity of DC motors. One is that DC power systems are still common in cars, trucks and aircraft. When a vehicle has a DC power system, it makes sense to consider using DC motors. Another applications for DC motors is a situation in which wide variation in speed are needed. Moreover, DC motors are cheap in price and controlling of those is easy.

2.6.1 Types of DC motors

There are five major types of DC motors in general use.

1. The Separately Excited DC motor.
2. The Shunt DC motor.
3. The Permanent-Magnet DC motor.
4. The Series DC motors.
5. The Compounded DC motor.

2.6.2 Chosen DC motor and reasons for choosing it

For our thesis project, series Direct Current (DC) motor will be used in which there is only one current is flowed, so high power can be achieved. Series DC motors are well-suited to use broadly in adjustable-speed drives and position control applications. As speed control method for series DC motors are simpler that is why DC motors are chosen where wide-speed range control is essential. In addition, series DC motors are immensely popular because of their high starting torque and are best used for loads that require a lot of power to get them moving so it is feasible to acquire speed control over wide range. Moreover, series DC motor is classified as a constant speed motor. If the load slows down, the current in the rotor goes up. Since the rotor and field winding are wired in series, the winding current will go up too. This increases the torque of the motor and its ability to return the load to the correct speed.

2.6.3 Series DC Motor

A series DC motor is a DC motor whose field windings consist of a relatively few turns connected in series with the armature circuit. In series DC motor, the armature current, field current and line current all are same. Series DC motor falls under the self-excited DC motors. The Kirchhoff's voltage law equation for this motor is-

$$V_T = E_A + I_A\ (R_A + R_S)$$

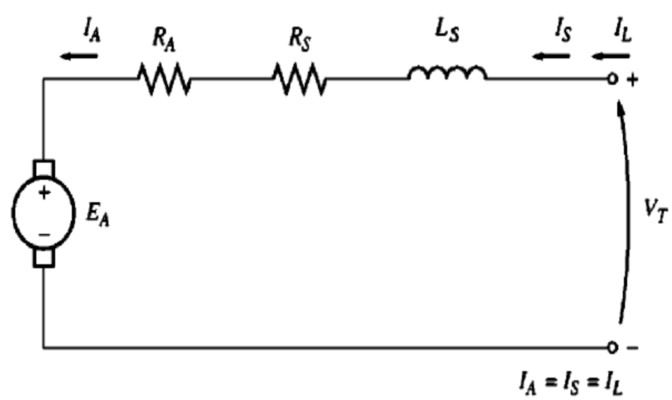


Figure 2.9: The equivalent circuit of the series DC Motor

2.6.4 Series DC Motor Operation Principles

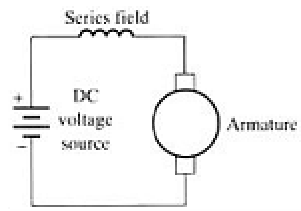


Figure 2.10: Simple Series DC Motor

The series configuration of the field winding and armature is connected with an external DC voltage source such that the positive end of the voltage source is connected with the winding and the negative end is connected with the armature through brushes.

After supplying the voltage initially the motor draws a huge amount of current as the winding and the armature are constructed with large conductors offering low resistance in the current contour. Strong magnetic field is achieved by the winding because of the huge amount of current.

High torque to the armature shaft is produced by strong magnetic field, therefore calling upon the rotating action of the armature. As follows, at the initiation the motor starts rotating at its maximum speed. The revolving armature with the occurrence of the magnetic field is responsible for creating counter EMF (Electro Motive Force) which limits the current.

This is how series DC motor, at the beginning shows maximum speed and torque but steadily with the increase of the speed, torque comes down because of the reduced current. As a result of the high torque, the load on the shaft is set to rotate initially but afterwards, the lesser torque keeps the load on the move.

2.7 DC Motor Control

The main intention which is concerned for this thesis project is to design a system or driver circuit to control the speed of the DC motor efficiently and safely. The principle of the system that will control the speed of the DC motor is to take a signal representing the demanded speed, and to drive a motor at that speed. The DC motor driver circuit is implemented in both literature and practical view. Theoretically, to implement this thesis project, a system will be designed to control the speed of the DC motor through relations among torque, speed, terminal voltage and armature current, resistances, flux. Besides, there will be two graphical representations related to the torque, speed and armature current to obtain the variation of the speed. Using those relations an equation is found that will show how to control the speed of the motor. In this part, the theoretical way of controlling the speed of the DC motor is included and the practical way is incorporated in the hardware implementation part.

2.8. Theoretical way to control the speed of DC motor

The basic behavior of a series DC motor is due to the fact the flux is directly proportional to the armature current, at least until saturation is reached. As the load on the motor increases, its flux increases too and an increasing in flux in the motor causes a decrease in its speed. The result is that a series DC motor has a sharply drooping torque-speed characteristic.

The induced torque in series DC motor is given by this following equation-

$$\tau_{ind} = \mathrm{K}\Phi I_A \qquad \text{(Eqn-1)}$$

The flux in this motor is directly proportional to its armature current. Therefore, the flux in the motor can be given by-

$$\Phi = \mathrm{c}\, I_A \qquad \text{(Eqn-2)}$$

where c is a constant of proportionality. The induced torque in this motor is thus given by-

$$\tau_{ind} = \mathrm{K}\Phi I_A = Kc(\, I_A)^2 \qquad \text{(Eqn-3)}$$

In other words, the torque in this motor is proportional to the square of its armature current. So we can say that, upto saturation, if armature current is doubled, torque is quadrupled. Consequently, torque vs. armature current curve upto the saturation region is a parabola. The torque vs. armature current characteristics in linear (before saturation) region is given below-

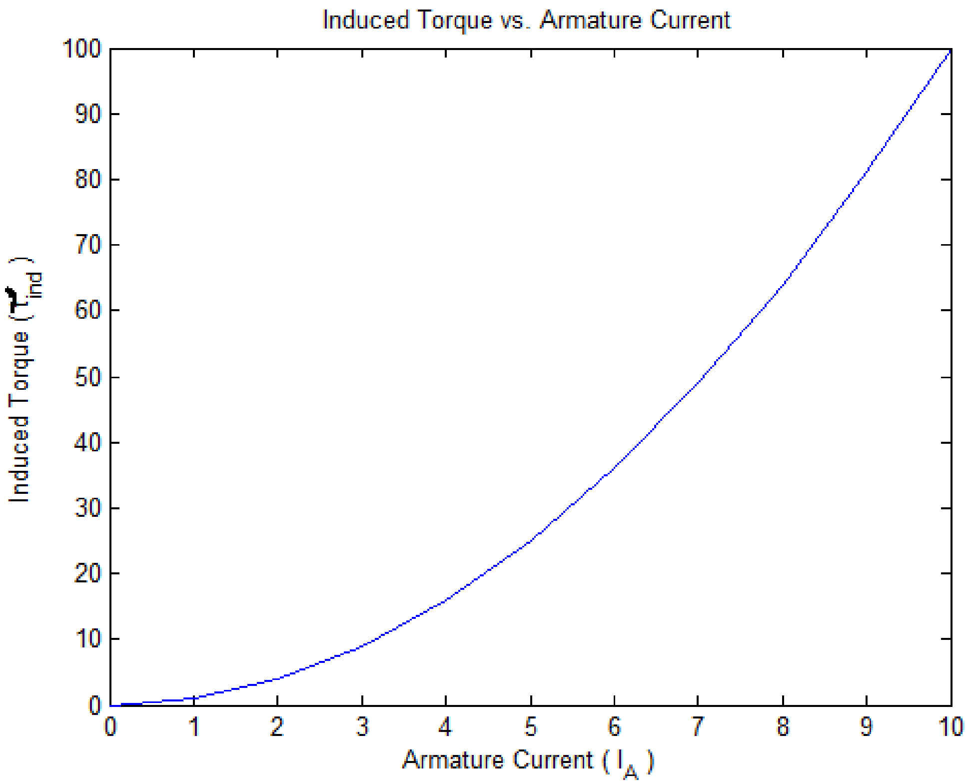


Figure 2.11: Torque-Armature Current characteristics of a series DC motor

Now, for our convenience, we assume that no saturation occurs and flux is proportional to the current. Eqn-2 will be used to derive the torque-speed characteristics curve for the series motor. The derivation of a series motor's torque-speed characteristics starts with Kirchhoff's voltage law:

$$V_T = E_A + I_A\,(R_A + R_S) \qquad \text{(Eqn-4)}$$

From Eqn-3, the armature current can be expressed as-

$$I_A = \sqrt{\frac{\tau_{ind}}{Kc}} \qquad \text{(Eqn-5)}$$

We know,

$$E_A = K\Phi\omega_m \qquad \text{(Eqn-6)}$$

Putting the value of I_A and E_A in Eqn-4, we get

$$V_T = K\Phi\omega_m + \sqrt{\frac{\tau_{ind}}{Kc}}\,(R_A + R_S) \qquad \text{(Eqn-7)}$$

If the flux can be eliminated from this expression, it will directly relate the torque of a motor to its speed. To eliminate the flux from the expression, notice that-

$$I_A = \frac{\Phi}{c}$$

And the induced torque equation can be rewritten as

$$\tau_{ind} = \frac{K}{c}\Phi^2$$

Therefore, the flux in the motor can be rewritten as

$$\Phi = \sqrt{\frac{c}{K}}\sqrt{\tau_{ind}} \qquad \text{(Eqn-8)}$$

Substituting Eqn-7 into Eqn-8 and solving for speed yields

$$V_T = K\sqrt{\frac{c}{K}}\sqrt{\tau_{ind}}\,\omega_m + \sqrt{\frac{\tau_{ind}}{Kc}}\,(R_A + R_S)$$

$$\sqrt{Kc}\sqrt{\tau_{ind}}\,\omega_m = V_T - \frac{(R_A + R_S)}{\sqrt{Kc}}\sqrt{\tau_{ind}}$$

$$\omega_m = \frac{V_T}{\sqrt{Kc}\sqrt{\tau_{ind}}} - \frac{(R_A + R_S)}{Kc} \qquad \text{(Eqn-9)}$$

Eqn-9 represents the relationship between torque and speed.

The ideal torque-speed characteristic of a series DC motor is given below-

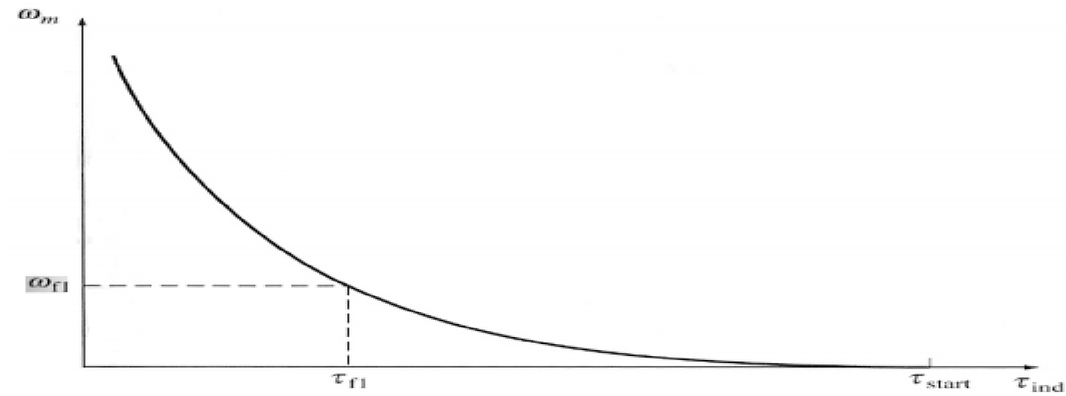


Figure 2.12: Torque-speed characteristic of a series DC motor

The torque-speed characteristic of a series DC motor shown in Figure-1.4 makes it clear that series motor develops high torque at low speed and vice-versa. It is because an increase in torque requires an increase in armature current which is also the field current. The result is that flux is strengthened and hence the speed drops.

There is only one efficient way to change the speed of a series DC motor. That method is to change the terminal voltage, V_T of the motor. If the terminal voltage is increased, the first term in Eqn-9 is increased, resulting in a higher speed for any given torque and vice-versa. As, the speed of the series DC motor is proportional to the terminal voltage, by increasing V_T motor speed will be increased and by decreasing V_T motor speed will be decreased.

