Solar Pump Motor for Irrigation in Rural Areas

by

Hazle Bin Ibrahim

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Dissertation submitted in partial fulfilment of
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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical and Electronic l Engineering Programme
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Approved by,

(Mr. Zuhairi Hj Baharudin)

Mr. Zuhairi Baharudin
Lecturer
Electrical & Electronic Engineering
Universiti Teknologi PETRONAS

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

HAZLE BIN IBRAHIM

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Great deals appreciated go to the contribution of all technicians - Department of Electrical and Electronic. I am also will like to thankful the Coordinators of Final Year Project for Electrical and Electronic Department, that patient in helping us complete this program.

ABSTACT

This report gives an overview about the solar pump motor that will be design. The main objective of this project is to design a solar pump motor system for the irrigation in rural areas.

Usually the water pumping systems for irrigation in rural areas use the animal or human power source to pump the water. Even though there is electric energy from the suppliers to operate the pumping system, it will coast highly. This is due to the implementation of the transmission line needed. Chapter 1 briefly explained the background of study, problem statement, objective and scope of study.

In the Chapter 2, the report will discuss on the literature review and the theory behind this project. To design a solar power pump motor the understanding on each system components on how it work and basic idea of it are needed. The scopes of study for this project will include the concept of solar energy, photovoltaic (PV) panel, photovoltaic (PV) cell storage, operation of direct current (DC) and alternating current (AC), rectifier and converter and control unit.

There are several methodology used in this project. The major is literature research on the internet about the present solar pump method. Beside that, the additional reading related to the solar pump motor design is also made. The Auto CAD also will be used in the design drawing of the system. All of this will be explained more on the Chapter 3.

Several findings have been discovered during the research. It was found that actually the photovoltaic (PV) cell is consisting of N-type and P-type material as like a semiconductor device. The AC motor can be used even though the supply from photovoltaic (PV) cell is direct current (DC). This can be done by using an inverter.

The concept of solar battery storage also has been studied during the research. There will be more explanation of findings in the Chapter 4.

CHAPTER 1
INTRODUCTION

1.1 Background of Study

This project is more on the conceptual design of the solar pump motor. In the first semester the student is only do the research on the project. The implementation of the project whether in prototype form or real systems will be completed in the second semester. In this project all the solar pump motor system components will be studied. The design of the system will include the solar photovoltaic (PV) structure, motor size and a control unit. The major part focused in the project is designing the circuit switching that will controlled the operation the system (PV and battery) the load (motor)

1.2 Problem Statement

Rural areas are always facing the water-pumping problem. In developing countries they are used extensively to pump water from wells and rivers to villages for domestic consumption and irrigation of crops. Many methods have been discovered to pump water with a minimum of effort. Usually the method used is by operating the motor pumping using electricity. The conventional electric supply from suppliers will cost highly for the rural area. This is due to the transmission line need to be implemented. This problem can be solving by solar pump motor system that will be design. The system is use the solar energy to operate the pump motor where it will save the money in implementation of transmission line for the rural area.

1.3 Objectives

1. To study and design control unit of solar pump motor system for irrigation in rural area.
2. To study the concept battery sizing of solar pump motor system.
3. To study and design the basic switching circuit that will evaluate the role of power conditioning and control elements
4. To study the battery operation in photovoltaic systems.

1.4 Scope of Study

The scope of study of the project will more concentrate on designing concept the solar system for irrigation in rural areas and designing the switching circuit. To make sure this project will successfully done the study and deeply understanding on these area are needed.

- Basic idea of solar energy.
- Operation of photovoltaic (PV) cell and conversion of solar energy to electric.
- Operation of the motor, alternating current (AC), direct current (DC), rectifier and converter.
- Concept of solar energy storage in a battery.

- Concept of control unit as a switching for the solar pump motor.

In the second semester the scope of study for the project has been change a little bit. The previous scope of study is on the designing the solar system for motor pump. But after discussion with the supervisor, in the second semester the scope of study for the project is designing solar system for the lighting.

CHAPTER 2
LITERATURE RIVIEW / THEORY

2.1 Overview of Photovoltaic System

The solar pump motor will designed is consisting of photovoltaic (PV) panel, power storage (battery), a control unit as a switching part, inverter (DC to AC converter) and motor. Photovoltaic (PV) panel will collect the solar energy and convert it to the direct current (DC). This electric energy then is stored in the battery. The electric energy in the battery is used by controlling a control unit (switching part). Then the direct current (DC) from battery is converting to alternating current (AC) at the inverter before it will used to move the motor and drive a pump. This conversion of DC to AC source is depending on the usage of load. Generally the photovoltaic systems consist of a number of part or subsystems as shown in Figure 1:

a) The photovoltaic generator with mechanical support and suns tracking system
b) Batteries (storage subsystems)
c) Power conditioning and control equipment, including provision for measurement and monitoring
d) The system may contain a supplementary generator or back-up generator to form a hybrid system

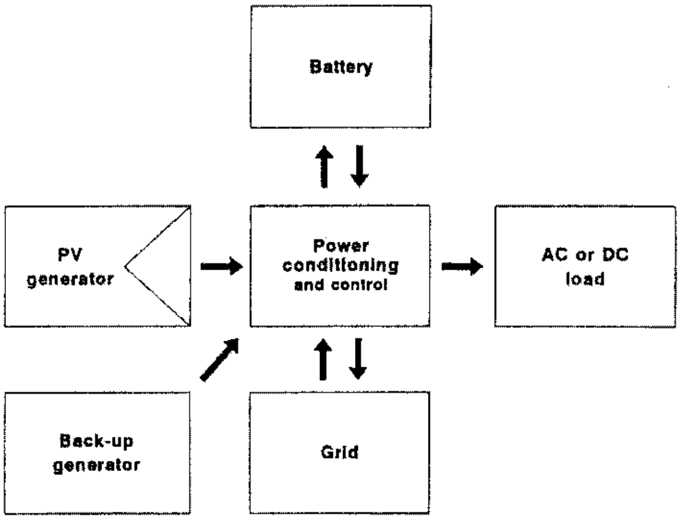


Figure 1: Photovoltaic System

There are two categories of the systems, grid connected and stand-alone. The type that usually used in water pumping system is stand-alone. This type is the simplest form of the latter consists simply of a photovoltaic alone, which supplies DC power to a load when there is adequate illumination. The systems will usually contain a provision for energy storage by batteries.

2.2 Photovoltaic (PV) Cell

Photovoltaic (PV) cell is a semiconductor device that can convert the sunlight direct current (DC). This is happened when the sunlight strike the photovoltaic surface (contain of two different material, N – type and P – type) that is will produce the current (electron). The photovoltaic cell is used in form of array arrangement that consist of several panel on it. Figure2 shows the arrangement of photovoltaic cell into a panel.

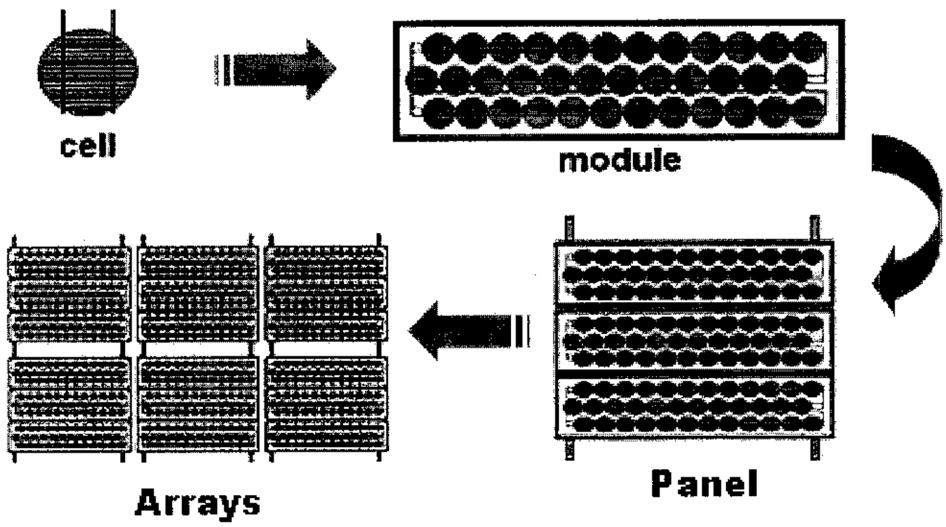


Figure 2: Photovoltaic cells, modules, panels and arrays

2.3 Battery

A battery, which is actually an electric cell, is a device that produces electricity from a chemical reaction. A battery consists of two or more cells connected in series or parallel, but the term is generally used for a single cell. A cell consists of a negative electrode, an electrolyte that conducts ions, a separator, also an ion conductor and a positive electrode. A solar battery stored the sun's energy that converts to electricity. The common type of battery used is deep-cycle battery. This battery can discharge more of their stored energy and can maintaining for long life. The most commonly used deep-cycle batteries are lead-acid batteries (both sealed and vented) and nickel-cadmium batteries.

2.4 Control Unit

Control unit is an important part in the solar pump motor for irrigation in rural areas. The function of the control unit is to choose the operation whether to charge the solar battery storage or to use the battery as an electric source to move the pump motor. It can be design in two ways manually or automatically.

CHAPTER 3
METHDOLOGY / PROJECT WORK

Methodology in this project can be divided into three stages, research, design, experiment on prototype and implementation of the project. In the first stage, the research on the each components of the solar pump motor system will be discovered. This research is conducted through the internet and reading from the book and technical paper on the solar pump motor present. In the design stage, the drawing of the system should be come out. This drawing is completed at the end of first semester. Beside the conceptual design, the experiment on the prototype built also will be conduct. This is important to understand the concept of solar motor pump will be design. The experiment on the circuit switching built has been conduct to see whether it can functional well or not. Beside that the drawing on the conceptual diagram of the solar system and solar cart are produce. This is done through the study on the book and internet. Below are the experiment conducted.

3.1 Experiment 1

The circuit is connected to a solar cell. The solar cell is connected to the circuit for 20 minutes to give or store the charge in the capacitor. During this time the LED (as a load is ON). After 20 minutes, the solar cell connection to the circuit is brake. It is found that the LED is ON all the time. The LED supposes to turn OFF when the capacitor is fully discharge in a certain time. The circuit that was built for the first stage is shown in Figure 3

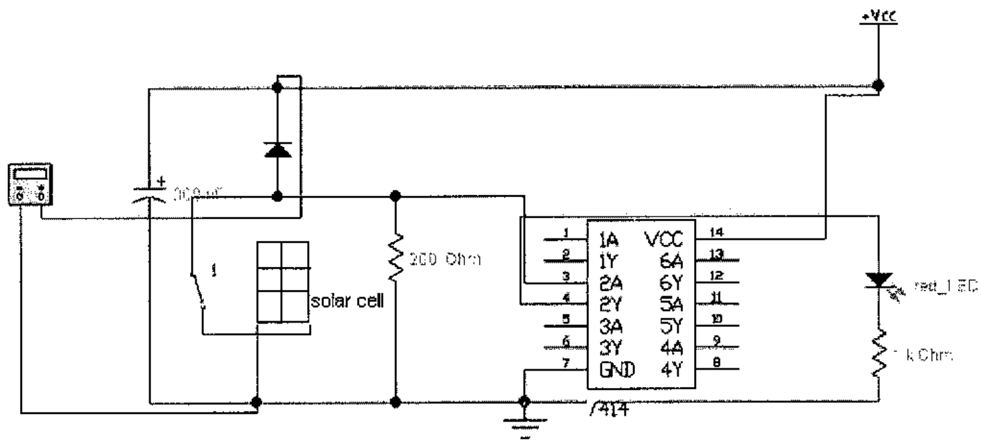


Figure 3: Basic idea of arrangement of switching circuit with the solar cell

3.2 Experiment 2

To overcome the problem in the experiment one, the student was connected four solar cells in serial. The student was assumed that the power produced by one solar cell is not enough. Before do the connection to the circuit switching, the output produced from the serial solar cell has been determined. The maximum voltage produced is 33.416 volt and the maximum current is 21 mA. The connection of solar panel is shown as in Figure 4.

