SMART RECYCLE AND REWARD BIN

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A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) of Electrical and Electronic Engineering

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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Approved by,

Signature : _________________________

Supervisor : Mr. Ng Choon Boon

Date : _________________________

Specially dedicated to
my loving family and supportive teammates

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SMART RECYCLE AND REWARD BIN

ABSTRACT

Smart Recycle and Reward Bin plays an important role to enable time-saving and efficient beverage containers recycling process such as in stores and supermarkets. The machine is powered by solar energy and is capable of auto-recognition of container material to separates them accordingly. The reward system uses Smart Card system to overcome the inconvenience faced by manual reward redemption as well as to save on paper usage. The microcontroller with the integration of sensors and mechanisms enable effective recognition and automatic separation of recycled items. After the sensor defferentiates the material, it will send the information to the microcontroller and the separation part will start working. The separation part involves 3 servo motors and 4 holes for reject item, tin container, plastic container, and glass container. Besides that, the microcontroller also performs auto-summation and stores the total of reward points into the smart card. LCD display gives a user friendly interface and to display the type of material and points rewarded. The implementation of solar energy involves a solar panel, a solar charge controller, and a battery. Testing results of circuits and overall system would show how the objectives and scopes of the project are achieved. The system itself is still imperfect with certain limitations. Possible future works will also be discussed. Overall, the system can be implemented successfully. The system as a whole provides a cost effective and convenient solution for recycling purpose in support of “Go Green” campaign in Malaysia.

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LIST OF SYMBOLS / ABBREVIATIONS

AC	Alternating Current
AGM	Absorbed Glass Mats
Ah	Ampere-hour
DC	Direct Current
DOD	Depth of Discharge
GEL	Gelled Electrolyte Sealed Lead Acid
PV	Photovoltaic
PWM	Pulse-Width Modulation maximum allowable pressure, kPa

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CHAPTER 1

INTRODUCTION

1.1 Background

A reverse vending machine is a device that accepts used (empty) beverage containers and returns reward to the user (the reverse of the typical vending cycle). The main vendors of reverse vending machines are Tomra of Norway and Wincor Nixdorf of Germany, while there is also some competition from smaller companies such as Envipco and Repant.

Reverse Vending Machines are widely used overseas as a way to motivate recycling. All the Reverse Vending Machines are using AC power supply from plug to operate the machine. It usually used a transformer to step down the voltage and a rectifier to convert AC to DC to operate the machine.

The reverse vending machines that are available in the market allows detection of one type of material only. In order to recycle plastic, glass, or tin, it requires 3 Reverse Vending Machines with each of them in charge of different types of material of container.

1.2 Motivation

Recycling is one of the best ways to have a positive impact to both the natural environment and us. We must act fast as the amount of waste we create is increasing all the time. Recycling is the best way to curb pollution but the inconvenience of the process often demotivates people from practicing it.

Hence, Recycle and Reward Bin is an idea to encourage recycling habit by giving rewards to recyclers for every recycled items in terms of reward points. These reward points may serve as commercial purpose where sponsors such as supermarkets and companies can participate in this recycling effort by giving gift vouchers in exchange to their redeemed points.

Recycling is part of the management of natural resources. Management of natural resources also encourage people to start using renewable energy because non renewable energy such as fossil fuels is going to finish. The major motivation for this project is to enable the implementation of Reverse Vending Machines in Malaysia by building a prototype which use renewable energy such as solar energy to generate electricity for the reverse vending machine. This not only motivates people to recycle but it also encouraged people to use solar energy to generate electricity.

1.3 Aims and Objectives

This project aim is to develop a solar powered prototype of Reverse Vending Machine that is called the Smart Recycle and Reward Bin where it will feature the integration between microcontrollers, sensors, stored value card, programming and mechanical mechanism. This prototype uses sensors to recognize the container material such as aluminium, glass and plastic beverage containers and gets reward points. The separation of containers is done by a mechanism using servo motor. The whole machine is operated by using the electricity from a battery. The battery is charged by solar panel using solar energy.

The objectives of this project are:

i. To develop a solar powered Smart Recycle and Reward Bin.

ii. To develop a mechanical mechanism to separate the aluminium, plastic, and glass containers.

iii. To build a suitable casing for Smart Recycle and Reward Bin.

1.4 Scope of Work

For this Reverse Vending Machines, it has a casing which has 3 parts for detection, separation and collection. The author needs to build the casing and mechanism to separate the aluminium, plastic, and glass containers, as well as program the microcontroller to operate the mechanism. The author also needs to find the suitable solar panel and solar battery for this machine and build a solar charge controller in prevent the battery from over charge.

Ng Chun Hoe is in charge for the detection of container material, where he needs to develop different types of sensor to differentiate aluminium, plastic, and glass containers. He also needs to build the mechanism for door lock.

Melissa Lim is charge on the reward system, where she needs to develop a card reader system to collect the point. She also needs to build the mechanism for display the point and types of item for recycle.

CHAPTER 2

LITERATURE REVIEW

In this chapter explanation about the theory related to the solar energy and the equipment require in order for the reader to understand the rest of the contents. Besides that give a summary of the various methods that has been tried to solve the problem or different ways of implementing the system, and compare their achievements/problems.

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 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 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. (Wikipedia 2010)

2.2 Solar Cell/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.

Sunlight is composed of photons and contains various amounts of energy 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. 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. (Mysore, 2008) The steps are as shown is figure 2.1

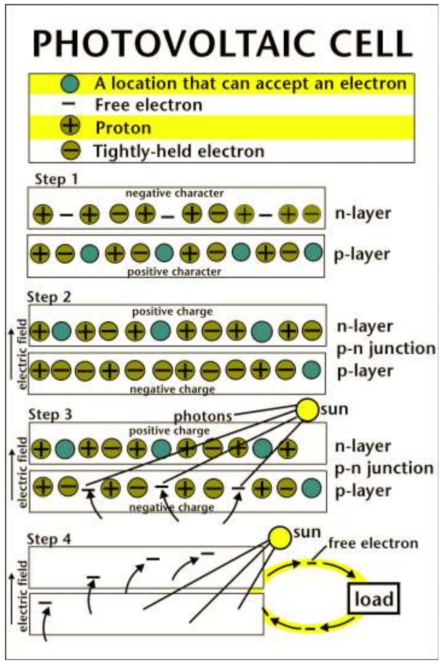

Figure 2.1: Photovoltaic Cell (Mysore, 2008)

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.

Solar panels are in variety of wattages depends on the size. The number of solar panels and the size require depends on the amount of electricity you are trying to produce and the insolation in your area. Insolation can be thought of as the number of hours in the day that the solar panel will produce its rated output and is not equivalent to the number of daylight hours.

There are four main types of solar panelswhich are Monocrystalline Silicon Panels, Polycrystalline Silicon Panels, String Ribbon Silicon Panels, and Amorphous Silicon Panels. (SolarPanelCenter.net, 2011)

Monocrystalline (or single-crystal) silicon solar panels have a return electricity rate of anywhere from 14% to 18%. These panels are made from one continuous sheet of silicon that has pieces of metal nailed to the edges to increase the conductivity and to excite the electrons. Monocrystalline panels are more expensive but they are more effective.

Polycrystalline (or multi-crystal) silicon panes have an electricity return rate of about 12%-14% so they are less efficient than monocrystalline silicon solar panels. These panels are made up of lots of individual PV cells that have metal conducting materials nailed to the sides that will help excite the electrons and also connect the cells together. Polycrystalline silicon panels are the cheapest solar panels and the maintenance costs of polycrystalline silicon panels is lower than monocrystalline solar panels because if one of the cells on a polycrystalline panel is damaged it can have the individual cell replaced without having to replace the entire panel.

