DESIGNING SMART CHARGE CONTROLLER FOR THE SOLAR BATTERY CHARGING STATION (SBCS)

Submitted to
Dr. AKM Abdul Malek Azad
Associate Professor, Department of EEE
BRAC University

Submitted by

Marufa Ferdausi
09310014
Department of Electrical and Electronics Engineering

BRAC University, Dhaka, Bangladesh

DECLARATION

I hereby declare that this thesis report has been written based only on the works and results found by me. Material of the works or research or thesis by other researchers are mentioned by their references. This thesis, neither in whole nor in part, has been previously submitted for any degree.

Signature of Supervisor

Signature of Author

ACKNOWLEDGEMENTS

I am very thankful to our thesis coordinator Dr. AKM Abdul Malek Azad, Associate Professor, Department of Electrical and Electronic Engineering, BRAC University for guiding me throughout our thesis work. Special thanks for helping by giving appropriate advice with the system devices, system designing, circuit works and other documentation. Special regards to our project engineer, Mr. Tahsin Faraaz for being with me throughout the whole thesis period with his extreme hard works and fantastic ideas.

ABSTRACT

Solar panels-the vital element of this SBCS makes use of exhausted energy. Compared to all other energy solar energy is abundant and free that can be used to charge batteries used for any module or electrical kits which are obvious for daily usage.

The Smart Charge Controller will be designed such, so that the solar battery does not get over charged thereby ensuring no reduction of durability of the battery. This kind of system requires sensors to sense whether the battery is fully charged or not. After fully charged, detection safety can be achieved by designing a logic system in the charger, which will automatically disconnect or cut power to the battery when it is fully charged.

When the solar batteries come into account, they get charged in a very short time period considering of the solar/sun/light hours per day, which is 5 hours in Bangladesh; wheras Diesel Battery Charging Stations (DBCS) take 1-2 days.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

CHAPTER 1

INTRODUCTION

Solar Energy, radiation produced by nuclear fusion reactions deep in the Sun's core The Sun provides almost all the heat and light Earth receives and therefore sustains every living being. Bangladesh being a country being concerned about environmental problems, sustainable energy sources is becoming more and more popular here. Solar energy can be converted to electricity directly by SHS systems. Flow of converted electricity from PV is determined by charge controller. An efficient charge controller can be used to do the battery charging and discharging process faster and better. The existing electric grids are not capable of supplying the electric need. Thus the Solar Battery Charging Station (SBCS) is a new project that has emerged to the rural Bangladesh as well as in urban areas to change the scenario. Now, the required manpower and economic problem is less.

The smart charge controller is designed with a view to decrease the battery charging time, making it capable of charging more than one battery at a time and getting the desired current from the PV panel.

Central Solar Battery Charging Station (CSBCS) provides power to trickle charging of batteries from stand-alone solar panels. People bring own their batteries or rent from the station for recharging up to a specific voltage level-which is monitored by the newly developed software dedicated for this project. CSBCS was initially conceived worldwide to bring the price per household of electrification within the capacity to pay of the rural poor, and to foster the establishment of community businesses supplying the modest electricity demands of end users far from the grid in an entrepreneur-based electrification model.

Considering the raising needs for electricity, Bangladesh strains solar energy as backup for electricity generation to enhance the shortage of power which the national grid is unable to provide. Moreover our poverty corrupted rural area faces the toughest criterions for crisis of electricity. Therefore, our aim is to make solar energy popular as one of the best renewable energy sources among our people by implementing Central Solar Battery Charging Station with a view to provide supplementary electricity. Resultantly, more and more people are now using solar energy as their main source of electricity. Using compound solar cells, solar panels manage to trap huge amounts of energy every single day. When the solar batteries come into account, they get charged in a very short time period considering of the solar/sun/light hours per day, which is 5 hours in Bangladesh; whereas Diesel Battery Charging Stations (DBCS) take 1-2 days.[1]The electricity is instantaneously converted and then stored in the charging station which is consumed by the batteries. If the panels produce power which is not required instantly, customers can at rest get hold of that energy in the outlook, whenever they oblige it. People whoever looking for savings and the future of the planet should indeed look into solar energy.

1.1 BACKGROUND

Crisis of electricity is a major problem in the present era. This problem is even more critical for a densely populated poverty corrupted developing third world country like ours. Many of our people live here without the basic facility of electricity. In some area outside the city side, there is general electricity service called 'PALLI BIDYUT' which can supply a very limited amount of electricity in those area that is unable cover up the basic demand of people from those area. Day by day crisis of electricity is increasing whereas no other solution is left for us without using the solar power or wind turbine to generate electricity. Again, not only we face electricity crisis but also day by the cost of gas and other natural resources like fuel, diesel , petroleum etc are rising up that is going beyond the availably of general people. Thereby such a system that can not only reduce the electricity crisis but also the crisis of petroleum or other natural resources for driving vehicles is desirable.
We have designed a whole Central Solar Battery Charging Station (CSBCS) along with the successful implementation of hardware and software to represent all activities not only visually but also can be monitored and controlled from remote region. Implementation of SBCS for also includes designing of a smart charge controller with a view to decrease the battery charging time, making it capable of charging more than one battery at a time and getting the desired current from the load.

1.2 MOTIVATION

Ours is a tropical country where the amount of sunlight is mostly available to meet up the demand of producing electricity. This type of project is not new but for our country of this can be implemented successfully for commercial purpose, it can bring a revolutionary change in the lifestyle and the economical prospectus that also can increase the GDP of Bangladesh. As ours is a massively power-deficient country with peak power shortages of around 25%. More than 60% of its people do not have access to the power grid. The country only produces 3500-4200 MW of electricity against a daily demand for 4000-5200 MW on average, according to official estimates. Solar energy is an ideal solution as it can provide griddles power and is totally clean in terms of pollution and health hazards. Since it saves money on constructing electricity transmission lines, it's economical as well. The solar panel providers in Bangladesh are now expecting the price of batteries and accessories to drastically reduce. Moreover, after the current budget of 2012 the price for per unit electricity will be amplified more. It is flattering tougher for ordinary mass to cope up with the mounting price of per unit electricity of PDB. So the best alternative is to development of SBCS in our country effectively.

Considering all these we are motivated to do this project as it will help our people in several ways. Our people are not too much efficient in monitoring. We can make use of software available too. Through monitoring we can control our system from remote areas thereby efficiently that paves us to do the development of software implementation thereby.

1.3 OBJECTIVE

1) We can charge the batteries used in solar home system or in IPS in our station and our well developed monitoring software will save the batteries from further destructions caused by the system.
2) Our charging station can be used to charge any battery including Rickshaw battery or batteries used in Solar Home System either in rental or in monthly payment basis.
3) Electric lanterns used in village area can be charged as well.

4) First objective of this thesis is to identify reasons for the failures of existing charge control algorithms that utilize existing technologies.

5) The next goal of the thesis is to create new charge control algorithms that will overcome the issue of false detection while protecting the battery from repetitive overcharges. We present a new voltage based charge control algorithm.

6) Ways to increase the charging speed are critical in this application as well as in most of other applications since portable solar panel generally have low power production per square meter. So, this research also develops ways to optimize solar panels' output power while charging the batteries.

7) Our software is able to eliminate costs.

8) Followed by some other countries we can also replace kerosene station with Solar Battery Charging Station too with further modification.

1.4 THESIS OUTLINE

This Photovoltaic Charge Controller final thesis is arranged into following chapter:

Chapter 2: Literature reviews of this project based on journals and other references.

Chapter 3: Methodologies for the development of Photovoltaic Charge Controller. Details on the progress of the project are explained in this chapter.

Chapter 4: The algorithm of the Charge Controller circuit and the code implemented in the microcontroller.

Chapter 5: Simulation and the whole system result.

Chapter 6: Design of the hardware and software of the prototype poject.

Chapter 7: The interfacing between the two groups.

Chapter 8: Results obtained and the limitation of the project. Discussions are concentrating on the result and performance of Photovoltaic Charge Controller.

Chapter 9: Concludes overall about the project. Obstacle faces and future recommendation are also discussed in this chapter.

CHAPTER 2

PROJECT OVERVIEW

2.1 PV PANEL

In a photovoltaic cell, light excites electrons to move from one layer to another through semi-conductive silicon materials. This produces an electric current.

Solar cells called photovoltaics made from thin slices of crystalline silicon, gallium arsenide, or other semiconductor materials convert solar radiation directly into electricity. Cells with conversion efficiencies greater than 30 percent are now available. By connecting large numbers of these cells into modules, the cost of photovoltaic electricity has been reduced to 20 to 30 cents per kilowatt-hour. Americans currently pay 6 to 7 cents per kilowatt-hour for conventionally generated electricity.

The simplest solar cells provide small amounts of power for watches and calculators. More complex systems can provide electricity to houses and electric grids. Usually though, solar cells provide low power to remote, unattended devices such as buoys, weather and communication satellites, and equipment aboard spacecraft.

2.2 CHARGE CONTROLLER

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life. The terms "charge controller" or "charge regulator" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery recharger.

Charge controllers are sold to consumers as separate devices, often in conjunction with solar or wind power generators, for uses such as RV, boat, and off-the-grid home battery storage systems. In solar applications, charge controllers may also be called solar regulators.

A series charge controller or series regulator disables further current flow into batteries when they are full. A shunt charge controller or shunt regulator diverts excess electricity to an auxiliary or "shunt" load, such as an electric water heater, when batteries are full.

Simple charge controllers stop charging a battery when they exceed a set high voltage level, and re-enable charging when battery voltage drops back below that level. Pulse width modulation (PWM) and maximum power point tracker (MPPT) technologies are more electronically sophisticated, adjusting charging rates depending on the battery's level, to allow charging closer to its maximum capacity. Charge controllers may also monitor battery temperature to prevent overheating. Some charge controller systems also display data, transmit data to remote displays, and data logging to track electric flow over time.

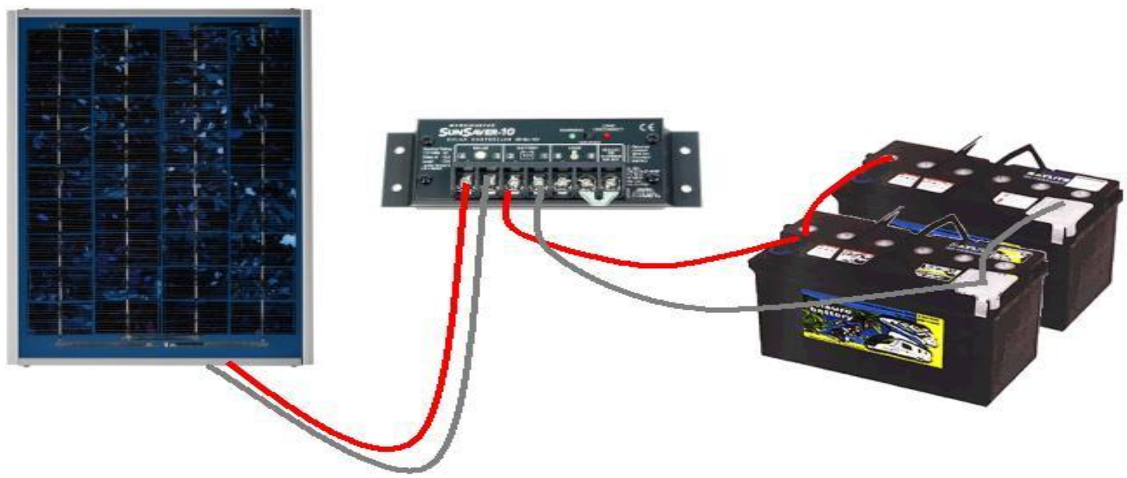


Figure 2.1: Charge controller and battery wiring

2.3 BATTERY

Battery condition and corresponding state of charge that we gathered from reading of formerly used batteries for solar system is used to measure the PWM states. It’s crucial to follow the ratings in our design so that it may work well with batteries from any organization. The following chart represents a clear idea about automotive battery condition that are generally used including charging and discharging both:

