# DESIGN A BATTERY CHARGER CONTROLLER FOR ELECTRIC VEHICLE (EV)

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2009

# DESIGN A BATTERY CHARGER CONTOLLER FOR ELECTRIC VEHICLE (MECHANICAL)

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A report submitted in fulfillment of the requirements for the award of the Bachelor of Mechanical Engineering with Automotive Engineering

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NOVEMBER 2009

"I hereby declare that I have read this project report and in my opinion this project report is sufficient terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering."

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I Mohd Hafizi bin Shaarani declare that this report entitled "*Design a Battery Charger Controller (Mechanical)*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I dedicated this meaningful project to my beloved mom..

## ACKNOWLEDGEMENT

Throughout two semesters, I met numbers of lecturers and professionals who have assisted me in many ways towards completing my research. Firstly, I would like to express my sincere appreciation to my supervisor, Dr. Yusnita Rahayu, who generously shared his insights and suggestions, for his critics, trust, encouragement, and attention. Without their continued support and interest, this project report would not have been the same as presented here.

I also would like to express my gratitude to the Faculty of Mechanical Engineering and Universiti Malaysia Pahang, for their assistance in supplying the relevant literatures.

I am also obliged to express my appreciation towards my beloved mom and also my family members for their enduring patience, moral and financial supports. My fellow friends should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. Thank you to all. Thank you for everything. May God bless all of you.

#### ABSTRACT

This report is an outcome of the work I have carried out in doing and completing my final year project, Design a Battery Charger Controller for Electric Vehicle (Mechanical). The paper presents another design of battery charger controller that potentially can be apart of an EV system or somehow an explanation on the idea of basic battery charger controller in EV development process. It is an electronically project which required knowledge in electric and electronic field. The overall duty is to analyze the previous design of battery charger controller circuits and come out with a better design as suggestion of the battery charger controller which using microcontroller as the controller of the controller. The report starts with an introduction on EV, the advantages and disadvantages. Then a further introduction describe on the variety of battery type and their suitability to be used in the project. After gathering all the relevant information, the project undergoes design process. The knowledge gathered before is used to make a design which refers to problem statements that suitable for the project. There are comparisons and considerations are made in the designing stage based on self ability and condition. The project follows with writing the programming for the microcontroller using Visual Basic software in C language. The circuit then will be test as it will be the result for the ability of solving the problem statements of the project. At the end, when all the process mentioned above is done, the material for report writing is gathered. The report writing process will be guided by the University Malaysia Pahang final year report writing guide. This process also included the presentation slide making for the final presentation of the project. The project ended after the submission of the report and the presentation slide has been presented

#### ABSTRAK

Laporan ini adalah hasil dari kajian saya dalam menyiapkan Projek Sarjana Muda saya bertajuk Rekaan Pengawal Pengecas Bateri untuk Kereta Elektrik (Mekanikal). Laporan ini membentangkan sebuah lagi rekaan pengawal pengecas bateri yang berpotensi menjadi sebahagian daripada sistem kereta elektrik masa hadapan atau paling tidak menjadi rujukan tentang idea asas sebuah pengawal pengecas bateri dalam proses menghasilkan sebuah kereta elektrik. Ia adalah sebuah projek elektonik yang memerlukan pemahaman dalam bidang elektrik dan elektronik. Keseluruhan tugas adalah untuk manganalisis rekaan litar pengawal pengecas bateri yang dihasilkan terdahulu dan memberikan cadangan lebih baik dalam merekabentuk sebuah pengawal pengecas bateri iaitu menggunakan microcontroller yang bertindak sebagai pengawal. Laporan ini dimulakan dengan pengenalan kepada kereta elektrik; kelebihan dan kelemahannya. Lanjutan pengenalan menyentuh kepelbagaian bateri yang digunakan dan kesesuaiannya untuk digunakan dalam projek ini.tentang kepentingan kekunci kereta dan kepentingannya kepada keselamatan kereta. Apabila semua maklumat berkaitan selesai dikumpulkan, projek ini akan diteruskan dengan fasa rekabentuk. Maklumat dan pengetahuan yang dikumpulkan digunakan untuk mengeluarkan sebuah rekaan berdasarkan kenyataan masalah yang sesuai dengan projek ini. Perbandingan dan pertimbangan telah dibuat dalam peringkat ini berdasarkan kemampuan dan keadaan sekeliling. Projek diteruskan dengan menulis kod program untuk microcontroller yang digunakan dengan menggunakan software Visual Basic dalam bahasa C. Rekaan litar akan diuji sebagai kayu ukur tentang kebolehannya menyelesaikan kenyataan masalah projek ini. Akhir sekali,laporan lengkap akan dirangka dan ditulis mengikut garis panduan yang ditetapkan oleh Universiti Malaysia Pahang.Selain laporan lengkap, slaid pembentangan juga akan disiapkan pada fasa teakhir projek ini. Projek ini berakhir dengan rasminya apabila ia berjaya dibentangkan dan laporan akhir dihantar.

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## LIST OF SYMBOLS

η	energy conversion efficiency
Pe	electrical input power
$P_m$	mechanical output power
V	input voltage
Ι	input current
Т	output torque
ω	output angular frequency
W	Watt
kW	kilowatt
h	hour
A/Am	Ampere
mA	miliAmpere
°C	degree celcius

## LIST OF ABBREVIATIONS

AC	Alternative Current
DC	Direct Current
V	Volt/Voltage
EV	Electric Vehicle
ICE	Internal Combustion Engine
RESS	Rechargeable Electric Storage System
FEV	Full Electric Vehicle
RPM	Revolution Per Minutes
PFC	Power Factor Correction
ESR	Equivalent Series Resistance
LCD	Light Crystal Display
LED	Light Emission Display

### **CHAPTER 1**

#### **INTRODUCTION**

#### 1.1 Introduction

An electric vehicle (EV) is a vehicle with one or more electric motors for propulsion. This is also referred to as an electric drive vehicle. The motion may be provided either by wheels or propellers driven by rotary motors, or in the case of tracked vehicles, by linear motors[18].

Unlike an internal combustion engine (ICE) that is tuned to specifically operate with a particular fuel such as gasoline or diesel, an electric drive vehicle needs electricity, which comes from sources such as batteries or a generator. This flexibility allows the drive train of the vehicle to remain the same, while the fuel source can be changed. The energy used to propel the vehicle may be obtained from several sources, some of them more ecological than others[21]:

- on-board rechargeable electricity storage system (RESS), called Full Electric Vehicles (FEV). Power storage methods include:
  - chemical energy stored on the vehicle in on-board batteries: Battery electric vehicle (BEV)
  - static energy stored on the vehicle in on-board electric double-layer capacitors

- kinetic energy storage: flywheels
- direct connection to generation plants as is common among electric trains, trolley buses, and trolley trucks (See also : overhead lines, third rail and conduit current collection)
- renewable sources such as solar power: solar vehicle
- generated on-board using a diesel engine: diesel-electric locomotive
- generated on-board using a fuel cell: fuel cell vehicle
- generated on-board using nuclear energy: nuclear submarines and aircraft carriers

It is also possible to have hybrid electric vehicles that derive energy from multiple sources. Such as:[18]

- on-board RESS and a direct continuous connection to land-based generation plants for purposes of on-highway recharging with unrestricted highway range
- on-board rechargeable electricity storage system and a fueled propulsion power source (ICE): plug-in hybrid

Electric vehicles can include electric airplanes, electric boats, and electric motorcycles and scooters. The power of a vehicle electric motor, as in other vehicles, is measured in kilowatts (kW). 100 kW is roughly equivalent to 134 horsepower, although most electric motors deliver full torque over a wide Rotational Per Minutes (RPM) range, so the performance is not equivalent, and far exceeds a 134 horsepower fuel-powered motor, which has a limited torque curve. Usually, direct current (DC) electricity is fed into a DC/AC inverter where it is converted to alternating current (AC) electricity and this AC electricity is connected to a 3-phase AC motor. For electric trains, DC motors are often used[6][7].

To calculate a motor's efficiency, the mechanical output power is divided by the electrical input power:[3]

$$\eta = \frac{P_m}{P_e}$$

where  $\eta$  is energy conversion efficiency,  $P_e$  is electrical input power, and  $P_m$  is mechanical output power.

In simplest case,

$$P_e = VI$$
, and  $P_m = T\omega$ ,

where V is input voltage, I is input current, T is output torque, and  $\omega$  is output angular frequency.

## 1.2 Project Background

Oil, coal, and natural gas are collectively known as fossil fuels. We can simply say that all moving things on this earth are generate by fuel to move or function. But either we realize it or not, there are a number of problems associated with fossil fuels, most of which stem from the by-products created when they are burned to create energy. Chief among those byproducts are carbon dioxide and nitrous oxide, greenhouse gases that are major contributors to global warming. Largely because of coal and petroleum combustion, the amount of carbon dioxide and nitrous oxide in the air today are thirty-five percent and eighteen percent higher, respectively, than they were before the industrial era. Other byproducts of fossil fuel combustion include sulfur oxides and nitrogen oxides, both of which contribute to acid rain, and hydrocarbons, which can react with nitrogen oxides to form smog[1].

In addition to their environmental harm, the byproducts of burning fossil fuels can cause health problems for humans. Nitrogen oxides, for instance, irritate the lungs Particulate matter such as soot and dust contribute to respiratory illness and cardiac problems, including arrhythmias and heart attacks[2]. On the hands, the matters about fuel price which is cannot be maintained as it is base on the ups and downs of world economy start annoying the society. Remember the latest issue, the fuel price hike in late 2008 where there have been a lot of demonstrations of unsatisfied in number of countries. Fuel matters are actually the problem of the entire world and shocking that the world is actually facing the real big problem about fuel which is coming their way. There already have speculations that the world will be finished up the fossil from the some of the trusted source, thus, there would be no more fossil fuel can be produced. Even the car inventor does not know about this when they first invent a car. So it is actually nowadays problem and it is the responsibility of the people of this generation to find the suitable solution that can save them from this upcoming problem.

## 1.3 Objective

• To design a battery charger controller for an Electric Vehicles (EV).

#### **1.4 Problem Statements**

- Over charging the battery can cause damage either to the battery itself or even the other components that related.
- It is better to have a system which can automatically charge the battery when it has insufficient voltage.

#### 1.5 Project Scope

- Limit to lithium ion battery (12V)
- Write a program for PIC 16F877A
- Voltage displayed on LCD
- Result showed by operating relay(s)

#### **CHAPTER 2**

#### **ELECTRIC VEHICLE OVERVIEW**

#### 2.1 Advantages of electric vehicle

There are a lot of benefits that electric cars can bring us. This improves the goodness of having electric cars on the roads and highways. Some of the advantages are discussed here. The electric motors are known for its ability to release almost no air pollutants at the place where they are operated. Reducing the polluted air means there are clearer air which will be inhale by humans surround somehow reducing the health problem caused by the polluted air.

Second, the efficiency of electric motors is far away better than internal combustion engine. Electric motors often achieve 90% energy conversion efficiency over the full range of speeds and power output and can be precisely controlled[17]. They can also be combined with regenerative braking systems that have the ability to convert movement energy back into stored electricity. This can be used to reduce the wear on brake systems (and consequent brake pad dust) and reduce the total energy requirement of a trip, especially effective for start-and-stop city use. Plus, they can be finely controlled and provide high torque from rest, unlike internal combustion engines, and do not need multiple gears to match power curves. This removes the need for gearboxes and torque converters. Another advantage is that electric vehicles typically have less vibration and noise pollution than a vehicle powered by an internal combustion engine, whether it is at rest or in motion[18]. Electricity is a form of energy that remains within the continent where it was produced and can be multi-sourced. As a result it gives the greatest degree of energy resilience.

Last but not least, the GM Volt, one of electric vehicle produced by Chevrolet, will cost less than purchasing a cup of coffee to recharge. The Volt should cost less than 2 cents per mile to drive on electricity, compared with 12 cents a mile on gasoline at a price of US dollar \$3.60 a gallon. This would be the equaling to paying 70 cents a gallon of gas[20].

#### 2.2 Disadvantages of electric vehicle

Electric Vehicles however still have the bad parts of it due to the electrical system they used. Many electric designs have limited range, due to the low energy density of batteries compared to the fuel of internal combustion engine vehicles. Besides, these batteries have long recharge times compared to the relatively fast process of refueling a tank.

A large number of electric cars would put significant strain on the grid if charged during peak use times, requiring additional investment in utility infrastructure. However, advocates have pointed out that the batteries of electric cars could be used to solve transmission problems if they are charged at off-peak times, by returning power to the grid at peak times. But this would reduce the daytime range of a parked electric car[14].

From a trusted resource give that overall average efficiency from United State power plants (33% efficient) to point of use (transmission loss 9.5%), (U.S. Department of Energy figures) is 29.87%. Accepting 90% efficiency for the electric vehicle gives us a figure of only 26.88% overall efficiency. That is lower than internal combustion engine

vehicles (Petrol/Gasoline 30% efficient, Diesel engines 45% efficient - Volvo figures). Diesel engines can also easily run on renewable fuels, biodiesel, vegetable oil fuel (preferably from waste sources), with no loss of efficiency. Using grid electricity entirely negates the efficiency advantages of electric vehicles. This comparison does not take into account the lower practical efficiency of the internal combustion engine, due to transmission and idling losses. It compares tank-to-flywheel efficiency of gasoline and diesel powered engines to the well-to-wheel efficiency of electric motors[7].

To achieve a sound conclusion, one would also have to take into account the refining and delivery losses of gasoline and diesel, and the energy efficiency of biofuel production. (Output fuel energy divided by the sum of the invested energy and energy in the biomass). The equivalent for fossil electricity production would also need to be considered (mining and transportation of coal to the power station for example, or the carbon dioxide produced building renewable electricity generation).

Last but not least, in cold climates considerable energy is needed to heat the interior of the vehicle, and to defrost the windows. With ICE this heat can come for free from the waste heat from the engine cooling circuit. If this is done with battery power cars, this will require extra energy from the battery, although some could be harvested from the motor and battery itself. There would not be as much heat available as from an engine.

#### 2.3 Issues with batteries

On an energy basis, the price of electricity to run an EV is a small fraction of the cost of liquid fuel needed to produce an equivalent amount of energy. Issues related to batteries, however, can add to the operating costs.

#### 2.3.1 Lead-acid

Traditionally, most EVs have used lead-acid batteries due to their mature technology, high availability, and low cost (exception: some early EVs, such as the Detroit Electric, used nickel-iron.) Like all batteries, these has an environmental impact through their construction, use, disposal or recycling. On the upside, vehicle battery recycling rates top 95% in the United States. Deep-cycle lead batteries are expensive and have a shorter life than the vehicle itself, typically needing replacement every 3 years[31].

Lead-acid batteries in EV applications end up being a significant (25%-50%) portion of the final vehicle mass. Like all batteries, they have significantly lower energy density than petroleum fuels, in this case, 30-40Wh/kg. While the difference is not as extreme as it first appears due to the lighter drive-train in an EV, even the best batteries tend to lead to higher masses when applied to vehicles with a normal range. The efficiency and storage capacity of the current generation of common deep cycle lead acid batteries decreases with lower temperatures, and diverting power to run a heating coil reduces efficiency and range by up to 40%. Recent advances in battery efficiency, capacity, materials, safety, toxicity and durability are likely to allow these superior characteristics to be applied in car-sized EVs[32].

Charging and operation of batteries typically results in the emission of hydrogen, oxygen and sulfur, which are naturally occurring and normally harmless if properly vented. Early City car owners discovered that, if not vented properly, unpleasant sulfur smells would leak into the cabin immediately after charging. While for discharging, voltage depression or memory effect from repeated partial discharge can occur, but is reversible through charge cycling[32].

#### 2.3.2 Nickel metal hydride

Nickel-metal hydride batteries are now considered a relatively mature technology. While less efficient in charging and discharging than even lead-acid, they boast an energy density of 30-80Wh/kg, far higher than lead-acid. When used properly, nickel-metal hydride batteries can have exceptionally long lives, as has been demonstrated in their use in hybrid cars and surviving NiMH RAV4EVs that still operate well after 100,000 miles (160,000 km) and over a decade of service[32].

Downsides include the poor efficiency, high self-discharge, very finicky charge cycles, and poor performance in cold weather. The NiMH battery has been produced which is used in the second generation EV-1, makes a nearly identical battery (ten 1.2V 85Ah NiMH cells in series in contrast with eleven cells for Ovonic battery). This worked very well in the Saturn EV-1. It remains a viable and practical solution today, as far as a superior alternative to the lead acid battery. However, for non-technical reasons neither company will provide their NiMH battery for automotive applications - a policy strictly enforced. Moreover, GM now owns patent(s) on some proprietary technology and processes used to manufacture this type of battery. Therefore no other company can produce a similar battery (with capacities large enough for electric vehicle propulsion) without infringing GM's patents. So, despite its technical success, unless GM will change their position on the issue NiMH traction battery technology, it is considered a dead end. In light of the latest developments in lithium based battery technology and patent issues of NiMH, lithium will most likely represent the future EV battery type[31].

## 2.3.3 Zebra

The sodium or "zebra" battery uses a molten chloroaluminate (NaAlCl4) salt as the electrolyte. Also a relatively mature technology, the Zebra battery boasts a good energy density of 120Wh/kg and reasonable series resistance. Since the battery must be heated for

use, cold weather doesn't strongly affect its operation except for in increasing heating costs. It has been used in several EVs. The downsides to the Zebra battery include poor power density (<300 W/kg) and the requirement of having to heat the electrolyte to 270 °C, which wastes some energy and presents difficulties in long-term storage of charge. Zebras can last for a few thousand charge cycles and are nontoxic [32].

#### 2.3.4 Lithium Ion

Lithium-ion (and similar lithium polymer) batteries, widely known through their use in laptops and consumer electronics, dominate the most recent group of EVs in development. The traditional lithium-ion chemistry involves a lithium cobalt oxide cathode and a graphite anode. This yields cells with an impressive 160Wh/kg energy density and good power density, and near lossless charge/discharge cycles. The downsides of traditional lithium-ion batteries include short cycle life (hundreds to a few thousand charge cycles) and significant degradation with age. The cathode is also somewhat toxic. Also, traditional lithium-ion batteries can pose a fire safety risk if punctured or charged improperly. The maturity of this technology is moderate. The Tesla Roadster uses "blades" of traditional lithium-ion "laptop battery" cells that can be replaced individually as needed.

Most other EVs are utilizing new variations on lithium-ion chemistry that sacrifice energy density (often resulting in batteries with 100Wh/kg or less) to provide extreme power density, fire resistance, environmental friendliness, very rapid charges (as low as a few minutes), and very long lifespan. These variants (phosphates, titanates, spinels, etc) have been shown to have a much longer lifetime, with A123 expecting their lithium iron phosphate batteries to last for at least 10+ years and 7000+ charge cycles[8], and LG Chem expecting their lithium-manganese spinel batteries to last up to 40 years.

Much work is being done on lithium ion batteries in the lab. Lithium vanadium oxide has already made its way into the Subaru prototype G4e, doubling energy density.

Silicon nanowires[9], silicon nanoparticle, and tin nanoparticles[10] promise several times the energy density in the anode, while composite and superlattice cathodes also promise significant density improvements.

#### 2.4 Other issues

#### 2.4.1 Charging stations and battery swapping

Assuming a 50 kilowatt-hour battery packs and ideal charging efficiency, a ten minute quick charge from 10% to 80% capacity would require a power draw of 210 kilowatts from the electric grid. At 240 Volts, this means a current draw of 875 Amperes from the outlet. In practice, the energy efficiency of quick charging is likely to be somewhat lowered due to the ohmic losses caused by the required high current. The lost energy is converted directly to heat, which causes wear to the battery pack and other electronics involved. Increasing the capacity of the battery pack increases the required power, current and heat loss linearly, which is why quick charging may become impractical or impossible as vehicles with increased range are developed[29].

The high peak power requirement of quick charging also puts additional stress to the local power grid and may put it to a risk of failure during periods of peak demand. The most obvious solution is to use another battery to act as a buffer between the charging station and the power grid. The battery as a buffer however, suffers a similar efficiency drop as the car itself, thus lowering the overall efficiency of the system. Another possibility is on-site, on-demand electricity generation[14].

Battery replacement is also proposed as an alternative. While it suffers from some problems (weight, standardization, etc), Project Better Place has already raised several hundred million dollars to build several electric vehicle networks of charging and battery replacement stations. One type of battery "replacement" proposed is much simpler: while the latest generation of vanadium redox battery only has an energy density similar to leadacid, the charge is stored solely in a vanadium-based electrolyte, which can be pumped out and replaced with charged fluid[13].

#### 2.4.2 Other in-development technologies

Conventional electric double-layer capacitors are being worked to achieve the energy density of lithium ion batteries, offering almost unlimited lifespans and no environmental issues. Lithium-sulphur batteries offer 250Wh/kg. Sodium-ion batteries promise 400Wh/kg with only minimal expansion/contraction during charge/discharge and a very high surface area[12].

#### 2.4.3 Mechanically rechargeable batteries

There is another way to "refuel" electrical vehicles. Instead of recharging them from electric socket, batteries could be mechanically replaced on special stations just in a couple of minutes. The general rule here is the more energy density does have a battery the more difficult to recharge it electrically.

There are Vanadium and Titanium diboride batteries which have great energy density, but can't be recharged electrically. Instead, thermal methods of recharging could be used. If coal, nuclear or geothermal energy used as a source, overall efficiency could be much better than in electrically rechargeable batteries, but can be environmental externalities[13].

#### 2.4.3.1 Battery charger for vehicles

There are two main types of charges for vehicles:

- To recharge a fuel vehicle's starter battery, where a modular charger is used.
- To recharge an electric vehicle (EV) battery pack.

#### 2.4.3.2 Electric vehicle's battery

These vehicles include a battery pack, so generally use series charger. A 10 Ampere-hour battery could take 15 hours to reach a fully charged state from a fully discharged condition with a 1 Ampere charger as it would require roughly 1.5 times the battery's capacity.

Public EV charging heads (aka: stations) provide 6kW (host power of 208 to 240 VAC off a 40 amp circuit). 6kW will recharge an EV roughly 6 times faster than 1kW overnight charging. Rapid charging results in even faster recharge times and is only limited by available AC power and the type of charging system[28].

On board EV chargers (change AC power to DC power to recharge the EV's pack) can be[28]:

- Isolated: they make no physical connection between the A/C electrical mains and the batteries being charged. These typically employ some form of Inductive charging. Some isolated chargers may be used in parallel. This allows for an increased charge current and reduced charging times.
- Non-isolated: the battery charger has a direct electrical connection the A/C outlet's wiring. Non-isolated chargers cannot be using in parallel.

Power Factor Correction (PFC) chargers can more closely approach the maximum current the plug can deliver, shortening charging time[28].

## 2.5 Basic idea of battery charger controller



Figure 2.1: The invention of a charging station that located at a car park [5].

This is the invention of previous researcher and it is unsure that it is already in the market or not. But clearly seen that it is locate at a parking lot in a building where there has a special plate on the floor.



Figure 2.2: A car park in the charging station and the charger start to operate[5].

And when a car park at this parking lot and it is leave for awhile, this plate create a magnetic reaction with the special equipment build under the car's body which can turn the

magnetic energy to the energy that can be charge the battery. Once it is fully charge it will stop or maybe the owner would leave before the battery could even finish charging.

So it is obviously that this invention is actually operated automatically where it detect the insufficient voltage battery then charge it until the battery is fully charge. The reaction will automatically stop once the battery is fully charge. What is important here is the concept of charging that is used where it is automatically charge and stop charge that is actually explain how the invention of this project will work out. Otherwise, it is only the concept or the idea that has been taken and it would not seem alike this invention.

#### 2.6 Battery charging

The circuitry to recharge the batteries of an EV is the important part for this project. The complexity (and cost) of the charging system is primarily dependent on the type of battery and the recharge time.

#### 2.6.1. Lithium Ion charging mechanism

The discussion about the battery had resulted that lithium ion battery is the best battery to be used in an EV. It is a unique, as it is charged from a fixed voltage source that is current limIted which usually referred to as constant voltage charging.

A constant voltage (C-V) charger sources current into the battery in an attempt to force the battery voltage up to a pre-set value (usually referred to as the set-point voltage or set voltage). Once this voltage is reached, the charger will source only enough current to hold the voltage of the battery at this constant voltage. Hence, the reason it is called constant voltage charging[25].

At present, the major Li-on cell manufacturer recommends 4.200 +/- 50 mV as the ideal set point voltage, and 1c (a charging rate equal to the Ampere/hour rating per cell) as the maximum charging current that can be used. The accuracy on the set point voltage is critical: if this voltage is too high, the number of charge cycles the battery can complete is reduced (shortened battery life). If the voltage is too low, the cell will not be fully charged.



Figure 2.3: A typical charge profile for a Li-Ion cell using 1c voltage charging[25].

The constant voltage charging cycle is divided into two separate segments:

- 1. The current limit phase and
- 2. The constant voltage phase

The current limit (sometime called constant current) phase of charging is where the maximum charging current is flowing into the battery, because the battery voltage is below

the set point. The charger senses this and sources maximum current to try to force the battery voltage up.

During the current limit phase, the charger must limit the current to the maximum allowed by the manufacturer (shown as 1c here) to prevent damaging the batteries. About 65% of the total charge is delivered to the battery during the current limit phase of charging. Assuming a 1c charging current, it follows that this portion of the charge cycle will take a maximum time about 40 minutes.

The constant voltage portion of the charge cycle begins when the battery voltage sensed by the charger reaches 4.20V. At this point, the charger reduces the charging current as required to hold the sensed voltage constant at 4.2V, resulting in a current waveform that is shaped like an exponential decay.

The constantly decreasing charge current during the constant-voltage phase is the reason that the Li-Ion charge time is nearly two hours, even though a 1c (maximum) charging current is used (this means that delivering the final 35% of the charge takes about twice as long as the first 65%). This is because of the fact that every real cell contains an internal ESR (Equivalent Series Resistance), and the voltage that the charger senses across the battery is influenced by the ESR.

The voltage measured at the terminals of the battery is the sum of the voltage drop across the ESR and the cell voltage. The battery is not fully charged until the cell voltage is 4.2V with only a minute current flowing into it which means the drop across the internal ESR is negligible, and the actual cell voltage is 4.2V.

During the 1c current limit charge phase, the battery reaches 4.2v with only about 65% of charge capacity delivered, due to the voltage drop across the ESR. The charger must the reduce the charging current to prevent exceeding the 4.2V limit, which results in the decreasing current as shown in Figure 2.3.



Figure 2.4: Battery Equivalent Circuit[25].

#### 2.7 The battery charger controller circuit

#### 2.7.1 Single cell 150 mA Charger

While a maximum charging current of 1 c is allowed for Li-Ion, charging a lower rate is also possible but it is correspondingly longer charge time. The design example presented next shows a simple solution for slow charging a single Li-Ion cell.

Figure shows the schematic of a battery charger that was designed to recharge the Li-Ion battery in a portable stereo. The specification for this charger was 150mA (minimum) charging current in the current-limit charge mode, and a voltage set point of 4.200V + 0.025V in the constant voltage charge mode.

An LP2951 regulator was selected because it has an output voltage that is very stable over temperature. Plus, the LP2951 has built-in current limiting that prevents the output current from exceeding 160 mA (typical), and the part is fully protected with thermal shutdown and short-circuit protection. The LP2951 is set for an output voltage of 4.20V using the resistors shown (the trimpot is required because of the tight tolerance specification). When the battery voltage is below 4.2V, the LP2951 will source maximum current (typi-cally 160 mA) in an attempt to force the battery voltage up to 4.2V (this is the current limit phase of the charge cycle).

Once the battery reaches 4.2V, the LP2951 will cut back the charging current as required to hold the battery voltage at 4.2V (this is the *constant voltage* portion of the charge cycle). The large resistor values used in this design are necessary to keep the "OFF" current drain below 2mA, and a 330pF capacitor is needed to prevent instability due to noise at the high-impedance feedback node. A blocking diode is used at the output of the LP2951 to prevent battery current from flowing back into the LP2951 output pin if the input power source is removed.



Figure 2.5: Single cell Li-Ion battery charger[25].

#### 2.7.2 3-Cell, 3A charger using the LP2952

Figure 2.6 shows a design which was developed to charge a 3-cell Li-Ion battery with a maximum of 3A. The set point voltage for the charger was specified as 12.60V, with a required precision of better than +/-1% over temperature. The design topology selected was a Low Dropout (LDO) regulator using the LP2952 as the controller and a D45H5 pass transistor to supply the 3A of current. The LP2952A is a precision LDO regulator which is rated for up to 250 mA of load current, and has a reference voltage specification limit of +/-1.2% (room temperature) on "A" grade parts.

In this design, U1 is used as a current sink for the base drive current of Q1. This base current flows through U1 (to ground) through R2. The current through U1 drives the base of Q1, which will source as much current as it can to try to bring the output up to the set voltage. This means the DC input source must be current limited so that the maximum charging current does not exceed the limit that the battery can safely handle (3A in this design).



Figure 2.6: 3-cell, 3A charger using LP2952 regulator[25].

The output voltage is set by the resistive divider made up of R3, R4, and R5. Since an absolute accuracy of better than +/-1% is specified on the set voltage, a voltage trimmer (R3) is required. C2 is used for compensation. A heatsink must be used with Q1, sized as required by the ambient temperature and input voltage used to power the circuit.

## 2.7.2.1 Improving the design

The circuit in Figure 8 works well, but has two "features" which are not optimal from the users standpoint. A voltage trim is required, because the cumulative tolerances of the components will exceed 1% before you even get started:

- If 1% resistors are used in a divider, they will contribute about 1.4% total error to the set voltage. 0.1% resistors are available but they are expensive.
- Adding to the resistor-induced error, the tolerance on the reference voltage of the best precision regulators is > +/-1%.
- Although sometimes necessary, voltage trims are not user-friendly, as they require hand labor in the manufacturing process.
- Another unpleasant feature of this design is that this circuit will continuously drain the battery through the R3, R4, and R5 divider if the power to the charging circuit is removed. Even though the drain is only 12mA, it does reduce standby time for the portable product whish is not recommended.

The next design presented will highlight a new product developed for Li-Ion charging which overcomes both of these drawbacks.

#### 2.7.3 LM3420 battery charger controller

Developed specifically for Li-Ion charging, the LM3420 provides a simple way to build a charger for one, two, or three Li-Ion cells. The LM3420 is a regulator (see Figure 9) which sources current from its output when the regulated voltage is applied from the input to ground. With voltage accuracy of 0.5% (room temperature) and 1% over the full temperature range for "A" grade units, external voltage trims are not required. Minimum board space is used by the SOT23-5 package, and voltage options of 4.2, 8.4, and 12.6V are provided to accommodate 1,2, and 3 cell charger designs.


Figure 2.7: Block diagram of LM3420[25].

### 2.7.4 3-Cell, 3A charger using the LM3420

Use of the LM3420 for Li-Ion charging offers significant advantages, as highlighted in the charger design shown in Figure 10. The design specification called out 12.60V for the voltage set point (with an overall accuracy better than 1%). The maximum charging current is 3A (and must be limited by the DC input source).The LM3420 has a factorytrimmed internal divider that is adjusted to 12.6V (tolerance better than +/-1%), so voltage setting resistors are not needed.

In the typical (constant-voltage) mode of operation, the LM3420 is the controller in a feedback loop that precisely regulates the voltage of the batteries. The circuit has a builtin "on/off switch" made up of Q3, R4, and D3. When a DC input is present, D3 turns on Q3 which allows current to flow through the LM3420 and Q1, causing the circuit to operate. If the DC input source is removed, Q3 will turn off and reduce the drain on the batteries to less than 1 mA (an important improvement over the previous design, as it prevents "off state" battery drain). R1, R2, D1, D2 and associated components are used to set up a bias current through Q1. About 600mA will flow through D1, D2, and R2 to ground, forcing current to flow through R3, R5, Q1, and Q3 (assuming Q3 is turned on). The current flowing through R5 is provided by the output of the LM3420 and the current flowing through Q1.

The 3A used for battery charging is provided by Q2, a P-FET which is turned on/off by Q1, D4, R5 and Q3. In the current-limit mode of operation (where the battery voltage is below 12.6V), Q1 is fully turned on, which pulls down the gate of Q2 and turns it on to the maximum. Since the FET Q2 is fully turned on, the charging current must be limited by the DC source which powers the circuit.



Figure 2.8: 3-cell, 3A charger using LM3420 regulator[25].

When the battery voltage reaches 12.6V, the LM3420 regulates the battery voltage by sourcing current, which adjusts the Q2 gate voltage as required to hold the battery voltage at 12.6V. In this constant-voltage mode of operation, both Q1 and Q2 operate in their linear regions in response to the feedback from the output of the charger circuit (through theLM3420) to maintain this fixed battery voltage. The Schottky diode used at D5 is necessary to prevent battery drain due to current flowing back through the internal diode of Q2 when the DC input is removed. A 16A diode was selected to minimize power losses, but a 6A could be used for cost savings.

# **CHAPTER 3**

# METHODOLOGY

### 3.1 Introduction

Methodology can best be described as the framework of the overall study contains the elements of work based on the objectives and scopes of the project. It is actually a guidance to manage a project properly where it ensure one will always on the line and always update the progress of their project.

In the developing a project, methodologies is the important element to be considered to make sure that the design and development of the case study is smooth in order to get the expected result. Here stated the project procedures, the activities for this project is listed below.

- Phase 1- Define problem (Literature review)
- Phase 2- Design or selecting a proper circuit (existing circuit)
- Phase 3- Determination (meet the specification)
- Phase 4- Develop program for PIC16F877A
- Phase 5- Test circuit
- Phase 6- Modification (if needed)





Refer to Figure 3.1, the project starts with the literature review and research on this project's topic which is to design a battery charger controller for EV. It consist the review on the study case background and the previous study of battery charging mechanism and design. These tasks have been done through research on the internet, books and other relevant sources.

After gathering all the relevant information, the project undergoes design process. This step required application of all the information gathered before to setup an appropriate design process that compatible the project requirements. There are several design of circuits had been studied for the advantages and disadvantages. And there are eliminations been made before the best design can be determined.

There are also some modifications to be made of the design chosen consider of self ability but still pushing all the effort to achieve the objectives of the project. The progress now moves on to the next level where the program code or source code for the microcontroller is to be setup. This required the ability to understand the C language as far as to write it out and setup such an appropriate code to be installed in the microcontroller. Visual Basic software used to setup this program code based on its compatibility with the microcontroller used.

At the end, when all the process mentioned above is done, the material for report writing is gathered. The report writing process will be guided by the University Malaysia Pahang final year report writing guide. This process also included the presentation slide making for the final presentation of the project. The project ended after the submission of the report and the presentation slide has been presented.

# 3.3 Design method

The framework of the project or the project's structure are now has been created and designed. The suitable methodology to be used are first discussed with the supervisor and chosen before the project can actually begin. It is important to ensure the project runs smoothly and successfully.

### 3.3.2 Design circuit

The method for this project begins with designing a proper circuit. This circuit must obey the concept of automatically charge and stop charge. So it can be the improvement for the previous invention which might challenge in marketing. There are a few steps on determination of the best design for the circuit.

There are several of circuits which can be used as references on designing a battery charger controller. Their advantages and disadvantages are being studied before the best design can be select based on self ability to design it. These circuits are getting from the articles and journals which produced by the expert. There are a lot of ways of charging and controlling the charger based on the information and some relevant references studied. They are using microcontroller, microchip, regulator or even single op-amp which can give almost the right criteria that needed in this project.

### 3.3.2.1 Hardware analysis

As for designing process is not an easy part, there are a lot of parameters to be considered to ensure that the current flow and the voltage source are constant during the charging mechanism take place. This is an important requirement specific for charging the Lithium Ion Battery. The important components that stand on the circuit are microcontroller, relay, regulator, push up button, Light Crystal Display (LCD), voltage sensor plus the small components like resistors and capacitor within their self values. Here, two of the components had been emphasized as they are the most important components on the circuit in order to do the controlling and charging the battery.

## 3.3.2.2 PIC 16F877A

This is one type of microcontroller that served in the market nowadays among a thousand of others. It is an 8 byte microcontroller which operates in range of 0-5 V internal voltage. Besides, it is a kind of components that lead-free which mean that there is no lead stored in it. The frequency of its operating speed is about 20 MHz and operates at 4.0-5.5V. Caution for its temperature range to avoid damage during operating over heat is that around  $-40^{\circ}$  to  $+85^{\circ}$ C. Last but not least, it is a self-reprogrammable type under control by suitable software which is most required in this project.





Figure 3.2: PIC 16F877A microcontroller

# 3.3.2.3 Relay

Relay is an electronic component that simply said as an electrically operated switch which means that it can act as a switch within a suitable voltage flow into it. Basically, when it turned on which mean that there has current flow into it, it switches on a way. Otherwise, when there is no current flow through it, simply say it turned off, it switches the other way.

This mechanism can be understood straightly when discover inside the relay itself. It is clearly seen that it has an electromagnet, called a coil, and a lightweight switch inside it. This coil can produce an electromagnetic energy which attracts the light switch to close the circuit and allow the circuit run.



Without power supply (OFF)

Within power supply (ON)

Figure 3.3: The basic idea of how a relay works.



Figure 3.4 : A 10 Amp relay

The relay that used in this project is a 10Amp contact type which have about 5000 ohm coil. And as we can see in the figure above, it is an "Ice cube" style relay that has 3 pin below it. Plus, it is normally open type of relay where it is open when there is no current flow into it.

## **3.4 Develop Program Code**

After having the best circuit for the project, a proper program code is then to be developed thus compiled into the microcontroller using a compiler. This is one of the important parts as the tasks done by the whole circuit are controlled by the microcontroller. Every single line of the program code refer to a specific purpose and overall it plays important role to ensure that the circuit runs well instead of overcharging which cause damage to the battery plus a continuous drain which reduce the standby time of the battery.

This program code or Source code is setup using software that serves C languages which is understand by human but not by the machine. So here, we need a compiler which comes out with software to reboot the program. After reboot, the program is then compiled to turn it into a set of binary code which can be read by the machine. There are numbers of software that relate such as Visual Basic and C++. For this project, the source code is written in Visual Basic software as it is recommended by the expert.

# 3.5 Modification

The best circuit is not achieve with just one try, so remind that it is quite a try and error solution which might need modifications before the best circuit can be achieve. There will have some considerations that made during the designing phase based on self ability of conducting the test accurately as the design made. It is very important to avoid failures in the earlier stage to avoid short circuit or even damages of circuit during tested. This might occur as we tested the circuit that the safety of it has not been assured yet

### 3.6 Analysis

After pass the selecting phase, the best circuit which can automatically charge and stop charge is successfully been designed. This circuit will be tested for the last time for satisfaction and analyze as it can meet the requirements of the project. This analysis is important to examine the ability of the circuit to run the tasks and also for its safety factor. So that it can come out within user's guide which can be its advantage to go marketing.

## **CHAPTER 4**

## **RESULT AND DISCUSSIONS**

### **4.1 Introduction**

This chapter will focus on the result and discussion that had been made based on the result get. Some of the important facts that bring in determination the best design of a battery charger controller have been focused on. There are comparisons and considerations made before come out with the best design. Once the circuit has been design, it is then compiled with a proper program setup to run the tasks well. Finally, there are the discussion and analysis are made refers to the result that collected at the end of the test. The best design cannot be determined just like picking up stuff in the market. It needs study, comparison and consideration to be made based on the project's objective and self ability so that the problems that will come out later can be reduced.

## 4.2 The battery charger controller circuit schematic diagram

There are a lot of circuits that served on the internet, articles and journals. From all the designs, this study would like to focus on three designs which using three different ways of charging and controlling the charger. Discussions of these three circuits are showed in the appendix.



Figure 4.1: The 12 V Lithium Ion Battery Charger Controller circuit that using PIC16F877A and 2 units of Relays.

Figure above showed the best circuit had been design after studying the all the circuits based on their ability of doing the charging and controlling better compared to others. This circuit is using 1 unit PIC16F877A microcontroller, 2 units 10Amp relays and Light Crystal Display (LCD) which combined together to be a battery charger controller that fulfill the requirements of the project.



**Figure 4.2:** The Block Diagram that simplify the 12 V Lithium Ion Battery Charger Controller circuit.

The circuit showed on Figure 4.1 is simplified for easy understanding and the result is show as in Figure 4.2. The charging mechanism of this circuit start from the input send by the sensor to the microcontroller. There could be two type of input to send to the microcontroller as it must come from the battery. For this circuit of course the voltage value is the important to be considered as it determine the need of charging job. Thus, the voltage sensor is used to sense the voltage value available in the battery that need to be charge. Otherwise, there is also have temperature sensor used to give the value of temperature of the charged battery as it can also effect the charging mechanism as it has been used in some of previous study done before.

This value of voltage is then send to the microcontroller through the A0 pin on the microcontroller. The microcontroller process the input send into it based on the program that installed in it which determined by the users using software. Here, as it is programmed, the microcontroller read the voltage value and determine if the charging job is needed. This

mean that the microcontroller here is actually act as the controller of the whole mechanism. Next, there would be two output that the microcontroller produce. First, as it accept the voltage value, this value would be printed out on the LCD. Next, it would command the current to flow into the relays through the pin C0 and C1 which conduct as the output of the microcontroller. As the relay act somehow like a switch, it would close the circuit to allow the current flow out.

Here, the circuit somehow act as a controller which determine the need of charging job, there would need an external supply to supply enough current to charge the battery. As this project suppose to charge 12 V of battery, so the extenal supply of 12 V is needed. This circuit somehow is very useful as it can be adjusted to charge different voltage of battery. Adjusting the external power supply and the program code will change the circuit to be different voltage of charger. Remind that this charger also need power supply to run, there would be a power supply connect before the push up button. Push this button to switch on the circuit and push again to swith it off.

# 4.3 Modifications

### 4.3.1 Voltage sensor

As for this circuit, it is quite difficult to get a proper voltage sensor which use to sense the voltage value of the battery and to send it to the microcontroller. Within deeper consideration, the best way to overcome this problem is to replace it with a potentiometer which can give variety of resistance values to the circuit. These values are then read by the microcontroller as voltage values.



Figure 4.3: Potentiometer

- 1-5k Ohm of potentiometer used to replace the use of sensor.
- Adjusting the potentiometer to increase or decrease the input value and display the voltage value on the LCD.

## 4.3.2 Battery test

The second consideration is, the result of controlling and charging job are showed by the operating relay(s). This consideration is taken as it has been advised by the expert that testing a circuit which is operating with a 12 V battery and it is not validate yet is could be danger and quite risk. It could be short circuit and even burn the circuit if the test is not success. This must be avoid as there is only one circuit that we have for this project and there will be a lot of waste to get another one to run the test over again.

# 4.3.3 Parameters consideration

Next, would be the battery parameters that really need an intention as we are working with battery for this project. These parameters are related to the Lithium Ion type of battery only.

• Maximum Charge voltage, usually 4.2 volts per cell, sometimes 4.1

- Maximum Charge Current, often expressed as 1 C or .5 C where C is the nominal battery capacity in mAH.
- Battery pin-out
- Thermistor nominal resistance at room temperature 10K is most common

This parameters need to be consider first before working with the battery especially when building a charger. The thermistor is usually used when the temperature is considered in the study. However, as the input for the microcontroller is only the voltage value so the parameters relate to the thermistor is ignored.

# LC PIC16F877A View of the second seco

# 4.4 The battery charger controller circuit

**Figure 4.4:** The 12 V Lithium Ion Battery Charger Controller using Potentiometer to give variety of value.

As shown by Figure 4.4, the real circuit is atually used a potentiometer to give the input to the microcontroller and the output determined by the operating relay(s). plus, the circuit come out with the Light Emission Displays (LED) connect to the relays, these LED would show the operating and nonoperating relays. This is a ready build circuit, so the connecter wires are used to connect all the other components to the microcontroller.

## 4.5 Writing the programming for PIC16F877A

The program has been written using Visual Basic software which is in C language. There have some parameters to be consider first before start with the command writing. Writing the programming required a good understanding of C languages .

```
#include <16f877a.h>
#device adc=8
#use delay(clock=20000000)
#fuses hs, protect, nowdt, nolvp
#define use_portb_lcd TRUE
#include <lcd.c>
#byte porta=5
#byte portb=6
#byte portc=7
void main()
{
   float myvolt;
   long int myadc;
   set_tris_a(0b00000001);
   set_tris_b(0b00000001);
   set_tris_c(0b00000000);
   setup_port_a(ALL_ANALOG);
   setup_adc(ADC_CLOCK_INTERNAL);
   set_adc_channel(0);

   lcd_init();
   lcd_putc("\fvolt Meter");
   output_high(pin_c0);
   output_low(pin_c1);
   delay_ms(2000);
   output_low(pin_c1);
   lcd_putc("\f");
   delay_ms(1000);
```

```
do
{
    myadc=read_adc();//read adc value
    //convert adc to voltage
    myvolt=myadc*12.0;
    myvolt=myvolt/255.0;
    //display on lcd
    lcd_gotoxy(1,1);
    printf(lcd_putc, "volt:%03f", myvolt);
    if(myvolt>=12)
    {
        output_high(pin_c0);
        output_low(pin_c1);
    }
    else
    {
        output_high(pin_c0);
        output_high(pin_c1);
    }
    delay_ms(500); //refresh data every 500ms
}while(1);
```

# Figure 4.5: The Program code setup for the Batter Charger Controller

Figure above is a setup of a program code that will run the circuit based on project's requirements. Some of the first lines are the required parameters to be stated before writing the program. The input of the microcontroller would be read from A0 pin. So, command

```
set tris a(0b0000001);
```

}

means the input. This input is then displayed on the LCD after it is process to convert it into the voltage value from the resistance value give by the potentiometer. This is showed by

```
myadc=read_adc();//read adc value
```

```
//convert adc to voltage
myvolt=myadc*12.0;
myvolt=myvolt/255.0;
```

//display on lcd
lcd\_gotoxy(1,1);

printf(lcd\_putc,"Volt:%03f", myvolt);

The circuit must allow the charging job take place when the voltage value is below 12 V. So, there would need the two relays work together to make fast-charge of the battery. The output of the microcontroller that goes to the relays are set to be on pin C0 for the first relay (R1) and C1 for the second relay (R2). On the other, when there is sufficient voltage of battery, one of the relay must switched off while the other one keep running. This will avoid the voltage drain out or discharging before the battery is removed. These are showed by the command

```
if(myvolt>=12)
{
    output_high(pin_c0);
    output_low(pin_c1);
    else
    {
    output_high(pin_c0);
    output_high(pin_c1);
    }
}
```

The program is written using Visual Basic software in C languages. It is then reboot using other software which usually comes along with the compiler. Rebooting means convert the c language used to the machinery language which using binary number. It is then compiled or installed into the microcontroller using the compiler.

# 4.6 The Circuit Testing

The circuit of battery charger controller is now ready for test. For the first run of testing, the input of 0 V is to be set. This is done by adjusting the potentiometer in anticlockwise direction which yields zero resistance sense by the microcontroller. So, just when the microcontroller read the value of zero, it would convert into the voltage value as it is programmed to be, thus, there would be zero value of voltage set as the input of the charger and this value would appear on the Light Crystal Display (LCD).



Figure 4.6a: The LCD show the input value of 0 V



Figure 4.6b: Both LED light on show that both of relays are operating

On the second run of testing, the input of 12V is to be set. This is done by adjusting the potentiometer in clockwise direction which yields maximum resistance sense by the microcontroller. So, just when the microcontroller read the resistance value, it would convert into the voltage value as it is programmed to be, thus, there would be 12V value of voltage set as the input of the charger and this value would appear on the Light Crystal Display (LCD).



Figure 4.6c: The LCD show the input value of 12 V



Figure 4.6d: First LED light off show that first relay is not operates

# 4.7 Discussion

Remind of the problem statements of this project either the analysis of the circuit testing result answering the problem statement or not. The first problem that claimed on earlier of this project is about charging the battery beyond the sufficient limit issue which can cause damage either to the battery itself or even the other components that related. So from the first run of the circuit testing, the input give is below 0 V which claimed as the initial voltage of a battery and seems that both of relays operating and light on the LED connected. So, the current from the external power supply can flow into the battery and start charging the battery. This condition proves that the circuit is automatically runs when it sense lack of voltage in a battery and will charge the battery which means that the first problem statement has been solved.

On the other way, the second problem statement would be considered. Recall the problem statement that is to have a system which can automatically charge the battery when it has insufficient voltage can give human a better way of life. So for the second run, it is tested by the input of 12V as the condition of the fully charged battery. The result, the first relay is operating and light on the LED while the other one is off. This means that the circuit is automatically stop charging the battery as it cut the connection of the external power supply to the battery while the first relay used to maintain the charge and avoid voltage drain out before the battery is removed.

This mean that the results get had answered the problem statements of this project. Based on this result, the objective of this project that is 'To design a battery charger controller for an Electric Vehicles (EV)" had successfully achieved. The circuit passes the requirements need for the Project; as it is design to charge 12V Lithium Ion type of battery, using the PIC 16F877A microcontroller, the voltage had been displayed on the LCD and the relay(s) operated show by the lighting of the LED.

## **CHAPTER 5**

# CONCLUSION AND RECOMMENDATION

### **5.1 Introduction**

This chapter will discuss about the recommendation and the overall conclusion of the project.

### **5.2 Recommendation on Future Work**

It is recommended to upgrading on the charging mechanism of the circuit as it has been recognized to be a charger within a controller. As it is an early design and quite basic, there are a lot parts or areas of the project that can be focused on for further study to get a better or even best design. One day, Electric Vehicles are widely used, the battery charger for it must be almost like something on petrol stations which can connect to the EV car and charge the large voltage of battery inside within a proper time based on users needed.

In order to achieve it, there must be a consideration about time in charging mechanism. It is recommended to the next inventor to further the study about the time needed to charge and discharge a battery. A proper analysis need to be proposed so that once the road is full of EV cars, there should not have a long queue at the station waiting for charging as it long time to finish.

However, the charging mechanism also had something to do with the value of current that flowing into the charge battery. And this is also related to the time needed to charge a battery. So, the other recommendation is to have further study about the relationship of current flowing into the battery with the time in order to charge a battery sufficiently. In this way, the best charger can be produce to meet the users need as one inventor should confront the problems of the society and not bring the problems to them.

### **5.3** Conclusion

Recall the objectives of this project; this is a project to design a battery charger controller for electric vehicle. To achieve it, there are numbers of circuit had been studied and compared to get the best design of battery charger controller. There are several designs and ways to charge and to control a battery especially lithium ion battery like using a microcontroller.

However, the best and simplest way to have the charging and controlling both working perfectly is to be chosen. So, the solution is by using a microcontroller which is programmable so that we can program it with a proper source code like what we need to get both of work done. It recommends the best design for doing the electrical task for the product. In this project, it is programmed to be a controller to conduct the charging mechanism like when to start and when to stop. Thus, the voltage parameter is to be considered and setup properly in the program code.

In the simple word, this design is actually running automatically start from the sensor sense the voltage value of the battery until it finish charging the battery sufficiently. This design somehow give solution on the battery problem as it can damage in the fact of over charging. But in this circuit, based on considerations the voltage sensor is then replaced by the potentiometer which gives the values of resistance to the microcontroller. The resistances are then read as variety of voltage value by the microcontroller.

As the circuit had successfully done its job that is to charge and stop charge automatically, the overall objectives of this project had been achieved. Having a controller in charging mechanism is the best designs of a charger which can contribute a lot in humanity in their daily life as it help users to keep their battery safe and last longer.

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# **APPENDIX A**



i) The closer look of the PIC16F877A schematic diagram



ii) The closer look of relay circuit schematic diagram



iii) The closer look of LCD diagram



iv) the closer look of the charged battery circuit diagram

# **APPENDIX B**

```
#include <16f877a.h>
  #device_adc=8
  #use delay(clock=20000000)
  #fuses hs, protect, nowdt, nolvp
#define use_portb_lcd TRUE
  #include <lcd.c>
  #byte porta=5
  #byte portb=6
#byte portc=7
   void main()
   {
         float myvolt;
long int myadc;
         set_tris_a(0b00000001);
set_tris_b(0b00000000);
set_tris_c(0b000000000);
         setup_port_a(ALL_ANALOG);
setup_adc(ADC_CLOCK_INTERNAL);
set_adc_channel(0);
do
{
      myadc=read_adc();//read adc value
     //convert adc to voltage
myvolt=myadc*12.0;
myvolt=myvolt/255.0;
     //display on lcd
lcd_gotoxy(1,1);
printf(lcd_putc,"volt:%03f", myvolt);
          lcd_init();
lcd_putc("\fVolt Meter");
output_high(pin_c0);
output_high(pin_c1);
delay_ms(2000);
output_low(pin_c0);
output_low(pin_c1);
lcd_putc("\f");
delay_ms(1000);
```

The program code for PIC16F877A which written using Visual Basic software in C

language

# APPENDIX C

PROJECT	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
ACTIVITIES														
Project														
confirmation														
Literature study														
Introduction														
Literature														
review														
Design														
Methodology														

First Semester Project Gantt chart

# APPENDIX D

PROJECT	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
ACTIVITIES															
Component															
surveying and		· ·													
purchasing															
Circuit															
development															
Circuit tested															
Modification															
Result analysis															
Presentation															
preparation															
Documentation															
Full Report															
submitting															

Second Semester Project Gantt chart

# **APPENDIX C**

PROJECT	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
ACTIVITIES														
Project														
confirmation														
Literature														
study														
Introduction														
Literature														
review														
Design														
Methodology														

First Semester Project Gantt chart

# **APPENDIX D**

PROJECT ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Component surveying															
and purchasing															
Circuit development															
Circuit tested															
Modification															
Result analysis															
Presentation preparation															
Documentation															
Full Report submitting															

Second Semester Project Gantt chart