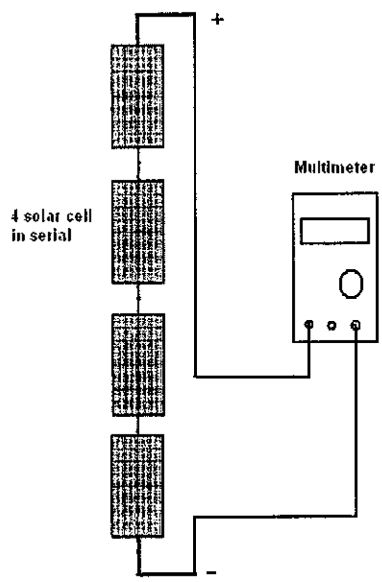


Figure 4: Connection of serial solar cell

This voltage and current supposedly is enough for the circuit to functional well. Then this serial solar cell is connected to the switching circuit for 20 minutes to operate the LED and store the charge in the capacitor. Again after the connection of solar cell is taken out, the LED is ON without any limit of time. It is supposed to turn OFF with depending to the concept of discharging the energy from the capacitor.

3.3 Experiment 3

In the third experiment, the student was trying and error to trouble shoots the switching circuit. It is found that the switching circuit is totally depending on the Vcc that supply to the Schmitt trigger. So it is mean that, the source or supply from the capacitor and solar cell is neglect. After presenting these things to the supervisor, he also agrees with that. So the solution is to find another method in implementing the circuit switching. Finally after all the design and understanding of each component is finish the actual solar pump motor will be implemented.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Review of the PV (Photo Voltaic) Solar System Concept.

PV (Photo Voltaic) Solar system is the conversation of solar energy to the electricity source. Basically the PV solar system consists of:

- PV panel - PV panels produce the electricity from the sunlight.
- Power storage - Used to store the energy collected.
- Switching part - function either to run the motor or charge the batteries.
- Inverter – convert the DC (Direct Current) voltage to AC (Alternating Current) voltage
- Energy conversion (motor) – as a mechanical tool to operate the pump system

The solar energy is collected through the PV (Photo Voltaic) cell. Then the electrically energy is store in the battery. Controlling the switching part uses the storage energy in the battery. After that the DC voltage from the battery is converted to the AC voltage. The AC voltage then is used to generate the motor which is will produce the mechanical force to spin the motor shaft. The design of Solar Pump System for Irrigation in Rural Areas is similar to Figure 5 shown.

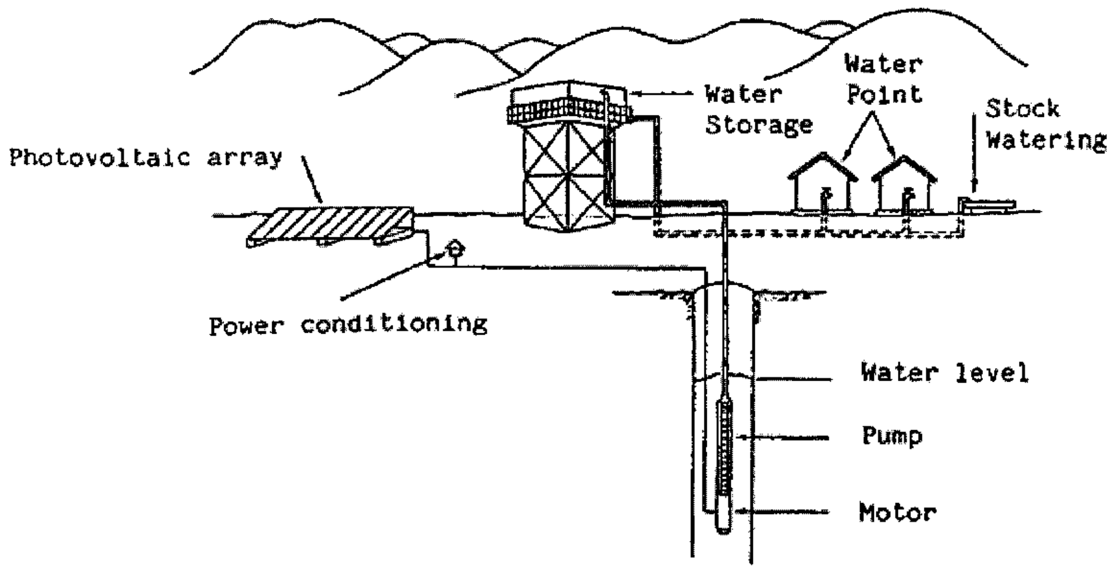


Figure 5: Design of Solar Pump System for Irrigation in Rural Areas

4.2 Basic Concept of Photovoltaic (PV)

A photovoltaic (PV) array is consists of PV panel which is contain a certain amount of PV module, and in this PV module there are many of cell. Figure 6 shows the architecture of the PV array.

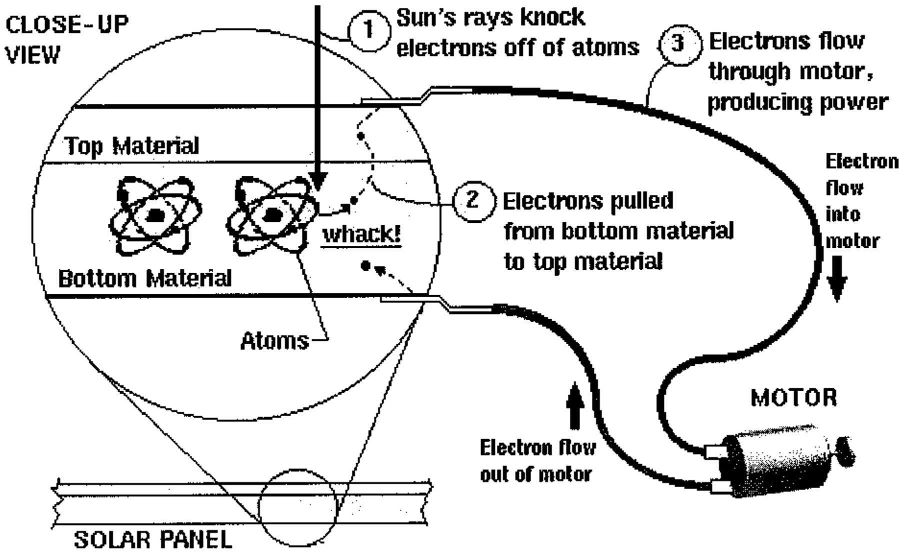


Figure 6: Concept Photovoltaic Cell

A photovoltaic (PV) cell is a semiconductor device that can convert sunlight into direct current (DC) electricity. The cell is built up from ultra – thin layer of phosphorous-doped (N-type) on the top of a thicker layer of boron-doped (P-type) silicon. Each material P-type and N-type is made of a millions of atoms. The atom consists of nucleus (negative charge) and electron (positive charge), which spin around the nucleus. The electrons are all attached strongly to atoms. These bonding of atom happen at the top of surface of the cell, where the P-type and N-type are in contact (P-N junction). At here the P-N junction creates an electric field. So when the sunlight strikes material (P-type and N-type), the energy from sun knocks the electron off of the atoms. The current will produced when the sunlight strike the surface of PV which is the electric field at top surface provides momentum and direction to light stimulated electrons.

4.3 Type of Photovoltaic (PV) Cell

Most of the photovoltaic (PV) cell is made from the silicon (sand). There are four general type of silicon photovoltaic (PV) cell:

i. Single-crystal silicon
ii. Polycrystalline silicon (multicrystal silicon)
iii. Ribbon silicon
iv. Amorphous silicon (thin film silicon)

i. Single-crystal silicon

Most of photovoltaic cells are single-crystal types. To produce it, silicon is purified, melted, and crystallized into ingots. The ingots are sliced into thin wafers to make individual cells. The cells have a uniform colour, usually blue or black. Normally, most of the cell has a slight positive electrical charge. A thin layer at the top has a slight negative charge. The cell is attached to a base called a backplane. This is usually a layer of metal used to physically reinforce the cell and to provide an electrical contact at the bottom. Since the top of the cell must be open to sunlight, a thin grid of metal is applied to the top instead of a continuous layer. The grid must be thin enough to admit adequate amounts of sunlight, but wide enough to carry adequate amounts of electrical energy

ii. Polycrystalline silicon

Polycrystalline cells are manufactured and operate in a similar as single-crystal silicon. The difference is that lower cost silicon is used. This make the efficiency of this PV cell is slightly lower, but polycrystalline cell manufacturers assert that the cost benefits outweigh the efficiency losses. The surface of polycrystalline cells has a random pattern of crystal borders instead of the solid color of single crystal cells

iii. Ribbon silicon

Ribbon-type photovoltaic cells are made by growing a ribbon from the molten silicon instead of an ingot. These cells operate the same as single and polycrystalline cells. The anti-reflective coating used on most ribbon silicon cells gives them a prismatic rainbow appearance.

iv. Amorphous Silicon or Thin Film Silicon

The three types of silicon above used for photovoltaic cells have a distinct crystal structure. Amorphous silicon has no structure like that. Amorphous silicon is sometimes abbreviated "aSi" and is also called thin film silicon. Amorphous silicon units are made by depositing very thin layers of vaporized silicon in a vacuum onto a support of glass, plastic, or metal. Amorphous silicon cells are produced in a variety of colors. Since they can be made in sizes up to several square yards, they are made up in long rectangular "strip cells". Because the layers of silicon allow some light to pass through, multiple layers can be deposited. The added layers increase the amount of electricity the photovoltaic cell can produce. Each layer can be tuned to accept a particular band of light wavelength. The performance of amorphous silicon cells can drop as much as 15% upon initial exposure to sunlight. This drop takes around six weeks. The efficiency of amorphous silicon photovoltaic modules is less than half that of the other three technologies. This technology has the potential of being much less expensive to manufacture than crystalline silicon technology.

4.4 Comparison of the Different Silicon Material

Figure 7 shows typical conversion efficiencies of silicon based PV modules. A lower efficiency means more PV modules are needed for the same electricity output. However, for the same electricity output the costs of all of these materials are similar. Efficiency is a measure of the electrical energy output from the module or system as a fraction of the light energy (sunlight) input into the module or system.