String ribbon silicon panels are made in a similar way to the polycrystalline silicon panels and have about the same electricity return rate. The difference between string ribbon silicon panels and polycrystalline silicon panels is that the PV cells in a string ribbon panel are made of strips of silicon attached to metal bars that connect the strips to form a cell. Using strips of silicon to form the cell instead of using one solid square of silicon make the production cost of string ribbon silicon panels a bit lower than the production cost of polycrystalline silicon panels.

Amorphous silicon panels have the lowest electricity return rate of any type of solar panels. Traditionally amorphous silicon solar panels have an electricity return rate of between 5%-6%. This is because these panels are not made with crystalline silicon. They are composed of a piece of semi conductive metal, like copper, with a thin silicon film over the top that is attached to some metal pieces. These panels are very cheap to produce but amorphous silicon panels are not cost effective in the long run.

In conclusion, Polycrystalline is suitable for this project with the advantages discussed earlier at above

2.3 Solar Charge Controller

Most stand-alone solar power systems will need a charge controller. The purpose of this is to ensure that the battery is never overcharged, by diverting power away from it once it is fully charged. Only if a very small solar panel such as a battery saver is used to charge a large battery is it possible to do without a controller. Most charge controllers also incorporate a low-voltage disconnect function, which prevents the battery from being damaged by being completely discharged. It does this by switching off any DC appliances when the battery voltage falls dangerously low.

Solar charge controllers are specified by the system voltage they are designed to operate on and the maximum current they can handle. The maximum current is determined by the number and size of solar panels used. A single panel would need a controller of between 4 and 6 Amps rating, while larger arrays may need controllers of 40 Amps or more. Different settings are needed if sealed batteries are used to prevent the loss of electrolyte through gassing. The controller is available with ratings of 8, 12, 20 and 30 Amps, and automatically selects between 12 and 24 Volts. (Stubbs, 2008)

In a solar charge controller, there is a circuit to measure the battery voltage, which operates a switch to divert power away from the battery when it is fully charged as shown is figure 2.2. Because solar cells are not damaged by being short or open-circuits, either of these methods can be used to stop power reaching the battery. A controller which short-circuits the panel is known as a shunt regulator, and that which opens the circuit as a series regulator.

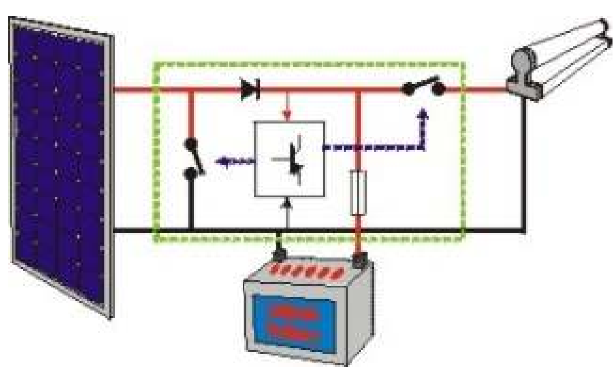

Figure 2.2: The operation of Charge Controller (Stubbs, 2008)

2.4 Solar Battery

The purpose of the solar battery is to store power that is generated by solar panel and then provide that power when it's needed. Without a battery, you can only use power at the time you produce it and at times when there was no sun, we would not have any power at all.

The number of times a battery can be discharged is known as its cycle life. Car batteries are the most common type of lead-acid battery, but will survive only 5 or 10 cycles are meant for providing a lot of current for a short amount of time to the cars starter, and then recharge relatively slowly via the alternator and are called as "shallow cycle batteries".

Solar power systems typically produce a smaller amount of charging current over a longer period of time, so the batteries are slowly charged. For solar applications a battery needs to be capable of being discharged hundreds or even thousands of times. This type of battery is known as a deep-cycle battery.

To maintain healthy batteries and prolong battery life, most manufacturers suggest limiting the depth of discharge to about 20%. (That means the deep cycle batteries will be at 80% capacity or better.) At the very least, do not allow the batteries to be discharged below 50% Depth of Discharge (DOD). (SC Origin, 2007)

Battery capacity is determined by the amount of electrical energy the battery can deliver over a certain period of time and is measured in Ampere hours (Ah) when discharged at a uniform rate over a given period of time. Ampere hours (Ah) are calculated by multiplying the current (in amperes) by time (in hours) the current is drawn. Amp-hour rating is commonly used on sealed lead acid batteries used in Wind and Solar systems. For example, a battery which delivers 1 ampere for 20 hours would have a 20 amp-hour battery rating.

The main types of batteries that are used in solar power systems are the Flooded Lead Acid type and the Sealed Lead Acid type which consist of AGM (Absorbed Glass Mat) type and the Gel type deep cycle batteries.

Flooded lead acid batteries have the longest track record in solar electric use and are still used in the majority of standalone solar systems. They have the longest life and the least cost per amp-hour of any of the choices buy they require regular maintenance in the form of watering, equalizing charges and keeping the top and terminals clean. Besides that, the flooded cell design is dangerous because the battery caps are not sealed and explosive hydrogen gas can vents from the top of the battery and if there is a spark near the battery, it will explode the cloud of gas. Additionally, if a battery is sloshed, tipped, or charged improperly, dangerous sulfuric acid will spill out of the battery. (SC Origin, 2007)

AGM BATTERIES are sealed batteries that use "Absorbed Glass Mats", or AGM between the plates. In an AGM battery, the sulfuric acid is absorbed into a mesh of glass fibers. These types of batteries are very rugged. Being maintenance free, AGM batteries are thus ideally suited for use in grid-tied solar power systems with battery back-up. They do not need periodic watering, and emit no corrosive fumes, the electrolyte will not stratify and no equalization charging is required. AGM's are also well suited to systems that get infrequent use as they typically have less than a 2% self discharge rate during transport and storage. They can also be transported easily and safely by air. Last, but not least, they can be mounted on their side or end and are extremely vibration resistant.   (Bright Green Energy, 2009)

GEL batteries contain acid that has been turned into a “gel” through the addition of Silica Gel, turning the acid into a solid state. In a gel battery, the sulfuric acid electrolyte is mixed with a block of gel, which immobilizes the acid and prevents spillage and gassing even if the case is cracked. The gelled electrolyte in these batteries is highly viscous and recombination of the gases generated while charging is occurred at a much slower rate.. For use in a grid-tie with back up system or any system where discharge rates are less than severe, gel batteries could be a good choice. (Bright Green Energy, 2009)

In conclusion, AGM battery is suitable for this project with the advantages discussed earlier at above.

2.5 Servo Motor

A "servo" is a generic term used for an automatic control system. In practical terms, that means a mechanism which adjusts itself during continued operation through feedback. Disk drives, for example, contain a servo system insuring that they spin at a desired constant speed by measuring their current rotation, and speeding up or slowing down as necessary to keep that speed.

Servo motor is composed of an electric motor mechanically linked to a potentiometer. Pulse-width modulation (PWM) signals sent to the servo are translated into position commands by electronics inside the servo. When the servo is commanded to rotate, the motor is powered until the potentiometer reaches the value corresponding to the commanded position.

. For this project, the mechanism to separate the containers requires accurate position. Servo Motor is chosen compare to other types of motor because the position of the servo motor is easy to control by using PWM signal and PWM signal can be generate easily by PIC16 F877A.

CHAPTER 3

METHODOLOGY

3.1 Solar Energy System Design

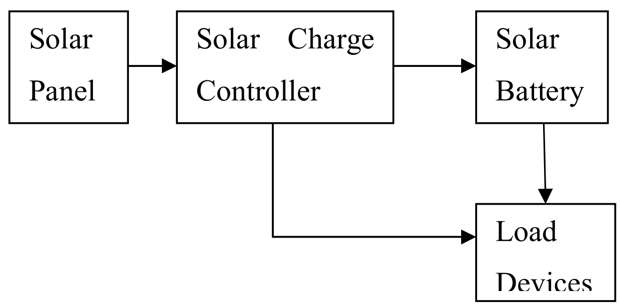

Figure 3.1: Block Diagram of Solar Energy System

As shown is figure 3.1, for a solar energy system, it uses a solar panel to generate electricity by the conversion of sunlight. This electricity is used to charge the solar battery or operate the load devices. To prevent the solar battery from overcharge, a solar charge controller is used. Without sunlight, the solar battery can use as a backup to operate the load devices. If the load devices require more current to operate, the solar battery can been used as a current booster to operate the load devices.