2.9 DC Motor Specifications

DC series motor is most preferable for our thesis project for further practical implementation. The information regarding this motor is given below-

1. Rated Power-1000W; which indicates the power that the motor is designed to deliver to the load for uninterrupted operation.

2. Rated Voltage-60V (DC); which presents the operating voltage on the input side of the motor.

3. Rated Current-22A; which indicates that above this rated current we cannot run the motor or it can be damaged.

4. Rated Speed-3600 min; which tells about the speed for which the motor is designed to operate for continuous operation.

CHAPTER 3

Calculation for System Size

3.1. Introduction

Calculations now need to be done in order to determine the parameters for a photovoltaic system to power a one seat car. The system will require a solar panel for the collection of sun energy, and a battery as a storage area for the collected charge and a motor to drive the car. Energy will thus be collected through the photovoltaic panel during day time, and be stored in the battery till it is drawn by Motor. As a result the size of the batteries and photovoltaic panels needs to be determined as to achieve maximum utilization of the system, based on the findings of the energy received from the sun and the energy required by the car depending on its speed. If is a rainy day and night the sun is absent then battery will charge from the electric source by a ac plug in charger .

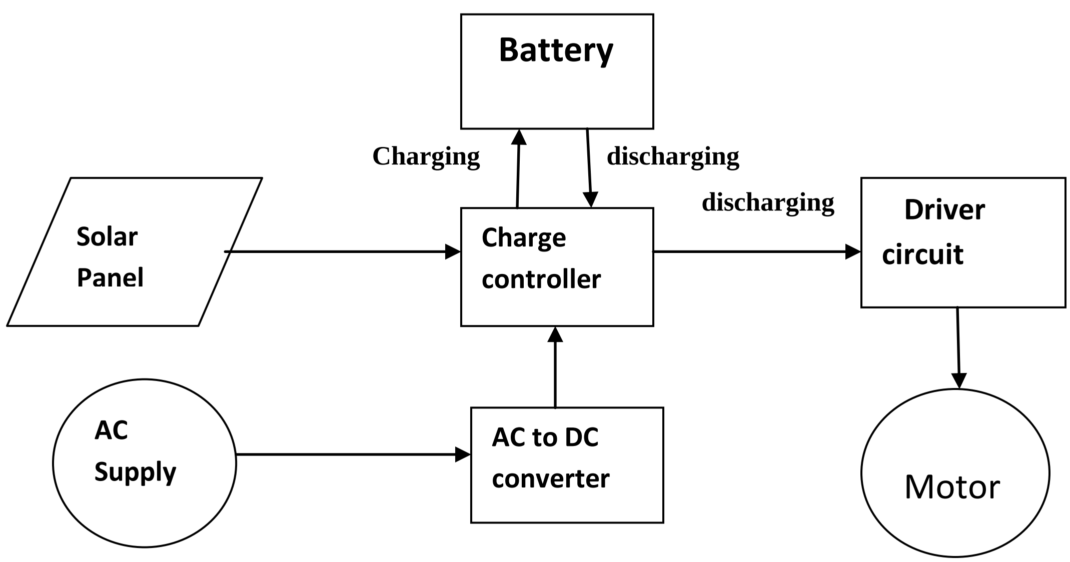


Figure 3.1: Block Diagram of the full Driving system

3.2 Estimation of Motor Power, Panel Size and Battery Capacity

3.2.1 Estimation of Motor Power

The power needed to drive the car can be calculated using (1) as,

$$P = F \times v \quad (1)$$

Where v is the velocity of the car and F is the force needed to overcome the frictional force between the road and the tires which can be calculated as,

$$F = m \times g \times C_{rr} \quad (2)$$

Where, 'm' is the mass of the car, 'g' is the gravitational acceleration and 'C_{rr}' is the coefficient of rolling resistance (resistance between the car tires and the road as the car rolls on the road). Different tires have different C_{rr} depending on the type of tires, load, road type, pressure etc. Tires used for solar car are typical bicycle tires and have rolling resistance of 0.0055 on asphalt/concrete roads.

Assuming car velocity v = 60km/h, mass m = 500 kg (this is an approximate value and also includes the mass of two passengers) and g = 9.81 m/s^2, the power required to drive the car is given by

$$\begin{aligned} P &= F \times v \\ &= m \bullet g \bullet C_{rr} \bullet v \\ &= 500\,\text{kg} \times 9.81\,\text{m/s}^2 \times 0.0055 \times \frac{60 \times 10^3\,\text{m}}{60 \times 60\,\text{s}} \\ &= 449.625\,\text{W} \end{aligned}$$

A motor with **power rating 1kW** which twice as big as calculated above will be used, considering a much a higher friction of the roads in Dhaka city, due to their uneven quality, A **DC Series motor** will be chosen for its long life span, almost zero maintenance cost and high efficiency.

3.2.2 Estimation of Battery Capacity

Battery capacity depends on the energy battery has to supply which in turn depends on the total distance travelled. As the solar car is contemplated to be used mainly by the office-goers in Dhaka, one of longest distances to travel from one end of Dhaka to the opposite can be represented by the distance between Matijheel and Uttara area which is approximately 17.5 km. With two return trip, the total distance d = 2(2×17.5)= 70 km. Then the total energy that should be supplied by the motor is given by,

$$\begin{aligned} E_M &= P \times t, \quad t = \frac{d}{v} \text{ is the total travel time} \\ &= P \times \frac{d}{v} = 1\,\text{kW} \times \frac{70\,\text{km}}{60\,\text{km/h}} = 1.167\,\text{kWh} \end{aligned} \tag{3}$$

If η_m is motor efficiency (90%), the maximum energy that should be supplied by the battery is:

$$E_B = \frac{E_M}{\eta_m} = 1.297\,\text{kWh} \tag{4}$$

If η_B (90%) is the battery efficiency, the battery capacity is given by,

$$\text{Battery Capacity} = \frac{E_B}{\eta_B \times DOD \times V_B}\ \text{Ah} \cong 30.02\,\text{Ah} \tag{5}$$

where V_B= 60 V is the battery voltage and *DOD* is the maximum allowed depth of discharge of the battery and is considered to be 80% in our calculation.

The battery voltage considered here is 24 volts, which will be achieved by connecting two 12V 40 Ah batteries in series. Sealed valve Lead Acid Battery will be chosen for the car, as opposed to the conventional Lithium Ion batteries used in many solar cars, due to its lower price, availability, and safer operation.

3.2.3 Estimation of Panel Size

The panel size can now be determined on the basis of the total energy the battery should supply plus the losses in the battery and the charge controller. Eq. (5) gives the energy required from the battery. Now, if η_B is the battery efficiency, η_{Ch} (90%) battery charging efficiency, and η_{CC} (90%) charge controller efficiency, then the total energy required from the solar panels:

$$E_P = \frac{E_B}{\eta_B \times \eta_{Ch} \times \eta_{CC}} \cong 1779.15\,\text{Wh} \tag{6}$$

where, E_P is the energy needed to be supplied from the Panel.

In Dhaka, the minimum solar insulation (solar radiation energy received) corresponds to 4.5 kWh/kWp in winter. Considering the minimum solar insulation so that adequate solar energy

$$\text{Panel Wattage} = \frac{E_P}{4.5\,\text{h}} \cong 395.4\,\text{W} \tag{7}$$

Thus a 75V 400 W panel can be chosen. If the panels have an efficiency of 10%, required panel size will be about 4 m^2, considering that every 100W panel requires an area of 1 m^2. However if the panels have an efficiency of about 15%, the required panel size will be reduced to 2.67 m^2 only. Thus panels with highest efficiency available should be chosen so that the car size can be kept compact.

3.3 Calculation of the ac plug in charger circuit

Transformer: N1/N2=312/104=3:1

The average and root-mean-square no-load output voltages of an ideal single-phase full-wave rectifier are:

$$V_{\mathrm{dc}} = V_{\mathrm{av}} = \frac{2V_{\mathrm{peak}}}{\pi}$$

$$V_{\mathrm{rms}} = \frac{V_{\mathrm{peak}}}{\sqrt{2}}$$

=104/1.1423

=73.5v

CHAPTER 4

Hardware & Software Implementation

4.1 Introduction

This chapter is dedicated to reflect how we used our research and design to build our prototype of the electric drive system of the solar car. Based on this project we designed our model of the 1000watt-one passenger-solar powered car. After an intensive research on all the available techniques and components, to meet the requirement of the desired car system and to satisfy the prime objective of the project, suitable methods and components were selected and implemented through electrical circuits. In our system we have three circuits - ac to dc converter circuit, charge controller circuit and DC motor speed controller circuit. Although the actual street light could not be developed because of time restraint, a prototype is built and all the experimental measurements are thus selected in proportion to the size of the prototype.

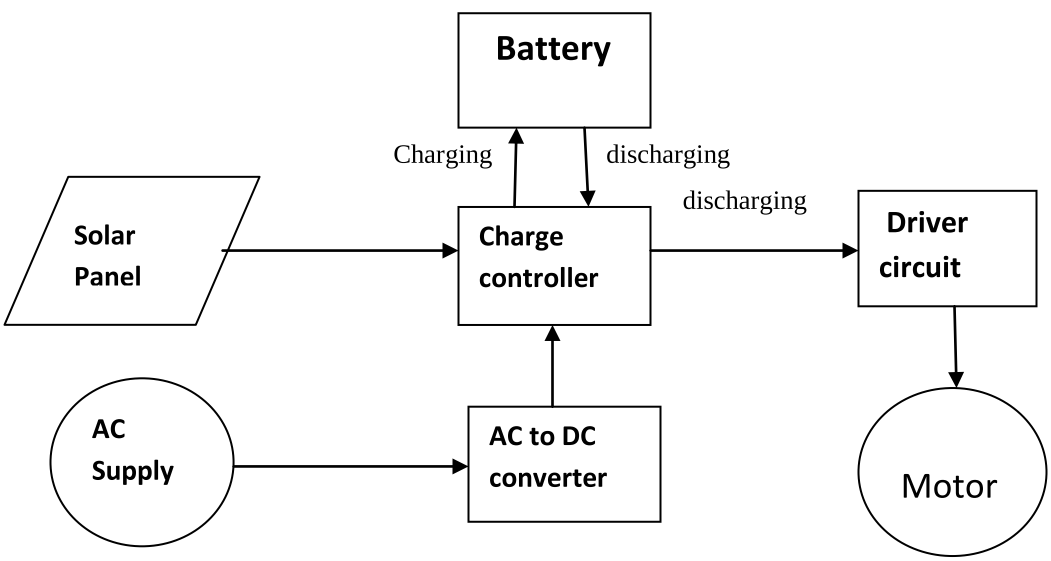


Figure 4.1: Block Diagram of the full Driving system

4.2 AC plug-in charger circuit

The primary application of rectifiers is to derive DC power from an AC supply. Virtually all electronic devices require DC, so rectifiers are used inside the power supplies of virtually all electronic equipment. In our electric drive system of a solar power car, we also used the rectifier circuit. We design our charging adapter using transformer and full wave rectifier.AC line voltage is very high that is not applicable for our system. So that first we transfer it in low voltage by using normal step down transformer and then rectified it by using full wave rectifier. For our purposes, we used a transformer that converts the 312 VAC available at the wall socket to a 104VAC signal. The transformer plugs directly into the wall socket and the wires coming out of the transformer terminate in the rectifier circuit. The transformer has been designed to convert a 312 VAC input into a 104 VAC signal output and current rating 10A. So this means that our transformer has a 3:1 turn’s ratio. The left-hand side of this circuit is the full wave bridge. This part of the circuit consists of four specially arranged diodes. The four diodes in full wave rectifier are arranged in such a manner that both the positive and negative parts of the AC waveform are converted to DC. A full wave rectifier uses both half-cycles of the sine wave to produce a DC output consisting of both negative and positive cycle. This is achieved by reversing the negative (or positive) portions of the alternating current waveform. Thus, the positive (negative) portions gets added to the reversed negative (positive) portions to produce a complete positive(negative) voltage/current waveform.

