PORTABLE SOLAR STREET LAMP

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JUDUL: **PORTABLE SOLAR STREET LAMP**

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PORTABLE SOLAR STREET LAMP

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This thesis is submitted as partial fulfillment of the requirement for the award of the Bachelor Degree Electrical Engineering (Power System)

Faculty of Electrical & Electronic Engineering
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NOVEMBER, 2008

DECLARATION

I declare that this thesis entitled "*Portable Solar Street Lamp*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …………………………………………………………..

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Date : NOVEMBER 2008

Specially dedicated to

My beloved parent

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Bismillahirrahmanirahim,

I am so thankful to Allah S.W.T for giving me patient and spirit throughout this project and the research is successfully complete. With the mercifulness from Allah therefore I can produces a lot of useful idea to this project.

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ABSTRACT

This system is designed for outdoor application in un-electrified remote rural areas. This system is an ideal application for campus and village street lighting. The system is provided with battery storage backup sufficient to operate the light for 10-11 hours daily. The project is about to develop and fabricate the circuit that can charge the lead acid battery during day time by using solar as the source. To control the circuit for charging, I have used the circuit charging that can implement the condition of the charging whether it's in charging condition of in float condition. When charging condition, red LED will turn on until the battery reach the full charge state that is in floating condition and green LED will turn on. For the switching, I used PIC16F877A to switch on the lamp, by using the photocell sensor. The PIC16F877A will determine whether it is daytime or night time. The light will automatically on when the photocell sensor give the input to the PIC and PIC will give the output to the relay to switch on the light. To control the intensity of the light, we need the other input from the sensor. When sensor detect, PIC will give the output to switch on for the second light. So the intensity of the light will increase and the timing will start counter. After finish the counter, PIC will automatically of the second light. By using this method, its can save the energy that we using from the battery. When night change to the day, photocell sensor detect the ray from the sun, PIC will give the output to off the lamp and the charging circuit will continue charge the battery for the day.

ABSTRAK

System ini direka untuk kawasan pedalaman yang masih tiada bekalan elektrik. Sistem ini amatlah sesuai untuk diaplikasikan dikawasan kampus dan kawasan pedalaman. Sistem ini mempunyai bekalan tenaga yang mencukupi yang mana dapat beroperasi sehingga 10-11 jam sehari. Projek ini adalah bertujuan untuk menghasilkan litar yang mana dapat mengecas bateri pada waktu siang dengan menggunakan tenaga solar sebagai sumber. Untuk mengawal litar dalam pengecasan, saya telah menggunakan litar yang boleh beroperasi didalam apa jua keadaan walaupun dalam keadaan ’floating’. Semasa mengecas, LED merah akan menyala dan setelah beteri sudah selesai mengecas LED hijau akan menyala iaitu pada keadaan ’floating’. Untuk penukaran tenaga kepada lampu saya menggunakn PIC16F877A. Dengan menggunakan sensor fotosel, PIC16F877A akan mengesan keadaan malam ataupun siang. Lampu akan menyala apabila sensor fotosel memberi input sebanyak 3.8V kepada PIC. Apabila PIC menerima input tersebut, PIC pula akan memberi output kepada relay untuk menyalakan lampu. Untuk mengawal tahap kecerahan lampu, kita memerlukan input lain daripada sensor. Apabila sensor mengesan, PIC akan memberi output untuk menyalakan lampu yang kedua. Maka tahap kecerahan lampu akan meningkat dan tempoh masa mula di kira. Selepas PIC selesai mengira tempoh masa tersebut,lampu kedua akan menyala.Dengan menggunakan cara ini,kita boleh menjimatkan penggunaan tenaga bateri .Apabila suasana malam bertukar menjadi siang,sensor cahaya akan mengesan cahaya dari matahari dan akan memberi arahan kepada PIC supaya memadamkan lampu tersebut dan proses mengecaj bateri akan belaku pada waktu siang.

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LIST OF ABBREVIATON

DC	**-**	**Direct Current**
AC	**-**	**Alternate Current**
PIC	**-**	**Programmable Intelligent Computer**
LED	**-**	**Light Emitting Diode**

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter describes about the project's introduction. It consists of overview of the project, the project aim, objectives and scopes of the project.

1.1 Project Overview

This project is about to develop and fabricate the circuit that can charge the lead acid battery when in day by using solar as the source. To control the circuit of the charging, I used the circuit charging that can implement the condition of the charging whether its in charging condition of in float condition. When charging condition, red LED will turn on until the battery reach the full charge that is in floating condition, when floating, green LED will turn on. For the switching to the load, I used PIC16F877A to switch on the lamp, by using the photocell sensor and relay 5V, the PIC16F877A will determine whether is in daylight or in night by determination of ADC in that come from the photocell sensor. The value to determine the intensity of the light we had set up it into the coding of the PIC.

When PIC gets the input from ADC, PIC gives the output to the relay to switch on the light. To control the intensity of the light, we need the other input from the sensor that is wave sensor. When wave sensor detect that have some wave from the user of the road, PIC will give the output to switch on for the second light. So the intensity of the light will increase and the timing will start counter. After finish the counter, PIC will automatically switch off the second light. By using this method, its can save the energy that we using from the battery. When night change to day, photocell sensor detect the ray from the sun, PIC will give the output to switch off the lamp and the charging circuit will continue charge the battery for the day.

1.2 Project Aim

The solar street lamp is designed specifically for portable use at the rural areas and energy backup if disaster happens. It's also as the new way to save the energy and use it more efficiently.

1.3 Objective

The main objective of this project is to develop the portable solar street lamp with the DC voltage as the source. There are two secondary objectives to be achieved in order to achieve the main objective stated above. The two secondary objectives were discussed in the following paragraph.

The first objective is to develop the charging circuit that can charge 12V lead acid battery by using the solar panel as the DC source. This charging circuit can implement the charging condition as we know we have several charging condition like charging condition and floating condition.

The second objective is to design and program the control circuit by that contain of PIC16F877A to control the circuit to switch on and off the lamp when the situation change like from the day to night. This circuit also to control the intensity of the light that can improve the efficiency of using the DC energy that only use when need.(e.g. when nobody use the road, this portable solar street lamp just switch on with the low intensity of the lamp that's can save the energy and when its detect that have the user, this solar street lamp will switch on the high intensity lamp to beam the place for the users)

1.4 Scope Of The Project

The scope of the project includes construct the circuit in order to charge the 12V lead acid battery. The acid battery will supply power to switch the lamp when there is no light or night condition. Integration between sensor and wave sensor was also concentrated in development of this system. In order to control the circuit for switching the PIC16F877A was developed. Finally, the system was combined together to complete the development of the system

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter, explanations about all the word history and literature review. The total figure related to this project will be added in this chapter along with the details.

Word History

2.1 Solar energy

Solar energy is the light and radiant heat from the Sun that influences Earth's climate and weather and sustains life. Solar power is sometimes used as a synonym for solar energy or more specifically to refer to electricity generated from solar radiation. Solar radiation is secondary resources like as wind and wave power, hydroelectricity and biomass account for most of the available flow of renewable energy on Earth.

Solar energy technologies can provide electrical generation by heat engine or photovoltaic means, space heating and cooling in active and passive solar buildings; potable water via distillation and disinfection, day lighting, hot water, thermal energy for cooking, and high temperature process heat for industrial purposes.

Solar energy refers primarily to the use of solar radiation for practical ends. All other renewable energies other than geothermal derive their energy from energy received from the sun.

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies.

2.2 Street Lamp

Before we have incandescent lamps, gas lighting was in use in cities. The earliest of such street lamps were built in the Arab Empire, especially in Cordoba, Spain. The first electric street lighting employed arc lamps, initially the 'Electric candle', 'Jablochoff candle' or ‘Yablochkov candle’ developed by the Russian Pavel Yablochkov in 1875. This was a carbon arc lamp employing alternating current, which ensured that the electrodes burnt down at the same rate. Yablochkov candles were first used to light the Grands Magasins du Louvre, Paris where 80 were deployed. Soon after, experimental arrays of arc lamps were used to light Holborn Viaduct and the Thames Embankment in London - the first electric street lighting in Britain. More than 4,000 were in use by 1881, though by then an improved differential arc lamp had been developed by Friederich von Hefner-Alteneck of Siemens & Halske.

Arc lights had two major disadvantages. First, they emit an intense and harsh light which, although useful at industrial sites like dockyards, was discomforting in ordinary city streets. Second, they are maintenance-intensive, as carbon electrodes burn away swiftly. With the development of cheap, reliable and bright incandescent light bulbs at the end of the 19th century, they passed out of use for street lighting, but remained in industrial use longer.

Incandescent lamps used for street lighting until the advent of high-intensity discharge lamps, were often operated as high-voltage series circuits. Today, street lighting commonly uses high-intensity discharge lamps, often HPS high pressure sodium lamps. Such lamps provide the greatest amount of photo illumination for the least consumption of electricity. However when photo light calculations are used, it can be see how wrong HPS lamps are for night lighting. White light sources have been shown to double driver peripheral vision and increase driver brake reaction time at least 25%. When S/P light calculations are used, HPS lamp performance needs to be reduced by a minimum value of 75%. This is now a standard design criteria for the roads.

