Hardware Implementation of the Central Solar Battery Charging Station (CSBCS)

Omaer Ahmed **ID: 09221126**

Syed Md. Musa Sunny **ID: 09221161**

Wasefa Ferdous **ID: 09221172**

Department of Electrical and Electronics Engineering

Summer 2012

BRAC University, Dhaka, Bangladesh

DECLARATION

We do hereby declare that the thesis titled **"Hardware Implementation of the Central Solar Battery Charging Station"** is 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.

Dhaka, Date 4th September, 2012

4/9/12 ....

Signature of the Supervisor

Dr. AKM ABDUL MALEK AZAD
ASSOCIATE PROFESSOR
DEPARTMENT of
ELECTRICAL & ELECTRONIC ENGINEERING,

....

Omaer Ahmed

STUDENT ID: 09221126

....

Syed Md. Musa Sunny

STUDENT ID: 09221161

Syed Md Musa Sunny ....

Wasefa Ferdous

STUDENT ID:

Wasefa Ferdous

ACKNOWLEDGEMENT

We are very thankful to our thesis coordinator Dr. AKM Abdul Malek Azad, Associate Professor, Department of Electrical and Electronic Engineering, BRAC University for guiding us throughout our thesis work. Special thanks for helping us by giving appropriate advice with the system devices, system designing, circuit works and other documentation. Special regards to our project engineer, Mr. Tahsin Faraz for being with us throughout the whole thesis period with his extreme hard work and fantastic management. Last but not the least to Mr. Asif from whom we learnt micro-controller programming which we successfully implemented it in our project.

ABSTRACT

Bangladesh is witnessing an increase in solar electricity generation as part of an ambitious plan to boost the provision of power from renewable energy sources. Solar energy is being harnessed and converted to electrical energy via solar panels and then stored in batteries which can then be used to power households and agricultural activities. This project deals with the prototype design of the pilot project, CSBCS or the Central Solar Battery Charging Station with an aim to aid the process of solar electrification in rural areas and take the load off the grid in urban regions. The batteries charged by these stations can also be used to power modified rickshaws that are torque sensor based and electrically assisted. Solar energy is the best form of renewable energy and this prototype project has the motto "Go Green-Save the Planet-work for existence". Hardware implementation of the CSBCS includes charging a 12 volt battery by using 75 watt solar panel providing discrete amount of power at different time periods of the day. This paper gives a full description of how a 12V solar charge controller is modified to be fed with any amount of voltage to give a desired voltage output.

The Solar Batteries get charge from the PV cells through the charge controller. Whether charging is complete, midway or beginning; at the same time the condition of the batteries, whether fully charged or not; all these information will be detected by the controller through the feedback and the pwm(pulse width modulation), will be changed accordingly according to the battery needs for efficient charging.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

Photovoltaic or in short term PV is one of the renewable energy resources that recently has become broader in nowadays technology. PV has many benefits especially in environmental, economic and social. In general, a PV system consists of a PV array which converts sunlight to direct-current electricity, a control system which regulates battery charging and operation of the load, energy storage in the form of secondary batteries and loads or appliances. A charge controller is one of functional and reliable major components in PV systems. A good, solid and reliable PV charge controller is a key component of any PV battery charging system to achieve low cost and the benefit that user can get from it. The main function of a charge controller in a PV system is to regulate the voltage and current from PV solar panels into a rechargeable battery. The minimum function of a PV charge controller is to disconnect the array when the battery is fully charged and keep the battery fully charged without damage. A charge controller is important to prevent battery overcharging, excessive discharging, reverse current flow at night and to protect the life of the batteries in a PV system. People bring their batteries or rent from the station for recharging up to a specific voltage level. 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 most accessible and affordable 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. 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.

1.1 Background and Motivation

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. 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 areas that is unable to cover up their basic demands. The existing electric grids are not capable of supplying the electric need. This project focuses on building a solar battery charging station in rural areas of Bangladesh with the aim of enabling people to have affordable access to renewable energy. The great foreseen advantages of SBCS were security of payment for the electricity service and operation under much higher system final yields and capacity factors. However, an analysis of the annual costs of SBCSs indicates that they are in reality more expensive alternative than solar home systems (SHSs) owing to the shorter lifetime of batteries. Moreover, battery transport for recharging and lower energy capacity, among other drawbacks, make users opts for the added convenience of a convenience of a solar home system. Because the battery is being transported to and from the battery charging station it could suffer damage in transport more often but maybe less likely to suffer from electrolyte stratification if it is a wet cell battery. The battery issues seem to be the area that will affect the economics to the greatest extent.

Considering cases on the successful implementation of SBCS in some foreign lands such as, Cambodia or Iraq or India, we are also motivated to use this concept too. It is one of the best alternatives for charging automotive batteries used either in solar home system or in solar Rickshaw/any solar powered vehicles or for charging purpose of lanterns.

The prototype design of "central solar battery charging station" can interchangeably charge one 12V battery of 80Ah and one 48V battery of 40Ah. The 12V battery is used in solar home systems (SHS) that can power basic household appliances like electric fans, lights and a television. The 48V battery is used to provide power to drive the motor in an electrically assisted hybrid rickshaw.

The charge controller and accompanying software has been designed to track the charging status of the batteries, prolong their life by preventing overcharging, and allow for charging to take place in the fastest possible time. The charged batteries can be supplied to rural household inhabitants at a reasonable price with convenient installments payment options that will encourage a more widespread implementation of a centralized SBCS.

In the short run, the incorporation of SBCS is a cheaper option compared to the incorporation of SHSs which are cheaper in the long run. However, the required initial investment for the purchase of SHSs makes them a little difficult to afford by people of low income groups in rural households. Diesel Battery Charging Stations (DBCS) are neither sustainable nor energy efficient.

1.2 DESCRIPTION

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.

1.3 REASONS BEHIND IMPLEMENTING MICROCONTROLLER IN CHARGER

It is obvious that, using a would reduce the size and complexity of the circuitry of the solar charger leaving most of the monitoring and management of the charging process on the programme (algorithm) burned into it. Moreover, it will be more accurate and the charging of the battery will be more efficient. The microcontroller used has many functions among which we have utilized its ADC (analog to digital conversion) and PWM (pulse width modulation) function. The ADC function monitors the battery's state of charge (SOC) by voltage feedbacks from the battery, whereas the PWM function controls the charging process according to the feedback received through the ADC.

1.4 OBJECTIVE OF THE PROTO-TYPE PROJECT

Energy from non-renewable sources cannot be considered as a long term contributor as they will soon run out. Moreover, Pollution grows greater through the by-products non-renewable energy sources leave behind and the mining of non-renewable energy sources is causing damage to our environment. Bangladesh is plagued by a serious power crisis. Nearly half of its population does not have access to electricity. And the other half that has access to electricity is constantly affected by power cuts and load shedding due to excessive demand for electricity. This growing need for electricity has led to a countrywide dissemination of solar energy based electricity generation systems. The Implementation of Central Solar Battery Charging Station can be one of the best alternatives that can broaden the way of getting rid of electricity problem in many ways

.