There are 3 steps to implement solar energy:

1) Determine the battery storage capacity to be use
2) Built the right type of solar charge controller
3) Determine the right type of solar panel to be use

3.1.1 Solar Battery

Before determine the type of battery use, we need to determine how much battery storage (in ampere-hours) is needed for the system and determine the voltage to switch on all the parts in the machine.

To work out what voltage is required,

1) Find the minimum voltage that needed to switch on the parts in the machine.
2) Record down the minimum voltage.
3) Find the maximum voltage that can handle by the parts in machine.
4) Record down the maximum voltage.

To work out what storage is required, we need to determine the load and the duration need to supply by the battery to the machine. To test the load,

1) Connect all the part together
2) Based on the maximum voltage, use a DC supply to supply that voltage to the circuit.
3) Use the ammeter to measure the current over the whole circuit before the servo motor start operation.
4) Use the ammeter to measure the maximum current when the servo motor move to separate reject item.
5) Record down the current.
6) Repeat step 4 and 5 with the servo motor move to separate plastic, glass, tin.

For example, if the load is 1.5A and the duration need to supply by the battery to the machine is 3 hours, the storage is 1.5A X 3hrs = 4.5Ahrs. So, we need to buy a battery that at least provides storage of 5Ahrs.

3.1.2 Solar Charge Controller

This solar charge controller involve a 9V voltage regulator, LM324 (comparator), 2N2222 (NPN transistor), 9V relay, LED, 5K Variable resistor, resistors and capacitors. Figure 3.2 shows the circuit for the battery charge controller. The simple charge controller will stop charging when the battery exceed a preset voltage level and re-enable charging when battery voltage drops back below that level.

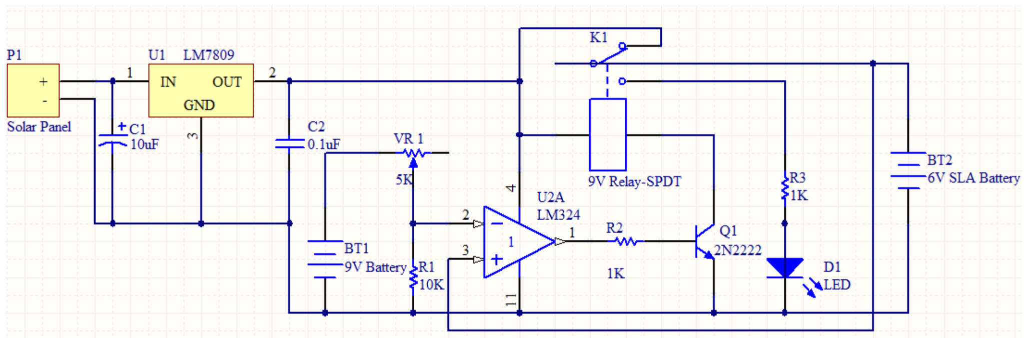

Figure 3.2: Block Diagram of Solar Energy Equipment

For this circuit, it uses a 9V voltage regulator to regulate the input voltage to 9V as long as the input voltage to the voltage regulator is more than 9V. This circuit is to protect the battery from too large of voltage supply from solar panel to the battery. It uses an operational amplifier (LM 324) to compare the voltage and a NPN transistor (2N2222) and 9V relay for switching to enable the charging circuit to turn on or off. The references voltage of comparator is based on a voltage divider circuit which consists of a 5K variable resistor and a 10k resistor. By adjusting the 5K variable resistor, we can obtain the references voltage we want. For comparator circuit, it used 6.2V as references (V-) and battery is connected to another input (V+). This means this controller circuit will charge the battery from 0 volt to 6.2V. After battery voltage exceeds the references, the comparator produces an output to turn on the NPN transistor. Once the NPN transistor is turn on, the 9V relay will turn on and disconnect the battery form solar panel and connect the battery to the LED to indicate fully charge.

This project are based on design a simple battery charge controller that will stop charging a battery when they exceed a set high voltage level and re-enable charging when battery voltage drops back below that level.

To calculate the 6.2 V reference, the equation below is used:

$$\frac{R2}{R1+R2}(Vout) = Vref$$

$$\frac{10k\Omega}{R1+10k\Omega}(9V) = 6.2V$$

$$R1 = \frac{10k\Omega(9V)}{6.2V} - 10k\Omega$$

$$R1 = 4.5k\Omega$$

After done designing the circuit, the circuit must do some simulation test to get the final result. This testing process is very important to check hardware result related to the theory study.

1) Apply 17 volts to the circuit to represent the solar panel and use another power supply to represent the battery voltage.

2) Increase the battery voltage from 0V up to 6.2V, record down the voltage that connect the solar panel to battery. If got reading means the battery is charging.

3) Increase the battery voltage to 6.3V. Observe whether the relay and LED are turn on.

4) Record down the voltage that connects the solar panel to battery. If no reading, means the battery is stop charging.

3.1.3 Solar cell/PV cell

During the operation, the current from PV cell will drop as the time increase because when time increase, temperature increase and the efficiency of the PV drop as temperature increase. To test the PV cell efficiency after a long time putting under the sun,

1) Put the PV cell under the sun when the sky is clear.

2) Immediately record down the open circuit voltage by using voltmeter.

3) For every 1 minute, record the open circuit voltage until the thermal equilibrium is reach where the voltage is become nearly constant for 10 minutes.
4) After the thermal equilibrium is reach, record down the current using ammeter. This current is the maximum current that can supply to the battery and the load after a long time.

3.2 Casing of Smart Recycle and Reward Bin

Figure 3.3 shows the draft drawing of the casing for the Smart Recycle and Reward Bin. It can be divided into top, middle and bottom part. Top part is used as detection part and for reject item to drop out from Hole 1. Middle part is used as a separation part where the servo motor will move to separate the containers to respective hole. Bottom part is used as a collection part where it collects the containers through respective holes.

When a container is drop in, servo motor with door 1 will close and the sensor will start working to differentiate the container. Once it differentiates, servo motor with door 2 and servo motor with door3 will move depend on which holes the container need to drop in. After that, servo motor with door 1 will open and the container will drop in to the collection part.

The Solidworks drawings of the casing are attached in Appendix A.

For this Smart Recycle and Reward Bin, the material used for the casing is plywood, perspex, plastic card board, aluminium L-shape bar. Plywood is the major material for the casing where it is used for the top, bottom, back and side of the casing. The perspex is used for the front part so the user can observe the operation of the servo motor. The aluminium L-shape bar is used as supporter bar to hold the parts together. The plastic card board is used as a door that attached to the servo motor because it is hard and light.

The actual drawings are shown in figure 3.4, figure 3.5, figure3.6 and figure 3.7.

