DEVELOPMENT OF BATTERY MANAGEMENT SYSTEM FOR LI-ION CELL

Major Project (EE7C04) report

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for the award of degree of Bachelor of Engineering
in

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ABSTRACT

Battery management system (BMS) is used in Electric Vehicles (EV) and Energy Storage Systems to monitor and control the charging and discharging of rechargeable batteries. BMS keeps the battery safe and reliable and increases the stability without going into damaging state. Battery Management Systems (BMS) are used in many industrial and commercial systems to make the battery operation more efficient and for the estimation to keep the battery state, as long as possible, away from destructive state, to increase battery life time. For this purpose, many monitoring techniques are used to monitor the battery state of charge, temperature and current. The monitoring system for battery powered Electric Vehicles (EV) has been implemented and tested. This system evaluates and displays the battery temperature, charging/discharging current and State Of Charge (SOC) for the considered LiPo battery. For monitoring purpose, analog sensors (ACS712 and LM35) with Arduino Uno are used.

The battery information and the obtained results explaining the main characteristics of the system are presented by photographs and some experimental results are given by the LED Display. The Biggest challenge in battery management system are designing the internal battery pack topology to allow for monitoring of each cell and including the mechanism for the BMS to balance the cell. The State of Charge is defined as the ratio of available capacity and the maximum possible charge that can be stored in a battery. The SoC provides the user with information of how much longer the battery can perform before it needs to be charged or replaced. Understanding the SoC is important because understanding the remaining capacity can help make a control strategy. We have used Proteus software to build the model. We have written the code to monitor the temperature, current and SoC in Arduino IDE and uploaded the code to the Arduino uno. According to the code, the Arduino uno processes the obtained information from the analog sensors and converts to the digital form and accordingly displays it on the LED display. For thermal protection, as soon as the temperature goes beyond 30 degree centigrade, the LED will display as “HIGH TEMPERATURE”. For current protection, the Arduino uno will display the current value on the serial monitor. For SoC, the Arduino uno integrates the current samples of 10 iterations and inturn it will display the integrated value and its corresponding SoC.

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1.INTRODUCTION

1.1 Battery:

Battery is most important component in electric vehicles and also for various energy storage applications. The battery is a device which converts chemical energy into electrical energy by electrochemical redox reactions. An electric vehicle battery is a rechargeable battery used to power the electric motors of a battery electric vehicle or hybrid electric vehicle.

1.2 Li-ion Battery:

A lithium-ion battery is an advanced battery technology that uses li-ions as a key component of its electro chemistry. Li-ion battery is the most used battery. Li-ion batteries are resistant to natural discharge (self-discharge). Li-ion batteries have a lifespan of more than 2000 cycles. They have high energy densities. Besides the advantages that have been approved, Li-ion batteries also have a shortage of side effects caused by the operation process. Side effects that cause aging in the material and decreased battery capacity, which in turn can cause a decrease in performance and unexpected damage to the electrical system. Li-ion battery consists of largely four main components: Cathode, Anode, Electrolyte and Separator. The Li-Ion battery cells are made up of prismatic or punch or cylindrical design. The performance and durability of the Li-ion Battery depends mainly on its charging and discharging. The optimized and quality charging and discharging of the Li-ion battery enhance the efficiency and life cycle of the battery storage system. The efficient charging and discharging controls remove the memory effect and boost the discharging period of battery.

1.3 Battery Management System and Function:

Battery management system (BMS) is a system that regulates all activities that occur between the battery and the required load. One of the activities carried out is the protection of battery cells from various kinds such as overcharging and overuse, short circuiting and so on as shown in the fig.1. Overcharging the battery can cause excessive heat and can even cause and explosion or flame.