STATE OF CHARGE	12 V BATTERY
20%	11.58
30%	11.75
40%	11.9
50%	12.06
60%	12.20
70%	12.32
80%	12.42
90%	12.5
100%	12.7

Table2.1:Battery State of charge

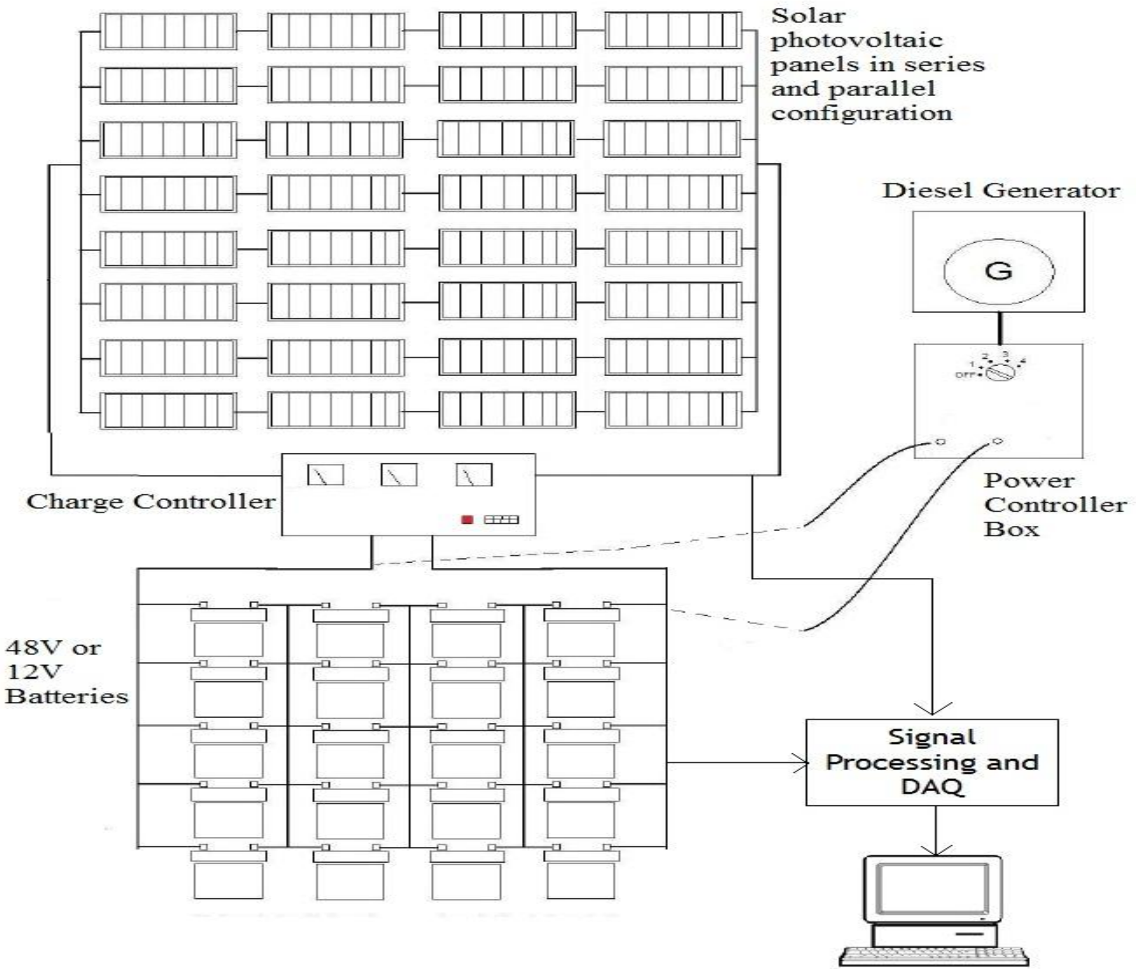


Figure2.2: Standard Model of SBCS

CHAPTER 3

SYSTEM DESCRIPTION

Solar Home System (SHS) generally have a common design and consists of the following components:

1. A PV Generator composed of one or more PV modules, which are interconnected to form a DC power-producing unit.
2. A mechanical support structure for the PV generator.
3. A 12V lead acid battery.
4. A charge controller to prevent deepdischarges and overcharges of the battery
5. Loads (LED lamps)
6. Wire connections (Cable, switches and connection box.)

Our whole project consists of two groups.

1. Hardware Implementation
2. Software Implementation

My project is on the design and implementation of the solar charge controller. For the Solar Battery Charging Station (SBCS), the proposed CARG project has the overall implementation and monitoring system for the Solar Home System (SHS).

Each component of the system must fulfill the quality and requirements. Size, voltage thresholds of the charge contoller, the quality of installation etc directly effects the lifetime of batteries and lamps.

3.1 Solar Panel

The use of the Sun as an alternative means to provide electrical energy has always been around us. Solar Power generation has emerged as one of the most rapidly growing renewable sources of electricity. Photovoltaic is a most elegant energy source. Light shines on a crystal and produces electricity. It is as simple as that. There are no moving parts. The fuel source (sunlight) is free, abundant and widely distributed, available to every country and person in the world. At over 165,000 TW the solar resource dwarfs the world’s current power usage of 16 TW or even our projected future usage of 60 TW. Doing serious battery charging with solar energy isn't that difficult. Actually, the most critical component aside from the solar panel itself - is a solar charge controller, which is available from many manufacturers. This device protects the battery from being overcharged, which can reduce its life. With a charge controller in hand, setting up a photovoltaic battery charging system is really a simple wiring procedure.

3.2 Battery

Solar batteries produce electricity by a photoelectric conversion process. The source of electricity is a photosensitive semiconducting substance such as a silicon crystal to which impurities have been added. When the crystal is struck by light, electrons are dislodged from the surface of the crystal and migrate toward the opposite surface. There they are collected as a current of electricity. Solar batteries have very long lifetimes and are used chiefly in spacecraft as a source of electricity to operate the equipment aboard.

The battery was rechargeable and of lead-acid systems. It should not be overcharged. Otherwise, the battery is completely sealed, maintenance-free and leak proof. It was rated as 12v and 80Ah. It should not be discharged below 80%.

	On Load	Off Load
T	V1	V2
11.3	12.55	12.55
11.45	12.19	12.55
12.15	12.17	12.48
12.45	12.16	12.46
13.15	12.14	12.44
13.45	12.11	12.41
14.15	12.09	12.39
14.45	12.06	12.38
15.15	12.03	12.35
15.45	12.02	12.28
16.15	12.01	12.29
16.45	11.96	12.28
17.15	11.93	12.25
17.45	11.9	12.22
18.15	11.87	12.17
18.45	11.84	12.18
19.15	11.79	12.15
19.45	11.76	12.11
20.15	11.71	12.07
20.45	11.67	12.04
21	11.66	12.04

Table3.1: Battery I-V Characteristics

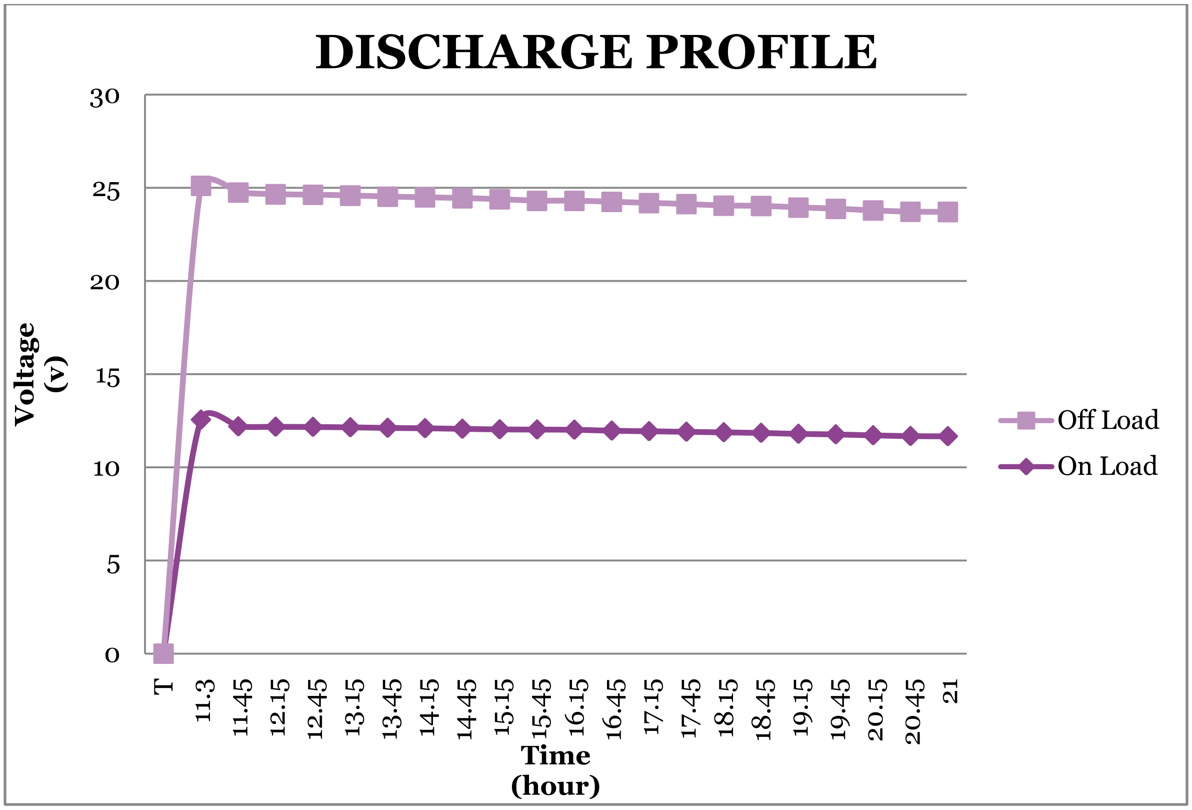


Figure3.1: Battery discharge profile

Very simple basic rules for charging the lead-acid batteries (the voltages mentioned are valid for 6 cell, 12V batteries):

• disconnect the load when the battery voltage decreases below typically 10.5V when loaded,

• it is possible to charge the battery indefinitely (float charging or also called preservation charging), if its voltage is kept below certain threshold (varies according to battery type between 13.4 and 13.8V),

• when cycled (going through charging and discharging phases consecutively), the battery termination voltages are higher than when charging indefinitely (14.2 to 14.5V),

• it is not good to charge battery beyond the gassing voltage (about 14.4V) for longer periods of time,

• it is good to change the voltage levels according to battery temperature, as the voltage values have a significant temperature characteristics,

• it is safe to charge most of lead-acid batteries by currents up to C/10h, where C is the battery capacity in Ah.

However, the ideal charging of lead-acid batteries consists of three stages: constant-current charge, topping charge and float charge.

Battery voltage and current levels per cell during these stages are illustrated in

Figure3.1.

Most of the energy is transferred to the battery during the first stage. The second stage overcharges the battery a little while the current decreases. This is important to recharge battery to 100% of its previous capacity. The losses due to self-discharge are compensated during the last stage.

3.3 Charger Unit

3.3.1 Charge Controller

The primary function of a charge controller in a Solar Home System (SHS) is to maintain the battery at highest possible state of charge, when PV module charges the battery the charge controller protects the battery from overcharge and disconnects the load to prevent deep discharge. Ideally, charge controller directly controls the state of charge of the battery.

Without charge control, the current from the module will flow into a battery proportional to the irradiance, whether the battery needs to be charging or not. If the battery is fully charged, unregulated charging will cause the battery voltage to reach exceedingly high levels, causing severe gassing, electrolyte loss, internal heating and accelerated grid corrosion. Actually charge controller maintains the health and extends the lifetime of the battery.

3.3.2 Pulse Width Modulation (PWM)

Pulse Width Modulation (PWM) controls adjusts the duty ratio of the switches as the input changes to produce a constant output voltage. The DC voltage is converted to a square-wave signal, alternating between fully on and zero. By controlling analog circuits digitally, system costs and power consumption can be drastically reduced. In nowadays implementation, many microcontrollers already include on-chip PWM controllers, making implementation easy. Concisely, PWM is a way of digitally encoding analog signal levels. PWM control can be used in two ways: voltage-mode and current-mode. In voltage mode, control the output voltage increases and decreases as the duty ratio increases and decreases. The output voltage is sensed and used for feedback. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then it will drop the voltage lower to sustain a "finish" or "trickle" charge. Two-stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy). It maintains a full charge but minimizes water loss and stress. The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly before the sun goes down, and mildly overcharging the battery. The determination of set points depends on the anticipated pattern of use, the type of battery, and to some extent, the experience and philosophy of the system designer or operator.

Determine the duty cycle, D to obtain required output voltage.

D = Vo/Vd

Where:

D = Duty cycle

Vo = Voltage output

Vd= Voltage input

D = 12V/17.4V

D = 0.7

%D = 70%

3.3.3 PIC 16F876A Microcontroller

The semiconductor division of General Instruments Inc originally developed the PIC (Programmable Interface Controller) line of microcontrollers. The first PIC's were a major improvement over existing microcontroller because they were a programmable, high output current, input/output controller built around a RISC (Reduced Instruction Set Code) architecture. The first PICs ran efficiently at one instruction per internal clock cycle, and the clock cycle was derived from the oscillator divided by 4. Early PICs could run with a high oscillator frequency of 20 MHz. This made them relatively fast for an 8-bit microcontroller, but their main feature was 20 mA of source and sink current capability on each I/O (Input/Output) pin. Typical micros of the time were advertising high I/O currents of only 1-milliampere (mA) source and 1.6 mA sink.

