"Design of State of Charge Estimation Method for Battery Management System of Electric Vehicle"

A

Project Report

Submitted in the partial fulfillment of the requirements

For the Degree of

Bachelor of Engineering

In

Electrical (Electronics & Power)

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DEPARTMENT OF ELECTRICAL ENGINEERING

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DEPARTMENT OF ELECTRICAL ENGINEERING
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2022-23

CERTIFICATE

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ABSTRACT

In a world where electric mobility is defining our way of living, electric storage is of great importance especially in applications such as electric vehicles. Although battery technologies are diverse, Lithium-ion technology dominates the market due to its high performance. However, in order to keep the security of this part, it is essential to use a battery management system (BMS) to ensure safe and optimum operation. As the key function of this system, accurate state of charge (SOC) estimation is crucial. In this work, an Extended Kalman Filter (EKF) method for the state of charge estimation is proposed. State of charge (SOC) estimation is an essential function of the battery management system, the heart of EVs and Extended Kalman filtering is a standard SOC estimation method .State of charge (SoC) represents the available battery capacity and is one of the most important states that need to be monitored to optimize the performance and extend the lifetime of batteries.

For highlighting the impact of the temperature on the SOC, the temperature coefficient is proposed . For increasing the accuracy of estimating the SOC we propose an Extended Kalman Filter (EKF) for the state of charge estimation . The proposed model is implemented in the MATLAB environment and in hardware and results show the impact of temperature on open circuit voltage (OCV) and SOC of the battery. Finally, a comparative study has been introduced to decide which Algorithm represents the most accurate estimation for the battery parameters, and it was found that the EKF gave the best and accurate results.

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INTRODUCTION

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INTRODUCTION

1.1 Background

Electric Vehicles (EVs) play a crucial role in solving the environmental problems in the world. Due to climate change, advances in renewable energy, battery chemistry, rapid urbanization, data capture & analysis, and energy security, most developed and developing countries have included EVs in their policies to mitigate carbon emissions and offer cost-effective zero-emission vehicles. The rapid development of EV technology has led to research into battery technology, as the battery is an essential component of EVs.Among several batteries, the Li-ion battery is the most suitable one due to its high energy density, long life cycle, low self-discharge rate, etc. Li-ion batteries are dangerous when used outside their safe operating range, especially when employed in electric vehicles. Because of the harsh operating conditions of EVs, the most superior battery technology for EVs necessitates a Battery Management System (BMS) for precise monitoring, cell balancing, limiting thermal runaway, and ensuring the battery's life duration.

In numerous key functions of BMS, SOC is an indicator to control the charging and discharging limits for the safe use of batteries. Like an energy gauge, SOC measures the amount of charge available in a battery to reduce the driver's range anxiety. Therefore, precise estimation of SOC is most important for EVs.

1.2 Understanding the Problem

Energy storage systems are the key to these electrics vehicles since they directly affect performance and especially the autonomy. The widely chosen technology is mainly Lithium-ion battery due to its satisfactory characteristics, but the price of such batteries remains a factor limiting the progression of clean vehicles. On top of the improvement made on their traction systems and the alleviation of the chassis a lot of research is devoted to the EV storage units, in order to render them competitive with conventional vehicles and increase their reliability.

Battery used in Electric Vehicles is often Overcharged or Undercharged. This leads to deterioration in the efficiency of battery and causes early aging. Thus, it is necessary to have a Battery Management System which can monitor the battery parameters continuously. State of Charge estimation in BMS of EVs is very crucial. Many methods are available for SOC estimation. But the reliability and accurate estimation is still a problem.

1.3 Concept

The Battery management system is the core component of electric vehicle. As one of its main function, the battery state of charge estimation has great significance to battery management system. When we charge and discharge the battery cell it should be monitored throughout the process. Every situation need to be identified and reported along with the activation of safety mechanism. When it comes to battery management system safety becomes the first concern. While the battery undergoes charging the EV. BMS operation is going on and when the electric vehicle is discharging the battery management system make sure that the voltage does not go much low. It constantly communicates with the motor controller to make sure this doesn’t happen at all. Obviously with time the battery cell fails, a smart EVBMS impact this deterioration that leads to change in battery parameters such as current and voltage. For instance, battery cell heat up and get damage and next starts getting charged but on lower voltage as compared to rest. The accurate estimation of soc is an important part of battery management system during charging and discharging process. State of charge estimation method based on kalman filter and extended kalman filter have been purpose.

1.4 Objectives

As the main objective is to develop a better estimation SOC algorithm and to improve the efficiency of SOC and voltage tracking, some of the factors that affect battery life such as aging, the temperature are taken into consideration. These factors taken into consideration for improvement in battery SOC

- The objective of the project is to design a new method for accurate estimation of State of Charge of batteries used in Electric Vehicle.
- Batteries used in EVs should not be overcharged or over-discharged
- To avoid damage of the battery, shortening the battery life, and causing fire or explosions.
- To improve the safety of lithium ion batteries.
- Optimize the utilization of the battery in EVs.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

Governments all across the world are enacting electric car legislation to reduce reliance on oil, cut greenhouse gas emissions, and improve air quality. Annual global electric car sales have risen steadily in recent years, from just a few hundred in 2010 to over 500,000 in 2015 and over 750,000 in 2016. In September 2015, the global market for electric vehicles hit 1 million units, fast increasing to 2 million units in January 2017. The early market growth for electric vehicles continues, but several barriers prevent their more widespread uptake. The new technology's higher cost, relative convenience in terms of range and charge periods, and customer awareness of the technology's availability and feasibility are among these obstacles. This final criterion, often known as "customer awareness," is critical. The widespread awareness and comprehension of the potential benefits of electric vehicles is crucial to the growth of electric vehicle markets.

- **A Review on Electric Vehicles with perspective of Battery Management System by Daisy Ranawat, M P R Prasad**

The present paper discusses the diffusion of electric vehicles. Also describes about the future of EV is bright as battery costs are dropping fast. Long range and affordable EVs are coming that operate fully on electricity and are capable of travelling 300 miles. One of the disadvantages is the lack of charging station. But this problem can be overcome as the number of EVs is increasing. Vehicles which are used for goods transfer are also moving towards electrification. Electric buses are already available in market although they have low efficiency.

- **SoC Estimation for Lithium-ion Batteries: Review and Future Challenges by Juan Pablo Rivera-Barrera , Nicolás Muñoz-Galeano and Henry Omar Sarmiento-Maldonado**

This paper critically reviews SoC estimation methodologies presented by scholars in the last five years, presenting the fundamentals and main drawbacks of each method. The approaches that have not been extensively used during recent years have not been cited here. From the review of the different approaches, it can be concluded that the hardest part of obtaining a battery SoC estimation is to build a model that reflects the reality inside the battery, including the impact of temperature dependencies on internal resistance and capacity fading. It can also be concluded that the accuracy of SoC estimation may be affected by factors such as modeling imperfections, parametric uncertainties, sensor inaccuracies, and measurement noise.

- **A comprehensive review on the state of charge estimation for lithium-ion battery based on neural network by Zhang, C.; Wang, L.Y.; Li, X.; Chen, W.; Yin, G.G.; Jiang, J.**

This paper gives the perspective to estimate state of charge by Neural network method .This study first outlines the definition of SOC for lithium ion batteries and shows that there is a non-negligible link between SOC and battery aging.. Researchers can find an overview of various existing neural network methods and recommendations from this review, significantly contributing to future research on SOC estimation methods

- **A review on the key issues for lithium-ion battery management in electric vehicles by Lu, L.; Han, X.; Li, J.; Hua, J**

This work addresses the issues related with the li-ion batteries . also this presents analysis of literature and in combination with our practical experience, gives a brief introduction to the composition of the battery management system (BMS) and its key issues such as battery cell voltage measurement, battery states estimation, battery uniformity and equalization, battery fault diagnosis and so on, in the hope of providing some inspirations to the design and research of the battery management system .In order to create a sustainable and cleaner transportation system, we need higher-efficiency vehicles with significantly lower fuel consumption.