Typical efficiency	Amorphous silicon	Monocrystalline silicon	Polycrystalline silicon
module	3 - 6 %	12 - 15 %	10 - 13 %

Source from http://www.solarexpert.com/pvtypes.html

Figure7: Comparison of efficiency of three type photovoltaic silicon

For the prototype built, type of PV module chooses is amorphous silicon. Even the efficiency of the module is less compare to the polycrystalline silicon, but the price is reasonable for the project budgets. So it is decide that to have the amorphous silicon.

4.5 Photovoltaic Arrays Arrangement

The solar panel that will be connected in the system must be connected with the blocking diode. It is because the system includes a battery storage system where a reverse flow of current from the batteries through the photovoltaic array can occur at night. This flow will drain power from the batteries. By using a blocking diode it can prevent the overcharging current flow from the solar panel to battery that will damage it. The connection of the blocking diode is shown Figure 8 below.

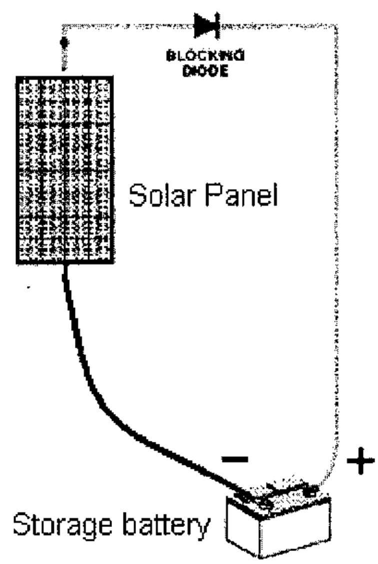


Figure 8: Connection of blocking diode

A diode is used to stop this reverse current flow. Diodes are electrical devices, which only allow current to flow in one direction. Basic operation of diode is shown in Figure 9 below.

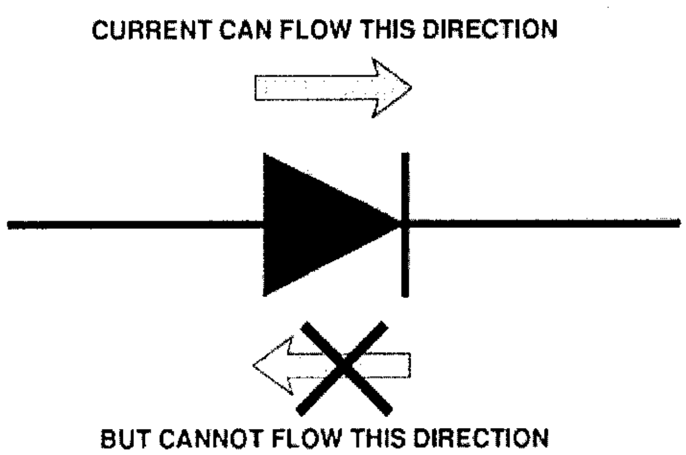


Figure 9: Basic Operation of a Diode

4.6 Solar Storage Battery

In some applications, such as the use of photovoltaic cells for pumping water for irrigation, the change in output of the cells through day and night is acceptable since the power is required only for a few hours in each 24-hour period. For many applications, however, the solar-cell array should be used together with a battery storage system that can provide continuous power. During peak sunlight hours, the batteries are charged by the solar cells, which produce more power than is required by the load. During the night, the batteries discharge to operate the motor for water pumping activity. The use of diode in the connection of battery with the solar cell is necessary to prevent the batteries from passing reverse current into the solar cells and a voltage-regulating circuit is normally provided on larger systems to keep the batteries from being overcharged by the PV array. There are two types of arrangement, blocking and bypass diode and bypass and isolation diode. Some voltage regulators will also disconnect the load to prevent damage if the battery charge gets too low.

Lead-acid batteries specially developed for photovoltaic-system applications are generally used, but any deep-cycle lead-acid battery may serve if necessary. Automobile batteries are not highly satisfactory for this application because daily charge and discharge cycles greatly shorten their useful life.

A solar-cell array with battery provides direct current (DC). The amount of energy can store in solar battery called capacity. The capacity is measured in ampere – hour (Ah). In order to understand the ampere-hour (Ah) concept, let's take the example of 100Ah of a battery. At here the battery can stand for 100 hour if it is discharge 1 ampere. The battery also can supply discharge current 4 amperes in 25 hours. So the more current discharge, the time for battery to stand is reduced. Figure 10 show the discharge current produce and the period for battery can stand.

Battery Capacity = 100 Ah

Discharge Current (ampere)	Period of battery can stand (hours)
1	100
4	25
10	10
20	5

Figure 10: Discharged current and period of 100 Ah batteries can stand

4.7 Solar Power System Sizing

Before determine to buy the component of solar water pumping system the calculation on the system sizing is done. The calculation involves are the battery sizing and autonomy back up that refer to the solar panel size that will be buy. The motor water pump used is 12V, 5.4A. For the model of water pumping will be built the operation of water pumping is half hour. So that the total current is:

Water Pump

Total current needed = 5.4A x ½ Hour

= 2.7 AH

For the charging rate, it is assume that the energy that will be getting from sunlight is 5 hour after considering the cloudy case. So for safe side 5 hours of the sunlight is assumed.

So that the charging rate:

Charge Rate = 2.7 Amps / 5 hours sunlight

= 0.54 Amps / Hr

1 Unit Amorphous Solar Panel 18.7 W = 1.2 Amps / Hr (Charge Rate)
Solar Battery 7.6AH – 70% (usable) = 5.32 Amps
Autonomy (back-up) = 1.9 hours

4.8 Power Conditioning / Control Unit

Control unit or power conditioning unit is an important part in the solar pump motor for irrigation in rural areas. The function of the control unit is to choose the operation whether to charge the solar battery storage or to use the battery as an electric source to move the pump motor.

The regulation approach used is known as series regulation. Figure 11 shows a block diagram of standalone PV system including a series charge regulator element.

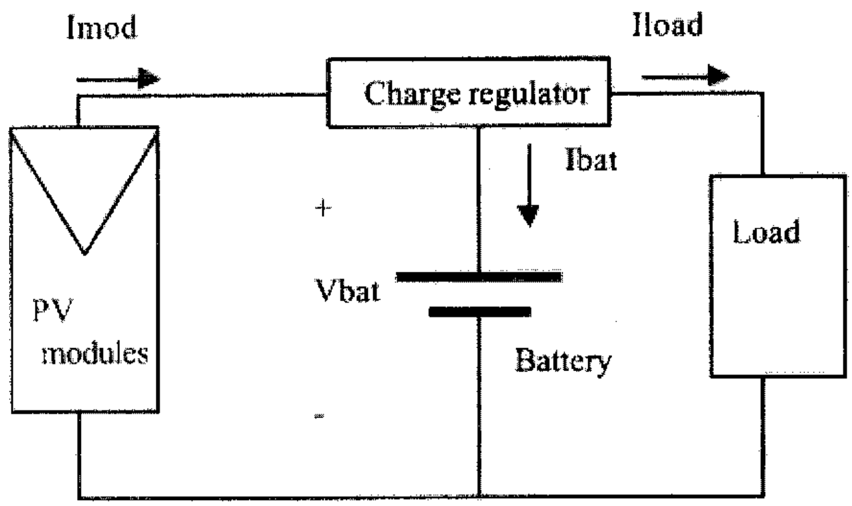


Figure 11: PV system including a series charge regulator

The battery has a recommended voltage window between the low (V_{min}) and high (V_{max}) where it operates at rated capacity and efficiency. If the battery is forced to operate outside of this window, it maybe damaged or operates incorrectly. The series charge regulator prevents the battery from working out of this voltage window.

Basically the way of charge regulator works is by opening the load when the battery reaches V_{min} and connecting the load circuit when the battery has been recharged enough so that its output voltage recovers. On the other hand, the charge regulator disconnects the battery from the PV array when full charged is achieved. This mean the battery voltage reaches V_{max} and reset the connection as soon as the battery has been discharged enough.

The series of regulation can be easily implemented using standard electromechanical controlled switches or relays as shown in Figure 12.

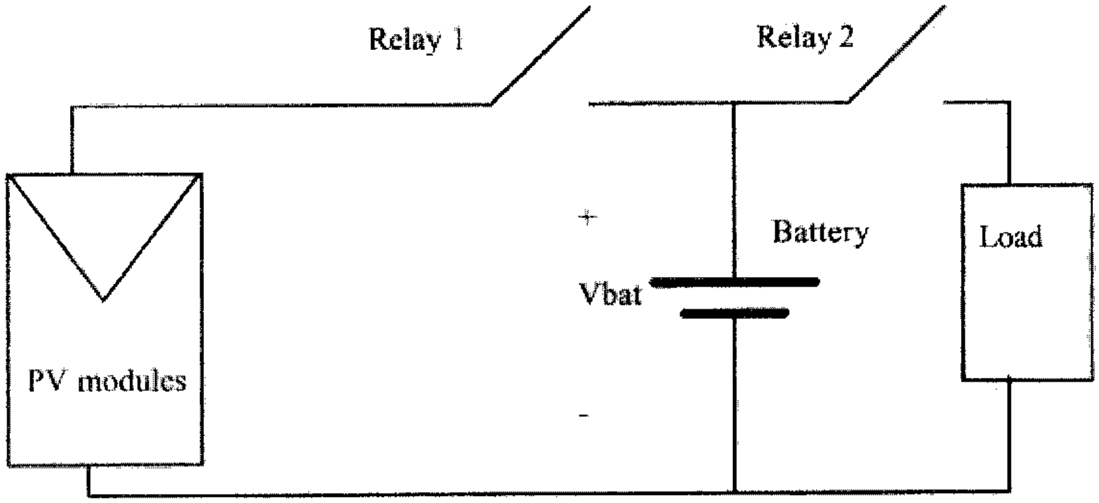


Figure 12: Schematic representation of charge series regulation

Figure 13 illustrates an example for a battery with nominal voltage of 12 V, showing the desire voltage for switching relays 1 and 2. In this case the battery voltage window operation is limited by V_{max} = 13.9 V and V_{min} = 11 V.

Relay 1 Battery-PV panel		Relay 2 Battery-load	
CLOSED PV module connected	OPEN PV module disconnected	OPEN Load disconnected	CLOSED Load connected
V_{bat} = 12.8 V	V_{max} = 13.9 V	V_{min} = 11 V	V_{bat} = 12 V

Figure 13: State of switches

Using two comparators with the hysteresis loop shown in Figure 14 can make the signal controlling the relay switching.