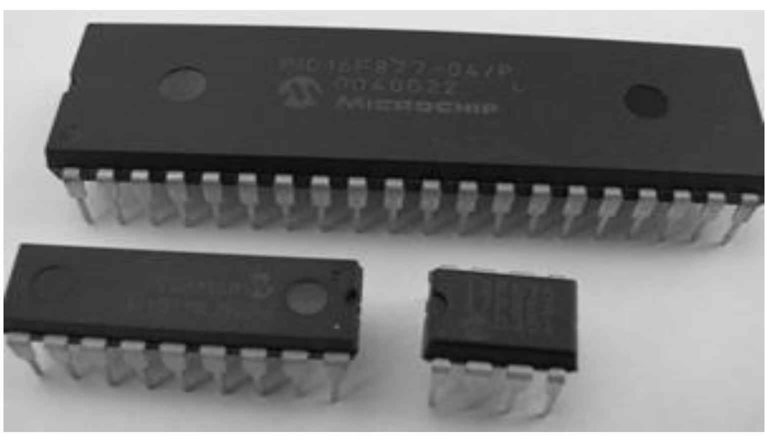


Figure3.2: Types of PIC Microcontroller

3.3.4 Mosfet

As previously mentioned the switch would be a MOSFET (Metal Oxide Semiconductor Field Effect Transistor). MOSFETS are by far the most popular transistors used for switching in circuits today, along with BJTs (Bipolar Junction Transistors). The main difference between MOSFETS and BJTs is that the former are voltage controlled (little or no current is used) and the later are current controlled (voltages are there to control currents). Therefore, MOSFETs require less power to drive them, so they are preferred choice.

MOSFETs are either N-channel, made mostly of N-type semiconductor material, or P-channel where they are made mostly of P-type semiconductor material. They operate in two modes – enhancement mode and depletion mode.
The circuit symbols for these are in figure.

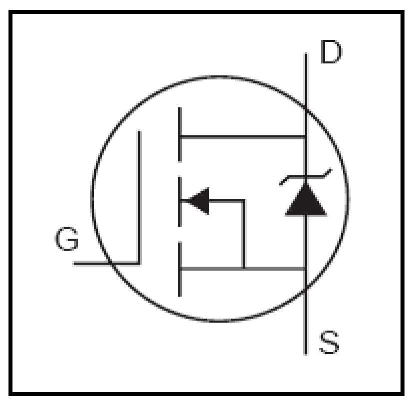


Figure3.3: IRFZ44N MOSFET

MOSFET has high switching speeds, high input impedence and is ideal for switching converters. The voltage in is applied at the gate (1), the battery ground is at the drain (2) and the panel ground is at the source (3).

CHAPTER 4

MICRO C CODING

4.1 Programming the PIC

These PIC microcontrollers can be programmed in high-level languages or in their native machine language (Assembly). In this thesis the C language was chosen, using the software MICRO C. The advantages of C language consist of better control and greater efficiency. Another reason for using C language is that the interface with the programmer is quite simple and easy to understand.

4.2 Charge Controller Algorithm

The charge controller algorithm is shown in flow chart below:

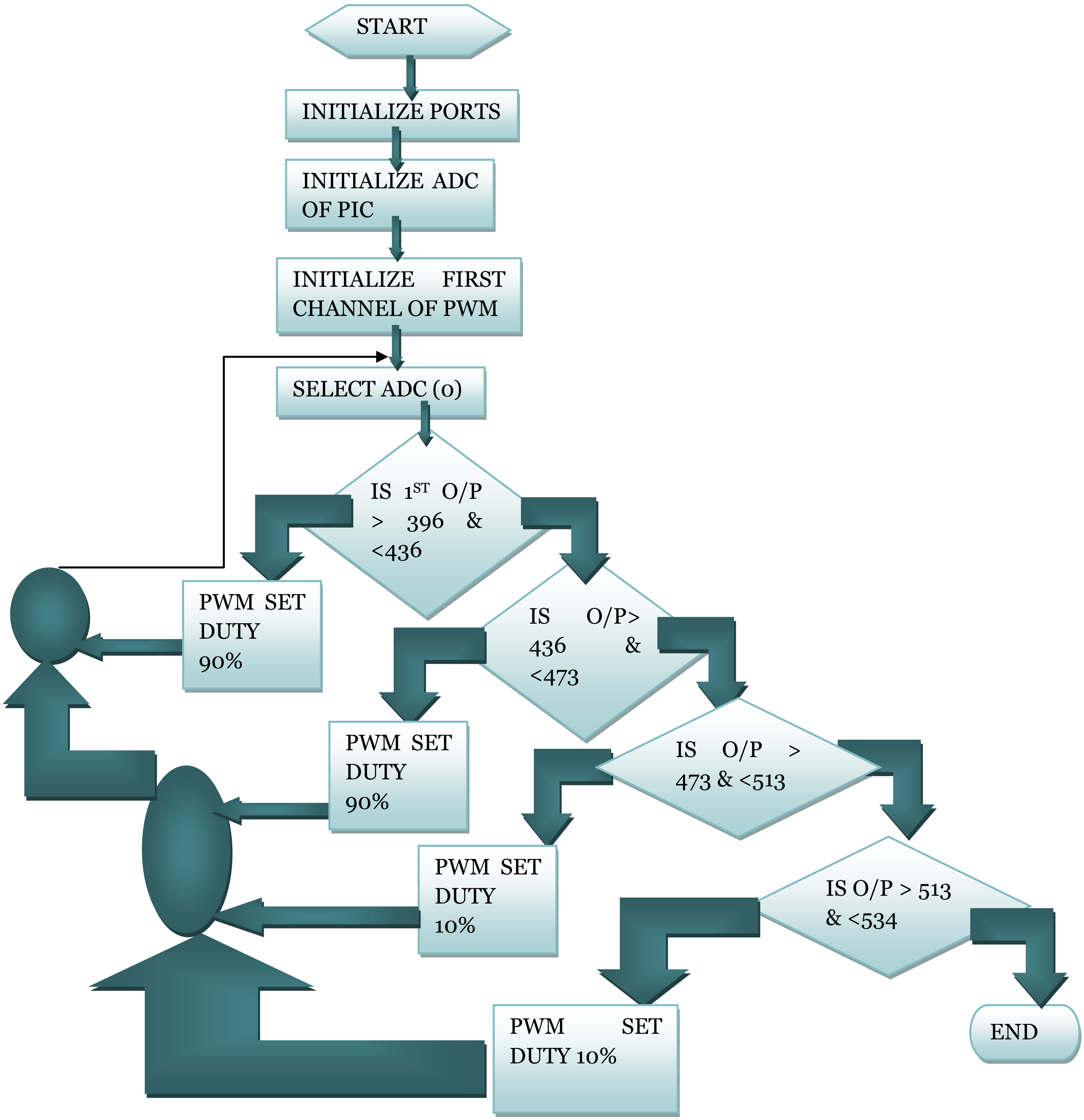


Figure 4.1: Charging Algorithm

4.3 Mikro c code

The PIC 16F876A microcontroller can be programmed using PIC writer software. The following code was written and implemented in the microcontroller:

```
unsigned int v1;
void main() {

      TRISA=0xFF;
      TRISB=0X00;
      PORTB=0X00;
      ADCON0=0x00;//0b00010101;
      ADCON1=0b00000000;
      pwm1_init(40000);
      ADC_Init();
      while(1)
      {

          pwm1_start();
          delay_us(50);
          v1=ADC_read(0);
  if(v1<=396){  // DISCONNECTED(if battery is DEAD)
   pwm1_set_duty(0);
   }
  else if(v1>396 && v1<=436){   // v>=396: if the battery already has charge, but less than 50%(for normal bettery) or 30%(for solar battery) of its capacity.
   pwm1_set_duty(230);
   }
   else if(v1>436 && v1<=473){  // BULK CHARGE
   pwm1_set_duty(230);
   }
   if(v1>473 && v1<=513){  // ABSORPTION CHARGE
   pwm1_set_duty(30);
   }
   else if(v1>513 && v1<534){  // FLOAT CHARGE
   pwm1_set_duty(30);
```

```
    }
    else if(v1>=534){  // DISCONNECTED(if battery is fully charged or DEAD)
    pwm1_set_duty(0);

    }
  }

  }
```

CHAPTER 5

IMPLEMENTATION IN PROTEUS

ISIS provides the development environment for PROTEUS VSM, our revolutionary interactive system level simulator. This product combines mixed mode circuit simulation, microprocessor models and interactive component models to allow the simulation of complete micro-controller based designs.

ISIS provides the means to enter the design in the first place, the architecture for real time interactive simulation and a system for managing the source and object code associated with each project. In addition, a number of graph objects can be placed on the schematic to enable conventional time, frequency and swept variable simulation to be performed.

Major features of PROTEUS VSM include:

- True Mixed Mode simulation based on Berkeley SPICE3F5 with extensions for digital simulation and true mixed mode operation.
- Support for both interactive and graph based simulation.
- CPU Models available for popular microcontrollers such as the PIC and 8051 series.
- Interactive peripheral models include LED and LCD displays, a universal matrix keypad, an RS232 terminal and a whole library of switches, pots, lamps, LEDs etc.
- Virtual Instruments include voltmeters, ammeters, a dual beam oscilloscope and a 24 channel logic analyser.
- On-screen graphing - the graphs are placed directly on the schematic just like any other object. Graphs can be maximised to a full screen mode for cursor based measurement and so forth.
- Graph Based Analysis types include transient, frequency, noise, distortion, AC and DC sweeps and fourier transform. An Audio graph allows playback of simulated waveforms.
- Direct support for analogue component models in SPICE format.
- Open architecture for ‘plug in’ component models coded in C++ or other languages. These can be electrical, graphical or a combination of the two.
- Digital simulator includes a BASIC-like programming language for modelling and test vector generation.
- A design created for simulation can also be used to generate a netlist for creating a PCB - there is no need to enter the design a second time.

Full details of all these features and much more are provided in the PROTEUS VSM manual.

5.1 Circuit Components

There is no panel or similar instruement available in PROTEUS. Therefore, a DC current source represented the panel. The source had constant current of 5A.

The voltage regulator 7805 was omitted from the simulation, as there is no pin 19 or VDD pin in PIC16F876A in PROTEUS. The purpose of the voltage regulator is to feed 5V to the microcontroller. Above this voltage microcontroller will burn.

A digital oscilloscope was connected to get the view of PWM. The digital oscilloscope is a virtual instruement that is available in PROTEUS VSM. It has four channels. Channel A is the channel that shows square waves.

5.2 Schematic Circuit

After the all components of the circuit have been added, the simulation was done. It was done using different values of the battery. With each battery value the value in digital oscilloscope was recorded. It corresponds to the exact value of the PWM.

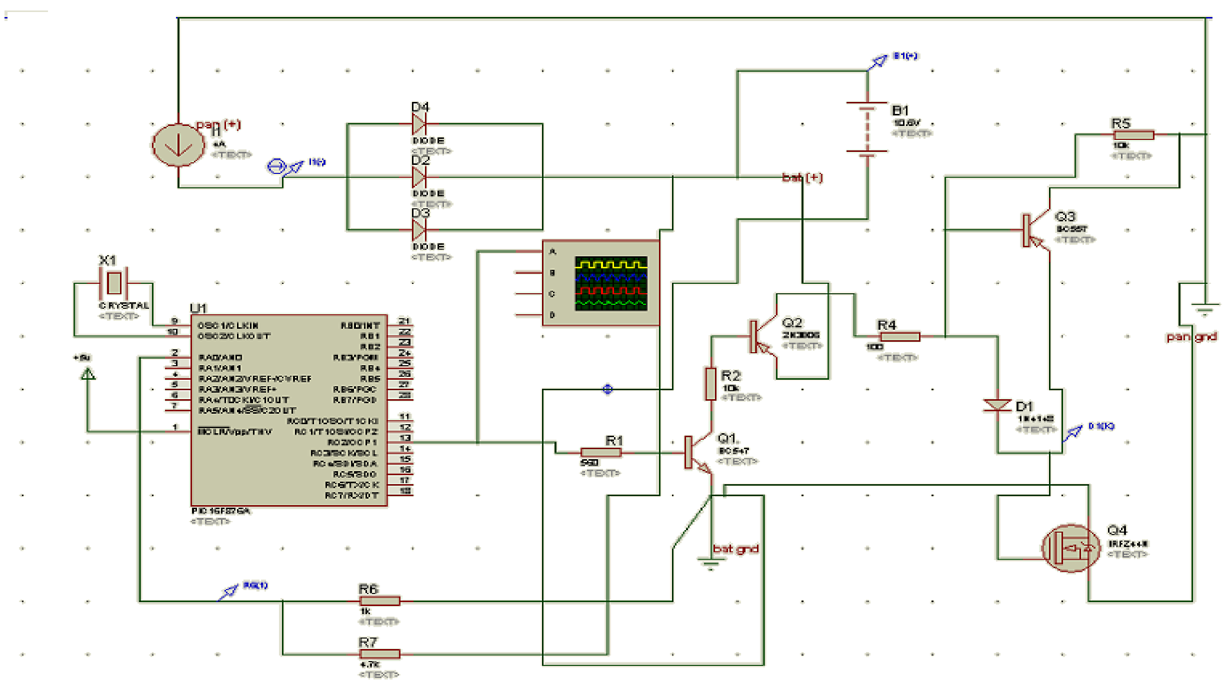


Figure 5.1: The schematic circuit

5.3 Simulation Result

PROTEUS VSM comes with the facility of using Virtual Instruement. Oscilloscope was used to get the PWM output from CCP1 pin. The CCP1 pin generates square waves. Therefore, the 13th pin of the microcontroller was connected to the Channel A of the oscilloscope. The output of three different voltage of the battery cell is given here.

