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Automatic Health Monitoring and Optimizing of Lithium-ion Battery in E-Vehicle

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ABSTRACT - This paper is working based on the concept of BMS. 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 lifetime. For this purpose, many monitoring techniques are used to monitor the battery state of charge, temperature and current. In the current paper, the monitoring system for battery powered Electric Vehicles (EV) has been implemented and tested. This system evaluates and displays the battery temperature/humidity, charging/discharging current and State Of Charge (SOC) for the considered model battery. For monitoring purpose, digital and analog sensors with microcontrollers are used. The project consists of two working blocks namely Mother-board and Dash-board. Wirelessly connected between these two blocks using Bluetooth 2.0. The battery information and the obtained results explaining the main characteristics of the system are presented by the LCD screen at Dash-board. A typical fan is used to cooling the battery while battery heat increased. However, BMS on the market is very expensive and not suitable for low-cost embedded systems. As the Arduino Uno R3 is widely used for low-cost microcontroller boards, easy programming environment, and open-source platforms for building electronic projects, therefore, this study focuses on Arduino Uno BMS based system. This system consists of current and voltage sensors, two Arduino Uno microcontroller, two Bluetooth modules, GSM module and an I^2C liquid crystal display (LCD). In order to develop this system, there are three objectives to be achieved. First, the relationship between input and output of the sensors must be derived mathematically. The mathematical expression obtained can be verified by connecting and disconnecting the circuit with load and monitoring the value of output sensors. The health status of the battery will be sending to Vehicle owner as SMS through a GSM module.

Key words:Battery Management System (BMS), Electric Vehicles (EV), State-of-Charge (SOC), Mother-board, Dash-board, Bluetooth 2.0, I^2C(Inter-Integrated Circuit),GSM.

I. INTRODUCTION

Environmental issues triggered by emissions from conventional vehicles have accelerated the adaptation of electric vehicles (EVs) for urban transportation. The most favorable battery technology which can closely fulfill the minimum goals of the United States Advanced Battery Consortium (USABC) for commercialization of EVs are the lithium-ion batteries. Although there are various types of lithium-ion batteries have been widely used to power the EVs, the performance characteristics of these batteries are not clearly specified in a more comparable way. A BMS (Battery Management System) is essential in a Lithium-Ion battery system. This device manages a real-time control of each battery cell, communicates with external devices, manages SOC calculation, measures temperature and voltage, etc.. In order to achieve real-time monitoring of battery status, prevent overcharging and over discharging of batteries, and prolong battery life. Beneficial to improve the utilization rate of the battery, the

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battery management system has become the focus of technology research and development in the battery industry. Working demo of this project incorporate with two ARDUINO UNO development boards and Bluetooth modules.

1.1.EXISTING SYSTEM

All the battery health conditions were monitoring separately. Voltage of the battery, Charging/discharging current are monitored using anlog/digital meters. No analysis or calculation employed. While measuring temperature on battery, it is an electrode material, electrolyte activity is greatly affected by temperature, practical engineering also to battery shell or plate temperature measurement, often used for lead-acid battery temperature measurement methods.

1.2.PROPOSED SYSTEM

"Automatic health monitoring and optimizing of Li-ion battery in e-vehicle" is a project based on the functions of Battery Management Systems (BMS). BMS deals with battery packs that are connected internally or externally. It calculates the battery quantities, with typical measurements performed for cell voltages, pack current, pack voltage, and pack temperature. BMS uses these measurements to estimate state of charge (SOC), state of health (SOH), depth of discharge (DOD), and the operational key parameters of the cells/battery packs. The measurements also help to increase battery life and keep pace with the demand requirements of the original power network. The main part of the proposed project is a Microcontroller ATmega328P with ARDUINO UNO R3 development board. Fig 1.1 explains the functions of a BMS.