- **Impact of temperature on State of Charge estimation for an Electric Vehicle by S. Mohite, U. Suryawanshi, A. Sheikh, S. Wagh, and N. M. Singh**

This work analyzes the effect of temperature on the SOC of the battery. The state space model of a battery is reframed by inserting the temperature coefficient in an existing battery model. For estimation of SOC, an extended Kalman filter algorithm is used in the proposed methodology. It also describes the Electric Vehicle (EV) is an emerging trend in the automobile industry. The critical component of an EV is the battery. For accurate estimation of the state of charge (SOC) and maintaining the battery in operating region a battery management system (BMS) is implemented in EV. In literature various methods have been proposed for SOC estimation, however, it has disadvantages such as accumulative error problem, high computation cost, and complex algorithm

CHAPTER 3

BATTERY MANAGEMENT SYSTEM

CHAPTER 3

BATTERY MANAGEMENT SYSTEM

A battery management system (BMS) is any electronic system that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its safe operating area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it and / or balancing it. A battery pack built together with a battery management system with an external communication data bus is a smart battery pack. A smart battery pack must be charged by a smart battery charge.

Battery management system (BMS) is used in electric vehicle to monitor and control the charging and discharging of rechargeable batteries which makes the operation more economical. Battery management system keeps the battery safe, reliable and increases the senility without entering into damaging state. In order to maintain the state of the battery, voltage, current, ambient temperature different monitoring techniques are used. For monitoring purpose different analog/digital sensors with microcontrollers are used. This paper addresses state of charge, state of health, and state of life and also maximum capacity of a battery. By reviewing all these methodologies future challenges and possible solutions can be obtained.

Battery storage forms the most important part of any electric vehicle (EV) as it store the necessary energy for the operation of EV. So, in order to extract the maximum output of a battery and to ensure its safe operation it is necessary that efficient battery management system exist the same. It monitors the parameters, determine SOC, and provide necessary services to ensure safe operation of battery. Hence BMS form an important part of any electric vehicle and so, more and more research is still being conducted in the field to develop more competent Battery Management System. Battery management system (BMS) makes decisions based on the battery charging and discharging rates, state of charge estimation, state of health estimation, cell voltage, temperature, current etc.

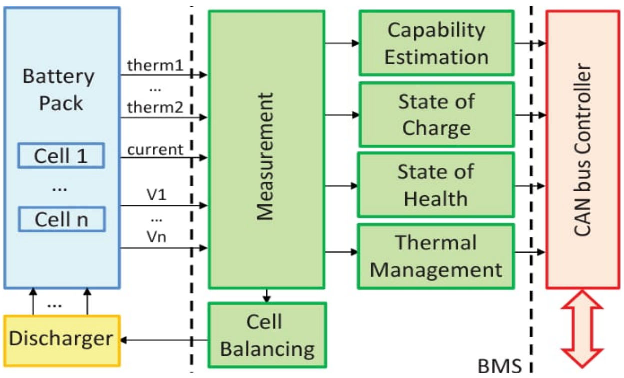

Figure 1.Block Diagram of Battery Management System

3.1Functions of the BMS

1. Charging control

In EV, charging of the battery consists of two stages: constant current, constant voltage. During the first stage, constant current is produced by charger due to which the voltage of battery increases and when the battery becomes nearly full, battery voltage reaches a constant value and enters into a constant voltage stage. Until the charging finishes, constant voltage is maintained as the battery current decays exponentially.

2. Discharging control:

During discharging, it is the function of BMS to protect cell from any event so that cell does not cross its limitations and damage.

3. **State-Of Charge determination**:

   SOC generally controls the charging and discharging process of the cells and provide signal to the user. SOC can be determined by direct measurement, coulomb counting, and combination of the two techniques.

4. **State-Of Health determination**

   SOH is the measurement of the long-term capability of the battery and reflects the general condition of a battery. It also gives an indication of particular parameter performance after comparing with a fresh battery as a reference.

5. **Cell balancing:**

   Cell balancing is one of the main functions of BMS. A battery is balanced when all of the cells are exactly at the same SOC.

   Passive balancing: Passive cell balancing balance the battery by sampling all cells voltages, leveling all voltages to the lowest among the cells by removing charge from these higher potential cells.

   Active balancing :Active cell also samples all voltages but in different way, by calculating the mean value of cells then transferring the charge from the cells over this mean value to the cells underneath mean value.

CHAPTER 4
STATE OF CHARGE

CHAPTER 4

STATE OF CHARGE

4.1 What is State of charge (SOC)?

State of charge is defined as the available amount of battery as the percentage of rated capacity of the battery. State of charge gives a crucial support to battery management system to assess the state of the battery which helps the battery to operate within the safe operating range by controlling charging and discharging. It also increases the life span of the battery. State of charge cannot be estimated directly. It is calculated by using the equation

$$SOC = 1 - \frac{\int idt}{Cn}$$

A good SOC calculation provides many advantages for EV such as; longer battery life, better battery performance and failure warning of the battery pack. The residual battery capacity can be determined by measurement of the density of chemical components of the battery; however it is not a practical solution [2]. Accordingly, various methods have been proposed based on battery voltage and current measurement. Most of these methods ignore the temperature effect in calculation of the battery SOC. The SOC should be determined accurately, especially for electrical vehicles applications to predict the travel / remaining distance of the vehicle.

4.2 Why SOC Estimation is important?

Battery management system (BMS) is a crucial tool to optimize power consumption, increase battery lifetime and assure safe operation. In addition, BMS provides battery protection from overcharge/discharge which might cause overheating and sometimes fire runaway. One of the important tasks of BMS is state of charge(SOC) monitoring, providing information on battery power level, since a poor control of li-ion technology charging process can lead to the destruction of the battery.

Following are some key points why soc estimation is essential for proper management of battery management system of electric vehicle

- Estimation of Energy consumption
- To make the cell work in best operating regions
- To analyze parameters battery performance and reliability
- To increase the lifetime of the battery
- Cell parameters are a direct function of SOC
- Cell balancing strategies are dependent on the cell SOC

4.3 Methods for SOC Estimation

There are various methods to estimate the state of charge. Following are the list of state of charge estimation method

1. Coulomb counting SOC estimation method

2. Fuzzy logic SOC estimation method

3. Impedance spectroscopy SOC estimation method

4. Kalman filtering SOC estimation method

5. Open circuit voltage SOC estimation method

Among all these various methods Kalman filtering method has been successful for the estimation of SOC for EV'S

Following is the detail description of some of the methods

4.3.1 Coulomb Counting (CC)

CC has been standardized in the industry as a SoC estimation method. At present, the CC method (also known as the ampere-hour balancing method), is the most used method for SoC estimation since it is the most accurate technique for short-term calculations. The CC method defines SoC as

$$SOC(t) = SOC(t_0) + \frac{1}{c_n}\int_{to}^{t0+t} I_{bat}(d\tau) \times 100$$

4.3.2 Artificial Neural Network (ANN)

It is inspired by biological neurons and requires intense computing for estimation. Such estimation requires training for a new battery. ANN depends on the hardware (a requirement for processors with parallel processing power). ANN with a back-propagation method is sensitive to noisy data.

4.3.3 Open Circuit Voltage-Based Estimation (OCV)

Open Circuit Voltage Method. There is approximately a linear relationship between the SOC of the lead-acid battery and its open circuit voltage (OCV) given by where is the SOC of the battery at, is the battery terminal voltage when SOC = 0%, and is obtained from knowing the value of and at SOC = 100%

The technique is not suitable for online testing since the battery requires having long time resting to reach balance and to get the OCV. The method is not practical due to the requirement of measuring OCV which means SoC estimation is not available while the battery is charging or discharging. OCV is also not accurate due to the flat region that exists in the mid-SoC region curve.