Figure 2.0: Old, new style and solar street lamp

2.3 SOLAR ENERGY

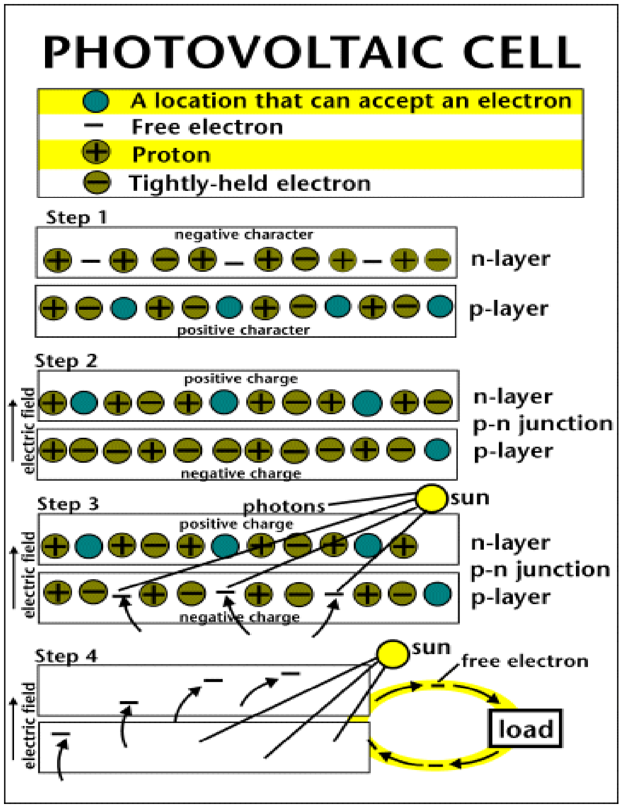


Figure 2.1 Photovoltaic Cell

Photovoltaic energy is the conversion of sunlight into electricity. A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. [1]

Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity.

When enough sunlight energy is absorbed by the material that is a semiconductor, electrons are come out from the material's atoms. Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to free electrons, so the electrons naturally migrate to the surface.

When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery.

When the two surfaces are connected through an external load, electricity flows.

Photovoltaic cells, like batteries, generate direct current (DC) which is generally used for small loads like electronic equipment. When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using inverters.

Advantages of photovoltaic systems are:

- Conversion from sunlight to electricity is direct, so that bulky mechanical generator systems are unnecessary.
- PV arrays can be installed quickly and in any size required or allowed.
- The environmental impact is minimal, requiring no water for system cooling and generating no by-products.

2.4 BATTERY CHARGER

A battery charger is a device used to put energy into a secondary cell or rechargeable battery by forcing an electric current through it.[2]

The charge current depends upon the technology and capacity of the battery being charged. For example, the current that should be applied to recharge a 12 V car battery will be very different from the current for a mobile phone battery.

A simple charger works by connecting a constant DC power source to the battery being charged. The simple charger does not modify its output based on time or the charge on the battery. This simplicity means that a simple charger is inexpensive, but there is a tradeoff in quality. Typically, a simple charger takes longer to charge a battery to prevent severe over-charging. Even so, a battery left in a simple charger for too long will be weakened or destroyed due to over-charging. These chargers can supply either a constant voltage or a constant current to the battery.

[1] - Energy Information Administration, *Electric Power Annual*, Form EIA-860, Annual Electric Generator Report database, 2006

[2] - http://en.wikipedia.org/wiki/Battery_charger

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

In this chapter, explanations about all the circuit that were done for this project will be told. This chapter will be divided to hardware configuration and software configuration since this project will be used both hardware and software. All the calculation also will be state into this chapter. The total figure related to this project will be added in this chapter along with the details.

3.1 HARDWARE CONFIGURATION

3.1.1 CIRCUIT DIAGRAM

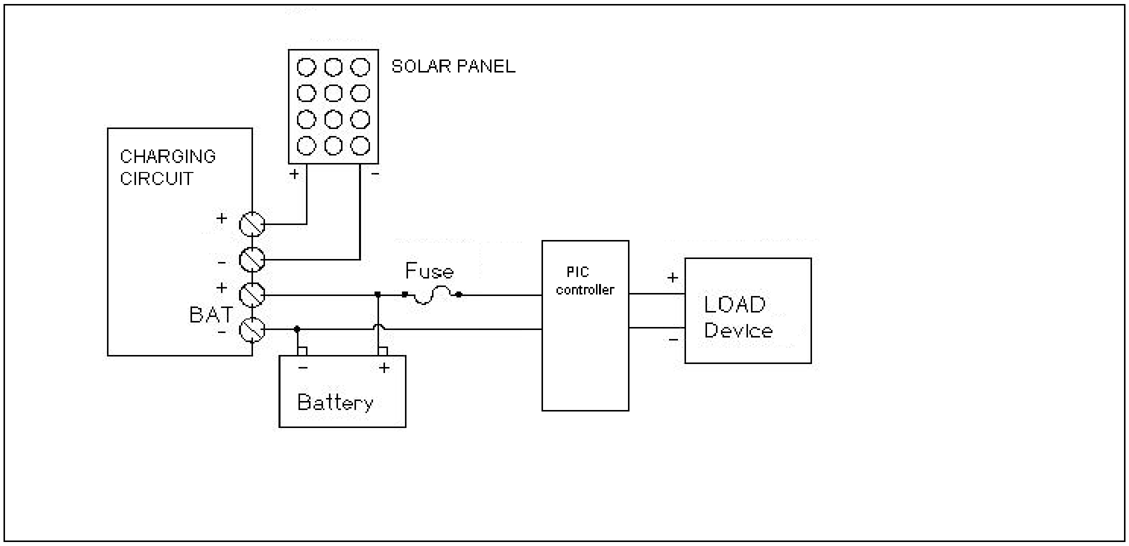


Figure 3.0: Block Diagram of Solar Street Lamp

This block diagram above is about the combination of the charging circuit and controller circuit to the load and the DC voltage source. At the day, solar panel will get the energy from the sun and the circuit charging will control the charging rate to the battery. The charging circuit will control the charging until the battery reaches the floating condition that is the full condition of the battery. The charging only occur when in the day because the solar need for the light to transfer the sunray to the electricity. When in the night condition the circuit charging automatically stop the charging and diode 20L15T are use to eliminate from current draw from the battery to the solar panel when in night condition. The features of the diode show below.

The circuit PIC controller will control the using of the energy of the battery to the load. This circuit controller is consisting of PIC16F877A, photocell sensor, wave sensor drivers. To control the switching of the load it’s depend on the sensor that will give the input to the PIC, PIC will give the output to the relays the same as the coding we had make. For this circuit, the photocell sensor will determine whether the situation is needed to switch on the lamp or not. So we should have the reference value. Some analysis I have made to choice the suitable value as a reference. The more detail about the photocell sensor will show below.

The control circuit also controls the intensity of the light beam. If there have user use the road, the PIC will switch on the high intensity of the light to light the place. This switching mode will trigger for the period that I had set that is about 10s. After 10s the PIC will switch on the low intensity of the light. By using this method, we can save the power of the battery. To detected whether that have or user of the road or not, I use wave sensor. The wave sensor will give the direction to the PIC to switch the suitable intensity of the lamp. The detail about the wave sensor will show below.

3.1.2 CHARGING CIRCUIT

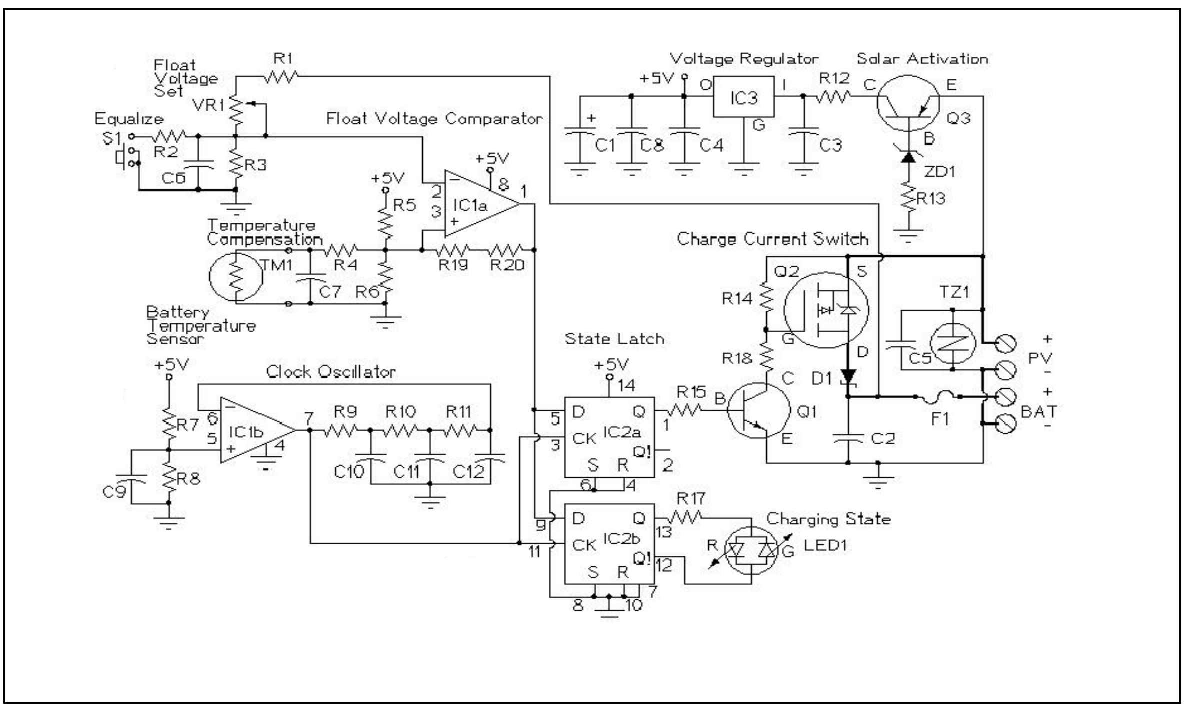


Figure 3.1: Charging Circuit

The above circuit is a solar charge controller; its function is to regulate the power flowing from a photovoltaic panel into a rechargeable battery. It features easy setup with one potentiometer for the float voltage adjustment, an equalize function for periodic overcharging, and automatic temperature compensation for better battery charging over a wide range of temperatures. This circuit is able to handle reverse polarity connection of both the battery and photovoltaic panel.

The design goals of this circuit were efficiency, simplicity, reliability and the use of field replaceable parts. A medium power solar system can be built with this circuit charging, a 12V solar panel that is rated from 100 milliamps to 20 amps and a lead acid or other rechargeable battery that is rated from 500 milliamp hours to 400 amp hours of capacity.

