Battery Management System Using Relay Contactor by Arduino Controller for Lithium-ion Battery

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Abstract: Currently, almost every lithium-ion used in many electronic products has new capabilities. When the battery's capacity is too large or insufficient, the battery's performance will be damaged. A battery management system (BMS) is currently order from China and other countries. This is expensive, thousands of, and cannot be modified. This research aims to design and develop an NMC18650 lithium-ion battery used in the battery management system (BMS) 3 cells of 12 V_{dc} can provide the highest circuit of 2000 mAh as a microcontroller to program according to the configuration of researchers. In this study, the discharge test's effect was 0.5A. The results show that the critical point decreases at 2.8 V_{dc} This battery management system will lower the discharge voltage of any battery by 3 V_{dc} To prevent danger from occurring in the battery.

Keywords: Battery Management System, Lithium-ion batteries, Arduino Controller, Relay Contactor.
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1. Introduction

Lithium-ion batteries (LIBs) are widely used. There is a strong power supply. Moreover, stable all the time and can be recharged into a new charge (SoC). Long service life. It is environmentally friendly and can store more energy than other types of batteries in both mass (gravimetric energy density) and volumetric energy density (volumetric energy density). Light weight makes it convenient, as shown in Figure 1, so it has many applications with electrical appliances. That need to be charged, such as batteries of mobile phones, digital cameras, electric bicycles, laptops, and medical equipment, including the application of LIBs to electric vehicles (EV) [1] to power vehicles such as the Tesla electric car, the Honda e: HEVs, for example, by LIBs are based on electrochemical principles when charged, lithium ions move out of the anode structure through the semipermeable membrane into the cathode, forming a compound of lithium and carbon. Furthermore, at the same time, electrons will move from the positive to the cathode through the external circuit. Furthermore, the reaction occurs in the opposite direction at the discharge time. The process by which lithium ions are inserted into the anode or cathode material is called lithium intercalation.

Therefore, the voltage imbalance between batteries may be caused by various factors, such as the change of use environment, lifetime, and voltage imbalance between cells.

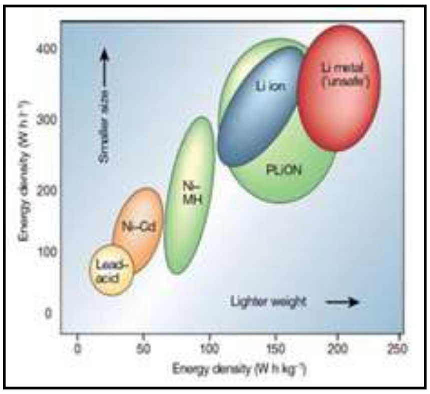


Fig. 1. The ability to store electrical energy from different types of batteries [2].

Therefore, a battery management system (BMS) is used in conjunction with a small control system. (Microcontroller) to control the system's operation and can program to configure various conditions (Condition), which can be applied in various applications, as well as program commands to control the Input / Output pins. In this research, we choose Arduino UNO R3, which can receive both Analog and Digital [3] and can be commanded to control various devices connected to the circuit with Arduino. It is also cheap and easy to buy.

2. Literature Review

2.1 Principle of Lithium-ion battery

Lithium-ion batteries operate based on the electrochemical principle. The electrical energy that we charge causes a chemical reaction inside the battery. Chemical reaction forces the lithium ions to flow out of the structure of the cathode material. Then flows through the electrolyte, then through the separator, and intercalate is in the structure of the anode material. This reaction causes the cathode materials such as LiMO2, LiM2O4, and LiMPO4 and the anode materials such as C, Sn, and Si to become unstable. While in use is discharge, chemical reactions in the battery can occur as Spontaneous reactions. In other words, lithium ions flow out of the structure of the cathode material. They are, moreover, inserted into the anode terminal. It flows out of the anode material structure and into the original cathode material structure, re-stabilizing the system and allowing electrons to pass through the electric circuit, where electrons flow through the current metal collector and output electrical energy. Whenever all the lithium ions flow back to their original state, the reaction will either end or run out of charcoal. Which the battery is used, it must be charged again, which continues until the battery is depleted and the life of that battery type is reached.

In general, each type of battery has different discharge characteristics. As can be seen, lithium-ion batteries have a higher voltage than other types of batteries. It depends on how to look at the green line as shown in Figure 2 with voltage. The maximum power is about $4.2V_{dc}$. Then when the load is connected to the battery, there will be a slight decrease in voltage and gradually decreases according to the duration of the current consumption of the load that is used to a particular value; it will cut off. The work point is called the cutoff point about $3V_{dc}$. In this research, a lithium-ion battery type NMC was selected. The material used for the cathode is nickel manganese cobalt, and the anode is silicon because it has a long life, provides more voltage than other types of batteries, and is lightweight. In addition, be easy to carry and suitable for experiments or research, which can be used as a prototype in the future and can increase the voltage even more.