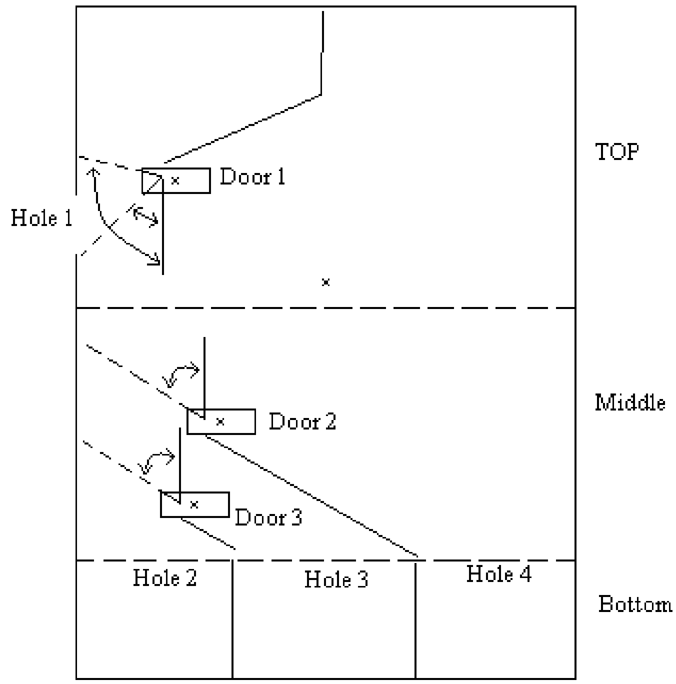

Figure 3.3: Draft drawing of the Casing

Figure 3.4: Combined casing

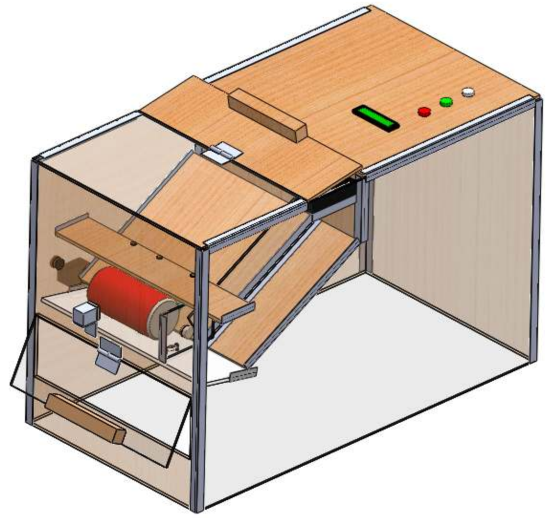

Figure 3.5: Top part of casing

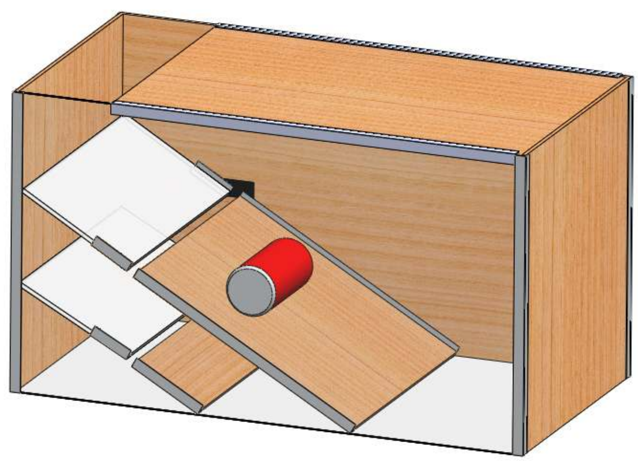

Figure 3.6: Middle part of casing

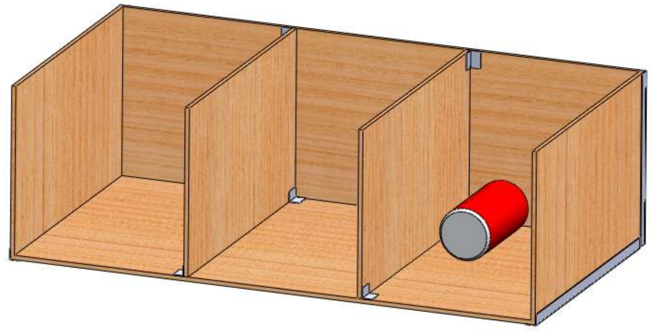

Figure 3.7: Bottom part of casing

The torque of the servo motor depends on the voltage ratings. Lowest voltage rating give the lowest torque and highest voltage rating give the highest torque. Most servos are operated at 4.8V DC or 6.0 V DC The unit of torque of servo motor is kg-cm. It means how many kg the servo motor can support for the spine distance (cm) of the servo motor. For example, the torque of the motor is 5.0 kg-cm. The spine distance of the servo motor is 10cm. So 5.0 kg-cm divide by 10cm is 0.5kg. This mean the servo motor can support 0.5kg of thing for the spine distance of 10cm. When the shaft distance is increased, with the same load, the current will increase in order to move to the require position.

In this project, for door 1, door 2 and door 3 to close the door, we need the shaft distance to be 15 cm. The servo motor that the author had chosen is HYX-S3006. The data sheet of the HYX-S3006 servo motor is attached in Appendix B. From the data sheet provided, when the apply voltage is 4.8V, the torque is 6.0kg-cm. When the apply voltage is 6.0V, the torque is 7.1kg-cm. Based on the data sheet, if we apply 6.0V, the load that is allowed by 15cm is 473g. Based on this data, the plate must be hard to support the item and light enough for the servo motor to lift the door. So, plastic cardboard was chosen because it is hard and the weight is around 100g only

The author had used 3 servo motors. 1 servo motors for detection part and for separation part and 2 servo motor for separation part only. For every servo motor is attached with a plastic cardboard to work as a door.

As shown in figure 3.3, the function of servo motor1 (door1) at detection part is move the servo motor output spine to left 100 degree to close the door 1 for stopping the item for detection. After detection, it move the servo motor output spine to 0 degree (servo motor shaft facing down) to open the door 1 for the recycle item to drop to door 2 or move the servo motor output spine to left 45 degree for the reject item to drop to hole 1.

The servo motor2 (door 2) move the servo motor output spine to 0 degree (servo motor shaft facing up) to open door 2 to allow either plastic or tin to drop to door 3 or move the servo motor output spine to left 60 degree to close the door 2 to allow the glass to fall to hole 4. The servo motor3 (door 3) move the servo motor output spine to 0 degree (servo motor shaft facing up) to open the door 3 to allow the plastic to drop to hole 2 or move servo motor output spine to left 60 degree to close the door 3 to allow plastic to drop to hole 3.

3.3 Microcontroller PIC16F877A

In this project, microcontroller has been used to control the servo motor output spine of 3 servo motor. For a clearer view, the pin connections are given in the following figure 3.8 Pin 34(PORTB,1) is used to provide PWM signal for servo motor1, pin 37(PORTB,4) is used to provide PWM signal for servo motor2 and Pin 38(PORTB,5) is used to provide PWM signal for servo motor3. Pin 19(PORTD,0) is used as the input when detect reject item; Pin 20(PORTD,1) is used as the input when detect tin container; Pin 21(PORTD,4) is used as the input when detect plastic container; pin 38(PORTD,5) is used as the input when detect glass container.

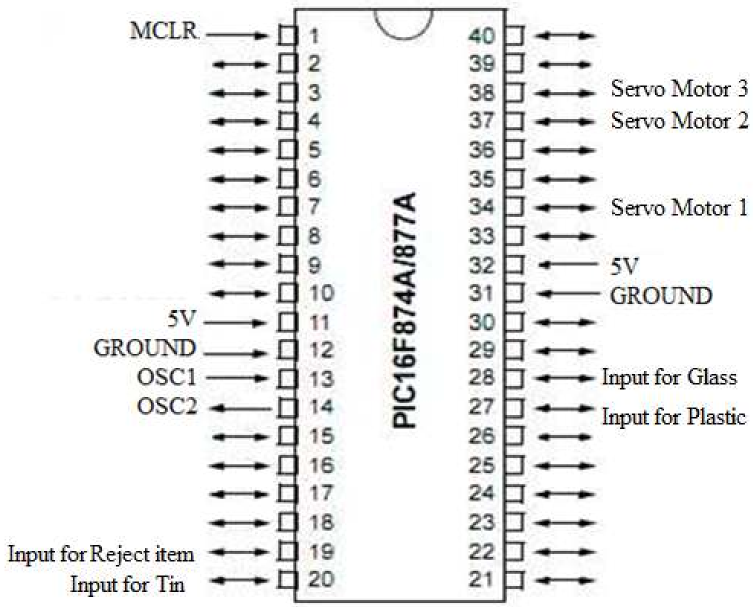

Figure 3.8: Pin connections for microcontroller

The servomotor is connected to ground, power (5 V), and control pin of the microcontroller. The signal that we need to create in order to control the servos is called a Pulse Width Modulation signal or PWM for short. So a PWM wave is just a signal that changes between 0 volts & 5 volts (digital logic 0 and 1) as shown in figure3.9.