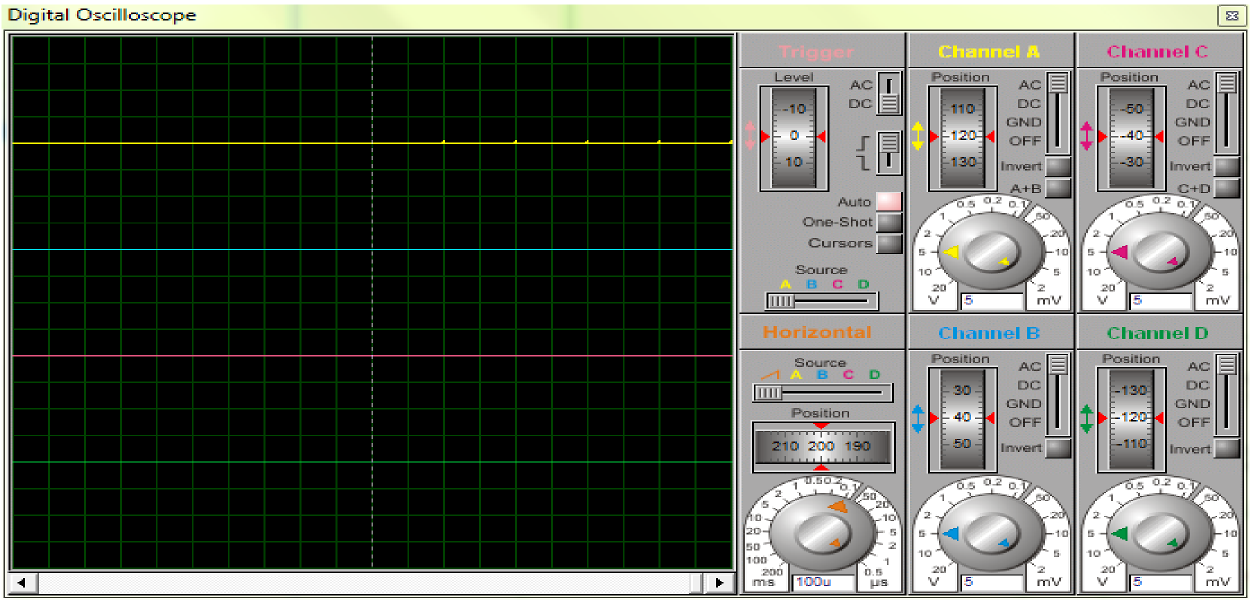


Figure5.2: No charge

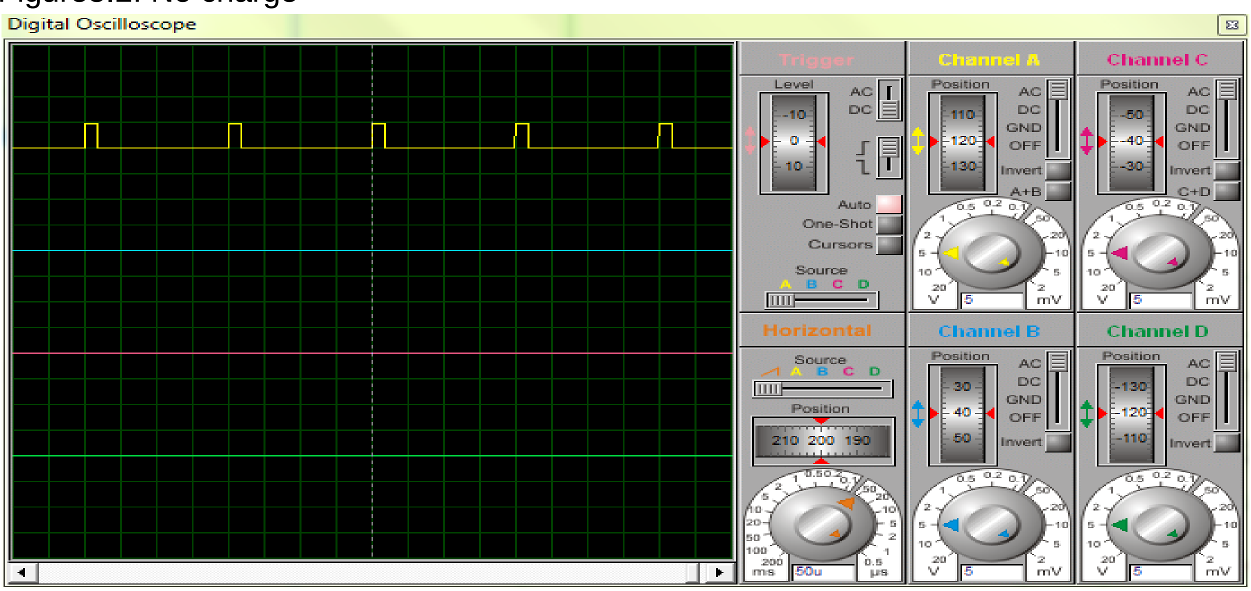


Figure5.3: 10% pulse width

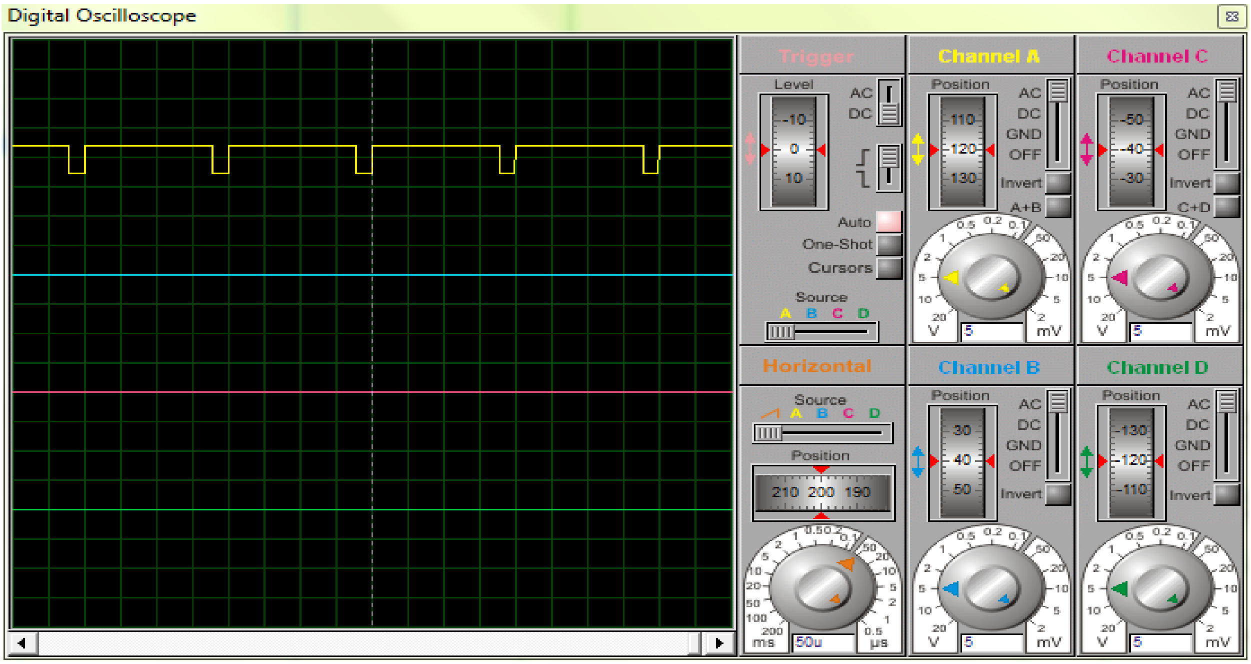


Figure 5.4: 90% pulse width

CHAPTER 6

DESIGN

In order to design a smart charge controller, the following circuit was simulated in ISIS 7 PROFESSIONAL. The PIC16F876A microcontroller can convert input voltage into PWM signal. The PWM signal range was 0 to 100%. There was a mosfet for switching between battery and panel. The simulation result was similar to the practical result.

The charge controller can be deviced in several stages, so that the simple guidelines for charging are met in the prototype stage. After this functionality is implemented and verified, the algorithms to achieve ideal charging (described above) can be implemented to improve the quality of charging process.

From the basic guidelines it is clear, that the minimum functionality that the hardware of the controller has to implement is voltage measurement and switching off the load and input from solar panel.

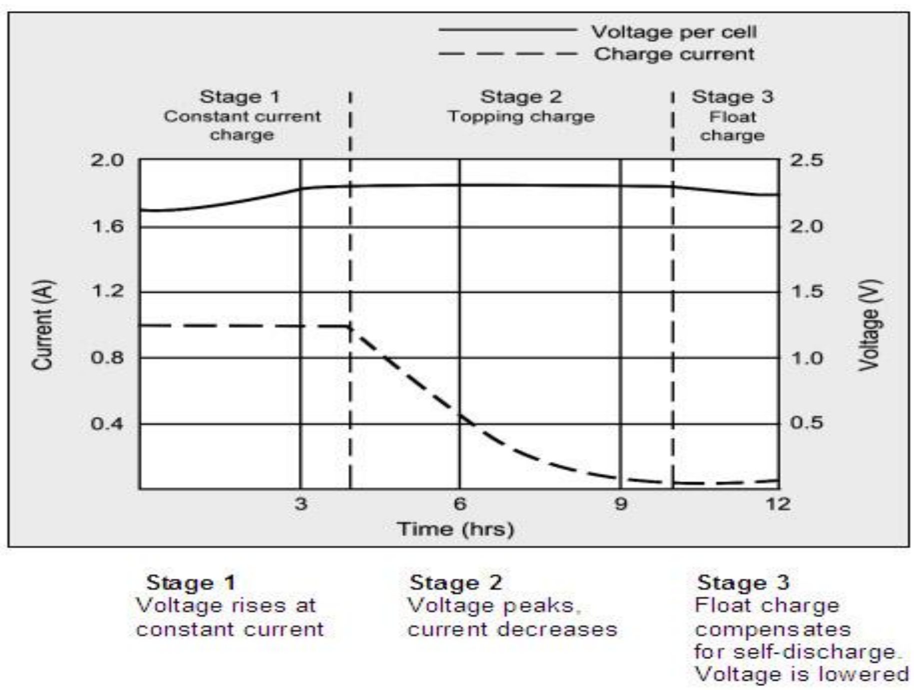


Figure6.1: The diagram of charging stages of lead-acid battery

6.1 Charge Controller Types

Two basic charge controller types exist:

6.1.1 Shunt Controller

All shunt controllers must have a blocking diode in series between the battery and the shunt element to prevent the battery from short-circuiting when the module is regulating. Because there is some voltage drop between the module and controller and due to wiring and resistance of the shunt element, the module is never entirely short circuited, resulting in some power dissipation within the controller. For this reason, most shunt controllers require a heat sink to dissipate power, and are generally limited to use in PV systems with module currents less than 20 amps.[6]

