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RESEARCH ARTICLE

DESIGN OF LITHIUM BATTERY CONTROL SYSTEM BASED ON SINGLE CHIP MICROCOMPUTER

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ABSTRACT

Charging and discharging of lithium batteries and their safety performance are one of the key indicators to determine their working ability. The state monitoring system of lithium battery pack designed in this paper not only fully meets the requirements of production, but also fully reflects the characteristics of reliability and cost-effective ratio. The system is based on single chip computer control, and fully considers charge and discharge signal monitoring, temperature signal monitoring, discharge maintenance and charge equalization in the design. In addition, the system can also realize voltage and current overload protection during battery charging and discharging, short circuit protection under various working conditions, temperature overload protection, open circuit protection of information acquisition system, etc. Through debugging and testing of the system, it shows that the system has high accuracy and reliability.

INTRODUCTION

With the development of new energy technology, lithium batteries are more and more widely used in various industries and fields. Lithium batteries are typical storage batteries with remarkable integration and precision. Compared with traditional lead-acid batteries, lithium batteries have certain advantages in condition monitoring and intelligent control management. Because the charging and discharging characteristics of lithium batteries are greatly affected by temperature, humidity and other external environmental conditions, such as underground coal mine, if the charging and discharging status of storage batteries cannot be monitored in time, there will be greater security and failure hidden dangers, which seriously affects the improvement of comprehensive mining efficiency in coal mine. In this paper, the lithium iron phosphate batteries for mining locomotives are taken as the research object, and the working status of the batteries is monitored and managed based on single chip computer control. For batteries, if a single battery fails (overcharge, over discharge and overheating), it will directly or indirectly lead to the abnormality of the whole power supply system, which requires the monitoring system to have the ability to monitor each single battery and battery.

The overall design scheme of the system

Functional design: In order to meet the optimum design requirements for reliability and safety of lithium battery condition monitoring system for mining electric locomotive, the working parameters of battery pack have specific requirements: (1) The capacity of standby power supply should be less than 60Ah; (2) When the rated working conditions are reached, the surface temperature of battery should not exceed 60 C; (3) After emergencies, the whole monitoring system can guarantee the battery pack. The protection time should not be less than 90 hours; (4) For each single battery in series, its initial technical parameters should be consistent with specifications; (5) The response time of charge and discharge should not exceed 1 s. According to the above basic requirements, the basic functions of the whole system are charge and discharge signal monitoring, temperature signal monitoring, discharge maintenance and charge equalization. Its protection functions mainly include: battery charging, voltage and current overload protection during discharge, short circuit protection under various working conditions, temperature overload protection, open circuit protection of information acquisition system, etc. Among them, overcharge and over discharge are the most common faults of electric locomotives, and are also the main factors inducing safety accidents. According to the power calculation of electric locomotive, it is known that the rated capacity and working voltage should not be less than 500 Ah and 24V, respectively, if the working parameters of battery pack are satisfied. Therefore, when the module voltage is lower than 22.4V or the single battery voltage is lower than 2.7V, the system automatically enters the protective state. At this time, the discharge state of the battery pack will be blocked. If there is no corresponding control instruction, the state will be maintained and the over-discharge fault will be avoided.

Structural design

In order to better implement the function design, the distributed control scheme is adopted in this paper. The hardware system is divided into general control terminal, single battery control terminal, display terminal and communication terminal. The system adopts CAN communication scheme, which can not only effectively integrate all functional modules into a whole, but also realize

