DEVELOPMENT OF ELECTRIC VEHICLE PROTOTYPE: ELECTRIC VEHICLE INTELLIGENT CONTROL SYSTEM (EVICS)

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

Faculty of Engineering and Science
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May 2011

DECLARATION

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

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APPROVAL FOR SUBMISSION

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Approved by,

Signature : _________________________

Supervisor : Assistant Prof. Dr. Chew Kuew Wai

Date : _________________________

Specially dedicated to

my beloved family, lecturers and friends

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DEVELOPMENT OF ELECTRIC VEHICLE PROTOTYPE: ELECTRIC VEHICLE INTELLIGENT CONTROL SYSTEM (EVICS)

ABSTRACT

The Electric Vehicle Conversion: Electric Vehicle Intelligent Controller System (EVICS) project aims to create a multiple platform controller that can control each and every function needed to be implemented in an electric car system such as battery management system, inverters, amplifiers, voltage converters, constant current controllers etc. The main common problem faced is that microcontrollers used in university assignments and projects such as PIC are not powerful enough to control multiple platforms in our electric car intelligent controller system. Even by using a few of the most powerful PICs, it is not possible to guarantee the reliability to control complex systems such as the Lithium-ion battery management system. However, with the use of the Intel Atom processor platform, it is possible to achieve this level of reliability and functionality. The electric car is expected to have a comprehensive intelligent controller system that can manage the battery profile accordingly, display the level of charges left in the battery on a monitor, interact with the user's commands accurately to operate the hardware, regulate the speed of the motor accordingly to the acceleration applied, ensure the safety aspect of the vehicle is always in good condition and display warnings if something is not right, manage the thermal or temperature level of the battery and controller accordingly and provide an alarm indicator if overheating of components occurs and many more. To conclude, the Intel Atom processor will provide us with the perfect platform to implement our system with reliability, confidence, comprehensive functionality, more accurate management control etc.

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LIST OF SYMBOLS / ABBREVIATIONS

Ω	Resistance, ohms
hp	Horsepower
V	Voltage, Volts
I	Current, Amperes
R	Resistance, ohms
EVICS	Electric Vehicle Intelligent Control System
LDR	Light Dependent Resistor
BMS	Battery Management System
BMU	Battery Management Unit
CAN	Control Area Network
BCU	Battery Control Unit
EV	Electric Vehicle
ECU	Engine Control Unit
SOC	State of Charge
AC	Alternating Current
DC	Direct Current

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CHAPTER 1

INTRODUCTION

1.1 Background

In an Electric Vehicle (EV) design, the power management system and controller plays an important role as a 'brain' of the EV, to ensure the car can run smoothly and in order. The main objective is to develop a battery performance management system, a smart monitoring system having the ability to manage individual cells and at the mean time isolating the weaker ones from the system. These criteria are strongly needed in today's EV. Very few microcontrollers can be used to control multiple and complicated functions in an EV controller design, therefore the Intel Atom platform provides one of the most suitable solution that can be implemented to manage the components of the EV without much problem.

The concept of this project is basically to develop a system that operates battery monitoring, in which it keeps track on the operational parameters of charging and discharging. This may also include monitoring of other crucial parameters, such as voltage, currents, battery internal and ambient temperature (temperature surrounding the vehicle). On the other hand, the controller in this case, must be smart enough to provide proper protection to the system by providing an appropriate indication to sound an alarm or electronically disconnect the battery from the load if any of the parameters exceeds its limit.

The main functions of a controller are basically to control the main contactor and kill switch contactor and incorporating appropriate safety measures and interlocks. Furthermore, it also controls the reversing contactor and power the vacuum pump in the EV braking System. Besides, it will wait for command to send power to the heater contactor and also the DC-to-DC-contactor, whereas the power management system ensured that the power distributions are in order and at the meantime achieving maximum transfer efficiency. The power management system includes converter circuit, charging circuit, motor drive and base drive circuit. In this project, the works are mainly focus on power management system and base drive circuit inclusive of their controller and converter circuit. The functionality of each of the controllers will be investigated and discussed.

Initially, an analogue controller using logic chips, transistors and op-amps is used to control the speed driver and direction of rotation of the motor. All these processes will be converted into a digital form which will be controlled solely by an Intel Atom platform to receive feedbacks from the motor and respond respectively to the source code programmed in the microprocessor. The expected performance of an Intel Atom should be much better than the analogue controller since digital circuits embedded into a microprocessor has less physical connections such as wire soldering and is only controlled by a set of programmable codes which reduces the chances of error and improves reliability.

1.2 Aims and Objectives

The aims and objectives of this project are to:

- Analyse and determine the functionality of the Intel Atom platform
- Design and build many different modules for monitoring and managing the performance of battery supply in the EVICS
- Design and build a fail-safe system which can protect, isolate and switch the whole system to a back-up power supply if the Intel platform fails.
- Determine the innovation and creative ideas from the EVICS project that can be a good selling point to win the Intel Competition
- Calculate the cost of project throughout the whole process and conduct a thorough budgeting at the end to ensure everything is spent within the budget.
- Compare and state the advantages of using the Intel Atom platform compared to other design architectures currently being used in electric vehicle's embedded systems such as the ARM platform.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The primary application of this BMS is to provide necessary monitoring and control, avoiding the cells from damaging due to over rating temperature condition. This is essential as the vehicle may be working under harsh conditions and it may also be affected by the diversity in climate (Tropical Climates, Subtropical Climates, Mediterranean Climates, Temperature climates, Arctic temperature and Desert Climates) within a particular continent which will have implications on the overall ambient temperature. Hence, individual cell in the automotive must be protected by isolating the batteries to detect the cause of the fault when an external fault takes place. For instance, the batteries should not be disconnected improperly as disconnecting the battery source when the heat is generated within a system is severe. However, for non-severe cases, we may turn on an additional fan attached in front of the battery.

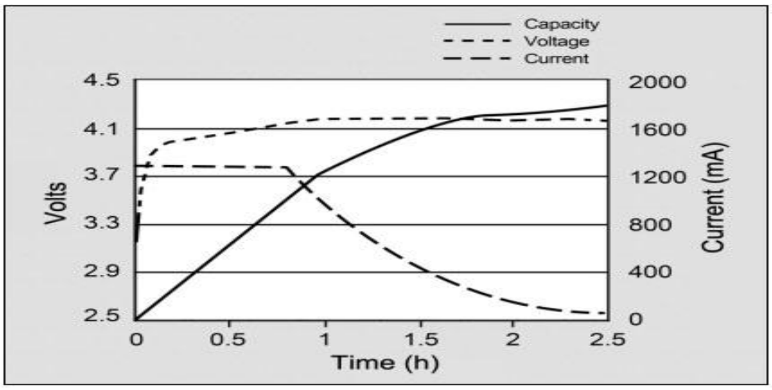


Figure 2.1: Charging Profile of Lithium Ion Battery (Battery University, 2011)

Secondary major development of BMS refers to state of charge (SOC) determination. This basically provides the user some indication about the amount of energy left in the battery packs before performing any recharging. This SOC estimation is also assumed as the "Gas Gauge" or "Fuel Gauge" function. In this design, SOC basically calculates each of the individual cells within the battery besides ensuring them from overstressed condition. Apart from that, with the SOC indicator, over-charging and over-discharging condition can be prevented since each of the charging and discharging cycle can easily be monitored.

Apart from that, electric cars are driven by large electric motors usually rated between 3.5 and 40 horsepower. Compared to gasoline engines, this may not seem like much power, but the rating systems used for gasoline engines and electric motors are different because gasoline engines are rated at their peak horsepower and electric motors are rated at their continuous horsepower. The peak horsepower of an electric motor is usually 8 to 10 times its continuous rating.

Electric vehicle drive motors can be divided into two basic groups, DC or direct current motors, and AC or alternating current motors. DC motors have a long history in EV use. The most commonly used version is known as a series-wound motor, which means the armature and field windings are wired in series. Other designs include shunt-wound, compound-wound, and permanent magnet motors. At the present time AC motors are most commonly found in commercially built EVs, as they require more sophisticated and complex control systems than DC motors.

Atom processor is a very powerful platform, capable of multitasking and modelling. Below are the functions of the Atom processor platform which can control and display as an interaction interface to the users.

2.2 Battery Monitoring Unit (BMU)

The Battery Monitoring Unit is a microcontroller mainly used to monitor the "health" of the battery bank. In other words, BMU calculates battery capacities apart from battery efficiency from time to time and simultaneously monitor each of the cells upon cell deterioration prior to failure as illustrated by three sub-module of BMU. This sub-module is separated for the purpose of clarification. Battery failure can easily be determined by monitoring the cell voltage during discharging. Note that, in this case, the charging voltage drop should not be long enough. This type of failure, however, can be classified as battery abuse in which the main causes are high temperature and excessive charge current. Other typical factors that may give rise to battery failure are aging and premature-failure where they are caused by corrosion and manufacturing defect respectively.

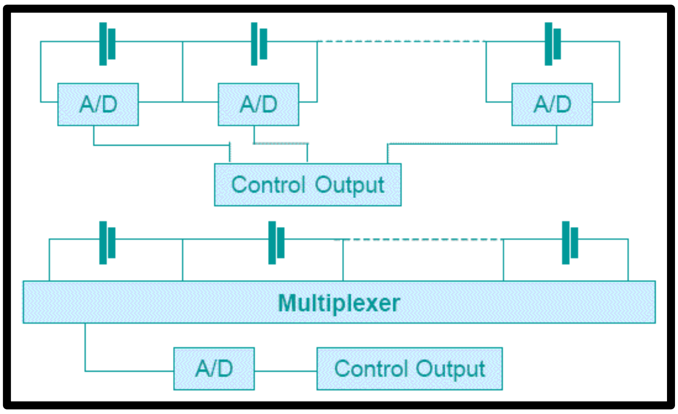


Figure 2.2: Multiplexer to reduce component count (The Electropaedia, 2005)

Apart from monitoring all of the cells in parallel, a multiplex architecture can be easily interfaced to the BMU in order to reduce cost. Based on this design, only a single analogue or digital output can be monitored from time to time. One of the drawbacks of this system is that only one voltage cell can be determined at a time. Hence, a very high speed mechanism is required, so that each cell can be monitored sequentially.

2.3 Battery Control Unit

Power electronics circuitry is the main component within the Battery Control Unit (BCU). From Figure 2, it is observed that BMU obtains its instruction in terms of control signal from the earlier block that is mentioned earlier, BMU carries out a specific task which is controlling battery charging profile. In this case, the BMU also controls the voltage and current charging profile while providing a top up charge to each of the individual cell serving as a purpose to equalize all of the charges within the battery. Furthermore, it also protects the batteries by fault isolation. Additionally, the BCU offers a responsive regenerative function (energy taken from electric motor due to regenerative braking) to charge battery whenever it is required and remove any excessive braking charges generated during braking. Last but not least, the BCU is able to respond corresponding to the vehicle's operation mode. In order to have these functions working properly, each of the battery cells must be equipped with highly expensive current switch, having the capability to do switching around 200 AMPS or more in order to perform necessary interconnect.

Apart from that, cell balancing concept plays an essential role to ensure that each of the cells is evenly distributed as discussed. Furthermore, the declines of weak cells are monitored from time to time until it has reached to a certain point where it cannot be used. This however reduces the probability of damage due to overcharging process. Besides that, excessive discharging rate is mainly due to the time during regenerative braking where it is characterized as shorted but powerful bursts of charging current may occur at excessive voltages. In this condition it may exceed the battery charge capability. Furthermore, the SOC determination and Thermal Management System can be embedded under this module as well in order to preserve the lifetime of the battery.

2.4 Controller Area Network

Controller Area Network (CAN) was developed back in 1985 by Bosch to be used in vehicle network. Back in the past, automotive manufacturers started of by using point to point wiring. As time passed by, it was realized that having a lot of wires was not only bulky and heavy but also expensive. Today, CAN is used instead of traditional wiring as it is not only cheap, less complex and reduced in weight but more importantly it has high-integrity serial data communication for real-time control application integrated into standard in-vehicle network.

2.5 Thermal Management System

Thermal Management System is designed to monitor the changes in temperature due to chemical reactions in the battery and it will then perform necessary tasks such as heating or cooling the battery cells depending on its state. Tests conducted in the laboratory and with EV urban driving suggest that using a thermal management system improves the mileage and battery life by at least 20%. Thermal management system plays a very crucial role when performing rapid charging. For instance, during the charging process, large amount of charge is delivered to the batteries, hence temperature issues are inevitable.

The primary design is to keep the battery insulated. The insulation will help to enhance heat generation especially during winter or summer. On the other hand, the second design allows air circulation to be properly distributed to ensure optimum temperature, achieving equilibrium between battery and the surrounding and most importantly maintaining the efficiency of batteries. Note different design criterion should take place under various operating conditions.

2.6 Component of an electric vehicle

The main components of an electrical vehicle are motor, controller, power supply and of course the transmission channel.

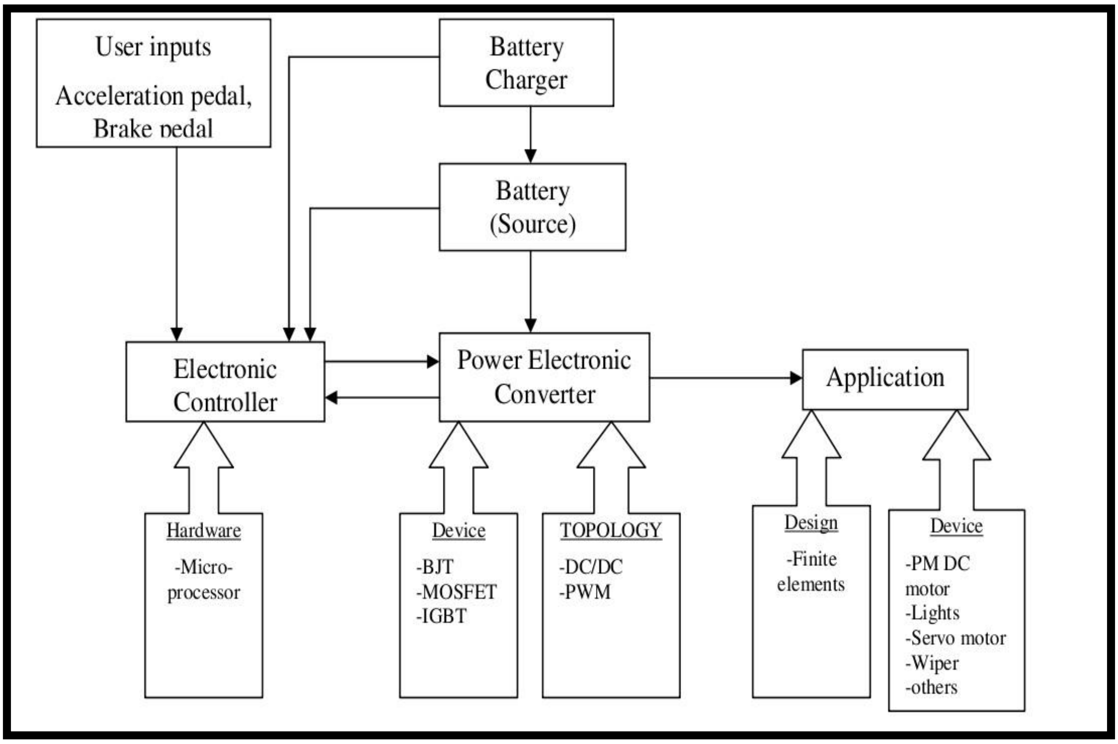


Figure 2.3: Illustration of major components and choices for an EV (Leitman, S., & Brant, B., 2009)

With reference to the diagram above, the power supply needs to be charged up in order to restore the energy level once its available energy is near to deletion usage. Note also that the electric motor is driven by a power-electronic-based power-processing unit that converts the fixed DC voltage available from a source into variable voltage to maintain the desired operation of the vehicle. Power electronics is always a key driving force in order to develop a more effective, efficient yet high performance power train unit for the battery. A drive train system simply refers to electromechanical conversion linkage system between vehicle energy source and wheels. In other words, the drive train has a combination of both electrical and electronic components.

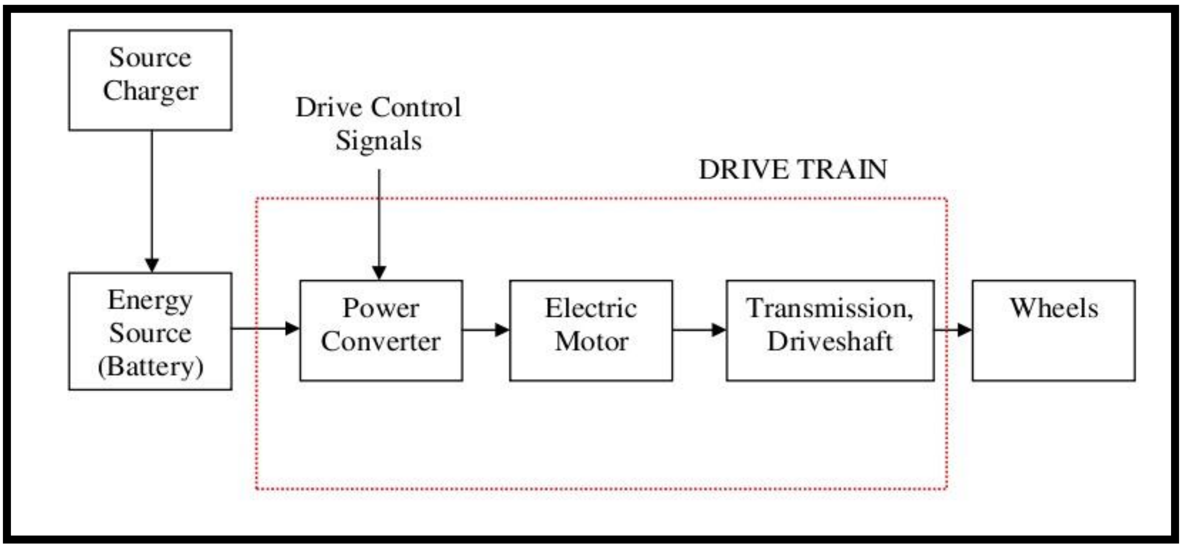


Figure 2.4: Top level perspective of a typical EV system (Husain, I., 2003)

2.7 Battery Management System (BMS)

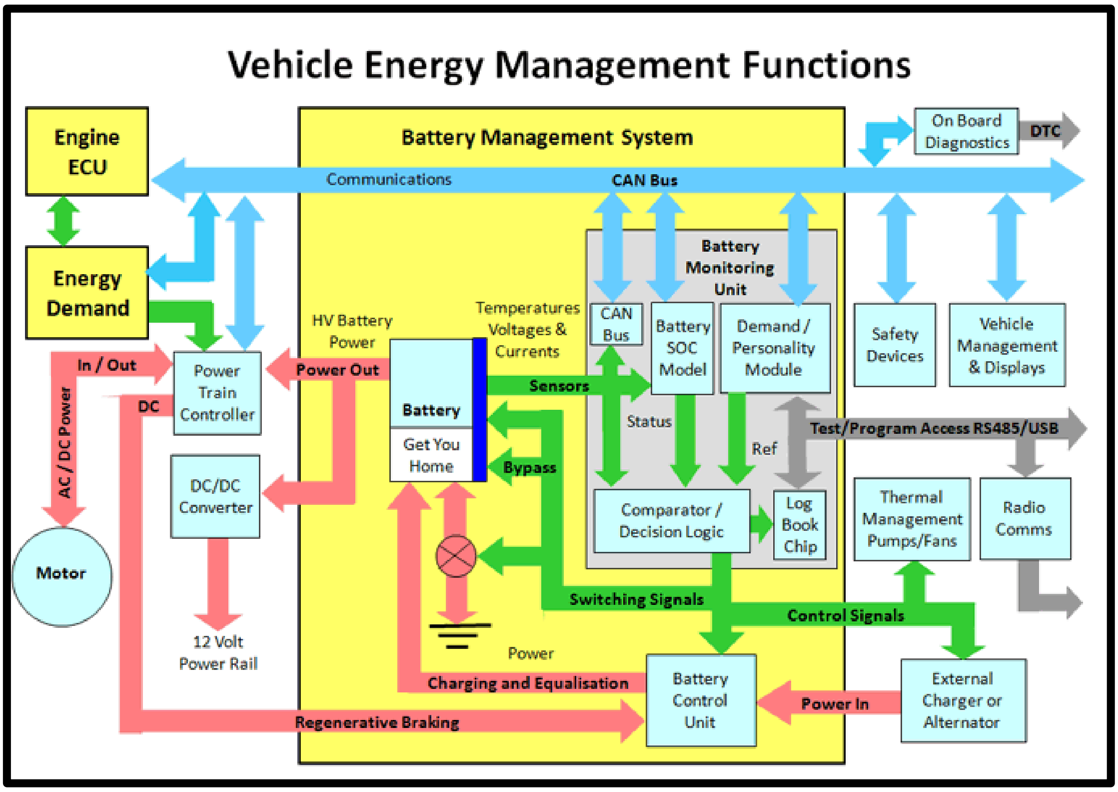


Figure 2.5: Conceptual Representation of BMS Primary Function (The Electropaedia, 2005)

The figure above shows a typical BMS for a hybrid vehicle. A hybrid shares almost the same features as any normal electrical vehicle. Thus, it can be used to model an electric vehicle BMS system. The ECU (Engine Control Unit) module is not needed in this case, since parameter concerning Internal Combustion Engine (ICE) is not being examined. The whole idea behind this BMS basically lies within Battery Monitoring Unit (BMU), Battery Control Unit (BCU) and Controller Area Network (CAN) bus vehicle communication network. Although, other parts of the vehicle systems may not only be connected to one another within a system, they are able to communicate with BMS via CAN bus such as Thermal Management System, including anti-theft devices which has the capability to disable the battery source.

CHAPTER 3

METHODOLOGY

3.1 Current Monitoring System

The main purpose of this circuit is to measure the charging current that is being supplied from the charger circuit into the 12V lead-acid battery. There are many ways to measure DC current such as using a Hall Effect current sensor, DC current clamp, multimeter etc. To save cost, the Intelligent EV Controller system makes use of a single very low resistance precision power resistor to measure the voltage drop and feed the values into the PIC. This method is effective and yet accurate because when the resistance is fixed, the current flowing across the power resistor will vary linearly to the voltage drop from the formula V=IR. The precaution step in this design is the power dissipation in the resistor where the maximum current flowing through it plays a significant role in selecting the power wattage of the resistor.

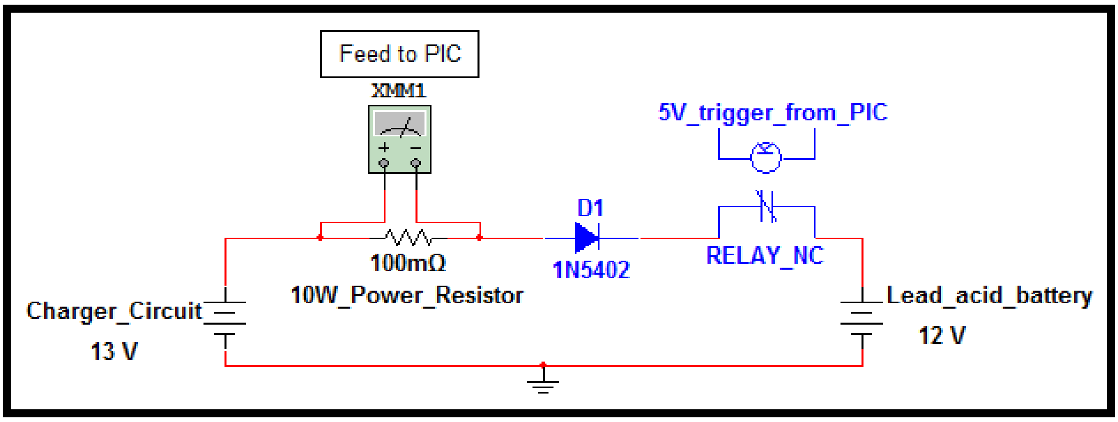


Figure 3.1: Multisim Simulation for Current Monitoring System

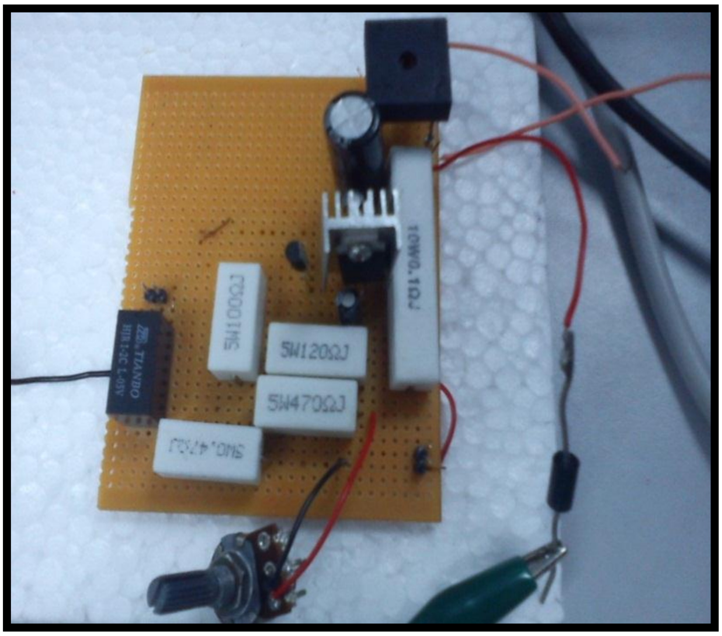


Figure 3.2: Current Monitoring System

3.2 24V/12V AC Supply

This module is important to serve TWO purposes:

- 24V AC supply for the charger circuit
- 12V AC supply for the +12V & -12V supply to the 741 op-amps

The basic design for this module is as follows. A 240V to 12V-0V-12V step down transformer is used for the design of this circuit. At the primary part of the transformer, a 2A fuse is used as the protection system and a switch is also included to turn the supply ON/OFF manually. At the secondary side, a red LED is used as an indicator to determine if the transformer is working properly and if the fuse has blown. The LED is connected in series to the 12V-0V terminals, together with a 1N4001 general purpose rectifier diode for forward biasing the AC supply and 1kΩ resistor.

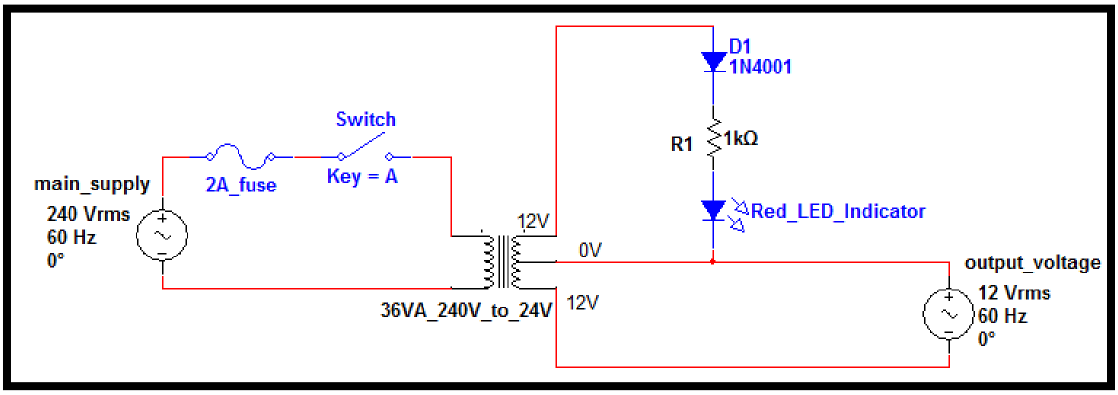


Figure 3.3: Multisim Simulation for 24V/12V AC Supply

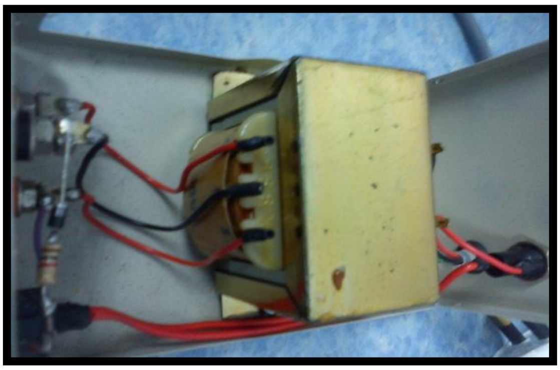


Figure 3.4: 24V/12V AC Supply

3.3 Positive & Negative Voltage Supply

The purpose of this module is to power up the positive and negative Vcc of the 741 op-amps used in the voltage monitoring system. This circuit design uses two different voltage regulator ICs:

- LM7812 for positive voltage regulation
- LM7912 for negative voltage regulation

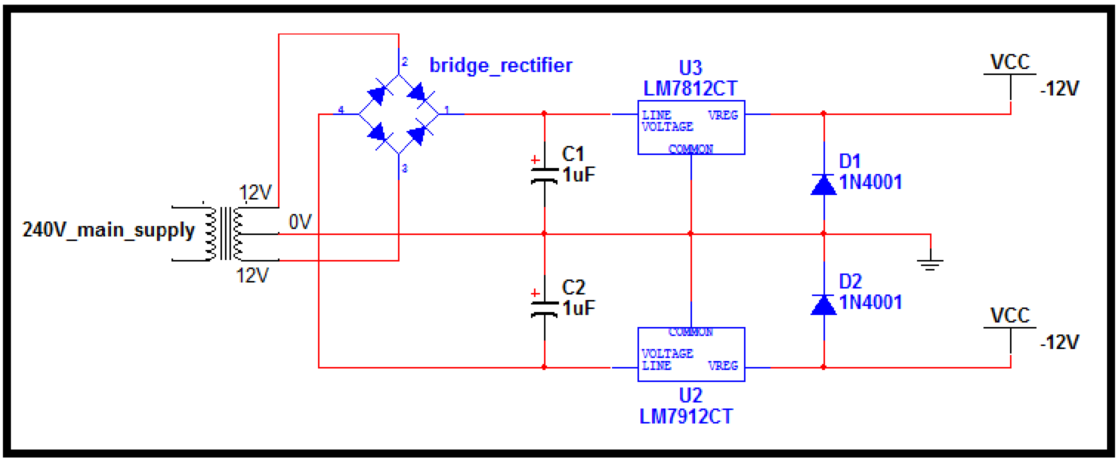


Figure 3.5: Multisim Simulation for Positive and Negative Voltage Supply

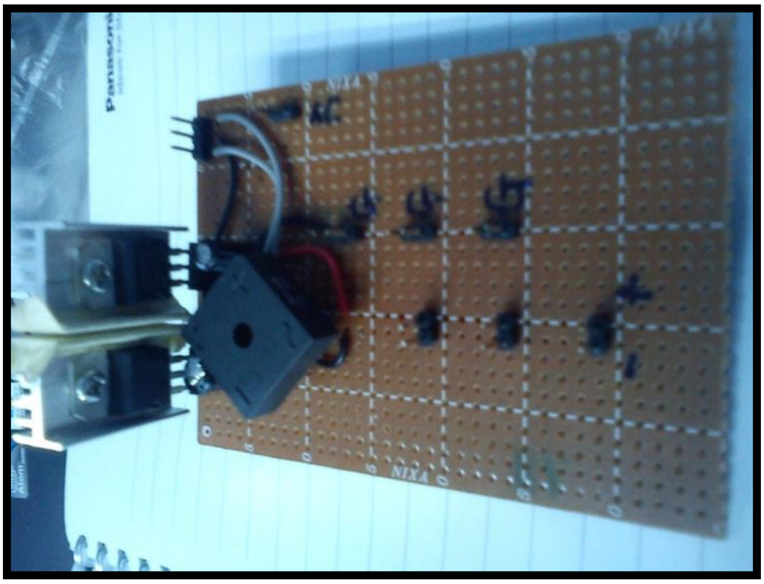


Figure 3.6: Positive and Negative Voltage Supply

3.4 Voltage Monitoring System

There are TWO similar voltage monitoring system in the Intelligent Controller to measure and monitor both the battery and motor voltage. The design of this system uses TWO 741 op-amps; first one for scaling the voltage down by 15 times so that the value can be fed into the PIC and the second one to invert the voltage from negative to positive. This method of measuring and monitoring voltage is low-cost and yet effective to get the results wanted. The Multisim simulation diagram of the circuit design is as below:

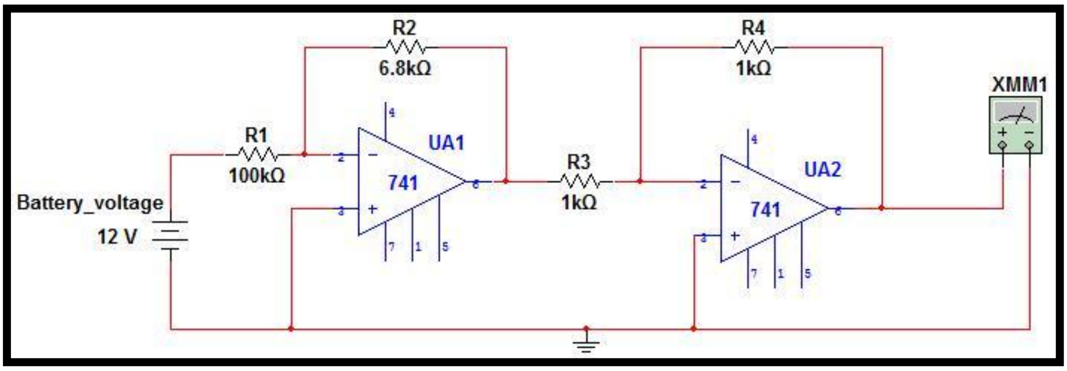


Figure 3.7: Multisim Simulation for Voltage Monitoring System

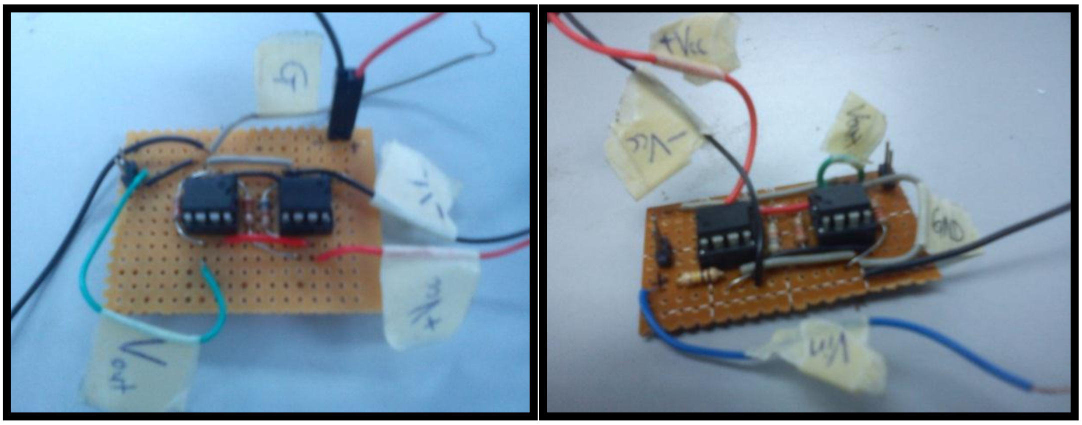


Figure 3.8: Voltage Monitoring System

3.5 Analogue Voltage Monitoring System

The Analogue Voltage Monitoring System is used to monitor the voltage level of the battery just in case the Intel platform suddenly fails to function. This is used because most of the monitoring systems are displayed onto the LCD screen which is connected to the Intel Atom platform. Therefore, if the Intel platform suddenly fails, this analogue voltage monitoring system is used to display the voltage level of the battery manually to the user.

This system uses an IC LM3914 dot/bar display driver to display the voltage levels of the battery from 8.5V up to 16.8V, a very comfortable range where lead-acid batteries can be operating on.

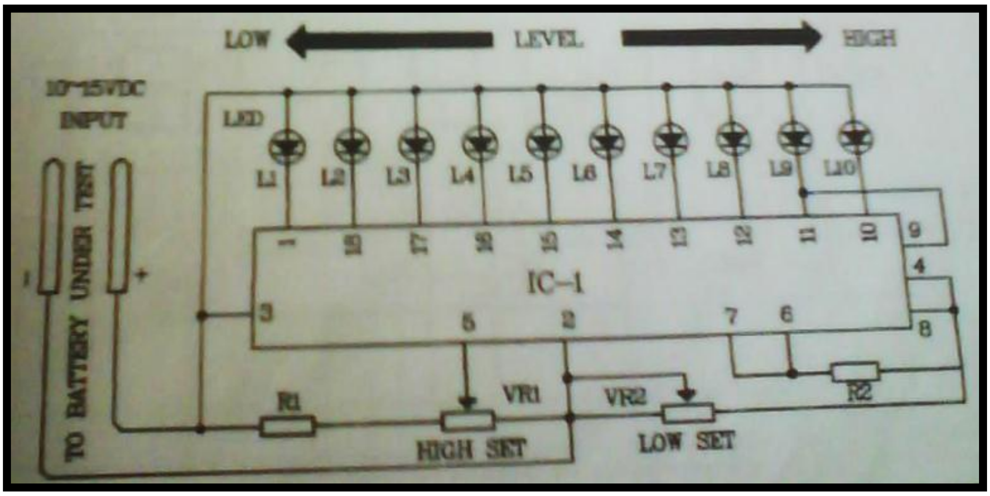


Figure 3.9: Analogue Voltage Monitoring System circuit design

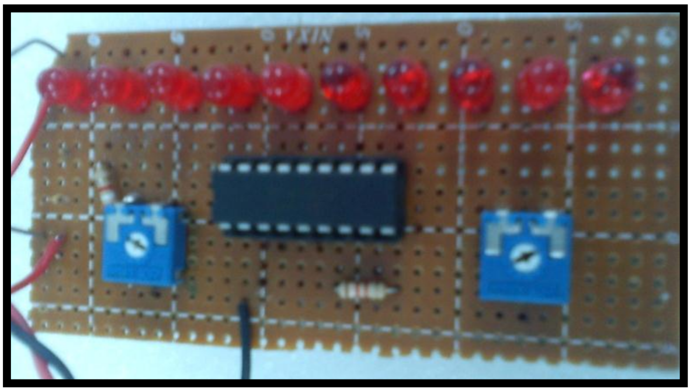


Figure 3.10: Analogue Voltage Monitoring System

3.6 LDR Lighting Monitoring System

In this module, the LDR lighting monitoring system is powered by the Intel board supply and there is a normal switch for the user to control the car lighting whenever they want. When the switch is turned ON, the two Luxeon LEDs will turn on as normal. Under this situation, the LDR (Light Dependent Resistor) will detect the ambient light intensity and adjust the brightness of the Luxeon LEDs according to the surrounding environment illumination. When the user switches off the car ignition, the Intel board's power supply will be turned off and this will automatically switch off the two Luxeon LEDs. Therefore, this will prevent the situation whenever the user forgets to turn off the lights after leaving the car.

At the same time, the Luxeon LEDs can be powered up manually if the Intel board suddenly stops functioning. There is an external power supply connected to the LDR lighting system directly from the car's accessory battery and a manual emergency switch is connected to the system. Therefore, if the Intel board stops functioning and the car is stranded by the roadside, the user can still power up the car's lights directly from the car battery using the manual emergency switch.

It is well known that power management and consumption in an electric car are very important because the power supply from the batteries to the whole system is very limited. Therefore, the purpose of using the LDR in an electric car's lighting system is to assist in saving energy whenever the lights are left ON under bright surrounding environment especially when the user forgets to switch off the lights during daytime. A more accurate light detecting device can be used to replace the LDR, which is the photo transistor as shown in the Multisim circuit diagram below which costs RM6. Therefore, to save cost for the overall project, the LDR which costs RM1.50 is used instead.

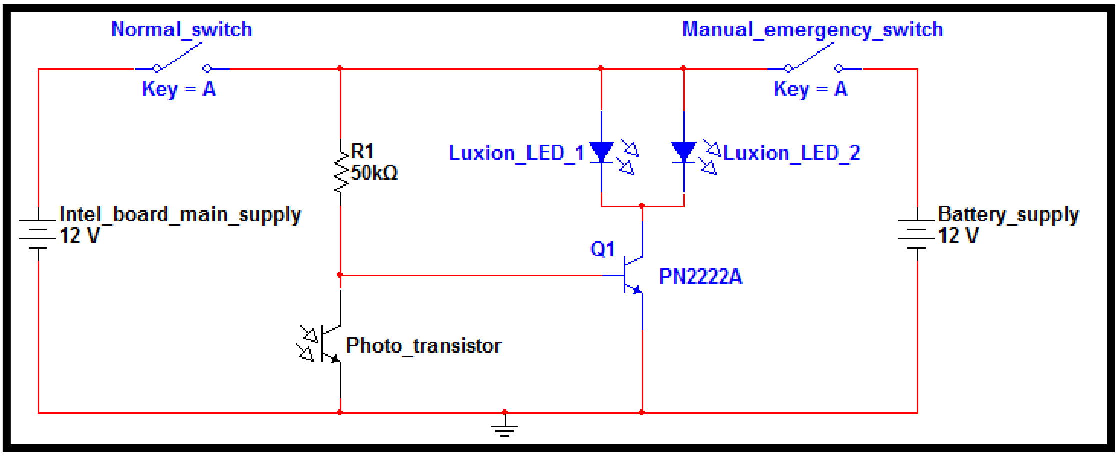


Figure 3.11: Multisim Simulation for LDR Lighting Monitoring System

In conclusion, the LDR lighting monitoring system is used to serve 3 main functions:

- Saves power and energy consumption by using high power LED lights
- Prevents LED lights from operating during daylight condition (LDR)
- Switches OFF the LED lights after user leaves the car (Intel platform)

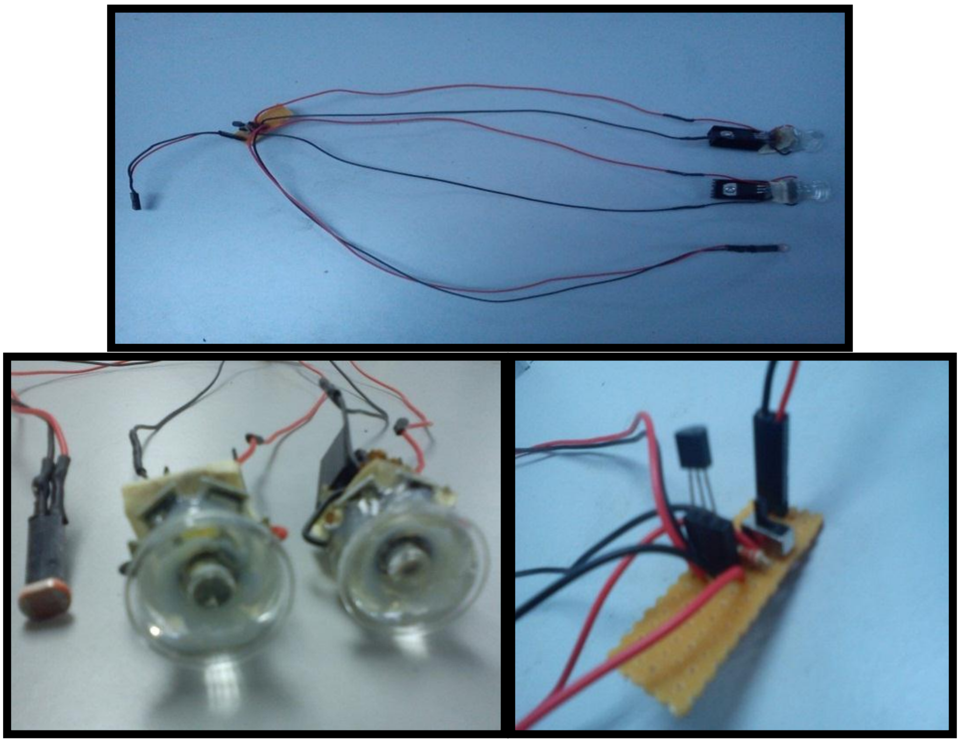


Figure 3.12: LDR Lighting Monitoring System

3.7 PIC Circuits and the 10 Commandments

To ensure that the monitoring system functions properly and without faults, the PIC must be in optimum condition all the time. Therefore, the stability of the PIC system and circuits must be taken into account seriously. There are a few commandments that are crucial to ensure that the PIC is working in stable condition all the time:

1. All VSS and VDD pins on the chip must be connected. Sometimes, there are two to three VSS and VDD pins on a PIC Microcontroller and they must all be connected together for the chip to work properly.

2. Bypass capacitor of 0.1uF must be connected across the VDD and VSS pins as close to the chip as possible. Bypass caps must be used regardless of any other capacitors in the power supply circuit. These may appear insignificant compared to large filter capacitors or capacitors used for the voltage regulator, but they must be used to regulate the 5V supply to the PIC.

3. MCLR (pin 1) must be connected to VDD with a 10k resistor or explicitly disabled in the source code. A floating MCLR pin may lead to intermittent operation, if the chip operates at all.

4. Ensure that multiplexed port pins are correctly set up. Many port pins can have multiple functions depending on how the PIC is configured. When using these pins, ensure that the desired function is enabled. Most notable are pins with analogue functions, which often default to the analogue state. When planning to use these pins for digital functions, such as driving an LED or reading a switch, the digital function must be specified.

5. If using a development board, verify the purpose and connection of jumpers and accessories on the board, and understand the effect these may have on the circuit. For example, if the development board has a pot connected to one of the analogue inputs, the sensor input will be inaccurate or not seen at all. Digital inputs may never change if the pot is rotated all the way to one end.

6. The first programming step is a blinking LED program. Trivial and silly but it verifies that the power supply is working, the chip is running, and the programmer can program the chip properly. If the LED flash rate is set to 1 second, it is also easy to verify that the clock is operating at the right frequency (Chandler, J., 2010).

7. Use a crystal oscillator. It is hard to beat the simplicity and reliability of an external crystal, with 22pF capacitors on each leg to ground. Internal oscillators may be used but this adds complexity to the code and there may be problems with start-up delays.

8. Use ICSP and the PICkit 2. Removing the chip each time it is programmed is a waste of time. Boot loaders can work well, but ICSP is by far the easiest way to program a chip. Using Microchip's PICkit 2 is the easiest and nearly the cheapest way to implement ICSP. The logic analyser and UART tool are additional benefits of the PICkit 2. When using ICSP, it is best to keep the PRGC and PRGD pins dedicated to programming. These pins may be used for other purposes if the design does not load the pins excessively. The Microchip documentation on ICSP is a great reference for design ideas. There are several designs for programmers that use a serial port or parallel port but these ports are rare on new computers, and available USB adapters do not always work.

9. A good starting point for many programs is a UART output. Even if a UART output is not part of the final project, setting up and testing a UART output can be a good idea. Since the PICkit 2 makes it simple to monitor a UART output, adding the code at the start can aid troubleshooting later. A message that says "subroutine 2, x = 5" is far easier to understand than an LED blinking on and off.

10. Keep data sheets, schematics and programming documentation close at hand. Having the necessary reference material handy makes programming easier.

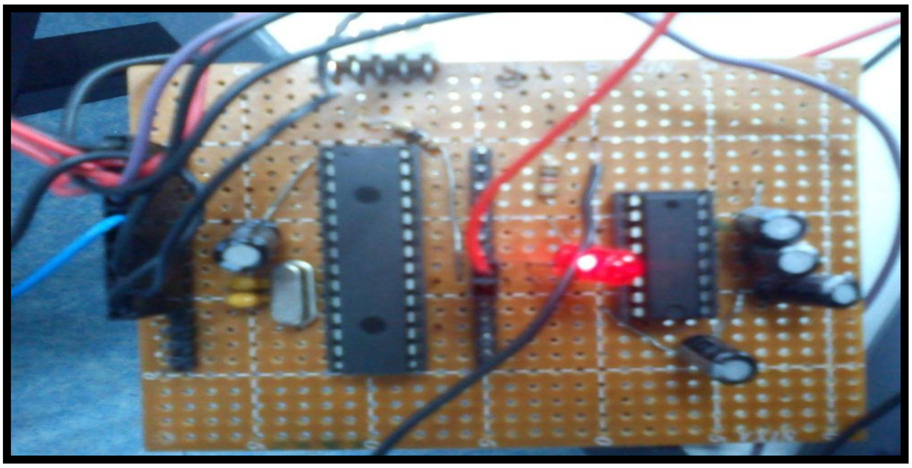


Figure 3.13: First PIC prototype

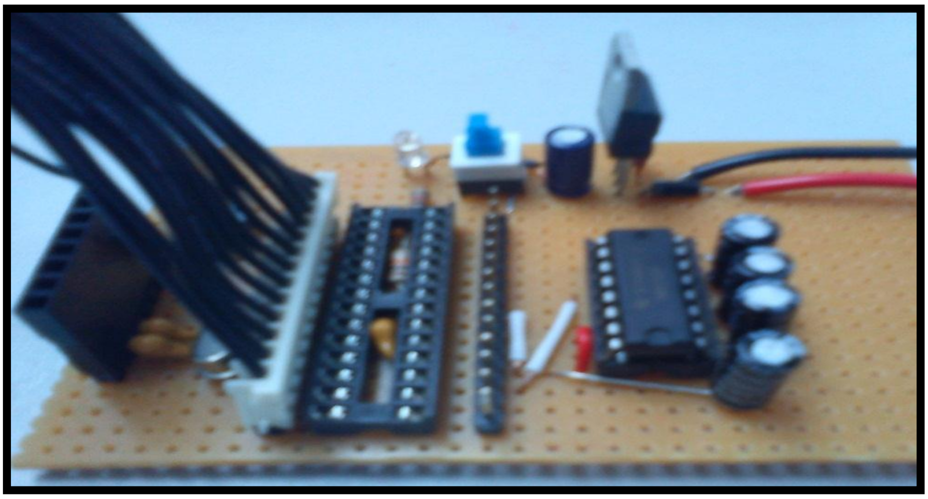


Figure 3.14: Second PIC prototype (neat and tidy)

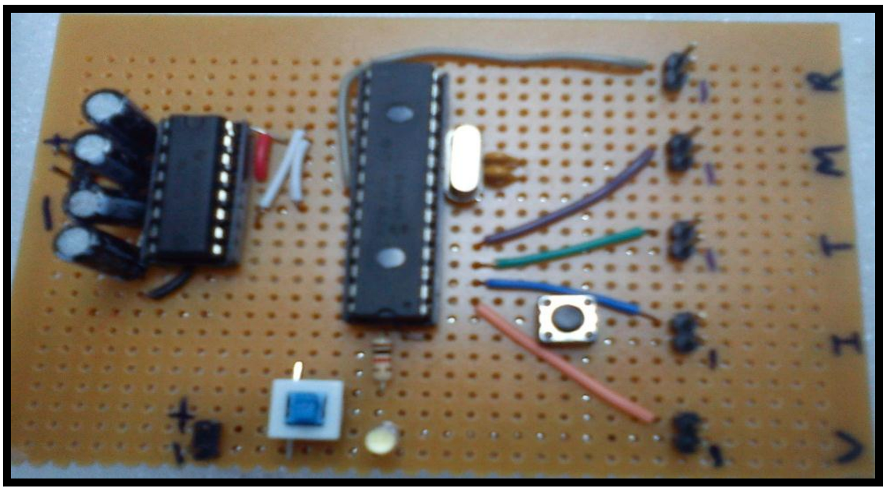


Figure 3.15: Third PIC prototype (wireless)

3.8 350W Inverter (12V DC to 240V AC)

In a practical electric car, the whole system is powered by either lead-acid or lithium-ion battery which is a DC power source. Therefore to power up the Intel board's power supply, it is necessary to have an AC power source. To do that, a DC to AC inverter is needed. The main criteria in selecting an Inverter is the output power. To determine the output power, it is essential to know the types of load that are being connected to the output of the inverter. In the Intelligent EV Controller system, the main loads that need to be powered up by the Inverter are Intel board, hard drive storage, LCD monitor, modem router and 36VA step-down transformer. The total maximum power load of all the main components is approximately 200W; therefore, a 350W inverter is used between the battery and the load. The inverter chosen and used is as below.

Figure 3.16: 12V DC to 220V AC Inverter

The features of the 350W inverter are as below:

- Has multiple protection circuit to protect equipment and automobile
- Special versatile / Universal socket, suitable for various kinds of plugs
- Insert 3-pin power plug of electrical appliance into the socket of inverter
- Insert the front part of inverter into the cigar socket of the automobile
- Make sure that the power indicator light is ON
- Voltage Protection, over-load protection and short-circuit protection
- USB output DC 5V 0.5A

Specifications (Comfort Surf., 2011):

Power Rating	**350W**
Max. Power	700W
Continuous Power	280W
Input Voltage	12V
Lower Voltage Stop	10V +/- 0.5V
Over Voltage Stop	15V +/- 0.5V
Protect temperature	50 degree Celsius +/- 20%
Output Voltage	220V +/- 10%
Output Frequency	50Hz +/- 2Hz
Volume (mm)	122.4x89x47
Weight (KG)	0.42

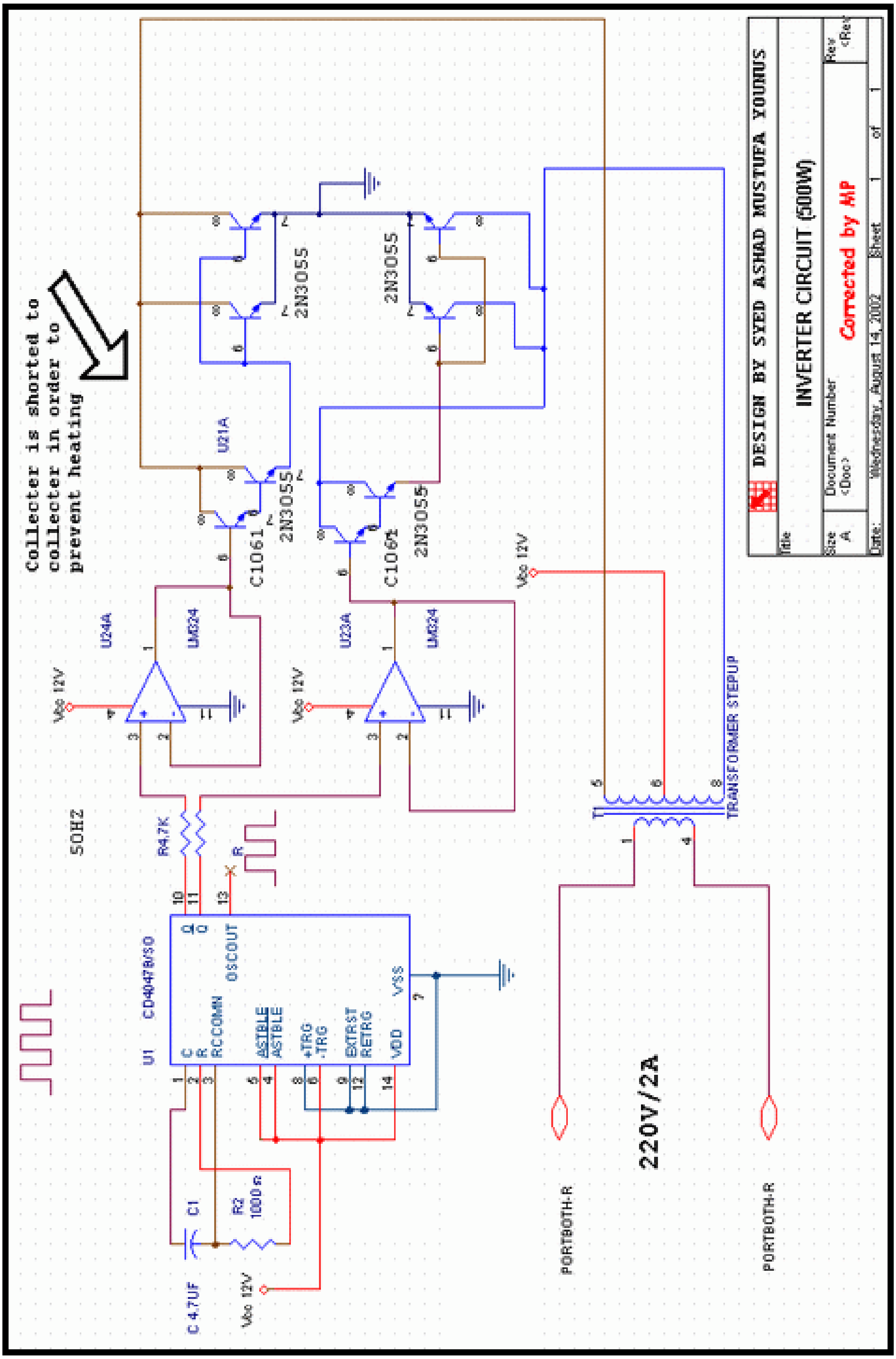


Figure 3.17: Sample circuit diagram of a 500W 12VDC-220VAC Inverter (Younus, S. A. M., 2002)

3.9 Protection Systems

The protection circuits use a very simple and yet effective concept of protecting important components such as lead-acid battery from overvoltage/overcurrent charging and motor from overvoltage supply.

Firstly, a relay is used and the ‘normally closed’ terminals are connected in series to the circuit that needs to be protected. The 5V triggering point of the relay is connected to an input of the PIC. Whenever the PIC receives a signal that is out of the range of the safety voltage or current values, the PIC will trigger the relay with 5V and the ‘normally closed’ terminals will open and disconnect the circuit. This is a simple, cheap and yet effective way of protecting expensive electrical components such as motors and batteries.

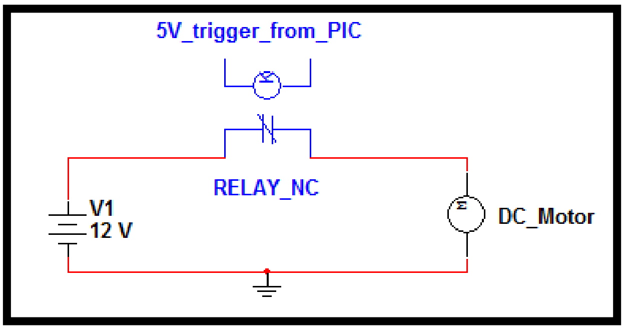


Figure 3.18: Multisim Simulation for DC Motor Protection Circuit

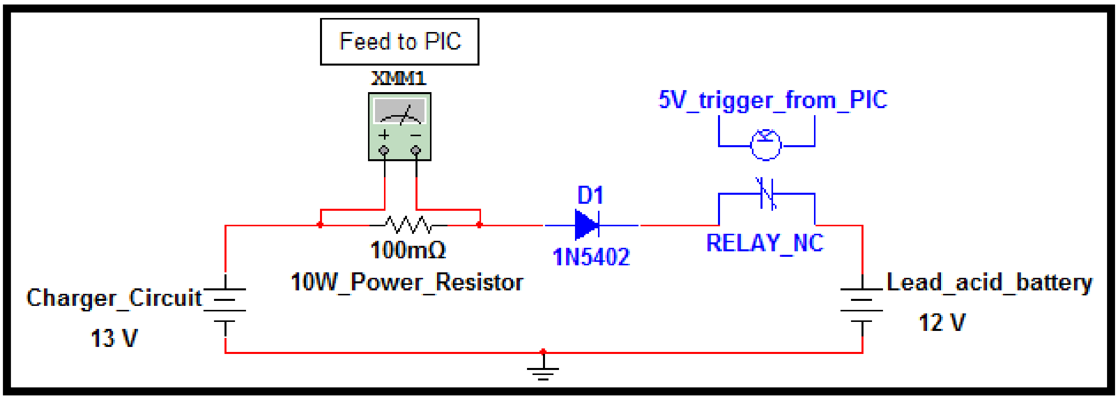


Figure 3.19: Multisim Simulation for Lead acid Batteries Protection Circuit

3.10 Back-up, Isolation and Switching Systems

The isolation and switching circuits are used to continue supplying power into the system even if the Intel Atom platform suddenly stops functioning. This feature is essential to ensure the important functions of the system such as monitoring circuits continue to run properly without any disturbance.

The concept of implementation is also very simple and yet effective. A battery supply is connected directed to the system with a relay ‘normally open’ terminals connected in series. The Intel Atom platform power supply 5V is used to power the relay and maintain the relay in a ‘normally open’ condition all the time. If there is any fault with the Intel platform and it suddenly stops operating, the power supply will shut off and effectively remove the 5V supply to the relay. As soon as the 5Vsupply is removed, the relay will close and connect the external power supply from the battery directly to the system and maintain it in operating condition.

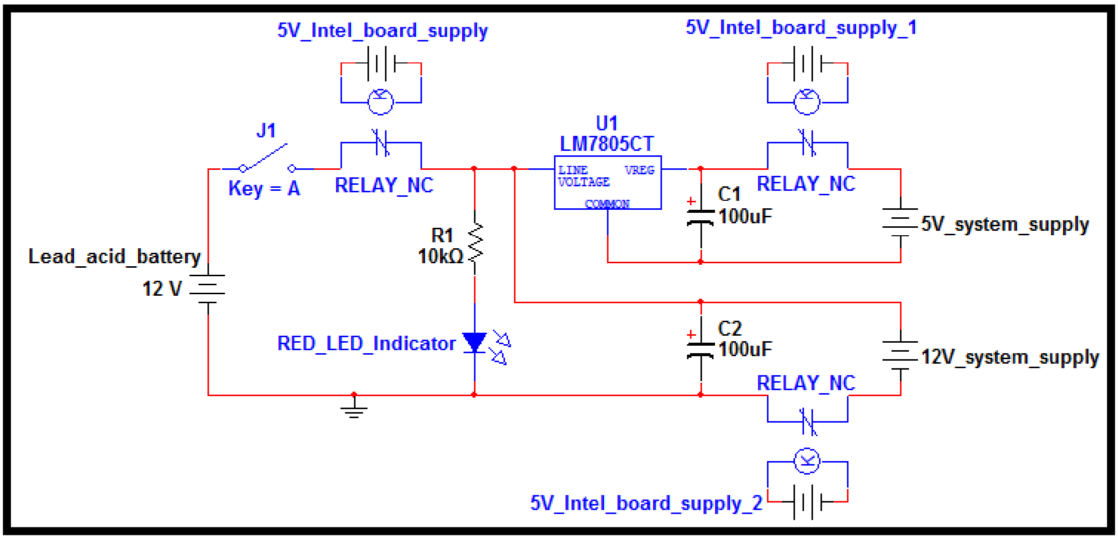


Figure 3.20: Multisim Simulation for Back-up, Isolation and Switching System

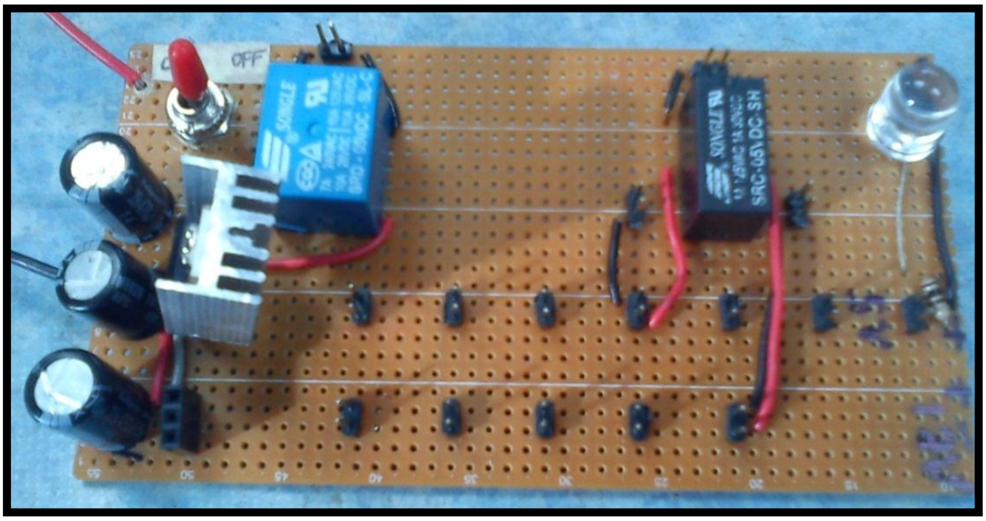


Figure 3.21: Back-up, Isolation and Switching System

3.11 Overall Project Budgeting

In every project, the overall project budgeting is one of the most important part of the whole process to identify and estimate how much a project actually costs. During the Preliminary Intel Presentation at the MSC Malaysia Innovation Centre, Cyberjaya, the Intel judges clearly mentioned that they would like to know the overall cost of the EVICS. Therefore, calculating and estimating the cost of the whole EVICS project had been part of the Final Year Project.

The EVICS project and budgeting for each and every module and the miscellaneous items spent are as below:

Table 3.1: EVICS Project Budgeting (Viewnet Computer System, 2011)

EVICS Project Budgeting				
Current Monitoring System	***Units***	***Cost (RM)***	***Total Cost***	
0.1Ω, 10W Power resistor	1	0.60	0.60	
1N5402	1	1.00	1.00	
5V Relay	1	3.00	3.00	
BR106 Rectifier	1	3.00	3.00	
1uF Capacitor	1	0.30	0.30	
Total:			7.90	***7.90***
24V/12V AC Supply				
36VA Transformer	1	20.00	20.00	
1N4001	1	0.40	0.40	
Red LED	1	0.30	0.30	
1kΩ, 5% resistor	1	0.05	0.05	
2A fuse and holder	1	1.20	1.20	
2 way switch	1	1.50	1.50	
Total:			23.45	***23.45***
Positive & Negative Voltage System				
BR106 bridge rectifier	1	3.00	3.00	
LM7815	1	1.50	1.50	
LM7915	1	1.50	1.50	
1uF capacitor	2	0.30	0.60	
1N4001	2	0.40	0.80	

Total:			7.40	***7.40***
Voltage Monitoring System				
741 op-amps	2	1.50	3.00	
5% resistors	4	0.05	0.20	
Total:			3.20	***3.20***
LDR Lighting Monitoring System				
1W, 3.3V Luxeon white LED	2	8.00	16.00	
LM317	2	1.50	3.00	
C9013	1	0.40	0.40	
heat sink	2	1.00	2.00	
1% metal film resistor	4	0.10	0.40	
5% resistor	1	0.05	0.05	
2 way switch	1	0.50	0.50	
LDR	1	1.50	1.50	
Total:			23.85	***23.85***
Two PIC Circuits				
PIC16F2550	2	25.00	50.00	
MAX232	2	3.00	6.00	
10uF Electrolytic capacitor	14	0.30	4.20	
White LED	2	1.20	2.40	
10MHz crystal oscillator	2	1.50	3.00	
Reset switch	2	0.50	1.00	
ON/OFF switch	2	1.50	3.00	
5% resistor	4	0.05	0.20	
Total:			69.80	***69.80***
Back-up, Isolation & Switching Systems				
5V Relay, 1 way	1	3.00	3.00	
5V Relay, 2 ways	1	4.00	4.00	
1uF, 25V capacitor	3	0.50	1.50	
ON/OFF switch	1	1.50	1.50	
LM7805	1	1.50	1.50	
heat sink	1	1.00	1.00	
Red LED, 10mm	1	1.00	1.00	
5% resistor	1	0.05	0.05	
Total:			13.55	***13.55***
5V, 12V supply system				
Connectors	1	5.00	5.00	
Donut board	1	0.50	0.50	

LM7805	1	1.50	1.50	
heat sink	1	1.00	1.00	
Total:			8.00	***8.00***
Three Temperature sensor systems				
LM35	3	4.00	12.00	
5% resistor	3	0.05	0.15	
Total:			12.15	***12.15***
Three 12V fan driver systems				
C9013	3	0.40	1.20	
12V DC brushless fan	3	5.00	15.00	
5% resistor	6	0.05	0.30	
470uF, 25V electrolytic capacitor	3	0.50	1.50	
White LED	3	1.20	3.60	
1N4001	3	0.40	1.20	
Total:			22.80	***22.80***
Opto-interrupter system				
LM317	1	1.50	1.50	
1% metal film resistor	2	0.10	0.20	
C9013	1	0.40	0.40	
5% resistor	3	0.05	0.15	
Opto-interrupter	1	3.00	3.00	
Total:			5.25	***5.25***
Miscellaneous				
350W Inverter	1	85.00	85.00	
17 inches LCD monitor	1	200.00	200.00	
Intel platform	1	200.00	200.00	
1GB DDR2 Kingston PC800 RAM	1	50.00	50.00	
450W power supply	1	44.00	44.00	
Aztech modem router wired, 1 port	1	49.00	49.00	
320GB, 8MB, 7200RPM, WD hard drive	1	100.00	100.00	
donut board	5	4.00	20.00	
Connectors	50	1.00	50.00	
6 gang extension adapter plug	1	10.00	10.00	
Tachometer system	1	20.00	20.00	
Analogue voltage indicator system	1	10.00	10.00	
Total:			838.00	***838.00***
Grand Total cost:				***1035.35***

The project budgeting calculated included everything that was used in the process of the project and not taking into account the cost-saving measures being done. Therefore, the budgeting below was the actual cost of expenditure of the EVICS project which took into account the sponsors provided, samples purchased, recycled materials obtained, and personal belongings:

EVICS Project Budgeting			
Cost saving measures	***Units***	***Cost (RM)***	***Total Cost***
24V/12V AC Supply *(UTAR Lab)*	1		23.45
PIC16F2550 *(Free samples)*	2	25.00	50.00
12V DC fan *(Spoilt power supply)*	3	5.00	15.00
17 inches LCD monitor *(Personal)*	1	200.00	200.00
Intel platform *(Sponsored)*	1	200.00	200.00
1GB DDR2 RAM *(Sponsored)*	1	50.00	50.00
450W power supply *(sponsored)*	1	44.00	44.00
Aztech modem router *(personal)*	1	49.00	49.00
320GB hard drive *(personal)*	1	100.00	100.00
6 gang extension plug *(personal)*	1	10.00	10.00
Total savings:			**741.45**
Grand Total spent:	1035.35 - 741.45 = ***293.90***		

Table 3.2: EVICS Project Budgeting after cost saving measures

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Current Monitoring System

To select the type of power resistor that is suitable for the circuit's application, it is important to know the maximum current that can flow from the charger circuit into the battery. Since the maximum current flowing is less than 10A, I=10A will be taken as reference for the power resistor selection.

Another criteria that must be taken into account is the resistance chosen. From the resistor's power dissipation formula of $P=I^2R$, it is known that the lower the resistance chosen, the lower will be the power rating needed for the power resistor. This factor is also important especially to save cost because the higher the power rating of the resistor, the more expensive will be the cost. Therefore, the lowest practical power resistor resistance that can be found in Jalan Pasar is 0.1Ω, so this will be taken as the reference.

Finally, since the current flow and resistance of the power resistor have been determined, the power rating of the power resistor can be calculated as below:

$$P=I^2R = 10A \times 10A \times 0.1\Omega = 10W.$$

Therefore, the ratings of the power resistor chosen are 0.1Ω, 10W.

After the circuit was built, there was a problem with the voltage tapped from the power resistor. The small voltage being tapped kept fluctuating and this made it impossible to be fed into the PIC Microcontroller because it would produce inaccurate reading results. The fluctuating was probably due to the loading effect from the battery's voltage because although the battery was being charged, it still had some capacity and charges in it that could flow back into the charger circuit and caused the inconsistent fluctuation at the voltage being tapped from the power resistor.

Therefore, one of the solutions implemented was to use a diode, connected in series to the circuit to remove the loading effect from the load flowing back into the charger circuit. This also helped to remove the effect it had on the 10W, 0.1Ω power resistor because the voltage values being tapped and sent into the PIC were very small and sensitive to loading effect and voltage fluctuation sent from the load. To solve this problem, a 1N5402 general purpose rectifier diode was used in this circuit.

The characteristic of this diode was very important and can affect the performance of the charger circuit. From the datasheet (Appendix F), this 1N5402 general purpose rectifier diode had a 3.0 Ampere average rectified forward current operation. This factor limits the current that could be charged into the battery to 3.0A. However, since this amount of current was more than sufficient to charge the 1.2Ah (Average charging current = 10%Ah = 0.12A) and 7Ah (Average charging current = 10%Ah = 0.7A) lead-acid batteries under testing, this 1N5402 diode was chosen to be used practically in the charger circuit.

For 10A charging application, the ideal diode needed to be used was the SDP10S30, 10A, 1.5V Silicon Carbide Schottky Diode (Appendix H). The 1N5402 diode also had a forward voltage of 1.2V, which meant that the charger circuit's charging voltage needed to be tuned approximately 1.2V higher than the previous charging voltage to not affect the charging performance. This could be done by tuning the charger circuit's potentiometer clockwise to supply a higher voltage into the lead-acid battery as shown in the photo below.

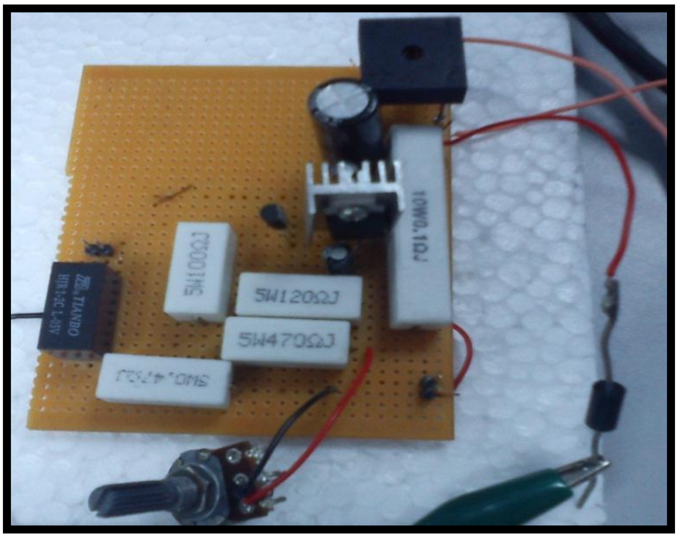


Figure 4.1: Current Monitoring System

After adding the diode, a more accurate and precise results could be sent into the Intel Atom platform and displayed onto the LCD screen.

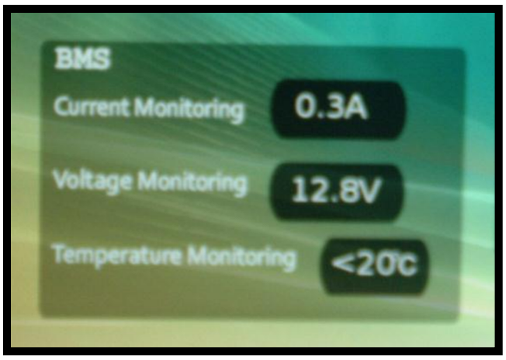
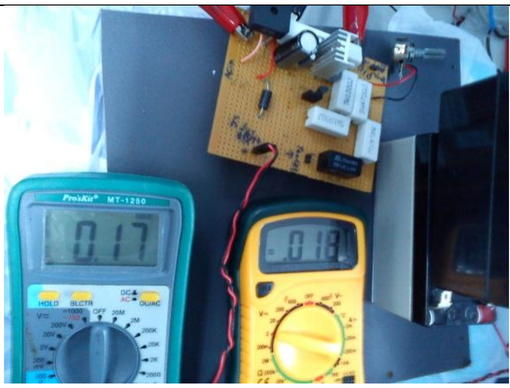


Figure 4.2: Charging steadily at 0.3A

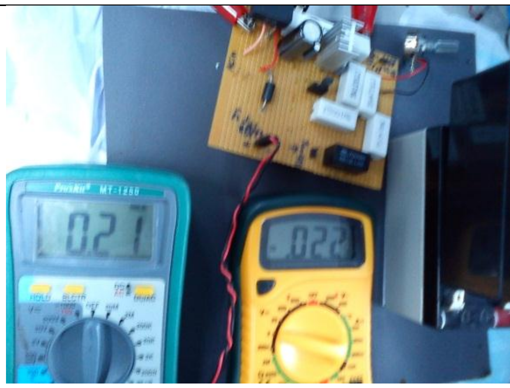
4.1.1 Experiment to determine the voltage tapped from the power resistor versus the charging current measured

To conduct this experiment, the charger circuit is connected to a weak 12V lead-acid battery and charged with different voltage level. Two multimeters are used to measure the voltage across the 0.1Ω, 10W power resistor and another to measure the current being charged into the battery. The results obtained are as below:



Current measured: 0.17A

Voltage tapped: 0.018V

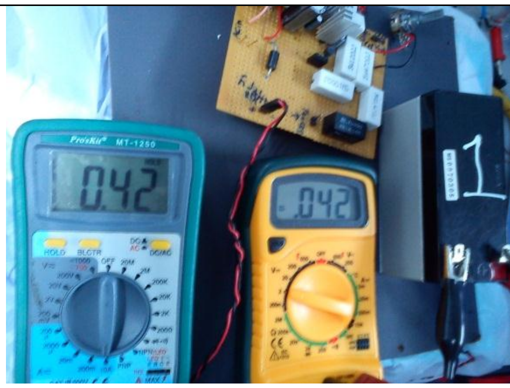


Current measured: 0.21A

Voltage tapped: 0.022V

Current measured: 0.38A

Voltage tapped: 0.038V

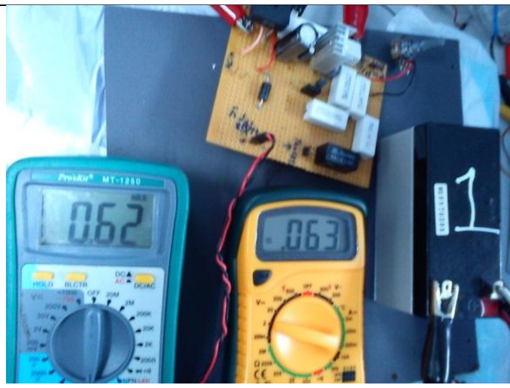


Current measured: 0.42A

Voltage tapped: 0.042V

Current measured: 0.51A

Voltage tapped: 0.052V



Current measured: 0.62A

Voltage tapped: 0.063V

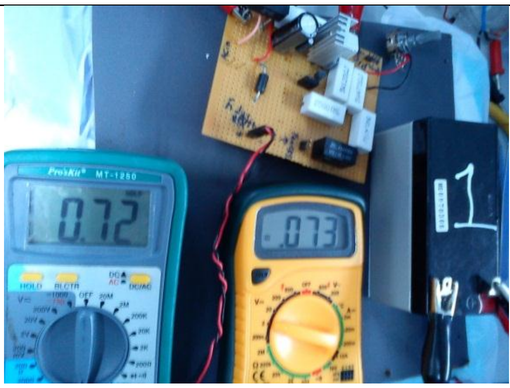
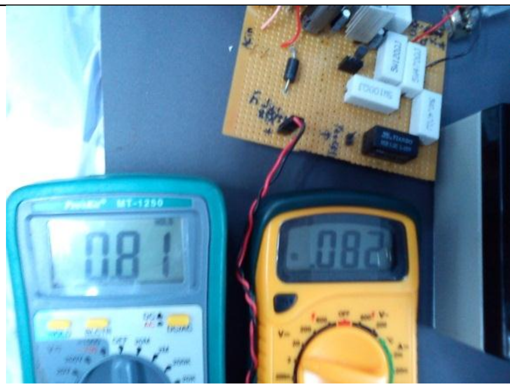
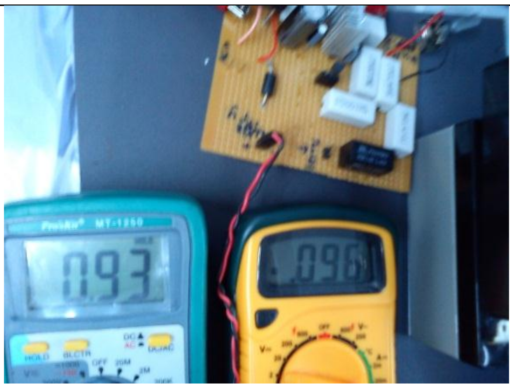
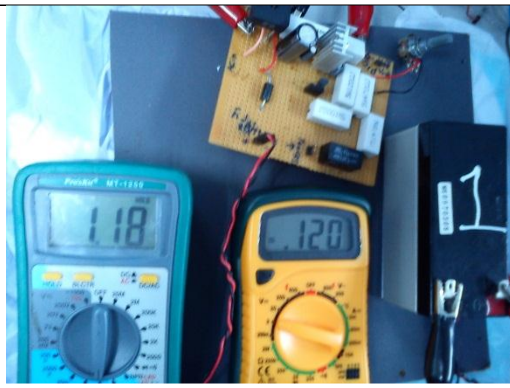
	
Current measured: 0.72A Voltage tapped: 0.073V	Current measured: 0.81A Voltage tapped: 0.082V
	
Current measured: 0.93A Voltage tapped: 0.096V	Current measured: 1.18A Voltage tapped: 0.120V

Figure 4.3: Results of voltage tapped from power resistor versus current measured

The results above produce two parameters which are the voltage tapped and current measured. To verify the accuracy of the voltage tapped to represent the current measured, the calculated current must be determined. Since the resistance value of the power resistor is fixed, the current calculated can be derived as:

I = V / R

Current calculated = Voltage tapped / Power resistor resistance

= Voltage tapped / 0.1Ω

The percentage of error can be calculated as:

% error = (|Current calculated – Current measured| / Current measured) x 100%

The results above can be summarised into the table below:

Voltage tapped (V)	Current measured (A)	Current calculated (A)	Percentage of Error (%)
0.018	0.17	0.18	**5.88**
0.022	0.21	0.22	**4.76**
0.038	0.38	0.38	**0**
0.042	0.42	0.42	**0**
0.052	0.51	0.52	**1.96**
0.063	0.62	0.63	**1.61**
0.073	0.72	0.73	**1.38**
0.082	0.81	0.82	**1.23**
0.096	0.93	0.96	**3.22**
0.120	1.18	1.20	**1.69**

Table 4.1: Current measured, current calculated and percentage of error

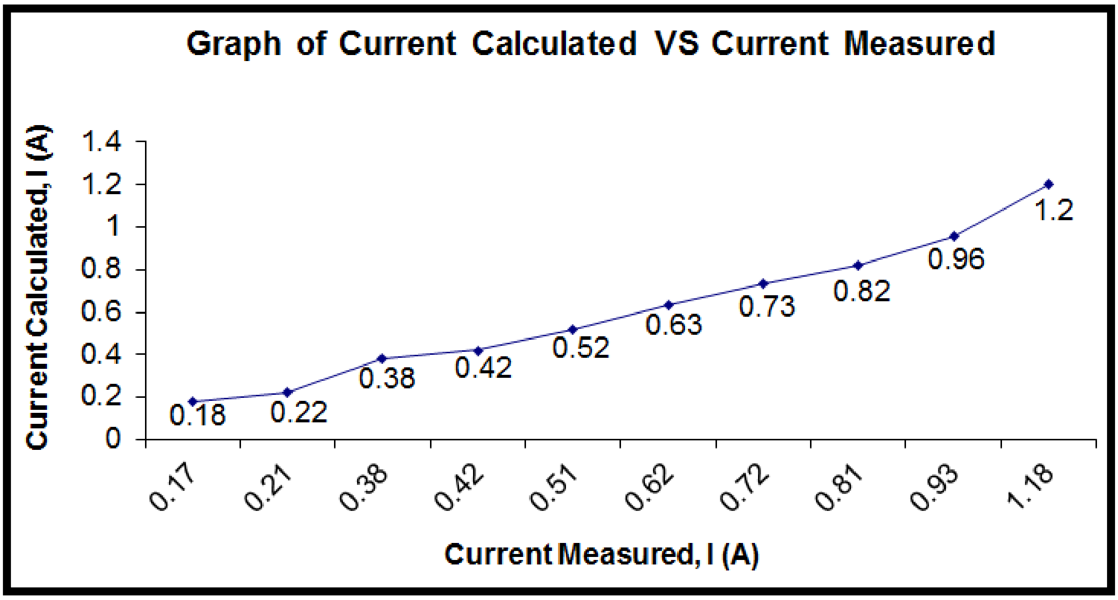


Figure 4.4: Graph of Current Calculated versus Current Measured

From the table above, the maximum percentage of error is 5.88% which is acceptable for an experimental result. The line graph plotted is also quite linear. Therefore to conclude, the voltage tapped can represent the current measured quite accurately.

4.2 Positive & Negative Voltage Supply

To design a positive and negative voltage supply, the first step needed to be taken is to measure the output voltage from the BR106 bridge rectifier. To do this, an experiment is conducted and the circuit below is constructed:

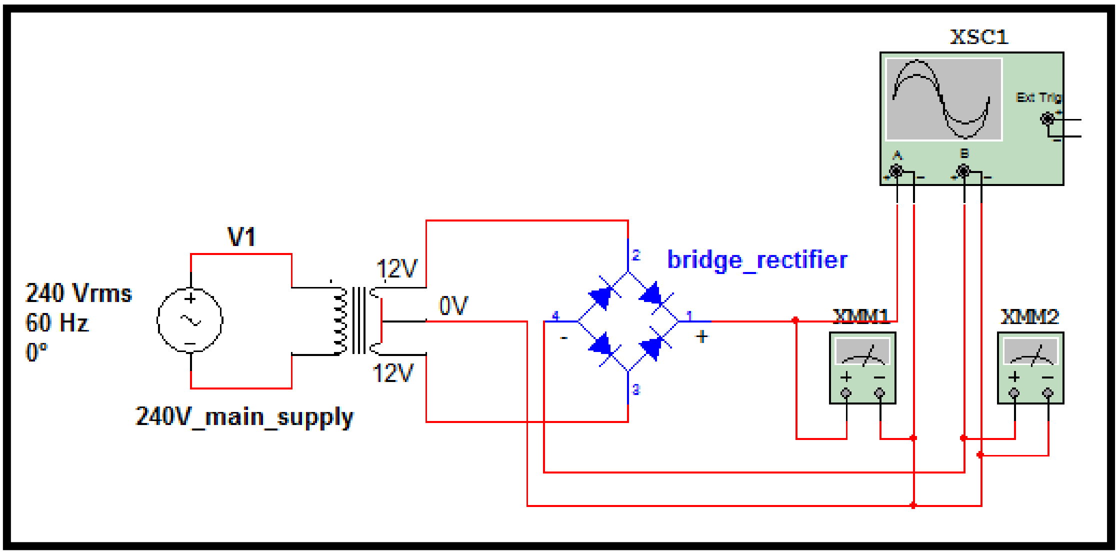


Figure 4.5: Positive and negative voltage supply experiment circuit

4.2.1 Experiment to determine the output waveform from bridge rectifier

The positive voltage is measured from the positive terminal of the bridge rectifier and centre tapped of the secondary side of 12V-0V-12V transformer using both an oscilloscope and digital multimeter. The negative voltage is measured using the same method. The only difference is from the negative terminal of the bridge rectifier. The results are as follows:

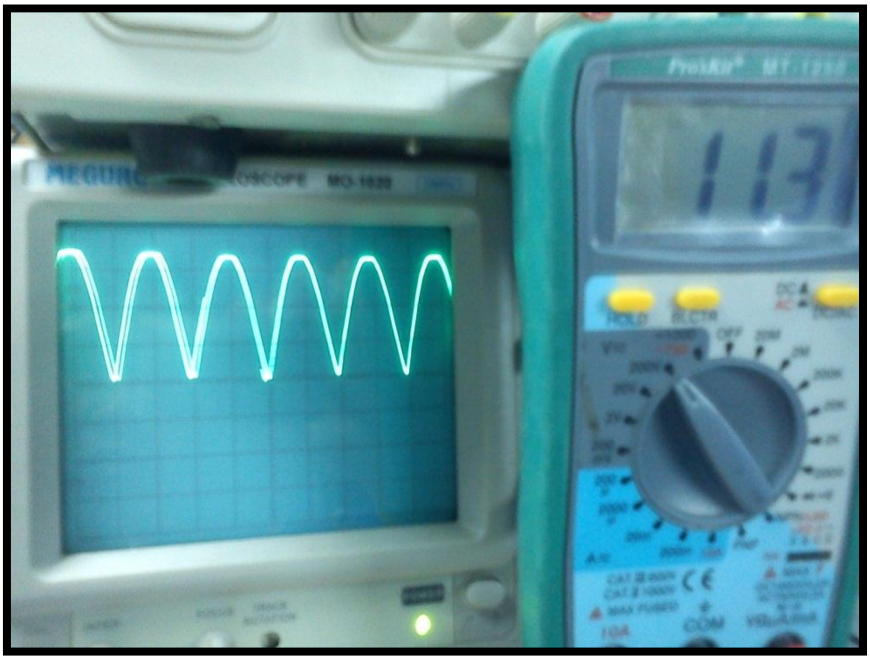


Figure 4.6: Positive terminal of bridge rectifier

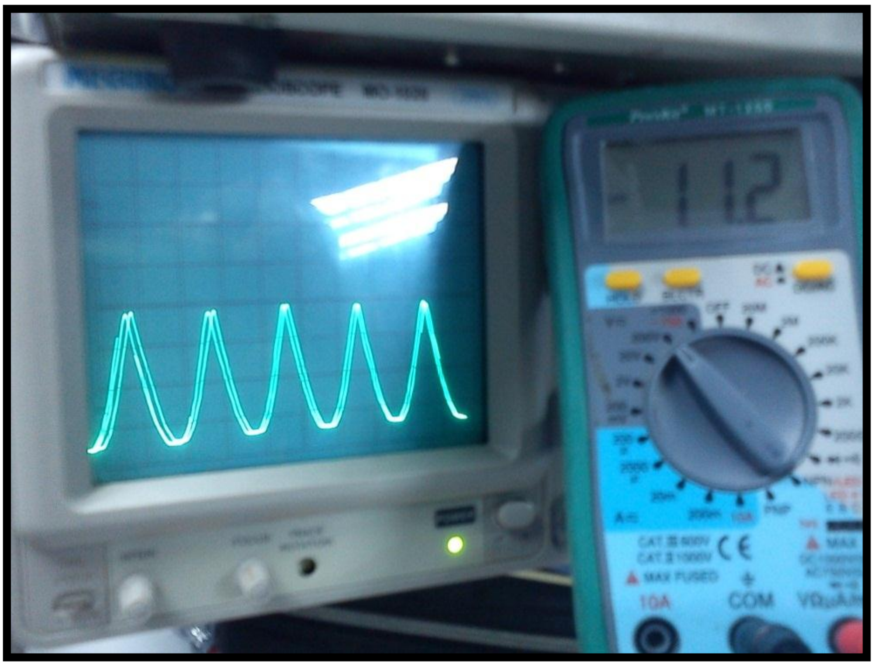


Figure 4.7: Negative terminal of bridge rectifier

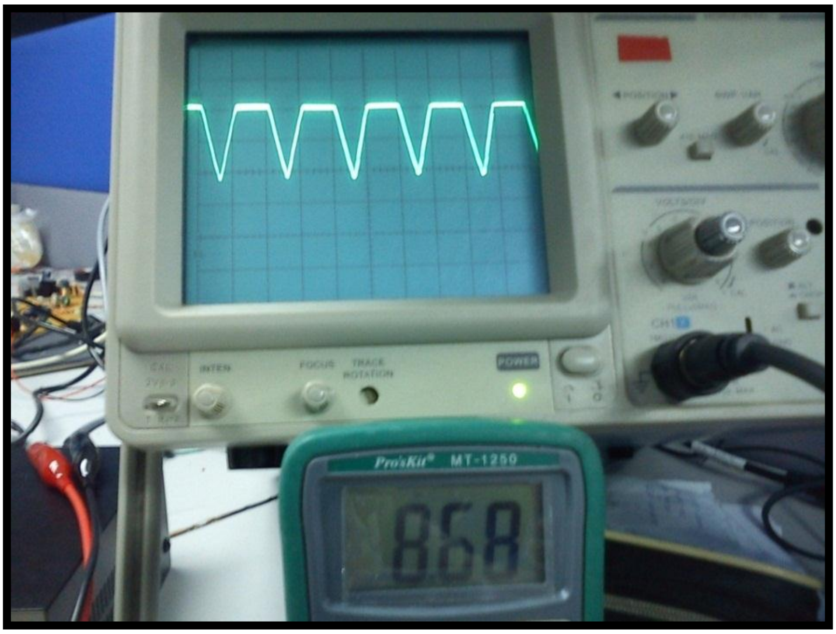


Figure 4.8: Regulated DC voltage after using LM7809 positive voltage regulator

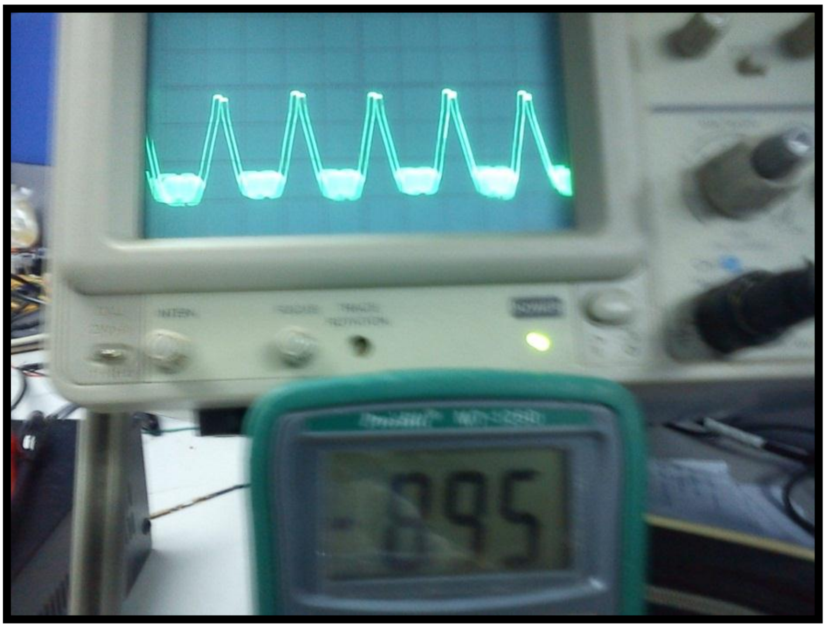


Figure 4.9: Regulated DC voltage after using LM7909 negative voltage regulator

From the results above, it can be seen that the output waveform from the bridge rectifier is a full-wave. However, the waveform shown on the oscilloscope is not a regulated DC voltage. Therefore, a suitable capacitor is needed to be connected in parallel to the voltage supply to smoothen and reduce the ripple of the DC voltage before it is being fed into the LM7812 and LM7912 voltage regulator.

4.2.2 Experiment to determine a suitable capacitor value for ripple reduction

For this experiment, five capacitors with different capacitance value are chosen as below:

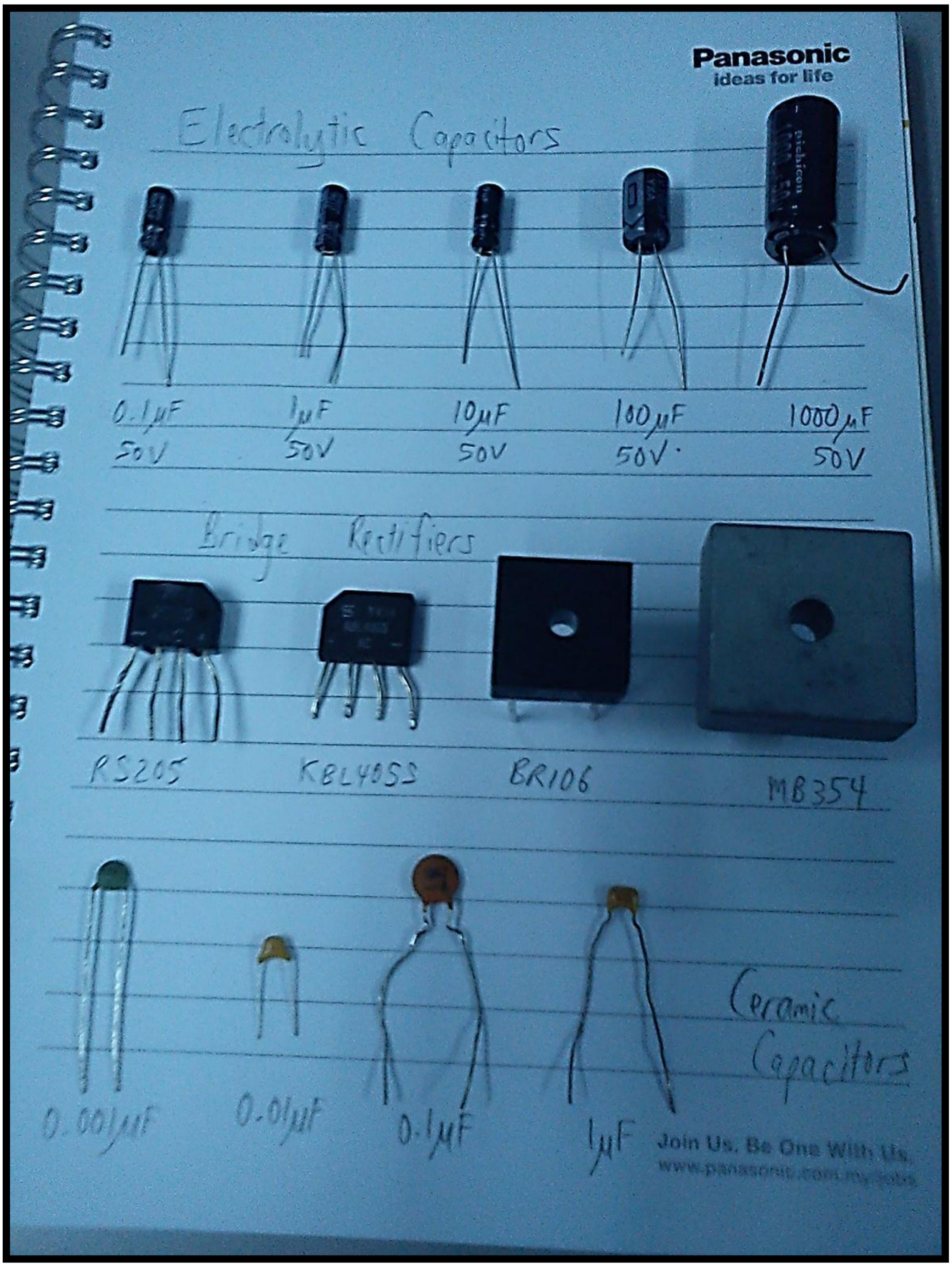
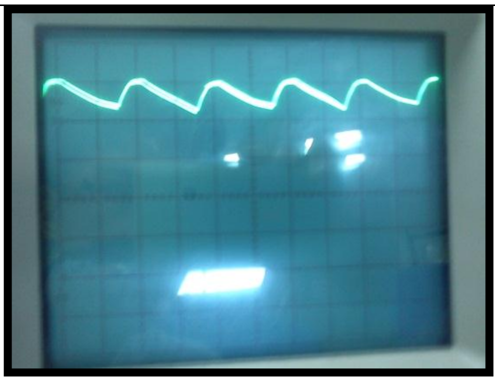
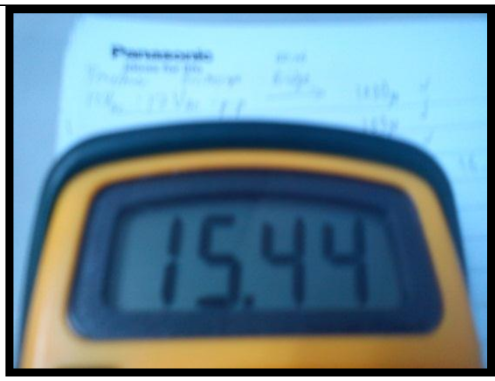


Figure 4.10: Experiment to determine capacitor value for ripple reduction

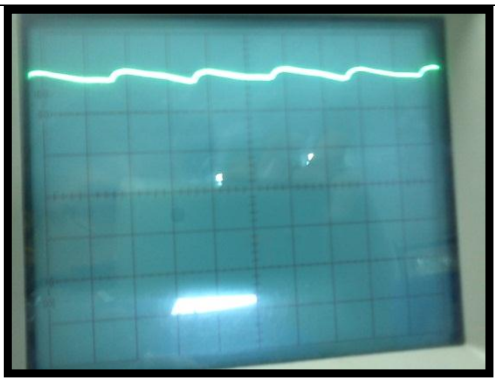
Figure 4.11: Results after connecting capacitors in parallel to bridge rectifier terminals.



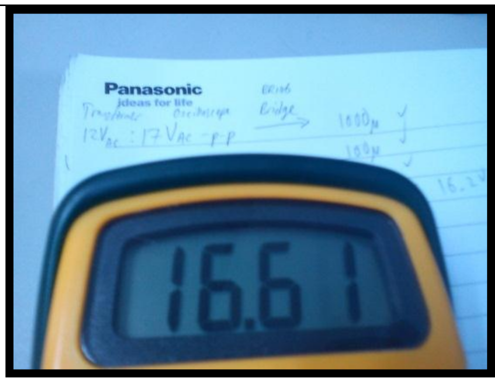
0.1uF ceramic capacitor waveform



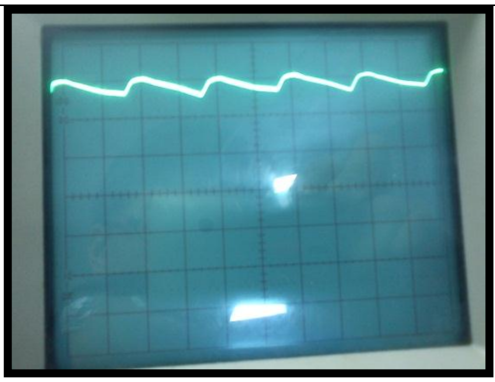
0.1uF ceramic capacitor DC voltage



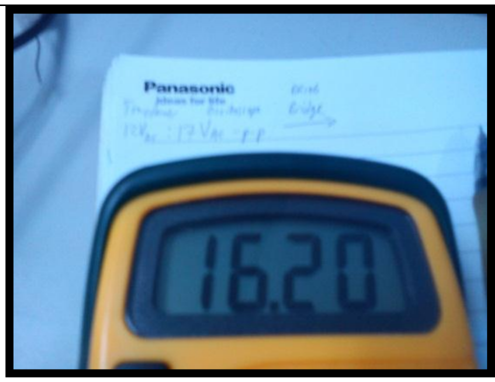
1uF ceramic capacitor waveform



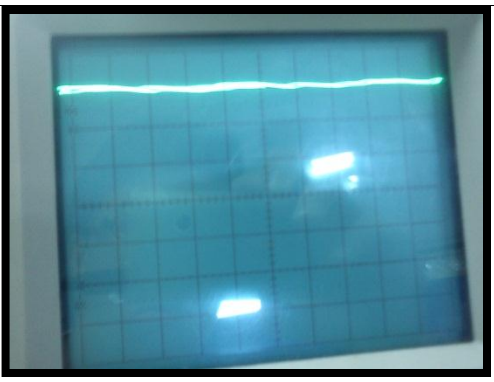
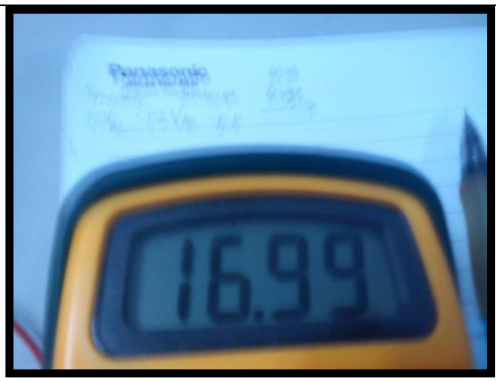
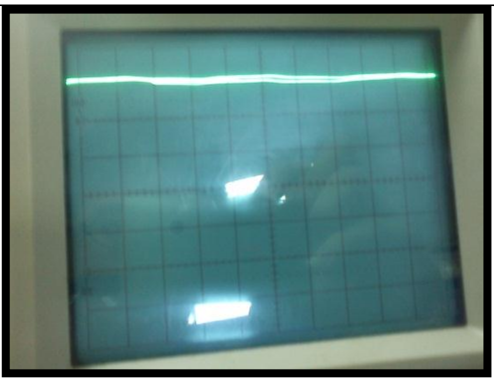
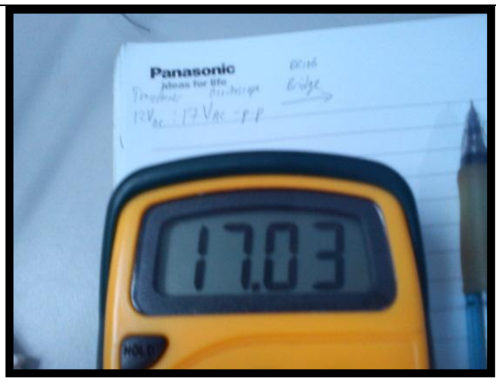
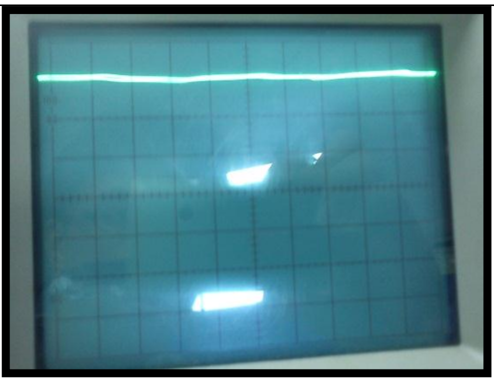
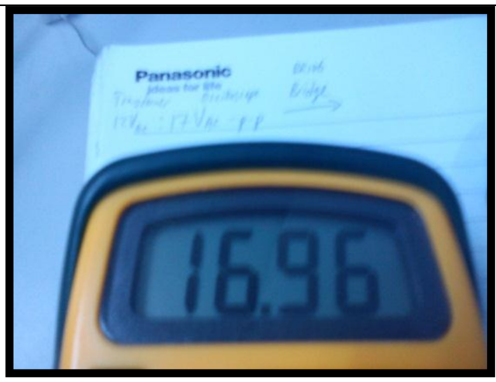
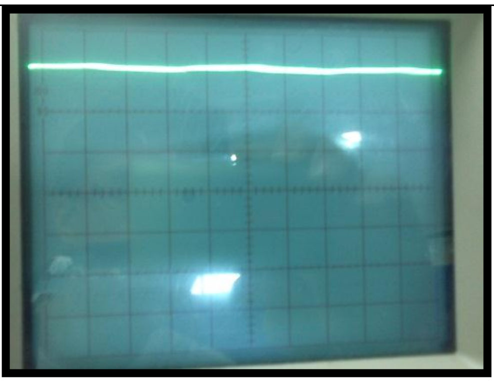
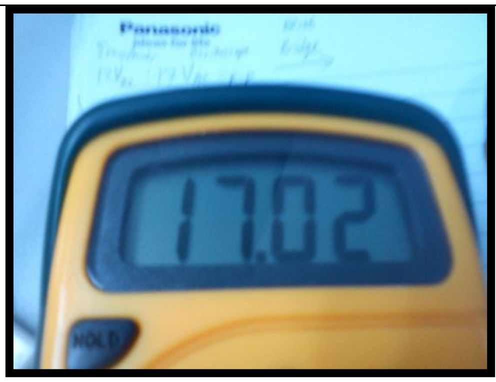
1uF ceramic capacitor DC voltage



0.1uF electrolytic capacitor waveform



0.1uF electrolytic capacitor DC voltage

 1uF electrolytic capacitor waveform	 1uF electrolytic capacitor DC voltage
 10uF electrolytic capacitor waveform	 10uF electrolytic capacitor DC voltage
 100uF electrolytic capacitor waveform	 100uF electrolytic capacitor DC voltage
 1000uF electrolytic capacitor waveform	 1000uF electrolytic capacitor DC voltage

From the experimental results above, the 0.1uF and 1uF ceramic capacitors cannot be used because they do not provide enough ripple reduction and smoothen the DC voltage enough to achieve 17V DC. On the other hand, comparing all the electrolytic capacitors used, the 1uF provides just enough ripple reduction and smoothen the DC voltage to 16.99V. Therefore, the 1uF electrolytic capacitor is the most suitable capacitor to be used because it provides an optimum ripple reduction and using it will save cost compared to the 10uF, 100uF and 1000uF capacitors.

Results after connecting 1uF electrolytic capacitor and LM7812/LM7912 voltage regulators:

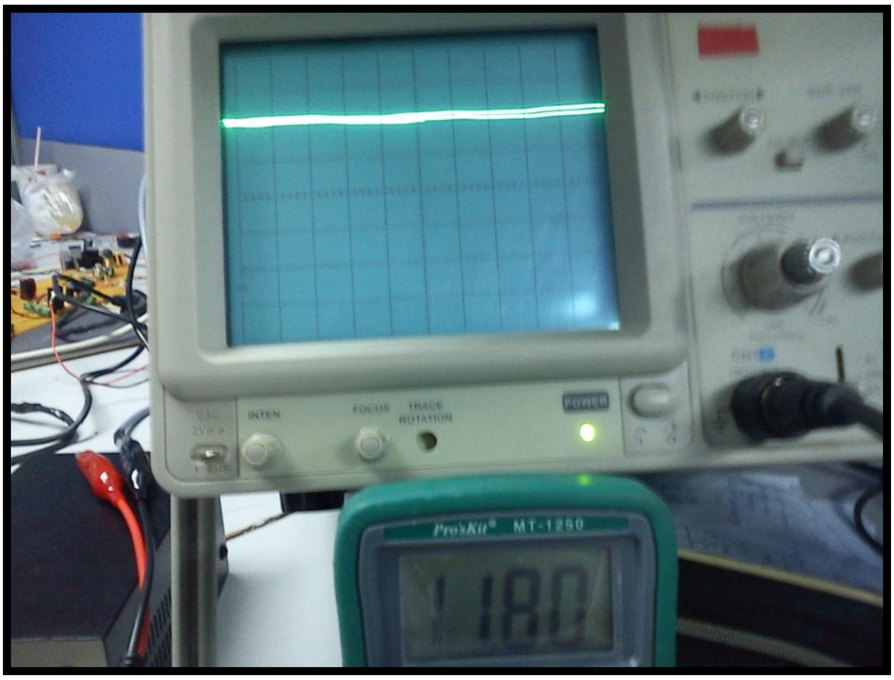


Figure 4.12: Results after 1uF capacitor and LM7812 positive voltage regulator are connected after the bridge rectifier

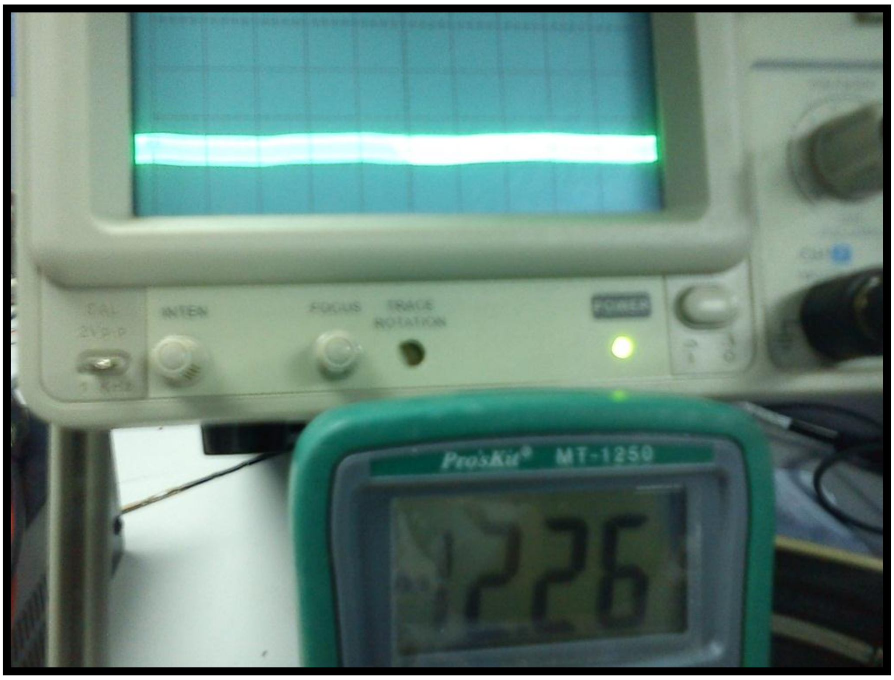


Figure 4.13: Results after 1uF capacitor and LM7912 negative voltage regulator are connected after the bridge rectifier.

4.3 Voltage Monitoring System

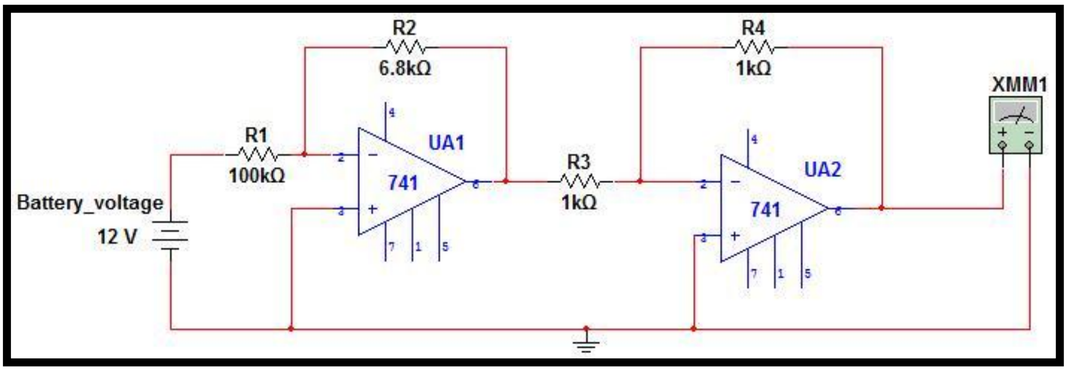


Figure 4.14: Multisim Simulation for Voltage Monitoring System

From the diagram above, the first 741 op-amp, UA1 is used to scale down the voltage by 15 times because the voltage of lead-acid battery falls in between the range of 11-13V and the PIC is programmed to accept voltage values in the range of 1V. Since we feed the voltage of the battery into the inverting side of the op-amp, the formula that we need to use to calculate the gain is –R2/R1. From here, we set R1=100kΩ and with a gain of 1/15;

$$-R2/100k\Omega = -1/15;$$

Therefore R2=6.667kΩ which is approximate to a 6.8kΩ practical resistor.

Since the battery voltage is fed into the inverting input side, the scaled down output value is a negative value. Therefore, we need to use another inverting op-amp to invert the voltage back to a positive value. As the output only needs to be inverted without changing the value, two resistors of the same value, R1=R2=1kΩ are used.

A similar circuit is built to measure and monitor the voltage of the motor because the range also falls in between 0-13V, which is suitable to be fed into the PIC after being scaled down by 15 times.

Figure 4.15: Experimental results for the battery voltage monitoring system.

5V Input voltage

6V Input voltage

7V Input voltage

8V Input voltage

9V Input voltage

10V Input voltage

11V Input voltage

12V Input voltage

13V Input voltage

14V Input voltage

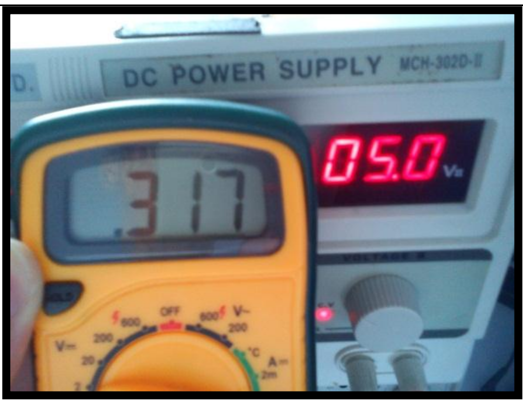
15V Input voltage

16V Input voltage

Input Voltage (V)	Output Voltage (V)	Scaled down ratio (V/V)
5	0.283	**17.667**
6	0.343	**17.492**
7	0.406	**17.241**
8	0.517	**15.473**
9	0.599	**15.025**
10	0.673	**14.858**
11	0.744	**14.784**
12	0.814	**14.742**
13	0.888	**14.639**
14	0.958	**14.613**
15	1.028	**14.591**
16	1.096	**14.598**

Table 4.2: Experimental results for the battery voltage monitoring system

Figure 4.16: Experimental results for the motor voltage monitoring system.



5V Input voltage

7V Input voltage

9V Input voltage

11V Input voltage

13V Input voltage

15V Input voltage

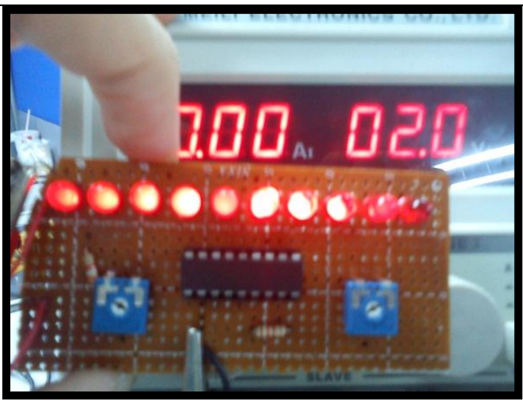
Input Voltage (V)	Output Voltage (V)	Scaled down ratio (V/V)
5	0.317	**15.772**
7	0.422	**16.587**
9	0.589	**15.280**
11	0.726	**15.151**
13	0.857	**15.169**
15	0.992	**15.120**

Table 4.3: Experimental results for the motor voltage monitoring system

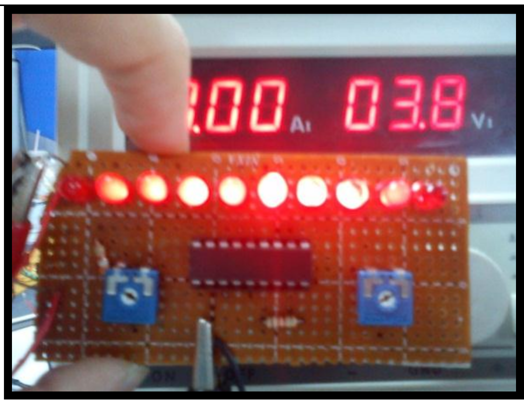
From the experimental results for battery voltage monitoring system, the scale down ratio ranges from 14.598 to 17.667 while from the experimental results for motor voltage monitoring system, the scale down ratio ranges from 15.120 to 16.587. The theoretical calculated scale down ratio is 15. Therefore, this shows that the circuit built for the motor voltage monitoring system is more accurate because it has a smaller range of scale down ratio compared to the battery voltage monitoring system. This factor may be due to the characteristics of the 741 op-amp used and also the exact values of 5% 1/4W resistors used during the circuit construction.

4.4 Analogue Voltage Monitoring System

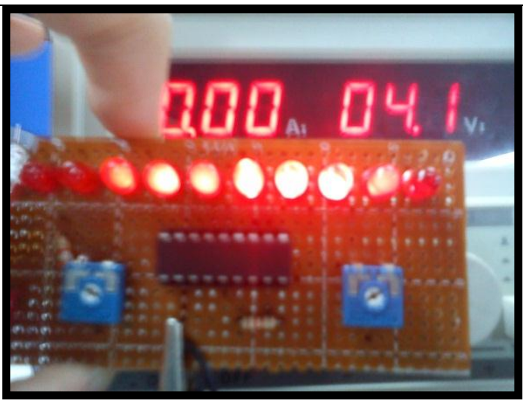
After constructing the analogue voltage monitoring system, a DC power supply is used to test out the circuit. The results are as follows:



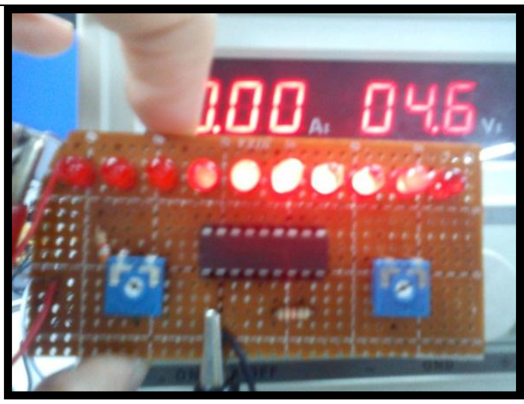
10 LEDs light up



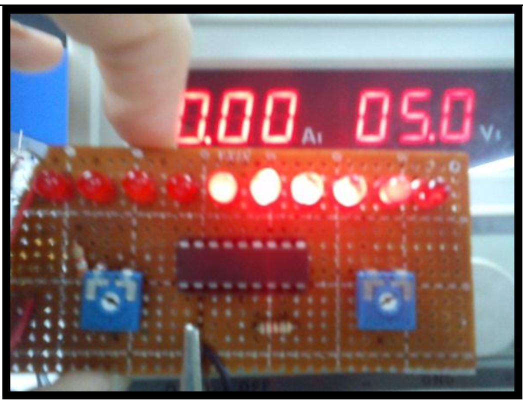
9 LEDs light up



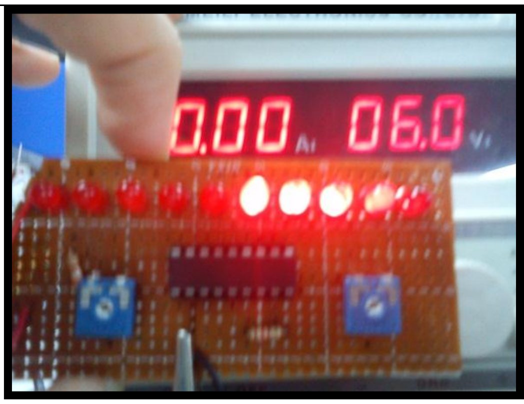
8 LEDs light up



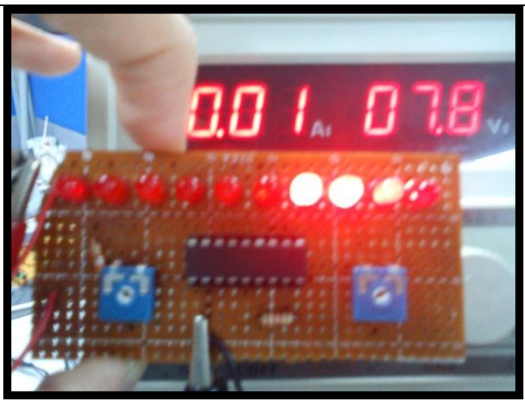
7 LEDs light up



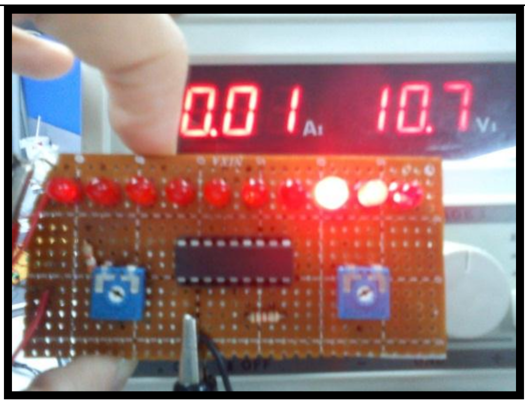
6 LEDs light up



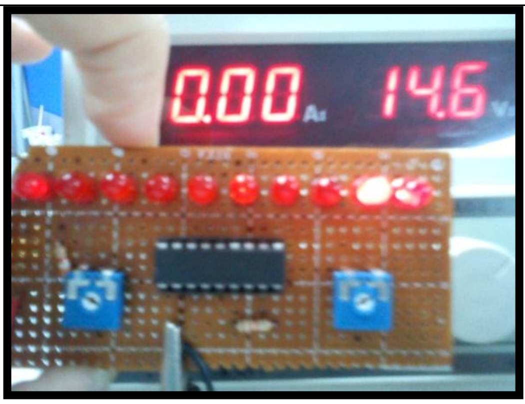
5 LEDs light up



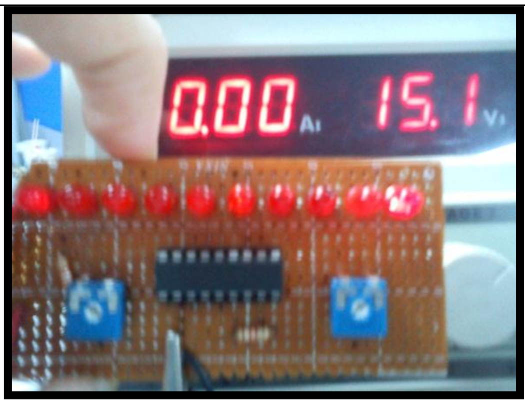
4 LEDs light up



3 LEDs light up



2 LEDs light up



1 LED lights up

Figure 4.17: Analogue voltage monitoring system before including zener diode

The table below is constructed from the results above:

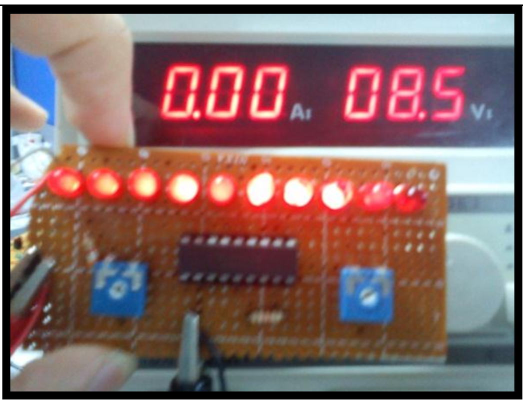
Number of LED lights up	Voltage indication level (V)
10	**2.0**
9	**3.8**
8	**4.1**
7	**4.6**
6	**5.0**
5	**6.0**
4	**7.8**
3	**10.7**
2	**14.6**
1	**15.1**

Table 4.4: Analogue voltage monitoring system before including zener diode

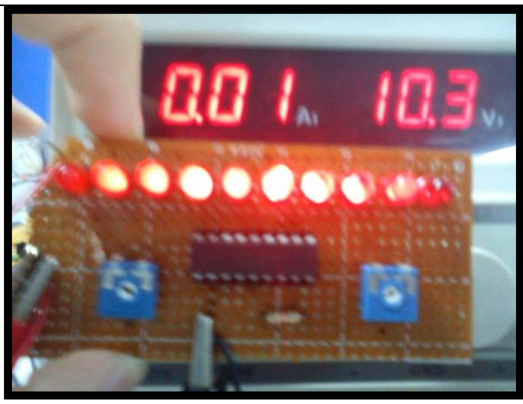
From the table above, it is obvious that the analogue voltage indicator built has a range of measuring voltage from 2.0V to 15.1V. This voltage range is not suitable to measure the battery's voltage level which usually ranges from 8-15V.

To solve the problem, a 6.5V, 1W zener diode is used to connect in series to the analogue voltage monitoring system. The purpose of the zener diode is to absorb 6.5V from the battery and feed the remaining voltage into the voltage indicator circuit to display the battery voltage level accurately through the red LEDs.

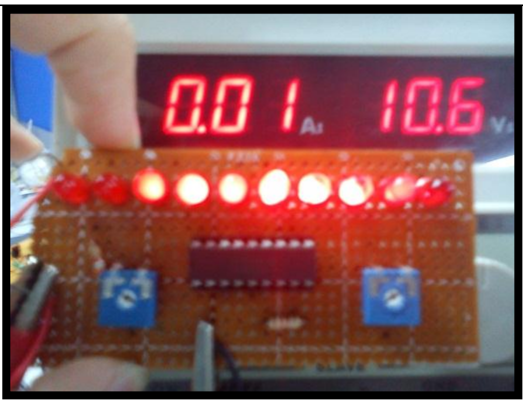
The results of the experiment are as follows:



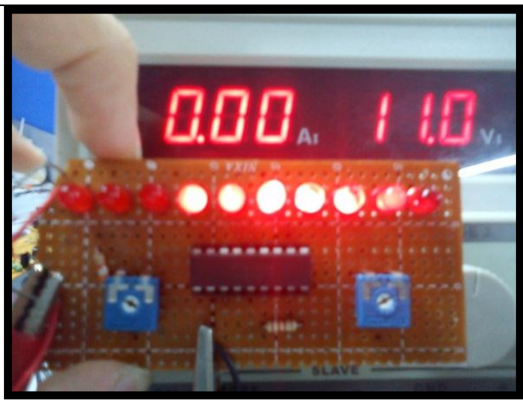
10 LEDs light up



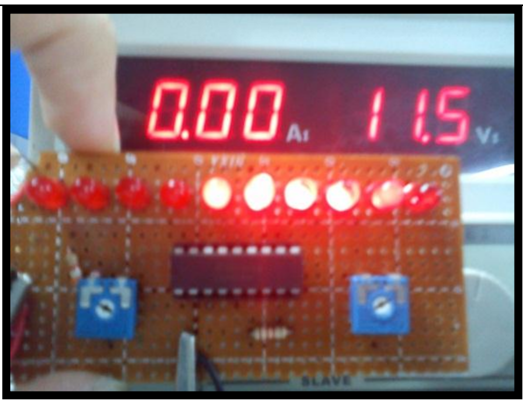
9 LEDs light up



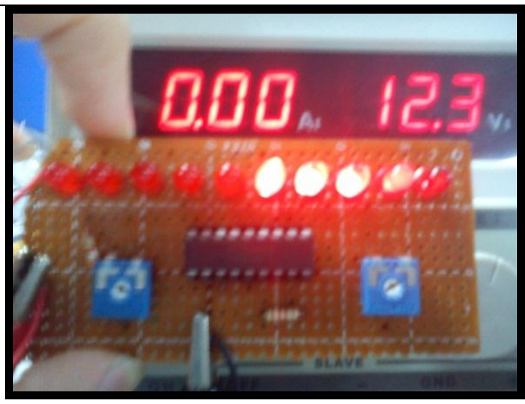
8 LEDs light up



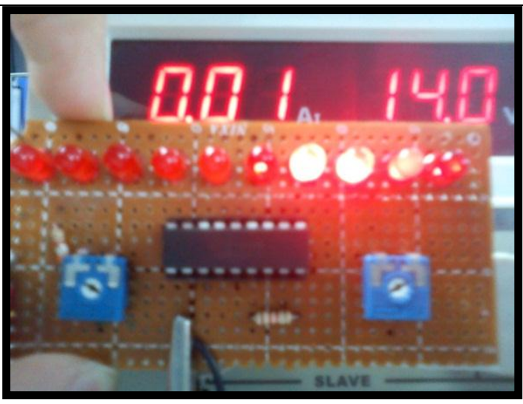
7 LEDs light up



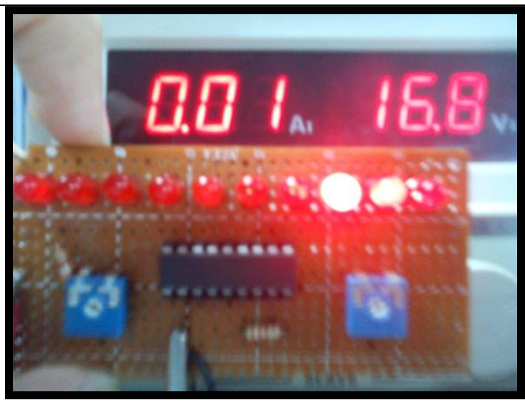
6 LEDs light up



5 LEDs light up



4 LEDs light up



3 LEDs light up

Figure 4.18: Analogue voltage monitoring system after including zener diode

The table below is constructed from the results above:

Number of LED lights up	Voltage level after including zener diode (V2)	Voltage level before including zener diode (V1)	Difference (V2-V1)
10	8.5	2.0	**6.5**
9	10.3	3.8	**6.5**
8	10.6	4.1	**6.5**
7	11.0	4.6	**6.4**
6	11.5	5.0	**6.5**
5	12.3	6.0	**6.3**
4	14.0	7.8	**6.2**
3	16.8	10.7	**6.1**

Table 4.5: Analogue voltage monitoring system after including zener diode

The results above show that after including the 6.5V zener diode in series to the analogue voltage indicator circuit, eight red LEDs now have a range of measuring the lead-acid battery from 8.5V to 16.8V which is more suitable and accurate.

Future Improvements

The analogue voltage monitoring system works in a way where the more numbers of red LEDs light up indicates a lower measuring voltage level and vice versa. This may not be very suitable for practical implementation into an electric vehicle because the conventional way of indication should be, the more LED lights up showing a higher level of voltage measured. Therefore, this improvement can be implemented into this circuit in the future to suit the practicality of the system.

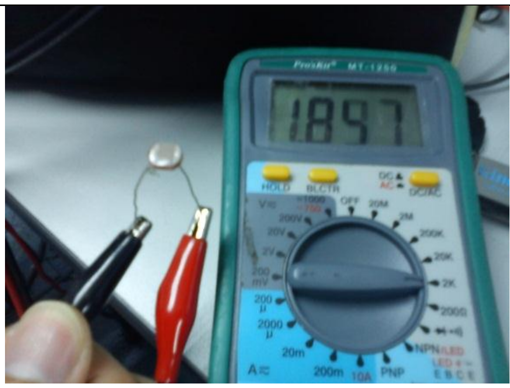
4.5 LDR Lighting Monitoring System

The basic circuit to control the high power white Luxeon LED lights is to use a PN2222A Fairchild NPN transistor. This transistor is chosen because it has a collector current capability of 1A which is essential for the operation of the high power Luxeon LEDs.

The method used to design this system is by varying the current entering the base of the transistor using a Light Dependent Resistor (LDR) connected to the base. When the resistance of this LDR changes with the light intensity of the surrounding, it will supply different current level into the base of the transistor to trigger the collector-emitter where the Luxeon LEDs are connected to. At the base, the LDR is connected in series to another resistor to work as a potential divider to supply different current level into the base whenever it is triggered by the surrounding light intensity.

To determine the functionality of the LDR, a simple experiment of varying the light intensity while measuring the resistance of the LDR is conducted.

LDR under direct lighting



LDR in normal lighting condition

LDR covered with hand

LDR in total darkness

Figure 4.19: LDR experiment under different lighting conditions

Lighting Conditions	LDR Resistance (Ω)
Direct lighting	**76.9**
Normal lighting	**1,847**
Lighting covered	**473,000**
Total darkness	**19,980,000**

Table 4.6: LDR experiment under different lighting conditions

From the table results above, the LDR will have an increase in resistance whenever the surrounding is darker. From these results, the position of resistor and LDR at the base of the transistor can be determined. In an intelligent lighting system, the LDR must be able to turn off the Luxeon LED lights when the user forgets to switch off the lights during daytime. At this instance, the base of the transistor must not be supplied by any current. For a potential divider, the lower the resistance, the lower the voltage absorbed by the resistor resulting in a lower current flow into the base. Since the LDR has a lower resistance under bright sunlight, it must be connected with respect to ground so that no current will flow into the base of the transistor and the Luxeon LEDs will turn OFF whenever the LDR is under a daytime sunlight. Therefore, the fixed resistor on the other hand must be connected to the 12V supply. The circuit connection is as below:

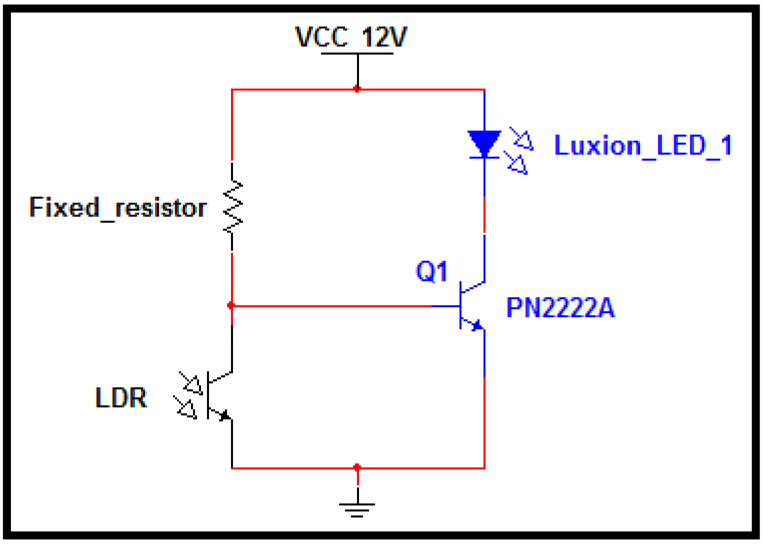


Figure 4.20: Positioning of LDR and fixed resistor

The next experiment needed to be conducted is to determine the resistance value of fixed resistor to be used so that the LDR can turn off the Luxeon LEDs under bright lighting condition and vice versa. To conduct this experiment, a potentiometer of 50kΩ is used to replace the position of the fixed resistor.

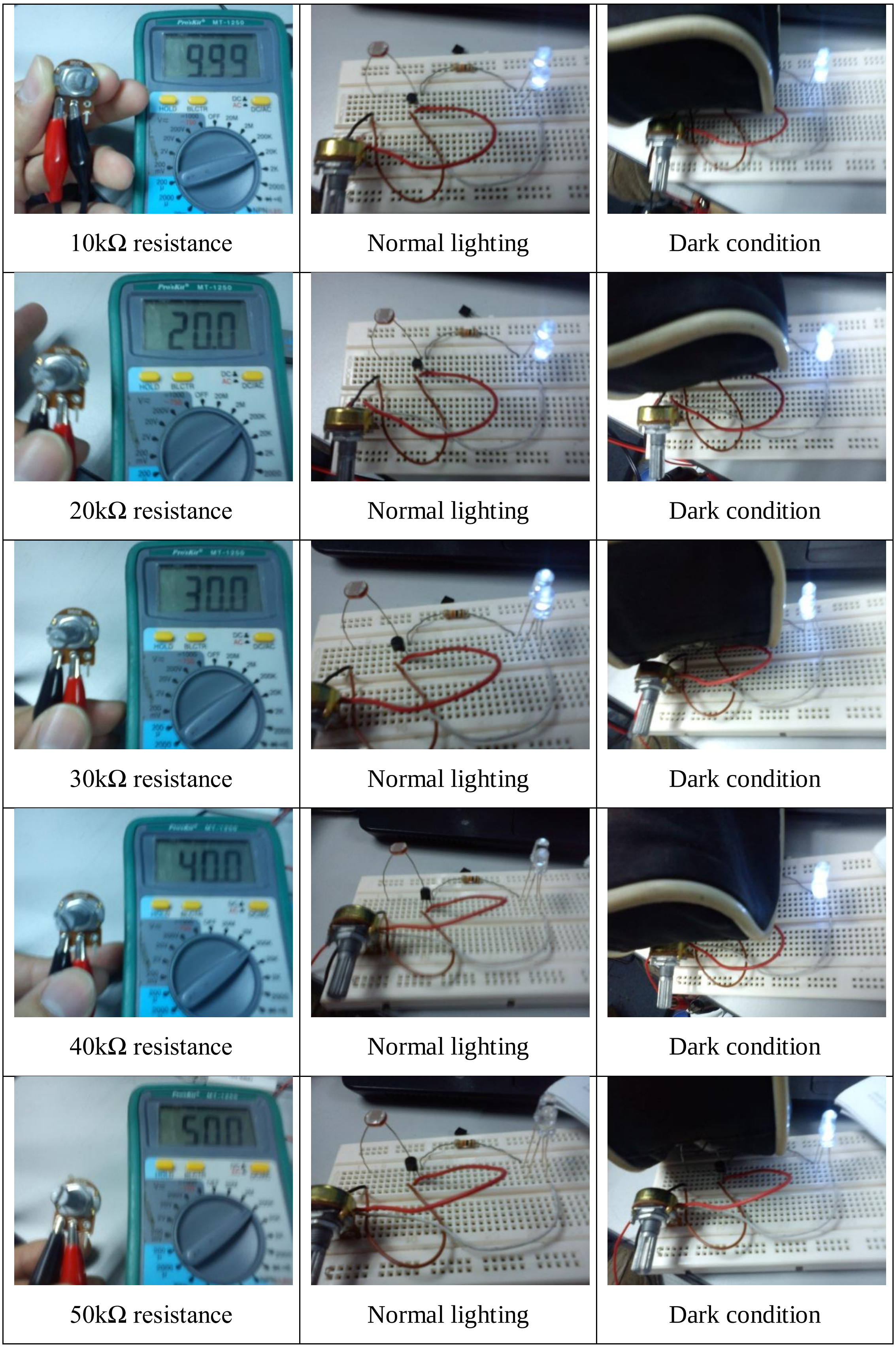


Figure 4.21: Experiment to determine the resistance of fixed resistor

From the results above, it is observed that the white LED only response to different lighting condition when the fixed resistor value is around 40-50kΩ. Therefore from this experiment, the fixed resistor chosen will be 50kΩ. The Luxeon LEDs are already regulated to 3.3V so there is no need of a resistor to be connected in series to it. Two Luxeon LEDs are connected in parallel at the collector to represent the two headlights of an electric car. A normal switch is connected to the Intel board supply which will be used by the user to switch ON and OFF the lights, while there is also a manual emergency switch connected directly to the 12V battery supply if the Intel board fails to function. The completed circuit design is as follows:

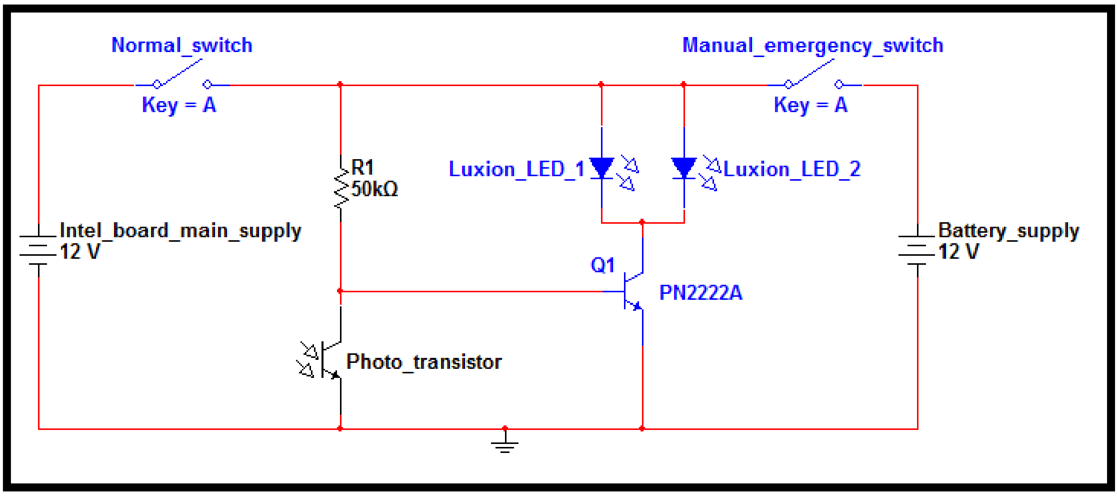


Figure 4.22: LDR lighting monitoring system

4.6 Protection Systems

PIC Microcontroller Source Code

```
/*****************************************************
MODULE : ACTION CONTROL MODULE
*****************************************************/
       if (i==1 || j==1 || k==1)
              PORTBbits.RB0=0xFF;
       else
              PORTBbits.RB0=0x00;
```

The programming source code above is designed for the protection systems of the EVICS. The protection system is designed to protect the battery from overcurrent charging, overvoltage charging and overheating (temperature). In the coding, there are three parameters that represent the respective protection systems in the EVICS:

- ‘i’ for voltage monitoring protection system

- ‘j’ for current monitoring protection system

- ‘k’ for temperature monitoring protection system

From the programming code above, if any of the ‘i’, ‘j’, or ‘k’ equals to 1, the program will trigger the relay to disconnect the charging circuit from the battery. This is because when the value of ‘i’, ‘j’, or ‘k’ equals to 1, it means that the voltage, current or temperature value has fallen out of the safety range. Therefore, these three parameters will trigger a single relay whenever the protection system voltage, current and temperature values are out of the normal range.

4.7 Innovations

4.7.1 Mobile Operating System

The Intelligent EV Controller System which includes the Intel Atom platform and an LCD display monitor is solely powered by a 12V DC battery supply which is the case in practical electric vehicles where they do not have an AC power supply. This smart design in the EVICS which makes use of a simple DC to AC inverter saves a lot of effort and time in trying to produce an AC supply for the whole EVICS to operate.

The EVICS is not just a prototype; this system is ready to be implemented into any electric cars as the system is already running on a practical 12V DC lead-acid car battery as the supply. The whole system is powered by a DC supply and an inverter, and not AC supply as in the real case of electric cars, and also a working and practical protection system that will protect the user from any electrical faults.

The LCD monitor used in the electric car must be touch-screen for the convenience of the user while driving at the same time. The buttons on the touch screen must also be large enough and preferably a capacitive touch screen so that it is sensitive to the lightest touch of the finger possible.

Figure 4.23: Inverter

4.7.2 Wireless LAN Communication

The EVICS can be controlled and monitored remotely using external computers, laptops and Android based smartphones. This feature is important for external computers and laptops to connect wirelessly to the Intel platform to monitor the performance of the car. Therefore, engineers and technicians can verify and determine problems with the electric car system remotely without needing to conduct the conventional hands-on approach.

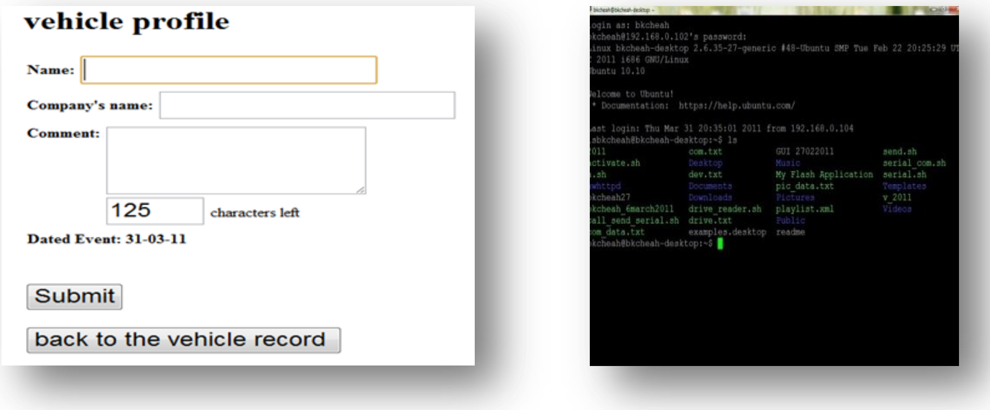


Figure 4.24: Wireless LAN Communication

4.7.3 Back-up system (Switching and Isolation)

The switching and isolation system will automatically connect and switch the system to an external power source whenever the Intel platform fails. By doing it this way, the functionality and purpose of the monitoring systems are always running in good condition and the car can still be controlled manually even when the system fails.

As for the lighting system, a system is designed where the lights in the electric car are supplied by the Intel Atom's power supply. When the Intel Atom suddenly stops functioning, the user can choose to operate the lights using a manual emergency switch which is connected directly to the accessories battery.

Therefore, even when the Intel Atom system fails, other monitoring systems and important accessories such as the lights can still be controlled and operated in a good condition.

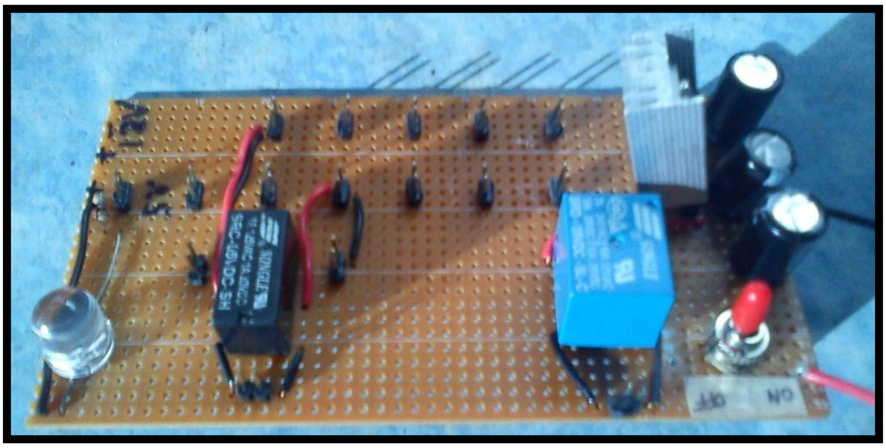


Figure 4.25: Back-up system (Switching and Isolation)

4.7.4 Regenerative charging voltage

The purpose of the regenerative charging voltage system is to provide a small charging to the supply battery and can be implemented into the battery compartment of the EVICS. How this system works is explained as below:

- Assuming the battery compartment is a square box and it is fully enclosed with no air gap.
- Three sides of the compartment are installed with DC fans used as a cooling system for inside the battery compartment.
- The remaining one side is installed with a DC motor fan used to circulate the air flow out from the battery compartment.
- This DC motor fan is normally not running, the compressed air flow from inside the battery compartment will be channelled out through this fan and will turn this fan automatically.

- When this fan is rotating naturally from the air flowing out from the compartment, voltage is generated at the positive and negative terminals of the DC motor fan.
- This voltage can be supplied to a boost converter and be used to charge the supply battery. Although the charging current may not be much, it is still a noble way of utilizing wasted energy to charge back the supply battery.

Figure 4.26: Regenerative charging voltage system

4.8 Creativity

4.8.1 Cost

UTAR EV Team managed to convince and obtain sponsorship from Yokohama batteries to sponsor sixteen 12V lead-acid batteries for the Intel Atom platform competition.

The most expensive electronic components after the batteries are the two PIC 18F2550 microcontrollers. Therefore, to keep our project cost low, we managed to obtain them through free samples from Microchip website and also free samples from Texas Instruments for other electronic component chips.

To keep the cost of our project even lower, we salvaged and used recycled materials such as taking out the 12V DC fans from spoilt computer power supplies to be implemented into our cooling system, and also step down transformers from old and spoilt electrical appliances from our electrical and electronic laboratory.

Many of the monitoring system circuits used simple but effective electronic ideas to carry out the necessary functions. These simple and efficient designs used very few electronic components which related to even more cost savings and ensures that the project was cost-effective.

Another factor that contributed to the low cost of project implementation was the use of serial bus port for communication on the Intel Atom platform instead of the customized PCI bus which was much more expensive.

Therefore, all the cost saving measures mentioned above ensured that the overall cost of the EVICS remained relatively low and fell within the budget given.

Figure 4.27: Texas Instrument samples & Yokohama batteries

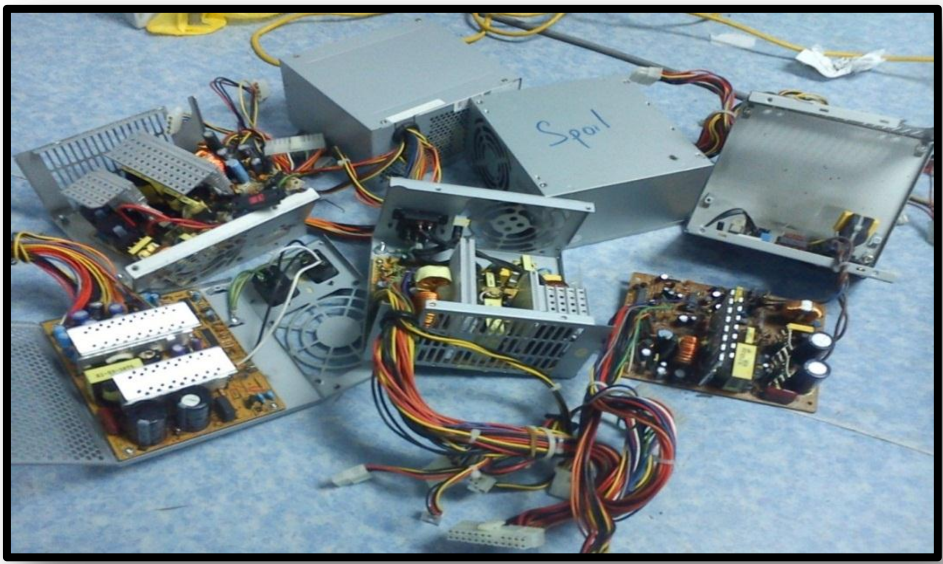


Figure 4.28: Salvaged power supplies

4.8.2 Low Power Consumption

To save power consumption of the 12V lead acid batteries, the EVICS utilizes 12V super bright Luxeon LEDs instead of the conventional 12V DC light bulbs currently used in engine cars.

Figure 4.29: High Power white Luxeon LEDs

4.8.3 Intelligent power management system

The LDR lighting system also helps to prevent users from accidentally leaving the lights on during the daytime with the LDR and also automatically switches the lights off whenever the user leaves the car.

4.8.4 Protection systems

An intelligent controller system is never complete without a protection system. Therefore, the EVICS is integrated with current, voltage and temperature protection systems that will protect the expensive electronic and electrical components and users from electrical faults. This system is simple, low cost and yet effective.

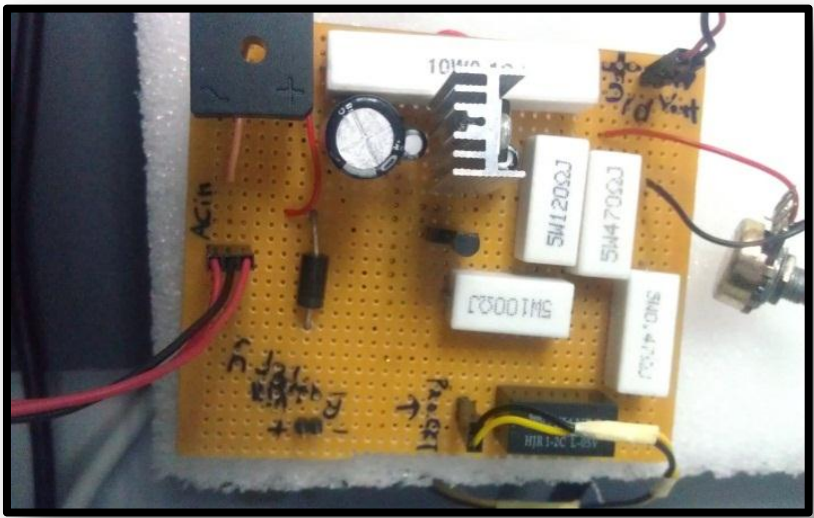


Figure 4.30: Relay in the Protection System

4.9 Practicality

Fossil fuels such as petrol and gas are depleting. Therefore, electric cars are the future vehicles that will be replacing our current engine and gas vehicles. This shows that the practicality of designing an Intelligent EV Controller System is definitely useful and important for the future as the global trend is moving towards the production of electric vehicles. Moreover, each and every electric car needs an intelligent controller system and here is where the EVICS comes into play.

4.10 Complexity

Having many different modules in the EVICS such as the voltage and current monitoring system, thermal monitoring with cooling system, LDR lighting system, protection, isolation and switching system, DC to AC inverter, motor rpm and kmh monitoring and remote wireless LAN communication shows that it is a very comprehensive and practical system that at the same time is working properly.

4.11 Intel Atom VS ARM development board

The ARM development board has been used in the electric vehicle embedded systems for quite a while. Therefore, for the Intel Atom platform to penetrate into this market segment, it needs to have a clear advantage over the current existing ARM platform to at least start as a competitive player in the electric vehicle embedded systems. Therefore, some of the advantages that the Intel Atom platform has over the ARM development board are mentioned as below.

4.11.1 Ability to connect to a router modem

This function is important for external computers and laptops to connect wirelessly to the Intel platform to monitor the performance of the car. Therefore, engineers and technicians can verify and determine problems with the electric car system remotely without needing to conduct the conventional hands-on approach.

4.11.2 Utilized as both infotainment system and intelligent controller system

At the same time, Intel Atom platform is only being used as a car in-vehicle-infotainment system, we have yet to see it being implemented into an electric car as an embedded intelligent controller system. Therefore, the Intel Atom platform now can be fully utilized as both infotainment system and intelligent controller system, a 2-in-1 function that other architectures do not provide.

4.11.3 Higher processing clock frequency of 1.66GHz

Another advantage of using Intel processors compared to other architectures such as ARM is the higher processing clock frequency of 1.66GHz while ARM's latest dual-core Cortex-A9 development board is running at 500MHz. The higher processing can give Intel Atom an edge in performing many multiple tasks at the same time (multitasking) without lag and delay especially when the platform is used to monitor many different management and monitoring systems and also being used as an infotainment system to play music and games at the same time.

4.11.4 Monitor and manage the energy and power consumption

One of the most important functions of the Intel platform is to be used for monitoring and managing the overall energy and power consumption of the whole EVICS system. This feature is very important because the Intel platform has been well known for its reliability and performance. This platform has already been used to monitor and manage the energy and power consumption of a smart home system; therefore there is no doubt that it can also be used in an electric vehicle's intelligent control system.

4.11.5 Can be customised for any applications to fit the customers' needs

Intel Atom platform can be customised for any applications to fit the customers' needs because one can control the amount of RAM and hard drive storage needed to be used with this platform. Embedded systems such as ARM do not have customisable hardware to cater to various customers' needs and therefore, the hardware specifications on their development board are fixed.

4.11.6 Has a graphic processing unit

Intel Atom platform has a graphic processing unit while ARM development board does not. This can give the Intel platform a significant advantage from the Infotainment point of view. Having a graphic processing unit enables the Intel platform to display different websites most of the time and having a wider range of browsing choices since surfing the internet has become a norm in nearly each and every modern person's living.

4.11.7 More user-friendly

The Intel Atom platform is also more user-friendly, in the sense that more people are familiar with the software and operating system that they use such as Windows 7 and it is more widely and commonly available everywhere.

CHAPTER 5

PROJECT ACHIEVEMENTS & EXPERIENCE

5.1 Collaboration with Yokohama Batteries & Sponsorship

At the very beginning of this Final Year Project, my team and I consisting of 6 final year students formed a team named UTAR EV Team under the guidance of Assistant Professor Dr. Chew Kuew Wai to work on the Electric Vehicle Conversion project.

During Year Four Semester One, UTAR EV Team managed to secure a sponsorship from Yokohama batteries to fund the whole Electric Vehicle Conversion project. The sponsorship agreement was to develop TWO electric cars; one using Yokohama's lead-acid batteries and another using Lithium-ion based batteries, both with the same specifications to compare the performance of both types of batteries in an electric car.

Figure 5.1: Yokohama Batteries sponsors

The sponsorship details and budgeting are as follows:

No	Item	Description	Unit price	Unit(s)	Amount
1	Conversion Kits + Controller + Charger	DC brushless motor, Charger, controller and accessories	RM33,280.00	2	**RM66,560.00**
2	Lead acid battery	Based on the 240V system: Yokohama 12V Deep Cycle Batteries N120-HD	RM800.00	20	**RM16,000.00**
3	Lithium battery	Based on the 240V system: Lithium Iron Phosphate Battery (EEMB) 48V	RM7040 / 2,200USD	6	**RM42,240.00/ USD13,200.00**
4	Budget notebook	Intel core i5, 4gb ram, 500GB hdd as a interfacing and programming tools to EV	RM3,000.00	1	**RM3,000.00**
5	Used car (same model)	Two units of same model car use as a basic conversion platform	RM8,000.00	2	**RM16,000.00**
6	Workshop/garage Tools Needed	Simple engine lift crane 2 ton car jack Complete tool set such as spanners, pliers Vacuum jet Bosch drill set 25mm cables, 50mm cables etc	RM5000.00	1	**RM5,000.00**
7	Miscellaneous	Shipping, transport, cooling system etc	RM51,200	1	**RM51,200**
8				**TOTAL:**	**RM200,000**
9		**Total without batteries & miscellaneous:**			**RM90,560**

Table 5.1: Budgeting for EV Conversion

DIRECT EXPENSES COST ESTIMATION

Conversion Kits (USD10,400 / RM33,280)

QUOTATION

ELECTRIC VEHICLES OF AMERICA, INC.
16 LEHNER STREET P.O. BOX 2037
WOLFEBORO, NH 03894
(603) 569-2100
FAX (603) 569-2115
EVAmerica@aol.com

240 V HV CAR
USING 12V BATTERIES

QTY	DESCRIPTION	UNIT PRICE	TOTAL PRICE
	DRIVE SYSTEM		
1	WarP 11HV Netgain Motor with dual shaft	$3,400.00	$3,400.00
	(72V - 240V) ??HP - ??HP		
1	WarP-Drive Controller Liquid Cooled, Upgradeable	$2,700.00	$2,700.00
	12V - 260V 1000 Amp		
	Requires HEPA or HETA and Liquid Cooling Kit		
1	Liquid Cooling Kit includes all hoses, pumps, nozzles	$300.00	$300.00
	necessary to connect WarP-Drive		
1	HETA - Hall Effect Throttle Assembly	$175.00	$175.00
2	Kilovac Czonka EV200 Contactor	$185.00	$370.00
1	Adapter Plate with Spacers (2)	$400.00	$400.00
	Manual Transmission - Clutchless		
1	Motor Coupling (Aluminum)	$325.00	$325.00
	Manual Transmission - Clutchless		
	BATTERY SYSTEM		
1	PFC-5000 110 VAC / 230 VAC 240VDC Sealed Charger	$1,585.00	$1,585.00
	Batteries to be determined later		
40	2/0 Battery Terminal Protective Covers (Red & Black)	$1.50	$60.00
90	ft 2/0 UltraFlex Cable (Orange)	$5.00	$450.00
60	2/0 lugs - Magna lug (includes 6 90 degree)	$2.50	$150.00
8	ft Heat Shrink with sealant	$6.00	$48.00
	INSTRUMENTATION		
1	200-400 Voltmeter (Westberg 2in Black)	$75.00	$75.00
1	0-400 Ammeter (Westberg 2in Black)	$65.00	$65.00
1	50 mV Shunt - 400A	$30.00	$30.00

	POWER BRAKES		
1	Gast Vacuum Pump (12V)	$225.00	$225.00
1	SquareD Vacuum Switch	$135.00	$135.00
1	In-line Fuseholders with 20 Amp Fuse	$5.00	$5.00
	SAFETY		
1	Littelfuse L25S-400	$55.00	$55.00
1	Littelfuse holder	$25.00	$25.00
1	Pair Anderson connectors SBX-350 (Red)	$64.00	$64.00
1	Fuseholder (4) - Control Board	$15.00	$15.00
1	First Inertia Switch - Auto Shutoff (12V Sys)	$45.00	$45.00

	TECHNICAL ASSISTANCE	
A/R	EVA calculations	N/C
1	EVA Installation Manual Includes schematics, drawings, etc.	N/C
1	Safety First & S-10 Conversion Video DVD	N/C
A/R	On-Line Assistance @ EVAmerica@aol.com	N/C
	1 year Subscription to EVAmerica	NC

	SUBTOTAL	$10,702.00
	EVAmerica Coupons - Package	-$302.00

	TOTAL (Shipping - not included)	$10,400.00

Battery Profile

Estimated price for Yokohama Deep Cycle N120-HD Lead Acid Battery											
TKY Code	JIS Code	Battery Size			Dry Weight	Wet Weight	Capacity		Category Type	Terminal Type	Price
		L	W	H			Ah (20h)	CCA			
N120-HD	115F51	505	184	257	24.4kg	35.7kg	120	575	C	4	RM800

Table 5.2: Estimated price for Yokohama Lead Acid Battery

Units required for Yokohama Deep Cycle N120-HD Lead Acid Battery: 20 units (12V) = 240V

Estimated Price for EV Lithium Ion Phosphate Battery (EEMB)						
Model	Pack	Voltage	Capacity	Weight	Dimension	Price
LP9067220F-10P16S	10P16S	48V	100Ah	45kg	9.0 x 67 x 220	RM7040 / 2200USD

Table 5.3: Estimated Price for EV Lithium Ion Phosphate Battery (EEMB)

Units required for EV Lithium Iron Phosphate Battery: 5 units (48V) = 240V

*PS: The Yokohama deep cycle lead acid batteries are subject to changes to match the energy (kWh) of the Lithium-ion batteries to compare both the EVs performance fairly. (The capacity, Ah of both types of batteries MUST be the same)

Supplier Address:

Hong Kong Office

Unit 12-13, 13/F., Delta House, 3 On Yiu Street, Sha Tin, Hong Kong Tel: +852-28841422 Fax: +852-28859822 EEMB Global Marketing Dept.

E-mail : global@eemb.com

Mainland China Office

A,B,C,D, 25/F, Building A, Fortune Plaza NO.7060, Shen Nan Road, Shen Zhen (zip code 518040) P.R.China. Tel: +86-755-83022275 Fax: +86-755-83021966 EEMB Sales & Technic Support Dept.

E-mail : global@eemb.com

Used Car Proposal (2 cars RM16,000 max)

Proton Wira (1995)	Proton Wira (1993)
RM6000	RM6000
1.3 Manual	1.6 Auto

Iswara	Saga
RM5000	RM5000
1.3 Manual	1.3 Manual

Nissan Sunny 130Y	Nissan Sunny 130Y
1.3 Manual	1.3 Manual
RM4500	RM3800
1993	1992 / 1984
Power steering	NO power steering

Water Cooling Kit System

Cooling Module

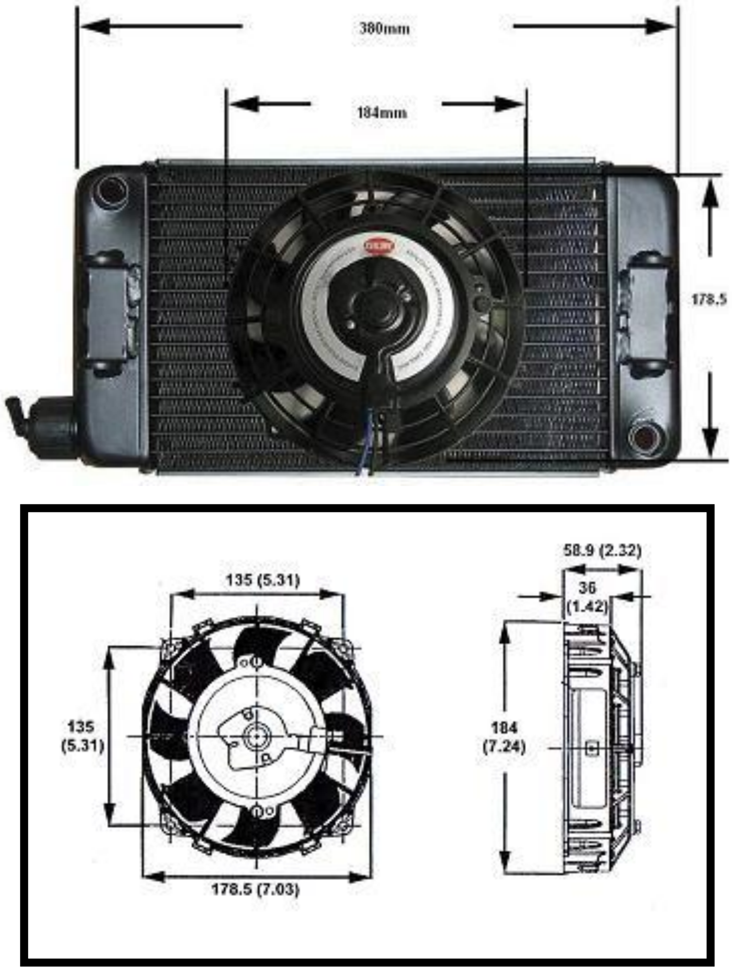
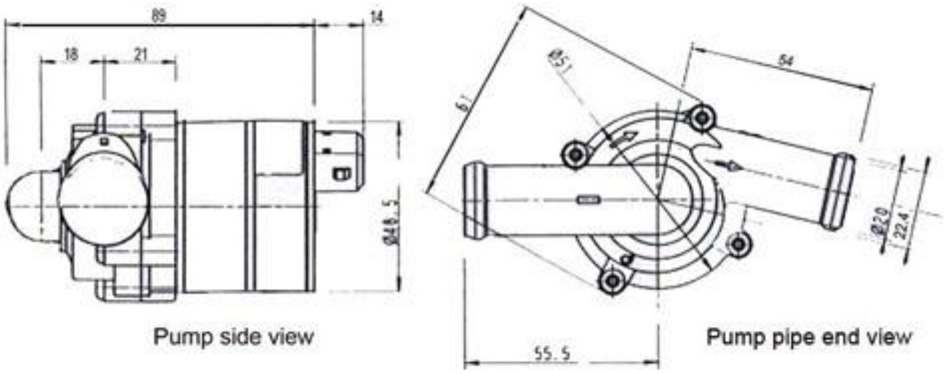


Figure 5.2: Water Cooling Kit Systems

Figure 5.3: Coolant Pump



19 mm coolant hose, coolant and DC cables are not included in our package, but can be made available if required. (based on using 2.5 meters of 19mm coolant hose, total coolant weight = 2.4 KG) 2.4 litres of Propylene Glycol antifreeze to be used, not Ethylene Glycol. Certified coolant must be used in GMS power trains to meet warranty requirements. Use of standard Ethylene Glycol will void the warranty, only use Propylene Glycol.

Price: $375 USD (MYR 1200) per set

Address: Lowcarbon-idea Co. Ltd. Electric Power Building, TianHe District, GuangZhou, GuangDong, China.

5.2 Research Paper Publications & Conference

5.2.1 Malaysian Universities Transportation Research Forum and Conference (MUTRFC 2010)

1. **Y. H. Gan**, K. W. Chew, G. D. Gan, Z. Y. Phuan, C. K. Leong, B. K. Cheah, et al. (2010). A Study on Electric Car Chassis and Design Principle, *Green Transportation for Future Generation*, 191-202

http://www.uniten.edu.my/newhome/uploaded/coe_civil/mutrfc2010/021%20A%20STUDY%20ON%20ELECTRIC%20CAR%20CHASSIS%20AND%20DESIGN%20PRINCIPLE.pdf
http://www.uniten.edu.my/newhome/uploaded/coe_civil/mutrfc2010/021%20UG.pdf

2. Z. Y. Phuan, **Y. H. Gan**, K. W. Chew, C. K. Leong, M. K. Yoong, B. K. Cheah, et al. (2010). Design of Battery Pack For Electric Vehicle Based on Lithium-Ion Technology, *Green Transportation for Future Generation*, 127-134

http://www.uniten.edu.my/newhome/uploaded/coe_civil/mutrfc2010/014%20DESIGN%20OF%20BATTERY%20PACK%20fOR%20ELECTRIC%20VEHICLE%20BASED%20ON%20LITHIUM-ION%20TECHNOLOGY.pdf

3. B. K. Cheah, **Y. H. Gan**, K. W. Chew, G. D. Gan, Z. Y. Phuan, M. K. Yoong, et al. (2010). Case Study of EV Controller and Power Management System, *Green Transportation for Future Generation*, 175-190

http://www.uniten.edu.my/newhome/uploaded/coe_civil/mutrfc2010/020%20CASE%20STUDY%20OF%20EV%20CONTROLLER%20AND%20POWER%20MANAGEMENT%20SYSTEM.pdf

4. G. D. Gan, **Y. H. Gan**, K. W. Chew, Z. Y. Phuan, C. K. Leong, M. K. Yoong, et al. (2010). Studies of Electric Motors For Light-Weight Electric Vehicle, *Green Transportation for Future Generation*, 135-148

http://www.uniten.edu.my/newhome/uploaded/coe_civil/mutrfc2010/016%20STUDIES%20OF%20ELECTRIC%20MOTORS%20FOR%20LIGHT-WEIGHT%20ELECTRIC%20VEHICLE.pdf

5.2.2 IEEE STUDENT (SusTainable Utilization and Development in ENgineering and Technology) Conference 2010 (Print ISBN: 978-1-4244-7504-9)

5. C. K. Leong, **Y. H. Gan**, K. W. Chew, G. D. Gan, Z. Y. Phuan, B. K. Cheah, et al. (2010). Ultra-Fast Charging System On Lithium-Ion Battery, *Sustainable Utilization and Development in Engineering and Technology*

6. M. K. Yoong, **Y. H. Gan**, K. W. Chew, G. D. Gan, Z. Y. Phuan, C. K. Leong, et al. (2010). Studies of Regenerative Braking In Electric Vehicle, *Sustainable Utilization and Development in Engineering and Technology*

5.2.3 Book Publications

- Green Transportation for Future Generation (ISBN: 978-967-5770-08-1)
    - Perpustakaan Negara Malaysia: Cataloguing-in-Publication Data

5.2.4 Award Achievement

- Best Presenter Award (Undergraduate Category) out of 48 participants

Figure 5.4: Book publication and the Best Presenter Award

5.3 Innovate Malaysia Design Competition 2011 (Intel)

Three members of the UTAR EV Team, Vincent Cheah Beng Keat, Gan Guo Dong, and myself, Gan Yu Han, participated in the Innovate Malaysia Design Competition 2011 Intel Track during May 2010 and the three of us worked on this competition as our Final Year Project. Up until now (28^{th} April 2011), we were the final FIVE teams that will be participating for the Intel Atom Platform Grand Finale that will be held in Altera, Penang on the 11^{th} June 2011. We managed to qualify through two rounds of eliminations; out of approximately 60 teams that submitted their proposals, we entered the top 23 finalist that need to present at the Preliminary Stage and Hardware Presentation and finally qualified through to the last FIVE finalists. Some of the exposures that we received from this competition were the Intel platform training at DreamCatcher, Penang in October 2010 for three days and the Preliminary Stage and Hardware Presentation at MSC Malaysia Innovation Centre, Cyberjaya in April 2011 as shown below.

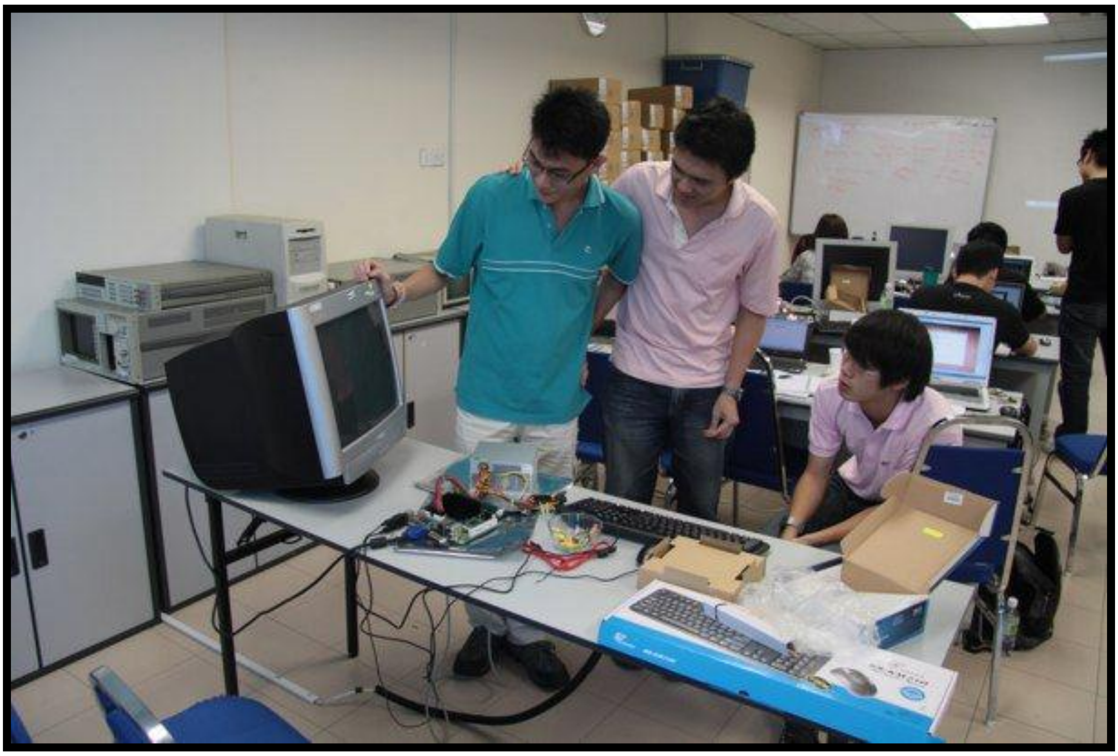


Figure 5.5: Intel platform training at DreamCatcher, Penang in October 2010

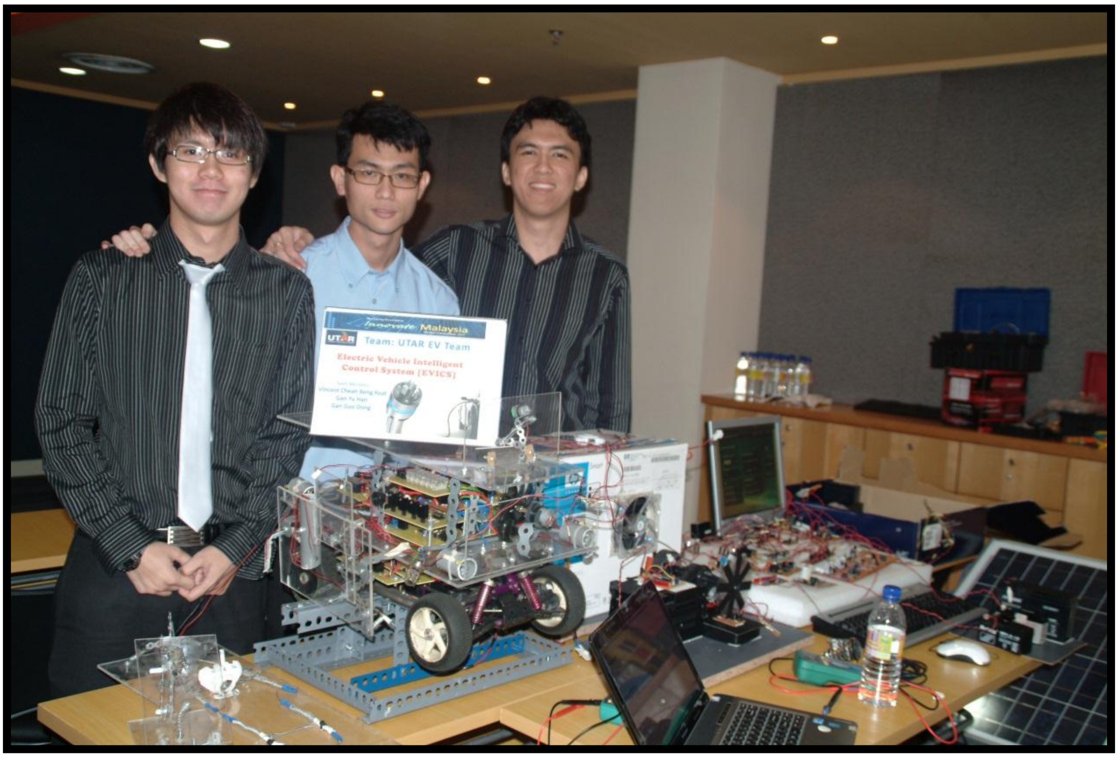


Figure 5.6: Preliminary Stage and Hardware Presentation at MSC Malaysia Innovation Centre, Cyberjaya in April 2011

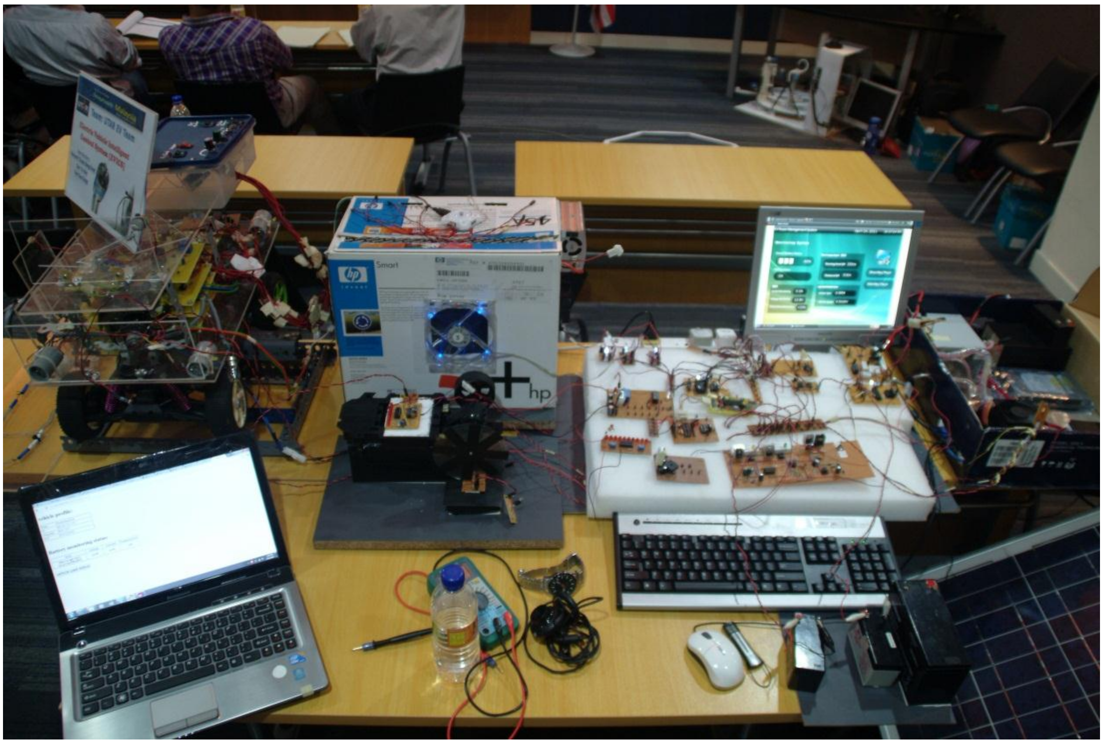


Figure 5.7: Completed Electric Vehicle Intelligent Control System (EVICS)

5.4 Schneider Electric University Challenge 2010

During Year 4 Semester 1, two of my friends, Mak Kwan Wuey, Liu Chee Wei and myself participated in the Schneider Electric ‘Green The World’ University Challenge 2010 and we managed to win the First Runners-Up prize of RM10,000 and trophies. My task in this competition was to design a heat extractor system to extract radiation from the sun to heat up water for daily applications in our University’s cafeteria to save energy from boiling water. I was also required to calculate the cost of construction for the whole system and determine the Return of Investment (ROI) for potential customers who might want to install this heat extractor system into their buildings.

Figure 5.8: Schneider Electric First Runner Up prize giving

Figure 5.9: Smart lighting, HVAC and heat extractor system hardware prototype

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Summary

In conclusion, the Intelligent EV Controller System consists of many different modules that perform many different purposes, ranging from monitoring systems, protection and isolation systems, wireless and communication systems etc. From the results derived and discussions, the project implemented was a great success. The modules designed and created were up to expectation and working as they should be. We also learned to compare the functions and advantages that the Intel Atom platform had compared to other embedded systems such as the ARM development board. At the same time, budgeting for the project was very important and we had learned to become resourceful and only bought those electronics and electrical components that we really needed and could not source from recycled items. We also learned to obtain sponsors and free samples from industry companies to help fund this exciting project.

The main purpose for the implementation of this project was to understand the functionality of the Intel Atom platform and how to make use of all the functions in an intelligent electric car controller system. The most important function that the Intel Atom platform could do for an electric car in the future would be the 'efficient and intelligent energy management system'. We managed to design and build a system which could intelligently control most of the essential functions of an electric car but we believed there would be rooms for improvement for an efficient energy management system. Future improvements could be done on the system to better manage the energy and power consumptions of each and every module to increase the durability of the battery

The main problem faced in this project was the communication between the Intel Atom platform and controller systems that existed in the electric car. Finally after much hard work, we managed to solve the communication problems by using the serial port on the Intel platform to communicate with the controller system modules through the Microcontroller PICs. Another breakthrough in this project was the wireless communication with the Intel Atom platform using an Android based smartphone and/or external laptop/computer to remotely control and monitor the faults and problems within the intelligent controller systems.

Many modules were created in this project and a lot of experience was built from there. However, there are still rooms for improvements as mentioned in the future improvements section of this thesis. We learned that there are many ways to solve a problem and to create a solution. All we need to do is to select the solution that fulfil all the requirements that we need in a system and to make sure that the solution to the problem is cost effective and yet workable at the same time.

6.2 Future Improvements

6.2.1 Battery Analyser

The Battery Analyser can be built as a future improvement to measure the capacity of the battery in percentage (%) much more accurately. Currently, the module built for battery capacity uses the battery's voltage as a reference to estimate the percentage of capacity that is left in the battery which is not so accurate.

6.2.2 Watchdog timer

The watchdog timer can be installed to monitor the state of each and every sensor implemented in the EVICS and tells the user which one of the sensors has failed to function such as the temperature sensor, ultrasonic sensor, infrared sensor etc.

6.2.3 Reverse parking ultrasonic sensor & webcam

The reverse parking can be implemented into the EVICS system using both the ultrasonic sensor and webcam like those that exist in luxury cars nowadays. Even better if a system can be designed to detect a parking spot and automatically parks the user's car into the empty parking spot provided.

6.2.4 Regenerative charging voltage system

The purpose of the regenerative charging voltage system is to provide a low current charging to the supply battery and can be implemented into the battery compartment of the EVICS. This system has been explained in the Innovation section.

6.2.5 Energy saving indicator (Honda Insight)

The energy saving indicator module that is available inside the control system of the Honda Insight hybrid vehicle can also be implemented into the EVICS. This module can perform three basic functions:

- indicates to the users if they are driving at a speed that saves petrol or battery energy
- tells the users if they are wasting energy by leaving something switched on in the car
- suggests measures and solutions to save energy consumption in the car.

6.2.6 Auto ON/OFF configuration

This function is very important in a smart control system where the user can just switch on the EVICS in the car and it will auto-configure itself to start monitoring and manage all the modules in the EVICS automatically. For the current EVICS, after it is turned on, there are still some settings and configurations needed to be done before the system can manage and monitor all the modules automatically.

6.2.7 Expandable external modules for easy plug-in provides flexibility and more functions

The EVICS can be designed to easily plug-in new and external modules such as fm radio module, reverse parking module and other intelligent monitoring and management modules. This will make it so easy for new users who need a certain extra function in their EVICS and they can just plug in their own module into the system with just a simple step-by-step guide.

6.3 FYP Learning Experience

- Design system's circuit with minimum electronic components as possible to reduce cost, while at the same time maintaining the functionality and reliability of the system.

- Troubleshooting and identify circuit problems, list out the available options and methods to solve the problem and finally, determine and execute the best and most suitable solution that can be taken to solve the problem.

- Design a system using suitable electronic components with the correct and optimum specifications and ratings by referring to the component's datasheet. Understanding the applications required from the datasheet to build a more effective and efficient system while at the same time reducing cost.

- Most of the system's circuit design uses NPN transistors because the electron mobility is higher than the hole mobility in the semiconductors, thus allowing greater current flow from the collector to emitter and faster operation compared to PNP transistors.

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Younus, S. A. M., Tabanao, R. B. (2002). *500W Power Inverter.* Retrieved April 18, 2011, from http://www.electro-tech-online.com/attachments/electronic-projects-design-ideas-reviews/13707d1185466433-distinction-between-2n3055-tip3055-500watts_inverter.gif

APPENDICES

APPENDIX A: PIC Microcontroller Source code for Current Monitoring System

```
/*******************************************************
MODULE : CURRENT MONITORING SYSTEM
CTRL : AN1 [INPUT] OUTPUT RB1
*******************************************************/

              ADCON0=0b00000101;   //AN1
              ADCON0bits.GO_DONE = 1;
              while(ADCON0bits.GO_DONE != 0);//Loop here until A/D conversion
completes

              if ( ADRESL < 0x14 && ADRESH==0b00){
              //PORTBbits.RB1=0x00;
              j=0;
              if (ADRESL >=0 && ADRESL <3)
              current='a';
              else if (ADRESL >=3 && ADRESL <5)
              current='b';
              else if (ADRESL >=5 && ADRESL <7)
              current='c';
              else if (ADRESL >=7 && ADRESL <9)
              current='d';
              else if (ADRESL >=9 && ADRESL <11)
              current='e';
              else if (ADRESL >=11 && ADRESL <13)
              current='f';
              else if (ADRESL >=13 && ADRESL <15)
              current='g';
              else if (ADRESL >=17 && ADRESL <19)
              current='h';
              else
              current='i';
              }//endif
              else {
              //PORTBbits.RB1=0xFF;
              j=1;
              current='j';
              }
```

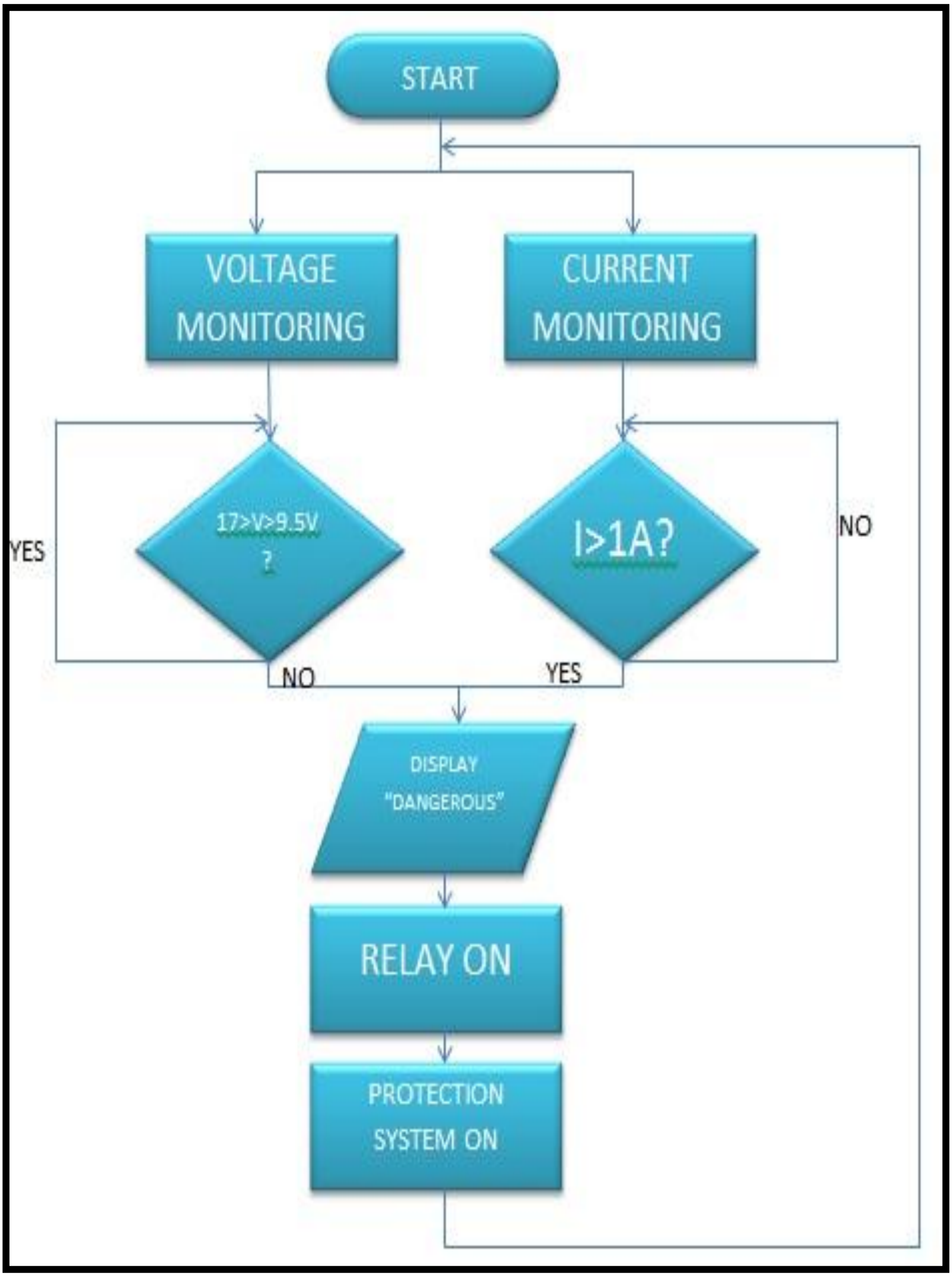
APPENDIX B: PIC Microcontroller Source code for Voltage Monitoring System

```
/*******************************************************
MODULE : BMS AND BMU
PIC INDICATOR [BKCHEAH]
PORTBbits.RB2=0xFF;
0x7A [0.6V]
0x89 [0.67V]
0x95 [0.73V]
0xA3 [0.8V]
0xB7 [0.9V]
0xCC [1.0V]
0xE0 [1.1V]
control using IJK control module
******************************************************
MODULE : VOLATGE INDICATOR
CTRL : AN0 [INPUT] RB0 [OUT]
*******************************************************/
		ADCON0=0b00000001;   //AN0
		ADCON0bits.GO_DONE = 1;
		while(ADCON0bits.GO_DONE != 0);//Loop here until A/D conversion
completes

		if ( ADRESL < 0xE0 && ADRESH==0b00){
			//PORTBbits.RB0=0x00;
			i=0;
//*****************************************************************************
*************
/*     [PROGRAMMING SAMPLING] <USING RB2 TEMP OUTPUT> */
			if ( ADRESL >= 204 && ADRESL < 224)//1.0
			battery='q'; //100%
			else if ( ADRESL >= 183 && ADRESL < 204)//1.0
			battery='p'; //80%
			else if ( ADRESL >= 163 && ADRESL < 183)//0.9
			battery='o'; //60%
			else if ( ADRESL >= 149 && ADRESL < 163)//0.8
			battery='n'; //40%
			else if ( ADRESL >= 137 && ADRESL < 149)//0.73
			battery='m'; //20%
			else if ( ADRESL >= 122 && ADRESL < 137)//0.67
			battery='l'; //0%

			else{
				/*PROTECTION CIRCUIT FOR LESS THAN 9V*/
				if ( ADRESL < 122){
					//PORTBbits.RB0=0xFF;
					i=1;
					battery='k';
				}
				else
					i=0;
					//PORTBbits.RB0=0x00;
		}////endif
			}
		else {
			//PORTBbits.RB0=0xFF;
			battery='r';
			i=1;
		}
```

APPENDIX C: PIC Microcontroller Source Code for Protection Systems

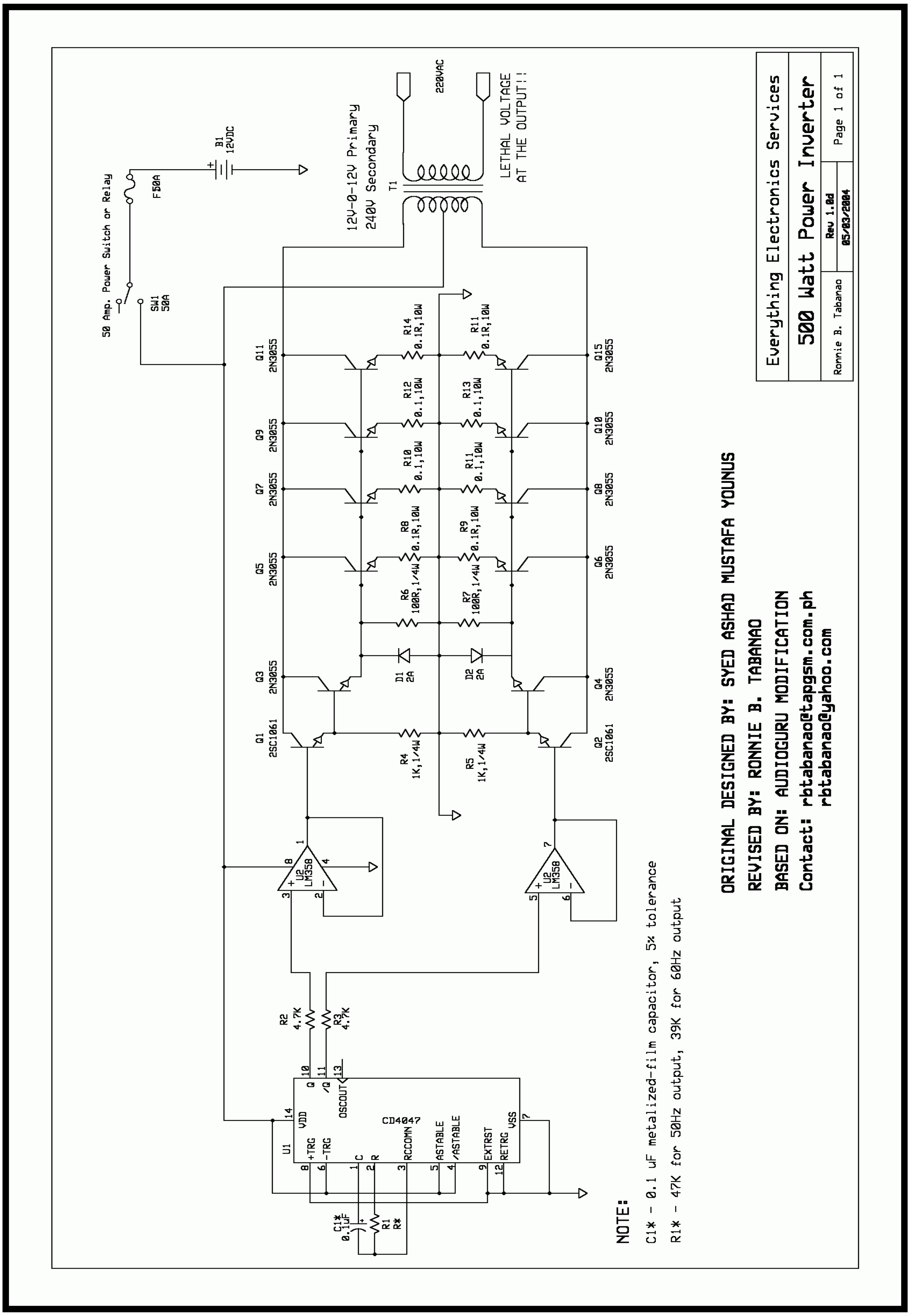
```
/*****************************************************
MODULE : ACTION CONTROL MODULE
*****************************************************/
       if (i==1 || j==1 || k==1)
              PORTBbits.RB0=0xFF;
       else
              PORTBbits.RB0=0x00;
```

APPENDIX D: Voltage, Current and Protection Systems flow chart



APPENDIX E: Sample circuit diagram of a 500W 12VDC-220VAC Inverter

(Younus, S. A. M., Tabanao, R. B., 2002)



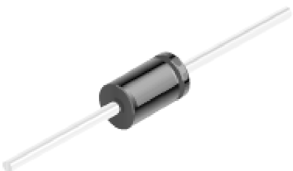
APPENDIX F: 1N5402 Datasheet

FAIRCHILD SEMICONDUCTOR®

1N5400 - 1N5408

Features

- 3.0 ampere operation at $T_A = 75°C$ with no thermal runaway.
- High current capability.
- Low leakage.



DO-201AD
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Maximum Ratings*

$T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Value									Units
		5400	5401	5402	5403	5404	5405	5406	5407	5408	
V_{RRM}	Maximum Repetitive Reverse Voltage	50	100	200	300	400	500	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ $T_A = 75°C$	3.0									A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	200									A
T_{stg}	Storage Temperature Range	-55 to +150									°C
T_J	Operating Junction Temperature	-55 to +150									°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	6.25	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	20	°C/W

Electrical Characteristics

$T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Device									Units
		5400	5401	5402	5403	5404	5405	5406	5407	5408	
V_F	Forward Voltage @ 3.0 A	1.2									V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle $T_A = 105°C$	0.5									mA
I_R	Reverse Current @ rated V_R $T_A = 25°C$ $T_A = 100°C$	5.0 500									µA µA
C_T	Toatal Capacitance $V_R = 4.0$ V, f = 1.0 MHz	30									pF

APPENDIX G: PN2222A datasheet

FAIRCHILD
SEMICONDUCTOR®

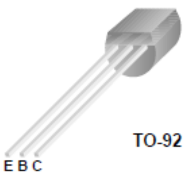
August 2010

PN2222A / MMBT2222A / PZT2222A
NPN General Purpose Amplifier

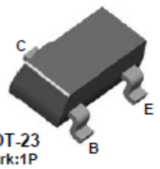
Features

- This device is for use as a medium power amplifier and switch requiring collector currents up to 500mA.
- Sourced from process 19.

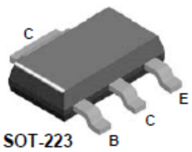
PN2222A



MMBT2222A



PZT2222A



Absolute Maximum Ratings * T_a = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	75	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector Current	1.0	A
T_{STG}	Operating and Storage Junction Temperature Range	- 55 ~ 150	°C

* This ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:

1) These rating are based on a maximum junction temperature of 150 degrees C.

2) These are steady limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics T_a = 25°C unless otherwise noted

Symbol	Parameter	Max.			Units
		PN2222A	*MMBT2222A	**PZT2222A	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	350 2.8	1,000 8.0	mW mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3			°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	125	°C/W

* Device mounted on FR-4 PCB 1.6" × 1.6" × 0.06".

** Device mounted on FR-4 PCB 36mm × 18mm × 1.5mm; mounting pad for the collector lead min. 6cm^2.

APPENDIX H: SDP10S30, 10A, 1.5V Silicon Carbide Schottky Diode datasheet

Infineon technologies

Preliminary data

SDP10S30, SDB10S30
SDT10S30

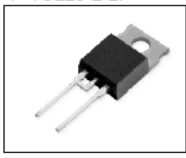
Silicon Carbide Schottky Diode

- Revolutionary semiconductor material - Silicon Carbide
- Switching behavior benchmark
- No reverse recovery
- No temperature influence on the switching behavior
- No forward recovery

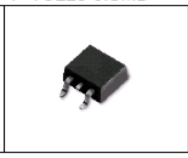
Product Summary

V_{RRM}	300	V
Q_c	23	nC
I_F	10	A

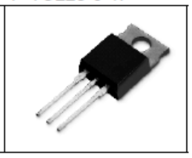
P-TO220-2-2.



P-TO220-3.SMD



P-TO220-3-1.



Type	Package	Ordering Code	Marking	Pin 1	PIN 2	PIN 3
SDP10S30	P-TO220-3-1.	Q67040-S4372	D10S30	n.c.	C	A
SDB10S30	P-TO220-3.SMD	Q67040-S4373	D10S30	n.c.	C	A
SDT10S30	P-TO220-2-2.	Q67040-S4447	D10S30	C	A	

Maximum Ratings,at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Value	Unit
Continuous forward current, T_C=100°C	I_F	10	A
RMS forward current, f=50Hz	I_{FRMS}	14	
Surge non repetitive forward current, sine halfwave T_C=25°C, t_p=10ms	I_{FSM}	36	
Repetitive peak forward current T_j=150°C, T_C=100°C, D=0.1	I_{FRM}	45	
Non repetitive peak forward current t_p=10µs, T_C=25°C	I_{FMAX}	100	
i^2t value, T_C=25°C, t_p=10ms	$\int i^2 dt$	6.5	A²s
Repetitive peak reverse voltage	V_{RRM}	300	V
Surge peak reverse voltage	V_{RSM}	300	
Power dissipation, T_C=25°C	P_{tot}	65	W
Operating and storage temperature	T_j , T_{stg}	-55... +175	°C

APPENDIX I: Intel Platform Training Certificate

dream CATCHER

This is to certify that

Gan Yu Han

has successfully completed

Intel Platform Quick Start

for Final Year Design Competition 2011

held

22 – 24 October 2010

Mr Percy Chen
Programme Instructor

Choo Wai Heng
Managing Consultant

APPENDIX J: Best Exhibition Award for Schneider Electric Hardware Certificate

IEEE Student Branch
UNIVERSITI TUNKU ABDUL RAHMAN
UTAR

STUDENT 2010

IEEE Conference on SusTainable Utilization and Development in ENgineering and Technology [STUDENT 2010]
20-21 November 2010

presents this

Winner of Best Exhibition Award

to

Mak Kwan Wuey, Liu Chee Wei, Gan Yu Han

for the project entitled

Smart Lighting, HVAC (Heating, Ventilating, and Air Conditioning) and Heat Extractor System

Taylor Ling Jia Zun
Conference Director
STUDENT 2010

Dr. Tan Ching Seong
Advisor of UTAR-IEEE Student Branch
STUDENT 2010

APPENDIX K: MUTRFC Paper Publication Presenter Certificate

UNIVERSITI TENAGA NASIONAL

CERTIFICATE OF PARTICIPATION

presented to

Mr. Gan Yu Han
(Presenter)

for successfully participated in

MUTRFC 2010
Malaysian Universities Transportation Research Forum and Conference
21st December 2010
Universiti Tenaga Nasional, Putrajaya

MALAYSIAN UNIVERSITIES TRANSPORTATION RESEARCH FORUM AND CONFERENCE 2010
"Green Transportation for Future Generation"

held at
UNIVERSITI TENAGA NASIONAL, PUTRAJAYA
21st DECEMBER 2010

Engr. Mohd Sufian Abdul Karim
CO-CHAIRMAN
MALAYSIAN UNIVERSITIES TRANSPORTATION RESEARCH FORUM AND CONFERENCE 2010

APPENDIX L: Schneider Electric 2010 1st Runner Up Certificate

Schneider Electric

Schneider Electric Green the World @ My Campus
University Challenge 2010

This is to certify that

GAN YU HAN

from team ECO-UNIVERSITY

was a 1st RUNNER UP for

Schneider Electric
Green the World @ My Campus
University Challenge 2010

Thank you for your effort, determination and creativity in contributing to a greener world!

Schneider Electric

Peter Cave
Country President
Schneider Electric Malaysia

APPENDIX M: MUTRFC and IEEE STUDENT 2010 Paper Publication Abstracts

A STUDY ON ELECTRIC CAR CHASSIS AND DESIGN PRINCIPLE

ABSTRACT:

In this project, the placement of components in an electric car (EV) and the system chassis design will be studied and explained. The scope covered is divided into 5 main portions:

Part 1: Placement of important components such as Lithium-ion polymer batteries, DC brushless motor, controller and driver circuits strategically in the chassis of an electric car.

Part 2: Study to maintain balance, aerodynamic and spacing optimization in the design of an electric car.

Part 3: Important criteria to be considered in the positioning of batteries, motor and controller in the chassis such as the size, weight, type of components used, specification requirements, etc.

Part 4: Balancing the front and back weight ratio of the car to ensure stability and safety of the driver and passengers.

Part 5: Design of good air ventilation and heat dissipation to prolong the lifetime of expensive equipment such as batteries and provide safety to the users.

Commercially available electric vehicles and prototypes still do not have a defined standard of component placements unlike engine vehicles. Therefore, these studies will provide a fundamental platform for further studies on commercially available electric cars in the market.

Keywords: balance, stability, safety, heat dissipation, spacing optimization

Design of Battery Pack for Electric Vehicle based on Lithium-Ion Technology

Abstract— In these modern days, electric vehicles are well known for its efficiency, it would be a cost saving choice compared to the ICE car, due to its advantages such as silent engine, zero emission which are totally green to the environment. However the selection of a suitable battery type such as lead acid, NiMH, Lithium ion in the long run plays a very important role in the construction or design of the electric vehicle due to its function and also the physical aspects. In terms of the functionality, the vehicle must be able to provide sufficient energy to allow the car to move or accelerate and at the same time, having a long lifespan or constant power supplied to the vehicle. Taking this into consideration, lithium ion battery have been selected as the main power source when designing an electric car, this can be viewed from the characteristics of a lithium ion battery such as fast charging rate, light weight, high capacity and long charge-discharge cycle, etc. Hence the design of battery pack using lithium ion battery inclusive of its compartment design, ventilation and the monitoring system will be discussed in this paper.

Keywords : Lithium Ion, fast charging rate, charge-discharge cycle

Studies of Electric Motors for Light-Weight Electric Vehicle

ABSTRACT:

In the development of the electric vehicle (EV), the parameters of electric motor, such as its torque, maximum speed, rotation per minute (rpm) and etc played an important role in determining the performance of a good EV. The electric motor is the heart of the EV which offers the driving element that moves the EV in various conditions. The electric motor comes in different shapes, driving methods, types and functions. However, the problems faced lies in the selection of the perfect electric motor for a four-seater, urban-bound vehicle that can muscle out the sufficient torque and deliver wide range of speed. Also, maintaining high efficiency in the long run to overcome the dominance of the combustion engine. The solutions are to do engineering research in the field of electric motor. Various experiments are performed to determine the motor parameters. In this paper, the arguments between the usage of DC motor and AC motor have been briefly discussed. The suitability of DC motor for light weight EV have been investigated and discussed.

Keywords: DC/AC motor, torque, maximum speed, rotation per minute (rpm), light weight EV.

CASE STUDY ON EV CONTROLLER AND BATTERY MANAGEMENT SYSTEM

ABSTRACT:

The application for the designed Pulse Width Modulation Motor Control circuit including Battery Management System is in the field of battery powered cars. This new move towards renewable energy and environmental friendliness is definitely a goal worth aiming for as the Earth's natural resources continue to diminish. Battery powered vehicles are indeed a very important component in the future of electrical and electronics engineering in this nation. This is evident considering Proton's latest offering, the Proton Saga EV Green Propulsion, and is Malaysia's first very electric vehicle. It is hoped that through the execution of this assignment, we as engineering students may someday contribute towards the technological development in the field of electronics of our very own country, Malaysia.

In an Electrical Vehicle (EV) design, the power management system and controller plays an important role as a 'brain' of the EV, to ensure the car can run smoothly and in order. The main functions of a controller is basically to control the main contactor and kill switch contactor, incorporating appropriate safety measures and interlocks, control the reversing contactor, incorporating appropriate safety measures and interlocks, power the vacuum pump in the EV braking System, power the toaster heater contactor and power DC-to-DC-contactor, where as the power management system ensured that the power distribution are in order and at the meantime achieving maximum transfer efficiency. The power management system includes converter circuit, charging circuit, motor drive and base drive circuit. In this report, the works are mainly focus on power management system and base drive circuit inclusive of their controller and converter circuit. The functionality of each of the controller will be investigated and discussed.

Keywords: BMS, BCU, BMU, SOC, CAN, cell protection, isolation of gate and base drive circuit.

Ultra Fast Charging System On Lithium Ion Battery

Abstract— Even with the advancement of the high technology nowadays, the popularity of electric vehicle is still limited and unable to make it a common usage. The main reason is due to the limitation of the battery pack which is bulky, heavy, slow charging, short lifespan and toxicity hazardous. Among these problems, slow charging speed becomes the main consideration when purchasing an electric vehicle. Hence, different charging methods have to be studied thoroughly to seek for the best solution to overcome these problems. In today's competitive battery charging method, a lot of charger manufacturers claim that they can amazingly short charge times of 30 minutes or less. In this project, different charging method such as Constant Voltage charging, Constant Current charging, Pulsed charge etc, have been studied and compared to optimize the charging time suitable for different kind of battery pack.

Keywords: fast charging, Lithium-ion batteries, pulse charging, constant voltage charging, constant current charging

STU10032- Studies of Regenerative Braking In Electric Vehicle

Abstract -Generally in electric and gasoline cars, the braking system is based on the hydraulic braking technology. However, this traditional braking methodology causes a lot of energy wastage since it produces unwanted heat during braking. Hence, the invention of regenerative braking in electric car nowadays is getting popular due to its technology that helps in saving energy and with higher efficiency to boost up the acceleration of the car. In regenerative braking, the motor act as a generator. It transfers the energy generated which is in the form of kinetic energy to restore the battery or capacitor energy in order to prolong the range or driving distance. Meanwhile, in regenerative braking system, the brake controller monitors the speed of the wheels and calculates the torque required hence the excessive energy from the rotational force can be converted into the electricity when the motor acts like generator, the generated electricity will be fed back into the batteries. The reasons of choosing regenerative braking is because of its advantages over conventional break such as energy conservation, wear reduction, fuel consumption, more efficient in braking, and it meet up the concept “go green” as it produce zero carbon dioxide. Besides, there are more advance technology now implementing in regenerative braking to improve the car efficiency such as using flywheel to save more energy thru the wheel and ultracapacitor with DC-DC converter to boost up the car acceleration and provide better performance for regenerative system for the electric car. In this paper, the working principle and some braking controller for the regenerative braking have been studied to promote the efficiency and to realize the energy saving in the electric vehicle.

Keywords: regenerative braking, generator, brake controller, energy conservation, flywheel, ultracapacitor