For example:

1) Our charging station can be used to charge any battery including Rickshaw battery or batteries used in Solar Home System either in rental or monthly payment basis.
2) Electric lanterns used in village area can be charged.
3) Saves valuable human power.
4) The unemployed people of the village area can earn their livelihood by being employed in the charging station that can be implemented in near future following our prototype design.

5) The load of national grid will be lessening resultantly.
6) Moreover, followed by some other countries we can also replace kerosene station with Solar Battery Charging Station too with further modification.
7) The charger circuit is a micro-controller based one so modifications can be easily made if needed by changing the code written in it.
8) Lastly, our project is an environment friendly one- i.e. no greenhouse gas emissions, no non-biodegradable waste products, etc.

1.5 OUTLINE OF THE THESIS PAPER

The entire paper reveals the up-coming possibilities that can be earned from using solar energy through building a Solar Battery Charging Station with hardware implementation involving a microcontroller base charger. Here details about the current development and procedure have been clearly notified. Chapter 2 is about both the system as well as circuit components used in the prototype project. There are different techniques of charging a battery, explained in chapter 3. Chapter 4 has detailed description of the charger circuit as well as the implemented protection standards set by IEDCOL. The algorithms programmed into the microcontroller based on chapter 3 are fully explained in chapter 5. The challenging issue- interfacing in between software and hardware in windows environment is explained in chapter 6. All test results starting from gathering data in each step in progress of the project till the final results as well as the problems faced/revealed, their analysis and solutions have been shown and discussed in chapter 7. Lastly, the conclusion and future works telling us about the success as well as the boundaries of this hand-shaking project along with the upcoming development of our hardware too are in chapter 8

CHAPTER 2

OVERVIEW OF THE PROTOTYPE PROJECT

2.1 DESCRIPTION OF THE WHOLE SYSTEM (PROTOTYPE)

A two-dimensional project with hardware and software implementation along with designing a microcontroller based solar charger for Central Solar Battery Charging Station has been designed. The hardware side consists of a simulation of a micro-controller based charger as well as its practical implementation and a comparative study between them. The software side of this project will be responsible for monitoring the battery state of charge via a DAQ card.