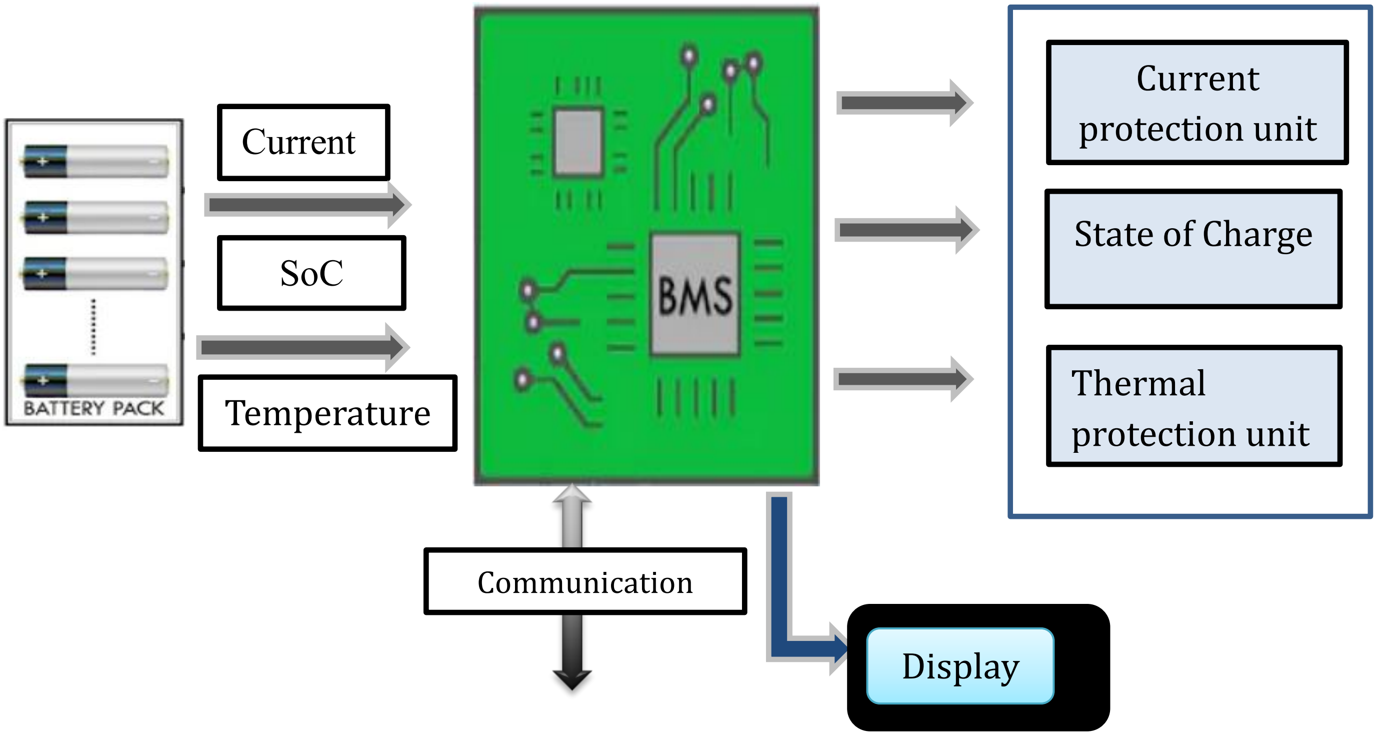

Fig 1. Block Diagram of Battery management System

Therefore, BMS play an important role in security and monitoring. BMS is a technology dedicated to the oversight of a battery pack, which is an assembly of battery cells to enable delivery of targeted range of voltage and current for a duration of time against expected load scenarios. A battery management system is any electronic system that manages a rechargeable battery. The functions of a battery management system are - it Manages cell balance, Safety Control, Over voltage / Over current / Under-voltage Protection, Thermal Management, Ground fault or leakage current detection and Maintenance. It is also used to maximise the range of vehicle by properly using the amount of energy stored in it. In this project we have built BMS using Arduino for the protection of battery against Thermal, Current and also we are determining State of charge (SOC).

1.4 State-of-the-Art in BMS:

- In January 2021, Texas Instruments has released wireless battery management system for the electric vehicles. It helps in wireless control and monitoring of the better cells, it has also resulted in elimination of cabling and weight savings.

- Brill power has announced the new intelligent battery management system in October 2021, which will help in extending the life of the battery by 60%. It is also expected to increase the storage capacity by 129% which will help the systems to run longer.

- In February 2018, Lithium Werk B.V acquired another company Valence technology in order to strengthen the product portfolio and its footprint. By expanding the product portfolio, the company is expecting good amount of sales.

