BATTERIES AND CIRCUIT DESIGN FOR A PORTABLE ELECTRIC SKATEBOARD AS ALTERNATIVE GREEN TRANSPORTATION

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PORTABLE ELECTRIC SKATEBOARD AS ALTERNATIVE GREEN TRANSPORTATION

SIM CHUN KIAT

Thesis submitted in fulfilment of the requirements
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ABSTRACT

In recent decades skateboarding has expanded from recreation into a form of transportation, by customizing a conventional skateboard into an electric skateboard. This research presents the design and methodology used in building an electric skateboard that has alternative solar power charging. The objectives of our design are to develop an alternative mode of transport that is high durability and reliable for daily commute with minimum maintenance needed. Foremost, this study focuses on the batteries and the circuit design of the electric skateboard. A wiring structure using wired connectors to connect the components of electric skateboard to the batteries and the controllers and also the wiring to the solar panel charger. Besides that, this study also set the electric skateboard into three type of speed that is beginner, intermediate and also expert level of speed to let user having a more better and interesting experience when using this skateboard. This electric skateboard also designed with the maximum 6 hours one cycle discharge time, which is equal to the electric skateboard ran around 57km. This project also sustainable based on the efficiency of speed of the electric skateboard and having a more faster charging time of its battery to achieve electric skateboard as one type of a main green transportation in the world.

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LIST OF SYMBOLS

mph	milli per hour
W	Watt
Wh	Watt hour
kg	Kilogram
Ah	Ampere hour
V	Voltage
rpm	Revolution per minute
rms	Root mean square
P	Power
I	Current
η	Power Efficiency
Rw	Winding resistance
mm	milli meter
π	Mathematical constant, Pi = 3.142

CHAPTER 1

1 PROJECT BACKGROUND

1.1 INTRODUCTION

Nowadays, skateboarding has moved from driveways and skate parks to city parks and streets, where it had expanded from a recreation activity to a form of personal mobility transportation (Walker & Dill, 2013). With higher demand of personal electric mobility transportation than ever, electric skateboards are gradually becoming more popular in urban transportation, which provide lots of benefits more than a regular bicycle which includes a healthy exercise, free parking, zero emissions, and freedom from gridlock. In most situations of traffic jam in the city, riding an electric skateboard will be faster and cheaper than car or public transit. Electric skateboard is a battery powered, four-wheeled of portable transport designed for individuals. It consists of a deck that attached to the wheel used to drift or skate by different type of tricks. Deck of electric skateboards can be made up from different materials such as wood, fiberglass, plexiglass, plastic and other composites.

Moreover, in urban area, parking issues had been an increasing conflicting situation for urban dwellers and it is always associated with the increased awareness of CO_2 emissions and the environmental consequences of profligate consumption of fossil fuels (McLoughlin, 2012). Electric cars have been invented to solve the environment pollution problem.

Unfortunately, electric cars are expensive and not everyone is able to afford one. Moreover, electric cars require parking spaces just like conventional vehicles, and thus will not solve parking problems (McLoughlin, 2012). Apart from that, electric cars are often a long term investment where owners have to pay insurances, maintenance, road tax payments and license payment over the years. By contrast, electric skateboard does not require insurance, attract no road tax and typically do not require a license to ride in most countries. Furthermore, they are efficient, environmentally friendly, and cheaper to buy.

Fundamentally, the electric skateboard is just a regular skateboard with an electric motor to provide additional assistance. Users can skate normally and only use the motor to help out on hills and headwinds, or use the motor all the time just to make riding easier. The electric assistance help people to save energy compare to walking or cycling. The use of electric boards is highly recommended to implement in university campus. Throughout the years, many students choose to walk for a short distance and take public transport or car along far distance buildings inside campus. Usually, students have to take at least 15-20 minutes to travel to classes around university because most campus have long distances between each building. The idea of having a portable and fast transportation, which people don’t have to use physical force, came to our mind when we saw a student skating and paddling constantly because he was late for class.

The use of electric skateboard is very common among youngsters but not every normal individual was able to enjoy these electric rides, especially for users in Malaysia, because of its high price tag. However, with the current advancement and development of technology, electric skateboards are becoming more accessible for public use with lower material cost. The speed and actual capacity of an electric skateboard depends on many variables including but not limited to, the battery used to power it, lithium or lead, the size of the battery, as well as the quality and the output of the motor and drive system.

In conclusion, an electric skateboard that will offer speeds up to 32.19 km/h delivered from a powerful max 1200W hub motor, along with a lithium polymer battery that is capable of providing riders with long period of use is designed. The electric skateboard is also built 3 for carving and cruising with its concave deck shape design by using lightweight and durable material. Another highlight of this design is that a single fully charge battery will take between 3-4 hours, and there is also a portable solar charger to give user an alternative charging experience when there is no power plug near them.

1.2 PROBLEM STATEMENT

Transportation is one aspect we cannot live without in these day and age. However, the transportation systems nowadays come along with lots of problems including global warming, environment degradation, health issues (physical, emotional, mental, and spiritual) and emission of greenhouse effect. In fact, the transport sector attributes to 23% of the globe's greenhouse gas emission resulting from burning of fossil fuels. All of this puts lot of burden on the national governments to devise policies to reduce greenhouse gas emissions as well as oil demands. Green transportation revolves around efficient and effective use of resources, modification of the transport structure and making healthier travel choices (Converse Energy Future, 2017). Besides, according to World Bank's 2015 Malaysia's Economic Monitor report, the congestion cost in Malaysia had amounted to 1.1%-2.2% of Malaysia's GDP in 2014, where this sum of cost is divided into 3 types of cost, including delays, fuel, and CO_2 and other emissions (Gil Sander, Blancas Mendivil, & Westra, 2015). It is common to know that that these recent years, fuel price is increasing. Moreover, buying a car is a long term investment as we need fuel to operate. Besides, maintenance service and road tax are also high cost expenses that vehicle owners couldn't avoid. By contrast, electric skateboard only requires minimum operation and maintenance fees, no insurance fees, attract no road tax and typically do not require a license to ride in most countries. Furthermore, they are efficient, environmentally friendly, and far denser, when parked and driven, than the equivalent rows of cars. Riding an electric skateboard could also help eliminate the requirement of parking spaces, especially in urban areas where parking spaces are highly limited. Therefore, a green technology transportation is needed to develop to replace the current transportation. In our research, using a solar charging skateboard to commute is another great mode of green transportation. Skateboarding has expanded from its predominant form of recreation into a recognizable form of transportation. Solar electric skateboard is an ideal form of transportation for trips that are too far to walk. A standard electric skateboard is normally control by a radio frequency remote control and have a maximum speed up to 30 km per hour. Hence, a solar electric skateboard is developed by many strong and best material to overcome those problems. Moreover, an electric skateboard charging design is portable and it can be charging everytime it low of battery and also long discharging time. So, people will not worry about battery used and it will bring a lot of convenience for all the people.

1.3 OBJECTIVES

1. To choose the best wiring structure using wired connectors to connect the components of electric skateboard to the batteries and the controllers.

2. To study the efficiency of speed, time for changing and discharge of the electric skateboard.

CHAPTER 2

2 LITERATURE RESEARCH

2.1 LITERATURE REVIEW

The different parts of an electric skateboard are needed to make up, and had compared with other alternative mode of electric transport that is readily available in the market. For motor and battery, different types of motor are compared and reviewed on the types of motor used in four different portable electric transportation. The same is done for solar panel.

2.1.1 BATTERY

VRLA (Valve-regulated Lead-acid) batteries is the current dominant battery technology in personal electric mobility transportation, while Li-ion (Lithium Ion) and Ni-MH (Nickel-Metal Hydride) batteries are trying to tap into the growing market. Usually, choosing a suitable battery depends on a few key factors, including cost, cycle life, weight, charging safety, and charge time. Figure 2.1.1.1 and Figure 2.1.1.2 shows the image of VRLA deep cycle batteries and Li-ion batteries respectively.

Figure 2.1.1. 1: VRLA deep cycle batteries

Figure 2.1.1. 2: Li-ion Battery

The dominance of VRLA batteries are mainly because of its relatively cheap price, despite the significant advantages in energy density and lifetime of Li-ion. Cycle life of Li-ion is much higher than VRLA, with 1300-1500 cycles as compared to 400-550 cycles in VRLA batteries. Lifetime of battery is critical because it affects users long-term operating cost. Besides, vehicle range is also important for users due to the period of recharging time. While range depends on the stored energy capacity, which is Watt-hour per km, determines battery weight. For a weight of 4kg-7kg for VRLA batteries, their average store energy capacity is merely 13Wh/kg, whereas Li-ion batteries with a weight range of 0.4kg-0.95kg, its average store energy capacity is an astonishing 106Wh/kg. Moreover, charging for VRLAs is considerably more flexible and tolerant to improper charging than Li-ion batteries in terms of risk of damage to self and property. The risk of using Li-ion batteries is amplified as cell size increases (Weinert, Wei, & Burke, 2007). Lastly, the charging time of both batteries with the same voltage shows a significant difference. VRLA batteries uses 4 more extra hours of charge as compared to Li-ion batteries, the yearly difference of this charging time difference is equivalent to 4000 litres of fuel, and 1500 running hours (Vader & Boonstra, 2015). In conclusion, there has been a rapid transition to electric bikes due to the technological advancement of batteries. Li-ion batteries do offers far better benefits over VRLA batteries, including about 3 times lesser weight for the same amount of energy, up to 10 times more discharging cycles depending on chemistry, technology, temperature and depth of discharge, 4 times lesser of self-discharge, and more than 4 times faster charging as compared to VRLA batteries (Avelar & Zacho, 2016).

There are two types of lithium batteries that is used in most of the portable electric transportation in the market, which is the Lithium-ion battery (Li-ion) and Lithium Ion Phosphate (LiFePO4) Battery. Gemini Hoverboard, Glion Dolly Scooter and Focus Jarifa Electric Bike uses replaceable Li-ion Battery in their product, and OneWheel uses LiFePO4. Gemini Hoverboard have a 4.4Ah, 18650 High Efficiency Battery cells, that is able to go 12mph maximum speed and 10miles maximum range. The charging time for this battery is 2 hours (Genesis, 2017). Besides, Glion Dolly Scooter Premium 36V, 6.6Ah lithium ion battery composed of 30 Sony NMC 18650 cells. This battery cell pack can have a maximum speed of 15miles and a range of 15miles on full charge. It has longer charging time, which is 3.25hours (Glion Scooters Inc., 2015). Focus Jarifa Electric Bike comes with a 26V/18Ah, 468Wh Lithium Polymer battery system. Riders can go up to 80mile range and it only have 2.5hour charging time (Hicks, 2012). OneWheel uses safe LiFePo4 batteries that can last for years even during everyday use with no decrease in range. This battery pack can go up to 15miles per hour and 6 to 7 miles range, with incredibly smooth and controllable power. It comes with a powerful Ultracharger that is able to fully charge its battery in just 20minutes (Future Motion Inc., 2017).

2.1.2 SOLAR PANEL

Light weight vehicles with incorporated with alternative renewable energy are slowly entering the transportation industry, especially in congested cities. This type of alternative mode of transport meets the demand of minimizing carbon footprint and also responds to the future energy transitions (Sivert, Betin, & Lequeu, 2014). Here, we reviewed on the implementation of solar panels in tricycle and boat. The tricycle (Beedu, 2015) for example features a few specifications that is able to help cyclist in better riding experience, including increased speed with minimum paddling, and help cyclist to climb up slopes. Tricycle are one of the major mode of transportation in rural areas, and most of the cyclist face problem while going up slope, hence with the modification on the tricycle, it can help cyclist to reduce fatigue at the same time providing shade. As part of the modification, a hub motor is incorporated into the front wheel of the tricycle, and two Li-ion batteries with a regulator is mounted below the carrier. Additionally, in order to reduce the battery charging time, the tricycle also have two solar panels fixed to a stand that is mounted on the back of the tricycle that is able to increase charging time up to 5% of the total charging time. Figure 2.1.2.1 shows the build of solar powered tricycle.