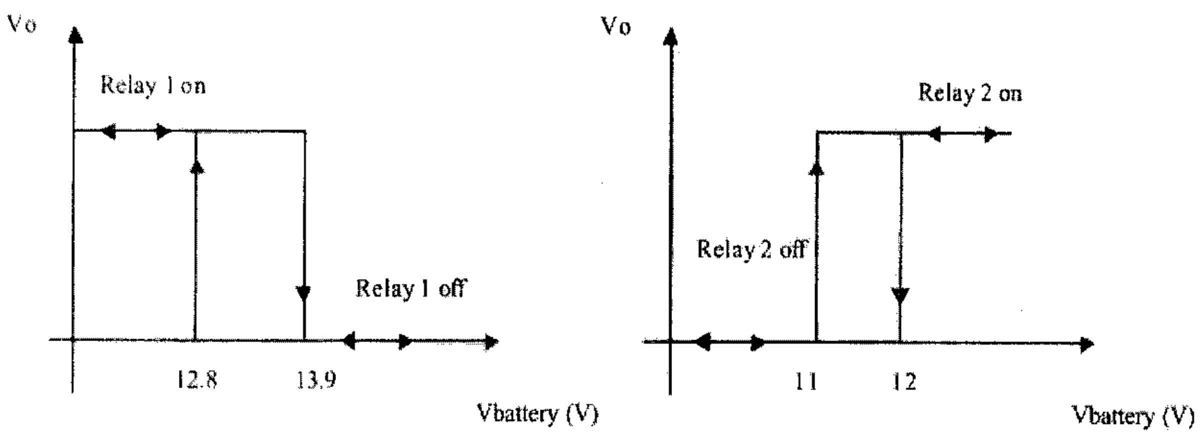


Figure 14: Hysteresis loops for the two comparator

By the same nature as series regulation, the only power losses at the relay, which are small compared to the losses resistor and transistor used in parallel regulation. The balance of energy suffers to some extend because part of energy generated by the PV models is lost when the input to the battery is switch is open.

4.9 Designing Stages

Instead of using two relays as shown in Figure 14, the SPDT (Single Pole Double Throw) switch can be used. The block diagram of this simplification is shown in Figure 15.

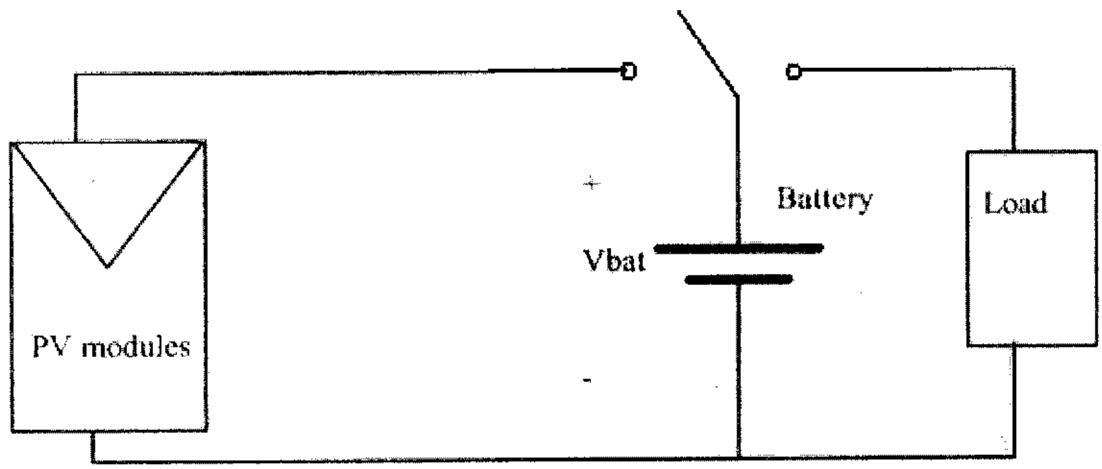


Figure 15: Schematic representation of charge series regulation with SPDT

The detail design of the basic control unit is shown in Figure 16.

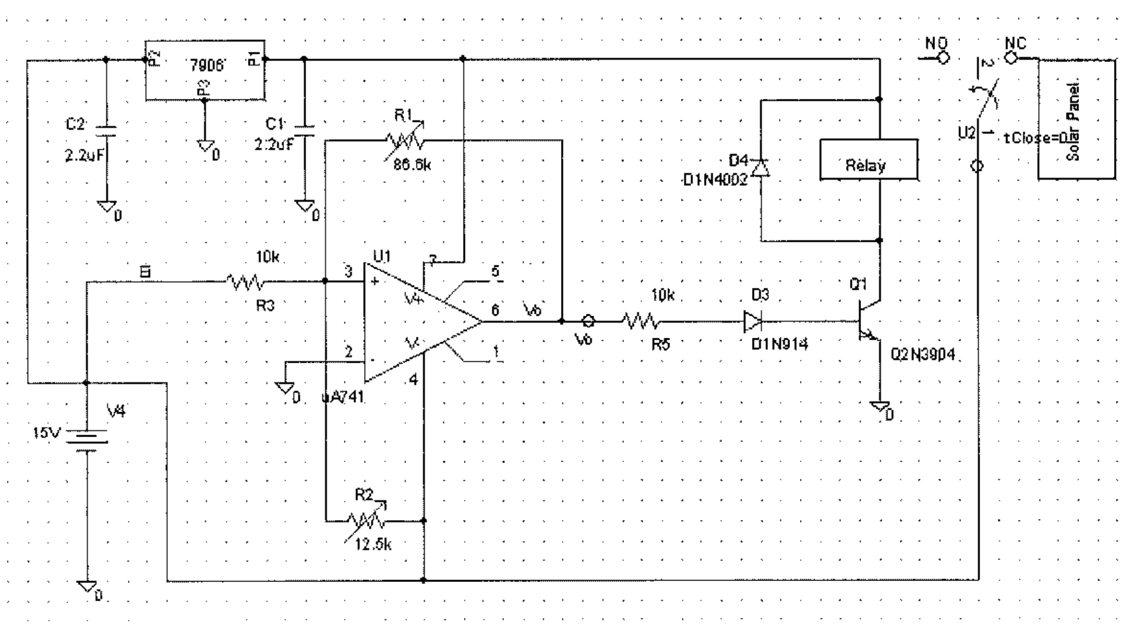


Figure 16: Basic idea of control unit switching

In this design stage, the rechargeable battery used is 12 V. So the circuit built will monitor the 12 V batteries. When the battery's voltage drops below 10.5 V, the battery will change its connection to the charger (solar cell). When the battery voltage reaches 13.5V, the battery will disconnect from the charger (solar cell). Therefore, V_{LT} = 10.5 and V_{UT} = 13.5. In this design, the –V supply voltage is used for V_{ref} and it is assume equals to -15.0 V. This voltage is gathered from +15V supply. Its value than converted to -15V for –Vsat by using voltage regulator 7906. The $\pm V_{sat} = \pm 13$ V. So that the parameter for V_H and V_{ctr}; resistor mR and resistor nR are calculated as below.

$$V_H = V_{UT} - V_{LT} = 13.5\text{ V} - 10.5\text{ V} = 3.0\text{ V}$$

$$V_{ctr} = (V_{UT} - V_{LT}) \div 2 = (13.5\text{ V} + 10.5\text{ V}) \div 2 = 12.0\text{ V}$$

Vctr is the nominal battery voltage. Arbitrarily the resistor R is choosing to be readily available value of 10 kΩ. The V_{ref} choose -15 V to make the sign of m positive:

$$m = -(V_{ref} / V_{ctr}) = -(-15 / 12) = 1.25$$

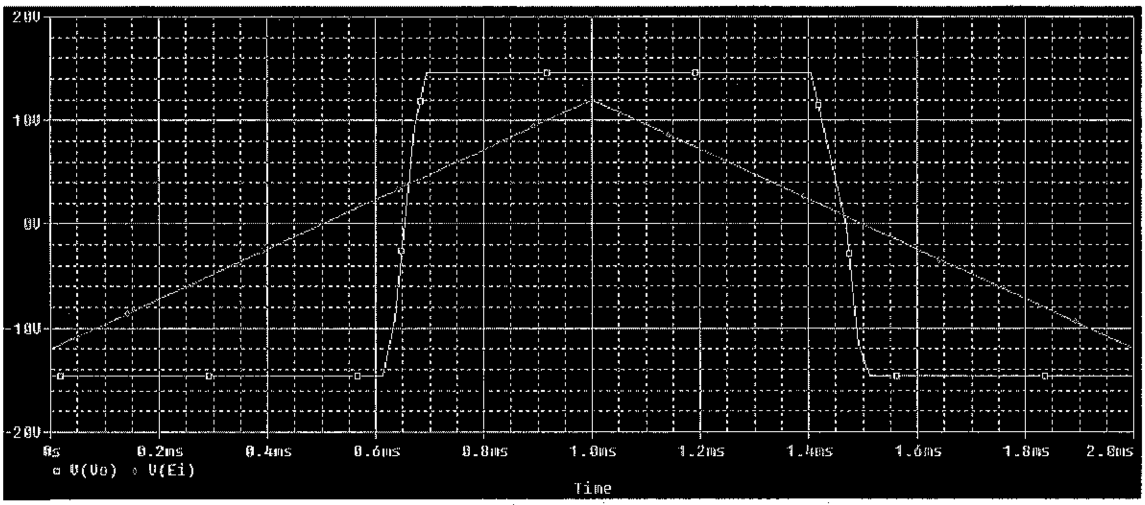
So that, mR = 1.25 x 10 kΩ = 1.25 kΩ

For n,

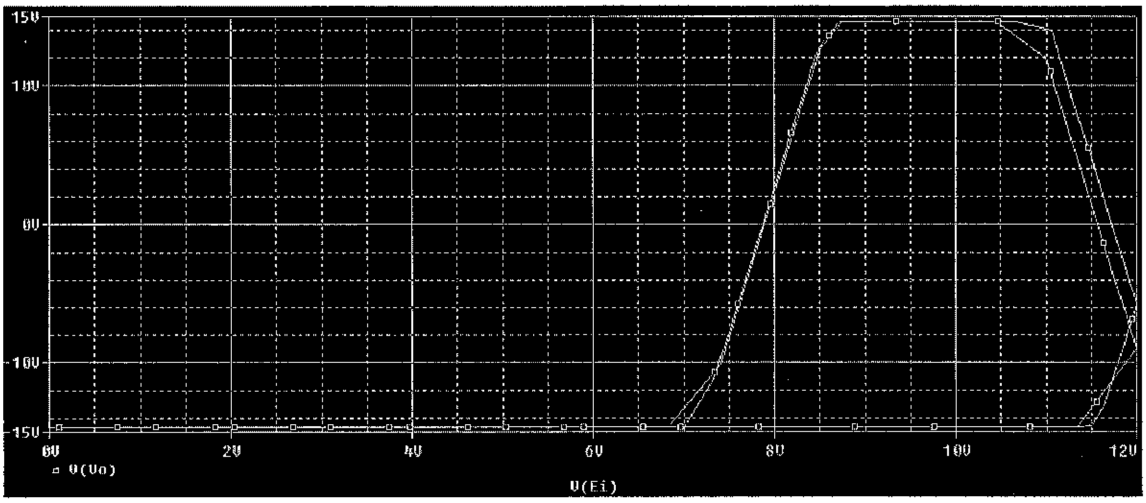
$$n = \{+V_{sat} - (-V_{sat})\} \div V_H = (13\text{ V} - (-13\text{ V})) / 3 = 8.66$$

So that, nR = 86.6 kΩ

Figure 17 below show the output wave for V_o and *Ei.*



a) Plot of Vo (Output Voltage of Comparator) and Ei (Battery Voltage) vs. Time from PSpice simulation



b) Plot of Vo (Output Voltage of Comparator) vs. Ei (Battery Voltage) from PSpice Simulation

Figure 17: Simulation of V_0 (Output Voltage of Comparator) and *Ei* (Battery Voltage)

After successfully built the basic switching control circuit, the circuit was modified to more functionality of display and the capability. The circuit in Figure 18 below shown the extended from the basic switching circuit has been design.