1.5 LITERATURE REVIEW

Sl.no	Title of the Paper	Features	Research Gaps
1.	Battery management system with Passive control method [2]	Processor:STM32f103C8 (Master)and PIC18f4520(Slave) Cell:4-Li-ion cells connected in series. Functions: Experimental results are presented for a prototype system consisting of 4 series connected 40Ah LiFePo4 battery cells . Battery cells voltage and current data are sent with serial communication to the computer interface. At the same time the voltage levels of the batteries could be monitored from the computer.	For each cell they have used separate processor which is one of the disadvantage. Since they have used Passive cell balance method, this method has low thermal management.
2.	Battery management system-Hardware design [3]	Processor: AVR128DA64 Cell:LTC6813-18 cells connected in series. Function: Version of masterboard for BMS was designed . This system allows to program different control signals and peripherals from the feedback given by the battery pack. The implementation of the AVR based Microcontroller was done along with the cell balancing and isoSPI communication ICs.	We need to send 1 wake up signal per IC connected in daisy chain to get proper communication in reverse direction.

		Various other communication protocol facilities are used for smooth functioning and wireless control of the BMS.	
3.	Arduino based battery Monitoring System with State of Charge and Remaining useful time estimation [7]	Processor: Arduino Uno. Cell:6 Lead acid Batteries. Features: The estimation of State-of-Charge, State-of-Health, Discharge Rate, and Remaining Useful Life are then derived by utilizing the concept of correlation and regression from the yielded real-time parameters recorded to the SD card module.	In this paper they have used lead acid battery which has some of the disadvantages like slow and inefficient charging , voltage sag ,limited cycle life and limited usable capacity.
4.	3 to 6 cells Battery-Management System Based On bq76925+MSP430G2xx2 [4]	Processor:bq76925+MSP430G2xx2 Cell:3-to-6 series cell Li-ion/polymer battery. Functions: This paper is helpful to solve solve the two types of problem.one is the driver power must provide enough high voltage and driving capability , other one is to ensure that FET’s can be turned on and off quickly. It also helps to monitor the status of cells by measuring and provides high accuracy value with the particular compensated algorithmic correction factor	Pre-charge controlling circuit will support only Zero voltage charging when the packet voltage is Zero Volt. chip also don’t work and DVCC(Distributed voltage and current control) should be Zero volt .
5.	A comprehensive review of battery modeling and state estimation approaches for advanced battery management systems [5]	Features: Battery modeling methods are systematically overviewed. Battery state estimation methods are reviewed and discussed. Battery management scheme based on big data and cloud computing is proposed.	
6.	Battery Management, Key Technologies,	Features:	

	Methods, Issues, and Future Trends of Electric Vehicles: A Pathway toward Achieving Sustainable Development Goals [6]	In this paper the authors have discussed about Battery cell monitoring , state of charge, State of Health, State of Energy ,Fault Diagnosis and Thermal Management.	
7.	Battery Management System design (BMS) for Li-ion batteries[1]	Processor: Arduino nano. Cells: 3 Series , 1parallel Li-ion cell. Features: • Protection • Monitoring • Balancing	

2. Problem Formulation

Battery management system is one of the main component of Electric Vehicle. So in order to avoid failures of this battery and to protect it, a Battery management system is proposed for protection of batteries under different scenarios such as undervoltage, overvoltage, high temperature and high discharge rate.

3. Objectives

- ✓ To build a 12V, 10Ah battery module from 3.7 V Li-ion cell.
- ✓ To implement overvoltage, undervoltage protection for battery module.
- ✓ To implement thermal protection and over-discharge rate protection to battery module.
- ✓ To implement state of charge (SOC).