It is important to match the solar panel's current rating to the battery's amp-hour rating. A typical maximum battery charging current is C/20, so a 100 amp hour battery should have a solar panel rating of no greater than 5 amps. It is advisable to check the battery manufacturer's data sheets to find the maximum charge current. On the other hand, if the solar panel output current is too low, the battery may take too long to charge.

3.1.3 Charging Operation

The power control circuit can operate current from the solar panel input through Q3 and IC3. When the solar panel voltage exceeds 12V, zener diode ZD1 conducts and turns on Q3, providing power to IC3. IC3 produces a regulated 5 Volt power source. The 5V is used to power the circuit's logic and as a reference voltage for comparing to the battery float voltage.

The float voltage comparator IC1a compares the battery voltage (divided by R1/VR1 and R3) to a reference voltage (divided by R5 and R6). The comparison point is offset by the thermistor TM1 for temperature compensation. The comparison point is also modified by the Equalize switch, S1 and R2. The output of IC1a goes high (+5V) when the battery voltage is below the float voltage setting. The output goes low when the battery voltage is above the float voltage setting. This provides the charge/idle signal that controls the rest of the circuit.

The charge/idle signal is sent to IC2a and b, a pair of D-type flip-flops. The flip-flops are clocked by the IC1b phase-shift clock oscillator. The clocking causes the flip-flop output to produce a square wave charge/idle signal that is synchronized with the frequency of the clock oscillator. The two halves of IC2 operate in synchronization, IC2a is used to drive the current switching circuitry, IC2b is used to drive the charging state indicator LED either red (charging) or green (floating).

The clocked charge/idle signal switches bipolar transistor Q1 on and off. The Q1 signal is used to switch power MOSFET Q2, which switches the solar current on and off through the battery. The solar charging current flows through the heavy lines on the schematic. Diode D1 prevents the battery from discharging through the solar panel at night. Fuse F1 prevents excessive battery current from flowing in the event of a short circuit. Transzorb TZ1 absorbs transient voltage spikes that may be caused by lightning.

3.1.3.1 SCHOTTKY RECTIFIER (DIODE 20L15TS)

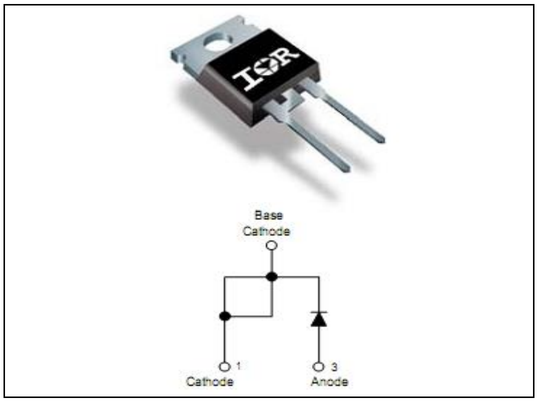


Figure 3.2: Schottky Diode

The Schottky rectifier module has been optimized for ultra low forward voltage drop specifically for the OR-ing of parallel power supplies. The proprietary barrier technology allows for reliable operation up to 125 °C junction temperature.

Typical applications are in parallel switching power supplies, converters, reverse battery protection, and redundant power subsystems.

- 125°C TJ
- operation (VR < 5V)
- Single diode configuration
- Optimized for OR-ing applications
- Ultra low forward voltage drop
- Guard ring for enhanced ruggedness and long term reliability

- High purity, high temperature epoxy encapsulation for enhanced mechanical strength and moisture resistance

3.1 Shottky Diode Characteristics

Characteristics		**Values**	**Units**
$I_{F(AV)}$	Rectangular waveform	20	A
V_{RRM}		15	V
I_{FSM}	@ tp = 5 μs sine	700	A
V_F	@ 19 Apk, T_J=125°C (Typical)	0.25	V
T_J	range	-55 to 125	°C

3.1.4 CONTROL CIRCUIT

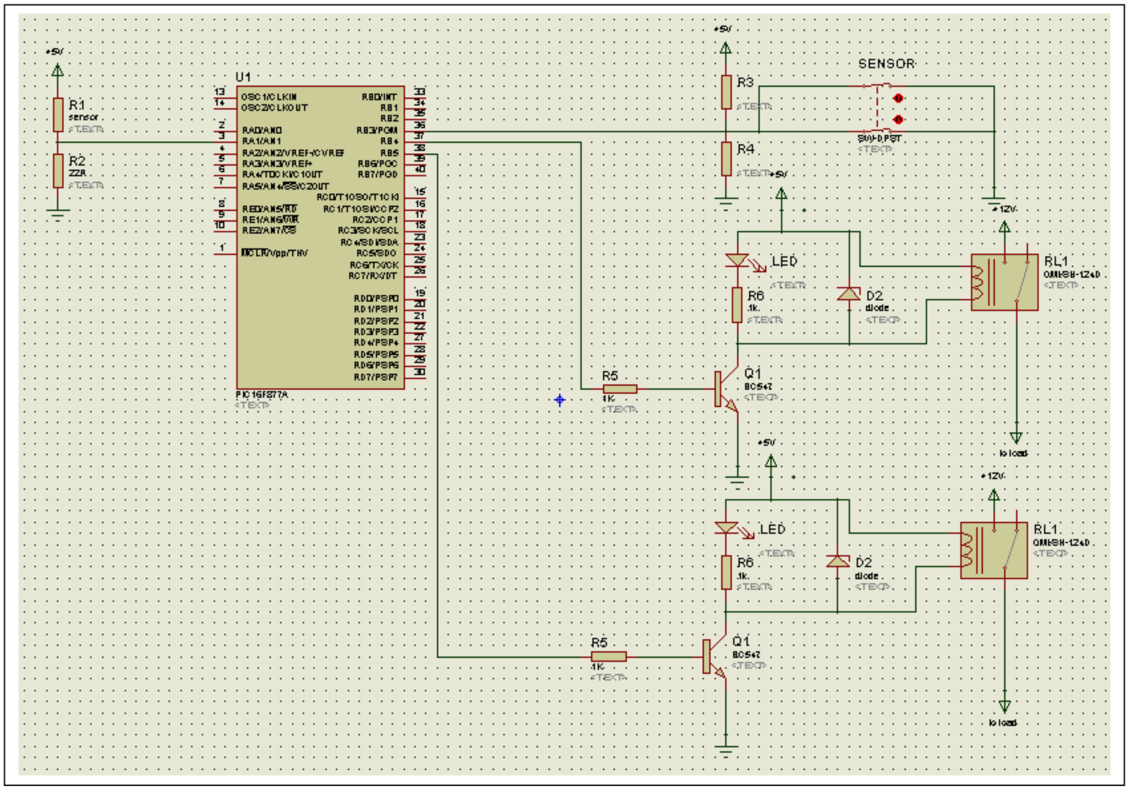


Figure 3.3: Control Circuit

Figure above is about the control circuit to the load. I use 2 sensors as the parameter to sense the input condition to the PIC. First sensor is the photocell sensor that detects the concentration of the light. When sensor detect that have light, ADC go in to the PIC and the PIC will determine to switch the lamp. For the second sensor that is to determine the user of the road, I use the wave sensor to detect the user, when the user come close to the lamp along the road, sensor will detect and give the input to the PIC and PIC will automatically switch on the high beam lamp for the 10s.The control circuit will switch off the lamp when the photocell sensor detect the light from the sun in the early morning and the charging process will continue until evening or no light (cloudy).

3.1.3.1 PIC16F877A

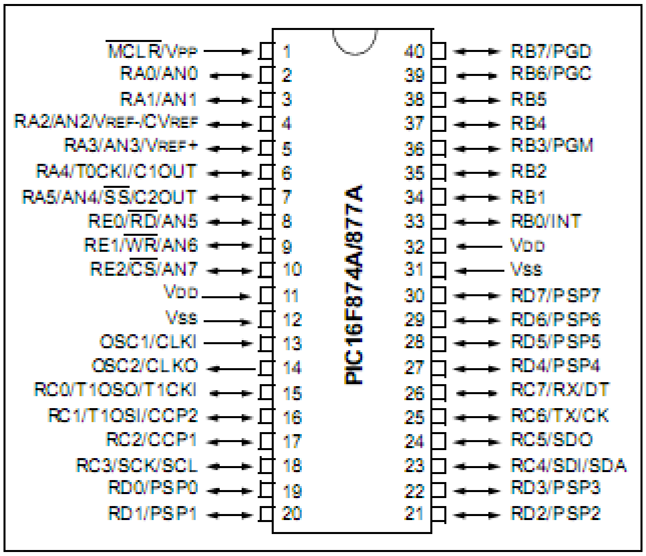


Figure 3.4: PIC16F877A

PIC is a family of Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1640 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to "Programmable Interface Controller", but shortly thereafter was renamed "Programmable Intelligent Computer". PIC are popular with developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability .

PIC16F785 is a small piece of semiconductor integrated circuits. The package type of these integrated circuits is DIP package. DIP stand for Dual Inline Package for semiconductor IC. This package is very easy to be soldered onto the strip board. However using a DIP socket is much easier so that this chip can be plugged and removed from the development board. PIC16F877A is very cheap. Apart from that it is also very easy to be assembled.

Additional components that need to make this IC work are just a 5V power supply adapter, an internal 20MHz crystal oscillator and two analog comparators. This IC can be reprogrammed and erased up to 10,000 times. Therefore it is very good for new product development phase.

Feature

The PIC16F877A microcontroller offers all of the advantages of the well recognized high performance RISC CPU that is only can operate 35 single word instruction except for the program branches which are had two cycle. For the speed operating that is 20Mhz clock input and the time of every instruction is about 200ns. This PIC has up to 8K x 14 words of Flash Program Memory, 368 x 8 bytes of Data Memory (RAM) and 256 x 8 bytes of EEPROM Data Memory. Its also has 10-bit, up to 8-channel Analog-to-Digital Converter (A/D), Brown-out Reset (BOR), Analog Comparator module with two analog comparators and Programmable on-chip voltage reference .Its also can programmable input multiplexing from device inputs and internal voltage reference and has Comparator outputs that are externally accessible

The special features are 100,000 erase/write cycle Enhanced Flash program memory typical, 1,000,000 erase/write cycle Data EEPROM memory typical, Data EEPROM Retention > 40 years, Self-reprogrammable under software control, In-Circuit Serial Programming™ (ICSP™) via two pins, single-supply 5V In-Circuit Serial Programming, Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation, programmable code protection, power saving sleep mode and also has selectable oscillator options.