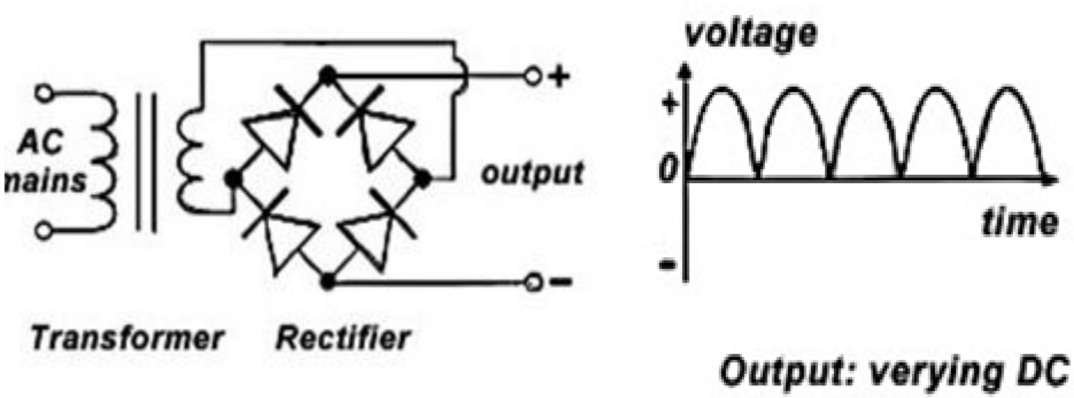


Figure 4.2: AC plug in charger circuit

This is our ac plug in charger that we made to converter the ac voltage to dc voltage

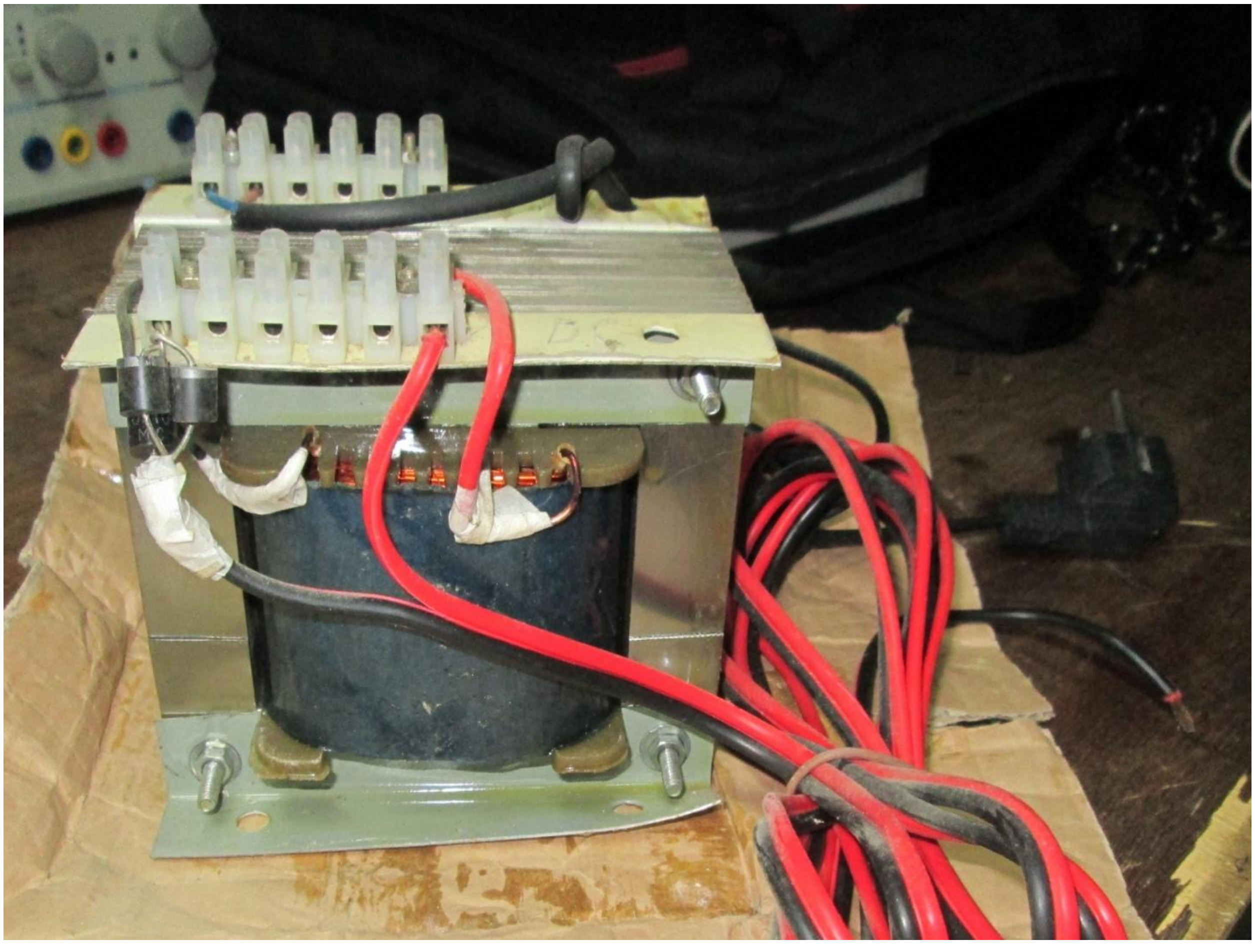


Figure 4.3: AC plug in charger

4.2 Charge Controller Circuit

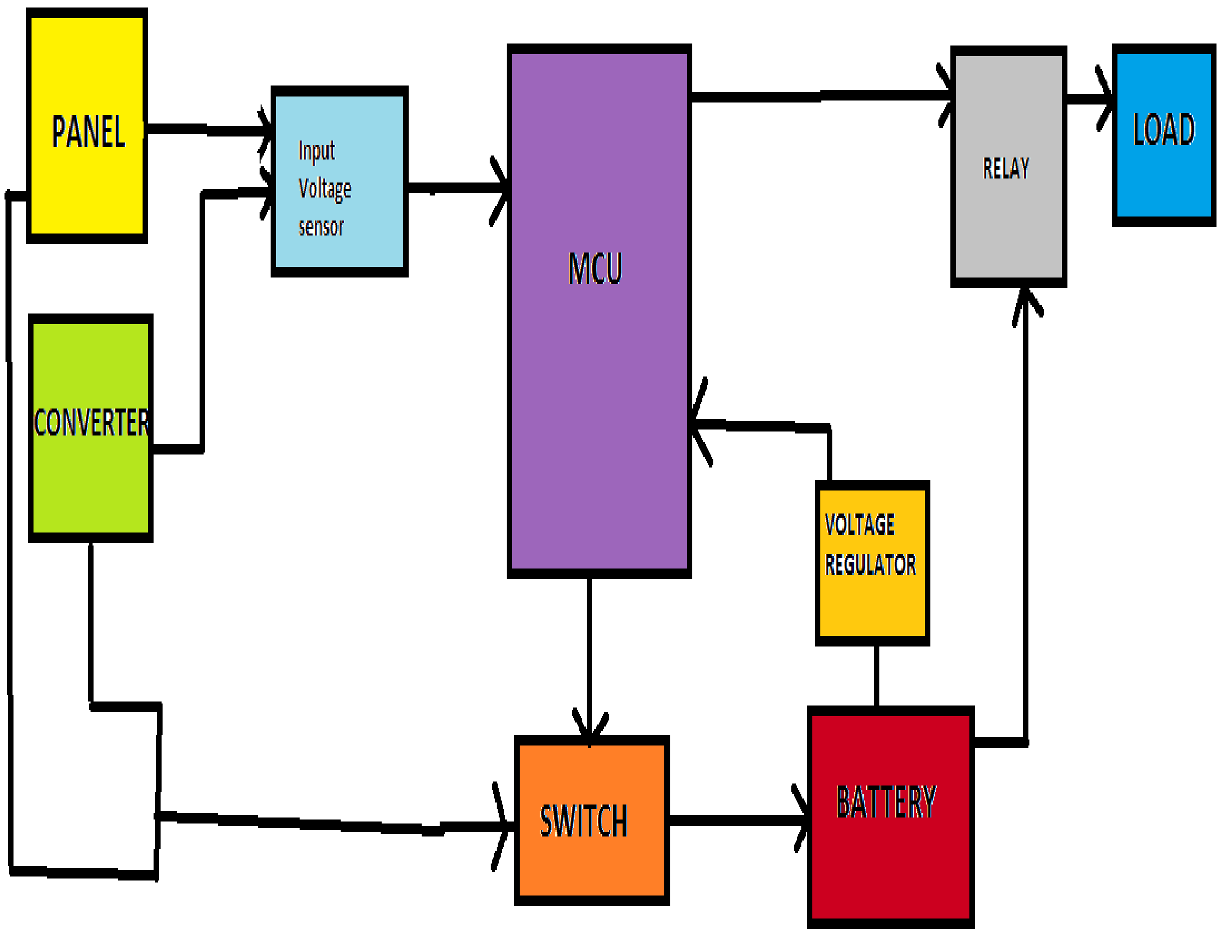


FIG 4.2 BLOCK DIAGRAM OF CHARGE CONTROLLER CIRCUIT

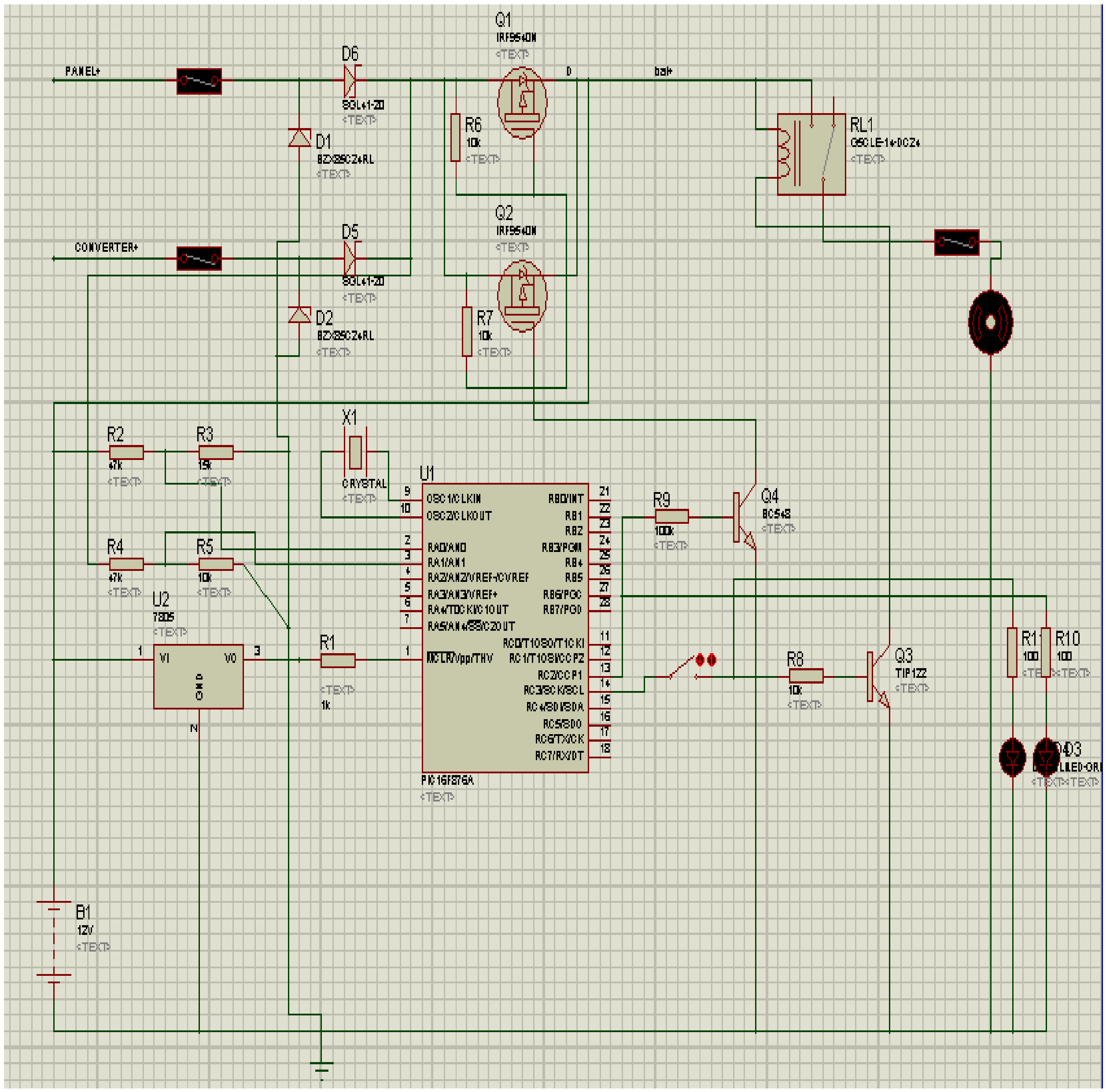


Fig 4.3 PROTESUS DESIGN OF THE CHARGE CONTROLLER CIRCUIT FOR THE SOLAR CAR

CHARGING

The charge controller basically reads the incoming voltages supplied by the solar panel and the ac-dc converter circuit and detects the voltage level of the dc battery. Based on the level of charge in the battery it allows flow of charge from the solar panel to the battery, and if the panel does not have sufficient charge then allows the converter to supply the voltage.