4.Methodology

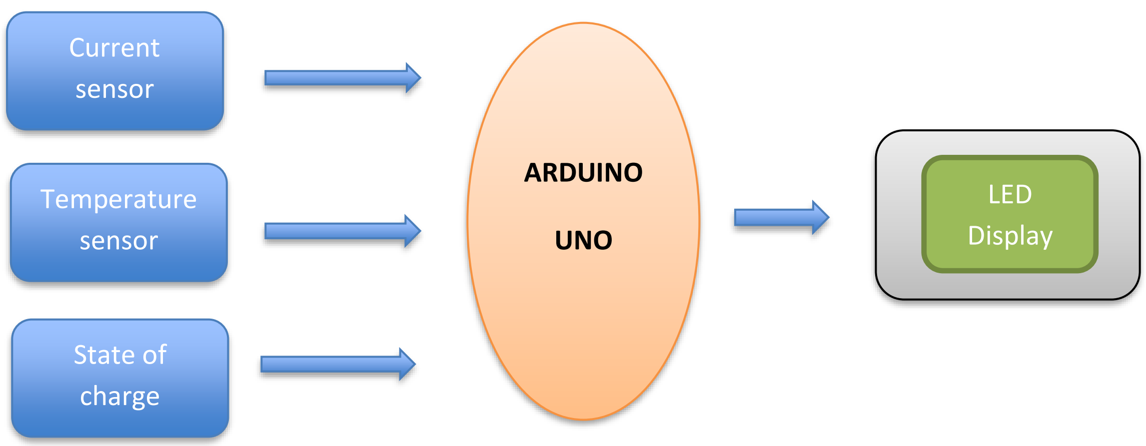

Fig 2. Model of Battery Management System

COMPONENTS USED:

1. Arduino Uno
2. LM35 Temperature sensor
3. ACS712 Current sensor
4. LED Display
5. Proteus software
6. Lipo battery 3.7V

ARDUINO UNO:

When compared to other existing microcontrollers it has minimum power consumption and an easily programmable interface. It is available in a cheap amount and provides simple interfacing to analog circuits. As Arduino is available as an open-source it enables the user to build their kit.

TEMPERATURE SENSOR:

The main working principle is, as the temperature changes its resistance also changes. As per this principle it categories into PTC (Positive Temperature coefficient) and NTC (Negative Temperature coefficient). In PTC, as temperature increases, the resistance of material also increases. We have used LM35 temperature sensor in this project to monitor the temperature and display an alert message on the LED display if the temperature goes beyond the preset value as shown in the fig.3. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. Since it has Linear + 10.0 mV/°C scale factor it is very easy to calculate temperature value. LM35 temperature sensor is basically a very low cost and easily available sensor. LM35 Sensor does not require any external calibration or trimming to provide typical accuracies. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy.

The features of LM35 temperature sensor include:

- Calibrated directly in Degree Celsius (Centigrade)
- Linear at 10.0 mV/°C scale factor
- 0.5°C accuracy guarantee-able (at a25°C)
- Rated for full -55°C to a 150°C range
- Suitable for remote applications

- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 mA current drain
- Low self-heating, 0.08°C instill air
- Non-linearity only 0.25°C typical
- Low impedance output, 0.1Ω for 1 mA load

Applications of LM35 temperature sensor:

- It provides thermal shutdown for a circuit or component used in a specific project.
- It can be used for battery temperature measurement.
- It can be used in HVAC applications as a temperature measurement device.

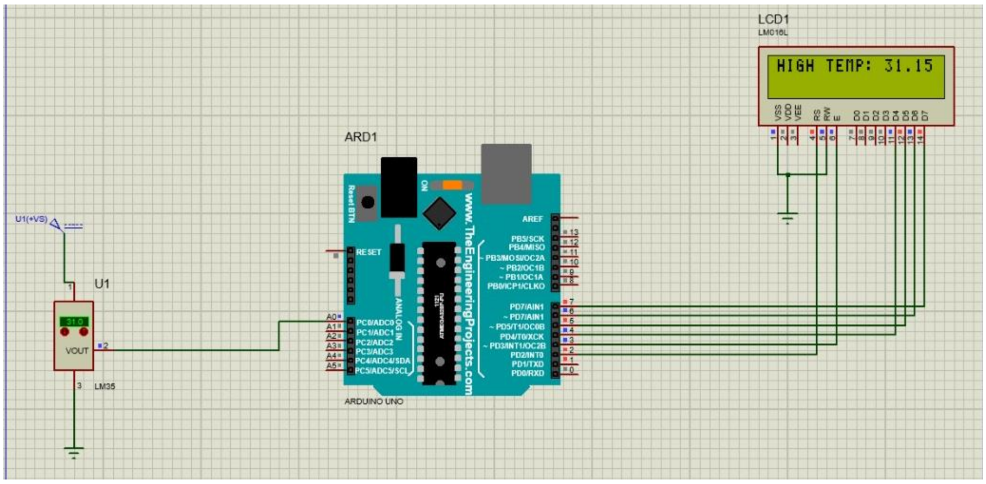

Fig 3. Circuit diagram for the protection of battery against temperature

CURRENT SENSOR

In this project, we have used ACS712 current sensor for measuring the current in battery. The hall effect sensor detects the incoming current through its magnetic field generation. Once detected, the hall effect sensor generates a voltage proportional to its magnetic field that's then used to measure the amount of current as shown in the fig.4. For current sensors that work by direct sensing, ohm's law is being applied to measure the drop in voltage when flowing current is detected.

ACS712 Current Sensor is a fully integrated, Hall-effect-based linear sensor IC.

The features of ACS712 includes:

- 80kHz bandwith
- 66 to 185 mV/A output sensitivity
- Low-noise analog signal path
- Device bandwith is set via the new FILTER pin
- 1.2 mΩ internal conductor resistance
- Total output error of 1.5% at TA = 25°C
- Stable output offset voltage.
- Near zero magnetic hysteresis

The applications of ACS712 current sensor include**:**

- Motor speed control in motor control circuits
- Electrical load detection and management
- Switched-mode power supplies (SMPS)
- Protection for over-current

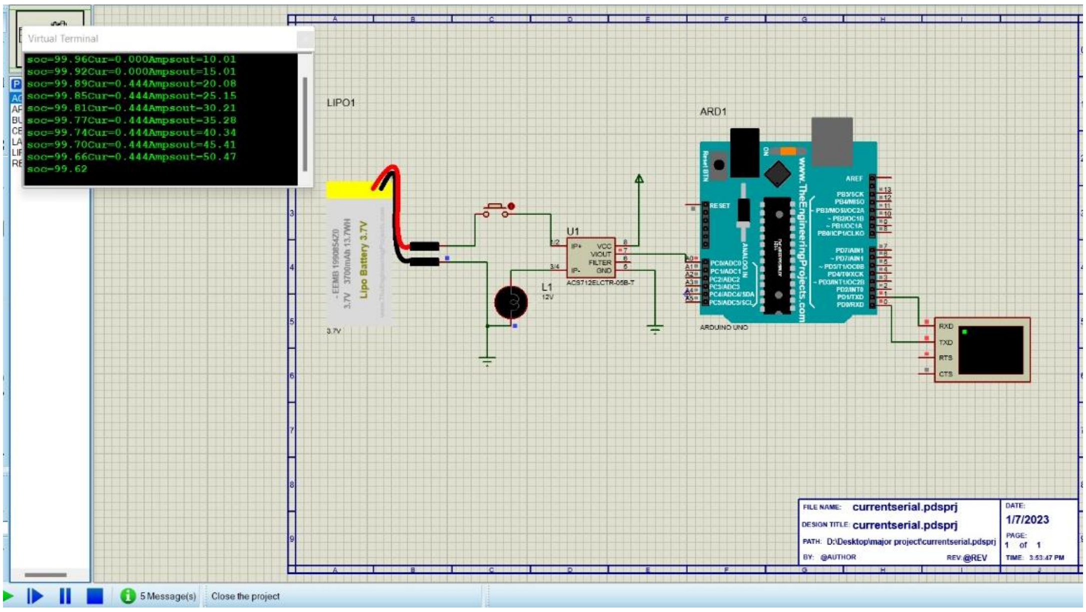

Fig 4. Circuit diagram for the protection of the battery against current

The State of Charge

The state of charge (SOC) is a measurement of the amount of energy available in a battery at a specific point in time expressed as a percentage. For example, the SOC reading for a computer might read 95% full or 10% full. The SOC provides the user with information of how much longer the battery can perform before it needs to be charged or replaced. Understanding the state of charge is important because understanding the remaining capacity of a batter can help make a control strategy.

The accurate estimation of the SOC involves many nonlinear effects such as open circuit voltage (OCV), instantaneous current, charge and discharge rate, ambient temperature, battery temperature, parking time, self-discharge rate, Coulomb efficiency, resistance characteristics, SOC initial value, depth of discharge (DOD), etc. These factors are affected by different materials and processes, and they also interact with each other, so the SOC calculation of power batteries is complex and difficult, which is a challenge that has not been overcome for many years. The dc-dc converter control typically also involves a cascaded control loop, but, in this case, the inner loop regulates the current fed to the battery through the charging connector, while the outer loop regulates the EV BMS commonly estimates battery SoC using Coulomb counting or model-based estimation methods

We obtained the state of charge by coulomb counting method using the formula,

$$SOC = \frac{\left(Qc - \frac{I}{3600}\right)}{Qc} * 100 \tag{1}$$

Where ,

Qc = Battery capacity.

I = Integrated current.

5. RESULTS

- ✓ In temperature protection, The Temperature Sensor LM35 senses the temperature of the battery and sends that information to Arduino UNO. This processor displays the temperature sensed by the LM35 sensor and displays it on the LED Display(Under normal conditions).

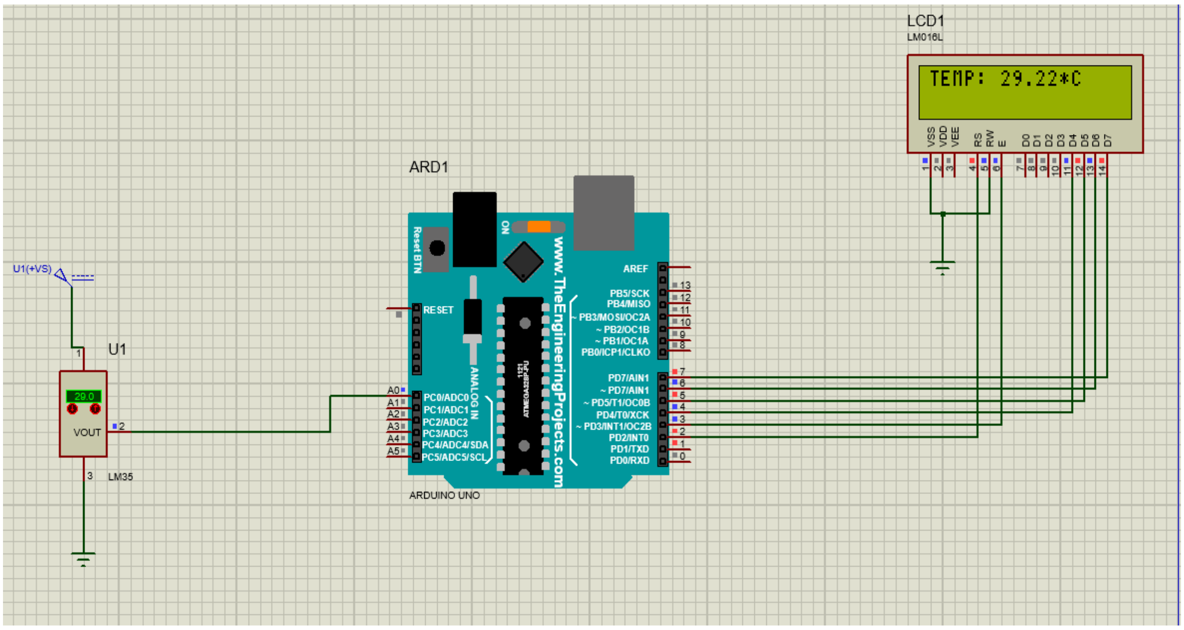

Fig.5 Temperature sensor model 1

- ✓ If the temperature goes beyond 30 degree Centigrade, the LED will display "HIGH TEMP".