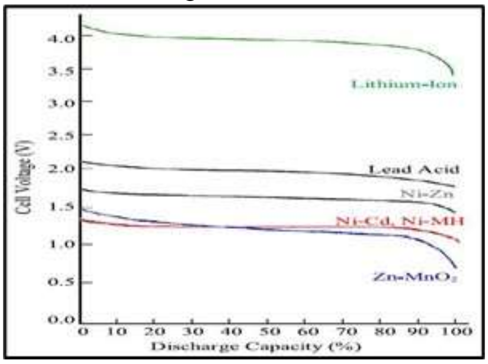


Fig. 2. Discharge characteristics of Li-ion, lead acid, Ni-Zn, NiCd, NiMH and Zn-MnO2 cells. [4]

2.2 Lithium-ion battery components

Lithium-ion batteries have four main components [5], as shown in Figure 3.

1) The electrode consists of the cathode and the anode.

2) The separator prevents the cathode from coming into contact with the anode terminal until a short circuit occurs.

3) electrolyte (Electrolyte) is a solution of lithium salts, which acts as a conductor that allows ions to flow but does not allow electrons to pass through. Therefore, it is a good ionic conductor. But it is a bad electronic conductor.

4) Current collector is the part of the conductor metal that allows electrons to flow through the external circuit and lead to the use of electrical energy such as copper (Cu), aluminum (Al), etc.

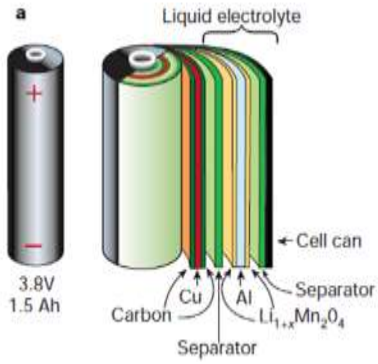
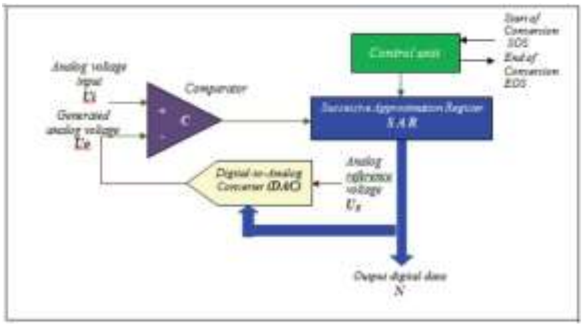


Fig. 3. Lithium-ion battery components [2]



2.3 Analog read for Arduino

For the Arduino board, the Analog output channel has a resolution (Resolution) at 10 bits, which means 2^{10} = 1024 level. It can accept Analog to Digital Converter (ADC) input voltage. The maximum value is VCC or $5V_{dc}$ ADC can be calculated from Equation 1

(1)

Where U_i is analog voltage input and U_0 is Ground voltage input. The Arduino board will accept both voltage values and process them through Comparator, as shown in Figure 4, and output them as Digital data enter the computer.

Fig. 4. Block diagram of analog to digital conversion [6]

3. Methodology

3.1 Equipment

The experiment used all equipment following as.

1) Lithium-ion batteries type NMC18650
2) Arduino UNO R3 Board.
3) Magnetic Relay 7 pcs.
4) Load spec 500 mAh.
5) Imax B6 80W digital charger

3.2 Prepare equipment

1) The NMC18650 lithium-ion battery was assembled by first connecting two batteries in parallel and then using spot welding to connect the nickel to the positive and negative terminals of the LIBs, as shown in Figure 7, to obtain three cells to increase the current.

2) Serialize all three battery cells to increase the battery voltage to $12V_{dc}$

Fig. 7. The battery pack has a capacity of $12V_{dc}$

3) Charge this battery pack and balance each cell's voltage with the Imax B6 80W digital charger. Then measure the voltage on the battery pack with a digital multimeter, and the total voltage is $12V_{dc}$. All three cells' voltage is $4V_{dc}$.

4) Connect the experimental circuit as shown in Figure 8.

5) Discharge of the battery by using a digital charger Imax B6 80W to find the current that the battery dissipates equally to 2000 mAh

6) Install all seven magnetic relays and connect the circuit to connect. With Arduino board by using a breadboard to help connect the electricity to flow fully, as shown in Figure 8.

7) Connect a lithium-ion battery to supply power. And then connect a 0.5A load.

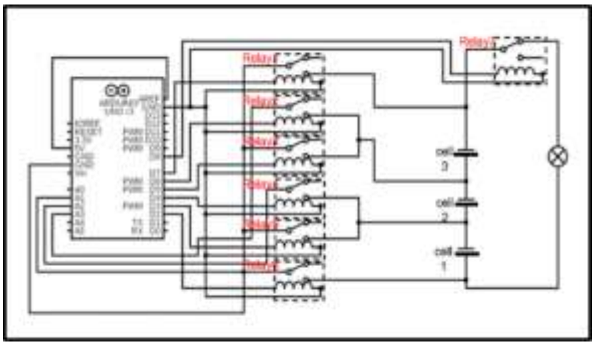


Fig. 8. The experiment circuit.