Fig 4.3 shows the full design of the charge controller circuit of our prototype; which is for a 12 volt lead acid battery. To fully understand the model, please refer to the block diagram of the charge controller given in fig 4.2 above. For our actual model we have determined a different calculation as discussed in the previous chapter. The brain of this device is the microcontroller chip. Here we used the chip MCU-16f876a. The MCU hold our algorithm which provides the logic controlling the flow of charge from the two sources to the battery. With help of different switching method using MOSFETs and BJTs, the algorithm was put to action.

The ADC function of the MCU, that is the analog to digital conversion, reads the values of the voltages in the panel and the converter. The MCU is powered by our battery via a voltage regulator LM7805 which takes input 12v and gives out a steady 5v. MCUs function at less or equal to 5 volts which why the supply voltages have to be converted to the range 0-5volts. Hence we used voltage division method to carry this out, by using high resistances, as we used 20 volts for both the supplies - panel and the converter. Similarly, the MCU also reads the level of voltage of the battery at any given time. We have used MCU pin no:2 /adc_pin0 and pin no:3/adc_pin1 to detect the battery and supply(either panel or converter) voltages respectively. The ADC converts the range 0-5v to ADC values 0 -1023. According to these ADC values the algorithm decides whether the panel is supplying sufficient charge or not. If it is, then based on the amount of voltage in the battery the algorithm carries out a three stage charging process. Fig 4.3 illustrates is arrangement below. If on the other hand the panel cannot supply the required charge then the algorithm instructs the MCU to let the battery draw charge directly from the converter circuit.

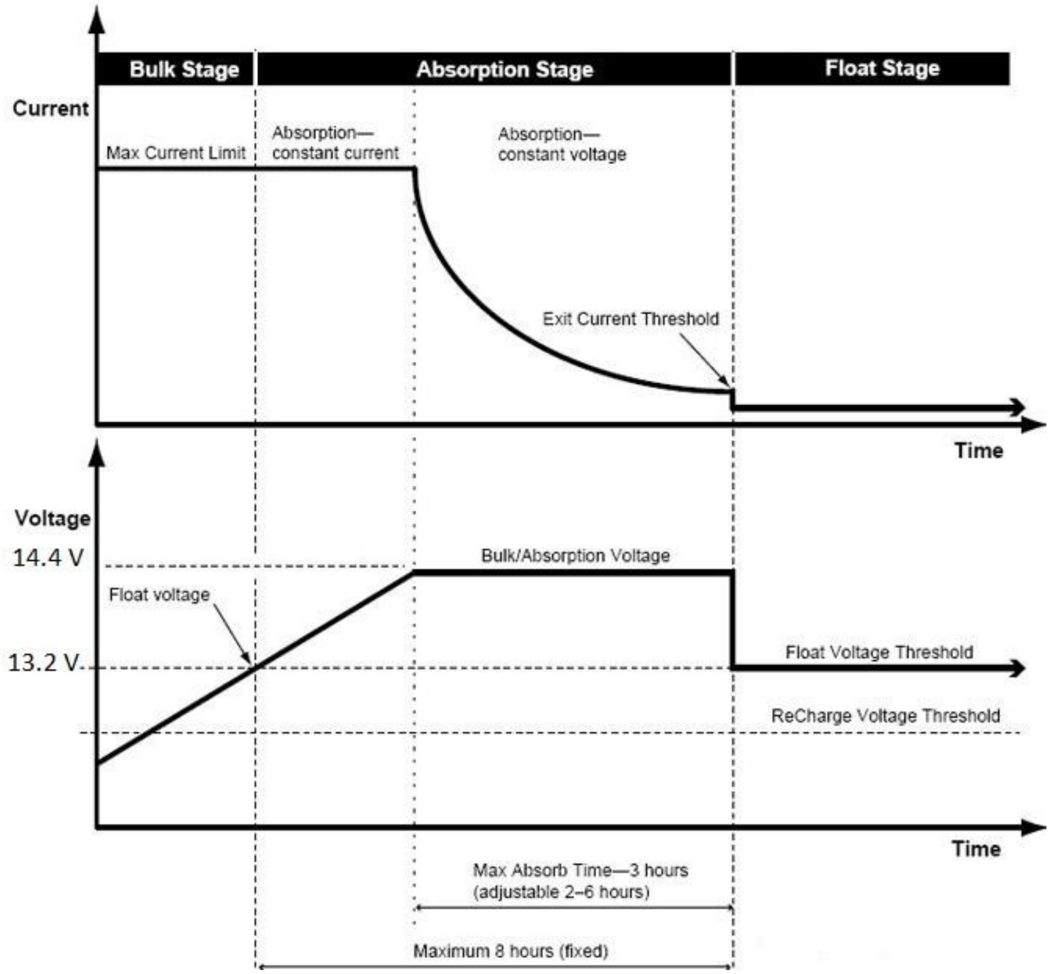


Figure 4.4: The 3 charging states in the battery

We have used MCU's Pulse Width Modulation (PWM) function to incorporate the three stage charging process of our battery. This switching method effectively controls the flow of charge between our variables. The MCU program is such that, if the supply has ADC equivalent of 15-20v then the charging should start provided the battery is at less than 14.4v. If our battery is at 11-14v the PWM will be at 90% duty cycle, that is, the switch would be 'ON'/ HIGH 90% of the time period. Accordingly, if the battery is at 14-14.2v then the PWM is set at 70% duty cycle and if the battery is 14.2 -14.4 then the PWM is set at 10% duty cycle. For the switching or PMW function we used pin no:13/ PMW1/CCP1 which connected to a BJT BC548 via a 100k resistor. The collector of this npn transistor is directly connected to the gate of a parallel network of P- channel MOSFET- IRF9540. This MOSFET is our main hardware – main switch controlling the actual transfer of charge from supply to the battery. The positive terminals of the two supplies are connected to the sources of the MOSFETs via a network of 6A fuse, 24Vzener diode and

10A schotky diode. The schotky diode basically stops the flow of charge among the two sources. The drains of the MOSFETs are directly connected to the battery; and the in each of the MOSFETs the source and the gate have a resistance of 10k between them providing a constant voltage to keep the MOSFET high. When the PWM1 pin of the MCU is high/on the BJT grounds and the collector sends a low signal to the gate which opens the p-channel and allows the charge to flow from the supply to the battery.

DISCHARGING

Our algorithm is designed for charging and discharging simultaneously – so that the user , that is whoever is driving our solar car, can charge the vehicle while on the move. The program allows the system to discharge while the battery is at or above 11v provided that the user has pressed the switch at pin no: 14 which controls the BJT - TIP122 via 10k resistor, which in turn powers the relay driving the motor. The collector of TIP122 is connected to one end of the relay coil.We have used a 12v dc motor for our prototype of the electric system. The 12v relay is powered by the same 12v battery we have used so far in our prototype. Hence whenever the user controlled switch is pressed, the signal passes to the BJT and grounds it powering up the relay coil that switches and turns the motor ON.

