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ABSTRACT

Automotive industry is moving forward for green technology which is Electric Vehicles. Battery is one of the critical components in an Electric Vehicle. Lithium Ion Polymer battery offers better performance compare to other types of the battery in the market. However, Lithium Ion Polymer battery is very sensitive to over voltage and under voltage which can be hazardous to the user. Moreover, the imbalanced cell in a battery affects the performance and life usage of the battery. By having a proper monitoring and balanced cell, it can prolong and maintain the performance of the battery. The purpose of this work is to adopt a passive cell balancing during the charging of Lithium Ion Polymer battery. This work produces State of Charge profile of Lithium Ion Polymer battery using measured parameters such as voltage, charging current and temperature. The work on battery testing was done to calculate the State of Charge and verified using Orion Battery Management System data. In this report, findings on both methods are discussed. A prototype of passive cell balancing was designed using a PIC16F877A microcontroller. However, the prototype is still under way. Therefore, the effectiveness cannot be determined at the moment.

ACKNOWLEDGEMENTS

I really appreciate Eng. M.Takawira, my supervisor, for his invaluable advice and assistance in making this work feasible. Additionally, I would like to thank my friends Eng. L.Namayenhema and Eng. T.Musikavanhu for all of their encouragement and support. Finally, I want to express my gratitude to the Almighty God for keeping me alive and guiding me through the whole process, as well as to my loving parents for their prayers and sacrifices.

Contents

CHAPTER 1: INTRODUCTION

1.1: Introduction

This chapter is going to highlight the problem statement which is the reason why the student decided to come up with the project design, the background information, the aim of the project, significance of the project, objectives and justification of the whole project.

1.2: Background study

Consumers are aware on this green technology to save the environment. Thus, automotive industry has develops a renewable energy which is Electric Vehicle to minimize petrol usage. Automotive manufacturers are moving forward in enhancing this technology as a reliable product in the market. Battery consumption on Electric Vehicles (EV) model leads to energy saving. At the moment NiMH battery type is the mainstream technology for Electric Vehicle. However, Lithium Ion Polymer battery is being introduced on the market because it produces equivalent energy as the NiMH for longer period and half of the weight. Lithium Ion Polymer battery characteristic needs to be monitor because of it is sensitive to overvoltage and under voltage where it can shorten the life cycle. The imbalanced of the cells while charging need to be monitored to observe the cells. State of Charge is an expression in percentage to indicate the charging capacity of the cells [1]. Different type of battery has different characteristic which need to be consider to calculate SOC.

1.3: Problem statement

Electric vehicles are surely the future of transportation but, the incidents of fire due to battery blasts are increasing as the EV market increases. So the project is done to solve the problem by using sensors and a battery pack based powered by a microcontroller.

1.4: Aim

The main aim is the design and implement a battery management system (BMS) that ensures the safe and efficient operation of the battery pack. The BMS monitors and controls various aspects of the battery, such as state of charge, voltage, temperature and current.

1.5: Significant of the project

The designing of the EV BMS is significant because it has the potential to improve the safety, performance, and efficiency of electric vehicles. By ensuring the safe and efficient operation of the battery pack, the BMS can help to extend the life span of the battery and reduce the risk.

1.6: Objectives.

- Ensuring safety of the battery by monitoring its voltage, temperature and current
- Providing data to user about the status of the battery and alerting the driver on the battery fault.
- Design a BMS with a GPS sensor to update the location of the car and calculate the distance left to reach the next charging point.

CHAPER 2: LITERATURE REVIEW

2.1: Introduction

This chapter will be focusing on the literature review of basic components used in the battery management system in electric vehicles. It will be stressing on the definition of terms and diagrams of each component as they are used in the BMS.

Automotive industry has open new renewable energy concept which is Electric Vehicle to reduce fuel consumption and carbon dioxide emission as global are concern on green environment. This powered by motor concept can produce power on acceleration and also generate energy from braking system which will be stored in large battery packs [3]

2.2: Electrical vehicle

According to previous research [1], 18% of the suspended particulates, 27% of the volatile organic compounds, 28% of Pb, 32% of nitrogen oxides, and 62% of the CO of air-borne pollution in America are produced by vehicles with internal combustion engines. In addition, 25% of energy-related CO2 (the principle cause for the greenhouse effect) of all the CO2 in the atmosphere are released from traditional vehicles. As an increasing number of people use public and personal transportation, the amount of air pollution increases every single day. Consequently, electric vehicles are becoming more and more popular.

An electric vehicle generally contains the following major components: an electric motor, a motor controller, a traction battery, a battery management system, a plug-in charger that can be operated separately from the vehicle, a wiring system, a regenerative braking system, a vehicle body and a frame. The battery management system is one of the most important components, especially when using lithium-ion batteries.

Currently, three types of traction batteries are available: the lead-acid, nickel-metal hydride and lithium-ion batteries. Lithium-ion batteries have a number of advantages over the other two types of batteries, and they perform well if they are operated using an effective battery management system.

2.3: Lithium –iron batteries

Lithium is the lightest metal with the greatest electrochemical potential and the largest energy density per weight of all metals found in nature. Using lithium as the anode, rechargeable batteries could provide high voltage, excellent capacity and a remarkably high-energy density.

However, lithium is inherently unstable, especially during charging. Therefore, lithium ions have replaced lithium metals in many applications because they are safer than lithium metals with only slightly lower energy density. Nevertheless, certain precautions should be made during charging and discharging. The Sony Corporation was the first company to commercialize the lithium-ion battery in 1991, which has since become popular and remains the best choice for rechargeable batteries.

The lithium-ion battery requires almost no maintenance during its lifecycle, which is an advantage that other batteries do not have. No scheduled cycling is required, and there is no memory effect in the battery. Furthermore, the lithium-ion battery is well suited for electric vehicles because its self-discharge rate is less than half of the discharge rate of lead-acid and NiMH batteries.

Despite the advantages of lithium-ion batteries, they also have certain drawbacks. Lithium ions are brittle. To maintain the safe operation of these batteries, they require a protective device to be built into each pack. This device, also referred to as the battery management system (BMS), limits the peak voltage of each cell during charging and prevents the cell voltage from dropping below a threshold during discharging. The BMS also controls the maximum charging and discharging currents and monitors the cell temperature.

2.4: Lithium battery challenges

The operating temperature and voltage are the most important parameters that determine the performance of lithium-ion cells [2]. Figure 1-1 and 1-2 shows that the cell operating voltage, current and temperature must be maintained within the area indicated by the green box labelled "Safe Operation Area" (SOA) at all times. The cell could be permanently damaged if it is operated outside the safety zone.

The batteries could be charged above its rated voltage or be discharged under the recommended voltage. If the recommended upper limit of 4.2 V was exceeded during charging, excessive current would flow and result in lithium plating and overheating.

On the other hand, overly discharging the cells or storing the cells for extended periods of time would cause the cell voltage to fall below its lower limit, typically 2.5 V. This could progressively break down the electrode.

2.5: Battery Management Systems (BMS)

There are different types of BMSs that are used to avoid battery failures. The most common type is a battery monitoring system that records the key operational parameters such as voltage, current and the internal temperature of the battery along with the ambient temperature during charging and discharging. The system provides inputs to the protection devices so that the monitoring circuits could generate alarms and even disconnect the battery from the load or charger if any of the parameters exceed the values set by the safety zone.

The battery is the only power source in pure electric vehicles. Therefore, the BMS in this type of application should include battery monitoring and protection systems, a system that keeps the battery ready to deliver full power when necessary and a system that can extend the life of the battery. The BMS should include systems that control the charging regime and those that manage thermal issues.

In a vehicle, the BMS is part of a complex and fast-acting power management system. In addition, it must interface with other on-board systems such as the motor controller, the climate controller, the communications bus, the safety system and the vehicle controller.

2.5.1: Definition of the BMS

While the definition of a BMS could differ depending on the application, the basic task of the BMS could be defined in the following manner, according to

- It should ensure that the energy of the battery is optimized to power the product;
- It should ensure that the risk of damaging the battery is minimal;

- It should monitor and control the charging and discharging process of the battery.

2.5.2: Objectives of the BMS

According to the definition, the basic tasks of the BMS are identical to its objectives. Although different types of BMS have different objectives, the typical BMS follows three objectives

- It protects the battery cells from abuse and damage.
- It extends the battery life as long as possible.
- It makes sure the battery is always ready to be used.

2.5.3: Functions of the BMS

- **Discharging control**

The primary goal of a BMS is to keep the battery from operating out of its safety zone.

The BMS must protect the cell from any eventuality during discharging. Otherwise, the cell could operate outside of its limitations.

- **Charging control**

Batteries are more frequently damaged by inappropriate charging than by any other cause.

Therefore, charging control is an essential feature of the BMS. For lithium-ion batteries, a 2 stage charging method called the constant current – constant voltage (CC-CV) charging method is used.

During the first charging stage (the constant current stage), the charger produces a constant current that increases the battery voltage.

When the battery voltage reaches a constant value, and the battery becomes nearly full, it enters the constant voltage (CV) stage. At this stage, the charger maintains the constant voltage as the battery current decays exponentially until the battery finishes charging.

- **State-of-Charge Determination**

One feature of the BMS is to keep track of the state of charge (SOC) of the battery. The SOC could signal the user and control the charging and discharging process. There are three methods of determining SOC: through direct measurement, through coulomb counting and through the combination of the two techniques.

To measure the SOC directly, one could simply use a voltmeter because the battery voltage decreases more or less linearly during the discharging cycle of the battery.

In the coulomb-counting method, the current going into or coming out of a battery is integrated to produce the relative value of its charge. This is similar to counting the currency going into and out of a bank account to determine the relative amount in the account. In addition, the two methods could be combined. The voltmeter could be used to monitor the battery voltage and calibrate the SOC when the actual charge approaches either end. Meanwhile, the battery current could be integrated to determine the relative charge going into and coming out of the battery.