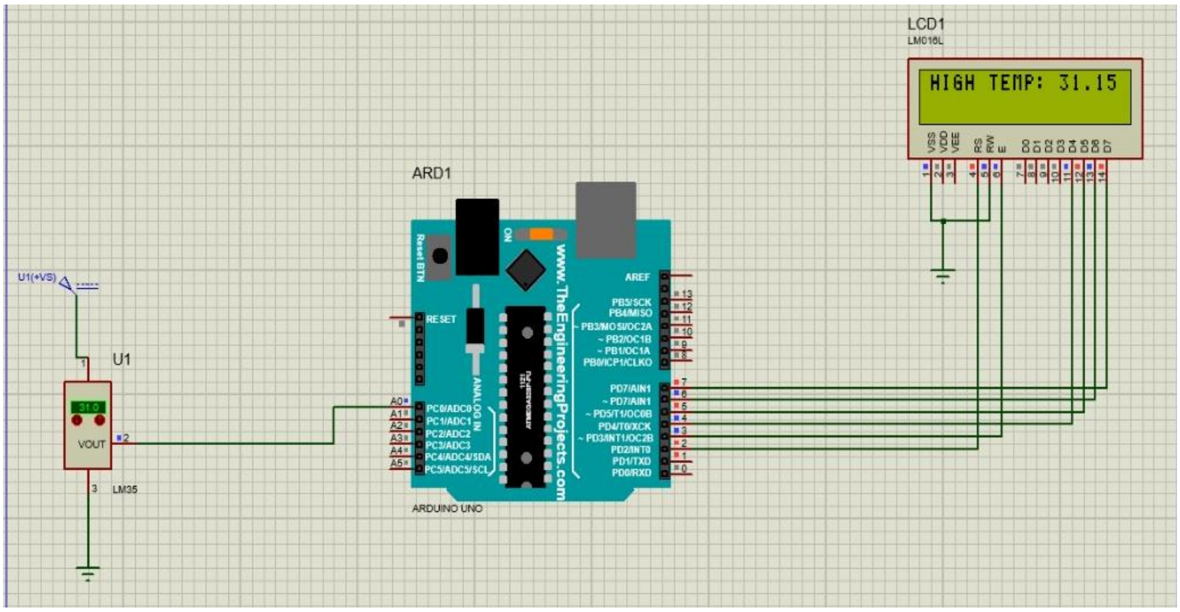

Fig.6 Temperature sensor model 2

CURRENT SENSOR WITH SOC

We have used ACS712 current sensor to measure the battery current. The current value gets displayed on the serial monitor. Then the current value is integrated for 10 iterations to obtain the state of charge and both the current value and the SoC value are displayed on the serial monitor.