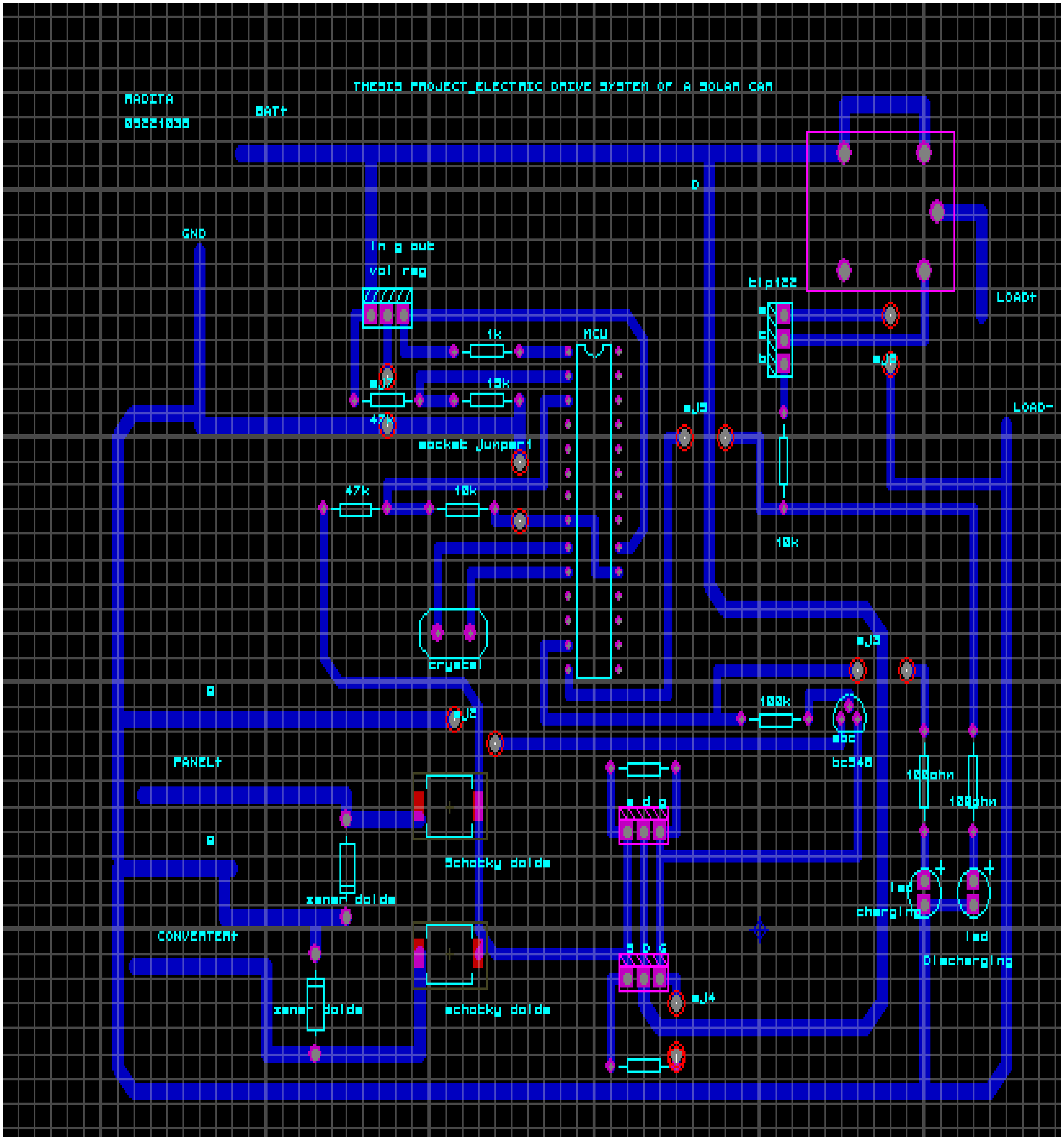


Fig. 4.5 PCB layout design of the Charge Controller Circuit

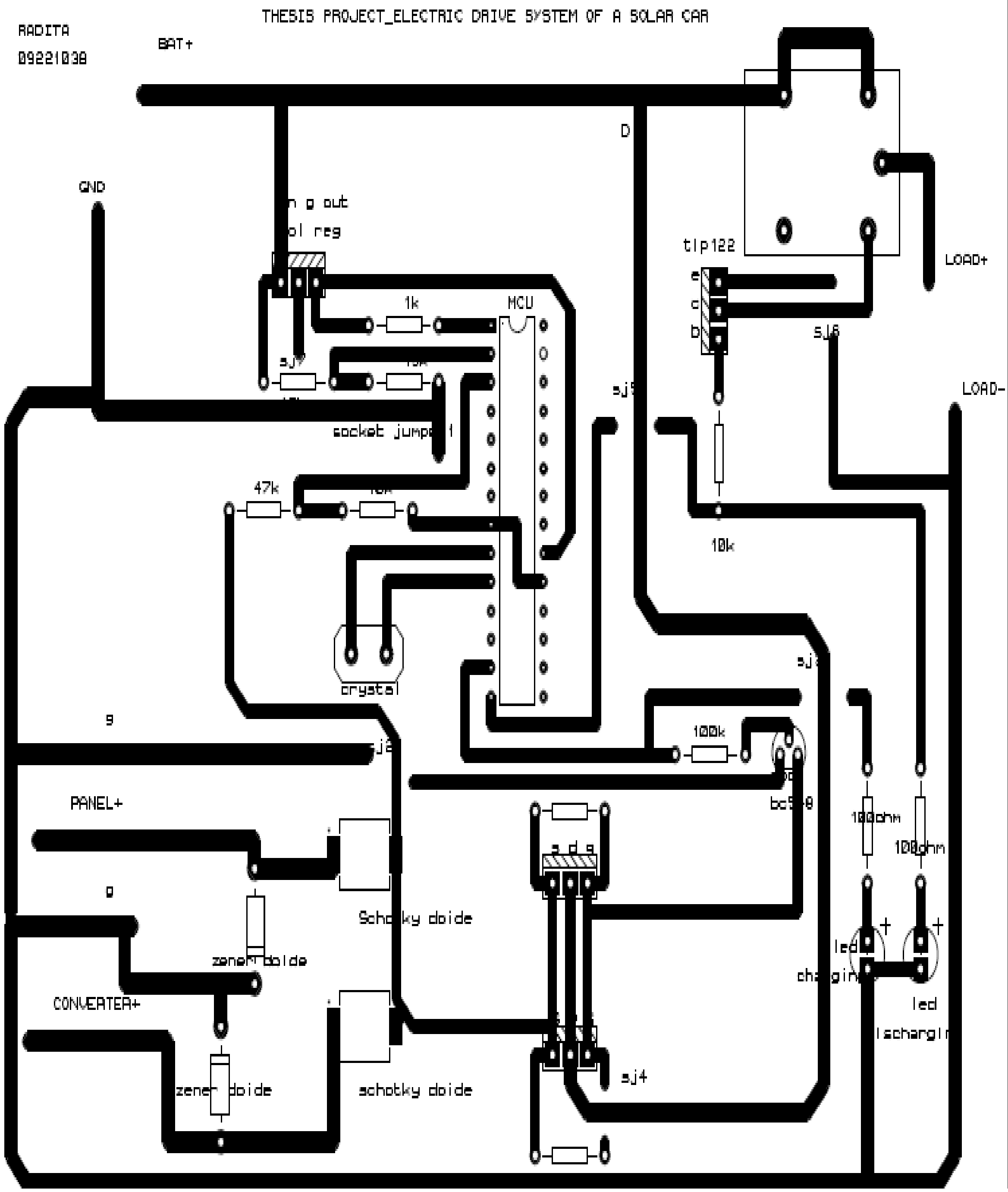


Fig.4.6 PDF of Bottom Copper PCB.

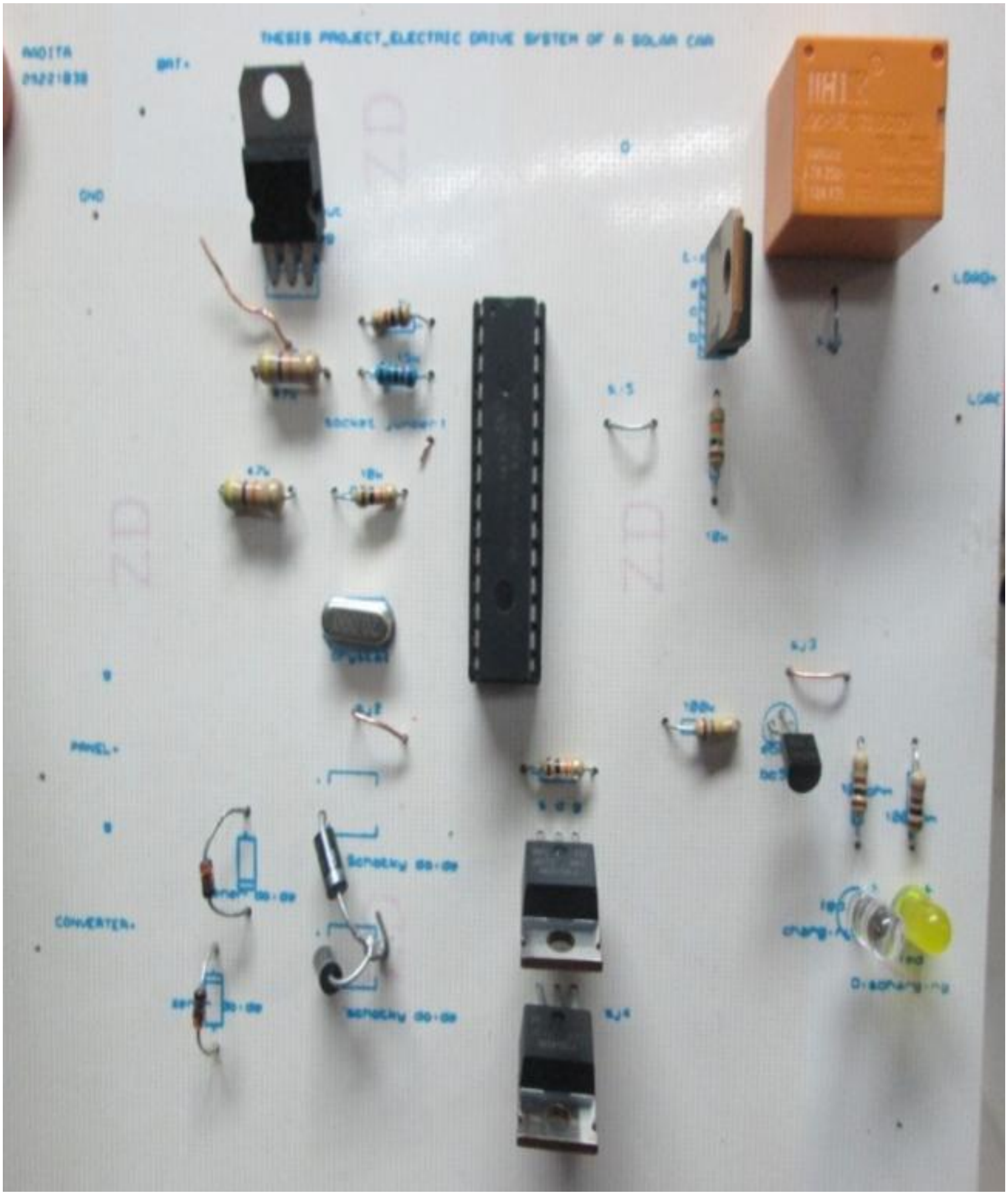
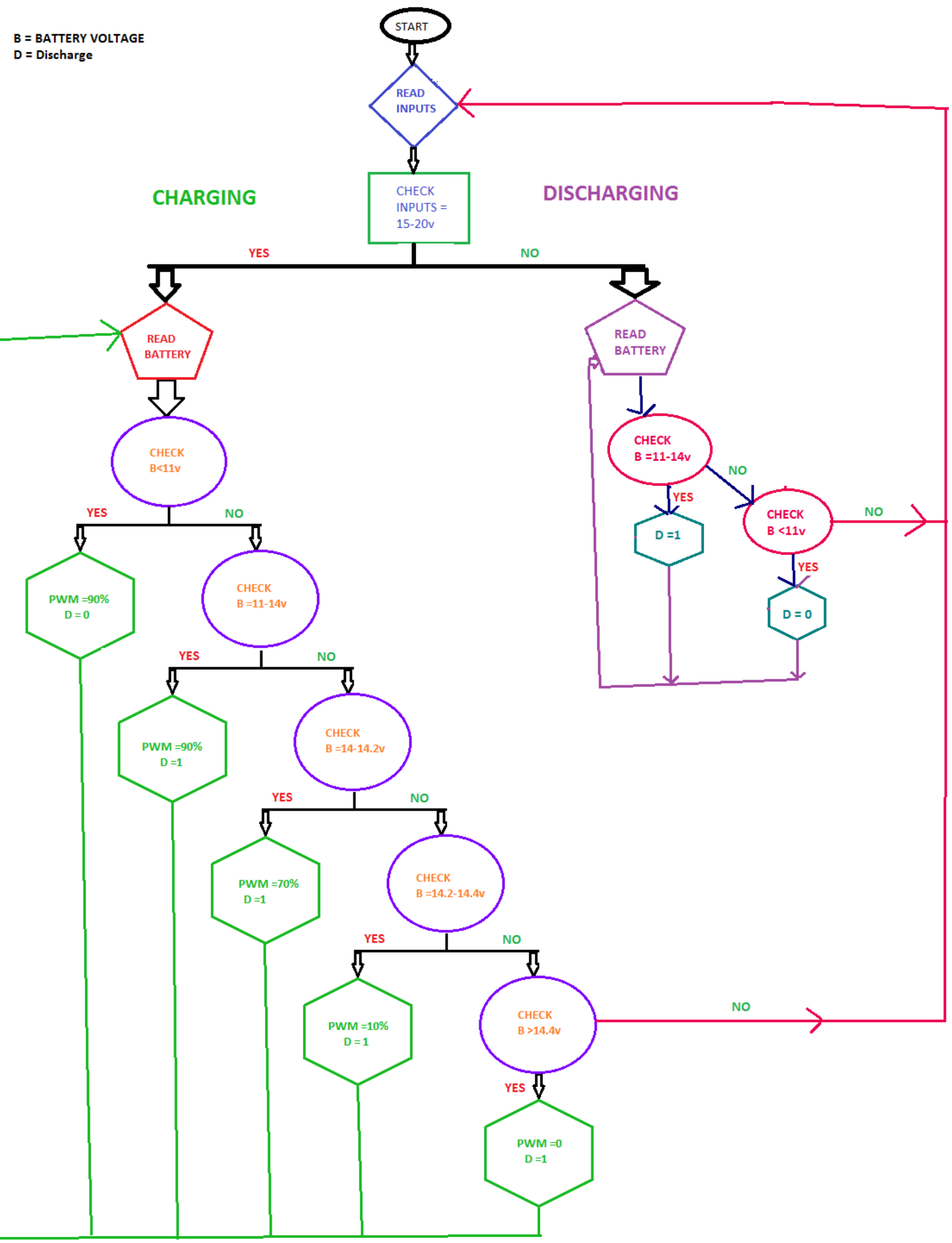


Fig.4.7 Complete Charge Controller Circuit.