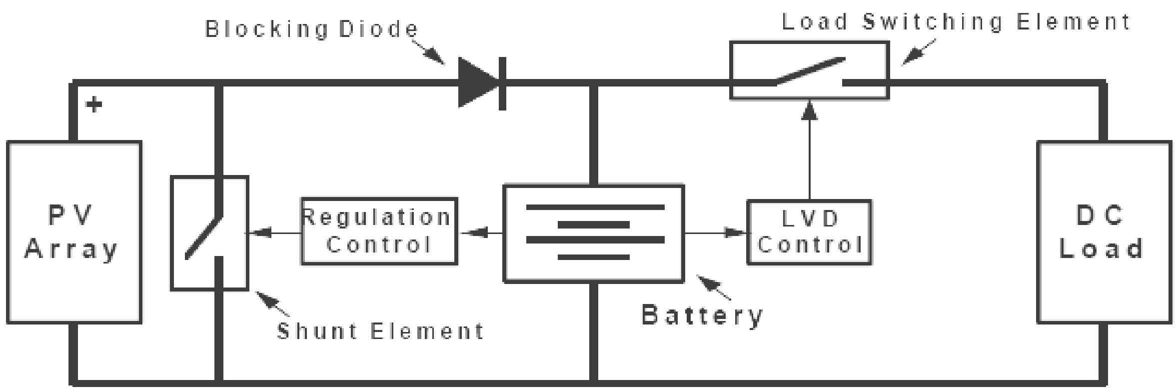


Figure6.2: Shunt Controller

Shunt-Interrupting Design

The shunt-interrupting controller completely disconnects the array current in an interrupting or on-off fashion when the battery reaches the voltage regulation set point. When the battery decreases to the array reconnect voltage, the controller connects the array to resume charging the battery. This cycling between the regulation voltage and array reconnect voltage is why these controllers are often called ‘on-off’ or ‘pulsing’ controllers. Shunt-interrupting controllers are widely available and are low cost, however they are generally limited to use in systems with array currents less than 20 amps due to heat dissipation requirements. In general, on-off shunt controllers consume less power than series type controllers that use relays (discussed later), so they are best suited for small systems where even minor parasitic losses become a significant part of the system load. Shunt-interrupting charge controllers can be used on all battery types, however the way in which they apply power to the battery may not be optimal for all battery designs. In general, constant-voltage, PWM or linear controller designs are recommended by manufacturers of gelled and AGM lead-acid batteries. However, shunt-interrupting controllers are simple, low cost and perform well in most small stand-alone PV systems.

Shunt-Linear Design

Once a battery becomes nearly fully charged, a shunt-linear controller maintains the battery at near a fixed voltage by gradually shunting the array through a semiconductor regulation element. In some designs, a comparator circuit in the controller senses the battery voltage, and makes corresponding adjustments to the impedance of the shunt element, thus regulating the array current. In other designs, simple Zener power diodes are used, which are the limiting factor in the cost and power ratings for these controllers. There is generally more heat dissipation in a shunt-linear controller than in shunt-interrupting types. Shunt-linear controllers are popular for use with sealed VRLA batteries. This algorithm applies power to the battery in a preferential method for these types of batteries, by limiting the current while holding the battery at the regulation voltage.

6.1.2 Series Controller

In a series controller, a relay or solid-state switch either opens the circuit between the module and the battery to discontinuing charging, or limits the current in a series-linear manner to hold the battery voltage at a high value. In the simpler series interrupting design, the controller reconnects the module to the battery once the battery falls to the module reconnect voltage set point.[6]

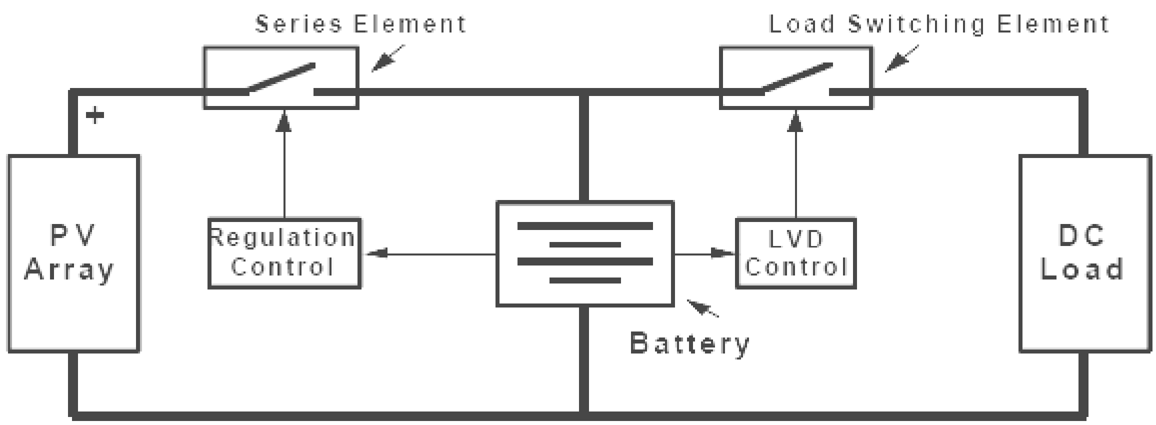


Figure6.3: Series Controller

Functions of Battery Charge Controller

Series-Interrupting Design

The most simple series controller is the series-interrupting type, involving a one-step control, turning the array charging current either on or off. The charge controller constantly monitors battery voltage, and disconnects or open-circuits the array in series once the battery reaches the regulation voltage set point.

After a pre-set period of time, or when battery voltage drops to the array reconnect voltage set point, the array and battery are reconnected, and the cycle repeats. As the battery becomes more fully charged, the time for the battery voltage to reach the regulation voltage becomes shorter each cycle, so the amount of array current passed through to the battery becomes less each time. In this way, full charge is approached gradually in small steps or pulses, similar in operation to the shunt-interrupting type controller. The principle difference is the series or shunt mode by which the array is regulated. Similar to the shunt-interrupting type controller, the series-interrupting type designs are best suited for use with flooded batteries rather than the sealed VRLA types due to the way power is applied to the battery.

Series-Interrupting, 2-step, Constant-Current Design

This type of controller is similar to the series-interrupting type, however when the voltage regulation set point is reached, instead of totally interrupting the array current, a limited constant current remains applied to the battery. This 'trickle charging' continues either for a pre-set period of time, or until the voltage drops to the array reconnect voltage due to load demand. Then full array current is once again allowed to flow, and the cycle repeats. Full charge is approached in a continuous fashion, instead of smaller steps as described above for the on-off type controllers. A load pulls down some two-stage controls increase array current immediately as battery voltage. Others keep the current at the small trickle charge level until the battery voltage has been pulled down below some intermediate value (usually 12.5-12.8 volts) before they allow full array current to resume.

6.2 Overcharge Protection

In a 12 V battery system the voltage vary between 10.5 volts and 14.4 volts, depending on the actual state of charge of the battery, charge current, discharge current, type and age of the battery.

When a normal full loaded battery and no charging or discharging current is flowing than the battery voltage is about 12.4 volts to 12.7 volts, when charging current is flowing the voltages jump to a higher level e.g. 13.7 V (depending on the current), when loads are switched on the voltage drops down to a lower lever e.g. 12.0volts or 11.8 volts (also depending on the current).

The PV module produces energy and the current is flowing into the battery so voltage level increases up to the range of 14.4 volts. Then the over charge protection starts the work.

When the battery voltage level is 14.4 volts, the charge controller is switched off the charging current or reduced it (by pulse wide modulation).

6.3 Deep Discharge Protection

When a battery is deeply discharged, the reaction in the battery occurs close to the grids, and weakens the bond between the active materials and the grids. When we deep discharge the battery repeatedly, loss of capacity and life will eventually occur. To protect battery from deep discharge, most charge controllers include an optional feature

to disconnect the system loads once the battery reaches a low voltage or low state of charge condition.
If the voltage of the system falls below 11.5 volts for a period of minimum 20 sec than the charge controller will be switched off for minimum 30 seconds. Than all loads which are connected to the controller is off. If the battery voltage increase above 12.5volts for more than 20 seconds than the charge controller will be switched ON the loads again for a minimum time of 30 seconds. The delay of 30 seconds is integrated to protect the system against a swinging situation.

6.4 Charge Controller Set Points

Controller set points are the battery voltage levels at which a charge controller performs control or switching functions. Four basic control set points are defined for most charge controllers that have battery overcharge and overdischarge protection features. The voltage regulation (VR) and the array reconnect voltage (ARV) refer to the voltage set points at which the array is connected and disconnected from the battery. The low voltage load disconnect (LVD) and load reconnect voltage (LRV) refer to the voltage set points at which the load is disconnected from the battery to prevent overdischarge. Figure 12-1 shows the basic controller set points on a simplified diagram plotting battery voltage versus time for a charge and discharge cycle. A detailed discussion of each charge controller set point follows.

6.4.1 High Voltage Disconnect (HVD) Set Point

The high voltages disconnect (HVD) set point is one of the key specifications for charge controllers. The voltage regulation set point is the maximum voltage that the charge controller allows the battery to reach, limiting the overcharge of the battery. Once the controller senses that the battery reaches the voltage regulation set point, the controller will either discontinue battery charging or begin to regulate the amount of current delivered to the battery.

6.4.2 Array Reconnect Voltage (ARV) Set Point

In interrupting (on-off) type controllers, once the module or array current is disconnected at the voltage regulation set point, the battery voltage will begin to decrease. If the charge and discharge rates are high, the battery voltage will decrease at a greater rate when the battery voltage decreases to a predefined voltage, the module is again reconnected to the battery for charging. The voltage at which the module is reconnected is defined as the array reconnects voltage (ARV) set point.

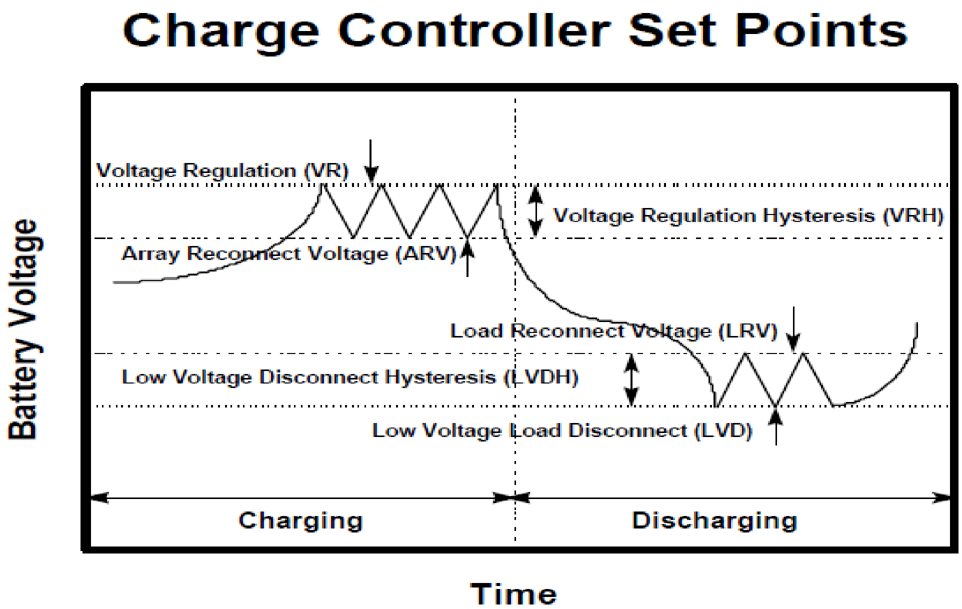


Figure6.4: Charge controller set points

6.4.3 Voltage Regulation Hysteresis (VRH)

The voltage differences between the high voltages disconnect set point and the array reconnect voltage is often called the voltage regulation hysteresis (VRH). The VRH is a major factor which determines the effectiveness of battery recharging for interrupting (on-off) type controller. If the hysteresis is too big, the module current remains disconnected for long periods, effectively lowering the module energy utilization and making it very difficult to fully recharge the battery. If the regulation hysteresis is too small, the module will cycle on and off rapidly. Most interrupting (on-off) type controllers have hysteresis values between 0.4 and 1.4 volts for nominal 12 volts systems.

6.4.4 Low Voltage Load Disconnect (LVD) Set Point

Deep discharging the battery can make it susceptible to freezing and shorten its operating life. If battery voltage drops too low, due to prolonged bad weather or certain non-essential loads are connected the charge controller disconnected the load from the battery to prevent further discharge. This can be done using a low voltage load disconnect (LVD) device is connected between the battery and non-essential loads. The LVD is either a relay or a solid-state switch that interrupts the current from the battery to the load.