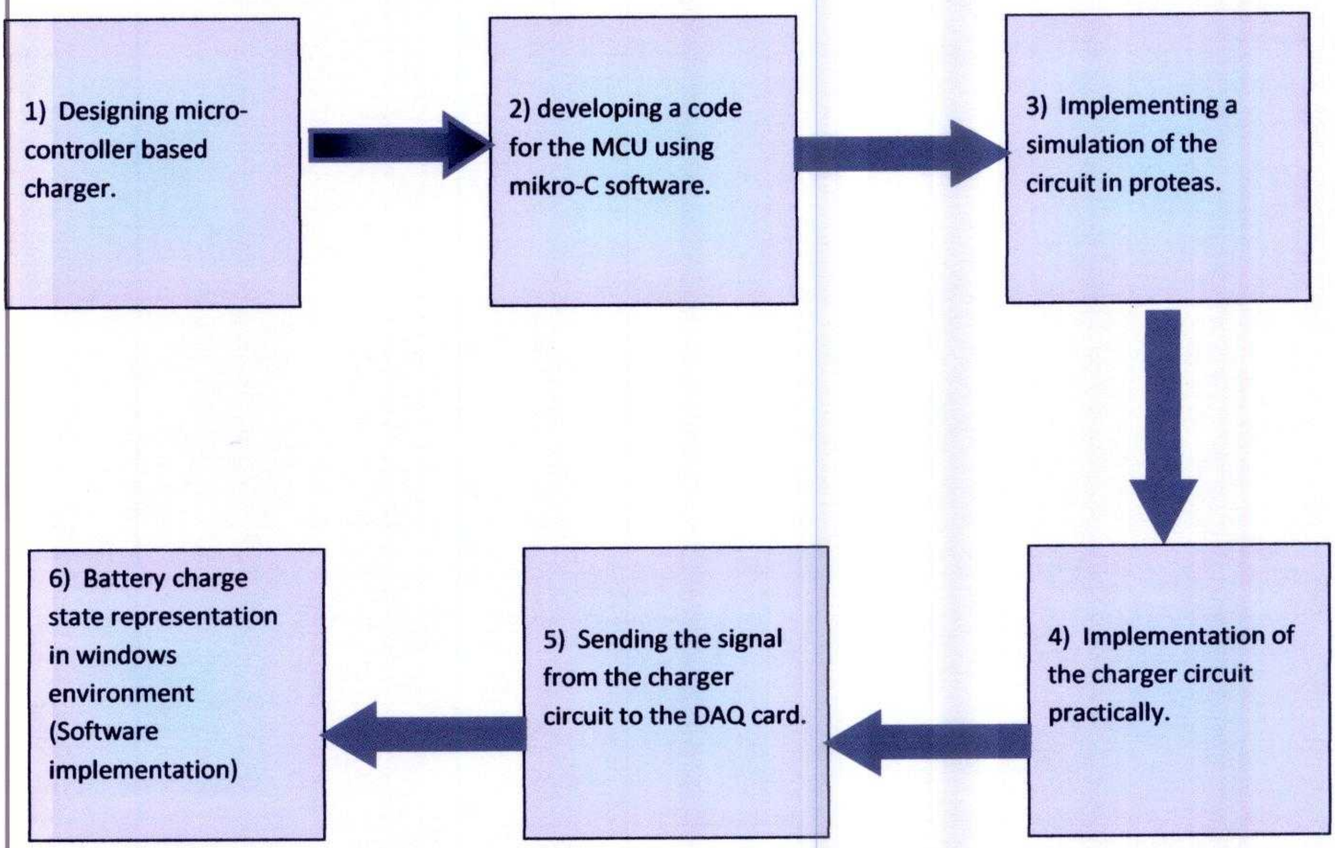


Fig 2.1: Flowchart Representation of the Whole Project

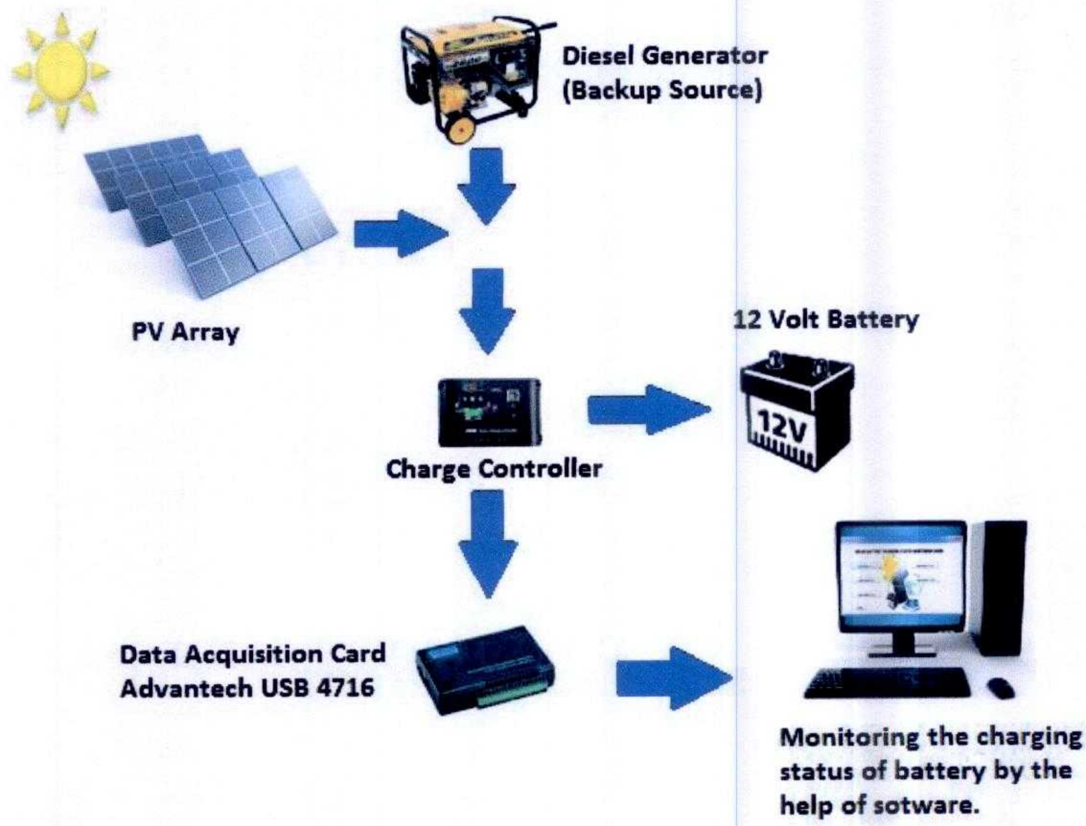


Fig2.2: overview of the project

2.2 HARDWARE IMPLEMENTATION

Solar energy is being harnessed and converted to electrical energy via solar panels and then stored in batteries which can then be used to power households and agricultural activities. The charger circuit is the main focus of our hardware side and since it is micro-controller based, the programming can be easily modified according to the battery capacity.

In the hardware implementation project following components are there:

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 deep discharges and overcharges of the battery

5. Wire connections (Cable, switches and connection box.)

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

2.3 SOFTWARE IMPLEMENTATION

Software implementation of SBCS is vitally important to monitor the system state of charge 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 cost effective.

The main reasons to implement efficient software are:

- ✓ A false practice to check charging status of battery using flashlight tends to damage battery due to overcharging
- ✓ The GUI of existing DAQ card has fewer features with few or no graphical representation of the voltage detected.

The software developed is a keen project where the full motivation is to create a GUI with VISUAL STUDIO 2010. The software implemented was based on all likely criterions that can arise in charging batteries in minimum time exclusive of causing any sort of damage. Initially the Data Acquisition System was designed using Data Acquisition Card (ADVANTECH USB 4716). This card is a 16 bit system with 5Volts-10Volts of reference to make the card resolution up to 0.7mv that is enough accurate for development. Afterwards, the processing of the DAQ card is done; the data received is sent to the computer. Lastly we have to perform the deployment the GUI that we have made.

CHAPTER 3

BATTERY AND THE CHARGER

3.1 BATTERY DESCRIPTION

Fig 3.1 A Volvo Solar Power 12V Battery

The ***battery*** stores the energy produced by the panels that is not immediately consumed by the load. This stored energy can then be used during periods of low solar irradiation.The most common type of batteries used in solar applications are ***maintenance-free lead-acid batteries.*** The most common batteries in photovoltaic solar applications have a nominal voltage of 12 or 24 volts. A 12 V battery therefore contains 6 cells in series. The battery serves two important purposes in a photovoltaic system: to provide electrical energy to the system when energy is not supplied by the array of solar panels, and to store excess energy generated by the panels whenever that energy exceeds the load. The battery experiences a cyclical process of charging and discharging, depending on the presence or absence of sunlight. During the hours that there is sun, the array of panels produces electrical energy.The energy that is not consumed immediately it is used to charge the battery. During the hours of absence of sun, any demand of electrical energy is supplied by the battery, thereby discharging it. These cycles of charge and discharge occur whenever the energy produced by the panels does not match the energy required to support the load. When there is sufficient sun and the load is light, the batteries will charge. Obviously, the batteries will discharge at night whenever any amount of power is required. The batteries will also discharge when the irradiance is insufficient to cover the requirements of the load (due to the natural v`ariation of climatic conditions, clouds, dust, etc.) If the battery does not store enough energy to meet the demand during periods without sun, the system will be exhausted and will be unavailable for consumption. On the other hand, the over-sizing the system (by adding far too many panels and batteries) is expensive and inefficient. When designing a stand-alone system we need to reach a compromise between the cost of components and the availability of power from the system. The battery used in this PV system is a deep-cycle (lead acid) battery in the 80 amp-hour rate.

3.2 Why PWM?

Pulse Width Modulation(PWM) is today the most effective means of achieving constant voltage battery charging by switching the solar system controller's power devices. When in PWM regulation, the current from the solar array tapers according to the battery's condition and recharging needs.

When a battery voltage reaches the regulation set point, the PWM algorithm slowly reduces the charging current to avoid heating and gassing of the battery, yet the charging continues to return the maximum amount of energy to the battery in the shortest time. The result is a higher charging efficiency, rapid recharging and a healthy battery at full capacity.

In addition, this new method of solar battery charging promises some very interesting and unique benefits from the PWM pulsing. These include:

1. Ability to recover lost battery capacity and desulfate a battery.
2. Dramatically increase the charge acceptance of the battery
3. Maintain high average battery capacities (90 per cent to 95 per cent) compared to on-off regulated state of-charge levels that are typically from 55 percent to 60 percent.
4. Equalize drifting battery cells
5. Reduce battery heating and gassing.

The most important factor is how it benefits the solar system user:

Longer battery life:

- Reduces the costs of the solar system.
- Reduces battery disposal problems.

More battery reserve capacity:

- Increases the reliability of the solar system.
- Reduces load disconnects.
- is an opportunity to reduce battery size to lower the system cost.

Greater use of the solar array energy:

- Enables 20 per cent to 30 per cent more energy from your solar panels for charging
- Stops wastage of solar energy when the battery is only 50 per cent charged.
- Is an opportunity to reduce the size of the solar array to save costs.

Greater user satisfaction:

- Gives more power when needed, for less money!
- A great deal of testing and data supports these benefits of PWM.

In our project, we programmed a microcontroller (PIC16F876A) to use this concept of PWM, with varying duty cycles of charging voltage to charge the deep cycle battery depending on the battery SOC (state of charge).

3.3 Battery State of Charge (SOC) :

There are 3 main stages in the charging process, namely, the bulk state, absorption, and float charge state. (It will be discussed in details in the section on battery charging later.)(page ....) The bulk charge state is the 1st stage in the battery charging process. It is when the charging state of the battery is from 0-50 percent. During the bulk charge, 40 percent of the total Ah (amp-hour) capacity should be used to charge the battery. The 2nd stage in battery charging is the absorption charge. It is when the battery state of charge is from 50-90 percent. For this stage, the current used to charge the battery should be 20 percent of the total Ah (amp-hour) capacity of the battery. The 3rd and final stage in the battery charging process is the float charge state. The battery state of charge here is at the end, at 90-100 percent. The current used in this stage should be a mere 5 percent of the total Ah (amp-hour) capacity of the battery.