FULL FLOWCHART OF THE ALGORITHM FOR CHARGE CONTROLLER CIRCUIT



4.3 Motor Controller implemented through Hardware

This project involves both hardware and software parts. For hardware implementation, Hub motor is chosen for availability which is driven by 24V supply voltage. The speed of the hub motor is controlled using microcontroller PIC16F876A. For controlling the speed in real, PIC microcontroller has been used along with PWM technique for controlling the speed of the DC motor. The block diagram of the whole system to control the speed of the motor is given below-

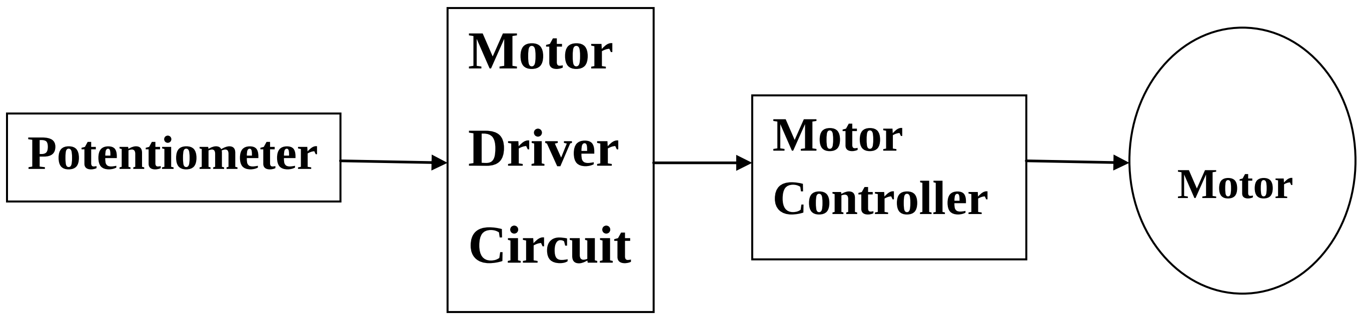


Figure 4.7: Block Diagram of the whole system for motor controlling

In this thesis project, the PIC microcontroller is programmed to execute a desired algorithm to implement the driver circuit of the motor. The program will control speed of the motor by sensing the variable voltages using ADC checker coming from potentiometer. After that by simply varying the input voltage, the speed of the motor can be controlled using PWM. Additionally, through the algorithm, result analysis and graphical representation will be shown to monitor the performance of the system.

4.3.1 Microcontroller

Microcontrollers are programmable compact integrated circuits used in embedded systems that prefer for intelligence. PIC16F876A microcontroller has been utilized for this project consisting 28 pin configurations along with memory of 368 bytes and external programmable memory (EEPROM) of 256 bytes. There are some important ports in the microcontroller used for this project which are Analog to Digital Converter (ADC) checker pin and Pulse Width Modulation

(PWM) pin. For basic connection 5V is supplied at pin 20 and pin 8 and pin19 are grounded which are actually configured as default in mikroC PRO for PIC software. Moreover, we used 20 MHz for crystal oscillator and RESET (pin 1) pin is supplied with 5V.

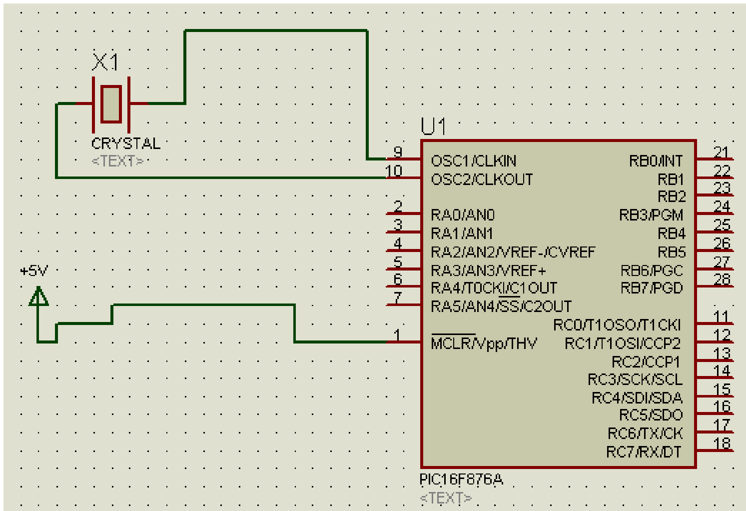


Figure: 4.8 RESET (pin1) supplied with 5V and Crystal Oscillator connected to pin 9 and 10

4.3.2 Analog to Digital Converter (ADC)

A microcontroller is a digital device which can read, execute and transmit only digital signals. Differently, the outputs of the most of the transducers are analog in nature. That is why it is tough to interface these transducers directly with controllers. Analog-to-digital convertor (ADC) checkers in ICs make it possible to create compatibility between the analog input and the microcontroller.

In the microcontroller built-in ADC checkers are present which are responsible for the conversion of analog to digital values. The ADCON registers is needed to be configured with assignment of a required value to enable the ADC checker pin to begin. AN2 pin is used as ADC checker for hardware implementation.

A Potentiometer (POT) has been utilized for supplying variable input voltage according which speed would be controlled. Among the three pins of the POT, the variable pin of the POT is connected with the AN2 pin of the PIC and the other two pins are connected with 5V supply and ground respectively. The analog inputs are divided into 1024 quantized levels by the ADC checkers which are counted from 0 to 1023 where 0 represents 0V input and 1023 represents 5V input. Thus from the POT voltage sensing is achieved.

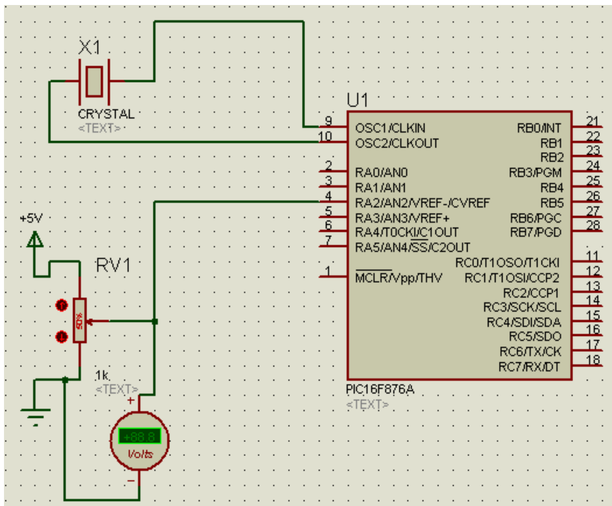


Figure: 4.9 Voltage sensing circuit diagram

4.3.3 Pulse Width Modulation (PWM):

PIC16F876A consists of two PWM pin-one is CCP1 (pin 13) and another is CCP2 (pin 12) which are known as CCP channels configured to perform capture, compare or PWM function. The output is achieved from the CCP1 (pin 13) because Pulse width Modulation (PWM) which is an effective technique used in control system are highly recommended for speed control.

By configuring the CCP1 pin as a PWM function in the code, the CCP module becomes programmed to generate a waveform with a certain frequency and duty cycle. Mostly important thing is this function is often used in motor control and some other applications.

In our algorithm, we set the PWM frequency as 20 kHz which is appropriate for Hub motor and CCP1 is declared as the PWM pin. The duty cycle changes with the voltage sensed in the ADC checker pin which is happened through a relation.

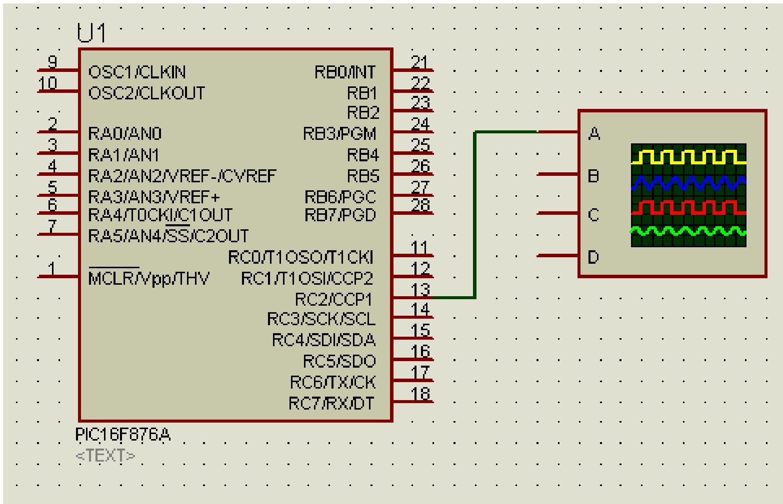


Figure: 4.10 Digital Oscilloscope connected with the CCP1 pin

4.3.4 Software used for Simulation and Programming

For software part, MikroC PRO for PIC has been used for writing the code. It is necessary to have the knowledge of programming to implement the software. The algorithm that is used is written using C# programming language on an interface known as MikroC PRO. The program built generates a “.hex” file which is burned onto the microcontroller by means of a lock burner.

The other software that have been used are ISIS Professional more commonly known as Proteus for simulation and MATLAB R2010a for Matlab coding and graphical representation.

4.3.5 The Complete Circuit Diagram

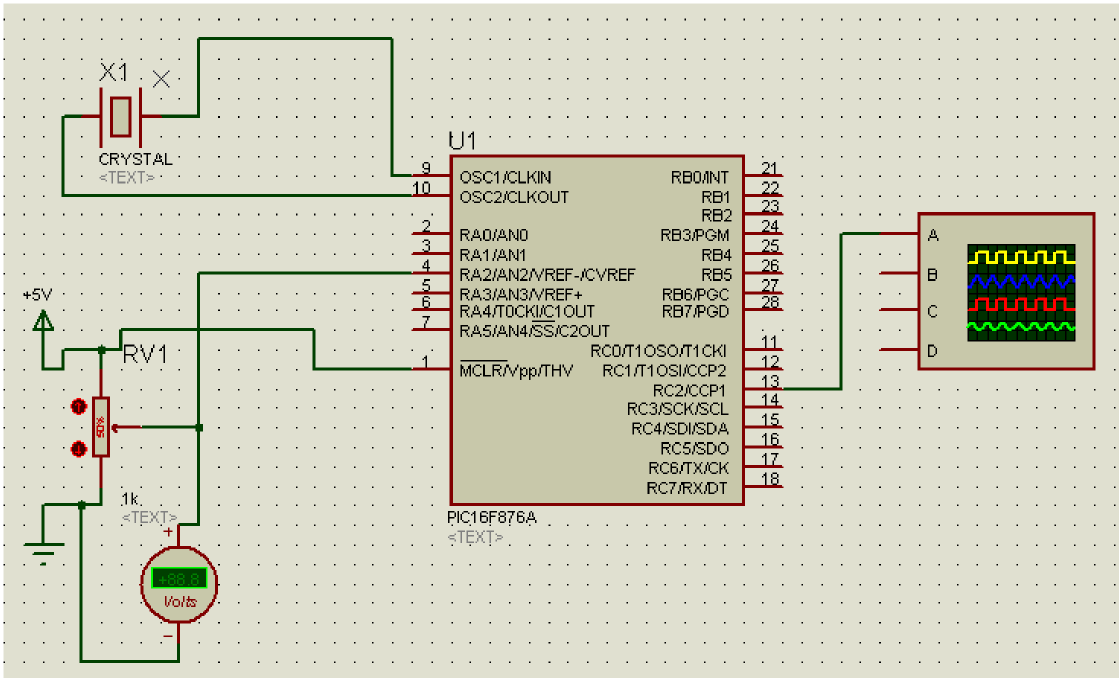


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Figure: 4.11 The schematic circuit diagram of the speed control system

Figure 1.4 shows the complete circuit diagram designed for control the speed of the motor. Input voltage is sensed by the activating the AN2 pin which is one of the ADC checker pins. After activating the CCP1 pin with a proper frequency it will be activated. Finally according to the code the duty cycle is set by a relation through which we get the output from CCP1 pin. The output is variable with the changes in the supply voltage coming from the pot. Thus speed control is achieved.

4.3.6 Motor Controller Circuit Implemented in Breadboard

Reset (pin 1), pin 20 and one side pin of the POT are connected with 5V supply. On the contrary pin 8, 19 and other side pin are connected to the Ground. ADC (pin 4) checker pin is connected with the middle pin which is the variable pin of the POT. For the output a wire is brought out from CCP1 (pin 13) which will go to the motor controller. There are connections between the motor controller and the motor.

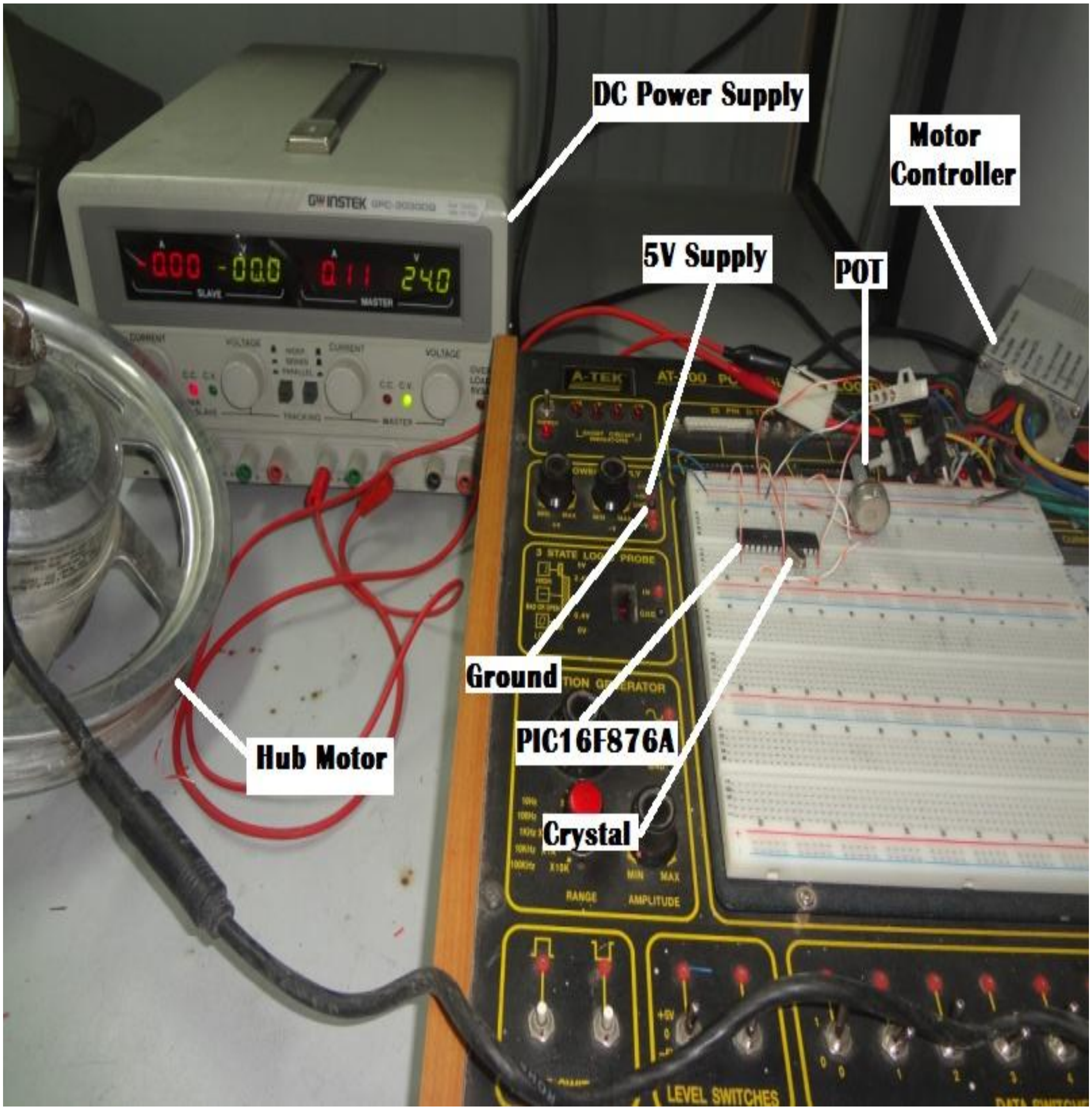


Figure: 4.12 Circuit implemented in Breadboard

4.3.7 Motor Controller Circuit Implemented in PCB

Printed Circuit Board (PCB) circuit was designed using Proteus Ares software. Basically, the copper side and component side of PCB have to be designed for both the software and hardware. Our software designs for PCB are given below-

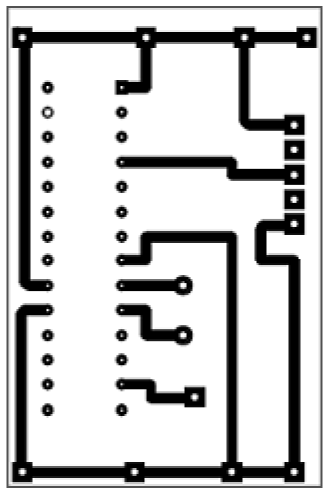


Figure: 4.13 Copper side design for PCB

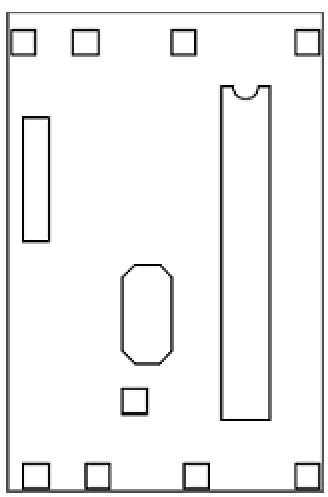


Figure: 4.14 Component side design for PCB

PCB connections are same as those of the breadboard but we have to solder the PCB circuit. We need PCB circuit for permanent use. Breadboard is not a good option for practical implementation of a circuit. That is why it is very important to make a PCB circuit. The hardware design for the PCB circuit and the overall circuit implemented through PCB are given below-

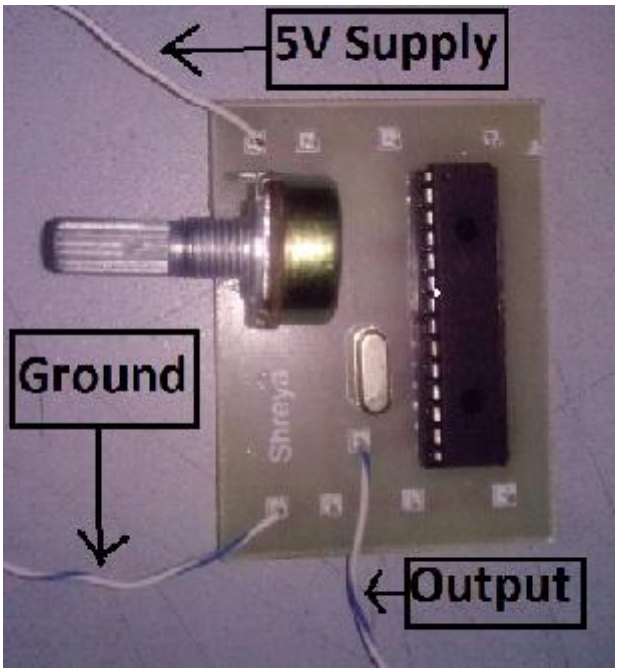


Figure: 4.15 Final PCB design for hardware implementation

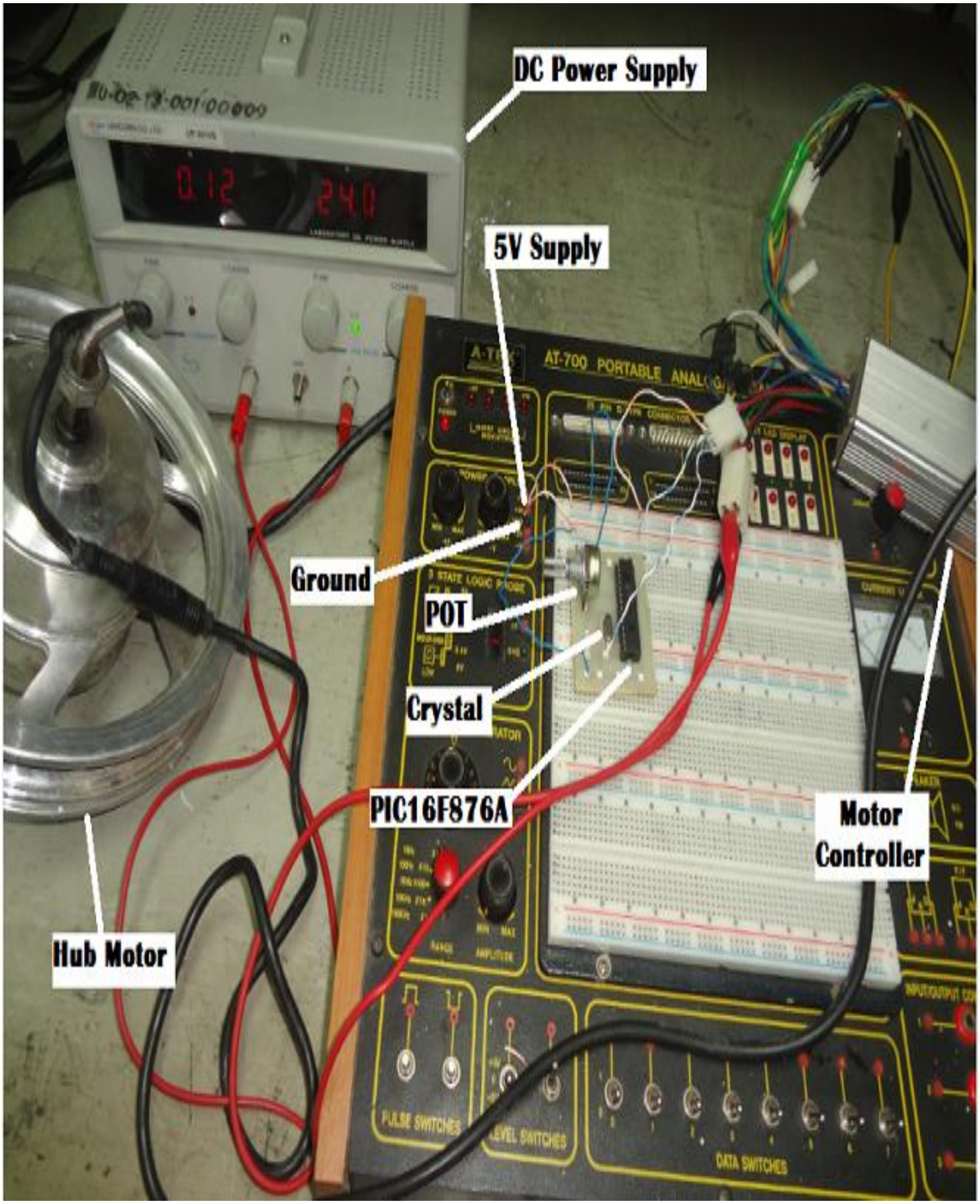
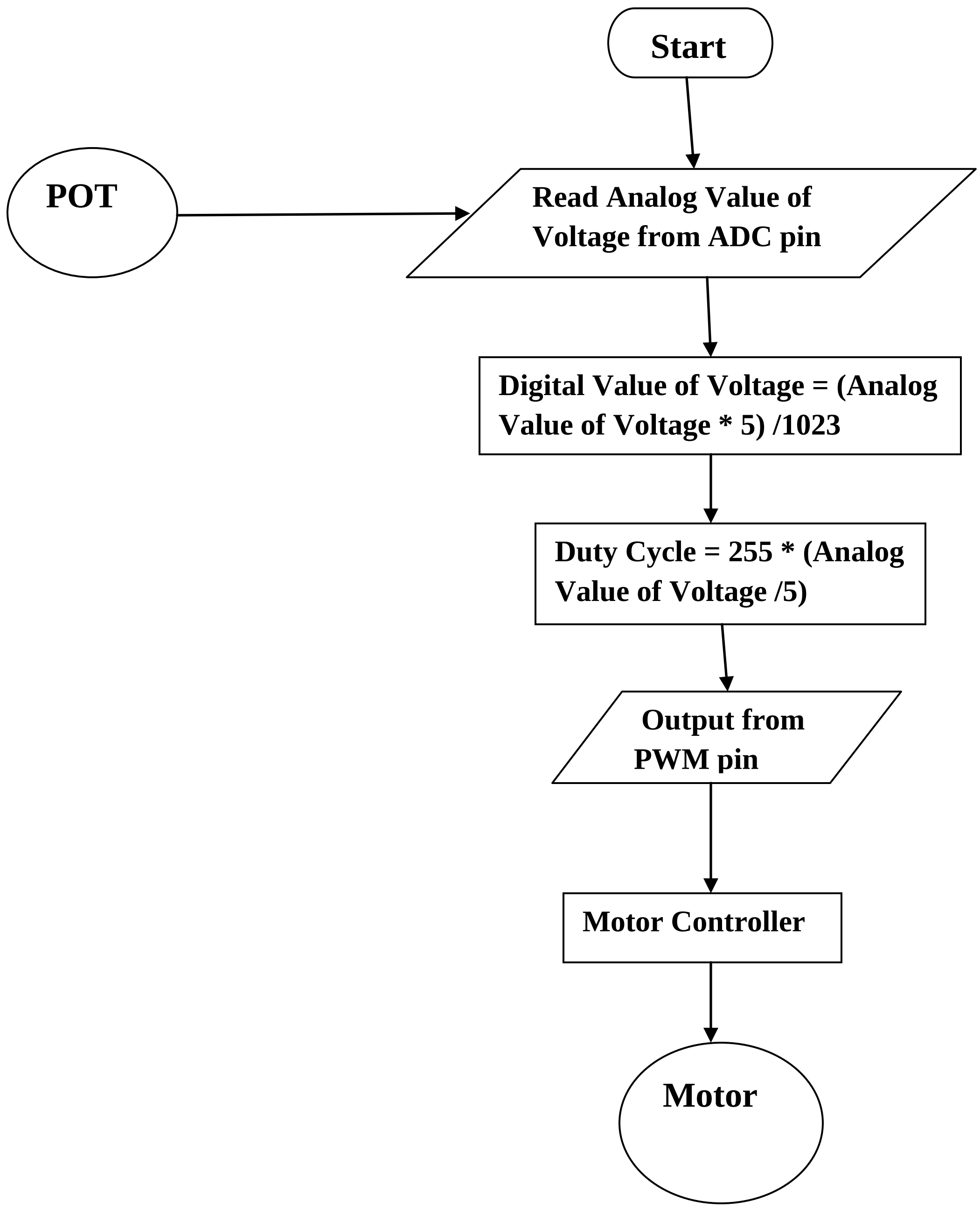