Figure 2.1.2. 1: Solar Powered Tricycle

With all the modification on the tricycle above, the maximum speed on flat road with zero slope without pedaling is 9kmph, while the maximum speed on road with 7.5degree slope without pedaling is 7kmph, and 5kmph at a 15degree slope. On a single charge, the tricycle is able to travel a distance of 19km in an hour without pedaling (Beedu, 2015).

2.1.3 MOTOR

Most Electric vehicles including the electric skateboards use direct current (DC) motors. A direct current (DC) motor is any class of rotary electrical machines that converts direct current electrical energy into mechanical energy. Among all the types of DC motors, the use of permanent magnets in motor has the biggest advantages over other types of DC motors in terms of higher efficiency, simple construction, lower cost of maintenance and higher output power per unit volume. Moreover, in permanent magnet motors, Brushless DC motor (BLDC) stands the best choice for high performance radio control (RC) models, such as aircrafts, tanks, cars, helicopters and boats (Rao, Obulesh, & Babu, 2012). Brushless DC (BLDC) motors operates similarly to the conventional DC motor, but with the mechanical commutation replaced by an electronically controlled commutation system. These motors have the rotating permanent magnets and stationary armature (Joice, 2014). This type of motor is becoming more popular in most of the RC models because of its performance advantages such as smaller sizes and lower cost, higher efficiency, reduced maintenance and better control over a wide range in torque (Santhoshkumar & Xavier, 2015). Efficiency in BLDC motor can be increased because there is no more voltage drop across the brushes and during commutation. With no brushes, internal friction is also reduced which resulted in higher speed of motor. Besides, the motor also has lower electrical noise and reduced Electromagnetic Induction (Harrington, 2013).

As for hub motor, 3 different types of portable electric transportation reviewed uses this type of motor, which are, Gilon Dolly Scooter, OneWheel, and Gemini Hoverboard. Gilon Dolly Scooter, as shown in Figure 2.1.3.2, features a quiet 250watt nameplate brushless, gearless, chainless DC hub motor, military tech honeycomb never flat airless rubber tires. Braking is smooth and secure, with an antilock electronic brake safely located inside the rear hub motor (Glion Scooters Inc., 2015). One wheel, as shown in Figure 2.1.3.3, is inspired by the feeling of snowboarding on powder, uses a brushless hub motor that gives out 2 horsepower and plenty of torque to climb over just anything (Future Motion Inc., 2017). For Gemini Hoverboard, as shown in Figure 2.1.3.4, has a hub motor in its 7.5in tire that is powerful enough to an incline of 25^{o} easily (Genesis, 2017).

Figure 2.1.3. 1: Focus Jarifa Electric Bike

Figure 2.1.3. 2: Glion Dolly Scooter

Figure 2.1.3. 3: OneWheel

Figure 2.1.3. 4: Gemini Hoverboard

CHAPTER 3

3 METHODOLOGY

3.1 THEORY

In this part of the report, it will discuss about the theories and calculations that is used in this project.

3.1.1 MOTOR PERFORMANCE

There are a few parameters that can measure a motor's performance, including motor speed, RPM, KV rating, power and power efficiency. The theory and calculation of these parameters are discussed below.

3.1.2 TORQUE & RPM

Torque is a measure of how much a force acting on an object causes that object to rotate. Revolutions Per Minute (RPM) is a measure of the frequency of rotation around a fixed axis in one minute. It is used as a measure of rotational speed of a mechanical component. Higher RPM motors tend to generate less torque.

3.1.3 MOTOR SPEED

In a motor, whenever there is relative motion between magnets and coils, a back electromotive force (EMF) is induced in the coils. Back EMF is proportional to the rotational speed of motor,

$$E = KV * \omega$$

Where E is back-emf, KV (Volts/RPM) is the back-emf constant and ω is the speed. In a basic circuit analysis, where resistor and back-emf is in series, it gets,

$$V = R * I + E$$

$$= R * I + KV * \omega$$

$$\omega = \frac{V - R*I}{KV}$$

Where V is the DC supplied voltage, R (Ω) is resistor, I (A) is current. From the equation above, we can see that the speed of DC motor is equal to the applied voltage minus voltage drop due to resistance and current in the motor. As the current in the motor increases, the speed of the motor decreases. Current is proportional to torque, which also means that when torque of motor increases, the speed decreases.

3.1.4 KV RATING

KV rating of motor is the indication of motor performance that describes the no-load rotation rate per input voltage, which is also known as RPM (revolutions per minute) per volt. A low KV motor have more windings and thinner wire, while high KV motors have less windings and thicker wire. For both low and high KV motor, as long as they have the same mass of copper, they are exactly the same in terms of max power, output, torque, efficiency, and max RPM; but at different currents and voltages. When more copper is squeezed into the stator, the better the motor is (Vedder, 2014). The formula to calculate KV for brushless motor is:

$$Kv = \frac{Speed}{Volts * 1.414 * 0.95}$$

Where speed is divided by the generated DC voltage measured and the 1.414 is to convert RMS voltage to peak voltage. In other words, lower KV motor has more torque, accelerates faster but lower top speed, which also means higher efficiency for applications like electric skateboard (Harrington, 2013). Besides, having low KV motor will also be better on start, in other words, less jerking on start and will also climb hills better.

3.1.5 POWER

Power is the rate at which energy is generated or consumed. The more wattage the motor has, the more power on demand it has. Additionally, instead of speed, greater acceleration and torque will be achieved with higher power, where these parameters are important for inclines. Besides, power used for an hour/Watt hour calculation is very important for building the electric skateboard because we can control the duration time and capacity needed of the skateboard function.

The formula that we use to calculate watt hour calculation is:

$$P = V \times I$$

Where P = Power, V = Voltage, I = Current

So, for example an electric skateboard roughly need 37volt to operation and 85Wh, therefore the current that we needed is:

$$P = V \times I$$

$$85Wh = 37volt \times I$$

$$I = 2297mAh$$

Thus, an electric skateboard needed 2297mAh capacity for an hour. If the skateboard design as 3hours function time, the capacity needed is triple for the capacity, that is around 6486mAh.

3.1.6 POWER EFFICIENCY

Power efficiency is a percentage of the output power per input power. A motor with higher power efficiency can run longer with less hear produced. It is also important to calculate power efficiency because we can know the exact output power of electric skateboard so that we can adjust the time duration more accurate.

The formula of Power Efficiency:

$$\eta = \frac{Po}{Pi} \times 100\%$$

$$= \frac{VI-(I^2Rw+VI_o)}{VI}$$

Where η = Power efficiency, Po = Output Power, Pi = Input Power, V = Voltage, I = Current, Rw = Winding Resistance, Io = Current the motor needs to run when it is unloaded.

3.2 BATTERY SYSTEM

A battery cell consists of cathode, anode, separators, terminals, electrolyte and a battery case. The chemical process happens at cathode and anode (Dhameja & Dhameja,2000). It has a negative and a position terminal and the electrolyte can be a gel, solid or liquid according to the battery type and it can be acidic or alkaline (Dhameja & Dhemeja,2000). The revolution of the battery is better and better year by year. It has been observed that use of lithium ion battery pack extends range of the vehicle because energy densities of the lithuium ion batteries are higher than lead acid battery at twenty first century.

Basically, there are two categories of batteries, which are rechargeable and non-rechargeable batteries. The commonly known non-rechargeable batteries are zinc carbon, zinc-alkaline-MnO2, zinc-air, and lithium batteries, while rechargeable batteries, which is also known as secondary batteries, include Nickel-Cadmium (Ni-Cd), Lead-acid, Nickel- Metal Hydride (Ni-MH), and Lithium-ion (Li-ion). Secondary batteries are distinguished by their ability to recharge, and therefore, it is normally used by EVs. The energy density and power density of secondary battery along with cost are major factors for suitability for personal electric mobility vehicles. Many commercial secondary batteries are manufactured with a series of cells packaged in a container. In general, a battery manufacturer provides the rated capacity of the battery in their datasheet or sometimes written on the body of battery. The rated capacity, expressed in Amp-Hour (Ah), is specified for discharging under a stated set of operating conditions. A common discharging condition is to discharge at the rate C 20 A, where C is the rated capacity in Ah until the specified cut-off voltage is reached. Figure 3 shows that the energy density and recharge time of different batteries.

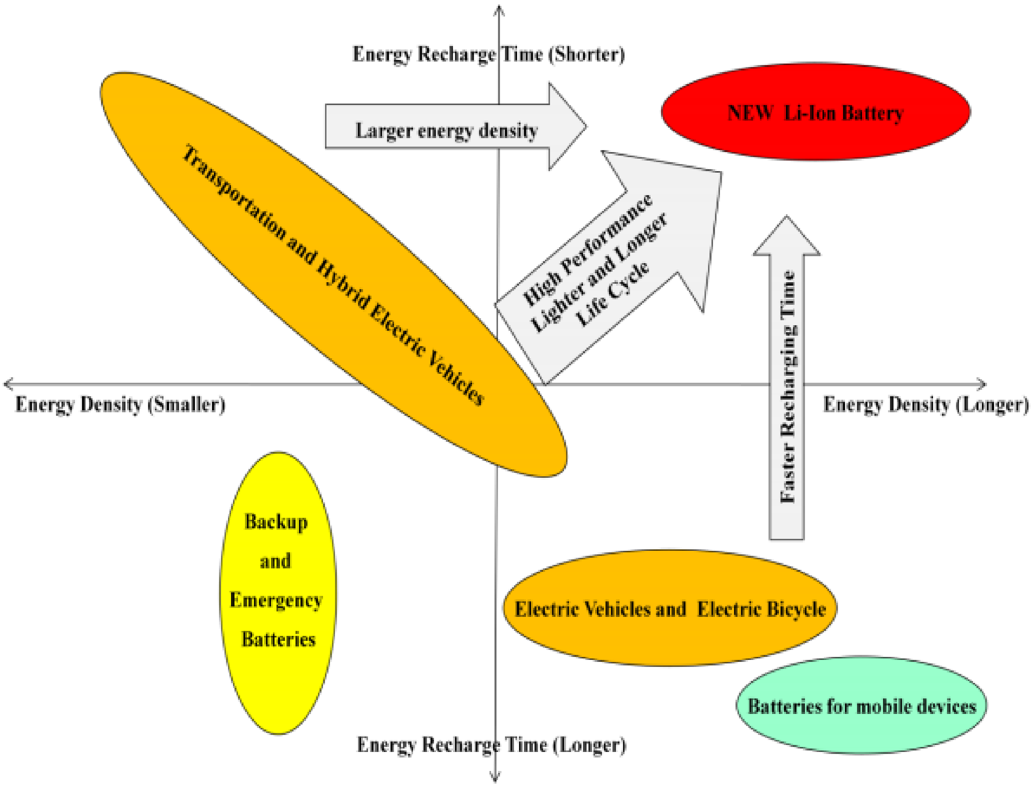

Figure 3.2. 1: Energy Density and Recharge Time of Different Batteries

The energy density, which is later known as specific energy, of the battery is the amount of energy stored per unit volume or mass. Figure 3.2.1 above shows the different energy characteristics of current batteries that are available in the market. We can see that Capacitor Type Battery have very short discharging time as compared to other batteries, but this kind of battery has very small energy density that is not suitable for electric mobility vehicles, whereas Li-ion Batteries have larger energy density but longer recharging time. As far as the personal electric mobility vehicles are concerned, higher energy density and short energy recharge time batteries are highly sought after, hence scientist and researcher are working on new Li-ion Batteries.