Since only one panel was used in the prototype experiment, the current obtained was rather low. Hence, only the bulk charge state and the float charge states were included in the code used in the micro-controller.

3.4 Charger Components:

The circuit components that have been used in the charge controller are

- Micro-controller(PIC16F876A)
- Bi-polar junction transistors → BC547(npn) , 2N3906(pnp) and BC557(pnp)
- Mosfet (IRFZ44N)
- Diodes (1N4148)
- Voltage Regulator (7805)
- Resistors(10k,1k,560,100,4.7k)
- Crystal Oscillator (20Mhz)

Micro-controller(PIC16F876A)

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.

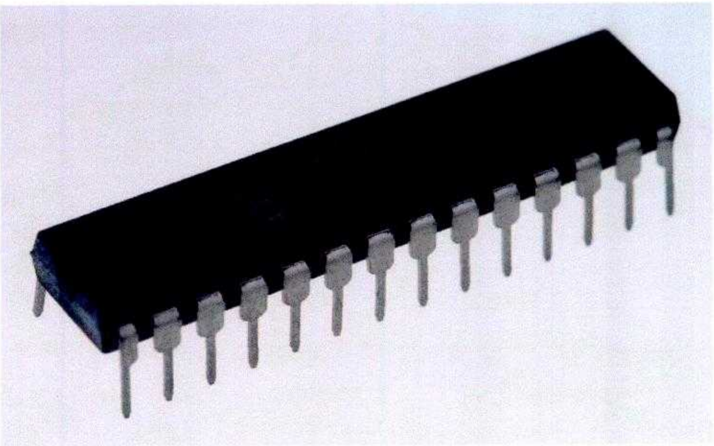


Fig3.2: Type of PIC Microcontroller

Bi-polar junction transistors

A **bipolar (junction) <u>transistor</u> (BJT)** is a three-terminal electronic device constructed of <u>doped semiconductor</u> material and may be used in <u>amplifying</u> or switching applications. Bipolar transistors are so named because their operation involves both <u>electrons</u> and <u>holes</u>. Charge flow in a BJT is due to bidirectional <u>diffusion</u> of <u>charge carriers</u> across a junction between two regions of different charge concentrations. By design, most of the BJT collector current is due to the flow of charges injected from a high-concentration emitter into the base where there are minority carriers that diffuse toward the collector, and so BJTs are classified as minority-carrier devices.

NPN transistor (BC547)

An NPN transistor can be considered as two diodes with a shared anode. In typical operation, the base-emitter junction is forward biased and the base–collector junction is reverse biased. In an NPN transistor, for example, when a positive voltage is applied to the base–emitter junction, the equilibrium between thermally generated carriers and the repelling electric field of the depletion region becomes unbalanced, allowing thermally excited electrons to inject into the base region. These electrons wander (or "diffuse") through the base from the region of high concentration near the emitter towards the region of low concentration near the collector. The electrons in the base are called minority carriers because the base is doped p-type which would make holes the majority carrier *in* the base.

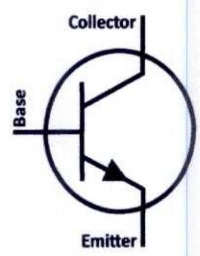


Fig3.3: NPN transistor

PNP transistor (2N3906 and BC557)

The PNP transistor works essentially the same as the NPN transistor. However, since the emitter, base, and collector in the PNP transistor are made of materials that are different from those used in the NPN transistor, different current carriers flow in the PNP unit. The majority current carriers in the PNP transistor are holes. This is in contrast to the NPN transistor where the majority current carriers are electrons. To support this different type of current (hole flow), the bias batteries are reversed for the PNP transistor. The first letter (P) in the PNP sequence indicates the polarity of the voltage required for the emitter (positive), and the second letter (N) indicates the polarity of the base voltage (negative). Since the base-collector junction is always reverse biased, then the opposite polarity voltage (negative) must be used for the collector. Thus, the base of the PNP transistor must be negative with respect to the emitter, and the collector must be more negative than the base. Remember, just as in the case of the NPN transistor, this difference in supply voltage is necessary to have current flow (hole flow in the case of the PNP transistor) from the emitter to the collector. Although hole flow is the predominant type of current flow in the PNP transistor, hole flow only takes place within the transistor itself, while electrons flow in the external circuit. However, it is the internal hole flow that leads to electron flow in the external wires connected to the transistor. Although current flow in the external circuit of the PNP transistor is opposite in direction to that of the NPN transistor, the majority carriers always flow from the emitter to the collector

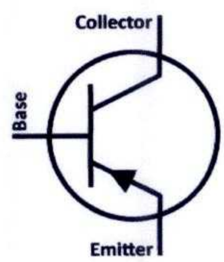


Fig3.4: pnp transistor

3.5 CHARGER CIRCUIT DESIGN AND ANALYSIS

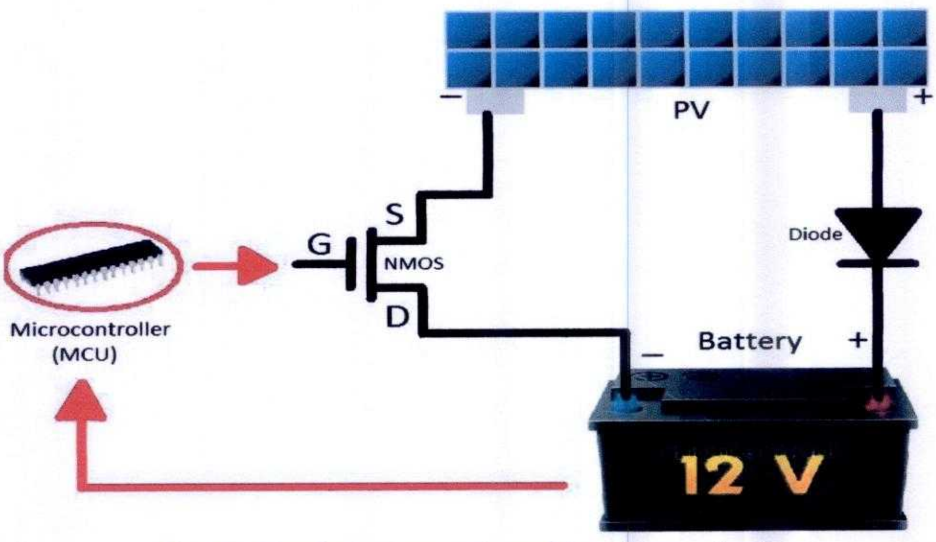


Fig3.5: Simple representation of the charger circuit

The basic setup of the PV(photovoltaic cell) panel and the battery will be such that the positive terminals of both the panel and the battery will be directly connected, whereas the negative terminals will be connected via a MOSFET(NMOS) acting as a switch.(see fig…) Thus the activation of the MOSFET will complete the circuit by shorting it and deactivating it will keep the circuit open preventing current flow. The switching of the MOSFET will be controlled by a PIC microcontroller using pulse width modulation (PWM).