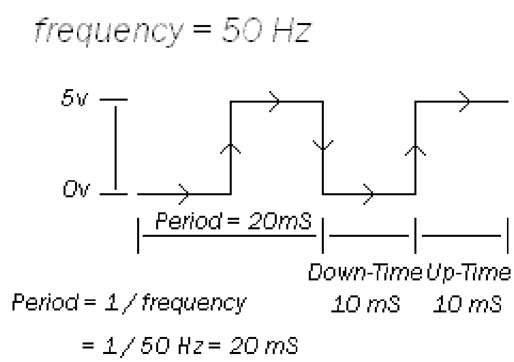

Figure 3.9: PWM wave at 50Hz

The servo will move based on the pulses sent over the control wire, which set the angle of the actuator arm. In order to set the servo motor at the angle require, the servo expects a pulse every 20 ms in order to gain correct information about the angle. The width of the servo pulse dictates the range of the servo's angular motion. (Paulo E. Merloti, 2008)

A servo pulse of 1.5 ms width will typically set the servo to its "neutral" position or 90°, a pulse of 1.00 ms could set it to 0° and a pulse of 2.00 ms to 180° as shown is figure 2.5. This mean if the pulse is shorter than 1.5 ms, then the motor will turn the shaft to closer to 0 degrees. If the pulse is longer than 1.5ms, the shaft turns closer to 180 degrees.

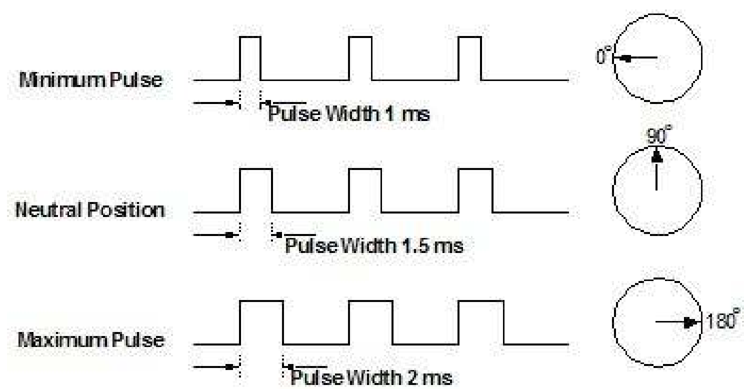

Figure 3.10: Different Direction of Servo Motor (Society of Robots, 2010)

3.3.1 Generate PWM Pulse

To set the servo motor maintain at the neutral position , first we turn on the PORT, make some 1.5 ms delay, then turn off the PORT, and make some 18.5 ms delay and repeat the step. To create the delay we can use Timer function of microcontroller

For PIC16F877A, it has 3 types of Timer which is Timer0, Timer1 and Timer2. The author had chosen Timer1 instead of Timer0 of PIC16F877A to operate the servo motor because for Timer0, by setting the Prescaler =256 and setting TMR0=0, the longest delay we can get is 0.1310sec or 13.1mS which is not suitable for our application because we need 18.0mS-19.5mS of delay. In this case, the author had chosen Timer1 for the application. By setting Prescaler =8 and setting TMR1=0, the longest delay we can get is around 1sec.

The Timer1 module, timer/counter, has the following features:

- 16-bit timer/counter consisting of two 8-bit registers (TMR1H and TMR1L)
- readable and writable
- 8-bit software programmable prescaler
- Internal (4 Mhz) or external clock select
- Interrupt on overflow from FFFFh to 0000h

Timer1 has a register called TMR1 register, which is 16 bits of size. Actually, the TMR1 consists of two 8-bits registers which are TMR1H andTMR1L. It increments from 0000h to the maximum value of 0xFFFFh

TMR1IF – TMR1 overflow Interrupt Flag bit The TMR1 interrupt is generated when the TMR0 register overflows from FFFFh to 0000h. This overflow sets bit TMR1IF is belong to PIR1 register bit-0. We can read, write and reset the value of the register TMR1

We can use Prescaler for further division of the system clock. The size of the register is 2-bit only, so the options are 1:1, 1:2, 1:4 or 1:8.

We perform all the necessary settings with T1CON register.

T1CON: TIMER1 CONTROL REGISTER (ADDRESS 10h)

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	T1CKPS1	T1CKPS0	T1OSCEN	$\overline{\text{T1SYNC}}$	TMR1CS	TMR1ON
bit 7							bit 0

Figure 3.11: Structure of T1CON register

The following is an example how we can initialize the T1CON register:

- TMR1ON=1; // the timer is enable
- TMR1CS=0; // internal clock source
- T1CKPS0=0; // Prescaler value set to “00”

- T1CKPS1=0; // which means 1:1 (no division)

Using External source (oscillator), the division is performed as follow:

$$fout = \frac{fclk}{4 * \text{Prescaler} * (65536 - \text{TMR1}) * \text{Count}} \quad where \quad Tout = \frac{1}{fout}$$

Figure 3.12: PIC TIMER1 formula for external clock

For example if we want to find the TMR1 for 1mS, so Tout=1m, Prescaler=2 and Count=1.

$$Tout = \frac{1}{fout}$$

$$fout = \frac{1}{Tout}$$

$$fout = \frac{1}{1m}$$

$$fout = 1000$$

$$TMR1 - 65536 - \frac{fclk}{fout * 4 * Prescaler * Count}$$

$$TMR1 = 65536 - \frac{20M}{1000 * 4 * 2 * 1}$$

$$TMR1 = 65536 - 2500$$

$$TMR1 = 63036$$

3.3.2 Source Code to Drive Servo Motor

Figure 3.13 shows the flowchart. The source code is attached in Appendix C.