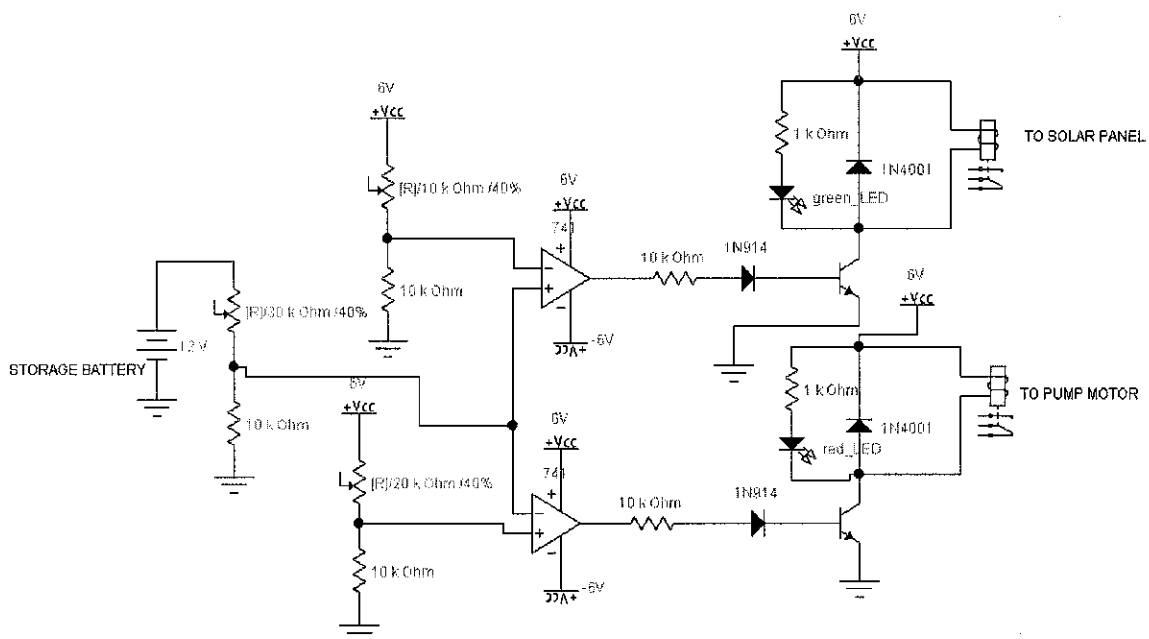


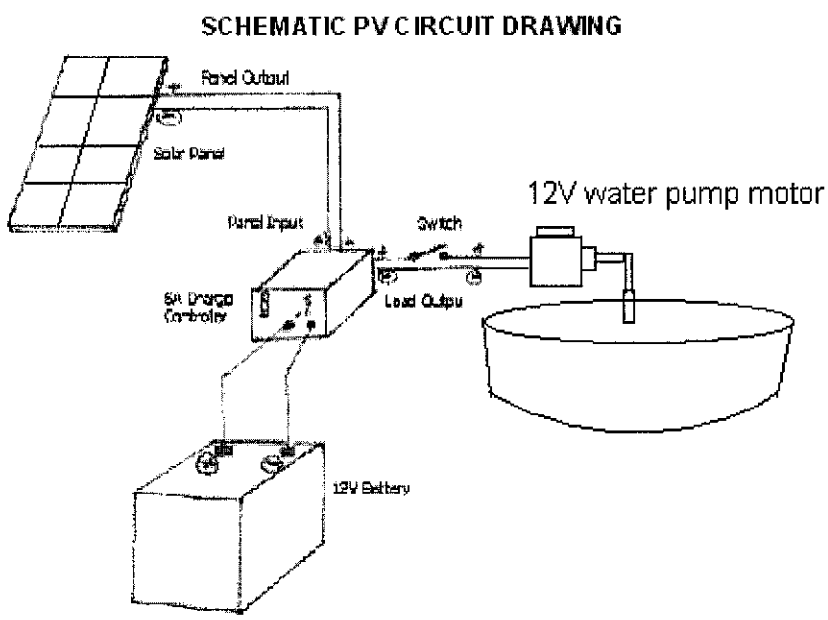
Figure 18: Extended circuit of basic switching circuit

4.10 Circuit Operation

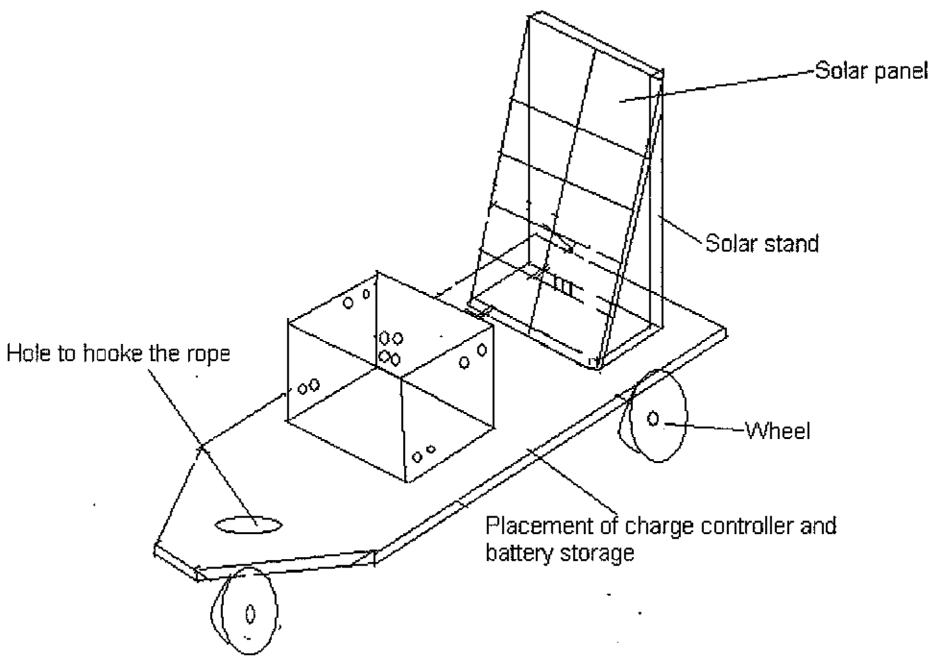
The circuit designed is shown in Figure 16. When the *Ei* drops below 10.5 V, V_o goes negative, releasing the relay to its normally closed position. The relay's normally closed (NC) contact connects the charger battery *Ei*. Diode D1 protects the transistors against excessive reverse bias when $V_o = -V_{sat}$. When the battery charges to 13.5 V, V_o switches to $+V_{sat}$, which turn on the transistor and operates the relay, whose NC contacts open to disconnect the charger (solar cell). Diode D2 protects both op-amp and transistor against transients developed by the relay's magnetic field.

4.11 Overall System of Solar Water Pumping and Conceptual Wiring Design

The solar component used in the model of solar water pumping system is solar panel, battery and 12 V water pump. The entire component was bought from the Sol Lite Company Malaysia. After the buying process is completed the component is assembled and interface with the switching circuit was built. Figure 19 is the illustrated of the solar water pumping system and its portable cart.



a) Schematic PV circuit drawing



b) Portable solar cart

Figure 19: Schematic PV Circuit Drawing

Before determine to buy the component above the calculation on the system sizing has been done. The calculation involves are the battery sizing and autonomy back up that refer to the solar panel size that will be buy. Below is the calculation that has been done.

The conceptual wiring design of the Solar Pump Motor for Irrigation in Rural Areas can be seen in the Figure 20 and Figure 21. The conceptual design is using 12 V light bulbs to represent the motor for water pumping.

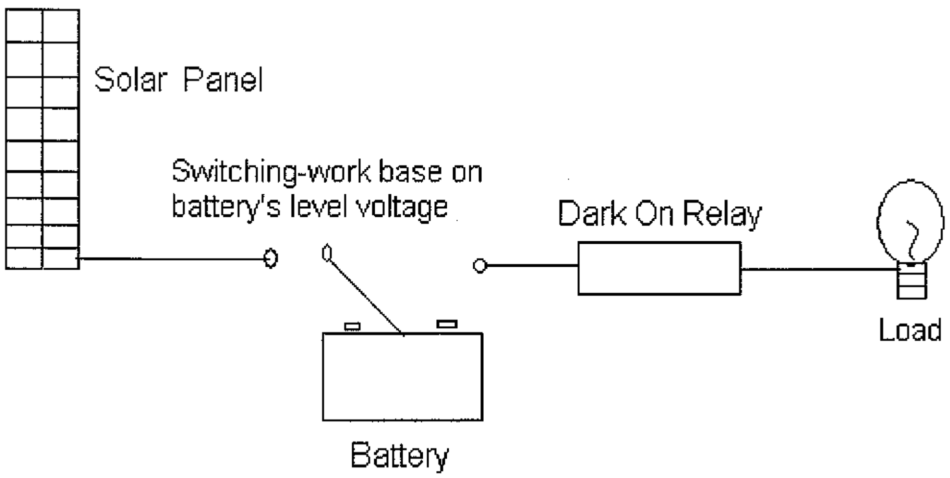


Figure 20: Wiring Diagram for switching circuit

The concept is as below:

- Switching part or controller is base on the battery's voltage-level hysteresis. The switch will move to the load when the battery reaches upper threshold voltage, V_{UT}. The switch will move back to the solar panel when the voltages reduce until lower threshold voltage, $V_{LT.}$

- When the switch is connected to the load, the current pass by must depend on the Dark On Relay, which is consist of LDR (light detector resistor). If the condition of the process is on the day, the load (light) is not on. Whereas when in the night condition the load (light) is on.

- So that the operation of the load are depends on the voltage-level of battery and the condition of day.

4.11.1 First Design

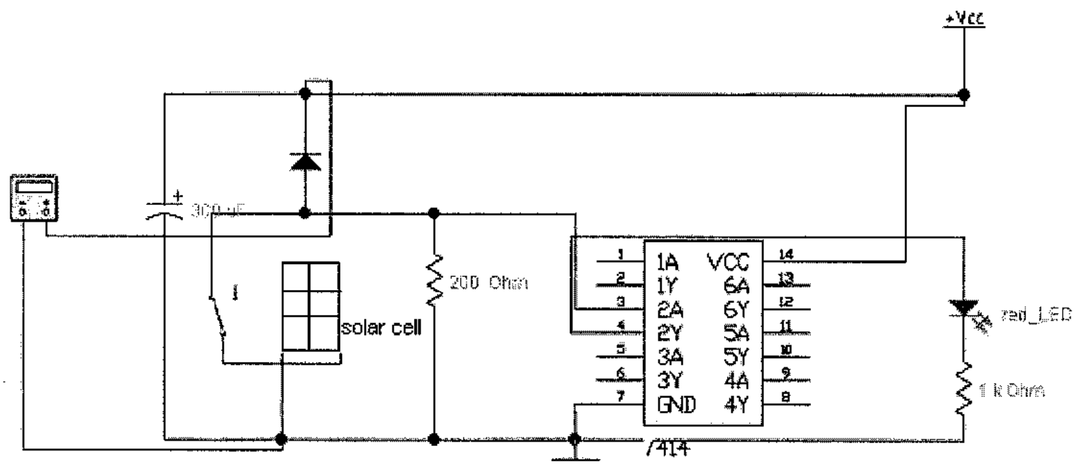


Figure 22: Switching Circuit Using Ls 7414

The first design of switching circuit is shown in the Figure 22. The circuit use LS 7414 to trigger the switch that connected between solar cell and capacitor. In this design the capacitor is used to represent the battery storage. There are several problems were encountered in the first design:

- The LED is ON all the time when the connection of solar cell to the circuit is broken
- Its suppose to turn OFF depending on the discharge time of capacitor
- No automatic changer from the solar panel to the storage and to the load

4.11.2 Second Design

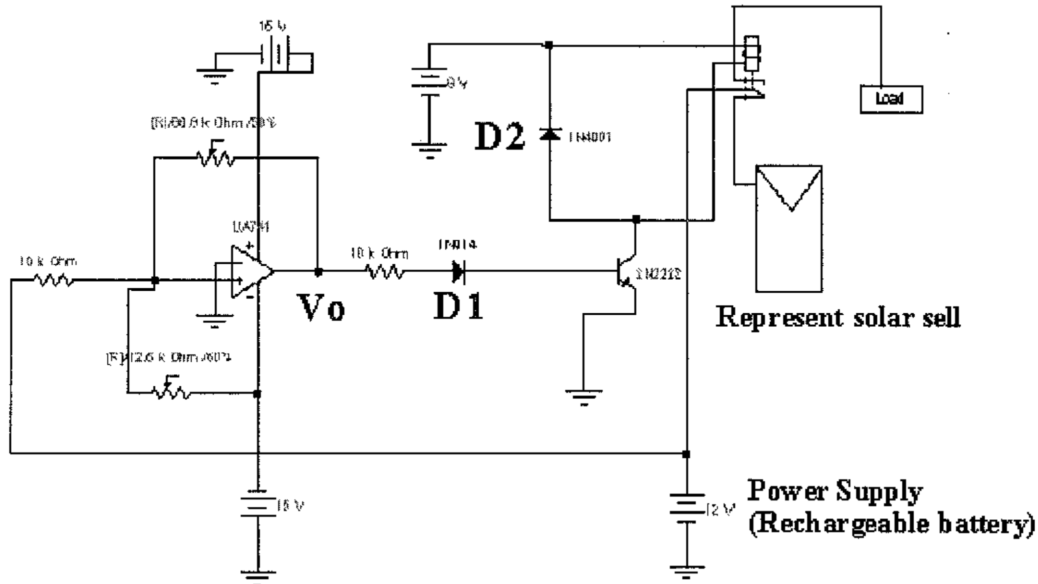


Figure 23: Second Design of solar switching circuit using LM 741.

The second design is shown in the Figure 23. The circuit use LM 741 to compare the battery's voltage level that has been set. The idea of the second design is as below:

- The circuit will monitor 12 V battery storage
- When the battery's voltage drops below 10.5V
    - Vo goes negative and will activate relay normally closed connect the battery to PV cells (charger)
    - D1 used in the design is to protect against excessive reverse bias when Vo = -Vsat
- When the battery's voltage reaches 13.5V

- Vo is equal to +Vsat. This will turn on the transistor and operate the relay connect to the load

- D2 used in the design is to protect both op-amp & transistor against transient develop by relay's collapsing magnetic field

The designing procedure of the second design is shown below:

- The design is based on the curve Vi vs Ei → amount of hysteresis voltage in comparator

- Designing step:

Determination of VH & Vctr:

$$VH = VUT - VLT = 13.5 - 10.5 = 3.0V$$

$$Vctr = (VUT + VLT) / 2 = (13.5 + 10.5) / 2 = 12.0V$$

Choose resistor R to be readily available = 10kΩ. Choose the Vref = -15V to make sign m positive:

$$m = -(Vref / Vctr) = - (-15 / 12) = 1.25$$

$$\text{therefore } mR = 1.25 \times 10k\Omega = 12.5k\Omega$$

Find n:

$$n = [+Vsat - (-Vsat)] / VH = [13 - (-13)] / 3 = 8.66$$

$$\text{therefore, } nR = 86.6k\ \Omega$$

The concept of this design is referred to the general plot of voltage-level detector with hysteresis shown in Figure 24.

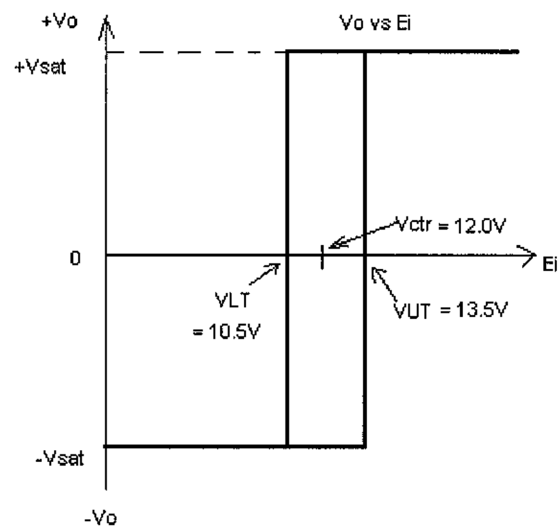


Figure 24: General plot of voltage-level detector with hysteresis.

4.11.3 Third Design

The third design is to construct the circuit will make a switch that will be activated by light falling on a sensor. It is a very useful device and can be used in automatism of solar switching circuit when it combined together. It is very sensitive, fast acting and reliable. The circuit uses a Light Dependent Resistor (LDR) as a sensor and timer 555 to amplify the signals from the LDR and drive the relay, which does the switching. The circuit of the Dark On Relay is shown in Figure 25.

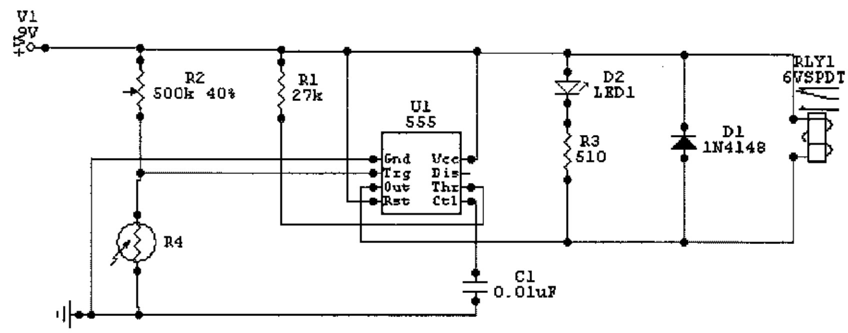


Figure 25: Dark On Relay Circuit

The dark on relay circuit will be combined with the switching circuit that was implemented in the first semester. The switching circuit implemented is shown in Figure 26.

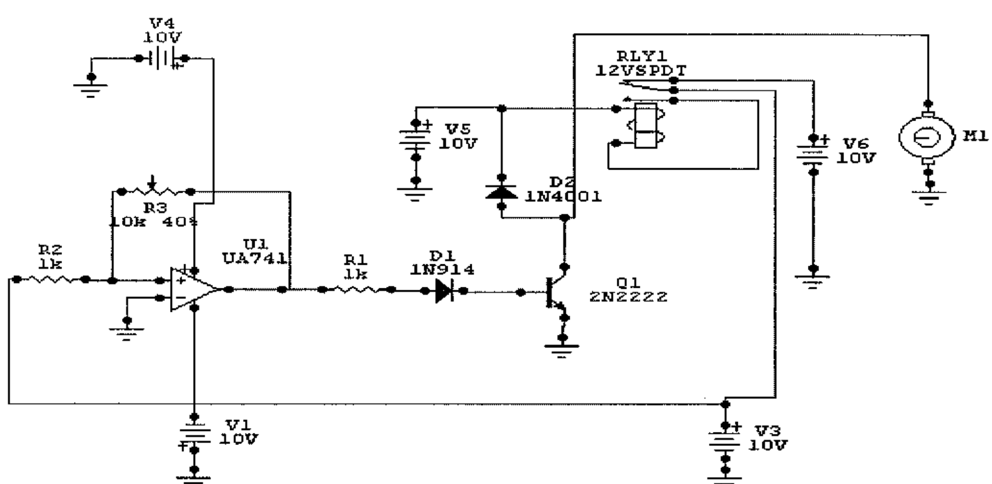


Figure 26: Switching circuit using LM 741

4.11.4 Fourth Design

Theoretically, the dark on relay circuit will activate the switching circuit when the LDR (light detector resistance) detect the light. Then the relay will switch to the switching circuit that will activate the relay to operate the load. This circuit will be tried in the lab to make sure that it will function properly. The idea of combination circuit with the switching circuit is illustrated in the Figure 27.

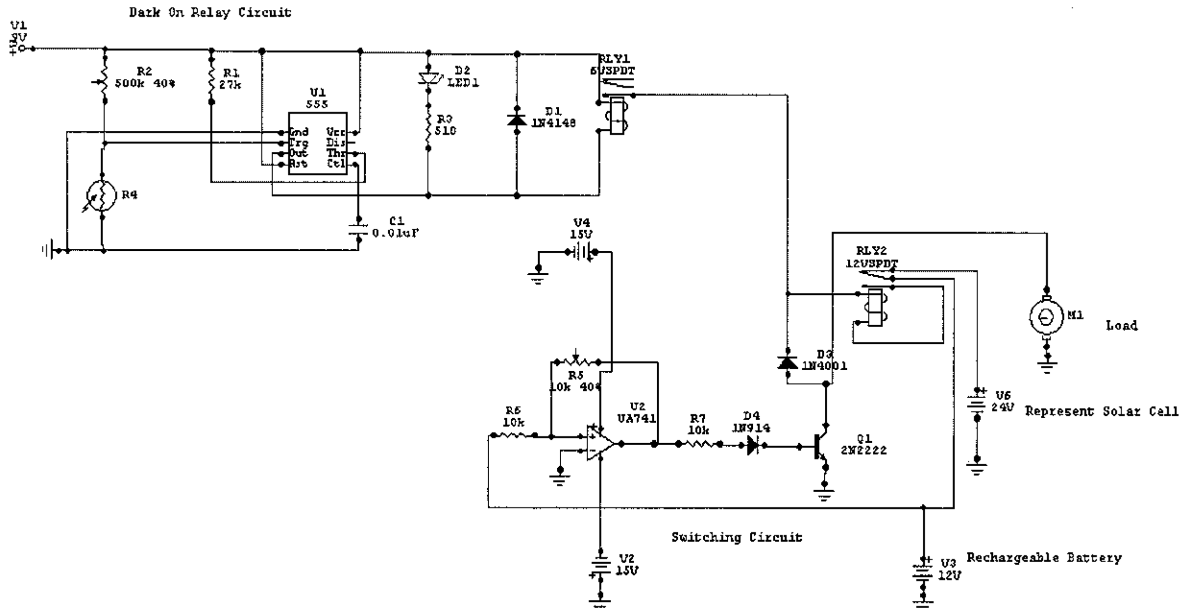


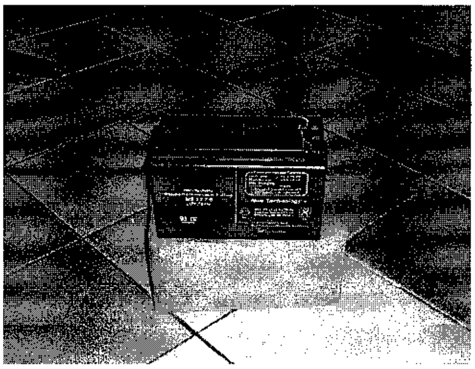
Figure 27: Combination of Dark On Relay Circuit with Switching Circuit

There are several problems facing by this design that has not been solved yet. The connection of the dark on relay to the switching circuit is not work properly. The combination of the circuit needs to be looking again.