3.3 Experimental design

The experiment tries to determine the critical voltage of lithium-ion batteries. First, connecting a 0.5A lamp device to the battery pack discharges its electricity to the point where one of the battery cells has a dramatic voltage drop. Then, all the recorded voltage values plot to show the theoretical trend, as shown in Figure 2.

From figure 9, found that the second cell battery has a critical voltage of $2.8V_{dc}$. Battery usage Therefore set the cut-off point of the discharge circuit at $3V_{dc}$

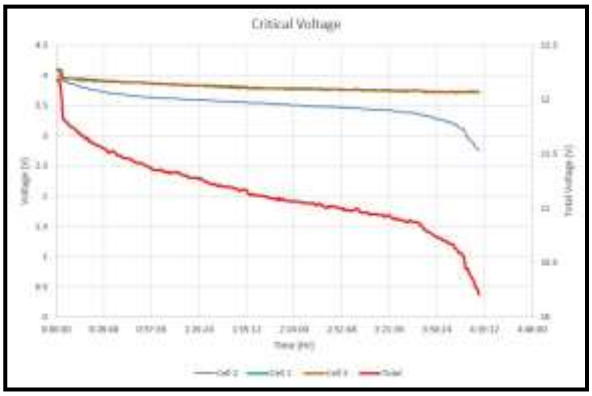


Fig. 9. Test the battery to discharge to determine the critical voltage.

3.4 The battery management system test

The researchers are Testing the battery management system by defining various conditions, as shown in Figure 10, to stop discharging to the load. Connecting a lithium-ion battery to a 1600 mAh load, the voltage measured from the battery's three cells is logged every minute.

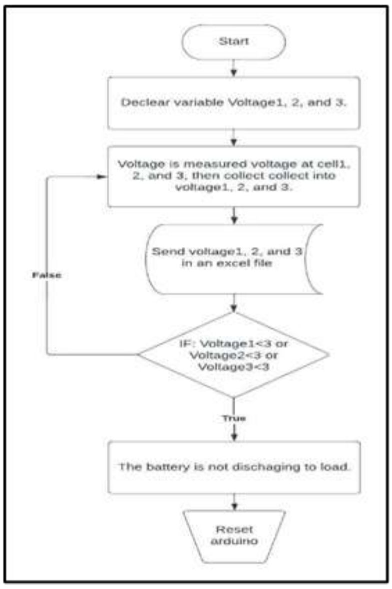


Fig. 10. BMS Program Operation Diagram.

4. Experimental Result

Voltage critical point from connecting the 0.5A load and letting the battery discharge from Figure 11, the voltage of each cell from $4V_{dc}$ will gradually decrease. The second battery has a voltage drop faster than the other cells, indicating that the second cell has lower battery health than the others. After the voltage is $3V_{dc}$, the second cell battery has a lower voltage drop. Rapidly, while cells 1 and 3 tended towards the same direction. The battery's total voltage is the yellow line with a starting voltage of $12.0V_{dc}$. When discharged, the voltage drops to a critical point of $10.7V_{dc}$. In testing, it found that the battery management system can cut the discharge from the battery to load according to user-defined conditions to prevent damage to the battery.

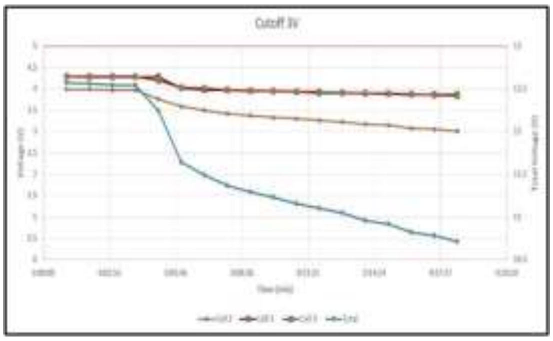


Fig. 11. BMS Program Operation Diagram.

5. Conclusion

This research aims to design and develop the NMC 18650 lithium-ion battery used in a 3-cell $12V_{dc}$ Battery Management System (BMS) capable of providing a maximum capacity of 2000 mAh. The experiment used a microcontroller For the user to set the voltage rating to stop the battery discharge. The results of the discharge test to a 0.5A load showed that this battery pack has a critical point of $2.8V_{dc}$, so this battery management system will not discharge to the load at any cell voltage below $3V_{dc}$ to prevent harm to the battery. Furthermore, the battery management system (BMS) can modify various program configurations and be researched and applied to batteries with higher voltages, such as $24V_{dc}$, $48V_{dc}$, $72V_{dc}$, Etc, making them applicable to a wide range of electrical equipment.

Acknowledgment

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