4.3.4 Impedance spectroscopy SOC estimation method

An impedance measurement system is obtained from sinusoidal excitations at different excitation frequencies in which both voltage and current are recorded, and their complex quotient is computed as the cell impedance. The impedance spectroscopy of a battery cell can be approximated with two circles on nyquist plane .This estimation method is suitable only for identical charging conditions. So, it is not suitable for EVs that could be charged inconsistently with different current. Due to high temperature influence, this method can only be made in high frequency range.

4.3.5 Kalman Filter

Kalman filter algorithms. This technique is the most popular and frequently used for real-time battery management systems, due to its higher level of computation compared to coulomb counting or artificial intelligence techniques. On account of the nonlinear behavior of the battery, extended Kalman filter is chosen for SOC estimation, which is a nonlinear version of the classical Kalman filter used for linear systems. Many previous works have addressed SOC estimation using EKF

Methods	Advantages	Disadvantages
Discharge test	Easy	Energy loss, time intensive, offline,
Coulomb counting	flawless current measurement	Sensitive to parasite reactions
OCV	Online, cheap	Need long rest time
Impedance spectroscopy	Sensitive to So Variation	Temperature sensitive
Neural network	Online ,do not need previous knowledge	Large number of training samples
Kalman filters	For all battery systems, Most accurate soc	Little expensive
Fuzzy logic	Online , robust	Large amount of memory in real world application

Table 1. Summerization of SOC Estimation Method

CHAPTER 5

KALMAN FILTERING

CHAPTER 5

KALMAN FILTERING

In 1960, R.E. Kalman proposed a recursive approach to solving the problem of linear filtering of discrete data in his Ph.D. thesis. Subsequently, this method was developed and extended to cases such as nonlinear filtering and is widely used in applications such as navigation and localization. In recent years, the Kalman filter algorithm has been applied to battery SOC estimation, resulting in a significant improvement in estimation accuracy.

Extended Kalman Filters

The Extended Kalman Filter (EKF) is a more widely used nonlinear filtering algorithm. As mentioned in the previous section, the classical Kalman filter algorithm can only be applied to linear systems. In order to apply the ideas of the Kalman filter algorithm to nonlinear systems, the EKF algorithm uses the Taylor expansion and omits the higher order terms to approximate the nonlinear model to a linear model, and then follows the process of the classical Kalman filter algorithm to complete the filtering form.

In this work Extended Kalman Filter method is used for the estimation of SOC among discussed method in previous section, because of its precision and accuracy.

The EKF algorithm can be widely applied to a variety of nonlinear systems and can achieve good state estimation for systems with weak nonlinearity. The EKF algorithm can be applied to a wide range of nonlinear systems and can achieve good state estimation for systems that are not strongly nonlinear.

Advantages of Extended kalman Filter:

- Applicable for all battery system
- Accurate estimation of SOC
- No initial SOC needed
- Easily filter noise
- It can handle non linear dependencies
- High precision

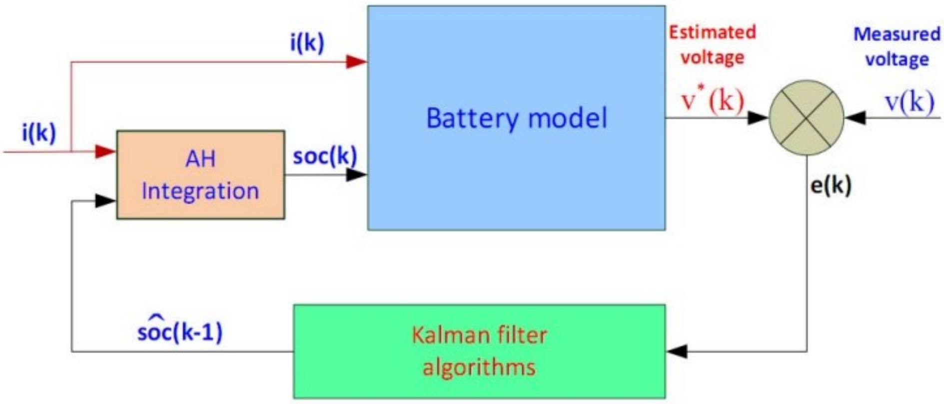

Figure 2. Kalman filtering SOC estimation model

CHAPTER 6

MATLAB MODEL OVERVIEW

CHAPTER 6

MATLAB MODEL OVERVIEW

6.1 State Of Charge Estimation

One of the most common battery models seen in literature is the 2RC ECM . It consists of the battery OCV, internal resistance, and two parallel RC pairs. Once these parameters have been optimized, the discrete-time state-space form of the battery model is used in the EKF algorithm. Given battery measurements (i.e. current, voltage, temperature) over time, the EKF will estimate the unknown variables in a dynamic system

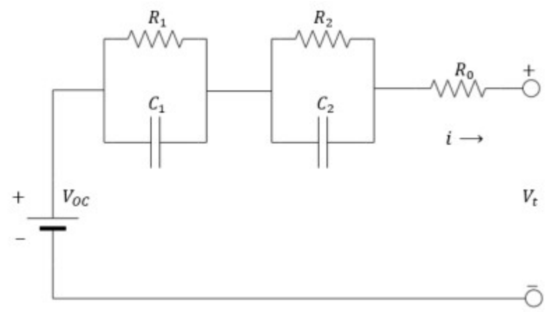

Figure 3. Second Order Resistor-Capacitor ECM Diagram

6.2 Battery Modeling

In Figure 3, the OCV is represented by VOC , the output terminal voltage by Vt, and the internal resistance of the battery by R0. The voltage across the first RC network is V1 and V2 across the second network. Equations describe the ECM dynamics in state-space

The state and measurement equations can be calculated in as follows:

$$X_{k+1} = A_k x_k + B_k u_k$$

$$Z_k = C_k x_k + D_k u_k (7)$$

Where X_{k+1} is the system state vector at time k+1, the state variables are x = [SOC, V1, V2] , system input is *uk* = *ik*, and system output is *zk* = *Vt*. The A, B, C, and D matrices are given by

$$A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & exp^{\frac{-\Delta t}{R1C1}} & 0 \\ 0 & 0 & exp^{\frac{-\Delta t}{R2C2}} \end{bmatrix} (8)$$

$$B = \begin{bmatrix} -\frac{\Delta t}{Q}\, n[k] \\ R1(1 - exp^{\frac{-\Delta t}{R1C1}}) \\ R2(1 - exp^{\frac{-\Delta t}{R2C2}}) \end{bmatrix}$$

$$C = \begin{bmatrix} \frac{\partial Voc}{\partial SOC} & \frac{\partial V}{\partial V1} & \frac{\partial V}{\partial V2} \end{bmatrix} = \begin{bmatrix} \frac{\partial Voc}{\partial SOC} & -1 & -1 \end{bmatrix}$$

$$D = - R0$$

6.3 Extended kalman Filter Algorithm

The EKF, a version of the regular KF, is used to estimate the states for a non-linear system. EKF uses a two-step prediction correction algorithm as described , where k denotes a discrete point in time, K is the Kalman gain, P is the covariance of the measurement error, Q is the covariance of the process, and R is the covariance of the output . First, a prediction or time update is done and then the correction or measurement update. This cycle repeats until the end of the data. Note, the hat symbol, ˆ, represents an estimate of a variable, |k denotes predicted or a-priori estimate, and |k + 1 denotes updated or a-posteriori estimate.