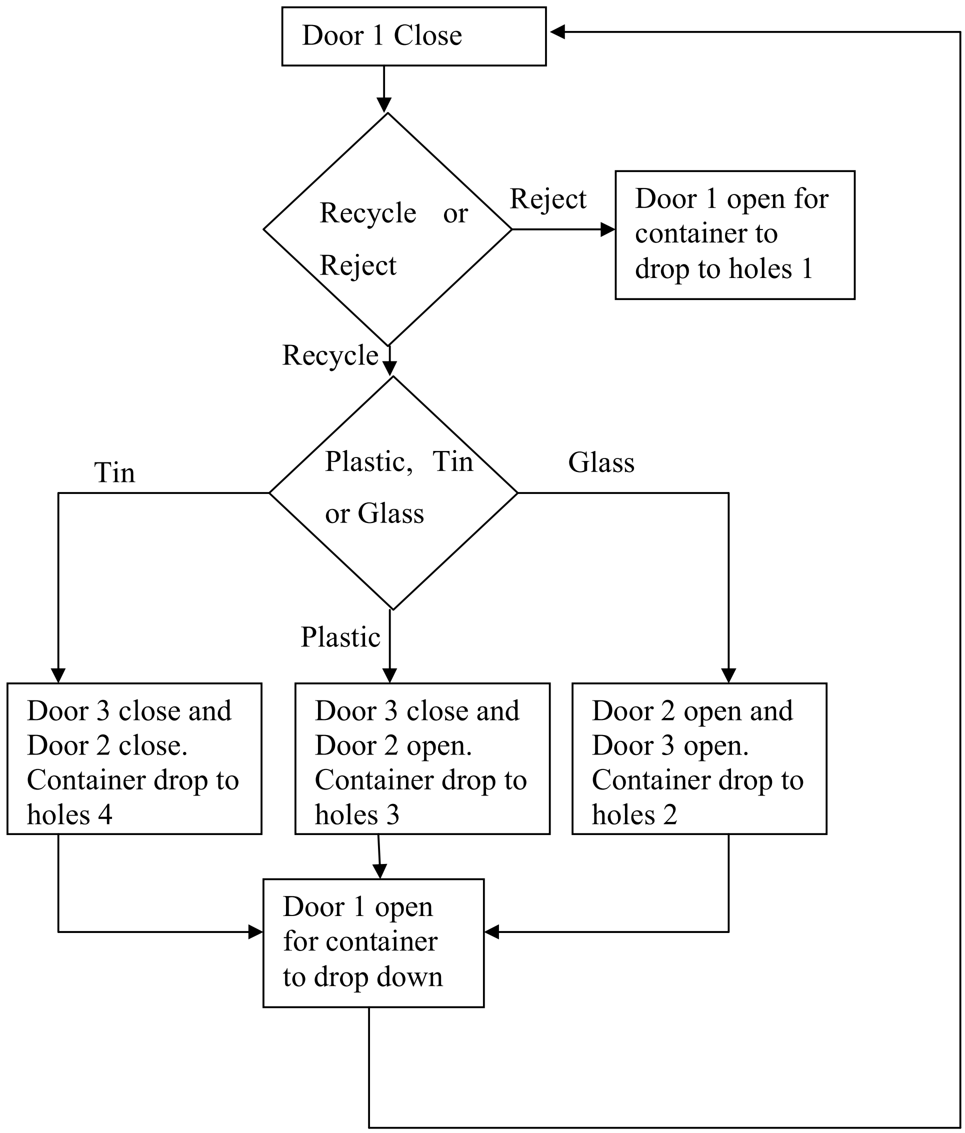

Figure 3.13: Flowchart

PORTB,1 is used to provide PWM signal for servo motor1, PORTB,4 is used to provide PWM signal for servo motor2 and PORTB,5 is used to provide PWM signal for servo motor3. At the beginning, for servo motor 1 to close the door, the On Cycle duration that chosen is 1mS. The value to put in TMR1H is F6 and the value to put in TMR1L is 3C. The Off Cycle duration will be 19mS, so next value to put in TMR1H is 46 and the next value to put in TMR1L is 74. At the same time, the

PIC16F877A wait for the input from another microcontroller using PORTD. PORTD,0 is used as the input when detect reject item; PORTD,1 is used as the input when detect tin container; PORTD,4 is used as the input when detect plastic container; PORTD,5 is used as the input when detect glass container.

When PORTD,0 detect an input, the servo motor1 output spine need to move to left 45 degree for the reject item to drop to hole 1, so the On Cycle duration that chosen is 1.6mS. The value to put in TMR1H is F0 and the value to put in TMR1L is 60. The Off Cycle duration will be 18.4mS, so next value to put in TMR1H is 4C and the next value to put in TMR1L is 50.

When PORTD,1 detect an input, the servo motor3 output spine need to move to left 60 degree to close the door 3 first, so the On Cycle duration that chosen is 2.0mS. The value to put in TMR1H is EC and the value to put in TMR1L is 78. The Off Cycle duration will be 18.0mS, so next value to put in TMR1H is 50 and the next value to put in TMR1L is 38. Then, the servo motor3 output spine need to move to left 60 degree to close the door 2 for tin container to drop to hole 4, so the On Cycle duration that chosen is 2.0mS also and the value to insert is the same like servo motor3. Finally, the servo motor1 output spine need to move to 0 degree for the containers to drop down, so the On Cycle duration that chosen is 2.0mS also and the value to insert is the same like servo motor3.

When PORTD,4 detect an input, the servo motor2 output spine need to move to 0 degree to open the door 2 first, so the On Cycle duration that chosen is 1.4mS. The value to put in TMR1H is F2 and the value to put in TMR1L is 54. The Off Cycle duration will be 18.6mS, so next value to put in TMR1H is 4A and the next value to put in TMR1L is 5C. Then, the servo motor3 output spine need to move to left 60 degree to close the door 3 for plastic container to drop to hole 3, so the On Cycle duration that chosen is 2.0mS also. Finally, the servo motor1 output spine need to move to 0 degree for the containers to drop down, so the On Cycle duration that chosen is 2.0mS also.

When PORTD,5 detect an input, the servo motor2 output spine need to move to 0 degree to open the door 2 first, so the On Cycle duration that chosen is 1.4mS.

Then the servo motor3 output spine need to move to 0 degree to open the door 3 for glass container to drop to hole 2, so the On Cycle duration that chosen is 1.4mS also. Finally, the servo motor1 output spine need to move to 0 degree for the containers to drop down, so the On Cycle duration that chosen is 2.0mS

3.3.3 Servo Motor Output Spine Test

To test the position of servo motor output spine,
1) Decide which timer of microcontroller that are suitable for generating the PWM signal.
2) Record the PWM signal (On Cycle Duration and Off Cycle Duration) that move the servo motor output spine to the most left position (0 degree).
3) Record the PWM signal (On Cycle Duration and Off Cycle Duration) that move the servo motor output spine to the most right position (180 degree).
4) Start form 0 degree, increase On Cycle Duration by 0.1mS and record down the angle (degree) until the servo motor output spine reach 180 degree.

To generate PWM signal, decide the On Cycle duration and calculate the value to put in the selected timer. For the Off Cycle duration, use the Total Cycle Duration and minus the On Cycle duration.

For example, the timer of microcontroller that is suitable isTimer1. The Total Cycle duration is 20mS. The On Cycle duration that chosen is 1mS. So calculate the value to put in TMR1H and TMR1L to generate 1mS. The value to put in TMR1H is F6 and the value to put in TMR1L is 3C. For the Off Cycle duration, the duration is 20mS minus 1mS which is 19mS. Then calculate the value to put in TMR1H and TMR1L to generate 19mS. The next value to put in TMR1H is 46 and the next value to put in TMR1L is 74.By using this way, we can get the PWM we want.

The value to put in the timer can be easily determined by using this webpage at http://eng-serve.com/pic/pic_timer.html.

1) Change the oscillator frequency value to the oscillator frequency of microcontroller which is 20MHz.

2) Select the PIC Timer # Register Calculator used which is Timer1 and select the Prescaler used which is 1:2

3) Adjust the delay value, for example, 1ms.

4) Click the calculate button and the result will show the value to put in TMR1H and TMR1L. The value is decimal value and need to be converted to Hex value. Beside that it also shows the binary value to be assigned to T1CON.

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CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter will show the analysis and result for this project. The result from circuit (hardware) be analyzed and further studied so that the project is based on the correct design. Testing and simulation is doing stage by stage. There are testing for solar battery, solar panel, simulation for solar charge controller circuit, and the application of servo motor. After the circuits are test in laboratory, the results are shown and discussion is made.

4.1 Solar Battery

Voltage and current testing on the hardware are done to determine the battery required. The hardware includes the servo motor, PIC microcontroller, sensors and magnetic door lock.

4.1.1 Voltage Testing

For this testing, the result is recorded at the table below:

Table 4.1: Parts Voltage Testing

Parts	Minimum Voltage to Turn On(V)	Maximum Voltage that can handle(V)
Servo Motor	4.8	6
PIC16F877A	5	6
IR sensor	5	8
Reflective sensor	5	8
Aluminum sensor	5	8
Force Sensing Resistor(FSR)	5	8
Magnetic Door Lock	5	12

Based on the result in table 4.1, 6V is the maximum voltage that can be handled by the servo motor and PIC16F877A and other part can be switch on at 5V and maximum voltage that can handle is up to 8V. So a 6V battery is suitable for this machine.