In our microcontroller (MCU) based charger we have used Microlab's PIC16F876A which will be receiving certain voltage inputs as feedback from the battery and based on this feedback the MCU will control the charging process of the battery using pulse width modulation (PWM).

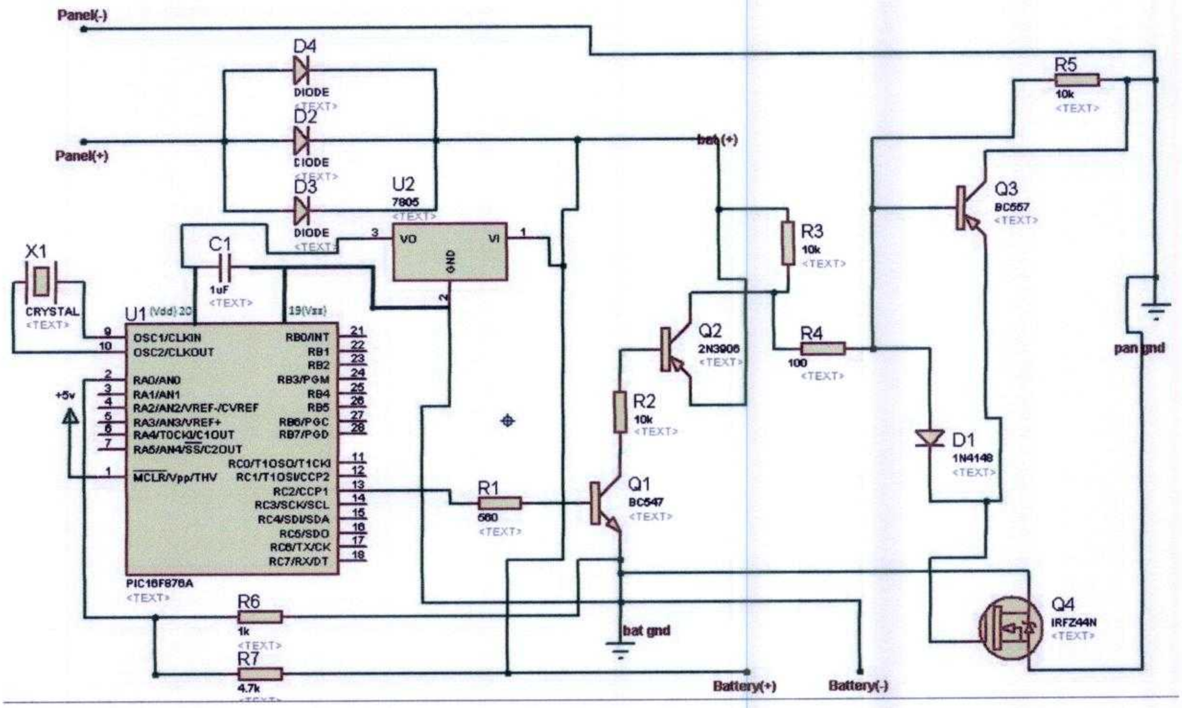


Fig3.6: Schematic Diagram of Charger Circuit:

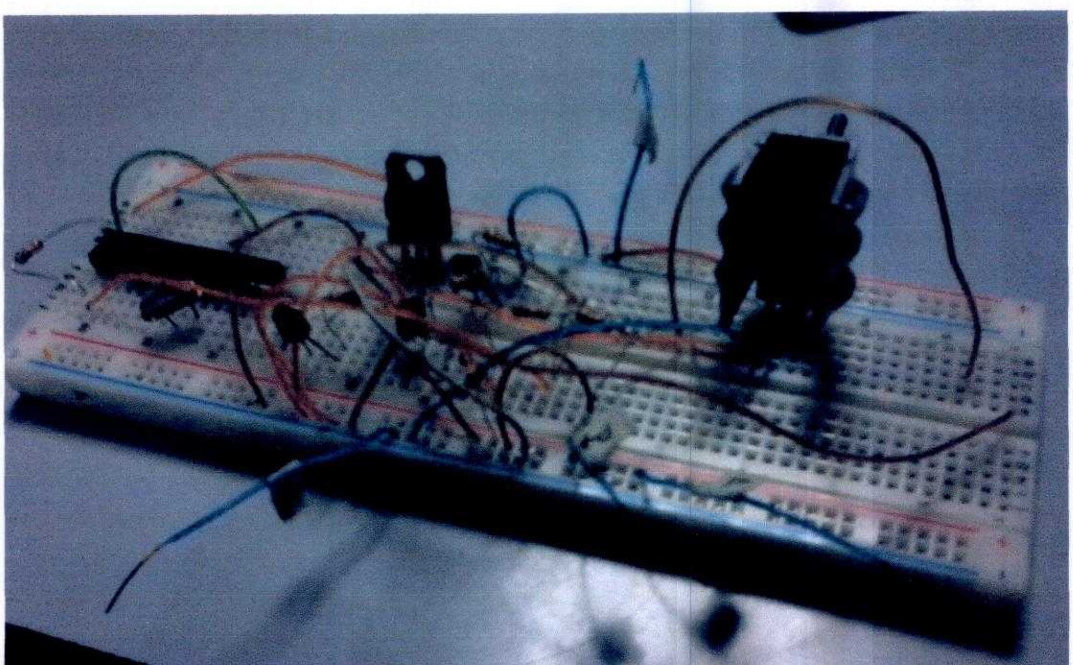


Fig3.7: Charger Circuit implemented on breadboard

Powering the MCU

Since the MCU used can juggle with a maximum voltage of 5V, it is powered by the charging battery itself via the voltage regulator 7805. Capacitors of capacitances 0.1uF and 100uF are used at the output of the voltage regulator to act as filters to provide a smooth 5V potential to the MCU's 20th pin(Vdd = power input pin) without any interruption and reduced noise.

Amplifying the MCU output

As the pulse width modulating signal produced by the MCU is within the 0V-5V range, it is not large enough to power-up the MOSFET (NMOS) gate, in other words the voltage from the MCU is less than that of the MOSFET's threshold voltage. In order to overcome this, a Darlington Pair composed of the BJTs BC547 (NPN) and 2N3906 (PNP) along with necessary resistors is used. The output of the Darlington Pair is fed to the gate of the MCU through a high speed switching diode (1N4148) since the PWM signals arriving are in the Kilohertz (KHz) frequency range.

Why not use Operational Amplifiers (Op-Amps) to amplify the signal from the MCU?

Op-Amps have a higher fall time compared to the mode of amplification used in this circuit. Higher fall time would lead to the loss of a considerable amount of the PWM signal from the MCU.

Feedback of Battery's Sate of Charge to the MCU

It is already known that a battery's sate of charge(SOC) can be monitored by the voltage across it. During pulse width modulation, in order to control the Duty Cycle at different states of charge of the battery, the MCU would require certain notification of the battery's charge state. To do this the MCU's ADC (Analog to Digital Conversion) function has been used in order to convert the different analog voltages of the battery into digital values, which are then easily recognized and used by the MCU with its code programming (algorithm).

According to the MCU's specifications it toggles with voltages that are far less than the battery SOC voltages meaning if such voltages are fed to the MCU, it will result in burning the IC. This factor was easily dealt with by using a voltage divider circuit consisting of a 1KΩ and 4.7KΩ resistors connected to the battery's positive and negative terminals and taking the output voltage from across the 1KΩ resistor to be fed to the MCU's ADC input pin.

Note: Entry of a certain command like "ADC_READ (channel no.)" into the programming of the MCU brings about an automated conversion of analog value input from a certain channel/pin of the MCU to a digital value.

Leakage Current

When the battery is fully charged, base on the feedback of this state of charge of the battery the MCU stops pulse width modulation (i.e. duty cycle becomes zero) resulting in the opening of the switch (i.e. no signal is send to the MOSFET thus keeping it off). Doing so stops the charging process/further charging of the battery preventing it from being damaged due to over-charged.

When the MOSFET is turned off, there is a small reverse leakage current (Isd) flowing from the source of the MOSFET to its drain. When thought of in a long term point of view this reverse leakage current has the tendency of damaging the panel in small amounts every time it flows. To deal with this problem a circuit involving certain resistors and the BJT BC557 (PNP) has been used. When the MCU stops its pulse width modulation, this zero signal is simultaneously send to the BC557. As the BC557 is a PNP type BJT it is turned on by this zero signal/pulse meaning it is only turned on when the charging process is off. When turned on this circuit helps to ground the reverse leakage current by sending it/directing its flow back to the panel ground.

Note: The BC557 is off all throughout the charging process due to getting pulses.

Reverse Flow Protection

The positive(+) terminals of both the panel and the battery are shorted but with three 5A capacity diodes between them with the diodes' directed from panel to battery to ensure one way flow of current(i.e. from panel to battery). This mechanism acts as a protection for: reverse polarity connection due to human error (mistake made by the user); as well as when battery voltage exceeds panel voltage and discharging of battery to panel is prevented thus protected from being damaged.

3.6 PCB Design of Charger:

Due to less current handling capacity of bread-board the PCB was incorporated. Another reason for doing so was due to unexpected loss of connection at certain points in the bread board at different times, which affected its function and was time consuming in being detected. The PCB design of the charger circuit was made using ARES Professional.

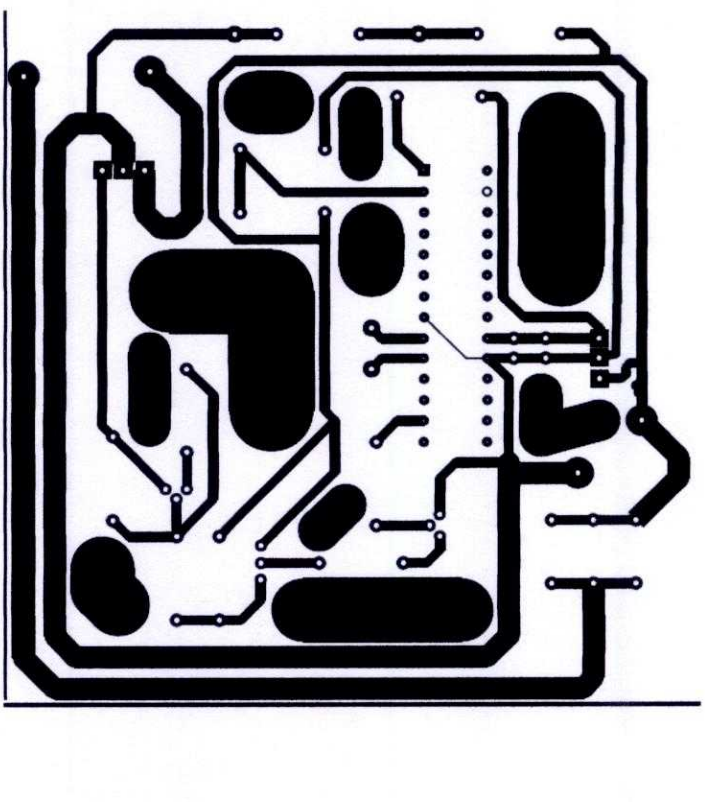


Fig3.8: Bottom copper layer

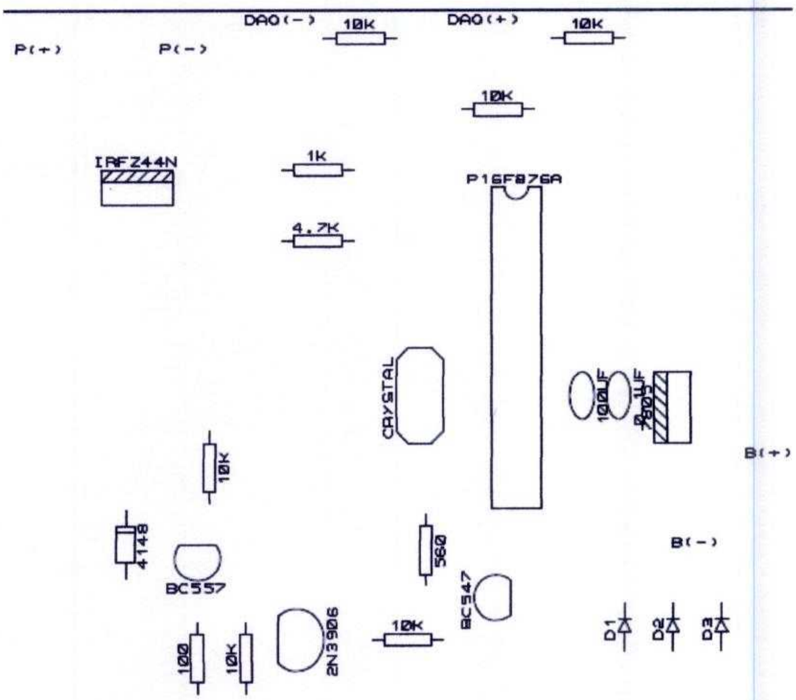


Fig3.9: Top Silk Layer

CHAPTER 4

MIKRO-C CODE

4.1 Efficient Battery Charging

The battery that has been used is a lead-acid deep cycle solar battery (12V, 80Ah,10 h). But before the battery can be used or implemented into the project it had to be tested for all the specificity declared in its manual as well as factors that are affected by and affect certain aspects of the battery.

For all batteries that fit the criteria of the one that we have, it must be made sure to give a new battery 24 hours of rest after it had been fully charged. Also, in cases where the need for the battery is crucial and there is less or no time for the battery to rest after being fully charged, then the degree of discharging the battery via load must be taken into consideration. For example: if the battery is to be discharged to 50-85%, then it will need to rest after being fully charged; whereas if it is to discharged to 10-15% of its full charge, then it can be used after a few minutes rest or no rest at all. But it is advised to follow IEDCOL's standard procedure of letting the battery rest unless faced with unavoidable circumstances.

The charge condition of the battery can be monitored, either by measuring the voltage(short circuit voltage) across it or by measuring its specific gravity. The specific gravity of a battery is basically the ratio of the acid concentration and water content of the battery. For the solar battery at our disposal, if its open circuit voltage is below 11.94V and increasing during the charging process, then it can be said that the battery is completely discharged. If the voltage is 14.4V and stable/constant then it can be said that it is fully charged.

The charging process of a battery has 3 basic stages: Bulk, Absorption, and Float:

Bulk Charge:

The first stage of the 3-stage battery charging. It is when the battery charge state is from 0-50 percent. Current is sent to batteries at the maximum safe rate they will accept until voltage rises to near (80-90%) full charge level. Voltages at this stage typically range from 10.5 volts to 15 volts. There is no "correct" voltage for bulk charging, but there may be limits on the maximum current that the battery and/or wiring can take. During the bulk charge,40 percent of the total Ah(amp-hour) capacity should be used to charge the battery.

Absorption Charge:

The 2nd stage of 3-stage battery charging. This is when the battery has a 50-90 percent charge state. Voltage remains constant and current gradually tapers off as internal resistance increases during charging. It is during this stage that the charger puts out maximum voltage. Voltages at this stage are typically around 14.2 to 15.5 volts. The current used here in this stage should be 20 percent of the total AH(amp-hour) capacity of the battery.

Float Charge:

The 3rd stage of 3-stage battery charging. This constitutes 90-100 percent charge state. After batteries reach full charge, charging voltage is reduced to a lower level (typically 12.8 to 13.2) to reduce gassing and prolong battery life. This is often referred to as a maintenance or trickle charge, since it's main purpose is to keep an already charged battery from discharging. PWM, or "pulse width modulation" accomplishes the same thing. In PWM, the controller or charger senses tiny voltage drops in the battery and sends very short charging cycles (pulses) to the battery. This may occur several hundred times per minute. It is called "pulse width" because the width of the pulses may vary from a few microseconds to several seconds. Note that for long term float service, such as backup power systems that are seldom discharged, the float voltage should be around 13.02 to 13.20 volts. The current used in this stage should be only 5 percent of the total Ah(amp-hour) capacity of the battery.

When discharging such batteries through any load say for example: a lamp; it must be made sure that the load has a less or moderate current reading, i.e. the load must not take up a huge amount of current from the battery when operating. If such were to happen, then the high current consumption will result in the formation of an electrolyte layer inside the battery which will prevent the exposure of the rest of the electrolyte, thus stopping the discharging process in very short period of time resulting in the lamp going out very quickly. On the other hand, if the current is consumed in a slower rate by the load then the electrolyte layer formation can be avoided, letting the discharging continue and the lamp lit for a longer time period.

A solar battery such as the one we used should never be fully discharged. This reduces the battery cycle(number of times the battery is charged and discharged) i.e. the lifespan of the battery. Considering standard 12V, 80Ah batteries for example: if such battery is completely discharged once then it can be used for 250 cycles; for 50% depth of discharge, about 480 cycles; for 30% depth of discharge, nearly 1300 cycles and so on. For standard usage it is suggested that the battery's depth of discharge is maintained within 50% for logical durability.

The first thing that was done after getting the battery was confirming its capacity. After the battery was filled with the correct amount of electrolyte, it was first charged fully, then discharged using a 50Watt lamp during which several readings were taken at constant time intervals of 30 minutes. The battery was discharged to a voltage of 11V avoiding deep discharge.

4.2 MikroC coding

```
unsigned int v1;

void main() {

    TRISA=0xFF;

    TRISB=0X00;

    PORTB=0X00;

    ADCON0=0x00;  //enabling ADC function of MCU and declaring the ADC port  being used

    ADCON1=0b00000000;

    pwm1_init(40000);

    ADC_Init();

    while(1)
```

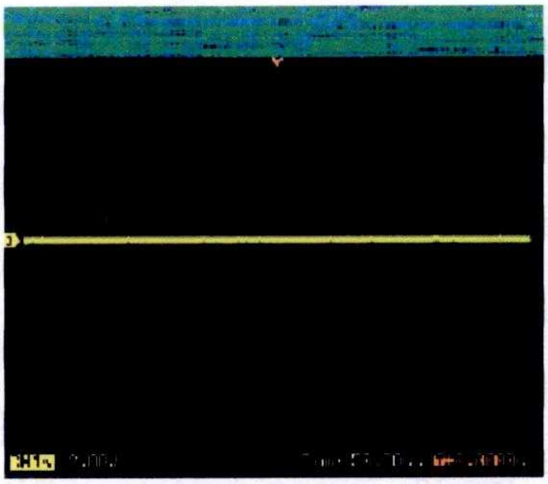
```
    {
        pwm1_start();
        delay_us(50);
        v1=ADC_read(0);    // storing analog-to-digital converted values in v1
  if(v1<=396){  // DISCONNECTED(if battery is DEAD) // v1<=10.5V
  pwm1_set_duty(0);
  }
  else if(v1>396 && v1<=436){  // v>=396: if the battery already has charge, but less than
50%(for normal bettery) or 30%(for solar battery) of its capacity. // 10.5V<v1<=11.6V
  pwm1_set_duty(230);
  }
  else if(v1>436 && v1<=473){  // BULK CHARGE// 11.6V<v1<=12.7V
  pwm1_set_duty(230);
  }
  if(v1>473 && v1<=513){  // ABSORPTION CHARGE// 12.7V<v1<=13.8V
  pwm1_set_duty(30);
  }
  else if(v1>513 && v1<534){  // FLOAT CHARGE// 13.8V<v1<14.4V
  pwm1_set_duty(30);
  }
  else if(v1>=534){  // DISCONNECTED(if battery is fully charged or DEAD)//v1>=14.4V
  pwm1_set_duty(0);
  }
}
}
```

CHAPTER 5

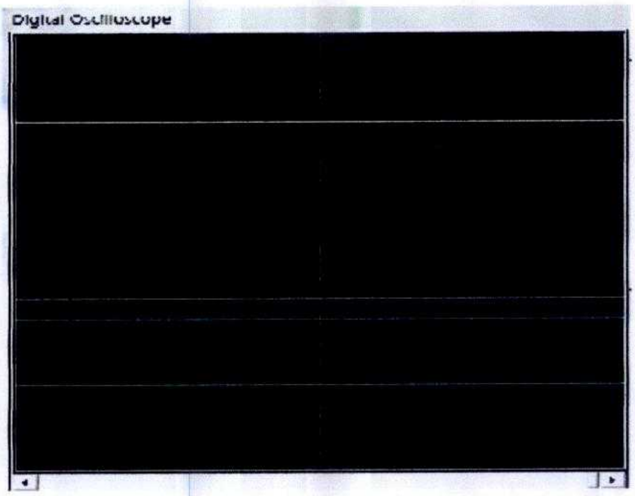
TEST RESULTS AND ANALYSIS

Testing and Analysis

In this section, a comparative description between the simulation test results as well as experimental test results along with comparative figures is shown. The figures include digital oscilloscope outputs from both the simulation(right) and practical tests(left). In the simulation oscilloscope results it can be seen that the upper yellow pulses represent the output from the MCU ccp1 pin whereas the blue ones under represents the pulse signals that are reaching the MOSFET gate



experimental results for 10.5

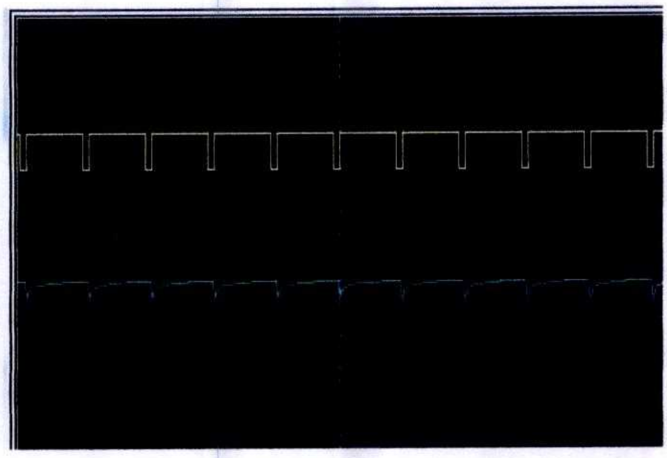


simulated result for 10.5V

figure:1

Fig5.1

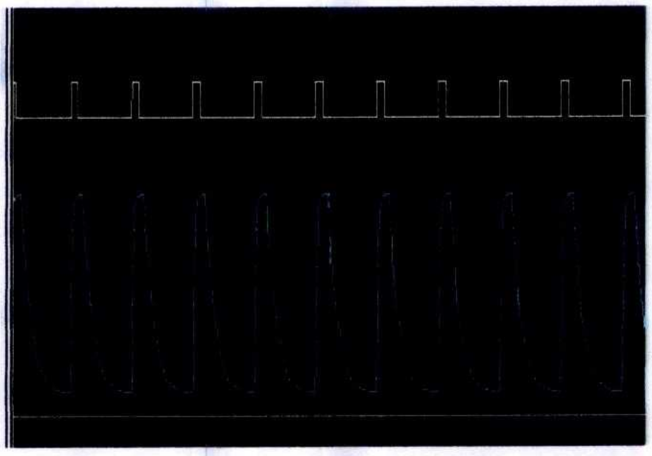
Experimental 11.6V



Simulated 11.6V

Fig5.2

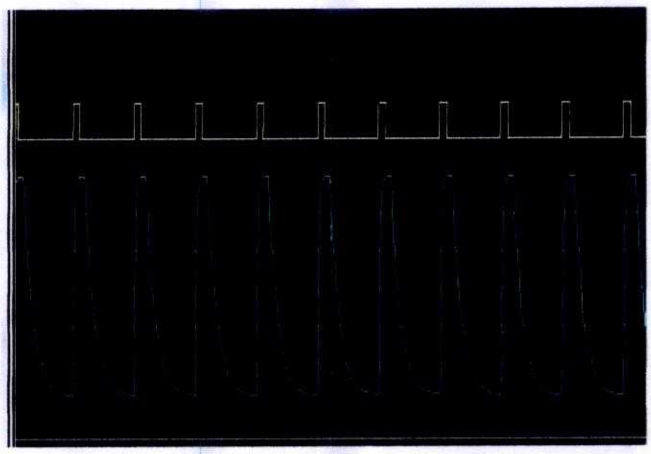
Experimental 12.7V



Simulated 12.7V

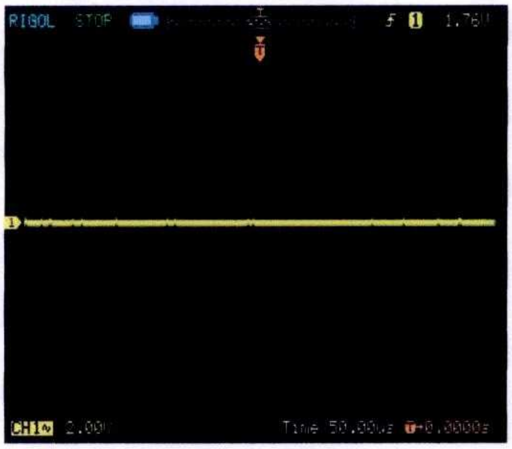
Fig5.3

Experimental 13.8V

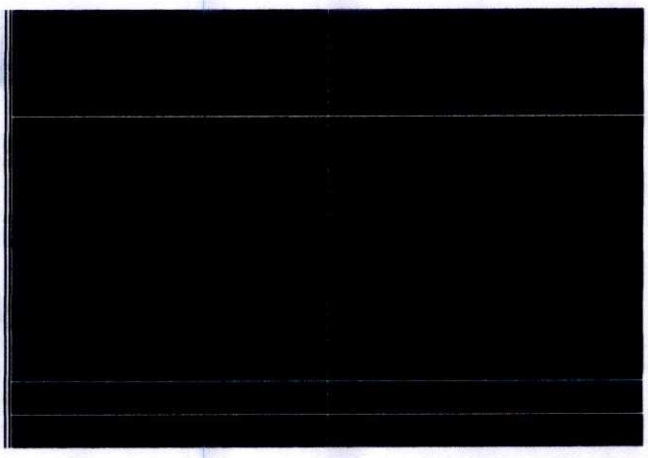


Simulated 13.8V

Fig5.4



Experimental 14.4V



Simulated 14.4V

Fig5.5

CHAPTER 6

CONCLUSION AND FUTURE WORK:

6.1 Success of the Hand-Shaking Project:

The hand-shaking or the interfacing between the hardware and the software of the prototype was successful with minimum error. The voltage value entering the DAQ card was taken through a potential divider consisting of a pair of 10K resistors. This was done in order to change the values of the battery voltage to a lesser scale so that the DAQ is not damaged due to high voltage as it can only take in a maximum of 10V.

6.2 Future Plans

- Upgrade 12V charger to 48V.

Commercialization in a Solar Battery Charging Station.

- Implement Load Management into charger.

For managing light loads in the station.

- Introducing Backup.

Automated continuation of charging incase of PV failure or emergency situation. This will be done by a Diesel Generator.

List of References:

1. http://www.windsun.com/Batteries/Battery_FAQ.htm#Battery Charging
2. http://www.morningstarcorp.com/en/support/library/8.%20Why%20PWM1.pdf
3. http://www.solarhome.ru/en/control/pwm/index.htm
4. http://www.solarhome.ru/en/control/pwm/pwm_chargers_faq.htm
5. www.electronics-tutorials.ws/**transistor**/tran_2.html
6. www.tpub.com/neets/book7/25b.htm
7. *en.wikipedia.org/wiki/Bipolar_junction_**transistor***
8. Building a Solar Battery Charging Station in Kandal Province Cambodia(Thesis Paper) ,URL: http://www.kamworks.com/projects/solar-battery-station.html

Appendix:

28-Pin PDIP, SOIC, SSOP