The Extended Kalman Filter algorithm are described as follows :

Prediction (Time Update)

1. Project the states ahead (a-priori):

$$\hat{x}_{k+1|k} = A\hat{x}_{k|k} + B_{u_k}$$

2. Project the error covariance ahead:

$$P_{k+1|k} = AP_{k|k}\ A^T + Q_k$$

Correction (Measurement Update)

1. Compute the Kalman gain:

$$K_{k+1} = P_{k+1|k}C^T\left(CP_{k+1|k}C^T + R_{k+1}\right)^{-1}$$

2. Update the estimate with measurement zk (a- posteriori):

$$\hat{x}_{k+1|k+1} = \hat{x}_{k+1|k} + K_{k+1}\left(z_{k+1} - C\hat{x}_{k+1|k}\right)$$

3. Update the error covariance:

$$P_{k+1|k+1} = (1 - K_{k+1}\ C)P_{k+1|k}$$

$$Q_k = k_k * Error_k * k_k$$

This are EKF algorithm which are taken into consideration .With the help of these algorithm a MATLAB function is proposed which gives following

6.4 Output Graphs

6.4.1 Output at 40°C

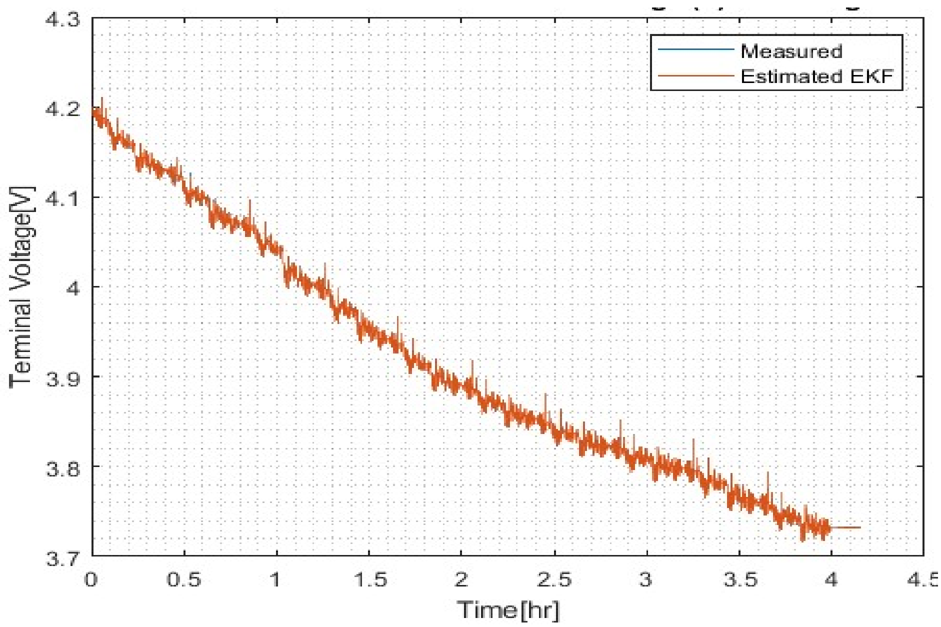

Figure 4. Terminal Voltage (V) Vs Time (hr)

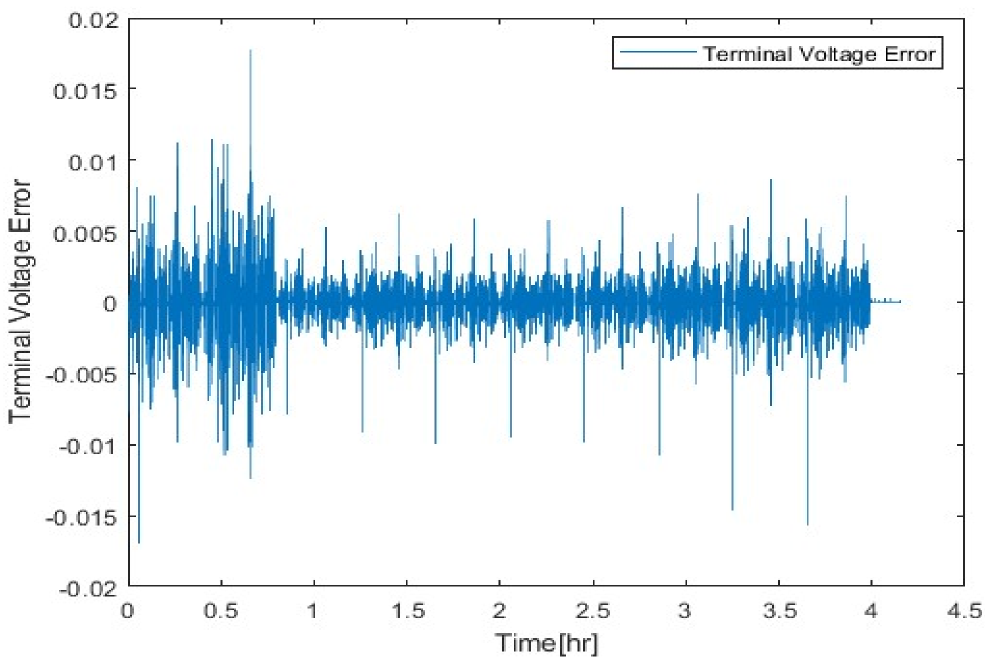

Figure 5. Terminal Voltage Error vs Time (hr)