4.1.2 Current Testing

For this testing, the result is recorded at the table below

Table 4.2: Maximum Current for Servo Motor Operation

Servo Motor Operation	Maximum Current(mA)
No operation	109.2
Separate Reject Item	153.2
Separate Plastic	185.0
Separate Glass	187.0
Separate Tin	180.0

Based on the result in table 4.2, the current that use by servo motor is between 0.1A to 0.19A. Another hardware that consumes a relatively high current is the magnetic lock which uses 0.05A to 0.1A to magnetize the lock. Other hardware like sensor and PIC16F877A do not include in the measurement because the current that consume is relatively small.

So, if using a 6V 4 Ah battery, with 4Ah divide by 0.29A (0.19A+0.1A), it can supply for almost 13.5 hours. Therefore this battery capacity is suitable.

4.2 Solar Panel

Based on result we get from table 4.2, we had bought a 5W, 18V solar panel which can ideally provide 0.278A of current. By using this solar panel, we conduct the testing and the result is recorded at below.

The first recorded open circuit voltage: 19.5V

The first recorded short circuit current: 200mA

Table 4.3: Open Circuit for Solar Panel

Time(minutes)	Open Circuit Voltage
1	19.4
2	19.3
3	19.3
4	19.2
5	19.2
6	19.1
7	19.1
8	19.0
9	19.0
10	19.0
11	19.0
12	19.0
13	19.0
14	19.0
15	19.0
16	18.9
17	18.9
18	18.9
19	18.9
20	18.9
21	18.9
22	18.9
23	18.9
24	18.9
25	18.9
26	18.9
27	18.9
28	18.9
29	18.9

The final short circuit current: 100mA

Based on the result in table 4.3, at first the solar panel is providing 19.5 V and 200mA. After 16 minutes, the open circuit voltage is constantly providing 18.9 V and the current is drop till 100mA. This proves that when temperature increases, the efficiency of the PV efficiency will drop. Although this current is not sufficient to switch on some parts of the machine but it is sufficient to charge the battery.

4.3 Solar Charge Controller

Table 4.4: Solar Charge Controller

Battery Voltage (V)	Voltage between Solar Panel and Battery (V)	LED(on/off)
1	7.81	Off
2	7.81	Off
3	7.81	Off
4	7.81	Off
5	7.81	Off
6	7.81	Off
6.2	1.50	On

Based on the result on table 4.4, when the battery voltage reaches 6.2, the relay will turn on and disconnects the battery with solar panel and connect the battery with LED and switch on the LED.

4.4 Servo Motor

4.4.1 Servo motor output spine test

Table 4.5: Servo Motor Position

On cycle duration(mS)	Off cycle duration(mS)	Angle(degree)
0.6	19.4	3
0.7	19.3	9
0.8	19.2	21
0.9	19.1	29
1.0	19.0	40
1.1	18.9	51
1.2	18.8	61
1.3	18.7	70
1.4	18.6	79
1.5	18.5	91
1.6	18.4	100
1.7	18.3	109
1.8	18.2	121
1.9	18.1	130
2.0	18.0	141
2.1	17.9	149
2.2	17.8	160
2.3	17.7	171
2.4	17.6	176

Based on the result in Table 4.5, by increasing the On cycle duration by 0.1ms each time, the angle will approximately increased by 10 degree.

4.5 Constructed Hardware

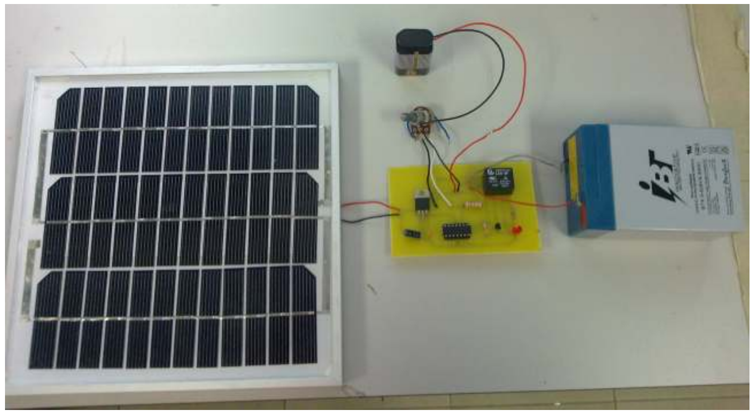

Figure 4.1: Solar Energy Equipment

In this project, Figure 4.1 shows the combine circuit of the solar energy equipment. For the solar panel, we had chosen a 5W, 18V solar panel which provided sufficient energy to charge the solar battery. For the solar charge controller, we had used solar charge controller which involve a 9V voltage regulator, LM324 (comparator), 2N2222 (NPN transistor), 9V relay, LED, resistors and capacitors. For the solar battery, we had chosen a 6v, 4Ah sealed lead acid battery.

Figure 4.2 show the photo of the combine casing. Figure 4.3 shows the photo of top part of casing. Figure 4.4 shows the photo of the middle part of casing. Figure 4.5 shows the photo of the bottom part of the casing.

Figure 4.2: Combine casing (photo)

Figure 4.3: Top part of casing (photo)

Figure 4.4: Middle part of casing (photo)

Figure 4.5: Bottom part of the casing (photo)

The maximum container size that allows to put in is 22cm*8cm and the weight that can be handle by servo motor is 300g.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The conclusion ends the report by providing the summary, problem encounter and recommendation for future work.

5.1 Summary

This final year project ("Smart Recycle and Reward Bin") is successfully gives me the understanding about the solar panel, solar charge controller, solar battery and servo motor

In a solar energy system, 3 major components which are solar panel, solar charge controller and solar battery. Solar energy is very important nowadays because it is a potential renewable energy that can replace the non-renewable energy. The problem that I encountered in this part is the charging time for the battery to be full is very slow because the current from the solar panel is very small. But circuit used to prevent the battery from overcharging the battery is achieved successfully

To develop a mechanical mechanism to separate the aluminium, plastic and glass containers, I had use 3 servo motor to control the doors in the casing to separate containers to respective location. The reason of using servo motor is because it is easy to control the direction by just sending PWM pulse from PIC16F877A to the servo motor. The difficulty faced in this part is finding the correct PWM to move the servo motor output spine to the position we want. The problem that I encountered is it does not move the servo motor output spine to the position require when the current supply to the servo motor is not enough. It will move the servo motor output spine to far right position (maximum position). Besides that, the torque of the servo motor is low causing the servo motor output spine to move slightly from target position when it holds a heavy container. But the concept with target to separate the aluminium, plastic and tin containers is achieved successfully.

To build the casing for Smart Recycle and Reward Bin, Solid Work software was used to design the casing. It was then constructed using various materials such as plywood, perspex, plastic card board, aluminium L-shape bar. The process to construct the design is using the machines in the mechanical lab

As the conclusion, this project achieves the objectives. All the devices are working and functioning as expected and Smart Recycle and Reward Bin can operate well with the designed circuit.

5.2 Recommendation for Future Work

In the future, this project should be continued in expanded scope to find more update idea to design the Smart Recycle and Reward Bin. Maybe the future project should be done to:-

1) Use higher power of solar panel to make the charging time faster.
2) Use higher torque of servo motor to prevent the servo motor output spine from moving from targeted position when hold heavy container.

By continuing this project, it can give a new and brilliant idea for the next researcher to design new equipment using new other material and devices which can work out to be the most efficient Smart Recycle and Reward Bin.