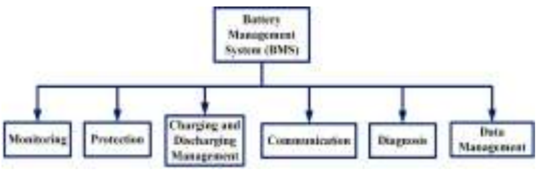

Fig1.1: BMS functions

All the BMS functions are carried out through this controller only. The project consists of two working blocks (Fig 1.2) are Mother-board and Dash-board. Wirelessly connected between these two blocks using Bluetooth 2.0. The battery information and the obtained results explaining the main characteristics of the system are presented by the LCD screen at Dash-board. A typical fan is used to cooling the battery while battery heat increased. Four 3.7V Li-ion battery in series providing 14.8V is charging through a current sensor circuit. Charging from a 15V charger circuit is turned on/off by a relay switching control. Another relay switching control is used to prevent from overload/short circuit. 0.1Ω/5W resistors are used to sense current while charging or discharging. Voltage drop across the resistors are in the range of mV only. Level shifting dc amplifiers will convert this mV into 0-5V necessary for ARDUINO inputs. Comparator circuits are also used to detect proper charging/discharging voltages or currents. The health status of the battery will be displayed always in an LCD also sending low battery or error message to the Vehicle owner as SMS through a GSM module. A regulated 5V dc dual power supply is used for op-amps used in sensor circuits.

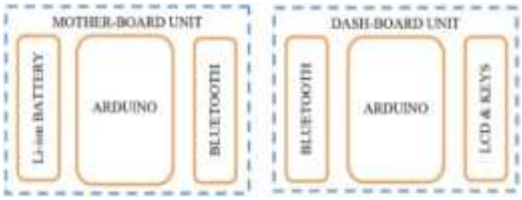

Fig1.2: Major functional blocks of the project

II. BLOCK DIAGRAM

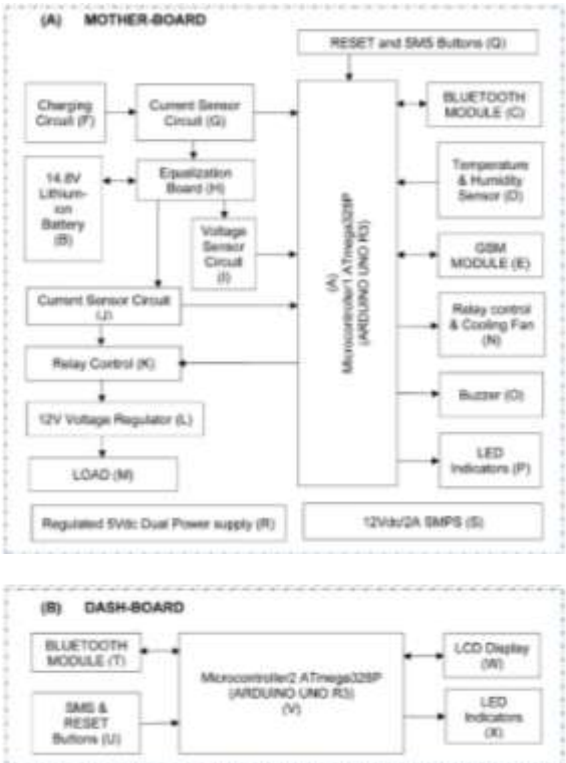

Figure 2: Block diagram of Automatic health monitoring and optimizing of Lithium-ion battery in e-vehicle

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III. EXPERIMENTAL SETUP

3.1.Configure and pair two HC-05 Bluetooth Modules as Master and Slave devices

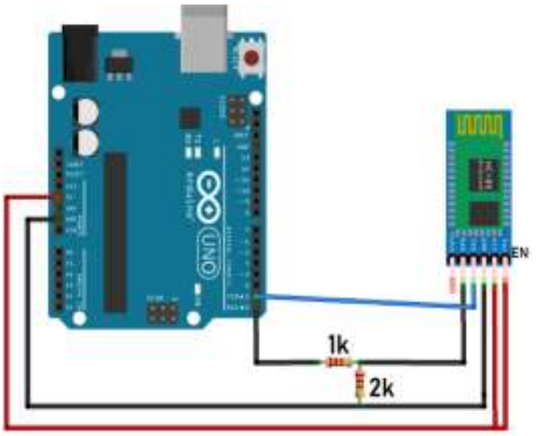

Fig. 3.1 Connection for configure and pair two HC-05 Bluetooth Modules as Master and Slave devices

How to get to AT COMMAND mode

1: Connect KEY pin to VCC.
2: Supply power to module. Then the module will enter into AT MODE. In this
mode you have to use baud rate at 38400. In this way, user should change
the baud rate for SLAVE AND MASTER mode.