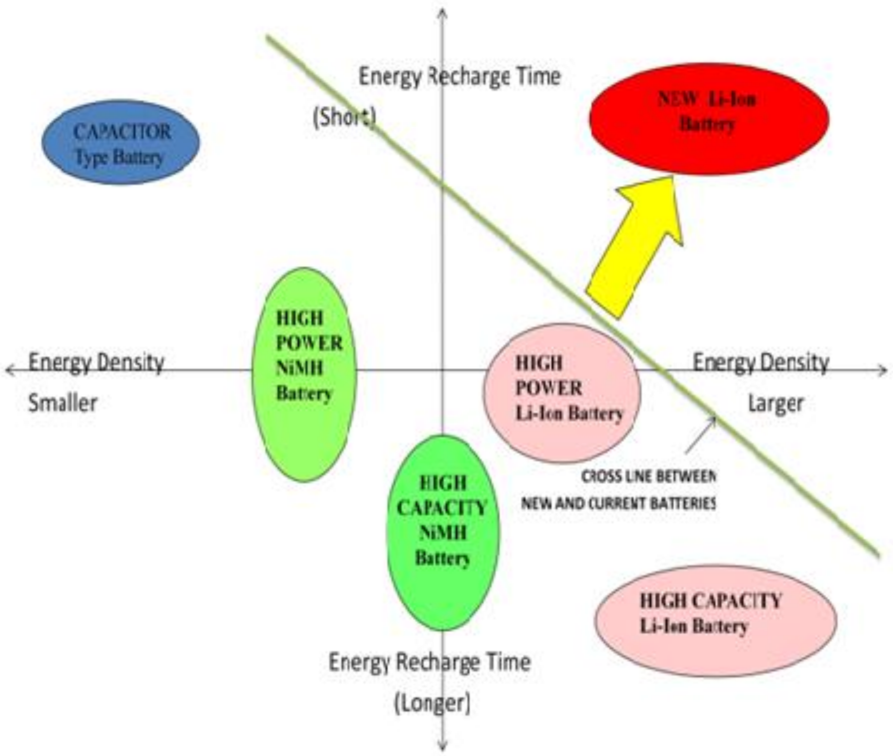

Figure 3.2. 2: Applications Wise Energy Density and Batteries

Figure 3.2.2 shows the range of energy density and energy recharge time for various applications of battery in vehicular sector. A battery with smaller energy density and moderated energy recharge time is preferred.

In order to choose the most suitable rechargeable battery for our project, there are a few parameters that we need to take into consideration, which is shown in Figure 3.2.3.

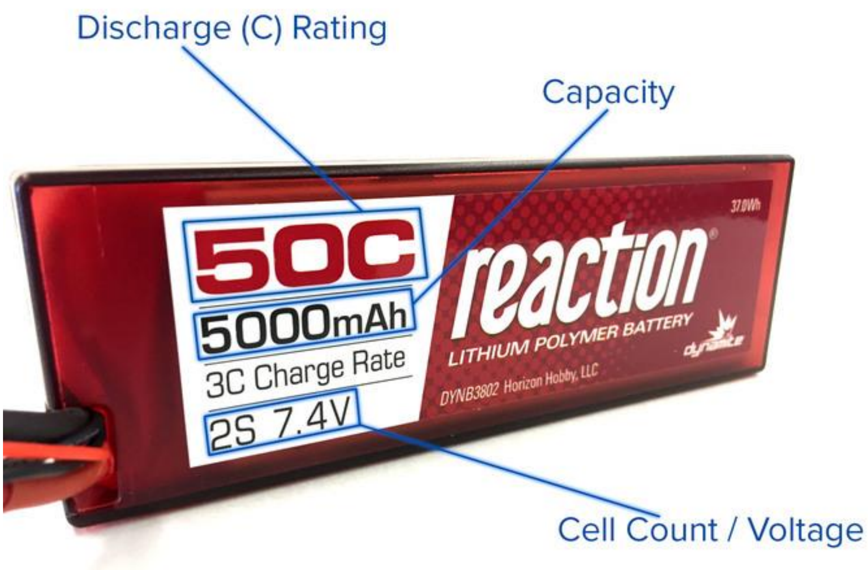

Figure 3.2. 3: Important parameters in a Li-ion Battery

i. Cell Count/Voltage

Cell count is the arrangement of cells in the battery itself, that is series or parallel arrangement. The "S"(series connection) or "P"(parallel connection) mention on batteries are the combination of how many individual cells either in series or parallel. For example, Figure 3.2.3 show that the battery cell count is 2S, which is it has 2 battery cells connected in series. The important of this cell count is, series connection will affect the voltage while the parallel will affect to the capacity of the battery cell.

Voltage shown on Li-ion battery packs are the nominal voltage, which is 3.7V per cell. Nominal voltage is measured at the mid-point between full charged and fully discharged of a cell, where the fully discharged voltage is 3.2V and fully charged voltage is 4.2V per cell. The minimum allowable voltage is, which is usually 3.2V, is also known as cut-off voltage.

ii. Capacity/mAh

Capacity of the battery is to measure of how much the battery can discharge in an hour, which is also mean the total Amp-hours available when the battery is discharged at a certain discharge current from 100% state of charge to the cut-off voltage. Capacity is calculated by multiplying the discharge current, in Amps, by the discharging time, in hours, and decrease with increasing C-rate

iii. Discharge Rating/ C-rate

The C-rate is s measure of how fast the battery can be discharged safely and without harming the battery, this limit is defined by battery manufacturer in order to prevent excessive discharge rates that would damage the battery or reduce its capacity. In worst condition, it could be burst into flames if the current exceed the C-rate. The formula for C-rate is given as:

$$\text{C-rate} = \frac{C \times Capacity}{I}$$

Example: C-rate for a 50C, 5A battery Cell which can handle a maximum continuous load of 250A.

3.3 BATTERY SELECTION AND INSTALLATION

3.3.1 TYPES OF BATTERY

Lithium ion batteries, are normally classify into 4 main chemistries batteries group which are Cobalt, Manganese, Nickel Manganese Cobalt (NCM) and Phosphate. For these four group of chemistries batteries, they have their main functions and applications. However, out of the characteristic of the 4 chemical groups, Lithium-ion Phosphate is used as battery chemical to power portable electric transportation like electric skateboard or hoverboard.

The Lithium-ion Phosphate batteries is used as the power source of electric skateboard because it has higher weight-energy rate, high voltage (single cell 3.7V), no memory effect, long lifespan(>500times). Besides that, it also can keep for long because of the low self-discharging rate. It also can quickly charge. The most important part is it is the most advanced “green” battery of the world. It is because it does not threaten the environment and does not have the heavy metal element like cadmium, lead or mercury.

3.3.2 VOLTAGE OF LIPO BATTERY

A LiPO battery normally having 3.7 nominal voltage and also 4.2 maximum voltage. The maximum voltage, also called rated voltage is the maximum voltage that the circuit-breaker can interrupt safely and without being damaged by excessive arcing. Besides that, the nominal voltage (average voltage) is the voltage for which the circuit-breaker is intended to be used. The nominal voltage must of course be lower than the rated voltage, so there's a satisfactory margin of safety. As the battery is used, the voltage will drop lower and lower until the minimum which is around 3.0V, that means the battery will cutoff circuit disconnects the battery on 3.0V. the figure below show that the discharge profile graph of the discharge cutoff at room temperature.

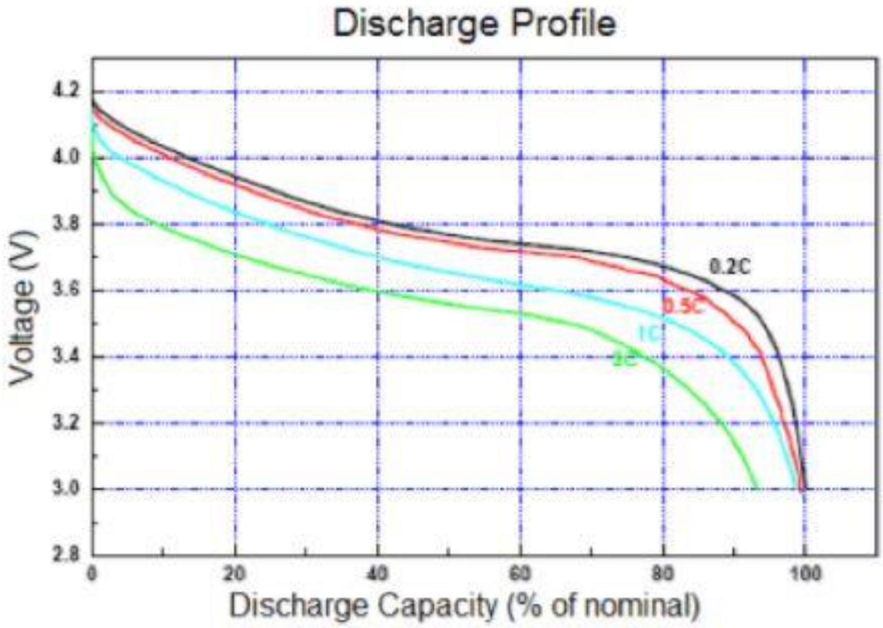

Figure 3.3.2. 1: Discharge Cutoff at Room Temperaturescharge Cutoff at Room Temperature

3.3.3 LITHIUM BATTERY CELL DESIGN

Lithium batteries have different cell design suitable for different applications. There are two type of lithium batteries cell design that available in market, which are pound cell and cylindrical cell. The electric skateboard design for this project need a nominal voltage of 29.6V. Therefore, a battery connection of 8series is used because the nominnal voltage of each lithium battery cell is 3.7V. To select the most suitable battery for our project, we have to look into a few important parameters, which include, discharge (C) rating, capacity of battery, cell count, and voltage of the battery.

Table 3.3.3.1 shows and compare between the specification of two different cell designs available in the market, that is widely used in the electric skateboard market. Pouch Cell is chosen as the type of battery cell design for our project because it is cheaper, better outlook and bigger range for use of environment. In the table below, pouch cell weights more and the price is higher than cylindrical cell. This is because, the weight of pouch cell has included all the important wirings to connect to the motor driver of electric skateboard whereas for cylindrical cell, wirings are not included. This is also the reason why pouch cell cost higher, cylindrical cell's cost does not include the important wirings.

Hence, the final design of these two cells, after including the important wirings and battery cover, both cell design will weight and cost almost the same.