6.4.5 Load Reconnect Voltage (LRV) Set Point

The battery voltage at which a controller allows the load to be reconnected to the battery is called the load reconnect voltage (LRV). After the controller disconnects the load from the battery at the LVD set point, the battery voltage rises to its open-circuit voltage. When the PV module connected for charging, the battery voltage rises even more. At some point, the controller senses that the battery voltage and state of charge are high enough to reconnect the load, called the load reconnect voltage set point. LRV should be 0.08 V/cell (or 0.5 V per 12 V) (see [1]) higher than the load-disconnection voltage. Typically LVD set points used in small PV systems are between 12.5 volts and 13.0 volts for most nominal 12 volt lead-acid battery. If the LRV set point is selected too low, the load may be reconnected before the battery has been charged.

6.4.6 Low Voltage Load Disconnect Hysteresis (LVLH)

The voltage difference between the low voltage disconnect set point and the load reconnect voltage is called the low voltage disconnect hysteresis. If the low voltage disconnect hysteresis is too small, the load may cycle on and off rapidly at low battery state-of-charge (SOC), possibly damaging the load or controller, and extending the time it required to charge the battery fully. If the low voltage disconnect hysteresis is too large the load may remain off for extended periods until the array fully recharges the battery.

6.4 Charger Circuit

The charger circuit for the SBCS project is microcontroller based and controls the MOSFET switching. It follows the requirements stated above. It can automatically disconect at HVD and recharge at LVD.

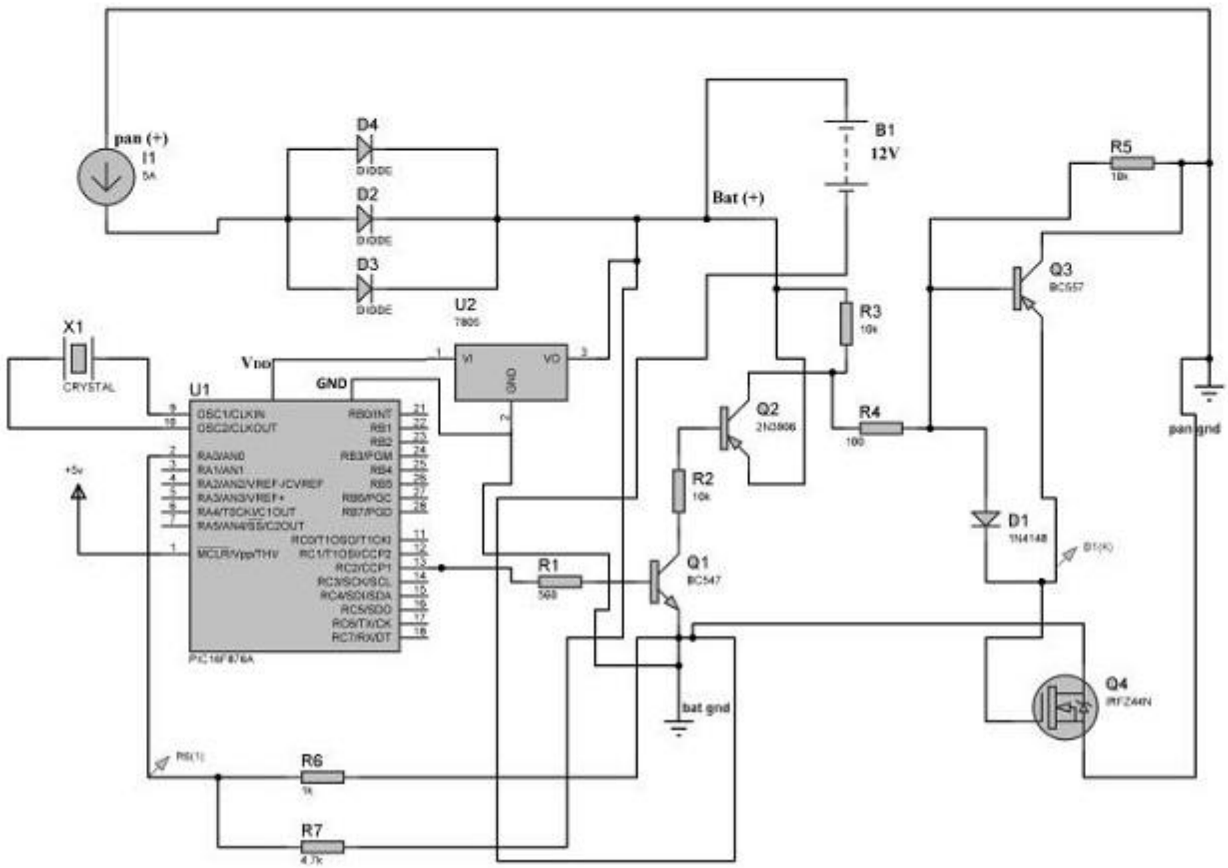


Figure6.5: The charger circuit

6.5 PCB Implementation

The PCB(Printed Circuit Board) was implemented to make the charge controller board.

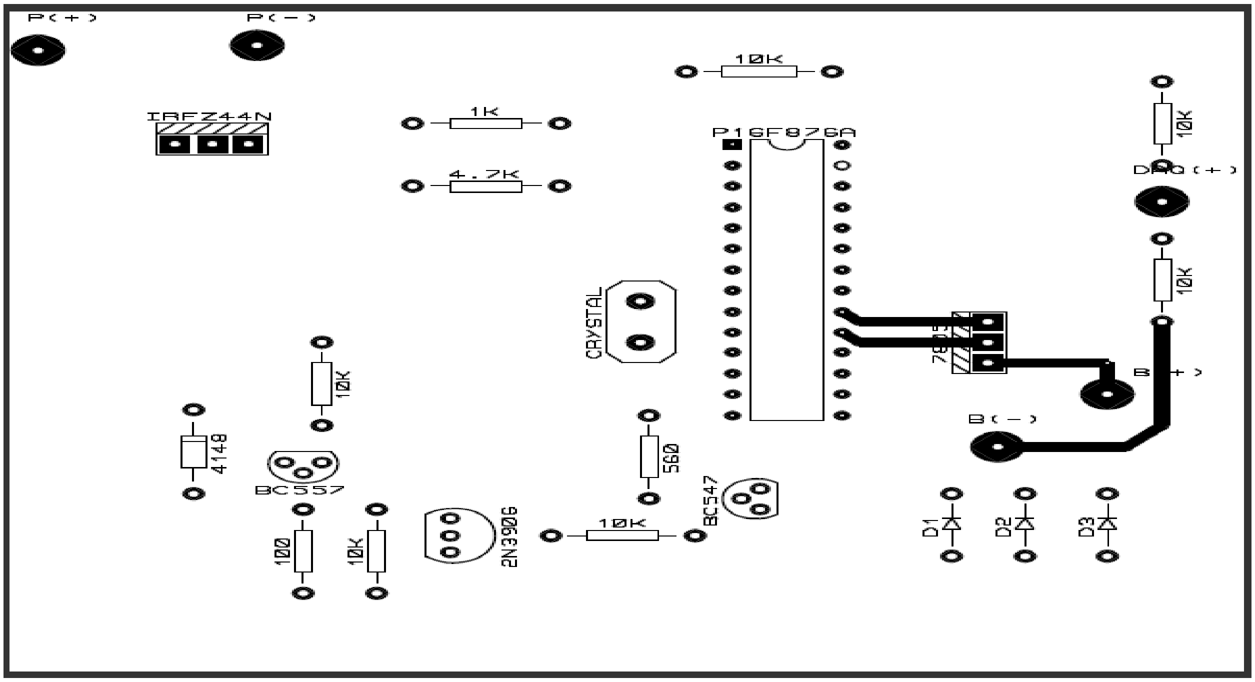


Figure6.6: PCB Implementation

CHAPTER 7

INTERFACING

7.1 Why Interfacing?

The data acquisition card USB-4716 provides a device driver which gives different functionality of the system. The device driver software-Active DAQ Pro gives different function to use the DAQ system and represent the data. The functions primarily classified as two categories which are Active DAQ Pro device control and Active DAQ Pro GUI control. We have used the device control functions to manipulate the data coming through the DAQ card .We integrated the device control function to our Graphical User Interface to control the data coming from the DAQ card.

7.3 How to Interface

Interfacing between the DAQ card and the visual studio 2010 edition that we are using is most important part in the project. The card takes the data from the charge controller and sends the data to the computer. The computer gets a digital data and software takes the responsibility for further processing of the data and shows it in specific manner. It is versatile to ensure the communication between the software and the card thereby. The steps of performing the interfacing are given below:

- Although we are not using Active DAQ Pro-the device driver software provided by the manufacturer company Advantech, we have to make sure that it is working properly as we are not re-writing the built in GUI, we are just grabbing necessary signals from the built in GUI.
- Therefore, first step is to install the software to we make sure that the windows will recognize the hardware. It just recognizes the hardware and creates communication with the developed software.
- Choose the necessary .dll functions needed to process the signal via our newly built GUI using the provided one.
- Needs the analog signal processing function AdvAI. As we used C# language for the graphical user interface we added the specified functions in C# development environment as reference. Here we are using VISUAL STUDIO 2010 version.

- Afterwards select a device by calling selectdevice function. It makes sure we are using the correct version of the product which is for us USB-4716.
- Then needs to select device name and device number by using device name and device number properties
- Lastly using Data analog properties to control analog input data coming from the Central Solar Battery Charging Station.
- After getting the analog input data software processes it as needed then represents it visually using the GUI which we converted into individual software afterwards.

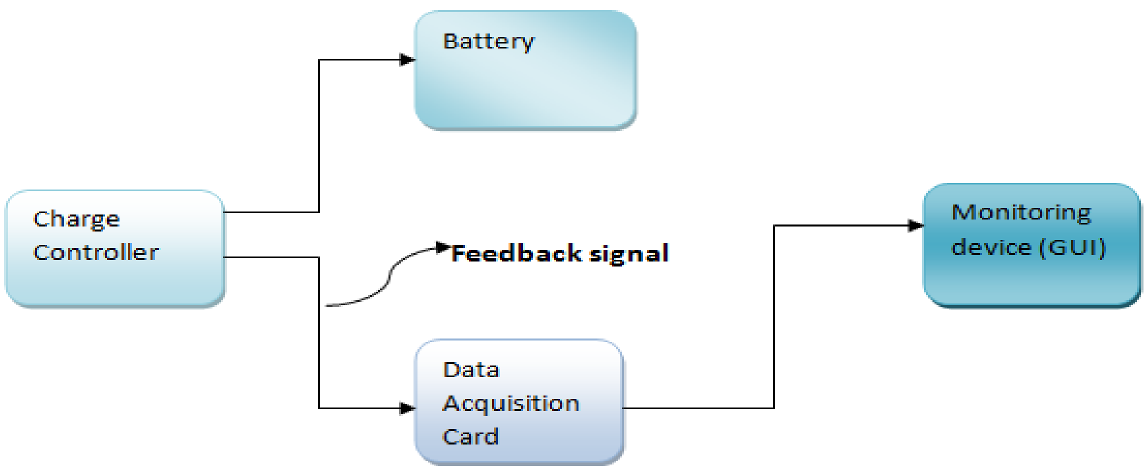


Figure 7.1: Signal flow into the software part

CHAPTER 8

EXPERIMENTAL RESULT

8.1 Balance of System (BOS):

BOS stands for balance of system, which is used for all non-photovoltaic parts of a PV system. They contribute significantly to the overall system and getting these wrong can seriously damage the system. BOS components can be separated into electrical and mechanical components.

The electrical components are:

- Cables
- Fuses
- Earthing
- Lightning Protection
- Battery
- Charge Regulation

Mechanical components are module support structure and tracing system.

8.2 Experiment on Different Charge Controller

Two different battery charge controller (a) Rahimafrooz charge controller, (b) Galchip charge controller both product of Bangladesh have been collected and tested. We observed the behaviour of the two different charge controllers.

The galchip charge controller was tested for primary requirements. It was tested for over current and overcharged protection. It did not have the IDCOL protections. It did not have the reverse leakage current.