How to set this module as "Master- Host" role

1: Input high level to KEY.
2: Supply power to the module. And the module will enter to AT COMMAND.
3: Set the parameters of the hyper terminal or the other serial tools (baud rate: 38400, data bit:8, stop bit:1, no parity bit, no Flow Control).
4: Sent the characters "AT+ROLE=1\r\n" through serial, then receive the characters "OK\r\n". Here, "\r\n" is the CRLF.
5: Sent the characters "AT+CMODE=1\r\n" through serial, then receive the characters "OK\r\n". Here, "\r\n" is the CRLF.
6: Default factory password passkey is: 1243, this must be the same in the Bluetooth slave module if you want to pair it. To read passkey use this command: "AT+PSWD?".
To Reset the password command sent the characters "AT+PSWD=XXXX".
The password must be 4- bits.
7: Leave free KEY, and supply power to the module again. Then this module will become master role and search the other module (slave role) automatically to build the connection (baud rate:9600, data bit:8, stop bit:1, no parity bit, no Flow Control).

How to set this module be the "Slave- Device" role

1: Input high level to KEY.
2: Supply power to the module. And the module will enter to AT COMMAND.
3: Set the parameters of the super terminal or the other serial tools (baud rate:
38400, data bit:8, stop bit:1, no parity bit, no Flow Control).
4: Sent the characters "AT+ROLE=0\r\n" through serial, then receive the characters "OK\r\n". Here, "\r\n" is the CRLF.
5: Sent the characters "AT+CMODE=0\r\n" through serial, then receive the characters "OK\r\n". Here, "\r\n" is the CRLF.
6: Default factory password passkey is: 1243, this must be the same in the Bluetooth master module if you want to pair it. To read passkey sent the characters "AT+PSWD?".
To Reset the password command sent the characters "AT+PSWD=XXXX".
The password must be 4- bits.
7: Leave free KEY, and supply power to the module again. Then this module will become slave role and wait to be discover it by the other module (master role) automatically to build the connection (baud rate:38400, data bit:8, stop bit:1, no parity bit, no Flow Control).

3.2. Charging Current (Ic) sensing

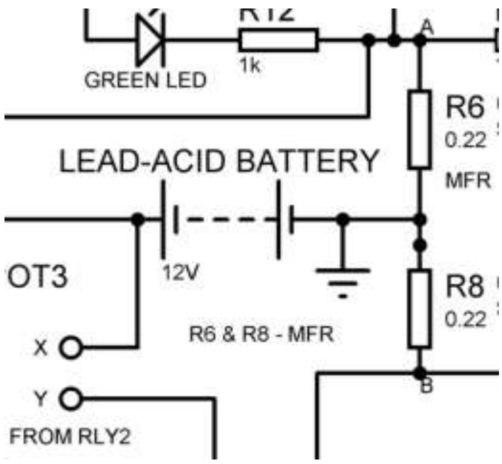

Fig 3.2. Charging Current sensor circuit

A -ve voltage developed across R6 at the point A while charging. An inverting amplifier will amplify this 100mV(max) signal into 5V(max) send to Arduino analog input (A3) of Arduino. ADC inside Arduino will convert this voltage into proper display. If Ic greater than 700mA, an over current alert display, Buzzer on and sms will send.