Pouch Cell	Specification	Cylindrical Cell
8 series 1 parallel	Cell Count to Rated Voltage of 33.6V	8 series 2 parallel
5000mAh	Standard Capacity	5000mAh
147 x 120 x 33mm	Size/mm	146.4 x 129.8 x 18.3mm
1104g	Weight	720g
Charge: 0~50°C Discharge: -20~75°C	Environment of use	Charge: 0~45°C Discharge: -20~60°C
RM268.56 (including connection wire and internal connect set up)	Price	RM201.60 (excluding connection wire, need to connect batteries manually)
	Picture	

Table 3.3.3. 1: Comparison between of Pouch Cell and Cylindrical Cell

3.3.4 LITHIUM BATTERY CHARGER

A battery charger is very important to an electric device. A good charger provides the base for batteries to have longer shelf life and perform well. High quality lithium battery chargers nowadays are almost all computerized and programmable. A programmable charger allows users to set parameters, including charging current, type of batteries, and charging period. These programmable chargers show users battery condition such as what the voltages is each cell, how much current has been charged into them and so on. It basically manages the charging to the batteries are charged safely and accurately. Some of the programmable chargers can also help users adjust charging current depending on charger temperature, auto- detecting battery cell counts and battery voltage level, or even discharge batteries for storage with some programmable chargers. Most of the Lithium chargers have the ability to perform balance charging. This process will check the voltages of each individual cell in your battery and ensure they all have the same voltage, because if one of the cells voltage increases or drops below the required voltage range the battery could get damaged, or worse, burnt. The important parameters to choose the most suitable battery charger is to compare its cell compatibility, charging current, power output, and power supply (Unmanned Tech Co., 2015).

Table 3.3.4.1 shows the specification of Lithium Battery Charger is chosen as this project is IMAX B6-AC LiPO NiMH 3S RC Battery Balance Charger. It had chosen because this device is most easy to use. By the way, this charges only can change maximum up to 6 series batteries. So that, it was using two 4s battery connect together to achieve 8 series power sources to the controller and separate charge to fit the requirement of the charges. Besides that, when charging a battery, the charger voltage must be confirmed is less than or equal to the battery voltage.

Type of Charger	IMAX B6-AC LiPO NiMH 3S RC Battery Balance Charger
Operation Voltage Range	DC 11.0 – 18.0V
Maximum Charge Power	50W
Charge Current Range	0.1 – 5.0A
Current Drain for Balancing LiPO	3000mAh/Cell
Li-Ion/Polymer Cell Count	1-6 series
Weight	749g
Circuit Power	AC to DC adaptor (DC 11.0 – 18.0V/5A)
Maximum Discharge Power	5W
Discharge Current Range	0.1 - 1.0A

NiCd/NiMH Battery Cell	1 – 15 Cell
Pb Battery Voltage	2V – 20V
Dimemsions	134 x 142 x 36mm
Picture	

Table 3.3.4. 1: Lithium Battery Charger Analysis

3.3.5 BATTERY MANAGEMENT SYSTEM

A battery management system(BMS) is an electronic system that manages a rechargeable battery. It is used in most devices that use rechargeable batteries. For example, laptop, smartphone, power bank, and many other rechargeable batteries electronic device. It is a system to protect the battery and prevent it overcharge when the charging process is doing. It is because, it might shut down the power flow in the irregular or dangerous conditions. Thus that, it is a safety system to protect the batteries of device and also affect battery life. It may monitor one-cell or multi-cell battery systems. Multi-cell systems may monitor and control conditions of individual cells.

Figure 3.3.5. 1: Balanced Charging Plate

3.4 CIRCUIT CONNECTION

This part will discuss about the implementation of the connection of internal circuit from battery to the charges and also to the controller of electric skateboard explaination.

3.4.1 CIRCUIT DESIGN TO CHARGING AND CONTROLLER PART

First, a circuit is design and connect the wire from a battery to a charger and also controller. The figure 3.4.1.1 show that the circuit that designed.

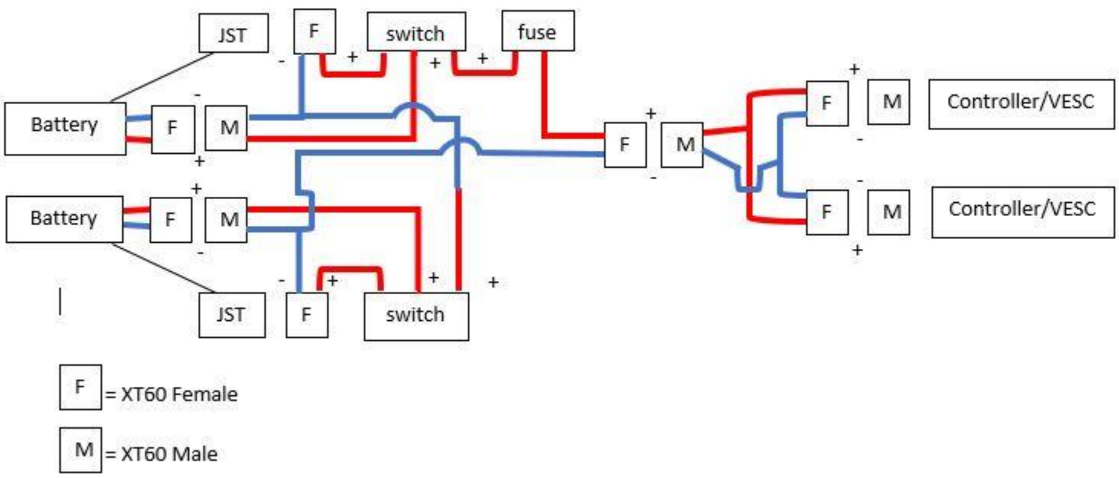

Figure 3.4.1. 1: Connection of The Circuit

The design shown at figure 3.4.1.1 is the connection that connected to control the electric skateboard. For the circuit is distribute into two part that is charging port circuit and controller circuit and this two circuit is controlled by a three-pin switch/ center off switch.

Firstly, the circuit connect to charging part is design as two batteries are connected to XT60, JST(Japan Solderless Terminal) and switch individually. So that, when charging the batteries, we just switch on the circuit and then connect the JST and XT60 to a charge balancing plate and also balancing charger controller to complete a circuit to charge the batteries.

Next, for the circuit which connected to the controller part is design as two batteries are connected into series connection and then connect a parallel circuit to two controllers.

Lastly, a fuse also had connected in the middle of the circuit from the batteries to controller. Thus, it is an emergency stop button insert on the skateboard.

3.4.2 CIRCUIT DESIGN TO SOLAR PANEL

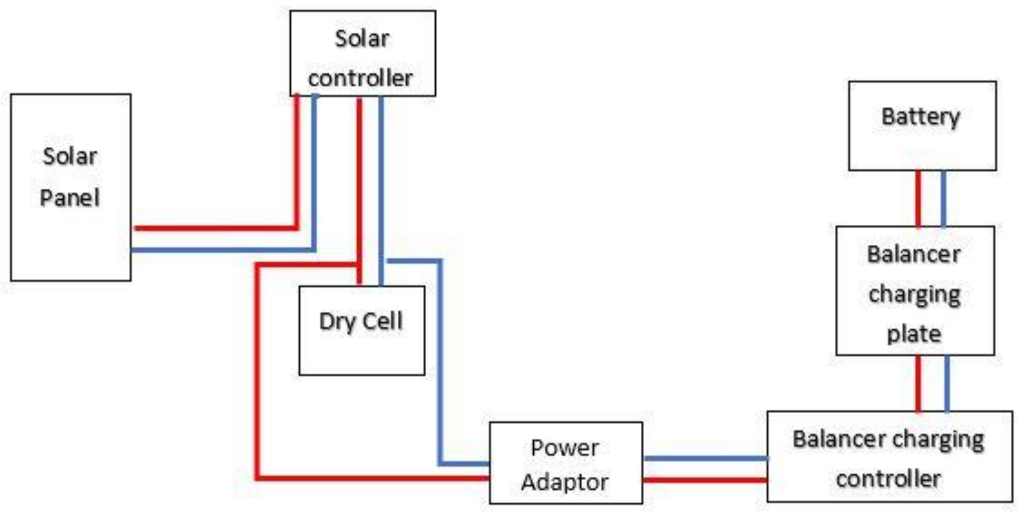

Figure 3.4.2. 1: Connection Circuit of Solar Panel

The design circuit in figure 3.4.2.1 is the connection for charge the battery by using solar panel. From the figure, the solar panel will send the solar energy to dry cell which controlled by solar controller. After it, a dry cell is act as a middle person to give the power supply to adaptor and balancer changing controller to charge the battery. It needed a middle person to transfer the energy because a solar energy cannot straight send the energy to battery and charge.

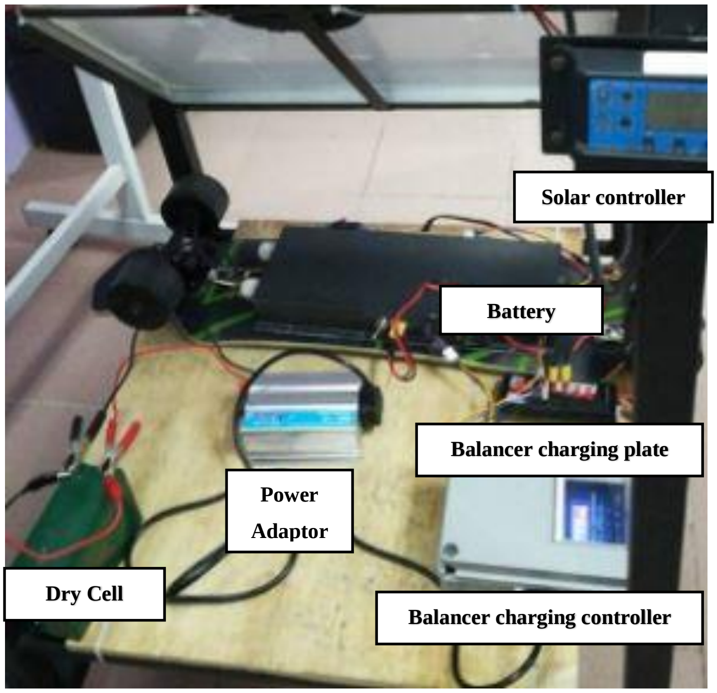

Figure 3.4.2. 2: Demo charging by using solar energy

3.4.3 STEP FOR CIRCUIT DESIGN

Figure 3.4.3. 1: Soldering, Clip pin and Entering the Wire into 5pin Connector Process

In figure above show that process of changing the wiring of the batteries.