Figure8.1: Off load test

Off Load Test:

Vrb	Ib	P
4.98	5.83	29.03

6	7.08	42.48
6.96	8.24	57.35
7.99	8.92	71.271
8.97	9.5	85.22
9.93	10.01	99.399
10.91	11.38	124.156
11.9	7.08	84.25
12.96	7.69	99.66
13.97	8.28	115.672
14.96	9.4	140.62
15.89	9.95	158.106

Table8.1: Charge Controller Off Load Test

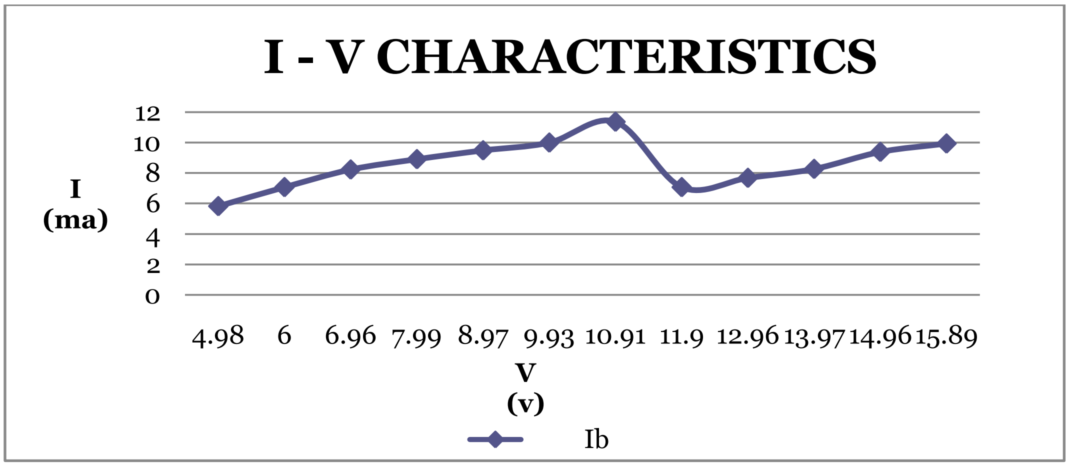


Figure8.2: Charge controller I-V characteristics

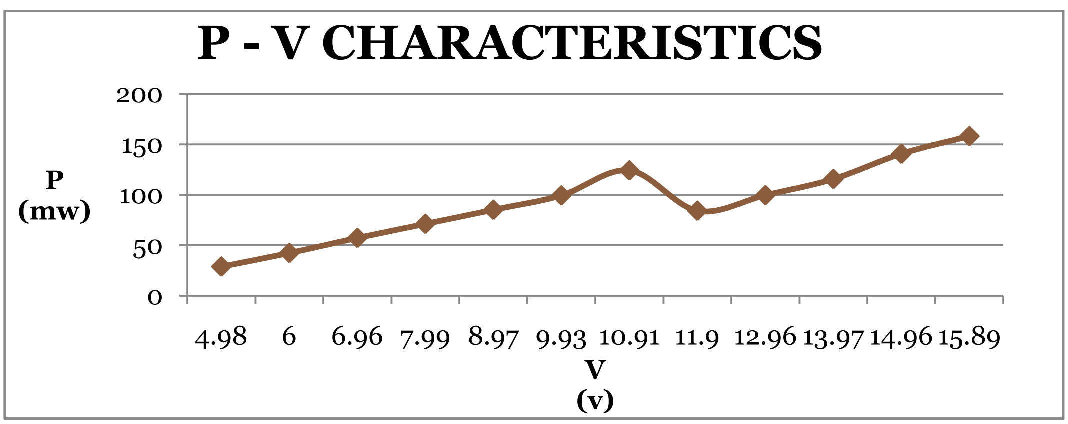


Figure8.3: Charge controller P-V characteristics

For this measurement a battery 2.2 Ah @20 hr was connected with Rahimafrooz battery charge controller and the battery were started to charging with a power pack 12V and constant current 200mA. At the beginning the voltage increased. So current was feeding into the battery. And the charge controller did not regulate and all the current was feeding into the battery.

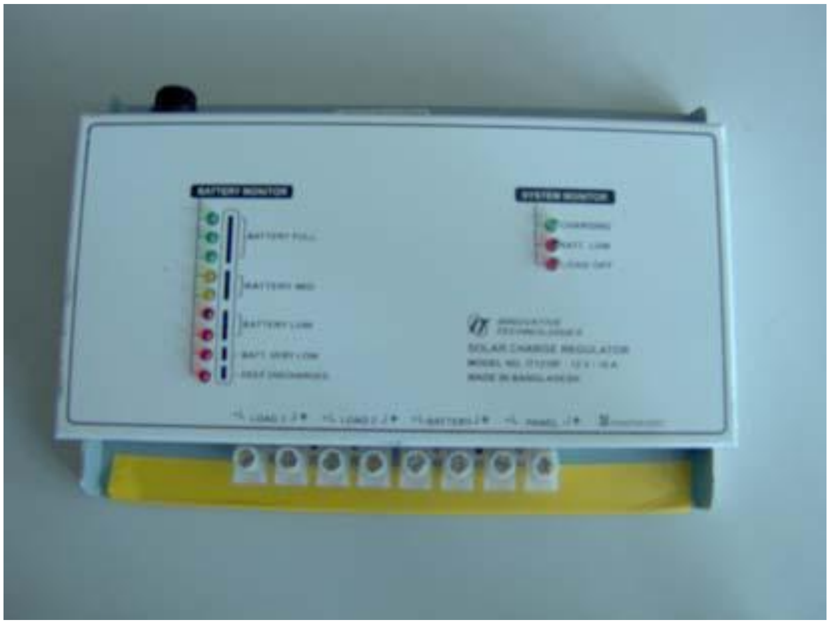


Figure8.4: Rahimafrooz charge controller

Approximately 75 minutes after the battery voltage was reached the regulation voltage set point (14.48 volts) of the battery charge controller, and the controller began to regulate the current. During regulation, the maximum battery voltage was between 14.4 and 14.5 volts. This maximum battery voltage corresponded to the voltage regulation set point for the battery charge controller. The minimum battery voltage was about 13.94 volts. The fact that the minimum voltage was consistent over the regulation period indicated that the controller was regulating the battery voltage between the voltage regulation and module reconnection set points. This voltage difference 0.54 volt is often referred to as the controller's hysteresis. The hysteresis is an important specification for a controller and must be selected properly to achieve good module energy utilization and proper battery charging.

Then a load (CFL lamp 12V/ 0.51 A) was connected in the system to start deep discharging process. The battery voltage decreased steadily from 12.8V to 12.18V after one minute the charge controller disconnected the load. It was observed in the oscilloscope that when battery voltage was 11.9V the charge controller disconnected the load. And there was a sharp rise in the battery voltage as it approached to an open-circuit (no load) voltage of about 12.9 volts. This voltage regulation set point might not be perfect for this type of SHS, because this charge controller was made for solar home system whose discharge battery rated at 100 hours discharge rate.

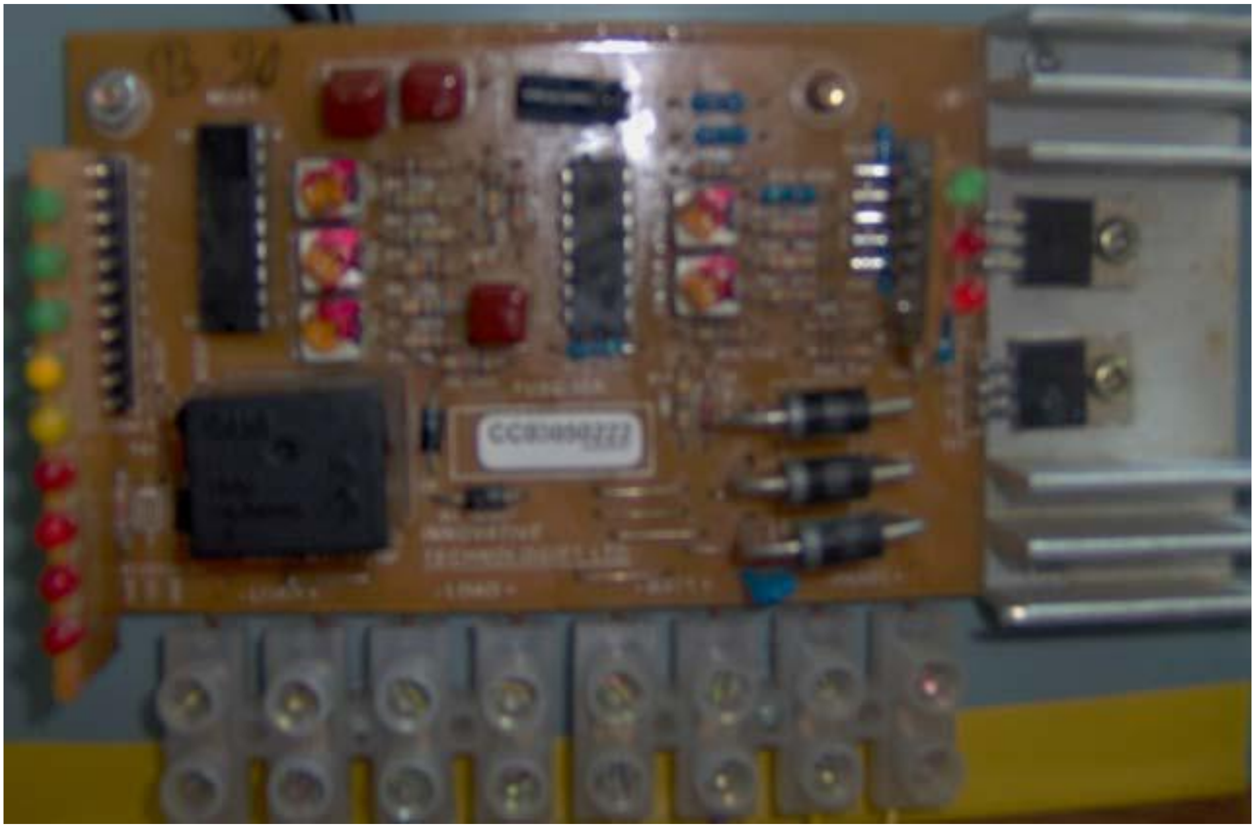


Figure8.5: Circuit of the Rahimafrooz charge controller

The charge controller cover was removed and found the circuit diagram shown in figure 8.5. It was found that there were five variable resistances, one of them for adjustment high voltages disconnect set point and another one was adjusting for the deep discharge disconnects set point. Again it was connected the load and the battery to the system and adjusting the variable resistance for deep discharge protection with the help of oscilloscope. It was fixed the deep discharge disconnect set point in11.5volts and load reconnection voltage set point in 12.5volts.

8.3 Laboratory Test Result

The simulation is the same as the actual test. The pulse shows the value that is needed to charge the battery. At different stages, the PWM duty cycle needs to be adjusted to control the battery charging. It is able to disconnect the battery at High Voltage Disconnect (HVD) and Low Voltage Disconnect (LVD).

Not Charging:

When voltage is below 10.5V

Duty cycle used: 0 %.

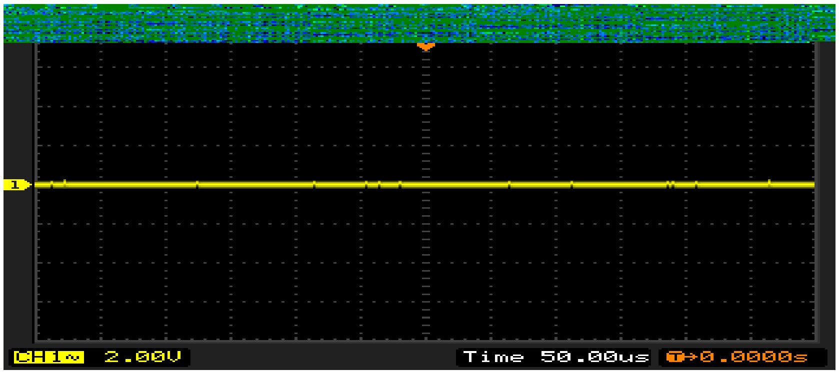


Figure8.6: No charge wave shape

Bulk Charge:

40% Ah to be used. It is when voltage is between 10.6 V to 12.6V.

Duty cycle used: 90 %

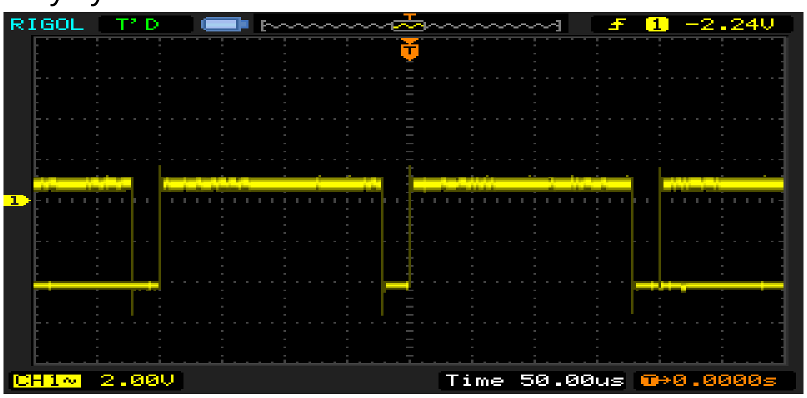


Figure8.7: Bulk charging wave shape

Float Charge:

5 percent of Ah to be used. It is when voltage is between 12.6 V to 14.3V.