3.1.4.2 PHOTOCELL SENSOR

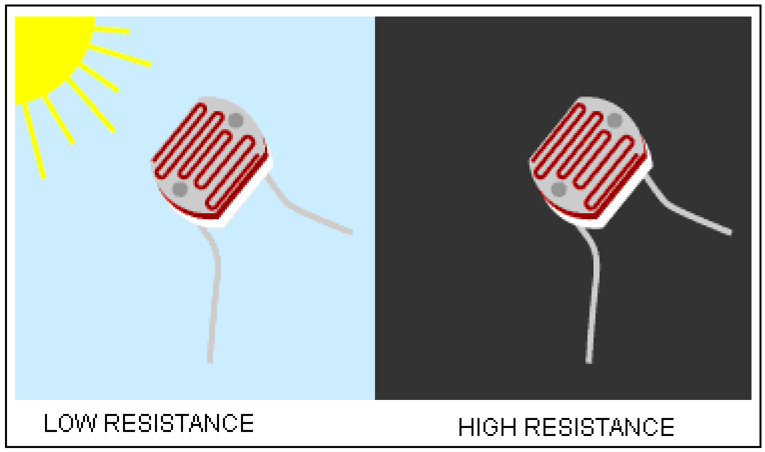


Figure 3.5: Photocell sensor

A photocell is a type of resistor. When light strikes the cell, it allows current to flow more freely. When dark, its resistance increases dramatically. Photocells need some calibration to be responsive in the exact lighting scenario you have. They can be used to detect large or small fluctuations in light levels to distinguish between one light bulb and two, direct sunlight and total darkness, or anything in between.

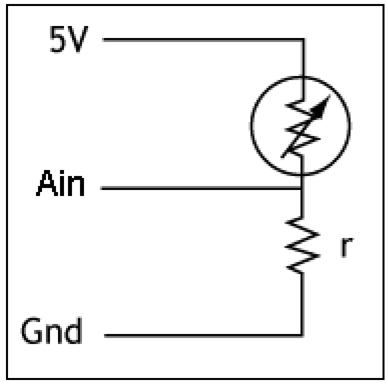


Figure 3.6: Circuit Driver Photocell sensor

The circuit used is a plain voltage divider. It is used since we need to present a voltage to the Analog In device and the photocell merely changes resistance. You can see in the circuit below that the as the resistance of the photocell reduces (as a result of more light reaching it) the voltage will go up towards 5V. If the resistance of the photocell increases (as a result of less light reaching it) the voltage will fall towards 0V.

3.1.4.3 WAVE SENSOR

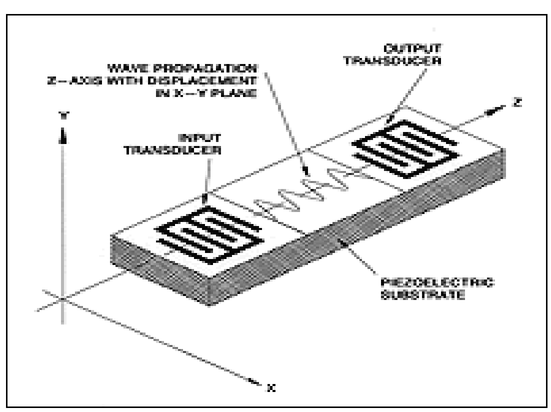


Figure 3.7: Wave sensor

In general, the sensitivity of the sensor is proportional to the amount of energy in the propagation path being perturbed. Wave sensors typically separate the energy from the surface through the material to the other surface. This distribution of energy minimizes the energy density on the surface, which is where the sensing is done. All wave sensors are sensitive, to varying input from many different physical parameters. Some commercially available wave sensors are shown in Figure 6. As a matter of fact, all wave devices manufactured for the telecommunications industry must be hermetically sealed to prevent any disturbances because they will be sensed by the device and cause an unwanted change in output.

3.1.4.4 RELAYS

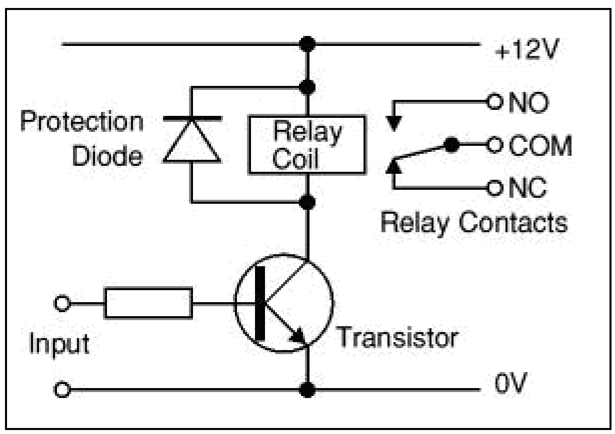


Figure 3.8: Relays

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw changeover switches.

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, which are magnetic and mechanical

Advantages of relays:

- Relays can switch AC and DC, transistors can only switch DC.
- Relays can switch high voltages, transistors cannot.
- Relays are a better choice for switching large currents (> 5A).
- Relays can switch many contacts at once.

3.1.4.5 12V LEAD ACID BATTERY

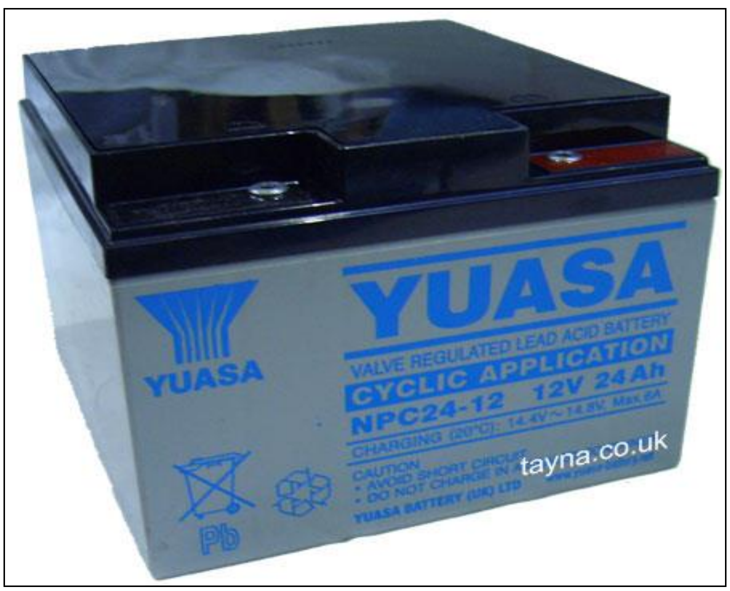


Figure 3.9: 12V Lead Acid Battery

A battery is a vital element of any battery-backed system. In many cases the battery is more expensive than the system it is backing up. Hence we need to adopt all practical measures to conserve battery life. As per manufacturer's data sheets, a 12V rechargeable lead-acid battery should be operated within 10.IV and13.8V. When the battery charges higher than 13.8V it is said to be overcharged, and when it discharges below 10.IV it can be deeply discharged. A single event of overcharge or deep discharge can bring down the charge-holding capacity of a battery by 15 to 20 percent. It is therefore necessary for all concerned to monitor the charge level of their batteries continuously. But, in practice, many of the battery users are unable to do so because of non-availability of reasonably-priced monitoring equipment.

3.2 SOFTWARE CONFIGURATION

3.2.1 Software Programming

For programming the PIC, MicroCode Studio programmer were using. There are many programming software that can such as C programmer but as advice from supervisor and we decide to use MicroCode Studio programming as well as PICBASICPRO. The reasons why this programmer were chosen because of the coding is easy to use.

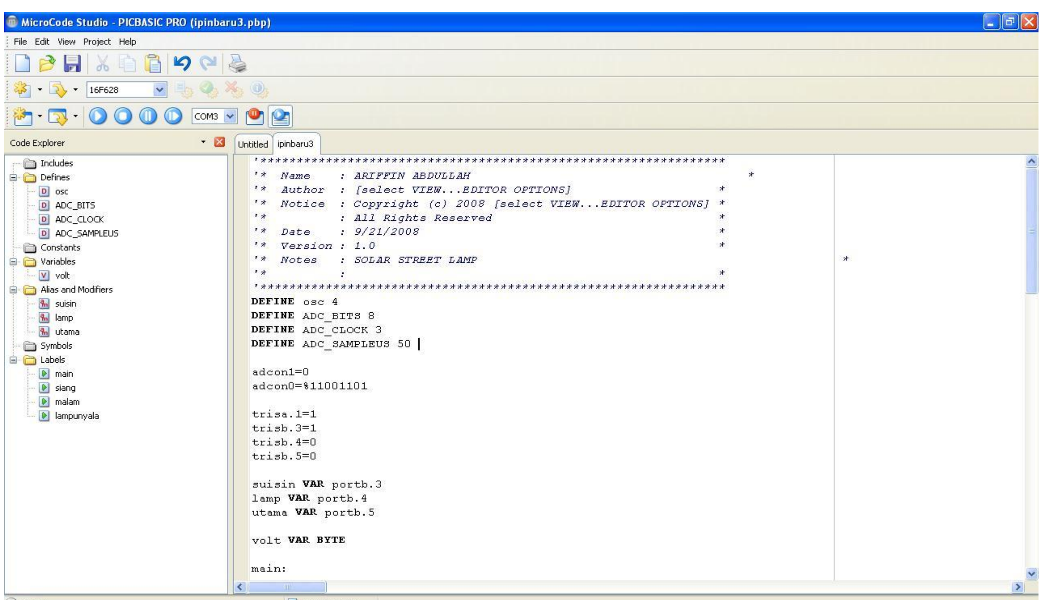


Figure 3.10 MicroCode Studio

CHAPTER 4

RESULT AND ANALYSIS

4.0 INTRODUCTION

In this chapter, the method of analyzing will include the result of the hardware testing and circuit troubleshooting. All the results are shown in the table below. Thus, the objectives of this assessment can be accomplished.