- **State-of-Health Determination**

The state of health (SOH) is a measurement that reflects the general condition of a battery and its ability to deliver the specified performance compared with a fresh battery.

Any parameter such as cell impedance or conductance that changes significantly with age could be used to indicate the SOH of the cell. In practice, the SOH could be estimated from a single measurement of either the cell impedance or the cell conductance.

- **Cell Balancing**

Cell balancing is a method of compensating weaker cells by equalizing the charge on all cells in the chain to extend the overall battery life. In chains of multi-cell batteries, small differences between the cells due to production tolerances or operating conditions tend to be magnified with each charge-discharge cycle. During charging, weak cells may be overstressed and become even weaker until they eventually fail, causing the battery to fail prematurely.

To provide a dynamic solution to this problem while taking into account the age and operating conditions of the cells, the BMS may incorporate one of the three cellbalancing schemes to equalize the cells and prevent individual cells from becoming overstressed: the active balancing scheme, the passive balancing scheme and the charge shunting scheme.

In active cell balancing, the charge from the stronger cells is removed and delivered to the weaker cells.

In passive balancing, dissipative techniques are used to find the cells with the highest charge in the pack, as indicated by higher cell voltages. Then, the excess energy is removed through a bypass resistor until the voltage or charge matches the voltage on the weaker cells.

In charge shunting, the voltage on all cells would be levelled upward to the rated voltage of a good cell. Once the rated voltage of the cell is reached, the current would bypass the fully charged cells to charge the weaker cells until they reach full voltage

- **Logbook Function**

Because the SOH is relative to the condition of a new battery, the measurement system must hold a record of the initial conditions or a set of standard conditions for comparison.

An alternative method of determining the SOH is to estimate the SOH value based on the usage history of the battery rather than on certain measured parameters, such as the number of charge-discharge cycles completed by the battery. Therefore, the logbook function of the BMS would record such important data to the memory system.

- **Communications**

The communications function of a BMS may be provided through a data link used to monitor performance, log data, provide diagnostics or set system parameters. The function may also be provided by a communications channel carrying system control signals.

The choice of the communications protocol is not determined by the battery; instead, it is determined by the application of the battery.

The BMS used in electric vehicles must communicate with the upper vehicle controller and the motor controller to ensure the proper operation of the vehicle.

There are two major protocols used by the BMS to communicate with the vehicle: through the data bus or the controller area network (CAN) bus. Data buses include the RS232 connection and EIA-485 (also called the RS485 connection). The industry standard for on-board vehicle communications is the CAN bus, which is more commonly used in vehicle applications.

2.6: BMS topology

- **Distributed Topology**

In distributed topology, voltage monitors and discharge balancers with digital communications that can cut off the charger and report its status are placed on each cell.

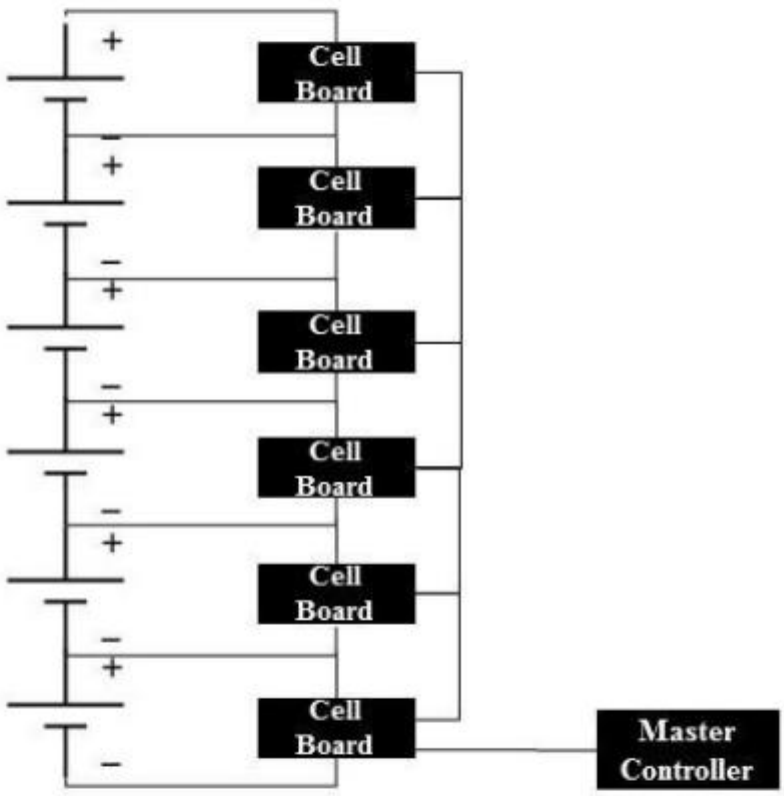


FIG 2.1: DISTRIBUTED TOPOLOGY.

The advantages of this design include its simplicity and high reliability. The disadvantages include the requirement of a large number of mini-slave printed circuit boards and the difficulty of mounting the boards on certain types of cells.

- **Modular Topology**

In the modular structure, several slave controllers are used to consolidate the data to a master controller.

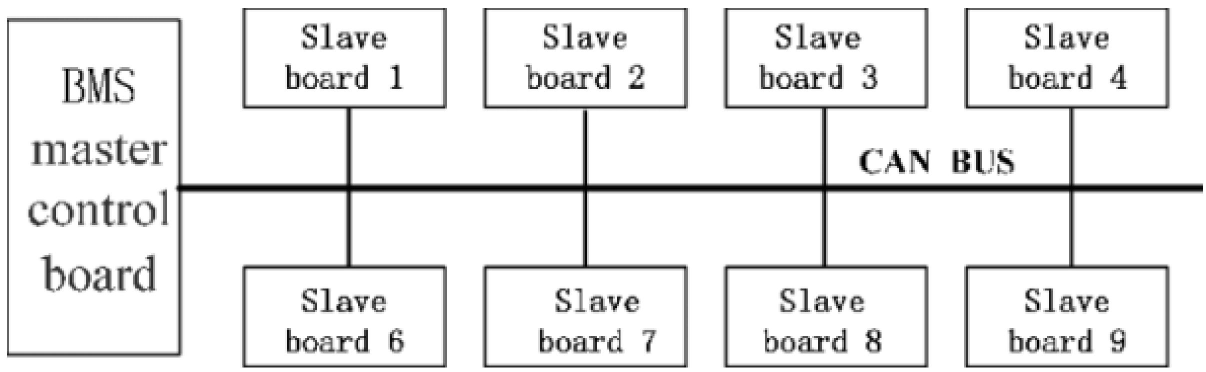


FIG 2.2: MODULAR TOPOLOGY

No printed circuit boards are necessary to connect the individual cells. However, isolated master-slave communications are difficult to achieve when this structure is used in electric vehicles.

- **Centralized Topology**

In centralized topology, a centralized master control unit is directly connected to each cell of the battery pack. The control unit protects and balances all cells while providing various other functions.

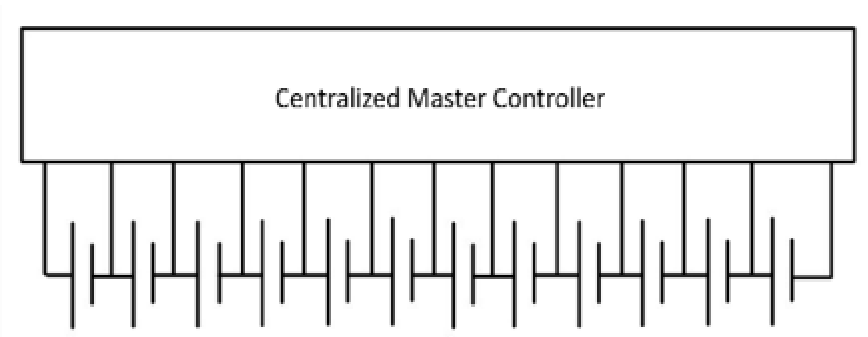


FIG 2.3: CENTRALIZED TOPOLOGY

Using this topology only requires a single installation point and no complex inter-vehicle communications. However, excess heat could be generated because the controller is the only source for cell balancing. In addition, the cells are distributed within various locations of the vehicle, which requires wiring to a central location.

2.6: Review of battery modelling

In the automotive industry, reducing greenhouse gas emissions is the most important issue. By using electric vehicles, greenhouse gas emission could be reduced; furthermore, the electricity distribution system would also be affected. One of the central components in an electric vehicle is the battery, which stores a large amount of energy and enables functions such as regenerative braking. In addition, it releases electrical energy when necessary and supplements slow dynamic energy sources such as fuel cells. The main goal for the BMS is to ensure that the battery is always charged. To achieve this goal, a detailed simulation of the traction system in the electric vehicle and a detailed battery model is required to design the BMS.

2.6.1: Shepherd model

Clarence M. Shepherd proposed a battery model [6] in 1965. In his work, he derived an equation that described the discharging processes of different cells by calculating the cell potential during discharge, which is a function of discharge time, current density, and other factors. Using only a small amount of experimental data, he provided a complete description of the characteristics of a discharging cell.

The model described cell charges, cell capacities, and the power evolution of the cells, while simultaneously pointing out experimental errors.

However, the following assumptions were required when the model was analysed mathematically:

- Porous active materials were present in the anode and/or the cathode.
- During discharging, the electrolyte resistance remained constant.
- The discharging current remained constant.
-
- The polarization was linear with the active material current density.

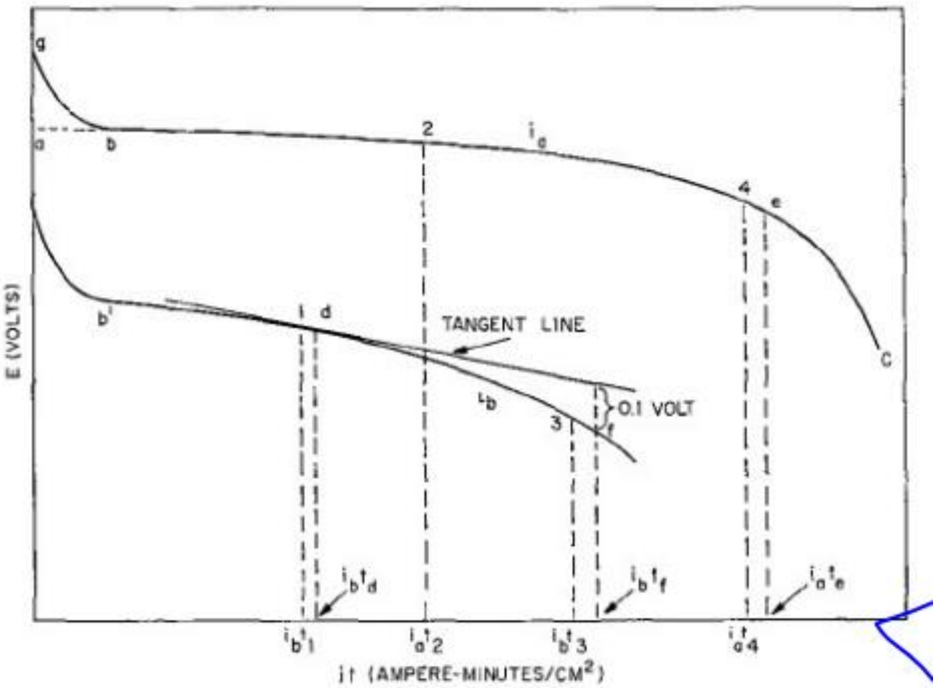


FIG 2.4: DISCHARGE CURVE

The two solid curves (ia and ib) shown in Figure 2.4 represent the typical battery behavior when they discharge. The potential (shown as the y-axis in volts) is plotted as a function of (it). The x-axis is the amount of electricity supplied by the battery at time t. The derivation that follows the polarization is linear to the right of point b and b', which are assumed. If only polarization is considered, then Ec, the cathode potential during discharge, is defined as:

$E_c = K_c - K_{Ci_{am}}$……………………………………[1]

where

Ec: the cathode potential (V)

Esc: the constant potential (V)

Kc: the cathode coefficient of polarization per unit active material current density (2 Ωcm) iam: the active material current density(A/ 2 cm)

Although this equation can be used as a fundamental equation in the derivation that follows, the theoretical factors associated with this equation may not apply to most discharging processes of a battery. The current density iam in a porous active electrode is inversely proportional to the amount of unused active material. In addition, iam is equal to i at the beginning of the discharge. Therefore,

$i_{am} = \left(\frac{Q_c}{Q_c - i_t}\right) i$ ……………………………………………… [2]

Where:

t: the time at any point during the discharge (h)

Qc: the amount of available active material in the cathode expressed as ampere-hours per unit area. (Ah/cm2)

iam: the current density (A/cm2) of the active material.

Sub equation 2 into equation 1:

$E_c = E_{sc} - K_{a(\frac{Q_c}{Q_c - i_c})i}$…………………………………………….. [3]

Similarly $E_a = E_{sa} - K_{a\left(\frac{Q_a}{Q_a - i_t}\right)i}$ ……………………………… [4]

If $Q_a = Q_c$

$E = E_s - K\left(\frac{Q}{Q-it}\right) i$ …………………………………………[5]

Where:

E is the potential of the cell in volts (neglecting internal resistance) at any time t during the discharge; it is also equal to the sum of Ea and Ec.

Es is a constant potential in volts equal to the sum of Esa and Esc.

K is the polarization coefficient and equal to Ka plus Kc (2 Ωcm).

Q is the amount of available active material, which is equal to Qa and Qc (Ah/cm2).

i is the current density (A/cm2).

t is the time at any point during the discharge (h).

When Qc is not equal to Qa, the value of Q is determined by the amount of available active material on the electrode that fails first or the controlling electrode. This equation can also approximate the battery potential when several cells are connected in series to form a battery.

When the internal resistance of a battery is considered, Eq. [5] become

$E = Es - K\left(\frac{Q}{Q-it}\right)i - Ri$ …………………………………………[6]

where

R is the internal resistance per unit area measured in Ωcm^2 .

The results from evaluating equation [6] mathematically are plotted in Figure 2.4. A dotted line is drawn from a to b, and a solid line is drawn from b to c in the figure. The initial potential drop at the beginning of the discharge was not observed in the curves drawn with the results from equation 6. Therefore, the potential calculated from equation [6] (shown as the dotted line) must be corrected by adding another term to the model to approximate the actual discharge potential (shown as the solid line from g to b). The expression Aexp(-BQ^{-1}it) was found to give an excellent estimate of the initial potential drop in virtually every case, where A and B were empirical constants. Therefore, the final equation was obtained after this term was added to equation [6]:

$$E = Es - K\left(\frac{Q}{Q-it}\right)i - Ri + \mathrm{A}\exp(-\mathrm{B}Q^{-1}\mathrm{it}) \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots [7]$$

In a number of cases, the initial potential drop was too sharp to be included in the experimental data; the expression Aexp$(-\mathrm{B}Q^{-1}$it) was neglected in these cases.

If the numerical values of Es, K, Q, and N were known, and the basic assumptions were true, equation [6] could be used to predict the discharge curve to the right of point b in Figure 2.4. However, discharge curves could be obtained more easily and accurately through experiments than through calculations. Nevertheless, empirical values of Es, K, Q, N, A, and B could be determined by numerically fitting equation [6] to experimental discharge data. One could then obtain an accurate description of the cell or battery discharge process that could also be used to describe energy evolution and cell capacity; it could even be used to predict cell capacities. Because the numerical values of K, Q, and N could be determined by numerical fitting, they could vary considerably from their true values as defined in the basic assumptions.

2.7: Review on BMS hardware

The research on BMS hardware systems has been conducted in both the academic field and the commercial field.

2.7.1: Review on commercial BMS

Because the concept of electric vehicles is relatively new, the BMS of electric vehicles is also under development. Commercialized BMSs, also called off-the-shelf BMSs, are only available from dozens of manufactures, and more systems may become available in the coming years. To understand the rapidly changing market, it is important to know the price of products, the types of products and their available features.

A larger number of commercial BMSs with basic functions suitable for smaller batteries and applications, such as laptops, is offered by Chinese manufacturers. Unfortunately, they are not suitable for large lithium-ion battery packs. High-quality BMSs are available to companies from large manufacturers that are more trusted and well known; however, these products are not available to the public.

Only several practical and economically advanced BMSs are available from small European and U.S. manufacturers that are reliable and effective.

Simple analogue BMSs use analogue technology, and their prices range from $16 per cell for a distributed BMS to $2 per cell for a protector. Although these BMSs have limited functions, various types of analogue BMSs could be used in large lithium-ion battery packs. More sophisticated digital BMSs have more functions, and they are used in electric vehicles.

2.7.2: Review on BMS research

In low-power applications that require only simple BMSs, such as cell phones and laptops, they could be designed from integrated circuits. However, electric vehicles require numerous large battery cells that are more problematic and more costly to repair.

A lithium-ion BMS for electric vehicles based on CAN-bus was proposed in [16]. This BMS could sample battery information, estimate the SOC of the battery and communicate with the vehicle controller. Although the BMS did not have the cell balancing feature, it worked successfully in the electric car manufactured by Tianjin Qingyuan Electric Vehicle Inc. The design structure is shown below.

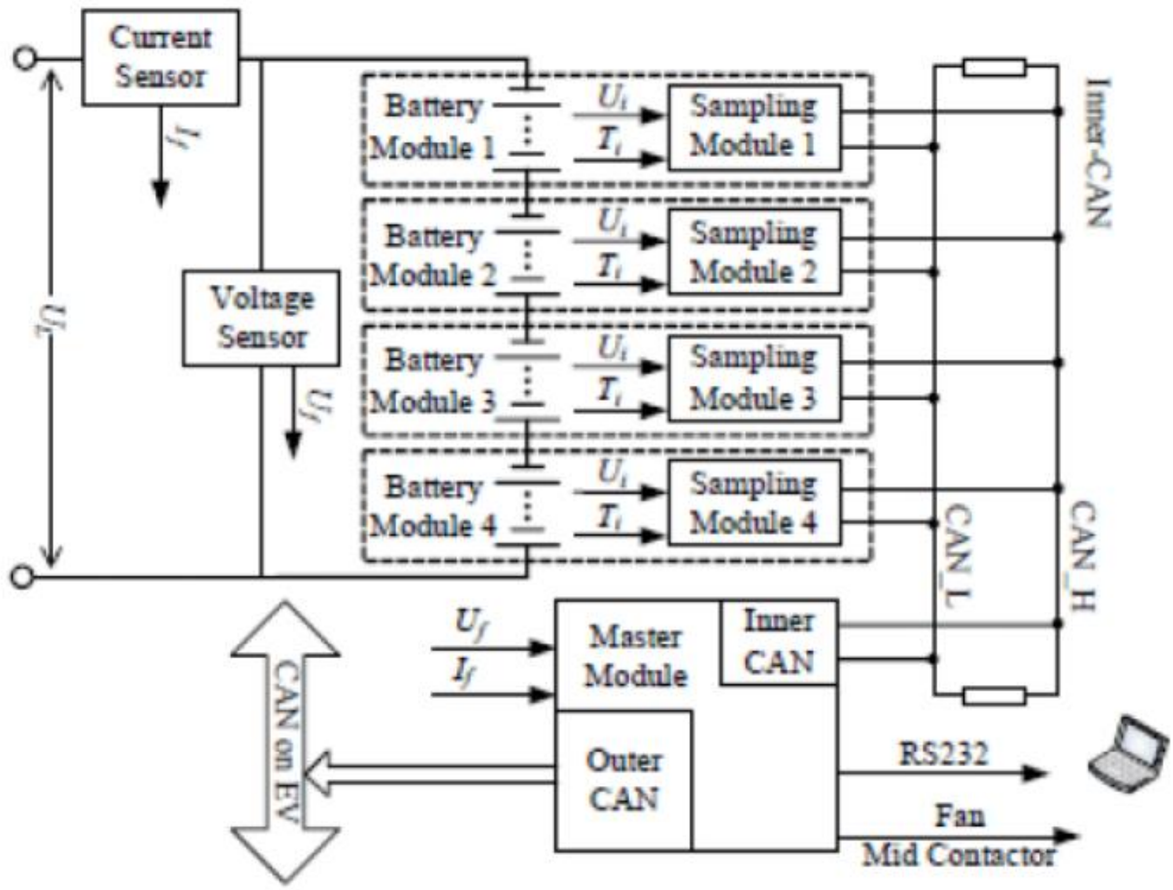


FIG 2.7: BMS BASED ON CAN BUS [16]

A generalized BMS was published in [17]. The main advantage of that system compared with the existing systems was that it provided a fault-tolerant capability and battery protection. It consisted of a number of smart battery modules, and each module provided the functions of battery equalization, monitoring, and battery protection to a string of battery cells. However, the reference did not specify the application of the BMS and was likely not designed for lithium-ion batteries.

A fully digital lithium-ion battery protection and charging system based on digital signal processor (DSP) TMS320LF2407A was discussed in [18]. Figure 2.8 shows the operation principles of this design. However, the price of the DSP was much higher than the price of the microcontroller, making the total cost of the BMS prohibitively expensive.

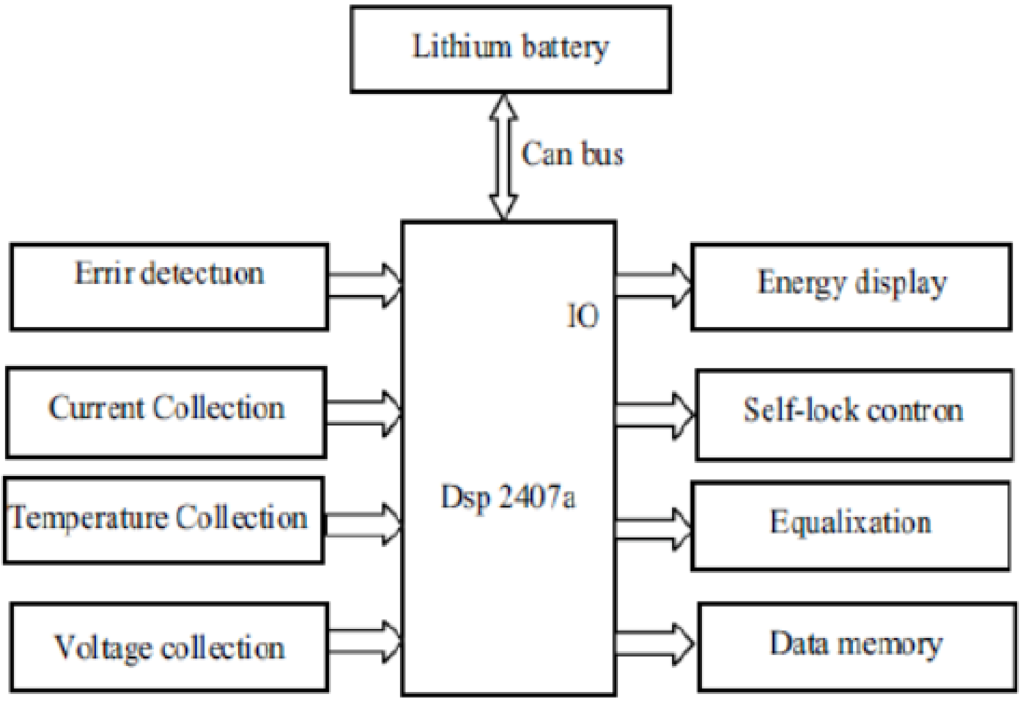


FIG 2.8: PRINCIPLE OF BMS BASED ON DSP

None of the previously mentioned BMS designs had a thermal management system, which is essential for electric vehicles2.8:

Hardware Components

2.8. 2: Buzzer

FIG 2.11: BUZZER

It is defined as a simple audio device that produces sounds in responses to an incoming electrical signal

2.8.2.1 Related Work

Buzzer was used as an alarming sound device by M. Ali, B.Ali and M. Shan (2020) in the GSM-Based Generator Fuel and Temperature Monitoring System project. The project was focused on detecting theft of fuel generators by raising an alarm with the help of a GSM modem. A GSM modem is used to send a text message to the server operators.

2.8.2: Temperature sensor

FIG 2.12: DALLAS TEMPERATURE SENSOR

A "Dallas temperature sensor" typically refers to a digital temperature sensor produced by Dallas Semiconductor, which is now a part of Maxim Integrated. These sensors are known for their accuracy, ease of use, and digital interface. The most popular models are from the DS18B20 series. A "Dallas temperature sensor" typically refers to a digital temperature sensor produced by Dallas Semiconductor, which is now a part of Maxim Integrated. These sensors are known for their accuracy, ease of use, and digital interface. The most popular models are from the DS18B20 series. A "Dallas temperature sensor" typically refers to a digital temperature sensor produced by Dallas Semiconductor, which is now a part of Maxim Integrated. These sensors are known for their accuracy, ease of use, and digital interface. The most popular models are from the DS18B20 series.

2.8.2.1: Features of the Dallas temperature sensor

Here are some key features of the Dallas DS18B20 temperature sensor:

Digital Output: The DS18B20 provides a digital output, which means it directly gives a digital reading of the temperature, eliminating the need for an analog-to-digital converter (ADC).

One-Wire Interface: It uses a one-wire communication protocol, which allows for data transmission and power supply over a single wire. This simplifies the wiring and makes it easy to connect multiple sensors in series on the same data line.

High Precision: The DS18B20 can measure temperatures with a high precision of ±0.5°C over a range from -55°C to +125°C.

Unique Address: Each DS18B20 sensor has a unique 64-bit serial code, which allows multiple sensors to be connected to the same data bus and individually identified.

Wide Operating Voltage: It can operate over a voltage range of 3.0V to 5.5V, making it versatile for different microcontroller platforms.

Programmable Resolution: The sensor's resolution can be programmed from 9 to 12 bits, allowing the user to balance between precision and data processing speed.

Thermometer Function: It contains an internal Non-Volatile (EEPROM) to store the user-defined settings for high and low trigger points for temperature alarms.

Applications of the Dallas DS18B20 temperature sensor include environmental monitoring, HVAC systems, thermostats, and any project requiring accurate temperature readings. Its ease of use and reliable performance have made it a popular choice among hobbyists and professionals alike.

2.8.2.1: Oscillators

Oscillators are used for timing generation. Pic microcontroller consists of external oscillators like RC oscillators or crystal oscillators. Where the crystal oscillator is connected between the two oscillator pins. The value of the capacitor is connected to every pin that decides the mode of the operation of the oscillator. The modes are crystal mode, high-speed mode and the low-power mode. In case of RC oscillators, the value of the resistor & capacitor determines the clock frequency and the range of clock frequency is 30KHz to 4MHz.

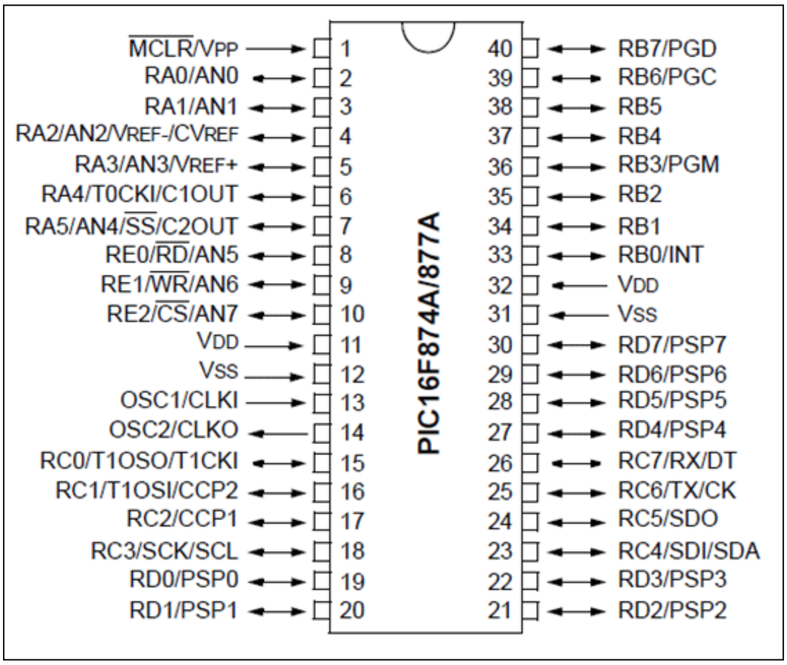


Figure 2.8 shows PIC16F877A/PIC16F874A

PIN 1: MCLR: The first pin is the master clear pin of this IC. It resets the microcontroller and is active low, meaning that it should constantly be given a voltage of 5V and if 0 V are given then the controller is reset. Resetting the controller will bring it back to the first line of the program that has been burned into the IC.

PIN 2: RA0/AN0: PORTA consists of 6 pins, from pin 2 to pin 7, all of these are bidirectional input/output pins. Pin 2 is the first pin of this port. This pin can also be used as an analog pin AN0. It is built in analog to digital converter.

PIN 3: RA1/AN1: This can be the analog input 1.

PIN 4: RA2/AN2/Vref-: It can also act as the analog input2. Or negative analog reference voltage can be given to it.

PIN 5: RA3/AN3/Vref+: It can act as the analog input 3. Or can act as the analog positive reference voltage.

PIN 6: RA0/T0CKI: To timer0 this pin can act as the clock input pin, the type of output is open drain.

PIN 7: RA5/SS/AN4: This can be the analog input 4. There is synchronous serial port in the controller also and this pin can be used as the slave select for that port.

PIN 8: RE0/RD/AN5: PORTE starts from pin 8 to pin 10 and this is also a bidirectional input output port. It can be the analog input 5 or for parallel slave port it can act as a ‘read control’ pin which will be active low.

PIN 9: RE1/WR/AN6: It can be the analog input 6. And for the parallel slave port it can act as the ‘write control’ which will be active low.

PIN 10: RE2/CS/A7: It can be the analog input 7, or for the parallel slave port it can act as the ‘control select’ which will also be active low just like read and write control pins.

PIN 11 and 32: VDD: These two pins are the positive supply for the input/output and logic pins. Both of them should be connected to 5V.

PIN 12 and 31: VSS: These pins are the ground reference for input/output and logic pins. They should be connected to 0 potential.

PIN 13: OSC1/CLKIN: This is the oscillator input or the external clock input pin.

PIN 14: OSC2/CLKOUT: This is the oscillator output pin. A crystal resonator is connected between pin 13 and 14 to provide external clock to the microcontroller. 1/4 of the frequency of OSC1 is outputted by OSC2 in case of RC mode. This indicates the instruction cycle rate. crystal interfacing with PIC16F877A

PIN 15: RC0/T1OCO/T1CKI: PORTC consists of 8 pins. It is also a bidirectional input output port. Of them, pin 15 is the first. It can be the clock input of timer 1 or the oscillator output of timer 2.

PIN 16: RC1/T1OSI/CCP2: It can be the oscillator input of timer 1 or the capture 2 input/compare 2 output/ PWM 2 output.

PIN 17: RC2/CCP1: It can be the capture 1 input/ compare 1 output/ PWM 1 output.

PIN 18: RC3/SCK/SCL: It can be the output for SPI or I2C modes and can be the input/output for synchronous serial clock.

PIN 23: RC4/SDI/SDA: It can be the SPI data in pin. Or in I2C mode it can be data input/output pin.

PIN 24: RC5/SDO: It can be the data out of SPI in the SPI mode.

PIN 25: RC6/TX/CK: It can be the synchronous clock or USART Asynchronous transmit pin.

PIN 26: RC7/RX/DT: It can be the synchronous data pin or the USART receive pin.

PIN 19,20,21,22,27,28,29,30: All of these pins belong to PORTD which is again a bidirectional input and output port. When the microprocessor bus is to be interfaced, it can act as the parallel slave port.

PIN 33-40: PORT B: All these pins belong to PORTB. Out of which RB0 can be used as the external interrupt pin and RB6 and RB7 can be used as in-circuit debugger pins. [11]

2.8: Summary

Battery modelling is a very complex procedure that requires a thorough knowledge of electrochemistry. However, two of the battery models mentioned above did not consider common battery behaviours, such as self-discharging and capacity fading, which made the models less accurate.

Neither of the models simulated actual battery performance because of their assumptions. These assumptions are listed below:

(1) The internal resistance was assumed constant during the charge and discharge cycles; it did not vary with the amplitude of the current.

(2) The models assumed that the parameters could be deduced from the charging and discharging characteristics.

(3) The capacity of the battery was assumed constant regardless of the amplitude of the current.

(4) The models assumed that the battery would not self-discharge.

(5) The battery was assumed to have no memory effect.

(6) The temperature was assumed to have no effect on the behaviour of the model.

2.9 Conclusion

Because commercial BMSs are costly and unable to meet the requirements of large electric vehicles, research on BMS hardware systems is still ongoing. It is necessary to develop an economical and fully functional BMS suitable for electric vehicles that can protect the lithium battery while prolonging its lifetime.

CHAPTER 3: DESIGN AND METHODOLOGY

3.1 Introduction

An electric vehicle generally contains the following major components: an electric motor, a motor controller, a traction battery, a battery management system, a plug-in charger that can be operated separately from the vehicle, a wiring system, a regenerative braking system, a vehicle body and a frame. The battery management system is one of the most important components, especially when using lithium-ion batteries.

Table 3.1 shows Expected Results.

MODULE	EXPECTECTED RESULTS
Temperature Sensor Design	Temperature should be not above 55 degrees 37 degrees else a fan is set ON .
Current sensing design	Discharge current should not exceed the maximum current, else a buzzer is set ON and if the load continues discharging the same current, the relay will be activated and isolate the load
Voltage sensing design	Individual cell voltages are measured and total pack voltage is displayed on the screen. From the pack voltage measurement calculate battery percentage display it on the screen.
CAN design	All battery data to be sent to the car through CAN.
GPS sensing design	A GPS sensor is used to update the user about the next charging point when the battery is running low.

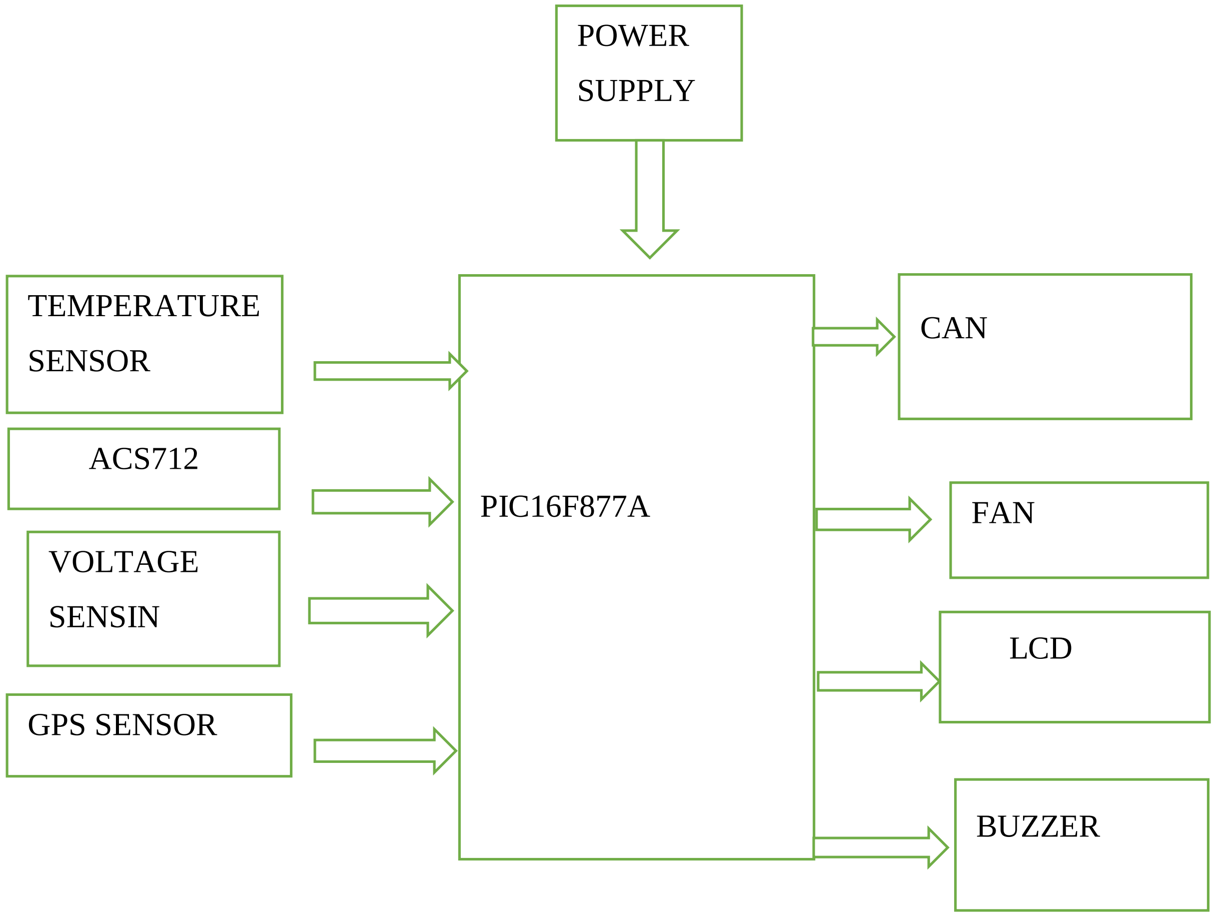


Figure 3.1 Block Diagram of Battery Management System

Figure 3.1 Shows a block diagram of a BMS for electric vehicle. The Power Supply provides power to all other components in the System. Temperature Sensor, current sensor, GPS Sensor are acting as inputs which measures the battery parameters and sends data to PIC16F877A Microcontroller. The Microcontroller receives the data from the sensors and processes it The LCD displays the data that is processed by the Microcontroller. Buzzer and red led which is used to generate alerts when certain conditions are met.th CAN is used for the communication between battery and the car.

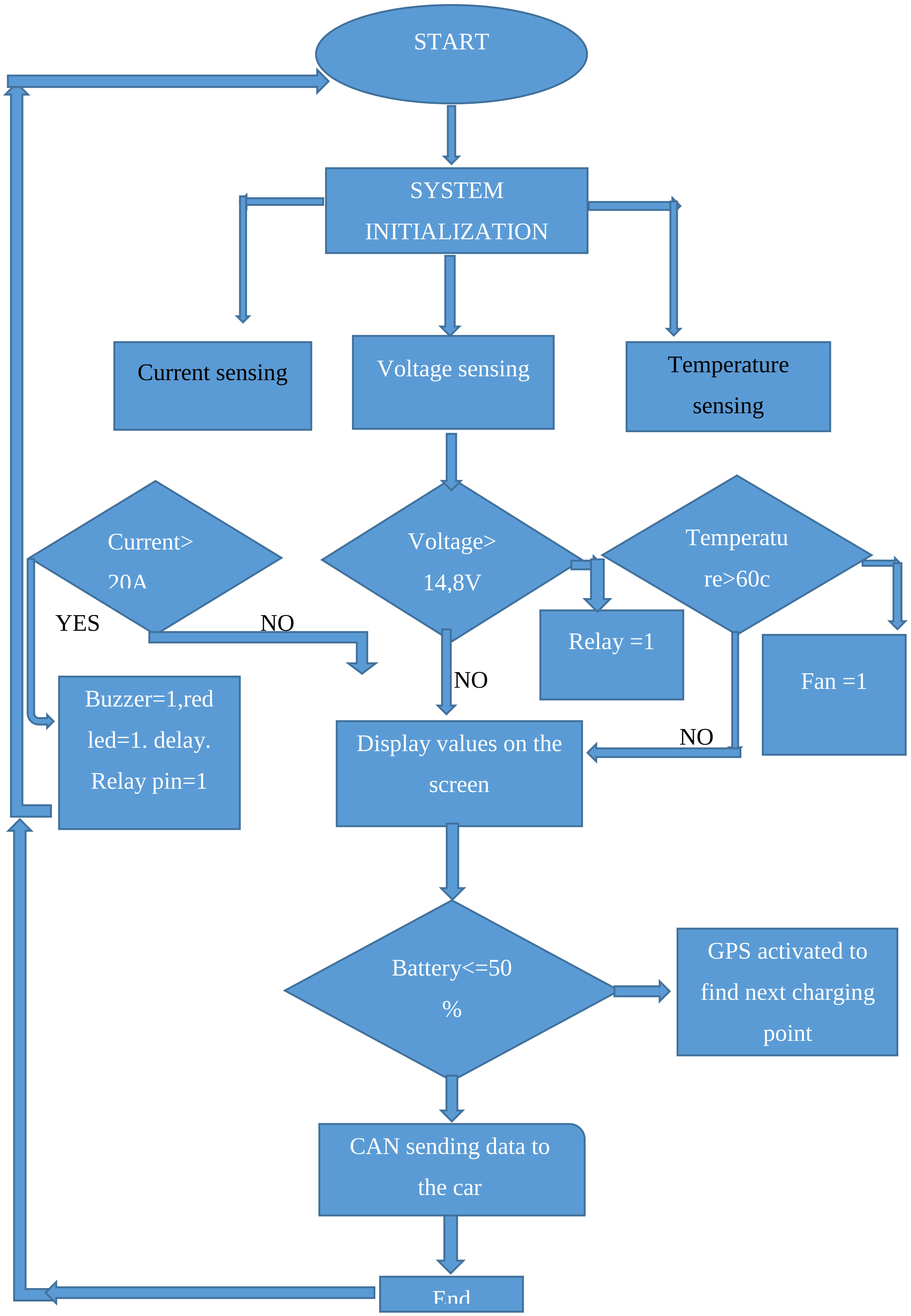

START
SYSTEM INITIALIZATION
Current sensing
Voltage sensing
Temperature sensing
Current> 20A
YES
NO
Voltage> 14,8V
Temperatu re>60c
Relay =1
Fan =1
NO
Buzzer=1,red led=1. delay. Relay pin=1
Display values on the screen
NO
Battery<=50 %
GPS activated to find next charging point
CAN sending data to the car
End

Figure 3.2 Flow Chart of BMS for EV

3.2: voltage sensing circuit

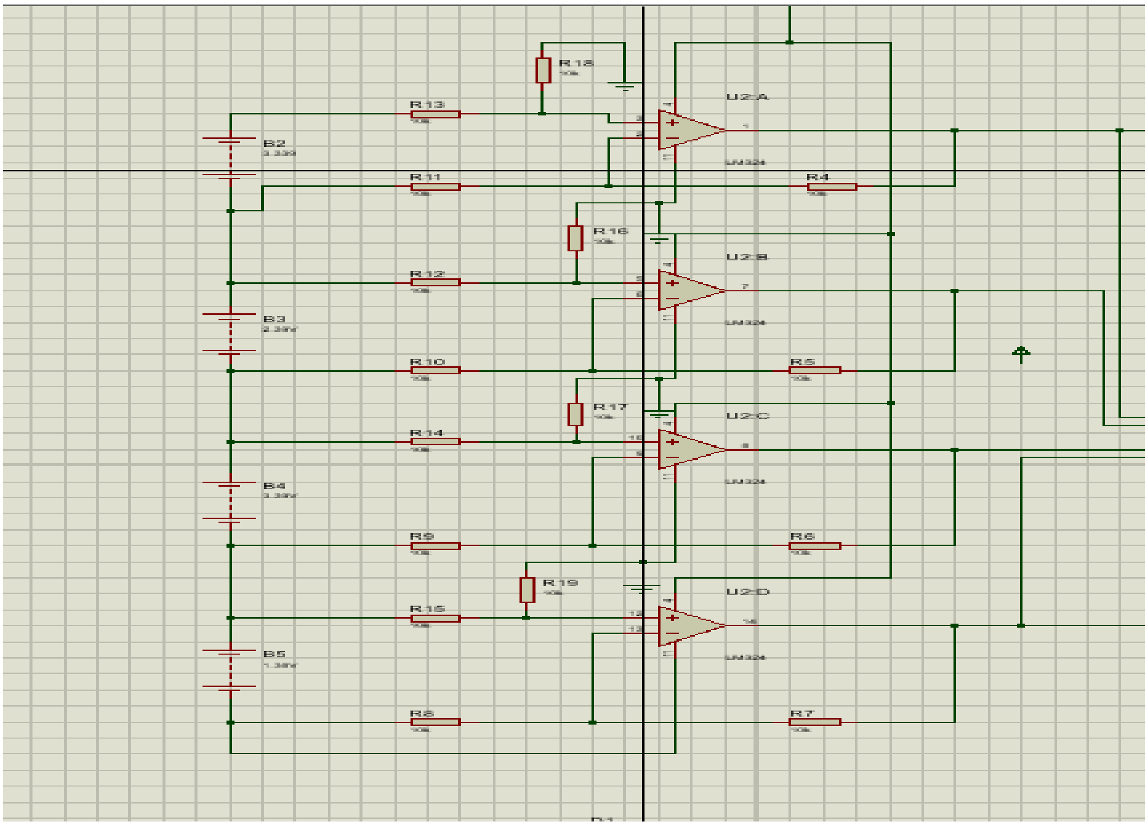


Fig 3.3: voltage sensing circuit design

The voltage sensing circuit was designed using a voltage divider circuit using 10k resistors and LM312 op-amp per cell. The measured individual cell voltage is added and the output on the screen is the total pack voltage

3.3: GPS and switching circuit

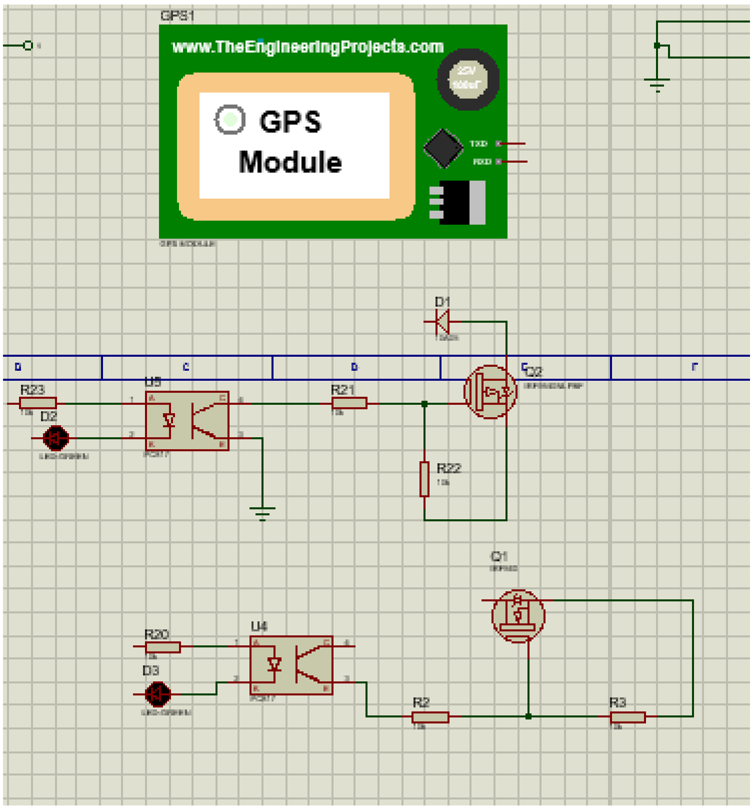
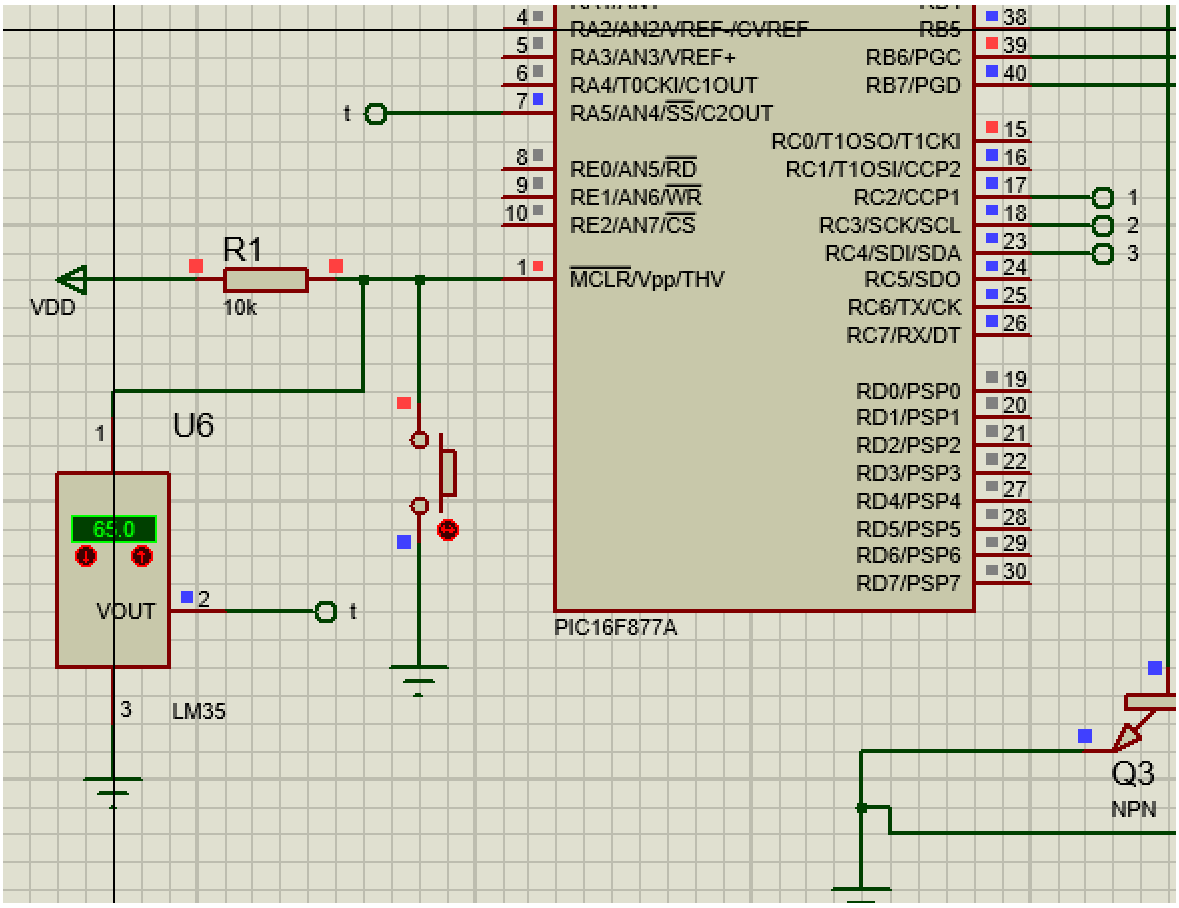


Fig 3.3: GPS and switching circuit design

The switching circuit shown above is used for charging and discharging to protect undercharge, overcharge and deep discharge of the battery.

The GPS sensing is used to track the nearest charging point of the car to be charged before the battery is empty.

3.4: temperature sensing circuit design



3.4: Temperature sensing circuit

Fig 3.4 shows the temperature sensing circuit which measures the temperature of the battery so that the battery is protected from over temperature since lithium cells are sensitive to high temperatures.

3.5: full schematic design of the BMS for electric vehicle design.

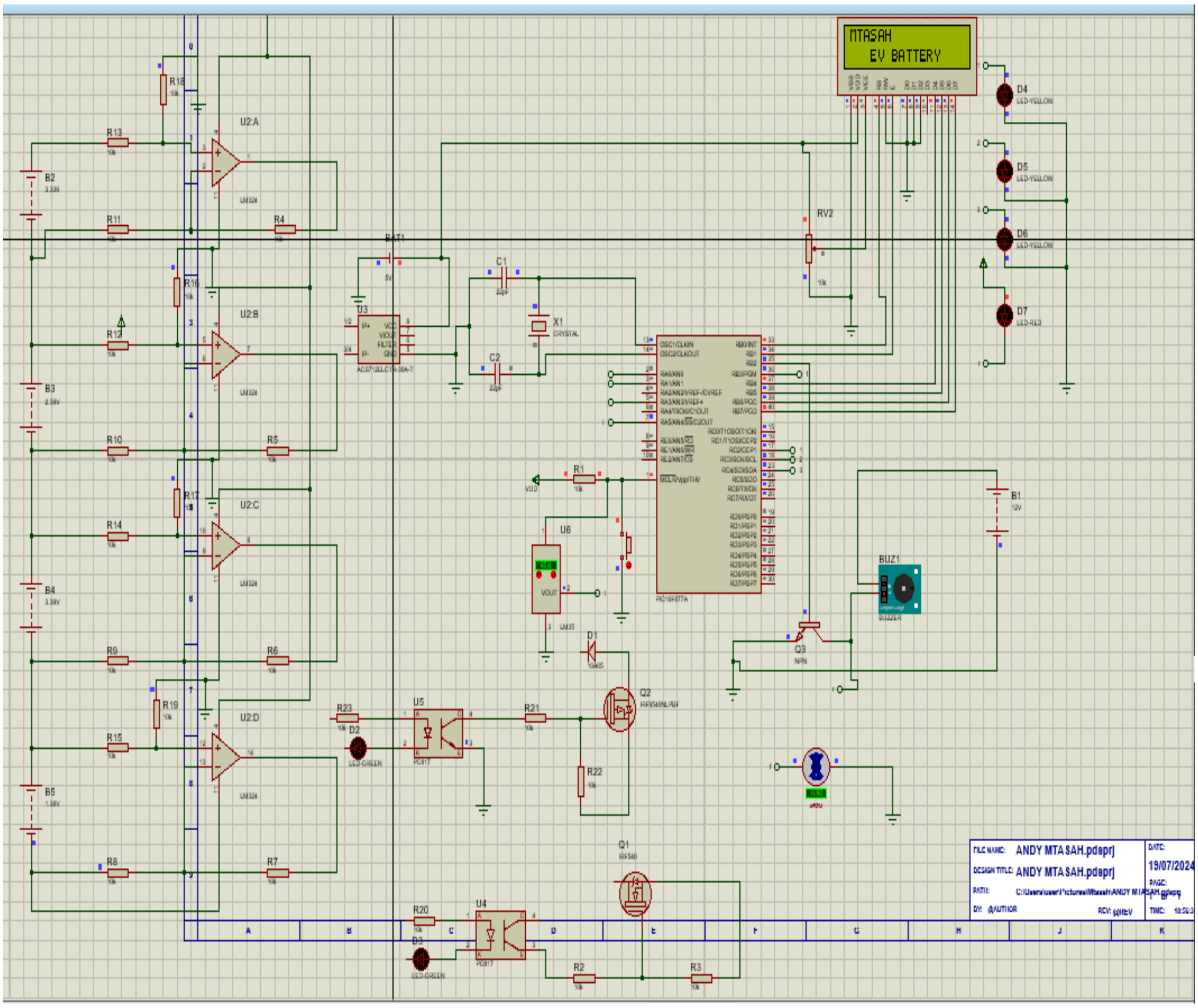


Fig 3.4 full functional schematic design.

3.6 Conclusion

CHARPTER 4: IMPLEMENTATION AND RESULTS

4.1: Introduction

This chapter is going to focus on the implementation and results of the project. It also going to show the discussion of the results and difficulties faced during the design stage.

4.2: Implementation using bread board

The system was first tested using bread board to make sure there will be no errors when go further to the soldering part.

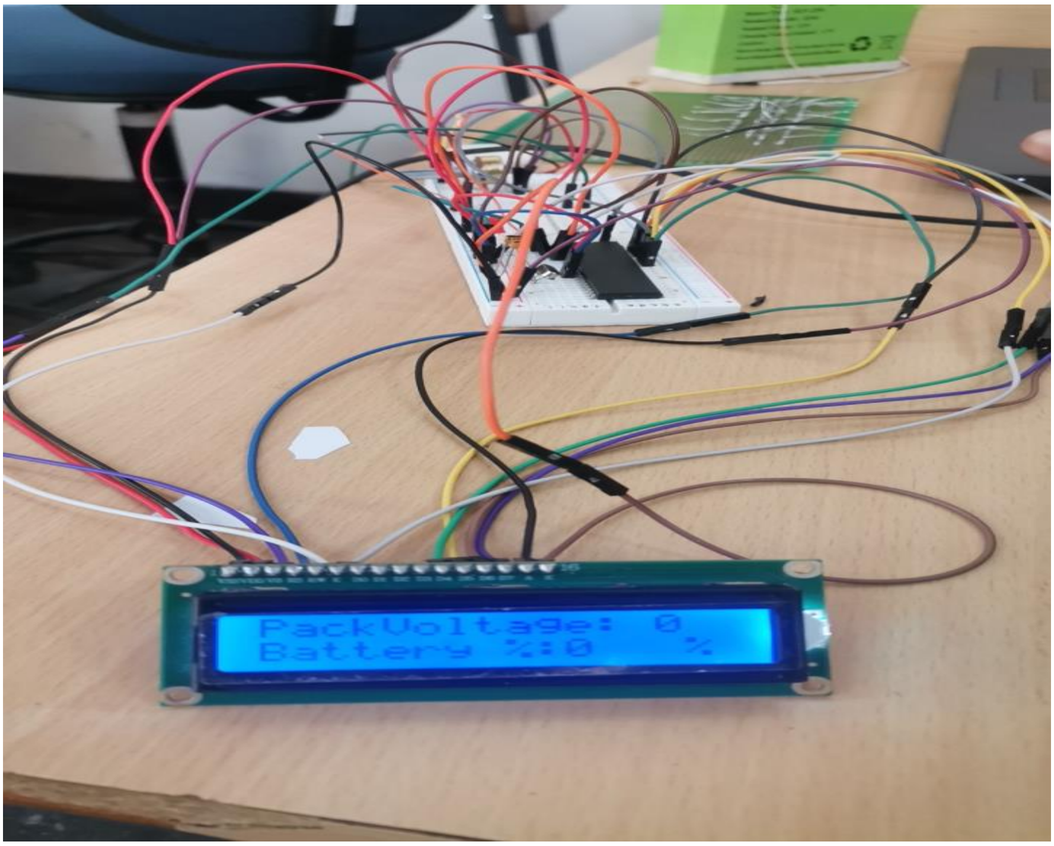


Fig 4.1 shows the circuit implementation using bread board.

The results on the screen shows zero measurements because of loose connections on the bread board.

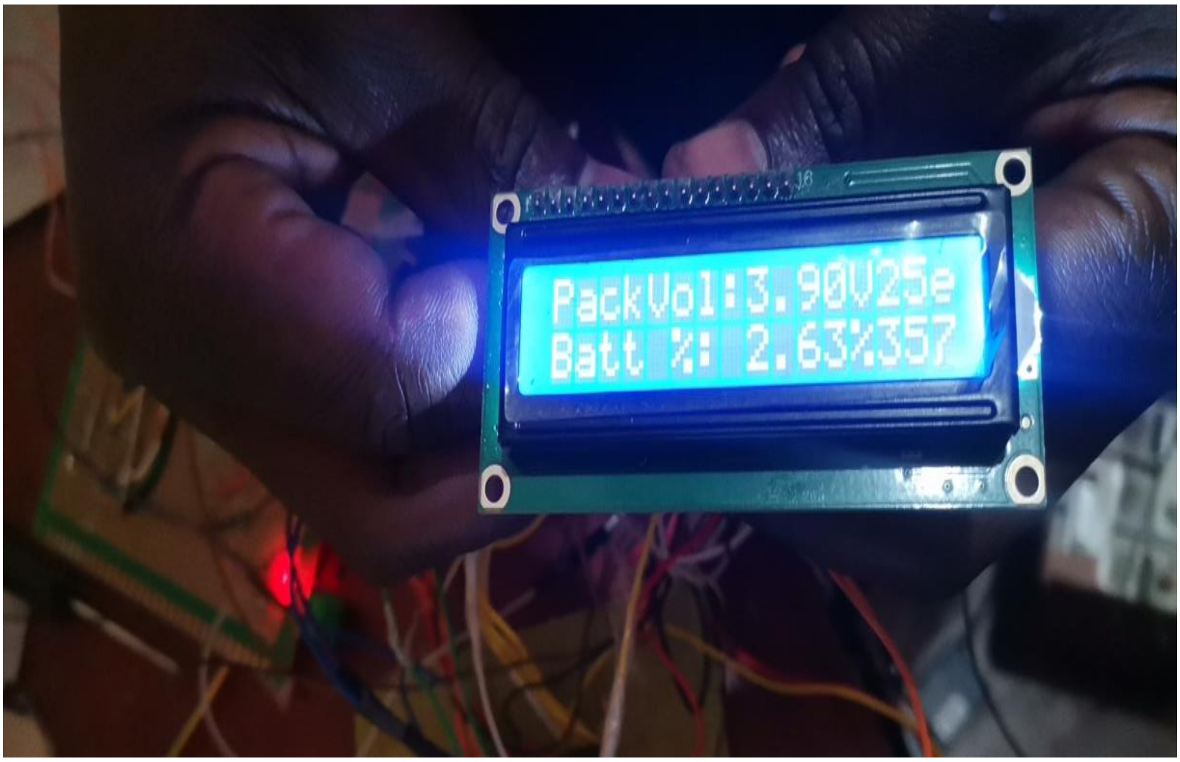


Fig 4.2 shows the circuit tested on a veroboard.

Now the screen is showing values coz the circuit is now on the veroboard.

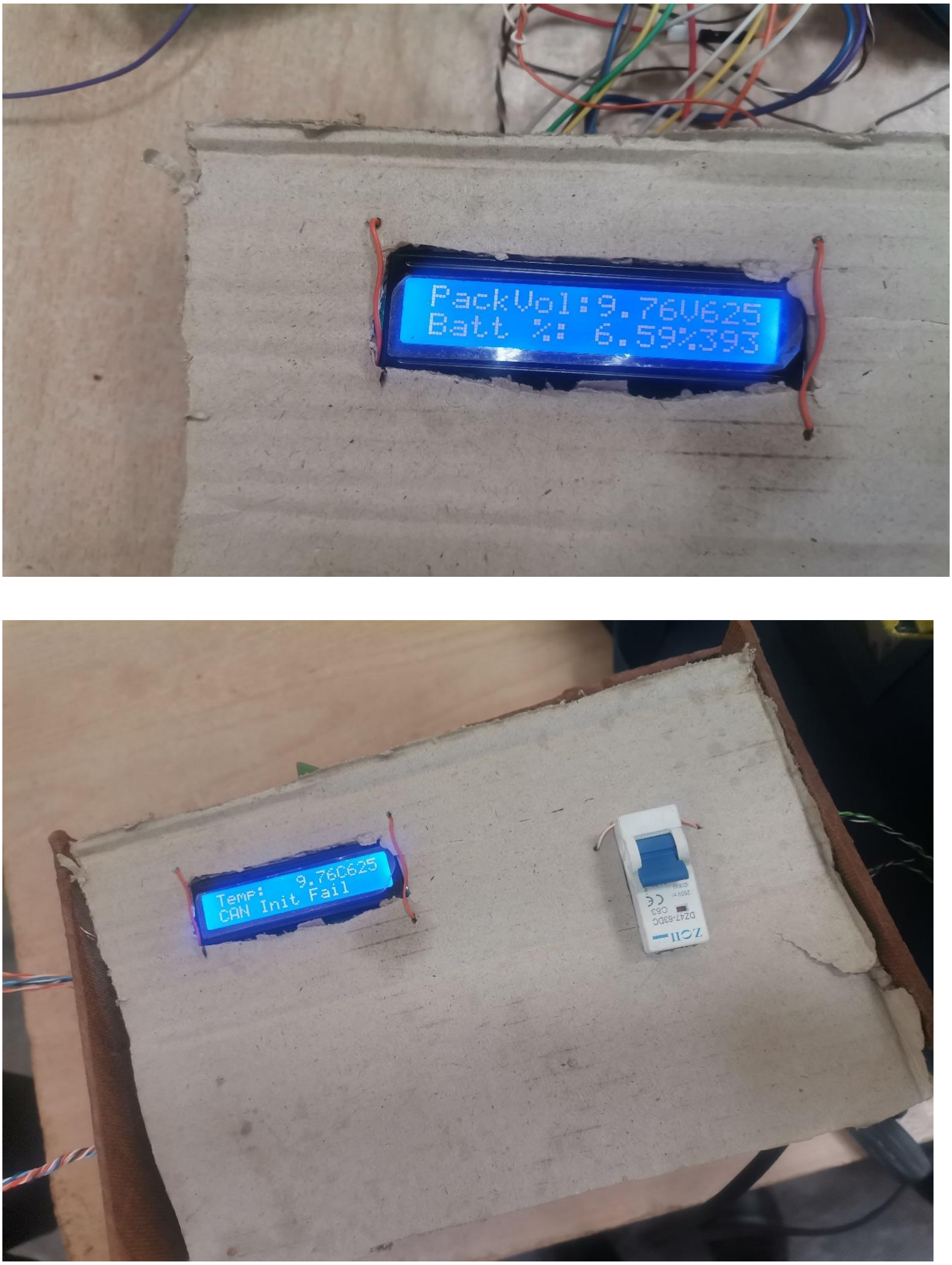


Fig 4.3 shows full functional prototype

4. 3 Functional testing of BMS

The BMS collects voltage, current, and operating temperature information of the power battery pack in electric vehicles running in cycle condition. As SOC cannot be directly measured, a BP neural network is employed to predict it. The BP neural network takes voltage, current, and operating temperature information as input and predicts SOC as output [12] . To overcome the issues of local minima, slow convergence, and reduced generalization ability of the BP neural network, the initial weights and thresholds of the network are optimized using genetic algorithms [13]. This optimization results in a neural network that predicts the output more accurately [14]. Figure 5 displays the voltage, current, temperature, and SOC data collected by BMS.

CHARPTER :5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This work first introduced the background of electric vehicles, lithium-ion batteries and the BMS. The details of the BMS, including its definition, objectives, functions and topologies were then discussed. The literature on battery modeling and BMS hardware system design were reviewed in the following section. The limitations of early battery models and the disadvantages of other BMS hardware systems were also reviewed. The objectives and outline of this thesis were then presented. An improved battery model was proposed in this work by considering the self discharging effect, the temperature effect and the fading-capacity effect observed in all batteries. The model was simulated using proteus 8.0 and the simulation results were discussed.

5.2 FUTURE WORK AND RECOMMENDATIONS

Many battery models do not simulate of the discharging behavior of actual batteries. When batteries are nearly fully discharged, and the load is removed from the battery, the voltage of the battery will increase; when the load is connected to the battery, and the current resumes, the voltage of the battery will drop to the nominal value. Such discharging behavior should be simulated in future battery models. In addition, the performance of battery models could be further improved. To improve BMS hardware systems, a method could be created to allow the BMS to communicate with vehicle controllers and other sub-systems in the vehicle, such as the motor controller. In addition, a protection device could be added to the system to switch off the battery pack when it operates out of its SOA. Furthermore, the cell-balancing function could be improved. A BMS could then be developed for use in electric vehicles

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