Duty cycle used: 10 percent.

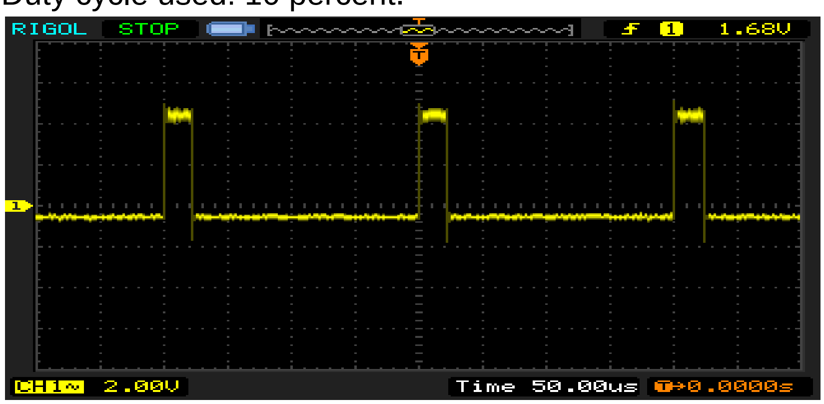


Figure8.8: Float charging wave shape

Full Charge(HVD):

Duty cycle used:0 %

When the battery voltage is 14.4V, circuit is open, the charging current is 0 A.

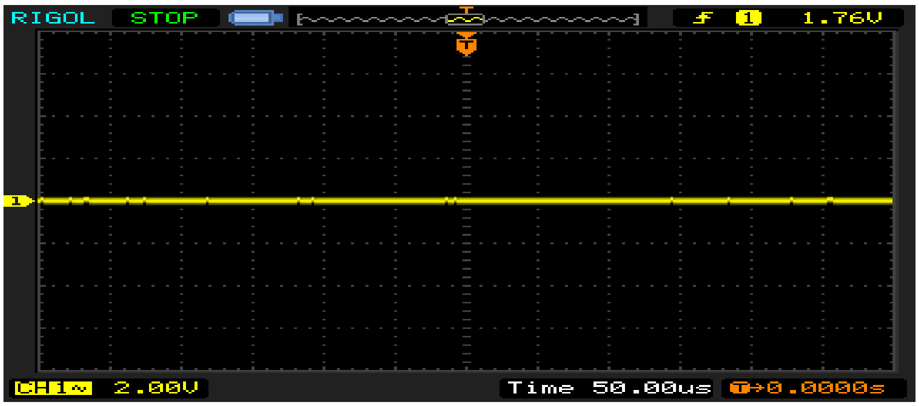


Figure8.9: Full charge wave shape

CHAPTER 9

CONCLUSION

The emergent need for electricity has led to a countrywide propagation of solar energy based electricity generation systems that integrate battery storage through the use of Solar Home Systems (SHSs) and a large portion of the country's population is dependent on a strenuous means of livelihood that is rickshaw (tricycle) pulling[5]. To tackle the problem, implementation of Solar Battery Charging Station (SBCS) has emerged to the rural Bangladesh as well as in urban areas to change the scenario. Thereby, software implementation of SBCS is vitally important to monitor the system and keep the batteries safe. While maintaining the batteries of the SBCS manually, there might occurs mistakes and batteries can get overcharged. But doing it using software is not only safe but also time and cost effective. Thereby our motto is to make the cost-effective software for monitoring the station from remote region even-though. With the completion of our GUI we will be able to screen multiple batteries concurrently under the same monitor and will allow for the real time visualization of all types of readings, such as the voltage and percentage charge of each battery.

9.1 Boundaries Of The Current Job

The present charge controller can charge the battery but it has many restrictions.

1. There are many times when current overflow occurred.
2. It also faced burnout.
3. The pcb is not so efficient.

9.2 Future Work

There are many oppurtunities ahead. The project can be a great prototype project in near future. Only some modifications can make great changes.

- 12V charger to be upgraded to 48 V later(few modifications required, easier than back calculation).
- Using a backup diesel generator.
- Making it more efficient so that it can resist burnout and current overflow.
- Building larger solar charging station connected to the national grid system to meet up increasing demand of load
- Vehicle charging, portable solar mobile phone chargers can be improved
- Building larger solar charging station connected to the national grid system to meet up increasing demand of load
- Can be used to make advanced charge controllers for advanced use

REFERENCES

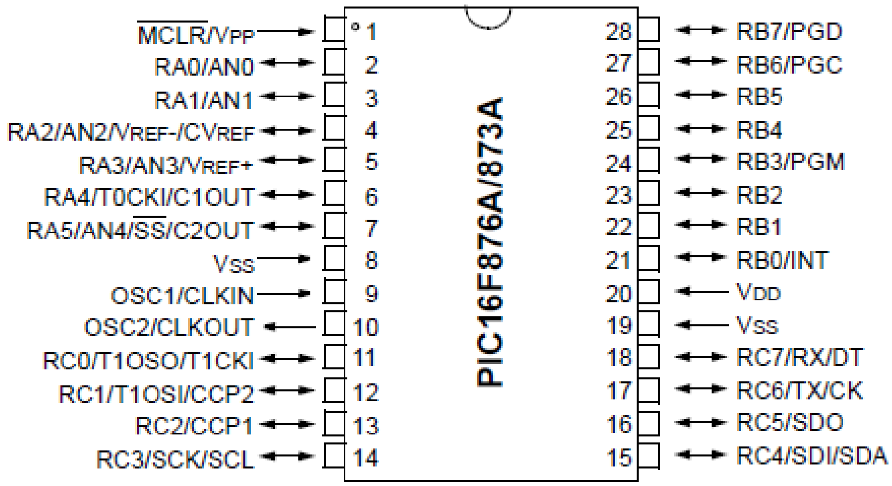
1. http://bdoza.wordpress.com/2009/05/11/solar-energy-alternative-source-of-energy-for-bangladesh/
2. http://en.wikipedia.org/wiki
3. Infrastructure Development Company Limited (IDCOL) Bangladesh. URL: http://www.idcol.org/energyProject.php
4. A N M Zobayer et al, Thesis on “Miniaturized Solar Home System For Lighting Purpose With Light Emitting Diodes”, Carl von Ossietzky University ,Oldenburg/Germany & Center for Solar Energy and Hydrogen Research (ZSW) ,Baden-Württemberg, Stuttgart /Germany
5. Rachaen M. Huq et al, Thesis on “Development of Torque Sensor Based Electrically Assisted Hybrid Rickshaw,” CARG Project, BRAC University
6. James P. Dunlop, P.E. et al, “Batteries and Charge Controller In Stand-Alone Photovoltaic Systems fundamentals and applications”

APPENDICES

PIC 16F876A datasheet:

Pin Diagram:

PDIP (28-pin), SOIC, SSOP



PWM:

8.0 CAPTURE/COMPARE/PWM MODULES

Each Capture/Compare/PWM (CCP) module contains a 16-bit register which can operate as a:

- 16-bit Capture register
- 16-bit Compare register
- PWM Master/Slave Duty Cycle register

Both the CCP1 and CCP2 modules are identical in operation, with the exception being the operation of the special event trigger. Table 8-1 and Table 8-2 show the resources and interactions of the CCP module(s). In the following sections, the operation of a CCP module is described with respect to CCP1. CCP2 operates the same as CCP1, except where noted.

CCP1 Module:

Capture/Compare/PWM Register1 (CCPR1) is comprised of two 8-bit registers: CCPR1L (low byte) and CCPR1H (high byte). The CCP1CON register controls the operation of CCP1. The special event trigger is generated by a compare match and will reset Timer1.

CCP2 Module:

Capture/Compare/PWM Register2 (CCPR2) is comprised of two 8-bit registers: CCPR2L (low byte) and CCPR2H (high byte). The CCP2CON register controls the operation of CCP2. The special event trigger is generated by a compare match and will reset Timer1 and start an A/D conversion (if the A/D module is enabled).

Additional information on CCP modules is available in the PICmicro™ Mid-Range MCU Family Reference Manual (DS33023) and in application note AN594, "Using the CCP Modules" (DS00594).

TABLE 8-1: CCP MODE - TIMER RESOURCES REQUIRED

CCP Mode	Timer Resource
Capture	Timer1
Compare	Timer1
PWM	Timer2

TABLE 8-2: INTERACTION OF TWO CCP MODULES

CCPx Mode	CCPy Mode	Interaction
Capture	Capture	Same TMR1 time-base
Capture	Compare	The compare should be configured for the special event trigger, which clears TMR1
Compare	Compare	The compare(s) should be configured for the special event trigger, which clears TMR1
PWM	PWM	The PWMs will have the same frequency and update rate (TMR2 interrupt)
PWM	Capture	None
PWM	Compare	None

REGISTER 8-1: CCP1CON REGISTER/CCP2CON REGISTER (ADDRESS: 17h/1Dh)

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	CCPxX	CCPxY	CCPxM3	CCPxM2	CCPxM1	CCPxM0
bit 7							bit 0

bit 7-6 **Unimplemented:** Read as '0'

bit 5-4 **CCPxX:CCPxY**: PWM Least Significant bits

Capture mode:
Unused

Compare mode:
Unused

PWM mode:
These bits are the two LSbs of the PWM duty cycle. The eight MSbs are found in CCPRxL.

bit 3-0 **CCPxM3:CCPxM0**: CCPx Mode Select bits
`0000` = Capture/Compare/PWM disabled (resets CCPx module)
`0100` = Capture mode, every falling edge
`0101` = Capture mode, every rising edge
`0110` = Capture mode, every 4th rising edge
`0111` = Capture mode, every 16th rising edge
`1000` = Compare mode, set output on match (CCPxIF bit is set)
`1001` = Compare mode, clear output on match (CCPxIF bit is set)
`1010` = Compare mode, generate software interrupt on match (CCPxIF bit is set, CCPx pin is unaffected)
`1011` = Compare mode, trigger special event (CCPxIF bit is set, CCPx pin is unaffected); CCP1 resets TMR1; CCP2 resets TMR1 and starts an A/D conversion (if A/D module is enabled)
`11xx` = PWM mode

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

ADCON0:

PIC16F87XA

11.0 ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The Analog-to-Digital (A/D) Converter module has five inputs for the 28-pin devices and eight for the 40/44-pin devices.

The conversion of an analog input signal results in a corresponding 10-bit digital number. The A/D module has high and low voltage reference input, that is software selectable to some combination of VDD, VSS, RA2, or RA3.

The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in SLEEP, the A/D clock must be derived from the A/D's internal RC oscillator.

The A/D module has four registers. These registers are:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register0 (ADCON0)
- A/D Control Register1 (ADCON1)

The ADCON0 register, shown in Register 11-1, controls the operation of the A/D module. The ADCON1 register, shown in Register 11-2, configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be the voltage reference), or as digital I/O.

Additional information on using the A/D module can be found in the PICmicro™ Mid-Range MCU Family Reference Manual (DS33023).

REGISTER 11-1: ADCON0 REGISTER (ADDRESS 1Fh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{\text{DONE}}$	—	ADON
bit 7							bit 0

bit 7-6 **ADCS1:ADCS0:** A/D Conversion Clock Select bits (ADCON0 bits in **bold**)

ADCON1 <ADCS2>	ADCON0 <ADCS1:ADCS0>	Clock Conversion
0	**00**	FOSC/2
0	**01**	FOSC/8
0	**10**	FOSC/32
0	**11**	FRC (clock derived from the internal A/D RC oscillator)
1	**00**	FOSC/4
1	**01**	FOSC/16
1	**10**	FOSC/64
1	**11**	FRC (clock derived from the internal A/D RC oscillator)

bit 5-3 **CHS2:CHS0:** Analog Channel Select bits
000 = Channel 0 (AN0)
001 = Channel 1 (AN1)
010 = Channel 2 (AN2)
011 = Channel 3 (AN3)
100 = Channel 4 (AN4)
101 = Channel 5 (AN5)
110 = Channel 6 (AN6)
111 = Channel 7 (AN7)

Note: The PIC16F873A/876A devices only implement A/D channels 0 through 4; the unimplemented selections are reserved. Do not select any unimplemented channels with these devices.

bit 2 **GO/DONE:** A/D Conversion Status bit
When ADON = 1:
1 = A/D conversion in progress (setting this bit starts the A/D conversion which is automatically cleared by hardware when the A/D conversion is complete)
0 = A/D conversion not in progress

bit 1 **Unimplemented:** Read as '0'

bit 0 **ADON:** A/D On bit
1 = A/D converter module is powered up
0 = A/D converter module is shut-off and consumes no operating current

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR reset	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown