Research on High Precision Lithium Battery Management System

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Abstract: Lithium battery has been used more and more in recent years due to its excellent performance such as high energy, high voltage, long service life, low self-discharge rate, environmental protection and so on. However, lithium battery also has the disadvantages of poor safety performance, complex protection circuit, high cost, etc. The high-precision lithium ion battery management system (BMS) is proposed to solve the charging and discharging protection problem of multiple lithium batteries. In order to solve this problem, we have designed a set of high-precision lithium battery management system by pulse width modulation based on previous studies.

1. Introduction
This system uses STM32F103ZET6 single chip microcomputer as the controller of the whole system, and uses PWM pulse output by the single chip microcomputer to control the switching of FET to indirectly control the charging and discharging voltage and current of lithium battery. When the battery voltage is lower than 3.7V, the charging voltage is controlled at about 4.2V, enabling the battery to charge quickly. When the voltage is higher than 3.7V, reduce the charging voltage to about 4.0V and gradually increase to 4.2V until the battery is full, alarm and close the charging switch. Electric resistance wires are used for discharging, and the discharge voltage difference between single batteries is controlled not to exceed a limited value. In addition, when overvoltage, overcurrent and undervoltage are detected, the charging and discharging process of the battery pack is fine-tuned by adjusting the charging voltage. When the battery temperature is too high, the system will give an audible and visual alarm and automatically cut off the power supply. The system also has protection circuits such as short circuit and anti-reverse connection. The system also uses serial port screen to display voltage, temperature and other information to realize data visualization.

2. The Background and Significance of the Works
In recent years, the rapid development of electric vehicles and various portable electronic products has promoted the upgrading of battery technology. Lithium-ion batteries are gradually favored by people for their advantages of high energy density, long service life, small self-discharge, no memory effect and high voltage of a single battery, and are beginning to be applied in more industries.

However, in some industries, the 3.7V voltage of a single lithium battery often cannot meet the needs of the industry. Therefore, in order to obtain higher voltage, people often connect multiple lithium batteries in series, which can provide higher voltage. However, when several lithium batteries are connected in series, it is necessary to install protective circuits in lithium batteries because the lithium batteries themselves are in danger of fire and discharge caused by overcharge. In the process of battery charging and discharging, precise voltage and current management can give full play to the maximum performance of lithium batteries. Lithium battery management system (BMS), as an
electronic component of real-time monitoring, automatic equalization and intelligent charging and discharging, can effectively protect lithium batteries.

In recent years, there have been more researches on lithium battery management systems at home and abroad, such as the lithium iron phosphate battery system designed by Shenzhen ou sai technology co., ltd. and the series of intelligent BMS control systems such as BMS24 and BMS16 designed by Shenzhen Chargery. Foreign countries such as JK Hall's lithium battery and Pak Trakr monitor, and Stack V1, Cage V2, Mini V3 and other lithium battery management systems produced by Black Sheep Technology. These companies have relatively mature research on the management system of lithium ion batteries. Many products have reached the level of mass production, but their selling prices are relatively expensive, and it is difficult to improve products according to different requirements. Based on this, we have designed a lithium ion management system with low cost and wider application range. Our lithium battery management system mainly has the following functions.

1. Sampling detection and equalization control of at least 10 lithium batteries can be realized at the same time with certain expansion capability.
2. Ensure that the voltage difference between the highest cell voltage and the lowest cell voltage is controlled within 60mv at any time of lithium battery charging and discharging.
3. It has the functions of battery safety management and early warning.
4. Visualization of key parameters (voltage, temperature) of the battery realizes the capability of human-computer interaction.
5. The overall cost of the system is relatively low and the application range is wide.

3. Difficulties and Innovation in Works

Abuse of lithium-ion batteries will shorten their life, cause battery damage, and even cause safety problems in serious cases. The main difficulties in the implementation of Li-ion battery management system include the following aspects:

1. Large-scale batteries consisting of a large number of single batteries in series are more likely to be overcharged and over-discharged due to the unbalanced voltage of internal single batteries. Overcharge and overdischarge of lithium battery will cause irreversible losses.
2. Compared with other chemical batteries, lithium ion batteries are more difficult to tolerate battery abuse.
3. Li-ion battery cannot handle the overshoot problem well by itself. Once the battery is fully charged, the lithium ion battery can not continue to absorb current like other unfilled batteries connected in series with it. On the contrary, the voltage of the battery will increase rapidly, possibly reaching a dangerous level.
4. In the process of lithium ion battery discharge, each unit cell will be unbalanced, and one unit cell will first reach the full discharge state and then reach the overdischarge state. Li-ion battery cannot handle the problem of over-discharge well. Once over-discharge occurs, it will cause irreversible damage to the battery.

4. Main Scheme Demonstration and Design

4.1 Voltage Balancing of Lithium Battery Charging and Discharging Circuit by PWM Control Field Effect Transistor

FET has the advantages of high input resistance (10–10Ω), low noise, low power consumption, large dynamic range, easy integration, no secondary breakdown phenomenon, wide safe working area, etc. Through PWM pulse, the output voltage of FET can be conveniently controlled, and the charging and discharging voltages can be accurately controlled in real time by adjusting different PWM duty ratios, thus dynamically adjusting the equalization of the charging and discharging voltages of each battery. Using PWM to control FET to balance the voltage of charging and discharging circuits has the following advantages:

1. Through PWM, the charge and discharge voltage can be controlled and output more accurately,
and the balanced control of the voltage can be realized faster;

(2) The charging and discharging voltage of the battery can be adjusted in real time according to the voltage of the battery, the charging current can be indirectly controlled, and the battery voltage can be brought closer to the rated voltage faster. Then, the charging voltage is reduced to realize slow charging and effective protection of the battery pack in the process of charging and discharging.