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3.3. Load Current (IL) sensing

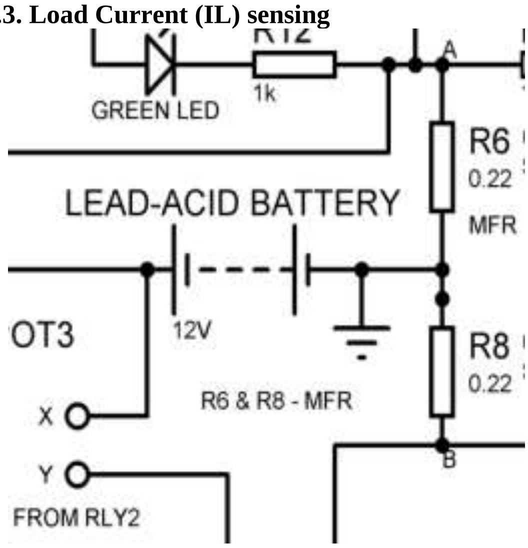

Fig 3.3. Load Current sensor circuit

A +ve voltage developed across R8 at the point B while charging. An inverting amplifier will amplify this 100mV(max) signal into 5V(max) send to Arduino analog input (A2) of Arduino. ADC inside Arduino will convert this voltage into proper display. If IL greater than 1000mA, an over current alert display and sms will execute and buzzer be on, load relay will disconnect battery from load.

3.4. Battery voltage sensing

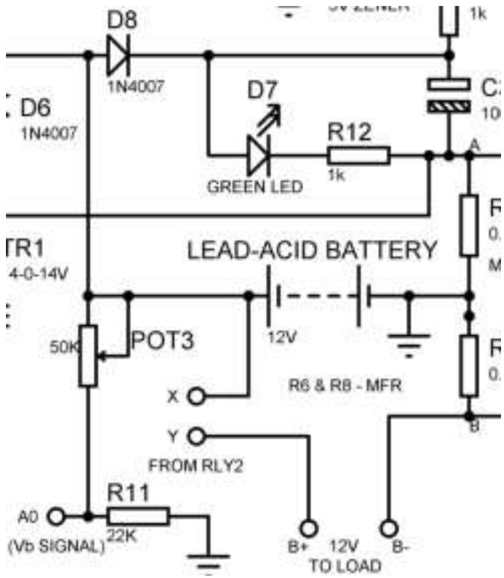

Fig 3.4. Voltage sensor circuit

The Vb sensor voltage is connected to the analog input A0 of Arduino. The POT3 is adjusted to calibrate output as 5V for input 14V.

Vb = Vin (R11/(R11+POT3)).

ADC inside Arduino will convert this voltage into proper display.

3.5. Analog to digital conversion

Input volage of ADC is 0-5V.The instruction analogRead() is used for ADC

o/p = analogRead(pin)* (5.0/1024).

For sensing current and voltages, this method is using.

IV. HARDWARE SETUP

The hardware set up is shown in figure 6.1 and 6.2. When the power supply is swiched 'ON' , all the sensors will get activated and controlled by arduino.They will start detecting. The arduino program runs and the measured data from the sensors are fed as input to the Start detecting controller. The sensors that are used mainly for blockage detection are the charging current, load current, battery voltage, temperature and Humidity.

Figure 4.1 Hardware setup:Mother-board

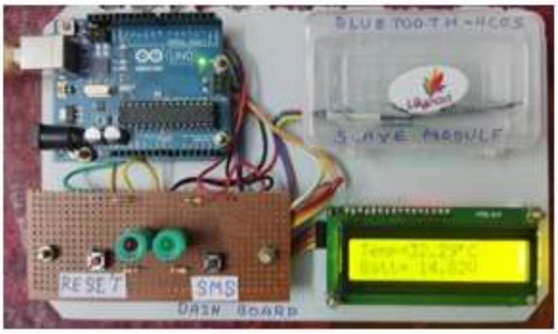

Figure 4.2 Hardware setup: Dash-board with LCD Output

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V. ENABLE GSM MODULE BY A SWITCH

Fig 6.4 SMS enable switch

This switch can operate only before switch ON the power supply. If you need to change the switch followed by press reset button in motherboard. If the switch is on, sms will enable but the buttons in dashboard will not working.