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APPENDICES

APPENDIX A: Solid Work Drawings

APPENDIX B: Data Sheet of HYX-S3006 Servo Motor

APPENDIX C: Source Code

```
;PWM With 3 speed
LIST p=16F877A
INCLUDE"P16F877a.inc"
__CONFIG _CP_OFF & _WDT_OFF & _HS_OSC & _PWRTE_ON

            org     0x200
            goto    start
            org     0x205

start:      BCF STATUS,RP1
            BSF STATUS,RP0
            MOVLW       0x00
            MOVWF       TRISB
            MOVLW       0xFF
            MOVWF       TRISD
            BCF         STATUS,RP0
            MOVLW       0X1D
            MOVWF       T1CON
            clrf        PORTB

            BSF         PORTB, 0
restart:    BCF         PIR1, TMR1IF        ;door1 close 1mS
            MOVLW       0xF6
            MOVWF       TMR1H
            MOVLW       0x3C
            MOVWF       TMR1L
            BSF         PORTB, 1
```

```
            BTFSS    PIR1, TMR1IF
            goto     $-1
            MOVLW    0x46
            MOVWF    TMR1H
            MOVLW    0x74
            MOVWF    TMR1L
            BCF      PORTB,1
            BCF      PIR1, TMR1IF
            BTFSS    PIR1, TMR1IF
            goto     $-1
            BTFSC    PORTD, 0
            goto     unknown
            BTFSC    PORTD, 1
            goto     tin
            BTFSC    PORTD, 4
            goto     plastic
            BTFSC    PORTD, 5
            goto     glass
            goto     restart

unknown:    MOVLW    0x96          ;door1 open for reject item    1.6mS
            MOVWF    0x21
again2close: BCF     PIR1, TMR1IF
            MOVLW    0xF0
            MOVWF    TMR1H
            MOVLW    0x60
            MOVWF    TMR1L
            BSF      PORTB, 1
            BTFSS    PIR1, TMR1IF
            goto     $-1
            MOVLW    0x4C
            MOVWF    TMR1H
            MOVLW    0x50
            MOVWF    TMR1L
```

```
                BCF         PORTB,1
                BCF         PIR1, TMR1IF
                BTFSS       PIR1, TMR1IF
                goto        $-1
                decfsz      0x21
                goto        again2close
                goto        restart

tin:            call    door4close          ;door3close    2mS
                MOVLW       0x32            ;door2close for tin containers 2.0mS
                MOVWF       0x21
again3close:    BCF         PIR1, TMR1IF
                MOVLW       0xEC
                MOVWF       TMR1H
                MOVLW       0x78
                MOVWF       TMR1L
                BSF         PORTB, 4
                BTFSS       PIR1, TMR1IF
                goto        $-1
                MOVLW       0x50
                MOVWF       TMR1H
                MOVLW       0x38
                MOVWF       TMR1L
                BCF         PORTB,4
                BCF         PIR1, TMR1IF
                BTFSS       PIR1, TMR1IF
                goto        $-1
                decfsz      0x21
                goto        again3close
                call    door1open           ;door1open    2mS
                MOVLW       0x96            ;door2close maintain  2mS
                MOVWF       0x21
again3close1:   BCF         PIR1, TMR1IF
                MOVLW       0xEC
```

```
                MOVWF       TMR1H
                MOVLW       0x78
                MOVWF       TMR1L
                BSF         PORTB, 4
                BTFSS       PIR1, TMR1IF
                goto        $-1
                MOVLW       0x50
                MOVWF       TMR1H
                MOVLW       0x38
                MOVWF       TMR1L
                BCF         PORTB,4
                BCF         PIR1, TMR1IF
                BTFSS       PIR1, TMR1IF
                goto        $-1
                decfsz      0x21
                goto        again3close1
                goto        restart

plastic:        call    door3open    ;door2open     1.4ms
                call    door4close   ;door3close    2.0mS
                call    door1open    ;door1open     2.0mS
                MOVLW       0x96     ;door3close maintain  2.0mS
                MOVWF       0x21
again4close1:   BCF         PIR1, TMR1IF
                MOVLW       0xF2
                MOVWF       TMR1H
                MOVLW       0x54
                MOVWF       TMR1L
                BSF         PORTB, 5
                BTFSS       PIR1, TMR1IF
                goto    $   -1
                MOVLW       0x4A
                MOVWF       TMR1H
                MOVLW       0x5C
```

```
            MOVWF     TMR1L
            BCF       PORTB,5
            BCF       PIR1, TMR1IF
            BTFSS     PIR1, TMR1IF
            goto      $-1
            decfsz    0x21
            goto      again4close1
            goto      restart

glass:      call   door3open    ;door2open    1.4mS
            call   door4open    ;door3open    1.4mS
            call   door1open    ;door1open    2.0mS
            MOVLW     0x5A
            MOVWF     0x21
            MOVLW     0xCD
            MOVWF     0x22
            MOVLW     0x16
            MOVWF     0x23
Delay_0
            decfsz    0x21
            goto      $+2
            decfsz    0x22
            goto      $+2
            decfsz    0x23
            goto      Delay_0
            goto      $+1
            goto      $+1
            nop
            goto      restart

door1open:  MOVLW     0x32          ;door1 open    2mS
            MOVWF     0x21
again1open: BCF       PIR1, TMR1IF
            MOVLW     0xEC
```

```
            MOVWF   TMR1H
            MOVLW   0x78
            MOVWF   TMR1L
            BSF     PORTB, 1
            BTFSS   PIR1, TMR1IF
            goto    $-1
            MOVLW   0x50
            MOVWF   TMR1H
            MOVLW   0x38
            MOVWF   TMR1L
            BCF     PORTB,1
            BCF     PIR1, TMR1IF
            BTFSS   PIR1, TMR1IF
            goto    $-1
            decfsz  0x21
            goto    again1open
            return

door3open:  MOVLW   0x32    ;door2open    1.4mS
            MOVWF   0x21
again3open: BCF     PIR1, TMR1IF
            MOVLW   0xF2
            MOVWF   TMR1H
            MOVLW   0x54
            MOVWF   TMR1L
            BSF     PORTB, 4
            BTFSS   PIR1, TMR1IF
            goto    $-1
            MOVLW   0x4A
            MOVWF   TMR1H
            MOVLW   0x5C
            MOVWF   TMR1L
            BCF     PORTB,4
            BCF     PIR1, TMR1IF
```

```
            BTFSS       PIR1, TMR1IF
            goto        $-1
            decfsz      0x21
            goto        again3open
            return

door4open:  MOVLW       0x32    ;door3open      1.4mS
            MOVWF       0x21
again4open: BCF         PIR1, TMR1IF
            MOVLW       0xF7
            MOVWF       TMR1H
            MOVLW       0x36
            MOVWF       TMR1L
            BSF         PORTB, 5
            BTFSS       PIR1, TMR1IF
            goto    $-1
            MOVLW       0x45
            MOVWF       TMR1H
            MOVLW       0x7A
            MOVWF       TMR1L
            BCF         PORTB,5
            BCF         PIR1, TMR1IF
            BTFSS       PIR1, TMR1IF
            goto        $-1
            decfsz      0x21
            goto        again4open
            return

door4close: MOVLW       0x32    ;door3close     2mS
            MOVWF       0x21
again4close: BCF        PIR1, TMR1IF
            MOVLW       0xF2
            MOVWF       TMR1H
            MOVLW       0x54
```

```
        MOVWF   TMR1L
        BSF     PORTB, 5
        BTFSS   PIR1, TMR1IF
        goto    $-1
        MOVLW   0x4A
        MOVWF   TMR1H
        MOVLW   0x5C
        MOVWF   TMR1L
        BCF     PORTB,5
        BCF     PIR1, TMR1IF
        BTFSS   PIR1, TMR1IF
        goto    $-1
        decfsz  0x21
        goto    again4close
        return
end
```