4.1 ESTIMATION TIME

Table 4.1: Estimation Time

Battery Model Code12V	NS40ZFT
Charge Acceptance (A)	3.5
Battery Capacity (mAh)	28000
Minimum Time To Full Charge (20% Efficiency Loss)	11..16 hours
Maximum Time To Full Charge (20% Efficiency Loss)	More than 24 hours (0.1A)
Discharge Current (mA)	2500 (always in high intensity)
Minimum Time of Discharging	560 Minutes = 11..2 hours

Table 4.1 is about the estimation time that I have calculated by using the battery charger calculator. The calculation about this estimation will show below. That I had use is the 12V lead acid battery that has capacity about 28000mAh. The minimum time to charge this battery to reach the full is about 9.6hours and the maximum time to charge this 12V battery is more than 24hours because the current that we get from the solar panel is very low. This is cause of the low intensity of light that hit the solar panel. For the discharging time it's depend of the using of the light. If we always use high intensity of the lamp, the battery will weak for the fast. So, to the energy from the battery I use the sensor that can sense the user to control the using of the lamp.

4.2 CALCULATION

4.2.1 Charging

Minimum time to charge

Acceptance current = up to 3.5A

Average current received ≈ 3.0A

Battery capacity = 28000mAh

Charging time = Battery capacity / current

= 28000 mAh / 3

=9.3 hours

Minimum Time To Full Charge = 120% x 9.3hours

(20% Efficiency Loss)

= 11.16hours

So the charging state should starts from 7.00am-7.00pm to reach the maximum capacity of the battery. If the day is cloudy from the morning till the night the battery take more time to charge. Let say the minimum current that battery accepts is about 0.1A.

<u>Minimum time to charge</u>

Acceptance current = up to 3.5A

Average current received ≈ 0.1A

Battery capacity = 28000mAh

Charging time = Battery capacity / current

= 28000 mAh / 0.1

=280 hours (more than one whole day)

4.2.2 Discharging

Power of the Lamp using = 55W

Current = 55 W / 12 V

= 4.58A (maximum intensity of the light)

Average current that use = 2500mA

Battery capacity = 28000mAh

Using current ≈ 3000mA

Minimum time ≈ 28000 mAh / 2500mA

≈ 11.2 hours

≈ 672 minutes

4.3 Graph of Charging 12V Lead Acid Battery

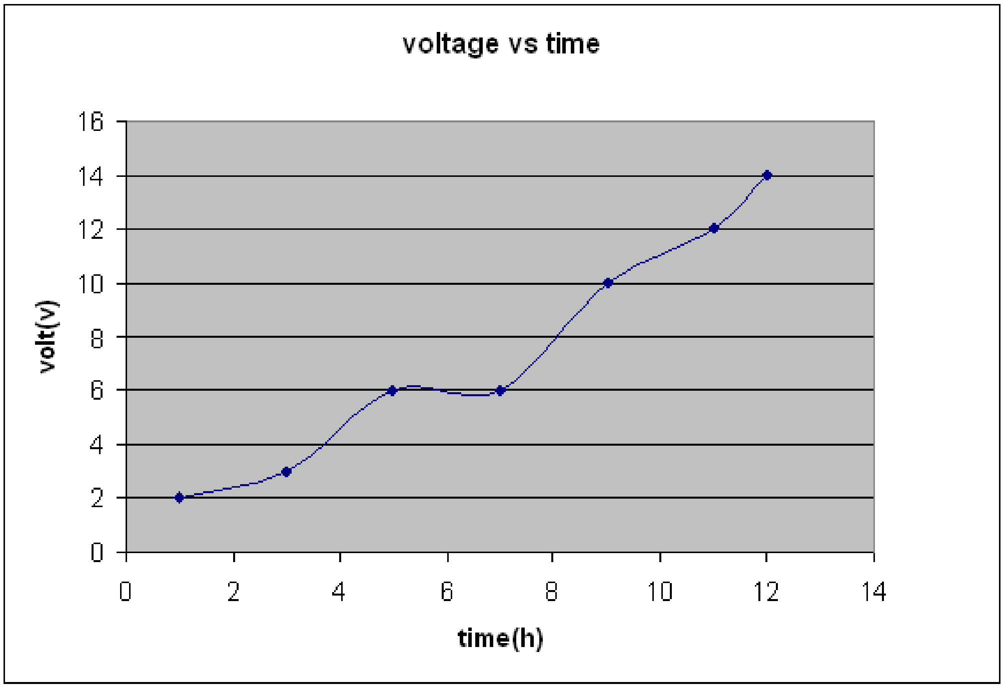


Figure 4.0: Charging Graph

The graph shows the charging graph, voltage (V) versus time (h).To reach the full charge of the battery it will take about 11hours .At the beginning of the charging its take too long time to increasing the voltage but after 6hours the battery is more easier to come up to full charge.

4.4 Graph of Discharging 12V Lead Acid Battery

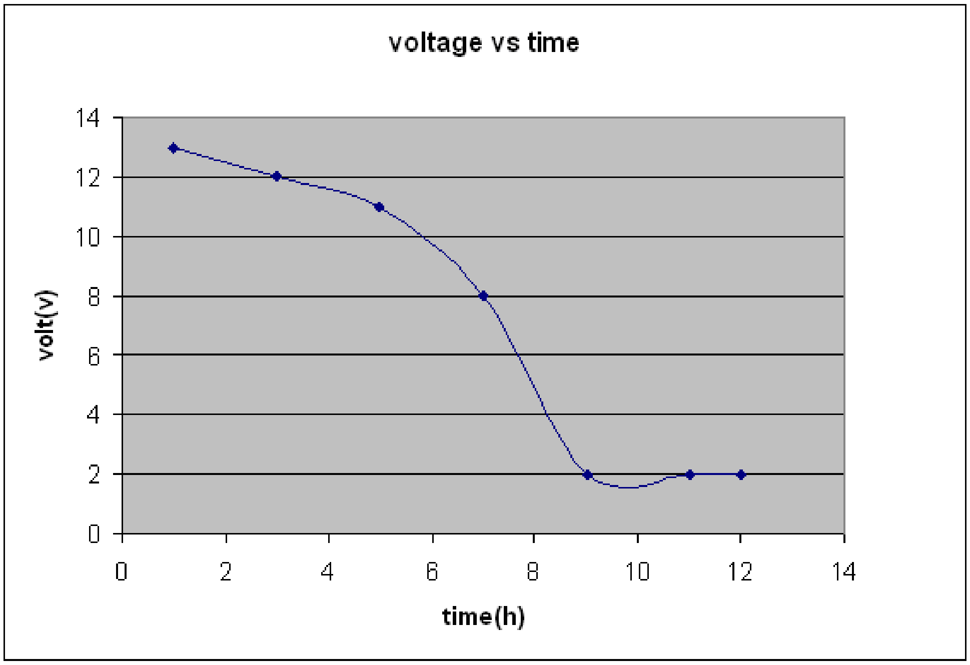


Figure 4.1: Discharging Graph

The graph shows the discharging graph, voltage (V) versus time (h).The discharging time take about 9hours to reach weak condition. At the beginning the battery maintains their charge and after about 1 hour the battery decreases to the lower volt.

4.5 Cost of the Project

Here I finalize all the project cost involved in this project, some of the component I bought by online and some I bought at the electronic components shop. There have also component I get from FKEE laboratory that include in the cost list, I also borrow the tool such as wrapping tool from the laboratory.

Table4.2: Cost of the Project

No	Component	Quantity	Cost (RM)
1	Resistor 15MΩ	4	1.60
2	Operational Amplifier	4	17.49
3	P-MOS	2	26.24
4	Diode	2	12.94
5	LED	2	0.40
6	Transzorb	2	4.10
7	Photocell sensor	1	0.80
8	12V Lamp	1	12.00
9	Resistor 270kΩ	1	0.20
10	Resistor 470kΩ	1	0.20
11	Resistor 75kΩ	1	0.20
12	Resistor 180kΩ	1	0.20
13	Resistor 620kΩ	1	0.20
14	Resistor 100kΩ	6	1.20
15	Resistor 200kΩ	1	0.20
16	Resistor 300kΩ	3	0.60
17	Resistor2.2kΩ	2	0.40
18	Resistor 10kΩ	1	0.20
19	Capacitor 470uF	1	0.40
20	Capacitor 100nF	11	4.40

21	Flip Flop	2	2.60
22	Voltage Regulator	2	1.80
23	Transistor	1	0.70
24	Transistor	1	0.70
25	Zener Diode	1	0.60
26	Thermistor	1	1.40
27	Fuse	1	2.00
28	Variable Resistor	1	1.80
29	Relays	2	10.00
30	PIC16F877A	1	30.00
31	Transistor	2	1.40
32	Lamp pole		90.00
	Total		226.97

Total costing of the project is about RM226.97.This cost of portable solar street lamp is lower than the cost to built AC street lamp that we use at the road. So for the future installation lamp for a new road, I suggest to use solar as the main source to charge the battery to save the cost of using the electricity energy.

4.6 Commercializes

The portable solar street lamp can be commercialized to the entire world because its can solve the problem and save the energy and cost of using the electricity. By adding a few parts, this portable solar street lamp can fulfill the needed of the user and can operate with more efficiency to reach the vision to safe our world.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.0 Project Problem and Solution

There are a lot of problems occur when doing this project. Firstly when doing this project I should read a lot of information to select the suitable method to control the switching of the circuit. As the solution of the problem I had chose to control this switching circuit by using PIC that is PIC16F877A.

I also had a problem with the component, to settle the problems that occur from the component I had used the suitable circuit driver to trigger the relays and the spider switch.

For the sensor that I use is the light sensor, it also need their own circuit driver. To find the suitable circuit driver I had ask from the others friend and also check from the internet and also at the library.