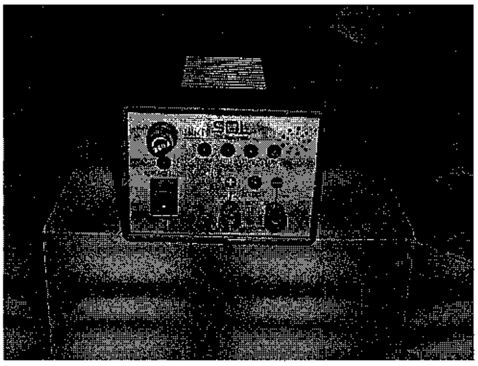
4.12 Components of Solar Water Pumping System

Below are the components used in the solar pumping motor model that has been built.

a) Water pump motor 12V

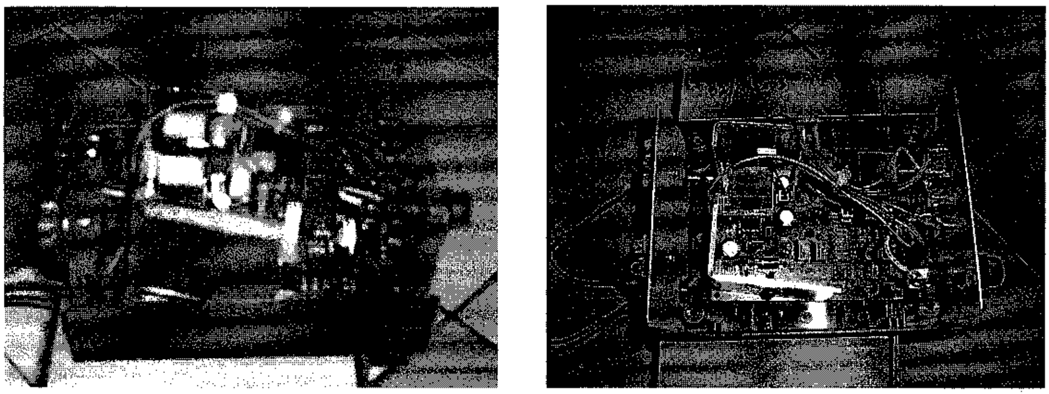


b) Deep cycle battery

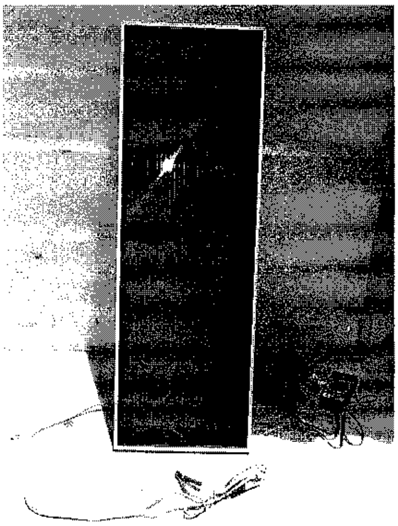


c) Front panel charged controller 5A

d) Back panel charged controller 5A



e) Internal part of charged controller 5A



f) Amorphous solar module 18.7W

Figure 28: Solar System Components

CHAPTER 5
CONCLUSION AND RECOMMENDATION

Most of the work done is follow the schedule. The concept for each part in the solar pump / lighting system in rural areas has been discovered studied and implement. The theoretical on voltage hysteresis has been implemented to produce the basic concept of charge controller for solar switching mechanism. The whole project had been outline into two-semester plan. The first semester is on intensive reading and research on solar components part and the previous related project. On the second semester is to build the basic charge controller and model of solar pumping system for irrigation in rural area. The project is more on the design of basic switching part (charge controller) for the solar pumping system. The mathematical procedures on the hysteresis voltage concept have been shown for design the basic charge controller.

Future work expansion and continuation may be implemented for this project especially on sensor part. This project may be implemented on the UTP basement. This solar system will pump out the water if the level is in critical limit. This may be implemented with interfacing the water level sensor and automatic controller in order to operate the pump if the level of water achieves the critical limit. This smart system will make sure the flood in basement can be avoided by using the solar system, which is more portable and cheap.

REFERENCE

1. Larry D.Partain. 1995, *Solar Cell and Their Applications,* New York, John Wiley & Sons

2. Roger Messenger, Jerry Ventre, 1999, Photovoltaic Systems Engineering, New York, CRC Press

3. Jack L. Stone < http://www.nrel.gov/research/pv/docs/pvpaper.html>

4. < http://www.energiesolar.com/energie/html/solar_pump.htm >

5. < http://science.howstuffworks.com/battery.htm>.

6. < http://www.solarexpert.com/pvtypes.html >

7. < http://www.energy.state.or.us/renew/solar/Pubs.htm >

APPENDICES

Appendix 1-1: Milestone for the First Semester of Final Year project

No	Details /Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of project title															
	- Topic assinged to students															
2	Preliminary research work															
	- project planning															
	- research on concept of solar pump motor															
	- research on photovoltaic (PV) cell															
	- research on solar battery storage															
	- research on AC and DC motor and inverter															
	- research on control unit															
3	Submission of Preliminary report				◇											
4	Detailed Design Work															
	- Auto CAD drawing of solar pump motor system															
	- Build model/ prototype															
5	Submission of progress report								◇							
6	Testing and Refinement															
	- Model/Prototype testing															
7	Submission of Interim Report Final Draft													◇		
8	Submission of Interim Report														◇	
9	Oral Presentation															◇

Progress ◇ Suggested Milestone Summary

Appendix 1-2: Milestone for the Second Semester of Final Year project

No	Details /Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Project work Continue																
	-continue the research left from first semester		■	■													
	- research on the price of solar system components				■												
2	Submission of Progress Report 1				◇												
3	Implementation of design (depand on component)					■	■	■	■								
4	Submission of Progress Report 2								◇								
5	Testing and refinement								■	■	■	■					
	- Experiment on the design implement																
6	Submission of Dissertation Final draft													◇			
7	Oral Presentation															◇	
8	Submission of Project dissertation																◇

■ Progress
◇ Suggested Milestone
■ Summary

APPENDIX 1-3: LM193/LM293/LM393/LM2903 Low Power Low Offset Voltage Dual Comparators

National Semiconductor

August 2002

LM193/LM293/LM393/LM2903
Low Power Low Offset Voltage Dual Comparators

General Description

The LM193 series consists of two independent precision voltage comparators with an offset voltage specification as low as 2.0 mV max for two comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM193 series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM193 series will directly interface with MOS logic where their low power drain is a distinct advantage over standard comparators.

The LM393 and LM2903 parts are available in National's innovative thin micro SMD package with 8 (12 mil) large bumps.

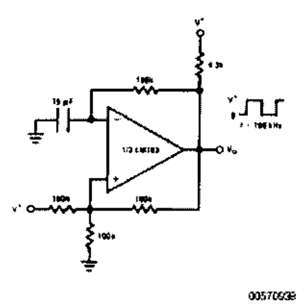
Advantages

- High precision comparators
- Reduced V_{OS} drift over temperature
- Eliminates need for dual supplies
- Allows sensing near ground
- Compatible with all forms of logic
- Power drain suitable for battery operation

Features

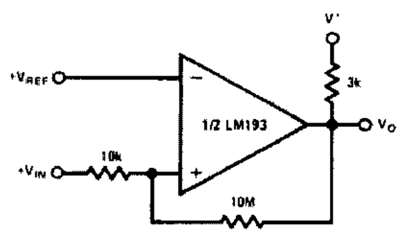
- Wide supply
  - — Voltage range: 2.0V to 36V
  - — Single or dual supplies: ±1.0V to ±18V
- Very low supply current drain (0.4 mA) — independent of supply voltage
- Low input biasing current: 25 nA
- Low input offset current: ±5 nA
- Maximum offset voltage: ±3 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage.: 250 mV at 4 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems
- Available in the 8-Bump (12 mil) micro SMD package
- See AN-1112 for micro SMD considerations

Squarewave Oscillator



00570938

Non-Inverting Comparator with Hysteresis



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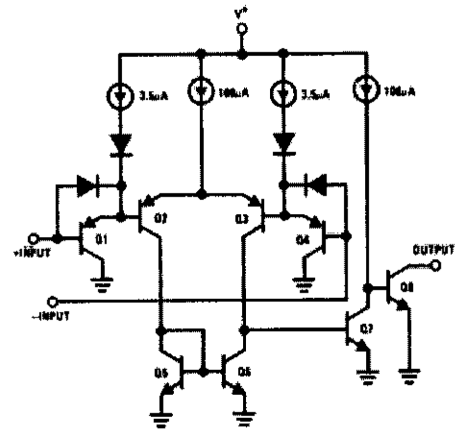
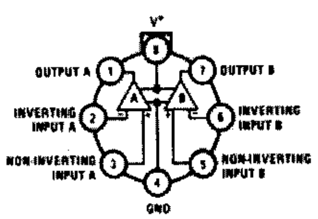
 www.national.com

Schematic and Connection Diagrams



00570002

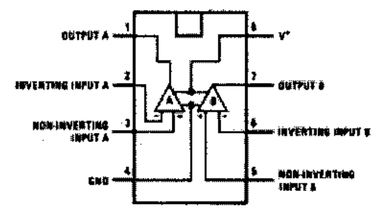
Metal Can Package



TOP VIEW

00570003

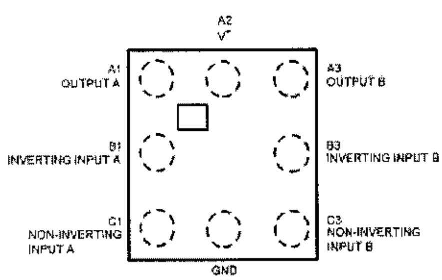
Dual-In-Line/SOIC Package



TOP VIEW

00570001

micro SMD



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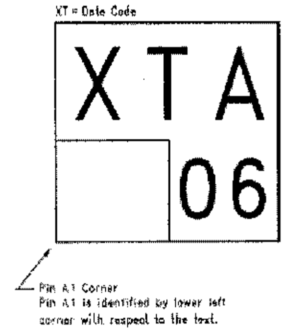
Top View

micro SMD Marking

XT = Date Code



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Top View

Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage, V+	36V
Differential Input Voltage (Note 8)	36V
Input Voltage	−0.3V to +36V
Input Current (V_{IN}<−0.3V) (Note 3)	50 mA
Power Dissipation (Note 1)	
Molded DIP	780 mW
Metal Can	660 mW
Small Outline Package	510 mW
micro SMD Pacakge	568mW
Output Short-Circuit to Ground (Note 2)	Continuous
Operating Temperature Range	
LM393	0°C to +70°C
LM293	−25°C to +85°C
LM193/LM193A	−55°C to +125°C
LM2903	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	+260°C
Soldering Information	
Dual-In-Line Package	
Soldering (10 seconds)	260°C
Small Outline Package	215°C
Vapor Phase (60 seconds)	
Infrared (15 seconds)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