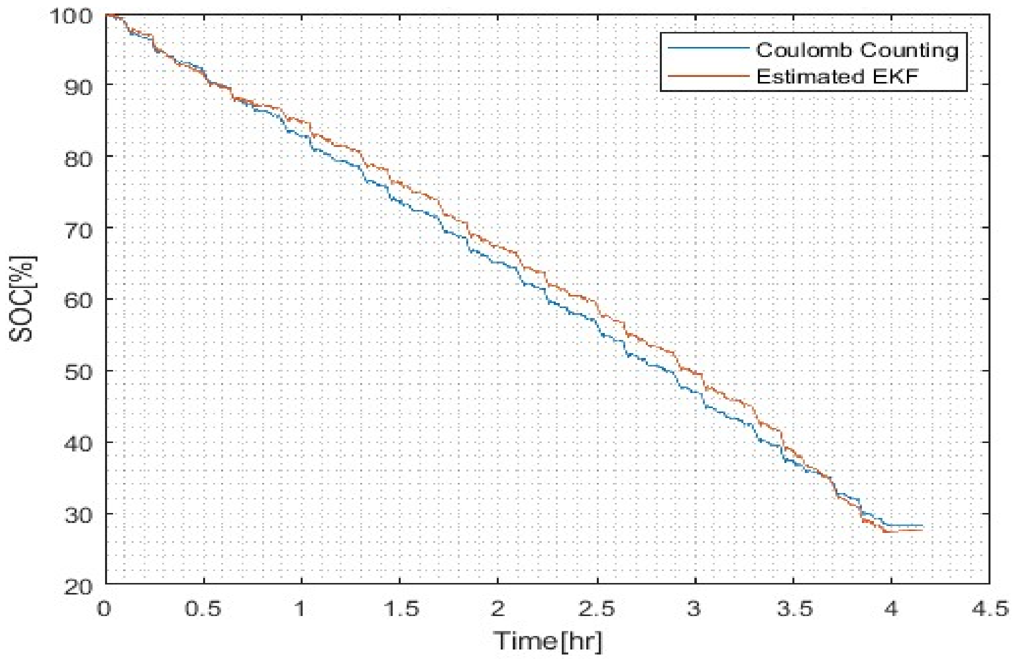

Figure 6. Soc estimated by Coulomb Counting Vs Extended Kalman Filter

6.4.2. Output at 25°C

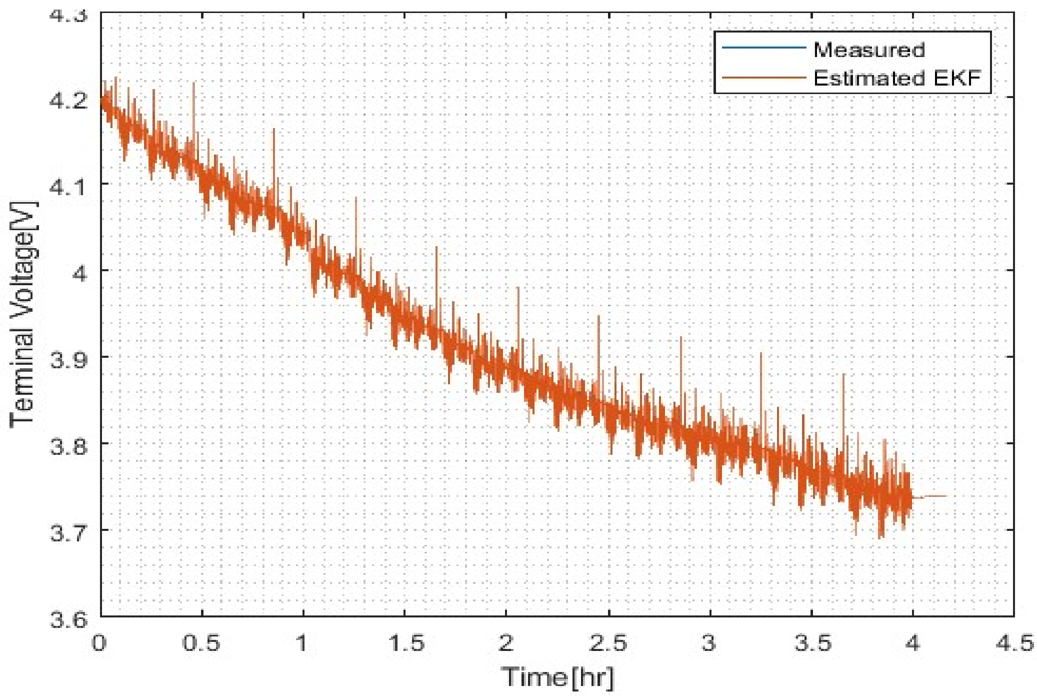

Figure 7. Voltage (V) Vs Time (hr)

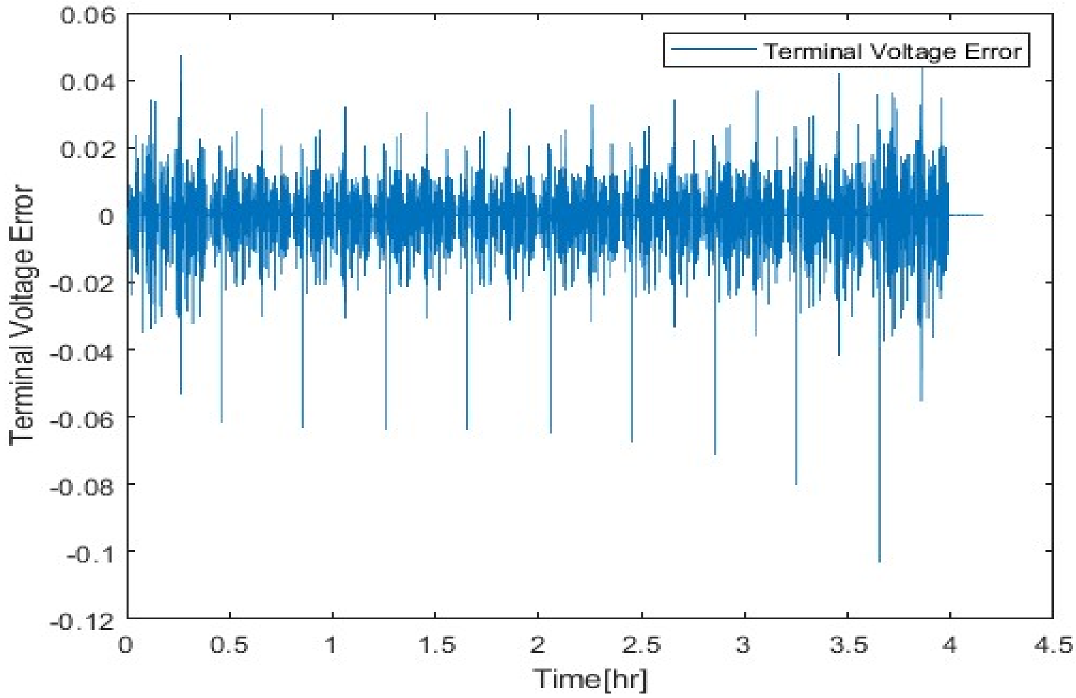

Figure 8. Terminal Voltage Error vs Time (hr)

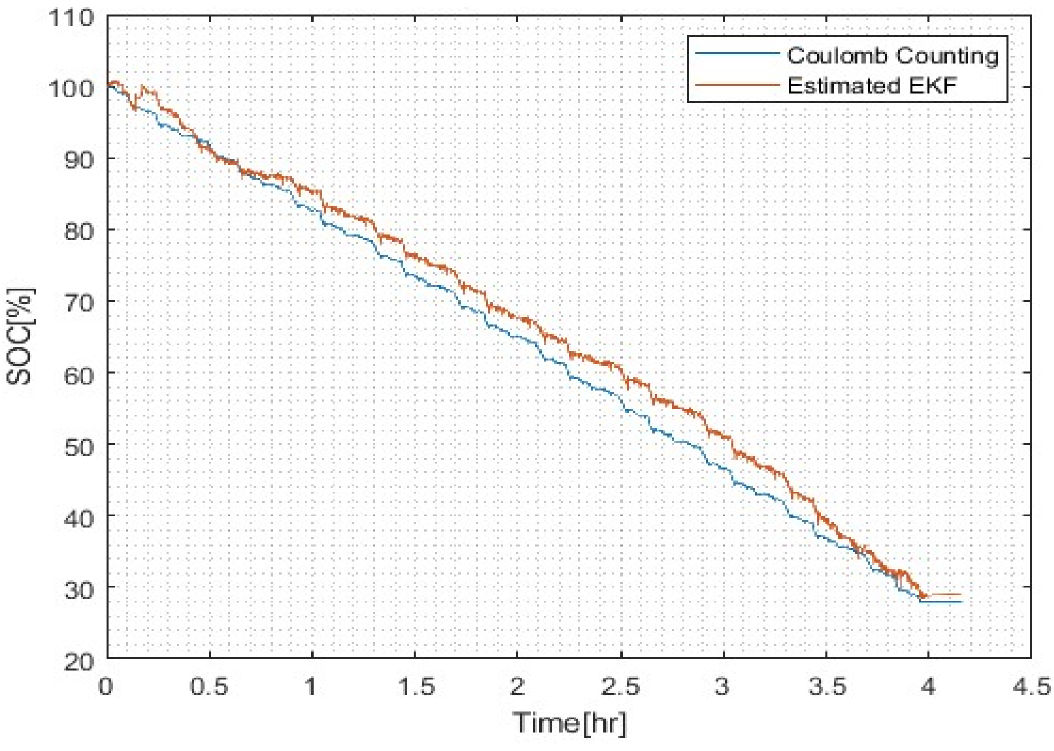

Figure 9. Soc estimated by Coulomb Counting Vs Extended Kalman Filter

CHAPTER 7

EMBEDDED SYSTEM

CHAPTER 7

EMBEDDED SYSTEM

7.1 Description

An embedded system combines computer hardware and software designed for a specific function. Embedded systems may also function within a larger system. The systems can be programmable or have a fixed functionality. Industrial machines, consumer electronics, agricultural and processing industry devices, automobiles, medical equipment, cameras, digital watches, household appliances, airplanes, vending machines, and toys, as well as mobile devices, are possible locations for an embedded system.