(3) The whole system mainly controls the voltage through software, which can avoid using more hardware circuits and improve the safety and reliability of the whole system.

(4) Compared with using chips to adjust the charging and discharging voltages evenly, the overall cost of the system is lower and is more suitable for commercial production.

5. Principle Analysis and Hardware Circuit Diagram

5.1 General Circuit Schematic Diagram and Its Analysis
This system mainly includes the following parts:

(1) Charging power supply: We use a 42V power charger as the charging power supply for the whole system. It reduces and rectifies 220V AC power to 42V DC power through a transformer, which can be used as the charging power supply for batteries.

(2) Discharge: In this system, we use the electric heating wire to discharge the battery. During the discharge process, the electric heating wire will emit relatively large amount of heat, which can achieve the purpose of rapid discharge.

(3) main controller: the system uses STM32F103ZET6 single chip microcomputer as the main controller of the whole system. the system mainly uses its I/O, PWM output, timer, serial communication, AD conversion and other functions to control the system.

(4) Display: A 3.2-inch serial port screen is used in the system to monitor and display the voltage and temperature of the charging and discharging batteries, thus realizing the function of human-computer interaction.

(5) Voltage equalization of charging and discharging circuits: The system uses 9 FET to reduce the power supply voltage one by one so that the adjacent voltage difference is 4.2V to charge each battery to achieve the purpose of equalizing the charging voltage. In addition, by adding a field effect transistor, excess electric quantity can be stored during charging, thus ensuring that the charging electric quantity is not too high and playing a certain role in protecting the charging and discharging voltage of the whole circuit.

(6) Charge and discharge protection circuit: Charge and discharge protection in this system is mainly realized by software. The main controller can realize the detection of charge and discharge battery voltage through AD, and adjust the voltage output by FET by PWM output according to different battery voltage values. If the battery voltage or current is too low, the charging voltage will be increased; if the battery voltage or current is too high, the charging voltage will be reduced until the voltage of each battery reaches equilibrium. After the battery is full, turn off the switch and stop charging.

(7) Voltage detection circuit: LM324 is selected as the operational amplifier chip in the system, and the subtractor is composed of peripheral circuits. LM324 is a four-op amplifier with a true differential input and has a true differential input. It connects the output of the LM324 operational amplifier chip with the I/O port of the single chip microcomputer, thus completing the battery voltage monitoring.

5.2 Principle Analysis of Pulse Voltage Regulation Equalization Circuit
The voltage equalization circuit of this system uses PWM pulse width modulation technology. PWM drives 9 field effect transistors to divide the 42V charging voltage into 10 voltages with gradually decreasing voltages. The difference between every two voltages is about 4.2V as the charging voltage of 10 lithium ion batteries. In addition, a field effect transistor is added to store part of redundant voltage during charging and discharging. Some circuit diagrams are shown in Figure 1.
6. Analysis of Main Technical Indicators

According to the system design requirements, the system we designed mainly met the following technical requirements:

1. The system can meet the requirements of sampling detection and equalization control for 10 lithium batteries, and has scalability, which can be theoretically applied to management systems for more lithium batteries.

2. When the lithium battery voltage is low, the lithium battery charge we tested is that the voltage error between the highest cell voltage and the lowest cell voltage is within 100mv. When the voltage rises to about 3.8V, the voltage error between the highest monomer voltage and the lowest monomer voltage can be controlled within the required 60mv error.

3. The safety management of batteries in this system mainly includes the management of over voltage, over current, under voltage, under current and battery temperature. When danger occurs, we set up an audible and visual alarm function.

4. The acquisition accuracy of battery voltage and temperature in this system is 1mv and 0.1℃ respectively.

Due to time constraints, the power consumption of this system has not been tested yet, and further tests and improvements are needed.

7. System Testing and Error Analysis

The charging power supply of this system adopts a +42V stabilized power supply with current limiting function. The lithium battery model adopted is TR18650. The specific parameters are as follows:
Rated voltage | Capacity | Internal resistance | Upper limit voltage | Lower limit voltage
---|---|---|---|---
3.7V | 1300mAH | <40mΩ | 4.2V | 2.75V

Charging data of lithium battery pack after discharge are as follows:

| Charging time (min) | Voltage (v) | Charging time (min) | Voltage (v) |
|---|---|---|---|
| 0 | 30.42 | 320 | 39.42 |
| 40 | 31.91 | 360 | 39.84 |
| 80 | 33.41 | 400 | 40.07 |
| 120 | 34.89 | 440 | 40.36 |
| 160 | 36.37 | 480 | 40.55 |
| 200 | 37.86 | 520 | 40.88 |
| 240 | 38.65 | 560 | 41.07 |
| 280 | 39.12 | 600 | 41.21 |

From the above experimental results, it can be seen that there are certain errors in the data measured by the system. The main reason is that there is a certain error in the voltage. Theoretically, the voltage of the lithium battery pack should be the same as that of the external power supply, and eventually reach 42V. However, due to errors, the voltage of lithium battery pack is slightly lower.

8. Conclusion

The main innovation of this system is to maintain the voltage balance between charge and discharge of lithium ion batteries by software design. It not only saves the cost of the product greatly, but also has higher precision and stronger stability than the traditional lithium ion battery management system. The charge and discharge protection part also uses software to adjust the charge voltage according to the collected voltage and current. In this way, the voltage difference between single batteries can be guaranteed to be minimum, the charging voltage can be dynamically adjusted in real time, the intelligent regulation of charging voltage and current can be realized, and the loss of battery charging and discharging can be reduced to the minimum. In general, this system provides an innovative solution to the management system of high-precision lithium batteries, which has certain realizability and popularity.

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