ESD rating (1.5 kΩ in series with 100 pF)	1300V

Electrical Characteristics

(V^+=5V, T_A = 25°C, unless otherwise stated)

Parameter	Conditions		LM193A Min	LM193A Typ	LM193A Max	Units
Input Offset Voltage	(Note 9)			1.0	2.0	mV
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output In Linear Range, V_{CM} = 0V (Note 5)			25	100	nA
Input Offset Current	$I_{IN}(+)-I_{IN}(-)$ V_{CM} = 0V			3.0	25	nA
Input Common Mode Voltage Range	V+ = 30V (Note 6)		0		V^+−1.5	V
Supply Current	R_L=∞	V^+=5V		0.4	1	mA
		V^+=36V		1	2.5	mA
Voltage Gain	R_L≥15 kΩ, V^+=15V V_O = 1V to 11V		50	200		V/mV
Large Signal Response Time	V_{IN}=TTL Logic Swing, V_{REF}=1.4V V_{RL}=5V, R_L=5.1 kΩ			300		ns
Response Time	V_{RL}=5V, R_L=5.1 kΩ (Note 7)			1.3		μs
Output Sink Current	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, V_O≤1.5V		6.0	16		mA
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA			250	400	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN}(+)$=1V, V_O=5V			0.1		nA

Electrical Characteristics

(V^+=5V, T_A = 25°C, unless otherwise stated)

Parameter	Conditions	LM193 Min	LM193 Typ	LM193 Max	LM293, LM393 Min	LM293, LM393 Typ	LM293, LM393 Max	LM2903 Min	LM2903 Typ	LM2903 Max	Units
Input Offset Voltage	(Note 9)		1.0	5.0		1.0	5.0		2.0	7.0	mV
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output In Linear Range, V_{CM} = 0V (Note 5)		25	100		25	250		25	250	nA
Input Offset Current	$I_{IN}(+)-I_{IN}(-)$ V_{CM} = 0V		3.0	25		5.0	50		5.0	50	nA
Input Common Mode Voltage Range	V+ = 30V (Note 6)	0		V+−1.5	0		V+−1.5	0		V+−1.5	V

Electrical Characteristics (Continued)

(V^+=5V, T_A = 25°C, unless otherwise stated)

Parameter	Conditions		LM193			LM293, LM393			LM2903			Units
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Supply Current	R_L=∞	V^+=5V		0.4	1		0.4	1		0.4	1.0	mA
		V^+=36V		1	2.5		1	2.5		1	2.5	mA
Voltage Gain	R_L≥15 kΩ, V^+=15V V_O = 1V to 11V		50	200		50	200		25	100		V/mV
Large Signal Response Time	V_{IN}=TTL Logic Swing, V_{REF}=1.4V V_{RL}=5V, R_L=5.1 kΩ			300			300			300		ns
Response Time	V_{RL}=5V, R_L=5.1 kΩ (Note 7)			1.3			1.3			1.5		µs
Output Sink Current	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, V_O≤1.5V		6.0	16		6.0	16		6.0	16		mA
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA			250	400		250	400		250	400	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN}(+)$=1V, V_O=5V			0.1			0.1			0.1		nA

Electrical Characteristics

(V+ = 5V) (Note 4)

Parameter	Conditions	LM193A			Units
		Min	Typ	Max	
Input Offset Voltage	(Note 9)			4.0	mV
Input Offset Current	$I_{IN(+)}-I_{IN(-)}$, V_{CM}=0V			100	nA
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output in Linear Range, V_{CM}=0V (Note 5)			300	nA
Input Common Mode Voltage Range	V^+=30V (Note 6)	0		V^+−2.0	V
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA			700	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN(+)}$=1V, V_O=30V			1.0	µA
Differential Input Voltage	Keep All V_{IN}'s≥0V (or V^-, if Used), (Note 8)			36	V

Electrical Characteristics

(V+ = 5V) (Note 4)

Parameter	Conditions	LM193			LM293, LM393			LM2903			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 9)			9			9		9	15	mV
Input Offset Current	$I_{IN(+)}-I_{IN(-)}$, V_{CM}=0V			100			150		50	200	nA
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output in Linear Range, V_{CM}=0V (Note 5)			300			400		200	500	nA
Input Common Mode Voltage Range	V^+=30V (Note 6)	0		V^+−2.0	0		V^+−2.0	0		V^+−2.0	V
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA			700			700		400	700	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN(+)}$=1V, V_O=30V			1.0			1.0			1.0	µA
Differential Input Voltage	Keep All V_{IN}'s≥0V (or V^-, if Used), (Note 8)			36			36			36	V

Note 1: For operating at high temperatures, the LM393 and LM2903 must be derated based on a 125°C maximum junction temperature and a thermal resistance of 170°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM193/LM193A/LM293 must be derated based on a 150°C maximum junction temperature. The low bias dissipation and the "ON-OFF" characteristic of the outputs keeps the chip dissipation very small (P_D≤100 mW), provided the output transistors are allowed to saturate.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 20 mA independent of the magnitude of V^+.

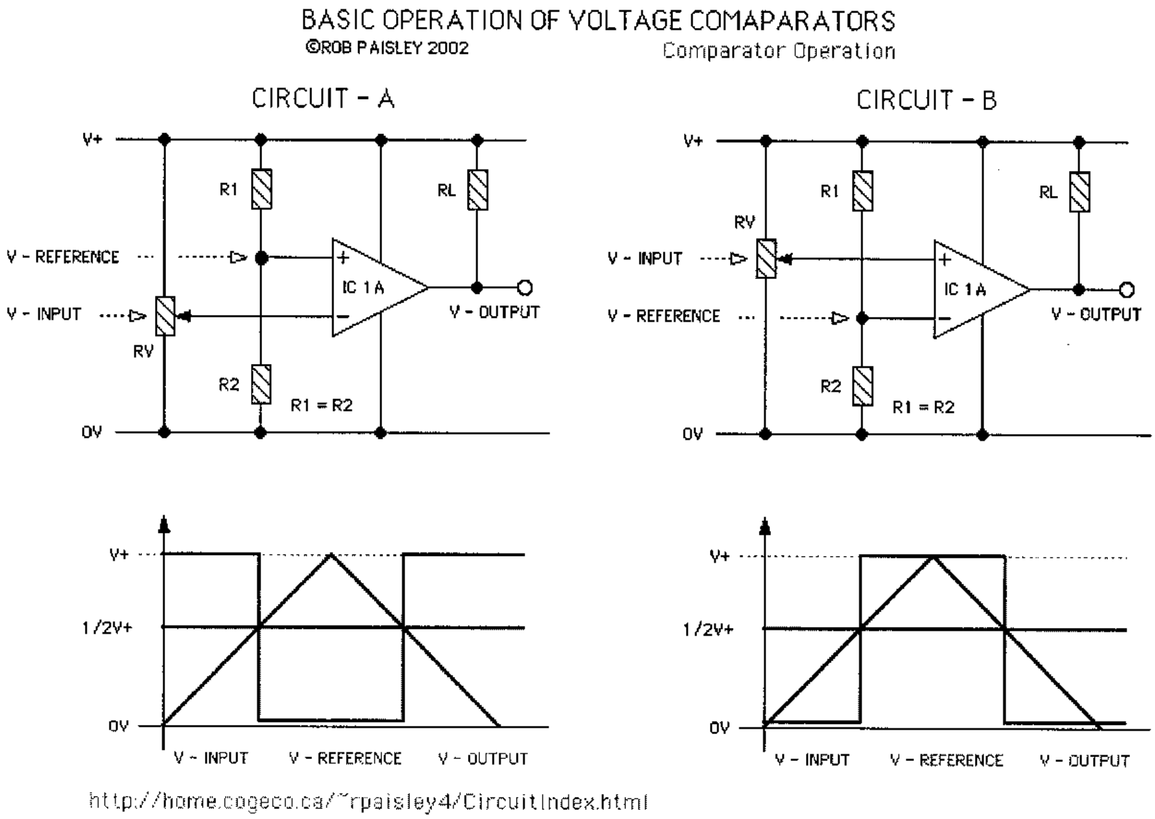
Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action

APPENDIX 1-4: Comparator Operation

The following drawing show the two simplest configurations for voltage comparators. The diagrams below the circuits give the output results in a graphical form.

For these circuits the REFERENCE voltage is fixed at one-half of the supply voltage while the INPUT voltage is variable from zero to the supply voltage.

In theory the REFERENCE and INPUT voltages can be anywhere between zero and the supply voltage but there are practical limitations on the actual range depending on the particular device used.

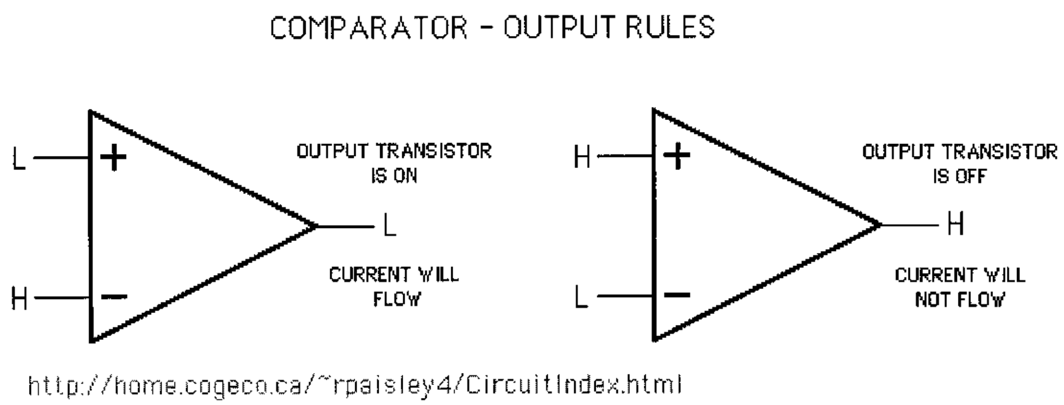


APPENDIX 1-5: Basic Comparator Operation

Basic Comparator Operation

Input Vs. Output Results

1. Current WILL flow through the open collector when the voltage at the PLUS input is lower than the voltage at the MINUS input.
2. Current WILL NOT flow through the open collector when the voltage at the PLUS input is higher than the voltage at the MINUS input.



Input Vs. Output Results