Figure: 4.16 Circuit implemented in PCB

4.3.8 Flowchart for Motor Controller



A variable resistor (Potentiometer) provides a voltage input to the ADC pin of the PIC which is converted to a digital value using the Analogue to Digital convertor; this in turn is used to set the PWM duty cycle. Since the PWM duty cycle is adjusted using a voltage signal input to the PIC it is possible to control of the duty cycle. In the original version of this project the input from the Analogue to Digital Converter (ADC) was fed directly to the duty cycle register of the PWM module on the PIC, therefore the PWM output duty changed linearly in direct proportion to the change in input voltage to the ADC; much the same as an analogue PWM. The switch input allowed the PWM period to be selected as 20 KHz. Finally, the output is derived from the PWM pin.

4.3.9 Results Analysis

For analysis the result if the speed of motor is controlled or not, a tabular form including data and a graphical representation of Output Voltage in terms of Volt vs. Value of Potentiometer (POT) in term of Kilo-Ohm are shown.

POT (Kilo-Ohm)	Output Voltage (V)
0	3.97
20	3.91
40	3.85
60	3.82
80	3.79
100	3.77
120	3.75
140	3.73
160	3.71
180	3.69
200	3.65

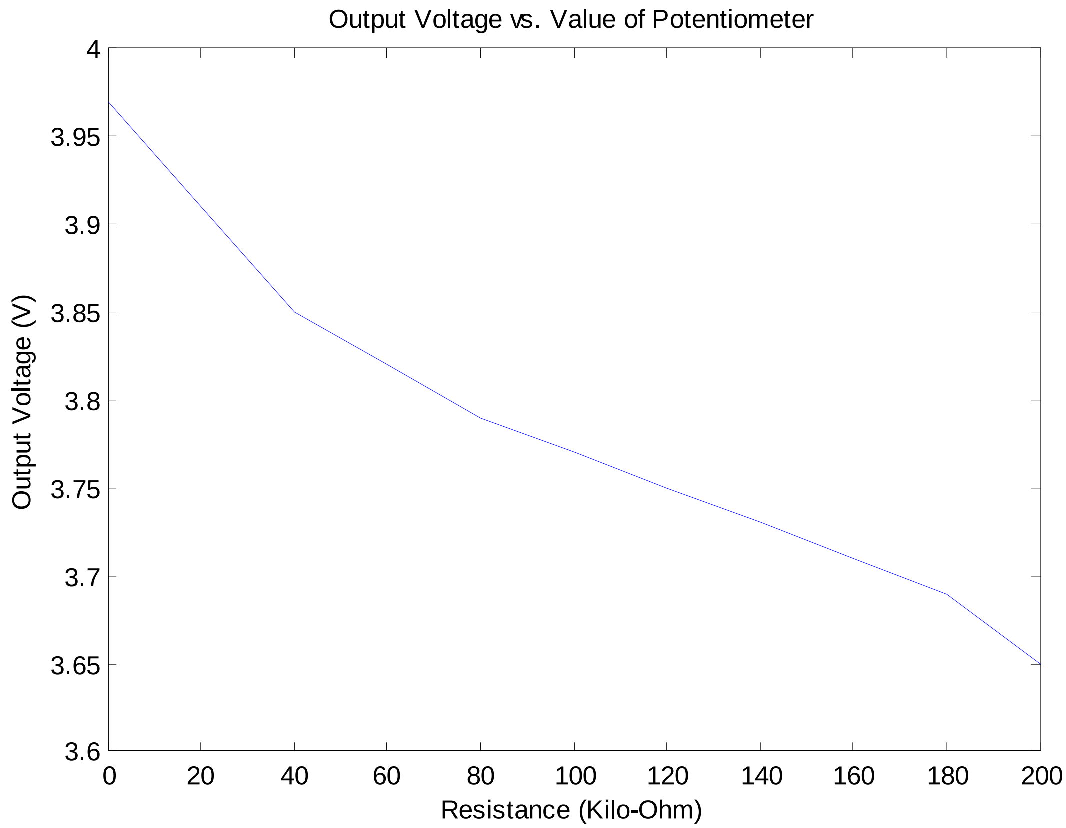


Figure 4.17: Output Voltage vs. Potentiometer

The tabular from shows that with the increasing of the resistance of the POT, output voltage decreases which is also presented by graphical illustration. As, it is known that PWM technique varies the voltage, it can be said that with the variation of the voltage, speed will be changeable. Therefore, a conclusion can be made up that PWM technique worked.

CHAPTER 5

CONCLUSION

The solar powered car driving system is an energy efficient system in many ways. Firstly, the use of solar energy as the power source instead of using petroleum power saves huge amount of energy, since the former source is free, infinite and non-renewable. A solar car is powered by an electric motor where there is petrol/diesel engines are used in gasoline vehicle. They have only half the initial cost of a gasoline vehicle. The power of solar vehicle is less than gasoline vehicle. But it is impossible to find out the difference among them while driving. While gasoline vehicle have a heavy noise and pollute the air, electric vehicle are smooth and silent and also have on pollution emits while driving. The idea of solar vehicle is new. The components of solar car are DC electric motors, Electric controller, Battery tray, 12V Lead acid batteries, Battery Charger and Many motors for driving smaller parts

From our thesis project we can come up to some certain observation. They are given below:

- 3 stage charge controlling varied by PWM which is charging the battery.
- The charge controller is providing the proper output voltage so that the relay is working.
- The converter is providing the adequate voltage & current to the battery through charge controller.
- Discharging the battery to run the motor through charge controller.
- Motor driver circuit controlling the speed

From these observations we get a clear picture of having a driver circuit of a car which can be powered by solar successfully.

Limitation

Our main objective was to build a charge controller & motor driver circuit for a 60v motor. But we do not have 60v battery. That's why we cannot check & implement a charge controller circuit for 60 v battery. That's why we build our circuit for 12 v battery by which we charge & discharge the battery successfully.

As hub is also categorized as the DC motor, therefore, to further implementation with the DC series excitation motor we need be familiar about problems encountered in the Hub motor experiment and according to which necessary modifications will be needed.

We are successful in hardware implementation using both breadboard and PCB to control the speed of the HUB. The drawback was the CCP1 pin which sometimes did not work properly and because of that we attempted many times and finally circuit worked. Another weakness was that with the increase in the load speed of the motor reduces. So it is suggested that series DC motor must be loaded before starting it.

Future improvement

Since our 12v charge controller & 24v motor driver circuit are working properly, in future we want to develop our charge controller & motor driver circuit for 60v motor which we can imply in a solar car with two passengers. We also want to control the mechanical movement of our solar car by using micro controller. So far our motor can rotate only in forward & backward direction. In future we want to build a motor driver circuit which will able the car to move as the driver's wish. The driver will control the movement & speed of the solar car.

We also want to make a suitable body and chassis for our solar car. It will also have advanced suspension and breaking system. The car will be making comfortable enough for the user.

So, finally we hope in the near future a great percentage of our country's people will use the discussed technology & it will be a successful project.

Appendiex

FULL ALGORITHM

To program our algorithm we have used MikroC complier which basically runs C programs.

```
void main() {
unsigned int p,b,in;                    //p = panel voltage & b = battery voltage
z
                                        // a= load flag & c = battery flag =RC0
adc_init();
TRISB = 0b00000000;
TRISC = 0b00000000;
pwm1_init(5000);
  while(1)
  {
pwm1_start();
            // CHARGING ALGORITH STARTS FROM HERE
            p = Adc_read(1);
            if (p>=546 && p<=729){          // ADC Values of panel voltage corresponding to 20V - 15V
            b = Adc_read(0);
            if(b<542){              //<11v
            pwm1_set_duty(242);
             RC3_bit=0;
            Delay_ms(500);
            }
                            // LED indicator for charging
```

```
 else if( b>=542 && b<=690  ){          // ADC values of Battery Voltage within 11v-14v, corresponds to charging of the battery to 95% of duty cycle(BULK)

               pwm1_set_duty(242);


                  RC3_bit=1;

               Delay_ms(500);

}

  else if(b>=690 && b<=700){      // ADC values of Battery Voltage within 14 - 14.2V, corresponds to charging of the battery to 70% of duty cycle(ABSORPTION)

               pwm1_set_duty(178);

               RC3_bit=1;

               Delay_ms(500);

}

 else if(b>=700 && b<=710){      // ADC values of Battery Voltage within 14.2 - 14.4V, corresponds to charging of the battery to 10% of duty cycle(FLOAT)

               pwm1_set_duty(26);

               RC3_bit=1;

               Delay_ms(500);

}

   else if(b>710){


                 RC3_bit=1;

               pwm1_set_duty(0);

               Delay_ms(500);

}}

       in= Adc_read(2) ;
```

```
if(in>=546 && in<=729){              // ADC Valu

                // ADC Values of inverter voltage corresponding to 15V - 20V


b = Adc_read(0);

if(b<542){                    //<11v

pwm1_set_duty(242);

 RC3_bit=0;

Delay_ms(500);

}


 else if( b>=542 && b<=690  ){          // ADC values of Battery Voltage within 11v-14v, corresponds to
charging of the battery to 95% of duty cycle(BULK)

pwm1_set_duty(242);

    RC3_bit=1;

Delay_ms(500);

}                         // LED indicator for charging


else if(b>=690 && b<=700){      // ADC values of Battery Voltage within 14 - 14.2V,
corresponds to charging of the battery to 70% of duty cycle(ABSORPTION)

pwm1_set_duty(178);

 RC3_bit=1;

Delay_ms(500);

}

else if(b>=700 && b<=710 && RC0_bit == 0){      // ADC values of Battery Voltage within 14.2 -
14.4V, corresponds to charging of the battery to 10% of duty cycle(FLOAT)

pwm1_set_duty(26);
```

```
                 RC3_bit=1;
                 Delay_ms(500);
}
                 else if(b>710){
               pwm1_set_duty(0);
                RC3_bit=1;
               Delay_ms(500);
}      }
                 else {
                    b= Adc_read(0); //discharge
 if(b>=690){              //14v start
 RB2_bit=1;          //a=loadflag
      }
 if(b>=542 && b<690){                        //  14v to 11v
 RC3_bit=1;
 RB2_bit=1;       //load connect
   }
 if(b<542) {
     RC3_bit=0;
              }
                Delay_ms(500);
                                   }}}
```

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