To build the programming of this controller I use the software that is MicroCodeStudio. With this software I can use try and error method to program the PIC16F877A.

I also had the problem with the voltage regulator that is my voltage regulator always burn and give the output that more than 5V.To solve this problem, I use double stage regulator to make sure the voltage that I want is accurate.

5.1 Future recommendations

There are many ideas and suggestion can be added towards developing this system in the future especially in the real life. As one of the recommendations is;

a) Add wind generator to ensure excellent complement to a solar power system. A wind generator is a device that generates electrical power from wind energy. Wind power is especially helpful here in the winter to capture both the ferocious and gentle mountain winds during the times of least sunlight and highest power use.

b) Use fast charger circuit to make the system operate better and will reach the full charge in the short time. From there we can minimize the charging time beside to ensure the system work efficiently.

c) Use larger capacity of battery to ensure the life time of the battery. It also can reduce the cost.

5.2 Conclusion

As for conclusion, the project's objective is to develop the portable solar street lamp with the DC voltage as the source and to develop the charging circuit that can charge 12V lead acid battery by using the solar panel as the DC source was successfully achieved. The acid battery will supply power to switch the lamp when there is no light condition. When in the day, the circuit will turn to charging mode by using solar energy. Integration between sensor and wave sensor was also concentrated in development of this system. In order to control the circuit for switching the PIC16F877A was developed.

Finally, the system was combining together to complete the development of the system. When nobody use the road, this portable solar street lamp just switch on with the low intensity of the lamp that's can save the energy and when it detect that there have the user, this solar street lamp will switch on the high intensity lamp to beam the place for the users. This project will give idea and suggestions to develop the more efficient solar street lamp where from there we can save the energy and use the energy with more efficiency.

REFERENCE

[1] 24rdJuly 2008, citing internet source URL

http://www.eia.doe.gov/kids/energyfacts/sources/renewable/solar.html

[2]12 August 2008, citing internet source URL

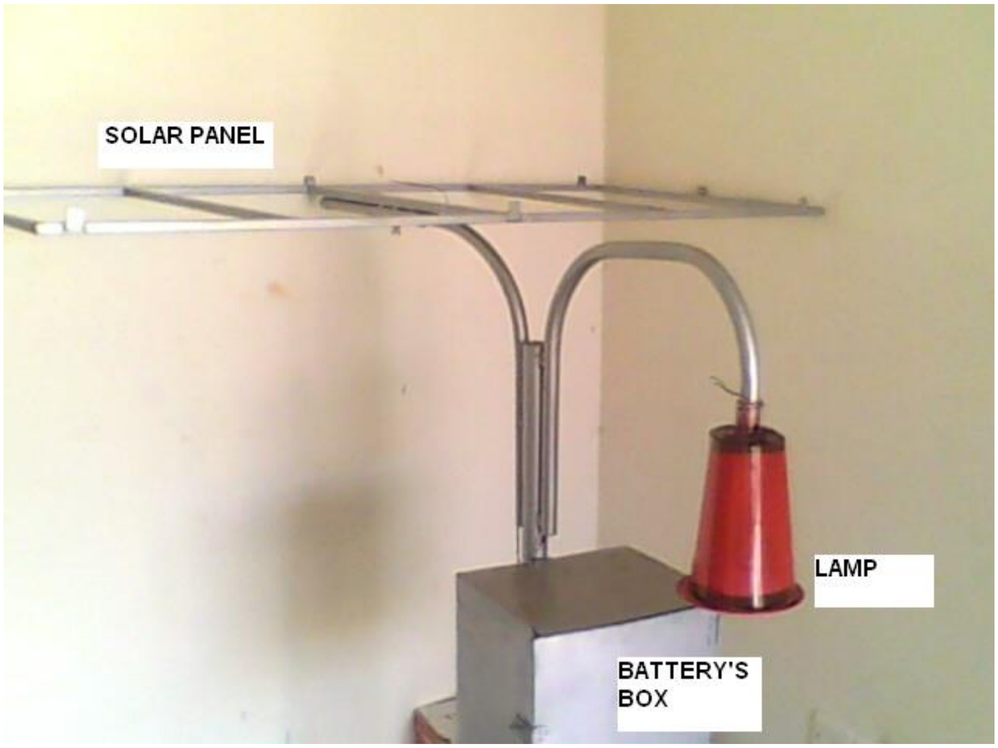
http://en.wikipedia.org/wiki/Solar_energy#Photovoltaics

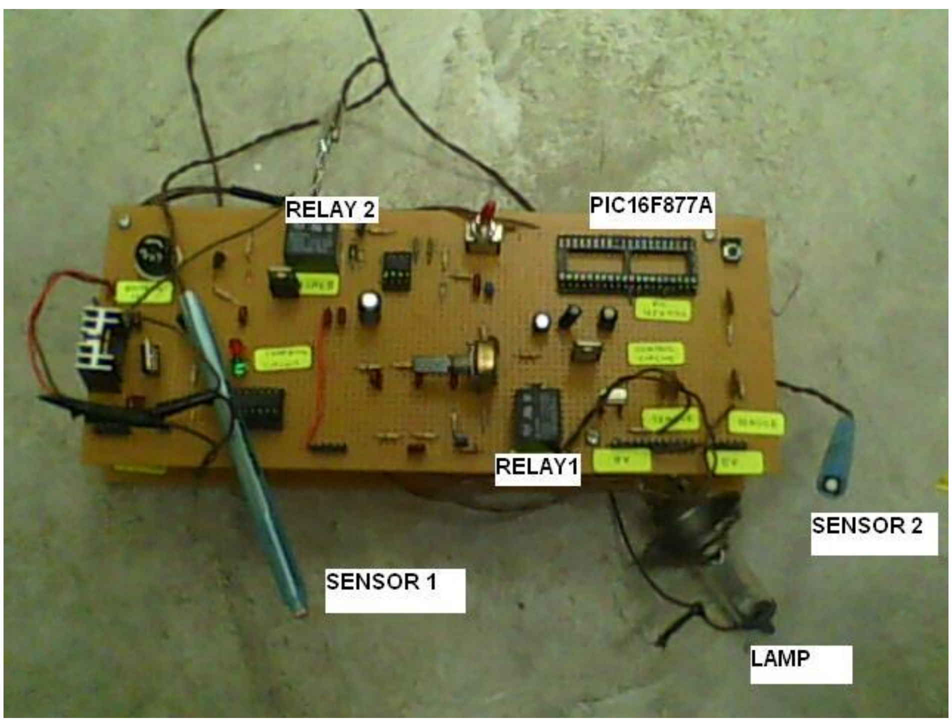
[3] Microchip Technology Incorporated: PIC16F87xa Datasheet

[4] - Energy Information Administration, *Electric Power Annual*, Form EIA-860, Annual Electric Generator Report database, 2006

[5] - http://en.wikipedia.org/wiki/Battery_charger

APPENDIX A


SOLAR PANEL
LAMP
BATTERY'S
BOX


RELAY 2
PIC16F877A
RELAY1
SENSOR 2
SENSOR 1
LAMP

APPENDIX B

```
define osc 4
Define ADC_BITS 8
Define ADC_CLOCK 3
Define ADC_SAMPLEUS 50

adcon1=0
adcon0=%11001101

trisa.1=1
trisb.3=1
trisb.4=0
trisb.5=0

suisin var portb.3
lamp var portb.4
utama var portb.5

volt var byte

main:

low utama
low lamp
adcin 1,volt
pause 100

if volt>77 then siang
if volt<77 then malam


goto main

siang :

low utama
low lamp
adcin 1,volt
if volt<77 then malam

goto siang

malam :
```

```
pause 100
high utama
low lamp
if suisin=0 then lampunyala
adcin 1,volt
if volt>77 then siang

goto malam


lampunyala:

if suisin=0 then lampunyala
high lamp
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala
pause 1000
if suisin=0 then lampunyala


goto malam
```

APPENDIX C

No	Component	Specification	Quantity
1	Resistor 15MΩ	0.25W	4
2	Operational Amplifi	TLC2272CP	4
3	P-MOS	IRF 4905 VDSS = -55V RDS(on) = 0.02Ω ID = -74A	2
4	Diode	20L15T	2
5	LED	RED/GREEN bicolor	2
6	Transzorb	V727/V7270	2
7	Photocell sensor		1
8	12V Lamp		1
9	Resistor	270kΩ	1
10	Resistor	470kΩ	1
11	Resistor	75kΩ	1
12	Resistor	180kΩ	1
13	Resistor	620kΩ	1
14	Resistor	100kΩ	6
15	Resistor	200kΩ	1
16	Resistor	300kΩ	3
17	Resistor	2.2kΩ	2
18	Resistor	10kΩ	1
19	Capacitor	470uF 16V	1
20	Capacitor	100nF 16V	11
21	Flip Flop	CD40113BE CMOS	11
22	Voltage Regulator	LM78L05	2
23	Transistor	2N3904	1
24	Transistor	2N3906	1
25	Zener Diode	1N5242	1
26	Thermistor		1
27	Fuse	20A	1
28	Variable Resistor	100kΩ	1
29	Relays	5V	2
30	PIC16F877A		1
31	Transistor		2

APPENDIX D

MICROCHIP

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:

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

Peripheral Features:

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

Analog Features:

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

Special Microcontroller Features:

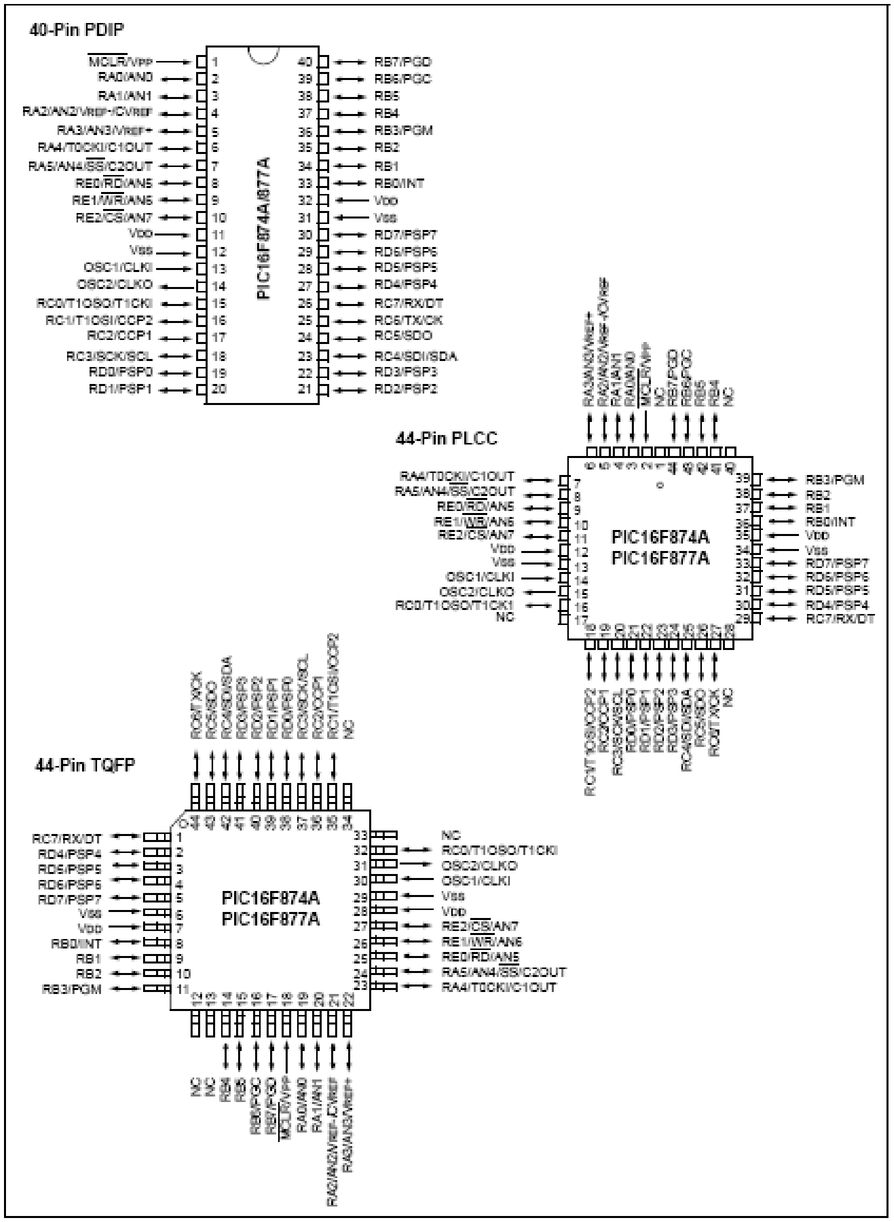
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming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

CMOS Technology:

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

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

Pin Diagrams (Continued)



1.0 DEVICE OVERVIEW

This document contains device specific information about the following devices:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

PIC16F873A/876A devices are available only in 28-pin packages, while PIC16F874A/877A devices are available in 40-pin and 44-pin packages. All devices in the PIC16F87XA family share common architecture with the following differences:

- The PIC16F873A and PIC16F874A have one-half of the total on-chip memory of the PIC16F876A and PIC16F877A
- The 28-pin devices have three I/O ports, while the 40/44-pin devices have five
- The 28-pin devices have fourteen interrupts, while the 40/44-pin devices have fifteen
- The 28-pin devices have five A/D input channels, while the 40/44-pin devices have eight
- The Parallel Slave Port is implemented only on the 40/44-pin devices

The available features are summarized in Table 1-1. Block diagrams of the PIC16F873A/876A and PIC16F874A/877A devices are provided in Figure 1-1 and Figure 1-2, respectively. The pinouts for these device families are listed in Table 1-2 and Table 1-3.

Additional information may be found in the PICmicro® Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip web site. The Reference Manual should be considered a complementary document to this data sheet and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

TABLE 1-1: PIC16F87XA DEVICE FEATURES

Key Features	PIC16F873A	PIC16F874A	PIC16F876A	PIC16F877A
Operating Frequency	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory (bytes)	128	128	256	256
Interrupts	14	15	14	15
I/O Ports	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C	Ports A, B, C, D, E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Analog Comparators	2	2	2	2
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions
Packages	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

PIC16F87XA

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	13	14	30	32		ST/CMOS(4)	Oscillator crystal or external clock input.
OSC1					I		Oscillator crystal input or external clock source input. ST buffer when configured in RC mode; otherwise CMOS.
CLKI					I		External clock source input. Always associated with pin function OSC1 (see OSC1/CLKI, OSC2/CLKO pins).
OSC2/CLKO	14	15	31	33		—	Oscillator crystal or clock output.
OSC2					O		Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO					O		In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	2	18	18		ST	Master Clear (input) or programming voltage (output).
$\overline{MCLR}$					I		Master Clear (Reset) input. This pin is an active low Reset to the device.
VPP					P		Programming voltage input.
							PORTA is a bidirectional I/O port.
RA0/AN0	2	3	19	19		TTL	
RA0					I/O		Digital I/O.
AN0					I		Analog input 0.
RA1/AN1	3	4	20	20		TTL	
RA1					I/O		Digital I/O.
AN1					I		Analog input 1.
RA2/AN2/VREF-/CVREF	4	5	21	21		TTL	
RA2					I/O		Digital I/O.
AN2					I		Analog input 2.
VREF-					I		A/D reference voltage (Low) input.
CVREF					O		Comparator VREF output.
RA3/AN3/VREF+	5	6	22	22		TTL	
RA3					I/O		Digital I/O.
AN3					I		Analog input 3.
VREF+					I		A/D reference voltage (High) input.
RA4/T0CKI/C1OUT	6	7	23	23		ST	
RA4					I/O		Digital I/O – Open-drain when configured as output.
T0CKI					I		Timer0 external clock input.
C1OUT					O		Comparator 1 output.
RA5/AN4/$\overline{SS}$/C2OUT	7	8	24	24		TTL	
RA5					I/O		Digital I/O.
AN4					I		Analog input 4.
$\overline{SS}$					I		SPI slave select input.
C2OUT					O		Comparator 2 output.

Legend: I = input   O = output   I/O = input/output   P = power
— = Not used   TTL = TTL input   ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	9		TTL/ST(1)	
RB0					I/O		Digital I/O.
INT					I		External interrupt.
RB1	34	37	9	10	I/O	TTL	Digital I/O.
RB2	35	38	10	11	I/O	TTL	Digital I/O.
RB3/PGM	36	39	11	12		TTL	
RB3					I/O		Digital I/O.
PGM					I		Low-voltage ICSP programming enable pin.
RB4	37	41	14	14	I/O	TTL	Digital I/O.
RB5	38	42	15	15	I/O	TTL	Digital I/O.
RB6/PGC	39	43	16	16		TTL/ST(2)	
RB6					I/O		Digital I/O.
PGC					I		In-circuit debugger and ICSP programming clock.
RB7/PGD	40	44	17	17		TTL/ST(2)	
RB7					I/O		Digital I/O.
PGD					I/O		In-circuit debugger and ICSP programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

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TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTC is a bidirectional I/O port.
RC0/T1OSO/T1CKI	15	16	32	34		ST	
RC0					I/O		Digital I/O.
T1OSO					O		Timer1 oscillator output.
T1CKI					I		Timer1 external clock input.
RC1/T1OSI/CCP2	16	18	35	35		ST	
RC1					I/O		Digital I/O.
T1OSI					I		Timer1 oscillator input.
CCP2					I/O		Capture2 input, Compare2 output, PWM2 output.
RC2/CCP1	17	19	36	36		ST	
RC2					I/O		Digital I/O.
CCP1					I/O		Capture1 input, Compare1 output, PWM1 output.
RC3/SCK/SCL	18	20	37	37		ST	
RC3					I/O		Digital I/O.
SCK					I/O		Synchronous serial clock input/output for SPI mode.
SCL					I/O		Synchronous serial clock input/output for I^2C mode.
RC4/SDI/SDA	23	25	42	42		ST	
RC4					I/O		Digital I/O.
SDI					I		SPI data in.
SDA					I/O		I^2C data I/O.
RC5/SDO	24	26	43	43		ST	
RC5					I/O		Digital I/O.
SDO					O		SPI data out.
RC6/TX/CK	25	27	44	44		ST	
RC6					I/O		Digital I/O.
TX					O		USART asynchronous transmit.
CK					I/O		USART1 synchronous clock.
RC7/RX/DT	26	29	1	1		ST	
RC7					I/O		Digital I/O.
RX					I		USART asynchronous receive.
DT					I/O		USART synchronous data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTD is a bidirectional I/O port or Parallel Slave Port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	38		ST/TTL(3)	
RD0					I/O		Digital I/O.
PSP0					I/O		Parallel Slave Port data.
RD1/PSP1	20	22	39	39		ST/TTL(3)	
RD1					I/O		Digital I/O.
PSP1					I/O		Parallel Slave Port data.
RD2/PSP2	21	23	40	40		ST/TTL(3)	
RD2					I/O		Digital I/O.
PSP2					I/O		Parallel Slave Port data.
RD3/PSP3	22	24	41	41		ST/TTL(3)	
RD3					I/O		Digital I/O.
PSP3					I/O		Parallel Slave Port data.
RD4/PSP4	27	30	2	2		ST/TTL(3)	
RD4					I/O		Digital I/O.
PSP4					I/O		Parallel Slave Port data.
RD5/PSP5	28	31	3	3		ST/TTL(3)	
RD5					I/O		Digital I/O.
PSP5					I/O		Parallel Slave Port data.
RD6/PSP6	29	32	4	4		ST/TTL(3)	
RD6					I/O		Digital I/O.
PSP6					I/O		Parallel Slave Port data.
RD7/PSP7	30	33	5	5		ST/TTL(3)	
RD7					I/O		Digital I/O.
PSP7					I/O		Parallel Slave Port data.
							PORTE is a bidirectional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	25		ST/TTL(3)	
RE0					I/O		Digital I/O.
$\overline{RD}$					I		Read control for Parallel Slave Port.
AN5					I		Analog input 5.
RE1/$\overline{WR}$/AN6	9	10	26	26		ST/TTL(3)	
RE1					I/O		Digital I/O.
$\overline{WR}$					I		Write control for Parallel Slave Port.
AN6					I		Analog input 6.
RE2/$\overline{CS}$/AN7	10	11	27	27		ST/TTL(3)	
RE2					I/O		Digital I/O.
$\overline{CS}$					I		Chip select control for Parallel Slave Port.
AN7					I		Analog input 7.
VSS	12, 31	13, 34	6, 29	6, 30, 31	P	—	Ground reference for logic and I/O pins.
VDD	11, 32	12, 35	7, 28	7, 8, 28, 29	P	—	Positive supply for logic and I/O pins.
NC	—	1, 17, 28, 40	12,13, 33, 34	13	—	—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

2.2.2.2 OPTION_REG Register

The OPTION_REG Register is a readable and writable register, which contains various control bits to configure the TMR0 prescaler/WDT postscaler (single assignable register known also as the prescaler), the external INT interrupt, TMR0 and the weak pull-ups on PORTB.