Case 1 : SoC obtained from 10 iterations – 99.62%

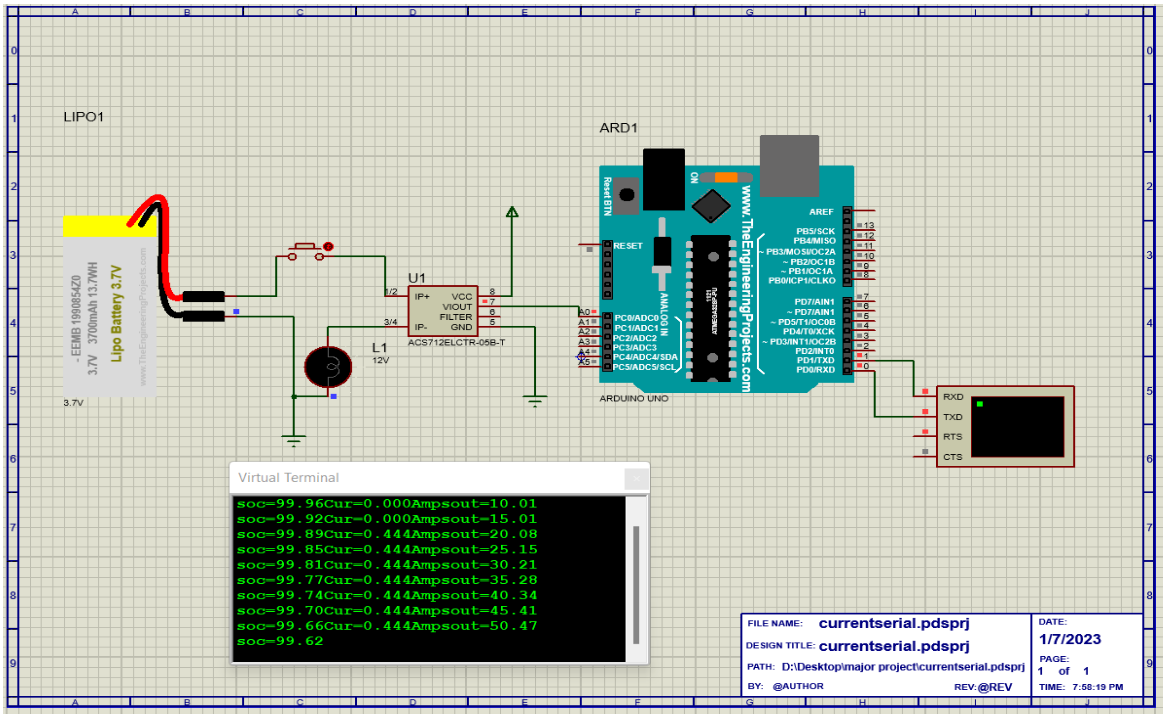

Fig.7 Current sensor model 1

Case 2 : SoC obtained from 50 iterations – 98.10%

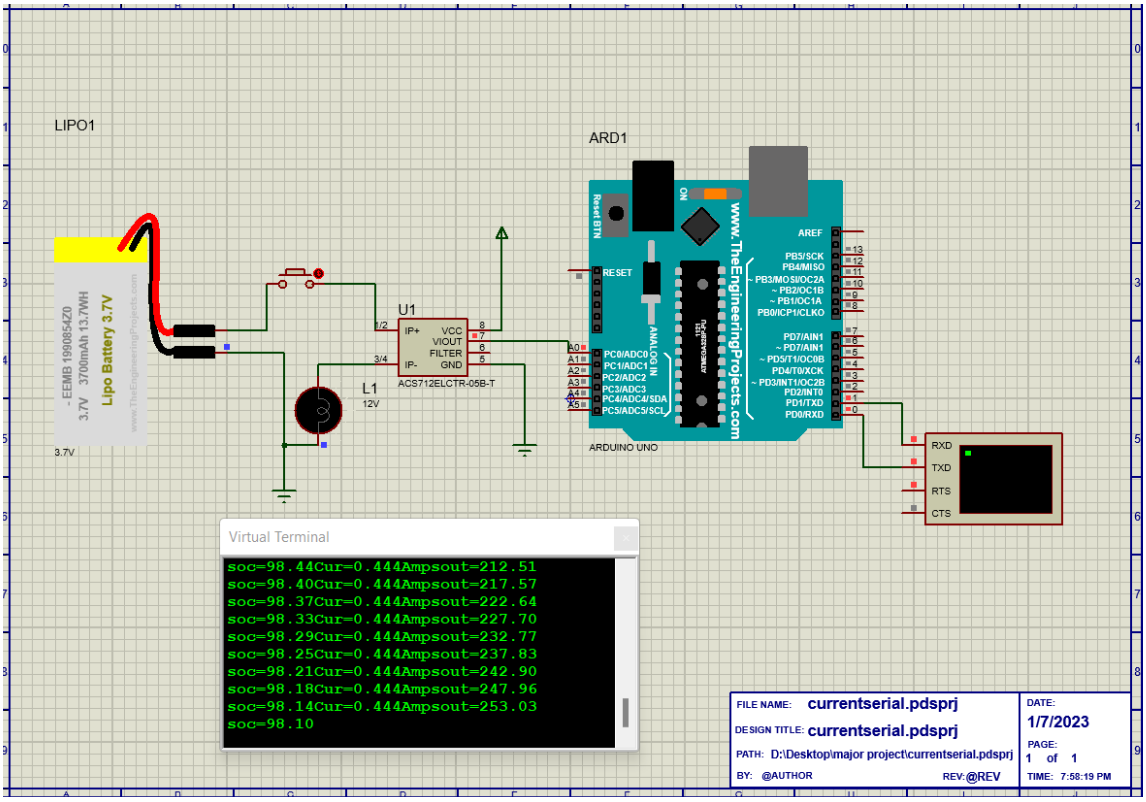

Fig.8 Current sensor model 2

5.1CONCLUSION

Battery management system (BMS) is a system that regulates all activities that occur between the battery and the required load. BMS keeps the battery safe and reliable and increases the stability without going into damaging state. In this project we have implemented the battery management system for the functionalities like current, temperature and the state of charge. In this way, we have developed the system model for battery management for electric vehicle by controlling the crucial parameters such as current, state of charge and temperature. It is very important that the BMS should be well maintained with battery reliability and safety. This report focusses on the study of BMS and optimizes the power performances of electric vehicles.

In this project BMS is implemented using Arduino UNO as a controller and functions such as Current monitoring, temperature monitoring and SoC monitoring is implemented. The operation is implemented in Proteus Platform.

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Data sheet links:

1. https://pdf1.alldatasheet.com/datasheet-pdf/view/428381/ALLEGRO/ACS712ELCTR-20A-T.html
2. https://www.alldatasheet.com/datasheet-pdf/pdf/517588/TI1/LM35.html
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