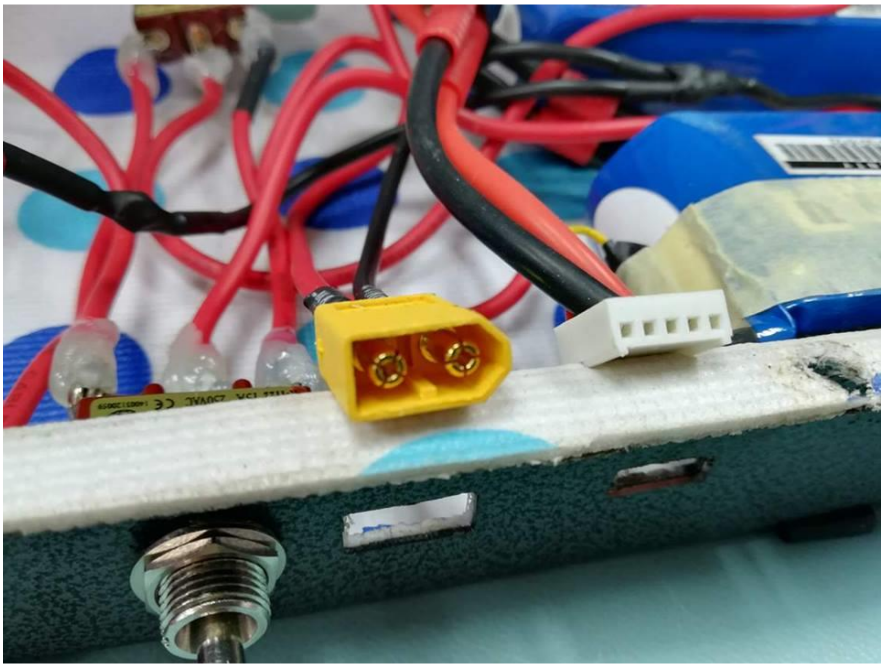

Figure 3.4.3. 2: XT60 and 5pin Connector

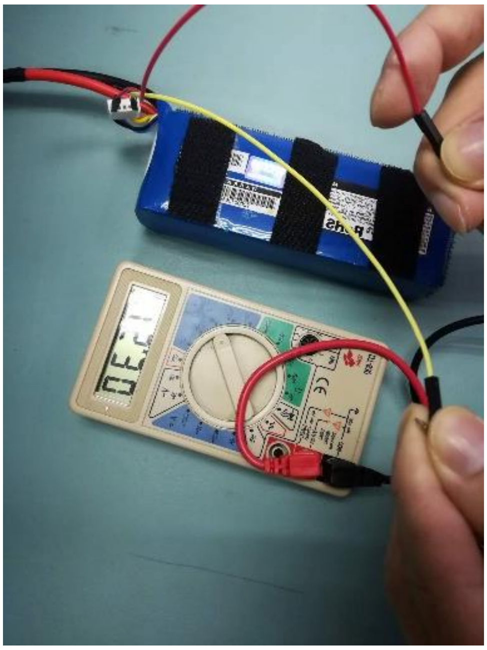

Figure 3.4.3. 3: Voltage Check for the Battery

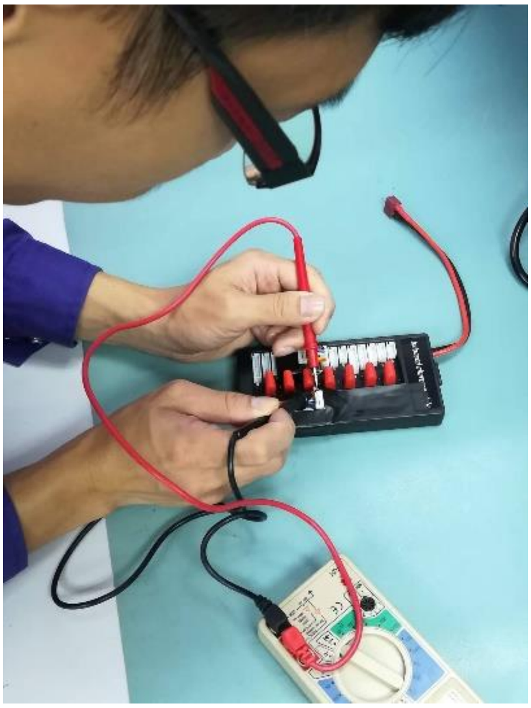

Figure 3.4.3. 4: Connectivity Check

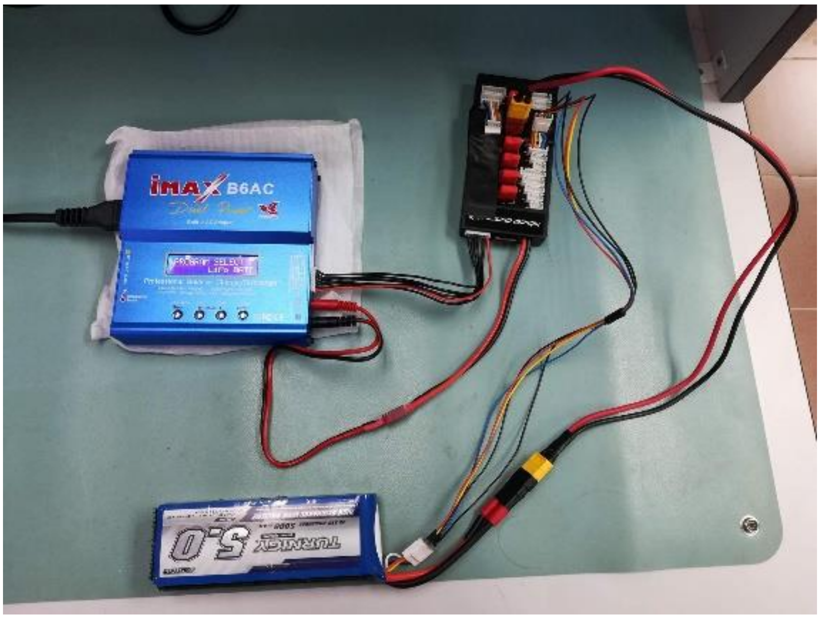

Figure 3.4.3. 5: Test for Charging Battery

After the wiring process is done, check the voltage of the battery and also the to get a connectivity check to ensure there are no short circuit. Next, test the batteries charging process to ensure that the circuit designed is work.

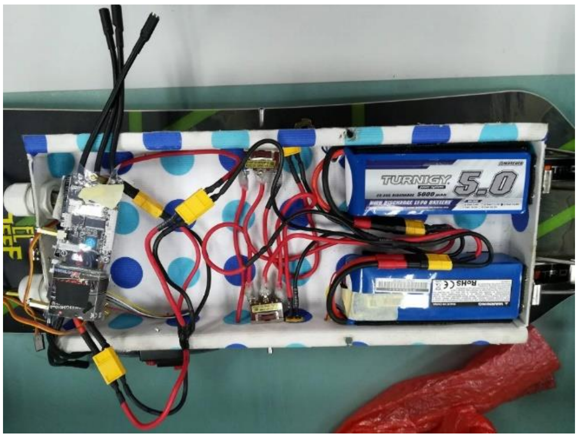

Figure 3.4.3. 6: Complete Design of Internal Connection

The complete circuit of the internal design is shown at figure 3.4.3.6.

Figure 3.4.3. 7: Battery Checker Tester Low Voltage BB Buzzle Alarm

Lastly, battery checker tester is connected to the cover of electric skateboard. The function of the battery checker is to let user know that the voltage of the electric skateboard. It will have BB sound when the voltage of battery is low. Thus, the user will know that it's battery nearly finished.

CHAPTER 4

4 RESULT AND DISCUSSION

4.1 BATTERY PERFORMANCE

From this point, the period for the battery for support the skateboard is calculated andtested to measure the maximum time of skateboard functioning. From the data that calculated, the percentage of efficiency also had calculated to know how perfect of the skateboard compare with the ideal design. The formula used to calculate the time used and the efficiency of charge time is:

$$\text{Time, T} = \frac{\text{Capacity,Ah}}{\text{Capacity,A}} \times 2$$

*It will multiple 2 because when charging state, each capacity will divine half to enter two 4S batteries due to the parallel connection.

$$\text{Efficiency, } \eta = \frac{\text{Theoritical time used,h}}{\text{Practical time used,h}} \times 100\%$$

Test	Current applied(A)	Theoritical time used for full charge(h)	Practical time used for full charge(h)	Efficiency of fully charge time
1	3.0	3.33	4.15	80.24%
2	4.0	2.50	3.10	80.65%
3	4.5	2.22	2.75	80.73%
4	5.0	2.00	2.40	83.33%

Table 4.1. 1: Charging Test for the Battery Cell

The table 4.1.1 shown that the charging testing with using few different currents. From the table show that 5.0A is the most ideally for charging the batteries until it full battery. It is because it having the highest efficiency of fully charge time.

In other hands, a discharging of the electric skateboard also had test for know the actually time of discharge battery and also efficiency for the batteries cell for supply the electric skateboard. For this electric skateboard had design and set into three types mode to diffentiate the speed, that is mode speed 1, speed 2 and speed 3. It also can call as beginner level speed, intermediate level speed and expert level speed. The table below show that the discharge time test by using different mode of speed of electric skateboard.

	Test 1	Test 2	Test 3	Test 4	Average
One Full Discharge Cycle Practical time for beginner mode (h)	5.967	6.133	6.000	5.900	6.000
One Full Discharge Cycle Practical time for intermediate mode (h)	2.830	2.917	2.750	2.800	2.824
One Full Discharge CyclePractical time for expert mode (h)	1.367	1.333	1.250	1.300	1.313

Table 4.1. 2: One Full Discharge Cycle Test

From the table above show that the discharge time with mode speed 1, speed 2 and speed 3 for the electric skateboard. After the test, the actual average time using for discharge the electric skateboard is 6.000hours (85.20% efficiency) for speed 1, 2.824hours (53.66% efficiency) for speed 2 and 1.313hours (30.46% efficiency) for speed 3. Besides that, it also can make a comparison by using the graph below shown.

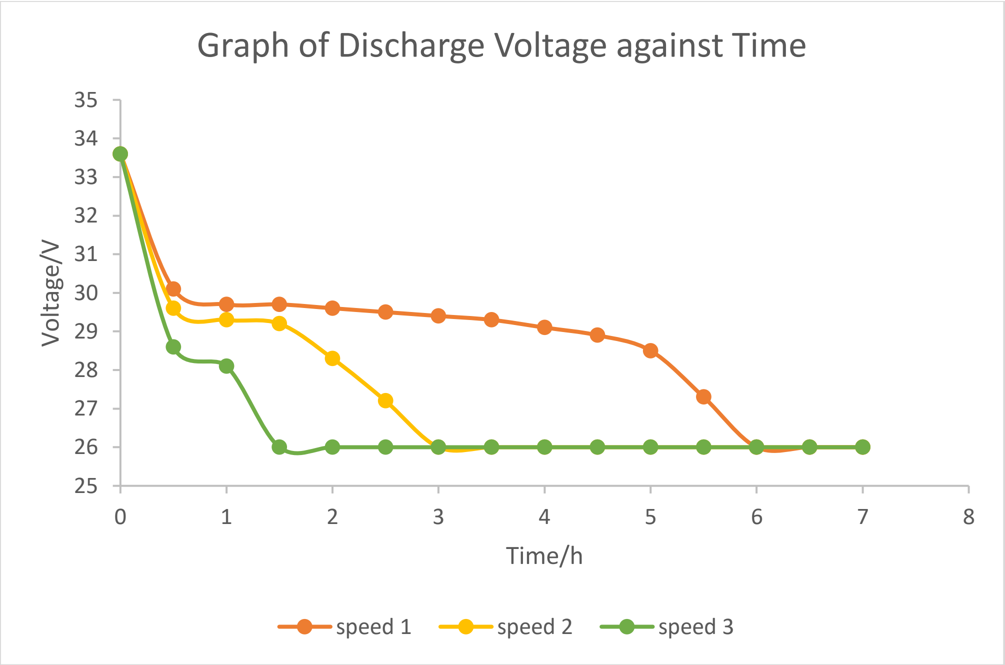

Figure 4.1. 1: Graph of Voltage Against Time

4.2 SPEED AND RANGE OF THE ELECTRIC SKATEBOARD

The speed of the electric skateboard also had tested and calculated. Firstly, a tachometer is used for measure the motor rpm. Table below show that the motor rpm measured.

Motor rpm	Test 1	Test 2	Test 3	Test 4	Average
Speed 1	1700	1667	1674	1680	1680
Speed 2	3211	3143	3191	3255	3200
Speed 3	5903	5806	5825	5866	5850

Table 4.2. 1: Motor Rpm Test by Tachometer

All the parameter is tested by using the Brushless DC motor (BLDC) tool. From this tool, the value of the motor current, electrical rpm, duty cycle is recorded. Besides that, the acceleration of the electric skateboard for both speed also calculated from the graph.