5.Sketch uploading

Figure 6.3 sketch done -Arduino IDE 2.0.1

VI. RESULTS

Starting with switch on the power supply, Bluetooth between Mother-board and Dash-board paired automatically. The battery voltage(Vb) and temperature(t) displayed on LCD. A 3.7V/2200mAh four battery battery is used for this project. So the total voltage id 14.8V. While pressing button1, LCD displays SMS sending and charging/discharging status. Both Mother-board and Dash-board provided buttons for RESET and SMS. The same time GSM will send SMS to a particular number to all the health status of the battery. If the battery voltage falls 12 volts up to 4 volts, the low battery information displayed on LCD also sent SMS. If the battery voltage greater than 16.9 volts, full battery status displayed on LCD. If the battery voltage less than 4 voltage, that means battery is damaged or disconnected. The information will be displayed in LCD. This message also sent as SMS. If the charging current greater than or equal to 700 milliampere, the overcharging information given as SMS. If load current is greater than 1 ampere it indicates overload message and relay cut off the load until reset button pressed. If the temperature greater than 32-degree Celsius, cooling fan will switched on. If it is falls 34-degree Celsius, fan will switched off. If the temperature greater than 48 degrees Celsius, the over temperature status is sending as SMS also buzzer on. Every unsatisfactory condition, buzzer will switched on. If reset button pressed, load relay switched off, fan and buzzer also switch off. All the input and output voltages are verified as per the circuit diagram and logic with the help of a multimeter.

VII. CONCLUSION

This project is a low-cost project using two Arduino uno R3 circuitry with Li-ion battery. Compared to lead-acid and other lithium batteries, lithium iron phosphate batteries offer significant advantages, including improved discharge and charge efficiency, longer life span and the ability to deep cycle while maintaining power for EV purpose. The Li-ion battery as the modern industrial production and life, modern battlefield necessary backup energy, its status and performance management directly affect the efficiency of industrial production, the trend of the battlefield, this paper summarizes the application on the outside of the battery management system of battery parameters testing method and the characteristics of different types of Li-ion battery management system, and discussed the future development of battery management system. Although not necessarily an advantage or disadvantage, it is probably worth mentioning that Li-ion batteries should be stored in a cool place. This slows the ageing process of lithium-ion (and other chemistries). Manufacturers recommend storage temperatures of around 15°C. In addition, the battery should be partially charged during storage. Manufacturers typically recommend a charge level of around 40% to 50%.

The main advantage of the project is to monitor health status of the battery will be sending through SMS. Also a Bluetooth data communication is used to transfer data between Mother-Board and Dash-Board for LCD and buttons for EVs. It operates in the 2.45GHz range. Data can be transferred at a rate of up to 1Mbps over a distance of ten meters.

7.1. FUTURE MODIFICATION AND SCOPE

In future this project can be improved to sort more categories of applications.

- Instead of Li-ion battery, upgrade to Li-Po, Solid-state batteries, Nickel-Metal Hydride Batteries, and Ultracapacitors. Conventional current and voltage sensors can be replaced by digital sensors. Here we used a basic version of Bluetooth module for this project. So one byte data only can send at a time. New version of Bluetooth modules can solve this issue.

- Here using three serial devices are connected with Arduino uno R3. It will restrict for two serial devices accurately. This issue already solved by implementing a 'GSM enable switch' at Mother-board. If the switch is on, the duplex communication of Dash-board Arduino will be disturbed. This kind of multiple serial devices interfacing can be achieved by using higher version of microcontrollers/development boards.
- The measuring range of Temperature and Humidity can be increased using selected sensors. Eg. DHT22 is better than DHT11.
- Another future modification is, it can implement 'SMS status replay' for request SMS.
- The status can be monitored in the dash board of the vehicle or in a mobile phone as wirelessly.
- The SMD components will reduce the size of the whole circuitry.
- Use of RTOS, the charging and discharging time can be determined to find out battery health condition exactly.
- It can be integrated with IoT features.
- New kind of batteries, new methods of BMS will enhance the life and perfection of the EV battery.

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