An embedded system involves combining hardware and software to design a dedicated computer system that performs a specific task in electronic, mechanical, and electronic devices.

They are designed to operate with little to no human interference and to complete tasks in the most efficient way. Embedded systems can be used in various industries such as healthcare, life sciences, military and defense industry, industrial automation, and other industries

The purpose of embedded systems is to control a specific function within a device. They are usually designed to only perform this function repeatedly, but more developed embedded systems can control entire operating systems

CHAPTER 8

METHODOLOGY

CHAPTER 8

METHODOLOGY

8.1. Proposed System

In this project we measure the SOC of lithium-ion batteries. For implementing the system we used Arduino UNO as a microcontroller. the voltage sensor, current sensor, and DHT11 sensor, for detecting the current of load and temperature and voltage of batteries. The LCD is connected to display all parameters like voltage and the temperature and current and SOC. for the load we used the LED as a light source.

8.2. Block Diagram and Description

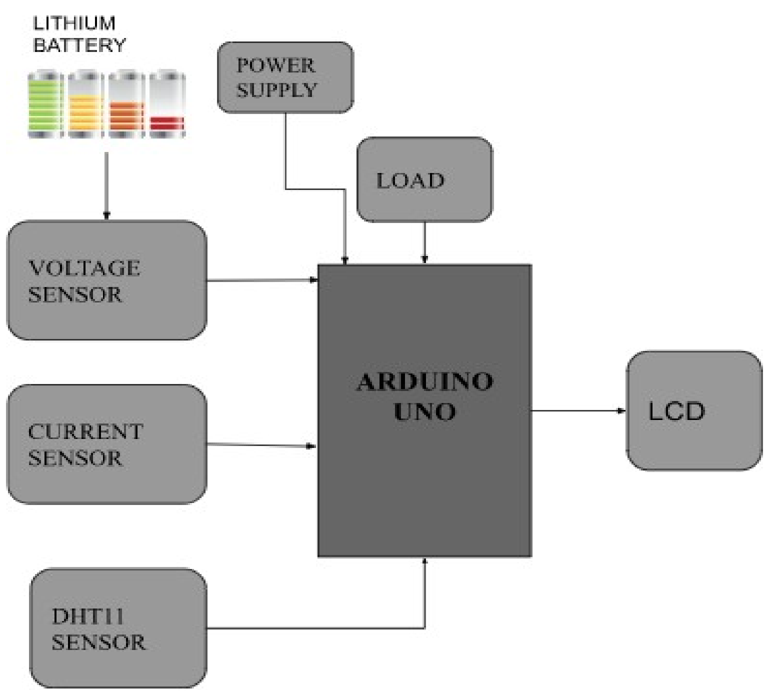

Figure 10. Block Diagram

8.2.1. Description

In this project, we use Arduino As a microcontroller. The voltage sensor, current sensor, and DHT11 sensor are connected as input devices to the microcontroller. The LCD is connected as an output device to the microcontroller.

In this project various sections are there, first is power supply, second is input section - where we different sensors are used ,Input section has lithium ion batteries of 3.7 volt / 2.6 ampere hour. 18650 is the model number of the battery and each cell has a capacity of 2.6 Ah. Total current of 4 batteries is 10.4 ampere hour.

In second section consist of various sensors like voltage sensor, current sensor and temperature sensor. Third is controlling unit we are using ATmega 328P microcontroller of 8 bit. This controller is SMD type which is mounted on arduino platform board and we are using display 16×2 LCD in 4-bit mode

At last this LCD screen will show the output in the form of voltage, current , temperature and State of Charge.