> **Note:** To achieve a 1:1 prescaler assignment for the TMR0 register, assign the prescaler to the Watchdog Timer.

REGISTER 2-2: OPTION_REG REGISTER (ADDRESS 81h, 181h)

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
bit 7							bit 0

bit 7 **$\overline{RBPU}$**: PORTB Pull-up Enable bit
1 = PORTB pull-ups are disabled
0 = PORTB pull-ups are enabled by individual port latch values

bit 6 **INTEDG**: Interrupt Edge Select bit
1 = Interrupt on rising edge of RB0/INT pin
0 = Interrupt on falling edge of RB0/INT pin

bit 5 **T0CS**: TMR0 Clock Source Select bit
1 = Transition on RA4/T0CKI pin
0 = Internal instruction cycle clock (CLKO)

bit 4 **T0SE**: TMR0 Source Edge Select bit
1 = Increment on high-to-low transition on RA4/T0CKI pin
0 = Increment on low-to-high transition on RA4/T0CKI pin

bit 3 **PSA**: Prescaler Assignment bit
1 = Prescaler is assigned to the WDT
0 = Prescaler is assigned to the Timer0 module

bit 2-0 **PS2:PS0**: Prescaler Rate Select bits

Bit Value	TMR0 Rate	WDT Rate
000	1 : 2	1 : 1
001	1 : 4	1 : 2
010	1 : 8	1 : 4
011	1 : 16	1 : 8
100	1 : 32	1 : 16
101	1 : 64	1 : 32
110	1 : 128	1 : 64
111	1 : 256	1 : 128

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

> **Note:** When using Low-Voltage ICSP Programming (LVP) and the pull-ups on PORTB are enabled, bit 3 in the TRISB register must be cleared to disable the pull-up on RB3 and ensure the proper operation of the device

2.2.2.3 INTCON Register

The INTCON register is a readable and writable register, which contains various enable and flag bits for the TMR0 register overflow, RB port change and external RB0/INT pin interrupts.

Note:	Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 2-3: INTCON REGISTER (ADDRESS 0Bh, 8Bh, 10Bh, 18Bh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF
bit 7							bit 0

bit 7 **GIE**: Global Interrupt Enable bit
1 = Enables all unmasked interrupts
0 = Disables all interrupts

bit 6 **PEIE**: Peripheral Interrupt Enable bit
1 = Enables all unmasked peripheral interrupts
0 = Disables all peripheral interrupts

bit 5 **TMR0IE**: TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 interrupt
0 = Disables the TMR0 interrupt

bit 4 **INTE**: RB0/INT External Interrupt Enable bit
1 = Enables the RB0/INT external interrupt
0 = Disables the RB0/INT external interrupt

bit 3 **RBIE**: RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2 **TMR0IF**: TMR0 Overflow Interrupt Flag bit
1 = TMR0 register has overflowed (must be cleared in software)
0 = TMR0 register did not overflow

bit 1 **INTF**: RB0/INT External Interrupt Flag bit
1 = The RB0/INT external interrupt occurred (must be cleared in software)
0 = The RB0/INT external interrupt did not occur

bit 0 **RBIF**: RB Port Change Interrupt Flag bit
1 = At least one of the RB7:RB4 pins changed state; a mismatch condition will continue to set the bit. Reading PORTB will end the mismatch condition and allow the bit to be cleared (must be cleared in software).
0 = None of the RB7:RB4 pins have changed state

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

2.2.2.4 PIE1 Register

The PIE1 register contains the individual enable bits for the peripheral interrupts.

Note:	Bit PEIE (INTCON<6>) must be set to enable any peripheral interrupt.

REGISTER 2-4: PIE1 REGISTER (ADDRESS 8Ch)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
PSPIE[1]	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE
bit 7							bit 0

bit 7 **PSPIE:** Parallel Slave Port Read/Write Interrupt Enable bit[1]
1 = Enables the PSP read/write interrupt
0 = Disables the PSP read/write interrupt

Note 1: PSPIE is reserved on PIC16F873A/876A devices; always maintain this bit clear.

bit 6 **ADIE:** A/D Converter Interrupt Enable bit
1 = Enables the A/D converter interrupt
0 = Disables the A/D converter interrupt

bit 5 **RCIE:** USART Receive Interrupt Enable bit
1 = Enables the USART receive interrupt
0 = Disables the USART receive interrupt

bit 4 **TXIE:** USART Transmit Interrupt Enable bit
1 = Enables the USART transmit interrupt
0 = Disables the USART transmit interrupt

bit 3 **SSPIE:** Synchronous Serial Port Interrupt Enable bit
1 = Enables the SSP interrupt
0 = Disables the SSP interrupt

bit 2 **CCP1IE:** CCP1 Interrupt Enable bit
1 = Enables the CCP1 interrupt
0 = Disables the CCP1 interrupt

bit 1 **TMR2IE:** TMR2 to PR2 Match Interrupt Enable bit
1 = Enables the TMR2 to PR2 match interrupt
0 = Disables the TMR2 to PR2 match interrupt

bit 0 **TMR1IE:** TMR1 Overflow Interrupt Enable bit
1 = Enables the TMR1 overflow interrupt
0 = Disables the TMR1 overflow interrupt

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

8.0 CAPTURE/COMPARE/PWM MODULES

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

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

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

CCP1 Module:

Capture/Compare/PWM Register 1 (CCPR1) is comprised of two 8-bit registers: CCPR1L (low byte) and CCPR1H (high byte). The CCP1CON register controls the operation of CCP1. The special event trigger is generated by a compare match and will reset Timer1.

CCP2 Module:

Capture/Compare/PWM Register 2 (CCPR2) is comprised of two 8-bit registers: CCPR2L (low byte) and CCPR2H (high byte). The CCP2CON register controls the operation of CCP2. The special event trigger is generated by a compare match and will reset Timer1 and start an A/D conversion (if the A/D module is enabled).

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

TABLE 8-1: CCP MODE – TIMER RESOURCES REQUIRED

CCP Mode	Timer Resource
Capture	Timer1
Compare	Timer1
PWM	Timer2

TABLE 8-2: INTERACTION OF TWO CCP MODULES

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

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

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

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

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

Capture mode:
Unused.

Compare mode:
Unused.

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

bit 3-0 **CCPxM3:CCPxM0**: CCPx Mode Select bits

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

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

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

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

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

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

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

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register 0 (ADCON0)
- A/D Control Register 1 (ADCON1)

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

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

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

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

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

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

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

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

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

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

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

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

REGISTER 11-2: ADCON1 REGISTER (ADDRESS 9Fh)

R/W-0	R/W-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	ADCS2	—	—	PCFG3	PCFG2	PCFG1	PCFG0
bit 7							bit 0

bit 7 **ADFM:** A/D Result Format Select bit
1 = Right justified. Six (6) Most Significant bits of ADRESH are read as '0'.
0 = Left justified. Six (6) Least Significant bits of ADRESL are read as '0'.

bit 6 **ADCS2:** A/D Conversion Clock Select bit (ADCON1 bits in shaded area and in **bold**)

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

bit 5-4 **Unimplemented:** Read as '0'

bit 3-0 **PCFG3:PCFG0:** A/D Port Configuration Control bits

PCFG <3:0>	AN7	AN6	AN5	AN4	AN3	AN2	AN1	AN0	VREF+	VREF-	C/R
0000	A	A	A	A	A	A	A	A	VDD	VSS	8/0
0001	A	A	A	A	VREF+	A	A	A	AN3	VSS	7/1
0010	D	D	D	A	A	A	A	A	VDD	VSS	5/0
0011	D	D	D	A	VREF+	A	A	A	AN3	VSS	4/1
0100	D	D	D	D	A	D	A	A	VDD	VSS	3/0
0101	D	D	D	D	VREF+	D	A	A	AN3	VSS	2/1
011x	D	D	D	D	D	D	D	D	—	—	0/0
1000	A	A	A	A	VREF+	VREF-	A	A	AN3	AN2	6/2
1001	D	D	A	A	A	A	A	A	VDD	VSS	6/0
1010	D	D	A	A	VREF+	A	A	A	AN3	VSS	5/1
1011	D	D	A	A	VREF+	VREF-	A	A	AN3	AN2	4/2
1100	D	D	D	A	VREF+	VREF-	A	A	AN3	AN2	3/2
1101	D	D	D	D	VREF+	VREF-	A	A	AN3	AN2	2/2
1110	D	D	D	D	D	D	D	A	VDD	VSS	1/0
1111	D	D	D	D	VREF+	VREF-	D	A	AN3	AN2	1/2

A = Analog input D = Digital I/O
C/R = # of analog input channels/# of A/D voltage references

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

Note: On any device Reset, the port pins that are multiplexed with analog functions (ANx) are forced to be an analog input.