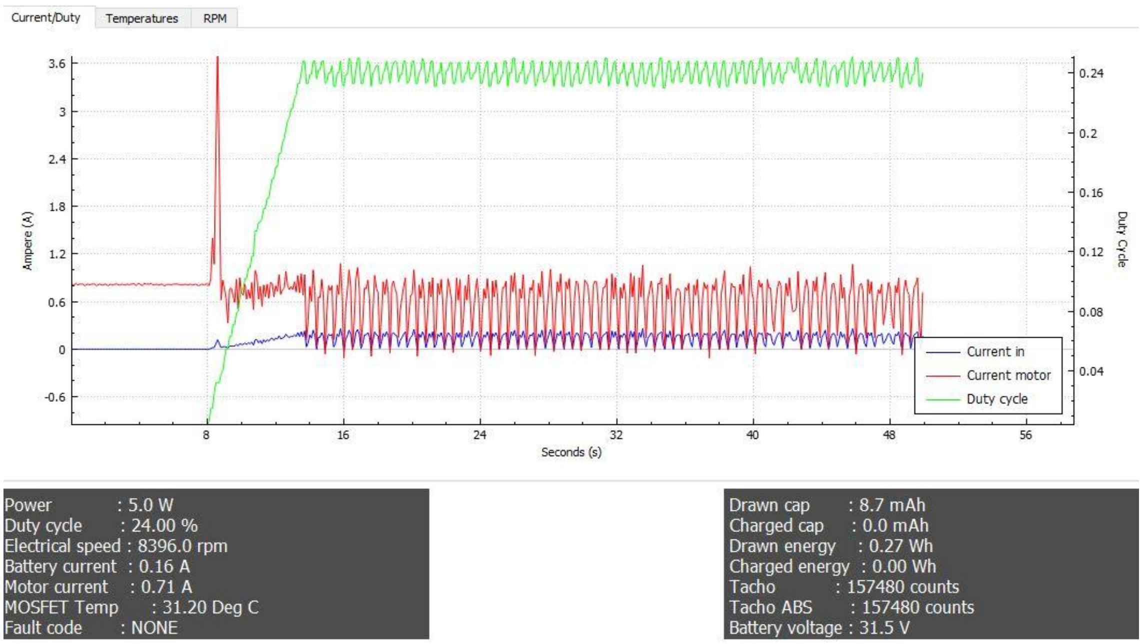

Figure 4.2. 1: Speed 1 Test by Using BLDC Tool

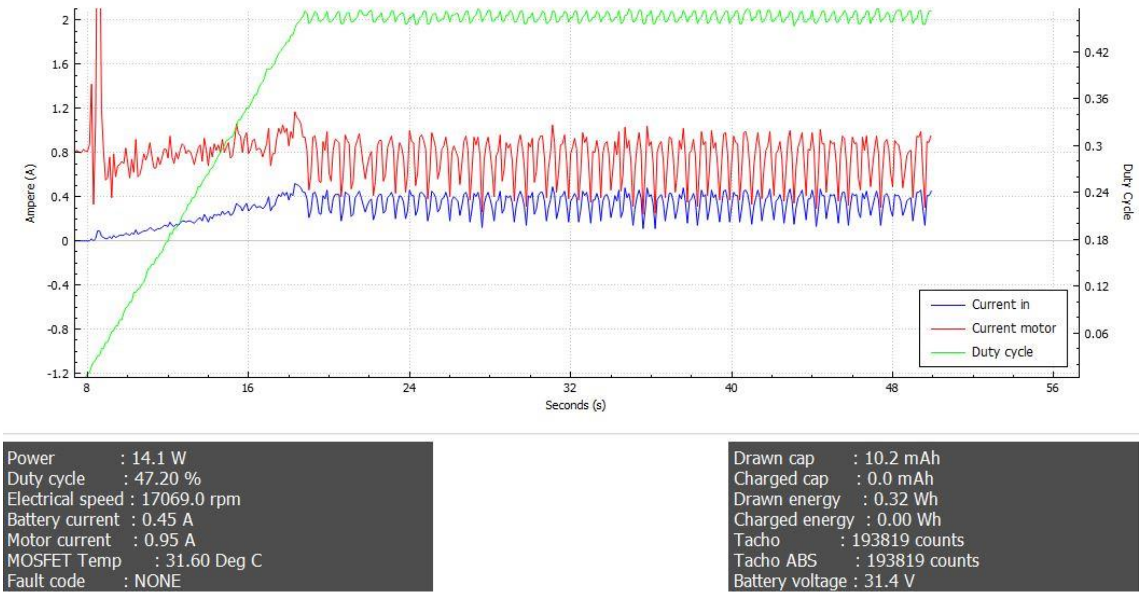

Figure 4.2. 2: Speed 2 Test by Using BLDC Tool

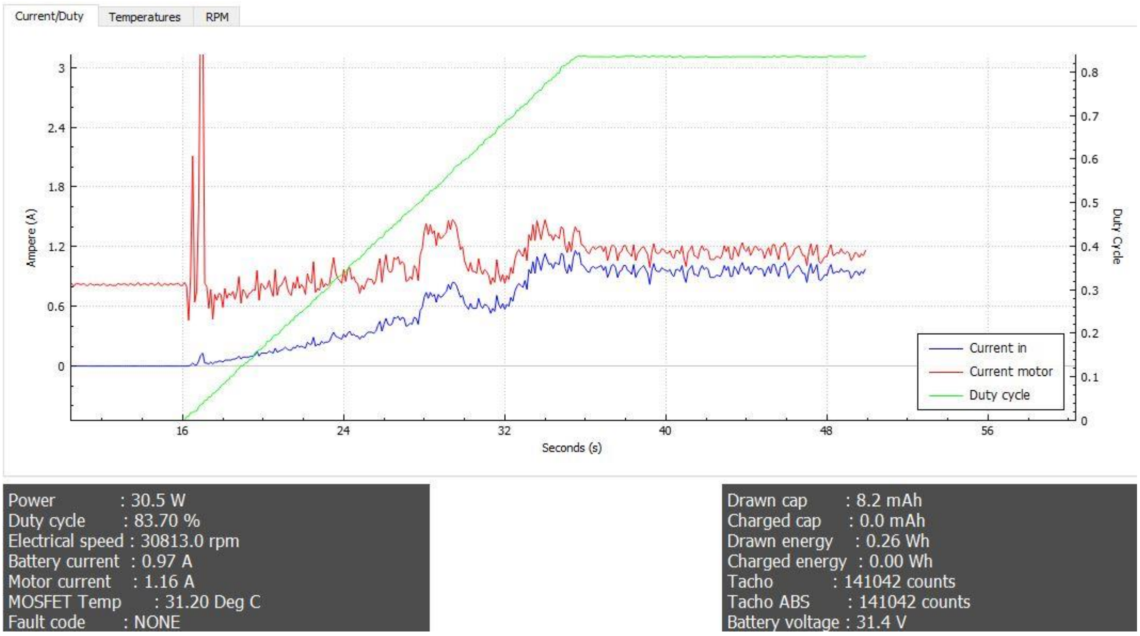

Figure 4.2. 3: Speed 3 Test by Using BLDC Tool

	Speed 1	Speed 2	Speed 3
Duty Cycle/%	24.00	47.20	83.70
Electrical rpm	8396.0	17069.0	30813.0
Motor Current/A	0.71	0.95	1.16
Acceleration time/s	$13.6 - 8.0 = 5.6$	$18.8 - 7.9 = 10.9$	$36.6 - 16.1 = 20.5$

Table 4.2. 2: Important Parameter Measure by BLDC Tool

From the data above, the maximum speed, range, acceleration and all the efficiency is calculated. The calculation is shown at APPENDIX A. Thus, from the calculation, the maximum speed for level 1 the electric skateboard is 9.62 kmh^{-1}, while speed for level 2 is 17.76 kmh^{-1} and speed for level 3 is 32.26 kmh^{-1}. In other hand, the maximum range of the electric travel for speed 1 is 57.72km, speed 2 is 50.15km and speed 3 is 42.36km. For the acceleration for the electric skateboard of speed l, speed 2 and speed 3 are 0.4772ms^{-2}, 0.4526ms^{-2} and 0.4371ms^{-2} respectively.

4.3 SPEED TEST OF DIFFERENCE TYPE OF SURFACE

A speed is a parameter that will affected by many factors. So that a there have two surfaces selected to test the speed. The table below show that the result that the electric skateboard run for 100meter range and the result is collected.

Speed Level	Time Run Test (s)			Average Time/s	Average Speed/ms^{-1}	Average Speed/kmh^{-1}
	1	2	3			
1	37.15	37.35	37.78	37.427	2.672	9.62
2	20.38	20.01	20.43	20.273	4.933	17.76
3	11.23	10.89	11.36	11.160	8.961	32.26

Table 4.3. 1: Speed Test on Flat Surface (Cement Tiles)

Time/s	Range of Speed 1 Run(m)	Range of Speed 2 Run(m)	Range of Speed 3 Run(m)
0	0	0	0
10	25.52	53.53	89.62
20	52.72	108.33	179.24
30	79.58	155.38	268.86
40	106.27	201.91	358.48
50	133.15	247.28	448.10
60	160.33	296.05	537.73

Table 4.3. 2: Data Collected for the Speed Test (Cement Tiles)

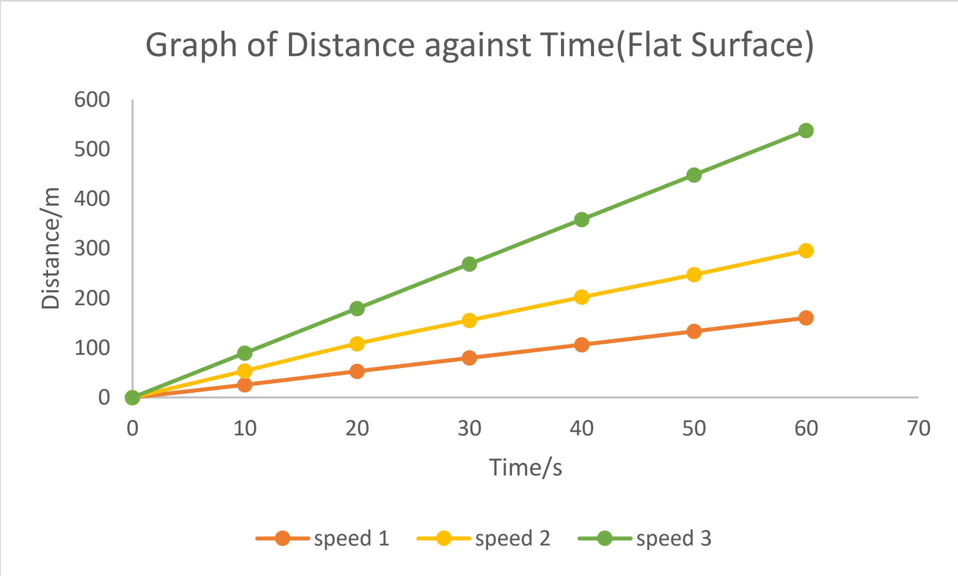

Figure 4.3. 1: Graph of Distance Against Time(Flat Surface)

Speed Level	Time Run Test /s			Average Time/s	Average Speed/ms^{-1}	Average Speed/kmh^{-1}
	1	2	3			
1	47.32	47.22	46.58	47.040	2.126	7.65
2	24.33	25.81	25.13	25.090	3.986	14.35
3	14.05	14.22	13.66	13.977	7.155	25.76

Table 4.3. 3: Speed Test on Rough Surface (Asphalt Road)

Time/s	Range of Speed 1 Run(m)	Range of Speed 2 Run(m)	Range of Speed 3 Run(m)
0	0	0	0
10	7.29	21.33	39.90
20	14.33	42.83	79.88
30	21.49	64.01	119.77
40	29.04	84.96	160.33
50	36.01	106.33	190.40
60	42.93	127.56	239.16

Table 4.3. 4: Data Collected for the Speed Test (Asphalt Road)

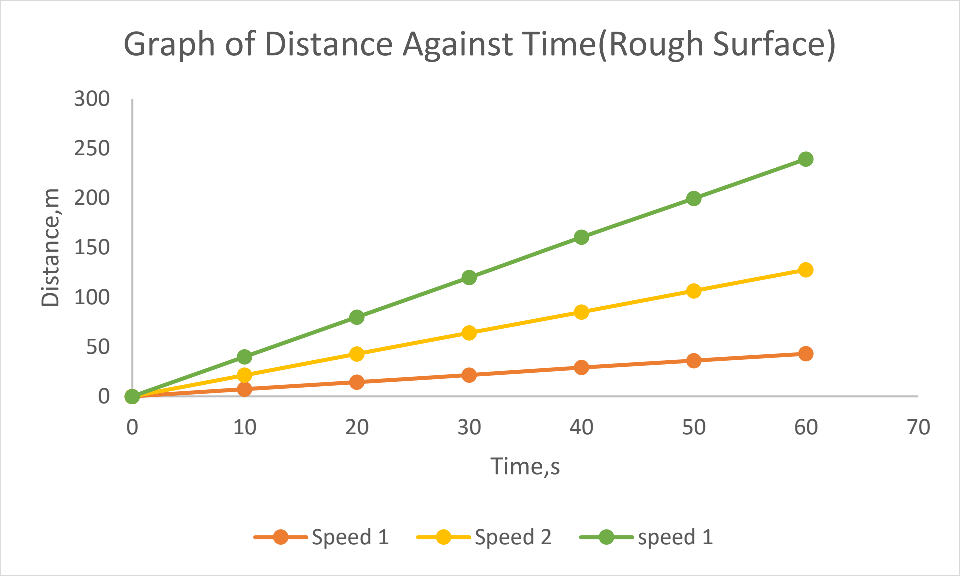

Figure 4.3. 2: Graph of Distance Against Time (Rough Surface)

From the data above shown that the average speed run on the flat surface is faster than rough surface because there has more energy loss (around 20% speed lost) due to the fraction of rough surface. In other hand, from the data show that the average speed for the electric skateboard on the rough surface is 25.76kmh^{-1}, it is a very fast speed for us. Thus, it does not recommend using the speed 3 run on the road. It is quite unsafety speed.

4.4 GANTT CHART

Month / Research	Feb'17	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '18
Title selection and review	•										.	
Research on Design		•										
Finalize Design			•									
Selection of suitable materials				•								
Proposal writing				•								
Proposal presentation				•								
Submission of final proposal				•								
Materials order				•	•							
First Prototype -Drawing								•				
Review Prototype -Solar Panel Rack										•		

-Enclosure cover -Cover box												
Finalize Prototype -Assembling -Testing											•	
Report preparation											•	
Submission of report											•	
Poster preparation											•	
Report presentation											•	
Report finalize												•

Some important dates to highlight:

5/9/17 – Getting all the materials.

6-15/9/17 – Prepared all designs needed.

1/10/17 – Start building the structure according design.

1-10/12/17 – Testing of the electric skateboard and writing individual thesis.

11/12/17 – Submission of presentation poster to print out.

11-15/12/17- Submission of Lab Handling Evaluation form.

11-17/12/17 – Group and Individual draft review.

18/12/17 – Submission of Logbook, peer evaluation, Group Report and Individual Report.

18/12/17 – Presentation of Project Report

4.5 COST ANALYSIS

Cost Analysis by Parts

A	**Basic Skateboard Build Parts**	
	Name of Part	Price List
1.	Deck	RM595.86
2.	Trucks (Front And Back)	RM106.00 x 2 = RM212.00
3.	Front Wheels (2pcs)	RM35.40 x 2 = RM70.80
4.	Coating	RM10
5.	Velcro Taps (6packs)	RM3.90 x 6 = RM23.40
6.	White Cable Glands	RM2.10 x 2 = RM4.20
7.	Universal Clip (2 Packets)	RM38 x2 = RM76
	TOTAL	RM 992.26
B	**Motor & Motor Driver**	
	Name of Part	Price List
1.	Hub Motors (2pcs)	RM 354.40 x 2pieces = RM708.80
2.	Motor Driver (VESC)	RM386.75 x 2 = RM773.50
	TOTAL	RM 1482.30
C	**Receiver Circuit & RFID, Relay Circuit**	
	Name of Part	Price List
1.	Arduino Uno	RM40.00
2.	ATmega328P	RM10.00
3.	HC05 Bluetooth Module	RM16.50
4.	RFID-RC522 Module	RM11.90
5.	Relay Module	RM5.00
6.	Buzzer	RM9.90
7.	LED	RM0.15 x 2 = RM0.30
8.	16Mhz Crystal	RM0.50
	TOTAL	RM 94.10

D	Handheld Controller & Transmitter Circuit	
	Name of Part	Price List
1.	Wii Nunchuck	RM18.57
2.	800mAH Lipo Cell	RM19.00
3.	ATMEGA328p	RM10.00
4.	HC05 Bluetooth Module	RM16.50
5.	TP4056 Charging Module	RM1.90
6.	Small Toggle Switch	RM0.80
7.	LED	RM0.15 x 2 = RM0.30
8.	16Mhz Crystal	RM0.50
	TOTAL	RM 67.57

E	Battery	Parts
1.	Hobbyking LiPO battery	RM353.03
2.	IMAX B6AC Balancing Charger	RM108
3.	Parallel Balance Charging Board Plate B6AC	RM40
4.	XT60 connectors	RM4 x 10 = RM40
5.	Toggle Switch	RM10.00 x 2 = RM20
6.	Circuit Beaker Manual Reset Switch Agu Fuse	RM37
7.	Lipo Battery Checker Tester Low Voltage BB Buzzer Alarm	RM 9.90 x 2 = RM19.80
	TOTAL	RM 617.83

E	Basic Solar System Parts	
	Name of Part	Price List
1.	Monocrystalline Solar Panel 90W 12V	Rm 625.00
2.	Monocrystalline Suitcase Solar Panel 100W 12V	Rm 799.00
3.	PWM 20A 12V Solar charger Controller	RM 41.10
4.	Lead Acid Battery 7.0Ah 12V	RM 70.00
5.	Solar Inverter 500W	RM 66.10
	TOTAL	RM 1601.20

Final Cost Analysis

	Parts	Total
A	Basic Skateboard Build Parts	RM 992.26
B	Motor & Motor Driver	RM 1482.30
C	Receiver Circuit & RFID, Relay Circuit	RM 94.10
D	Handheld Controller & Transmitter Circuit	RM 67.57
E	Battery Parts	RM 617.83
F	Solar Parts	RM 1601.20
	GRAND TOTAL	**RM4855.26**

Comparison

The total price of this electric skateboard is RM4831.86. Besides the basic electric skateboard set up, the price includes with two types of solar panel, one solar charging station and another foldable solar panel for charging on the go. As compared to other brands in the market with same dual motor set up and almost similar powerful capacity, this price is significantly lower. Within one fully charged cycle, the designed electric skateboard can go to a maximum range of 57km, equivalent to 6 hours of use. Besides, the top speed is 32km/h, and it weighed 7.6kg. In **Error! Reference source not found.**, the price and specification of electric skateboards with dual hub motors in the market will be compared with electric skateboard in this project. All prices below are not including shipping fee to Malaysia, which would cost an additional of RM200. The conversion rate of USD to MYR is 4.1.

Board		**Price (RM)**	**Range (km)**	**Speed (km/h)**	**Weight (kg)**
Jed Dual Wheel Drive		4892	20 km	35 km/h	6.4 kg
TORQUE Rocket Free Flow		5708	32 km	48 km/h	9 kg
TORQUE Rocket Dual		5708	27 km	48 km/h	7.3 kg
Inboard M1		5708	16 km	32 km/h	7.5 kg
Evolve Bamboo GT Street		5912	35 km	42 km/h	7.9 kg
Epic Racer 2800 Pro - Hub		5915	20 km	38 km/h	7.5 kg

Boosted Dual (2nd Gen) Ext		6116	19 km	32 km/h	7 kg
Enertion Raptor 2		6161	40 km	45 km/h	9 kg
Mellow Board		6500	15 km	40 km/h	6 kg
Unik Single & Dual Motor		6883	30 km	40 km/h	6 kg
Boosted Dual + (2nd Gen) Ext		6932	19 km	35 km/h	7 kg
Metroboard 41' Dual		7340	42 km	34 km/h	10.8 kg
Evolve Carbon GT Street		8156	50 km	42 km/h	7.9 kg
Carvon R- EVO		8156	35 km	56 km/h	8.2 kg
Ollin Freeride Dual Drive		8976	64 km	45 km/h	10 kg

Table 4.5. 1: Comparison of Electric Skateboards with Dual Motor in Market

According to the price and specification stated above, it can be concluded that the electric skateboard designed in the project has a very competitive value for money. With at least RM1k less, this electric skateboard can offer more advance charging option which is the first Solar Charged Green Electric Skateboard in market. Moreover, it also comes with additional anti-theft function with better range than at least 93% of electric skateboard in market, as shown in **Error! Reference source not found.** Hence, the electric skateboard in this project is reasonable in market and consider as cheaper as it has more advance charging function which is the First Green Electric Skateboard in market.

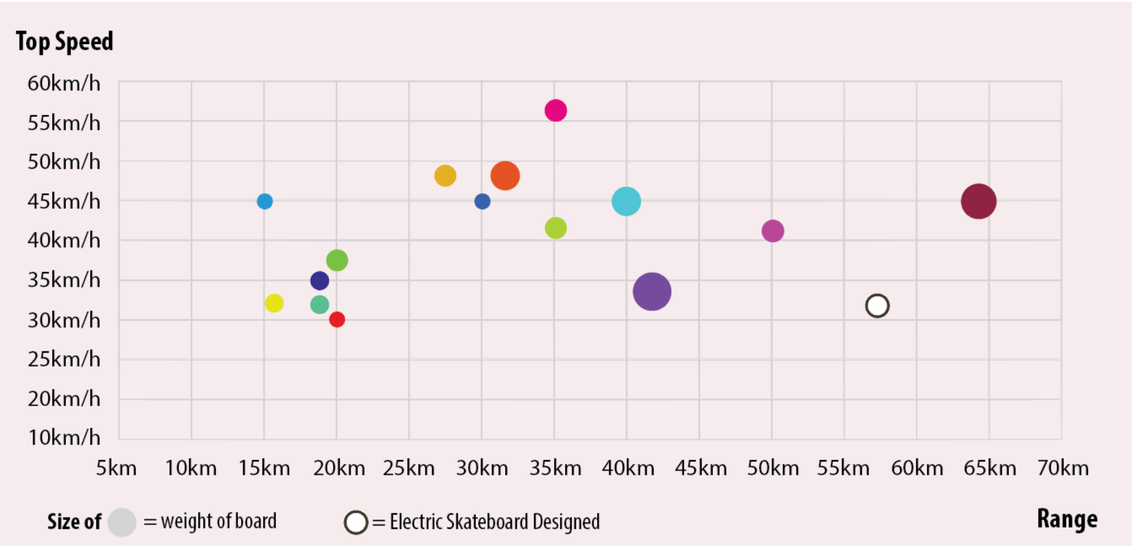

Figure 4.5. 1: Visual Comparison of Top Speed, Range and Weight

CHAPTER 5

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In conclusion, the electrical skateboard has been designed as alternative green transportation. This skateboard has 6 hours maximum life span, 32.26kmh^{-1} maximum speed and maximum range travel is 57.72km. It also designed with three different speed modes, that is beginner (9.72 kmh^{-1}), intermediate (17.76 kmh^{-1}) and expert mode (32.26 kmh^{-1}). By the way, the user is recommended use the beginner mode when playing on the rough road because it is more safety. Besides that, this skateboard also had designed which able to charging with solar panel, its function is absolutely new function that compare with the electric skateboard compare with the product available in market.

5.2 RECOMMENDATION

The electric skateboard parts that can be improved for future commercialization in market:

- Solar panel rack can modify to adjustable function so that the degree can adjust according to the sunlight position.
- Enclosure can changing materials to carbon fibre in order to reduce the weight.
- Modify the skateboard deck to fordable so that it is easily to keep and more portable.
- Using a sensor to sense the road infront and slow down when there have impedient infront .

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APPENDIX A

1 CALCULATION OF CHARGING FOR ELECTRIC SKATEBOARD

For charging current,

To calculate the time using to fully charge the battery when current supply is 4.0A, 4.5A, 5.0A and there are two batteries cell charging together, thus that it needed multiple two for the time used.

Time, T_4= (Ah/A) × 2
= (5/ 5.0) × 2
= 2 hours
=120minutes

T_3= (Ah/A) × 2
= (5/4.5) × 2
= 2.2hours
=133minutes

Time, T_2 = (Ah/A) × 2
= (5/4.0) × 2
= 2.5 hours
= 150minutes

T_4= (Ah/A) × 2
= (5/3.0) × 2
= 3.33hours
= 200minutes

Efficiency, $\eta_1 = \frac{3.33}{4.15} \times 100\% = 80.24\%$

Efficiency, $\eta_2 = \frac{2.50}{3.10} \times 100\% = 80.65\%$

Efficiency, $\eta_3 = \frac{2.22}{2.75} \times 100\% = 80.73\%$

Efficiency, $\eta_4 = \frac{2.00}{2.40} \times 100\% = 83.33\%$

*it can accept to maximum 5A for 5Ah battery with use it in safety, there is still able to accept higher current to charge but it will damage your battery and decrease your battery life span.

2 CALCULATION OF DISCHARGING TIME FOR ELECTRIC SKATEBOARD

Theoritical Discharging Time for speed 1= $\frac{5.000}{0.710}$= 7.042hours

Average Discharging Time for speed 1= $\frac{5.967+6.133+5.900+6.000}{4}$ = 6.000 hours

Efficiency of Discharging Time for speed 1, η = $\frac{6.000}{7.042} \times 100\%$ = 85.20%

Theoritical Discharging Time for speed 2= $\frac{5.000}{0.950}$= 5.263hours

Average Discharging Time for speed 2= $\frac{2.830+2.917+2.750+2.800}{4}$ = 2.824 hours

Efficiency of Discharging Time for speed 2, η = $\frac{2.824}{5.263} \times 100\%$ = 53.66%

Theoritical Discharging Time for speed 3= $\frac{5.000}{1.160}$= 4.310hours

Average Discharging Time for speed 3= $\frac{1.367+1.333+1.250+1.300}{4}$ = 1.313 hours

Efficiency of Discharging Time for speed 3, η = $\frac{1.313}{4.310} \times 100\%$ = 30.46%

3 CALCULATING MAXIMUM SPEED AND RANGE OF THE ELECTRIC SKATEBOARD

General Formula:

Maximum Speed= Wheel size × Motor rpm × π × Utility Frequency

Maximum Range= Speed × Full Discharge Time

Speed 1,

Motor Revolution per minutes measurd by tachometer, rpm= 1680 rpm

Electric Revolution per minutes measurd by tachometer, rpm= 1680 × 7=11760 rpm

Diameter of wheels = 90mm

Gear ratio of 1:1

Maximum Speed, $v = \frac{90\times\pi\times1680\times60}{1000000}$ = 28.50 kmh^{-1}

Practically Speed, $v = \frac{160.33 \times 3600}{1000 \times 60}$ = 9.62 kmh^{-1}

Efficiency rate:33.75%

Maximum Range with speed 1= 9.62×6.000= 57.72km

Speed 2,

Revolution per minutes measurd by tachometer, rpm= 3200 rpm

Electric Revolution per minutes measurd by tachometer, rpm= 3200×7=22400 rpm

Diameter of wheels = 90mm

Gear ratio of 1:1

Maximum Speed, $v = \frac{90 \times \pi \times 3200 \times 60}{1000000}$ = 54.29 kmh^{-1}

Practically Speed, $v = \frac{296.05 \times 3600}{1000 \times 60}$ = 17.76 kmh^{-1}

Efficiency rate:32.71%

Maximum Range with speed 2= 17.76×2.824= 50.15km

Speed 3,

Revolution per minutes measurd by tachometer, rpm= 5850 rpm

Electric Revolution per minutes measurd by tachometer, rpm= 5850×7=40950 rpm

Diameter of wheels = 90mm

Gear ratio of 1:1

Maximum Speed, $v = \frac{90 \times \pi \times 5850 \times 60}{1000000}$ = 99.24 kmh^{-1}

Practically Speed, $v = \frac{527.73 \times 3600}{1000 \times 60}$ = 32.26 kmh^{-1}

Efficiency rate:32.51%

Maximum Range with speed 3= 32.26×1.313= 42.36km

4 ACCELERATIONS OF THE ELECTRIC SKATEBOARD

General Formula = $\frac{\text{Speed}}{\text{time}}$

Speed 1,

Total accelerate time, s= 5.6

Acceleration= $\frac{9.62\times1000}{5.6\times3600}$= 0.4772ms^{-2}

Speed 2,

Total accelerate time, s= 10.9

Acceleration= $\frac{17.76\times1000}{10.9\times3600}$= 0.4526 ms^{-2}

Speed 3,

Total accelerate time, s= 19.5

Acceleration= $\frac{32.26\times1000}{20.5\times3600}$= 0.4371 ms^{-2}

Calculating Watt hours for Electric Skateboard

$$Watt\ hours, Wh = \frac{mAh \times V}{1000}$$

2 * 4S LiPO batteries connected in series

Nominal voltage, V = 3.7V

5000 milli ampere hour, mAh

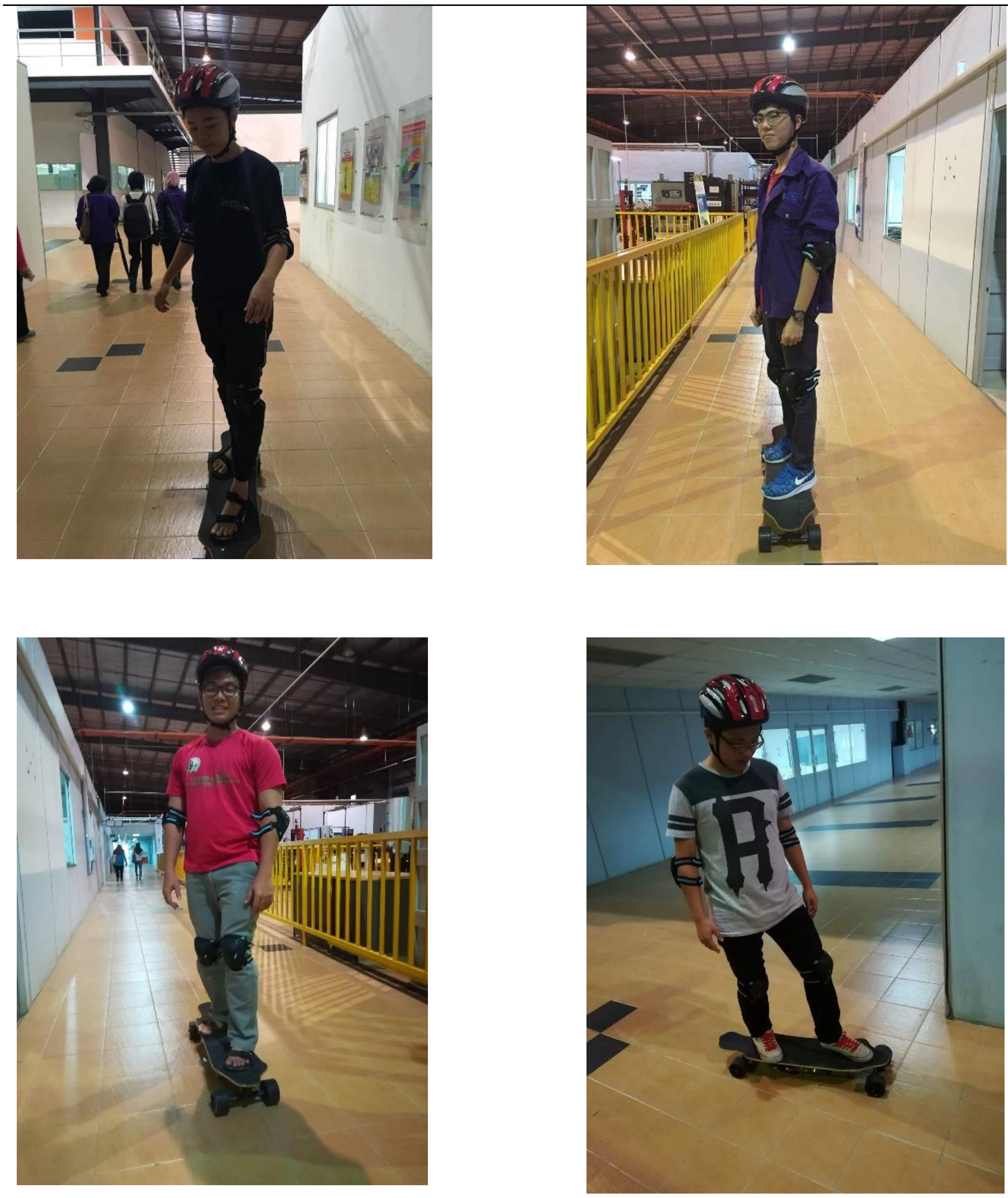
$$Wh = \frac{5000 \times 3.7 \times 4 \times 2}{1000}$$

$$= 148.0Wh$$

APPENDIX B

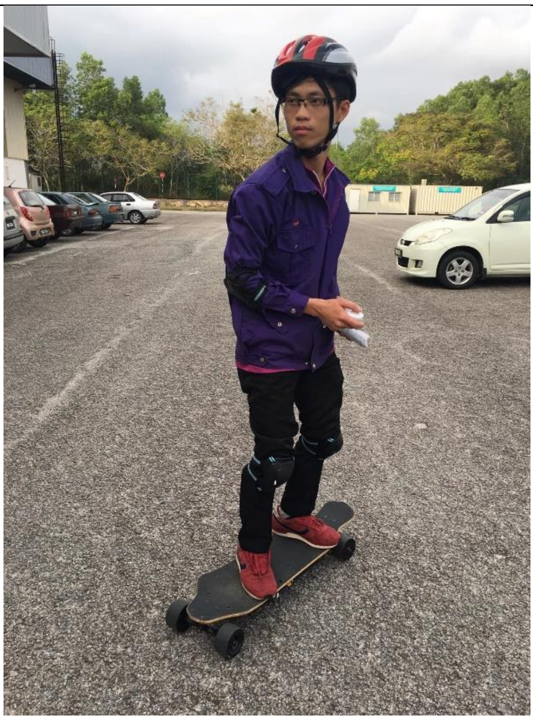
PHOTO

1 SPEED TESTS



Speed test surveying with different people

2 TESTS WITH DIFFERENT SURFACE OF ROAD



Test on the rough surface (Asphalt Road)


Test on the flat surface (Cement Road)

3 CHARGING TESTS

Control the mode of charging

Charging the battery

Charging the battery using solar panel