8.3. Flowchart

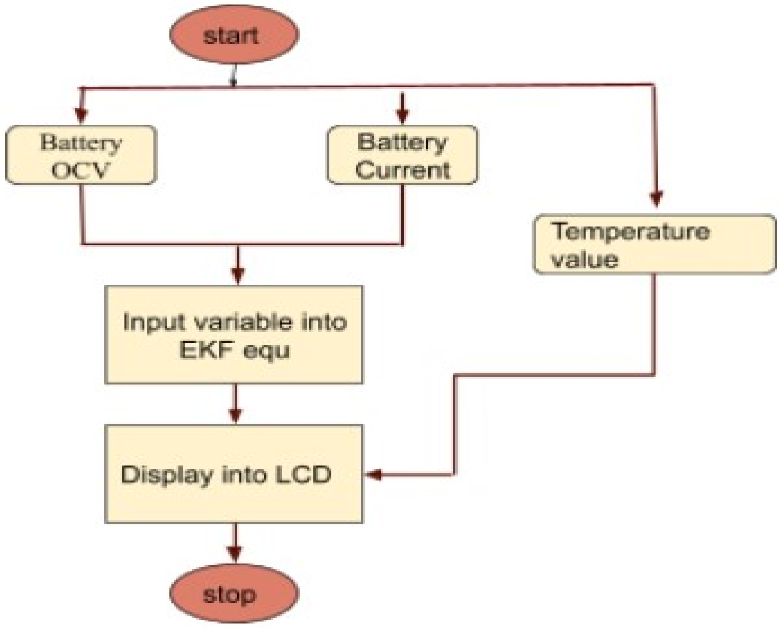

Figure 11. Flowchart

8.4 Circuit Diagram

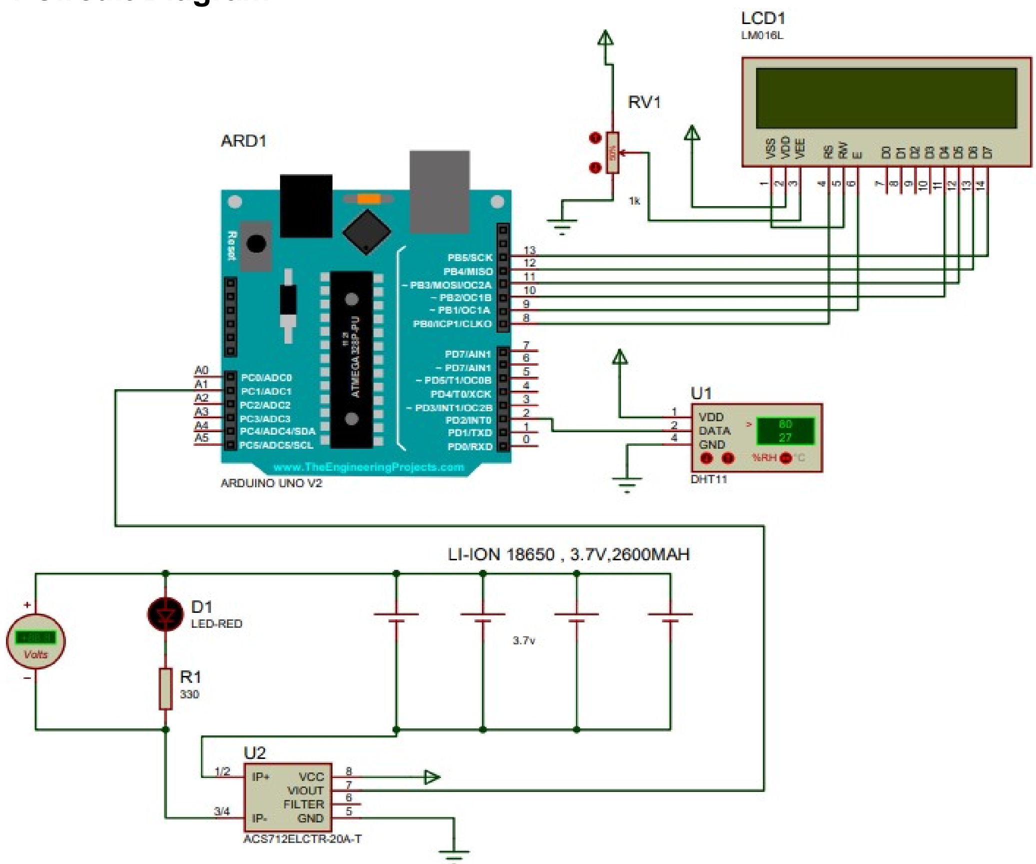

Figure 12. Circuit Diagram Of Proposed System

8.5. Working

The project Title “Design of State of charge estimation Method for battery management system of electric vehicle” describes that we want to detect the SOC of the lithium battery which we used in a recent Electric vehicle by using the Extended Kalman Filter. This project is divided into two parts where we used the detect the current of load and another where we want to detect The temperature and voltage and The SOC of Lithium Ion batteries. Modeling the battery can give important pieces of information about its internal state. The internal state is represented by the remaining energy inside the battery, which is signified by the state of charge (SOC). The main objective of modeling is to monitor the internal parameters of the battery, among them the voltage, current, and SOC. Firstly we start the power supply to power the system. We used lithium-ion batteries here which is rechargeable and arranged in parallel for detecting the other parameter of batteries and SOC. after the power supply the SOC and Voltage of the battery and current of the load display on the LCD.

CHAPTER 9

SYSTEM REQUIREMENT

CHAPTER 9

SYSTEM REQUIREMENT

9.1 HARDWARE REQUIREMENT

- Arduino UNO
- Voltage sensor
- Current Sensor
- DHT11 Sensor
- LCD
- Lithium-ion battery

9.2 SOFTWARE REQUIREMENT

- Arduino IDE

9.1. Hardware Requirement

A. Arduino

The Arduino UNO is a standard board of Arduino. Here UNO means 'one' in Italian. It was named UNO to label the first release of Arduino Software. It was also the first USB board released by Arduino. It is considered a powerful board used in various projects. Arduino. cc developed the Arduino UNO board. Arduino UNO is based on an ATmega328P microcontroller.

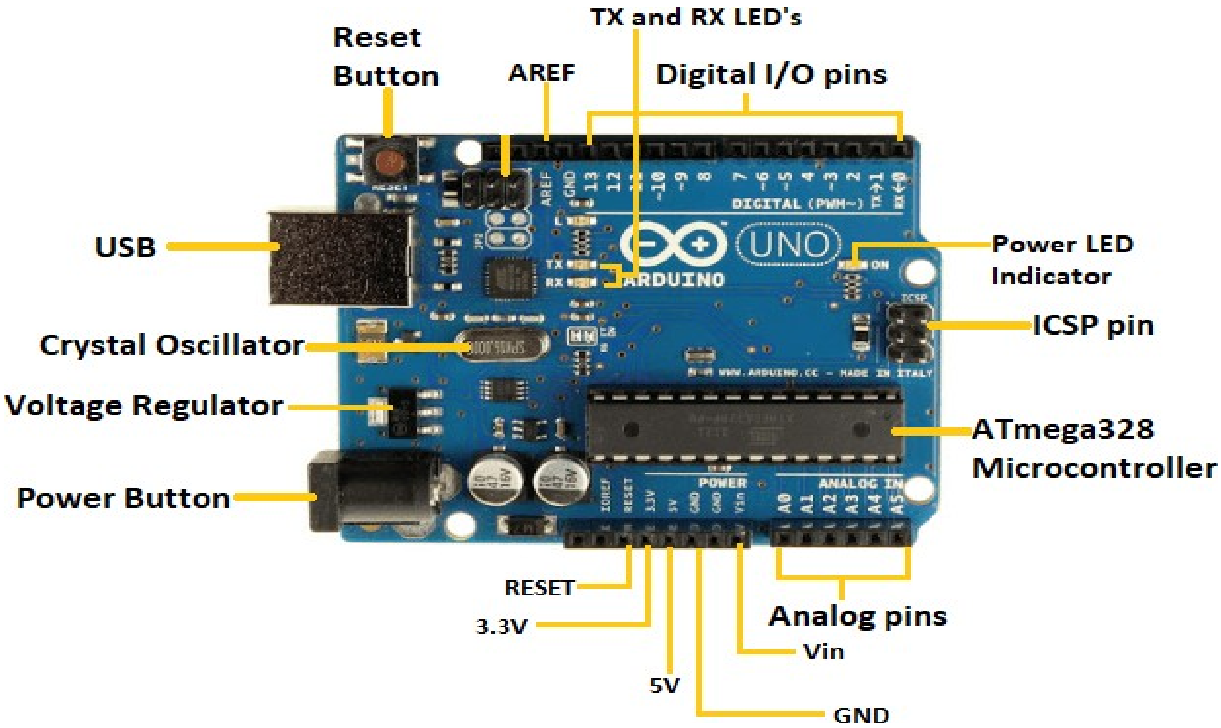

Figure 13. Arduino Uno

B. DC voltage sensor

A voltage sensor is a sensor used to calculate and monitor the amount of voltage in an object. Voltage sensors can determine the AC voltage or DC voltage level. The input of this sensor is the voltage, whereas the output is the switches, analog voltage signal, current signal, or audible signal

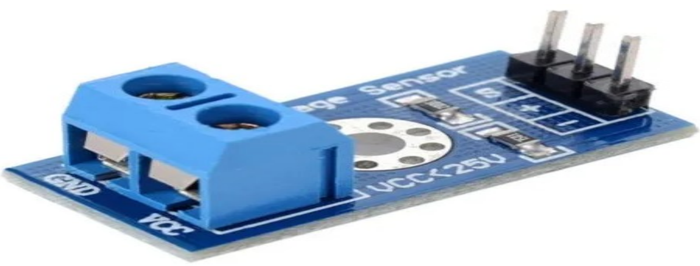

Figure 14. DC Voltage Sensor

Applications of Voltage Sensors

The application of voltage sensors includes the following:

- Power failure detection
- Load sensing
- Safety switching
- Temperature control
- Power demand control
- Fault detection

C. Current Sensor

Current flowing through a conductor causes a voltage drop. The relation between current and voltage is given by Ohm's law. In electronic devices, an increase in the amount of current above its requirement leads to overload and can damage the device. Measurement of current is necessary for the proper working of devices. Measurement of voltage is a Passive task and it can be done without affecting the system. Whereas measurement of current is an Intrusive task that cannot be detected directly as voltage

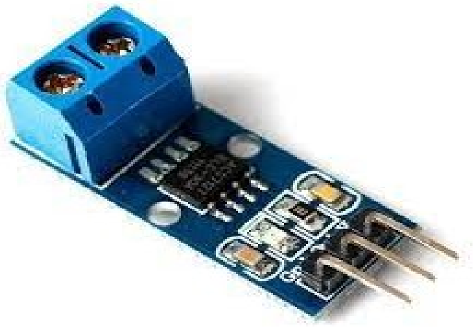

Figure 15. ACS 712 Current Sensor

D. DHT 11 Sensor

DHT11 is a Humidity and Temperature Sensor, which generates calibrated digital output. DHT11 can interface with any microcontroller like Arduino, Raspberry Pi, etc. and get instantaneous results. DHT11 is a low cost humidity and temperature sensor which provides high reliability and long term stability

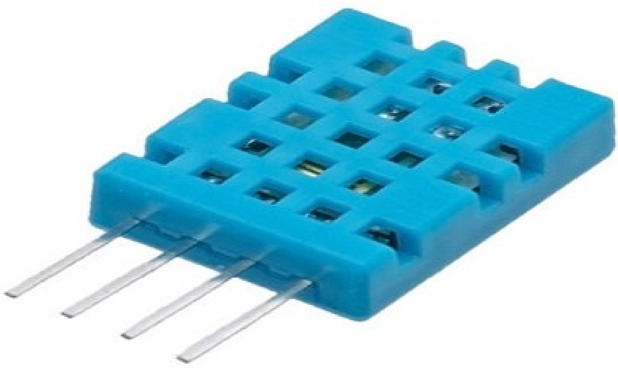

Figure 16. DHT11 Temperature Sensor

Specifications:-

- Power Supply： 3.3~5.5V DC
- Output： 4 pin single row
- Measurement Range： Humidity 20-90%RH, Temperature 0~50℃
- Accuracy： Humidity +-5%RH, Temperature +-2℃

- Resolution： Humidity 1%RH， Temperature 1℃
- Interchangeability： Fully Interchangeable

Pin Description:-

- Pin 1: Power +Ve (3.3VDC to 5.5VDC Max wrt. GND)
- Pin 2: Serial Data Output
- Pin 3: Power Ground or Power –Ve

E. LCD [Liquid Crystal Display]

A Liquid Crystal Display (LCD) can be of the character type or graphics type. 16x2 LCD modules are very commonly used in most embedded projects, the reason being its cheap price, availability, programmer friendly and available.

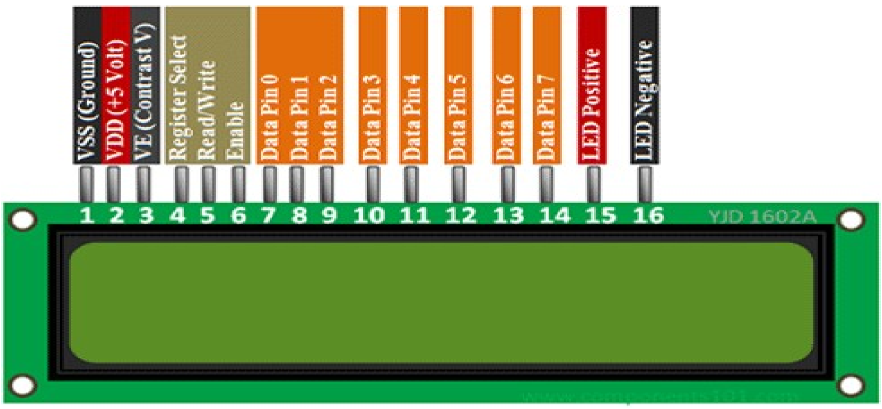

Figure 17. LCD

LCD Features and Technical Specifications

- Operating Voltage is 4.7V to 5.3V
- Current consumption is 1mA without backlight
- Alphanumeric LCD display module, meaning can display alphabets and numbers

- Consists of two rows and each row can print 16 characters.
- Each character is build by a 5×8 pixel box
- Can work on both 8-bit and 4-bit mode
- It can also display any custom generated characters
- Available in Green and Blue Backlight

F. LED [light-emitting diode]

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it. When current passes through an LED, the electrons recombine with holes emitting light in the process. LEDs allow the current to flow in the forward direction and block the current in the reverse direction.

Figure 18. LED

Below are a few standards LED uses:

- Used for TV back-lighting
- Used in displays
- Used in Automotives
- LEDs used in the dimming of lights

G. lithium-ion (Li-ion) battery

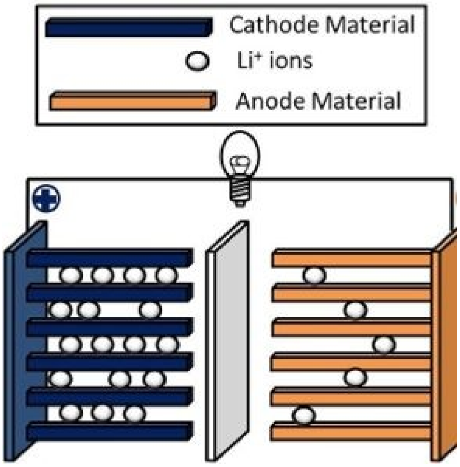

Figure 19. Lithium Ion Battery

Advantages

- Superior “Useable” Capacity
- Extended Cycle Life
- Size & Weight Advantages
- Fast & Efficient Charging
- Very Little Wasted Energy

CHAPTER 10

RESULT

CHAPTER 10

RESULT

10.1 Experimental Setup

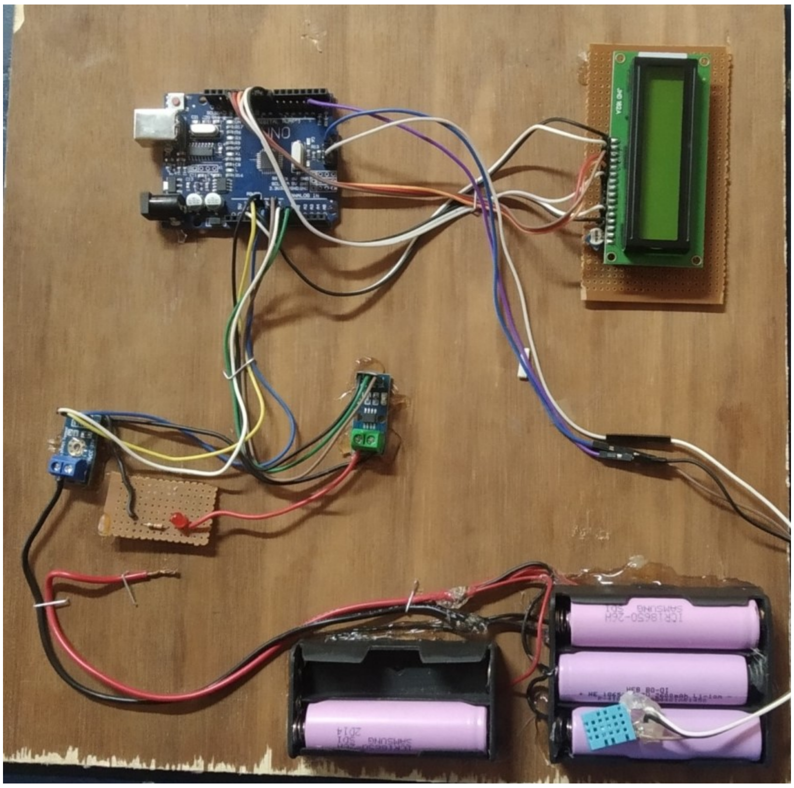

Figure 20. Experimental Setup of proposed System

10.2 Output

Figure 21. Final Output

After implementing the proposed system we get the output as a result where first figure shows that the parameter when the lithium battery is not connected and next figure shows that the parameter when the battery is connected . Temperature is the battery temperature where the voltage is 3 because we used 3.7-volt batteries and current is 9.65 ampere hour and the temperature is 28.70 Degree Celsius and SOC is 100 percent

CHAPTER 11

CONCLUSION

CHAPTER 11

CONCLUSION

BMS is a Necessary thing for the safety of batteries. The battery management system (BMS) is responsible for the accurate monitoring of critical parameters such as the battery pack state of charge (SOC). The various parameter should be studied for the BMS of Electric vehicles. Our proposed system is implemented successfully for the Electric vehicle by using extended Kalman filter. we get 100% SOC for the lithium-ion batteries. The parameter like the voltage was found to be 3 and the current detect is 9.65 ampere and the temperature is 34.70

In this work, we presented the extended Kalman filter for SOC estimation of li-ion battery, which is an important key in the efficient management of energy and battery power. Experiment tests have been conducted on a li-ion battery 3.7V/2.6Ah to get the discharge characteristics in real conditions. Followed by EKF design for SOC estimation. The results of the MATLAB model and implementation led to the conclusion that EKF provides accurate SOC estimation and errors rejection, and due to its robustness against the uncertainty of initial SOC, it can be concluded that EKF is suitable for SOC estimation of an electric vehicle li-ion battery.

CHAPTER 12

REFERENCES

REFERENCES

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