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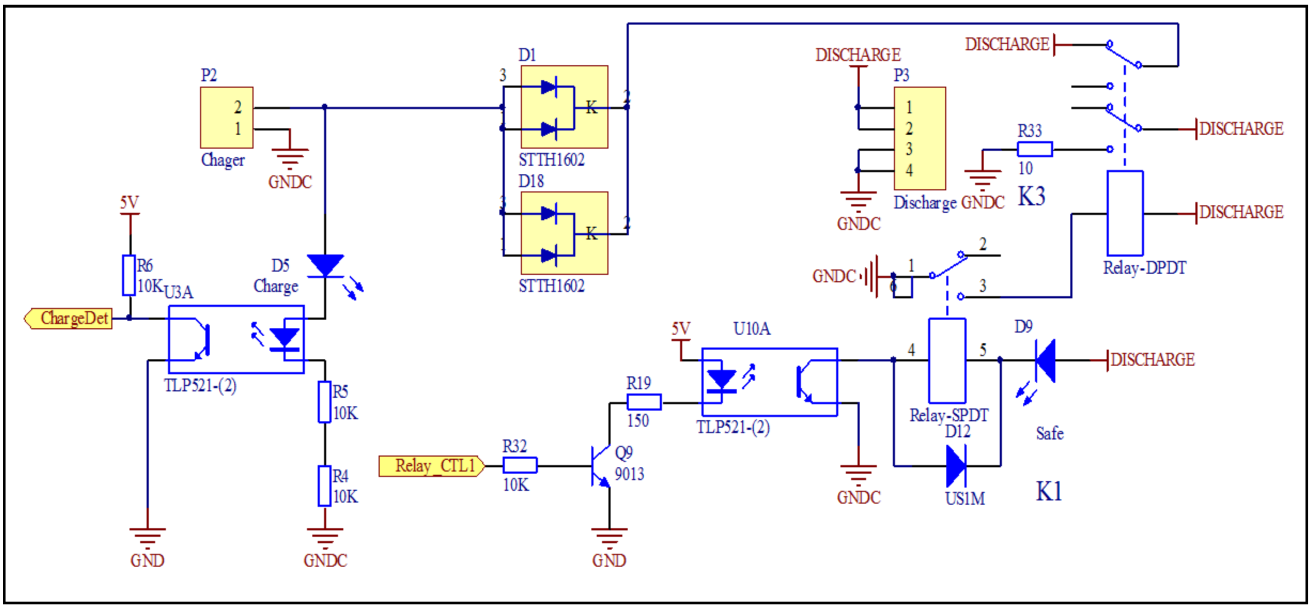

Fig. 1. Maintenance of discharge circuit

the parameter signal monitoring of single battery. In addition, the system is required to have maintenance, protection and early warning capabilities. In order to improve the efficiency and quality of communication between modules, the local isolation method is used to connect the block controller and the master controller in the whole control process.

System Hardware Design

Design of Main Controller and Filling and Placing Maintenance Circuit: In order to improve the exploitability of the system and facilitate the later function improvement and structure design, STM32F103RBT6 processor is used as the core of the assembly controller. When the main controller works, the related parameters of single battery are collected firstly, which is realized based on CAN_1 bus scheme. Then the collected information is identified and relevant control instructions are sent according to the data, including monitoring, protection and control. In terms of isolation control, WD5-24 isolation power supply is selected to isolate the bus from the main controller. A voltage converter 7850 is added at each control node, which can turn the voltage into a voltage regulator of 5V and provide power for CAN_1 network. According to the operation requirements of trams, if the battery pack does not work for a long time after it is full, it needs to be charged and discharged regularly.

In this system, automatic discharge is mainly realized based on relay, and its maintenance circuit is shown in Fig.1. It can be seen that port P2 is the access port of charging equipment and port P3 is the input/output port of lithium battery pack. The working state of charging equipment is determined by optocoupler. If the charging equipment fails, but still needs to continue charging, the process can be controlled by D1 and D18 together. K1 and K3 represent control relay and intermediate relay respectively, which are the main devices for circuit maintenance. When the optocoupler detects the normal discharge of the battery pack, the Relay-CTL1 interface will remain in a low level state, and the K3 relay will often open contacts and not operate. When charging, the Relay-CTL1 interface will maintain a high level, and the K3 relay will work with the action of the K1 relay to perform discharge maintenance tasks. The D1 and D18 in the circuit are MBR20100 devices, whose main working parameters are IF = 10A, IFSM = 150A, VRRM = 100V. SONGLE series is selected for control relay K1. Its main working parameters are: coil voltage 24 VDC, contact voltage 24 VDC, and contact current 1A. The intermediate relay K3 adopts Schneider series. This type of relay has plug-in structure. Its main working parameters are: coil voltage 24 VDC, contact voltage 19.2-26.4 VDC and contact current 12A.

Design of electric signal monitoring module

The working status of lithium batteries is based on the monitoring of electrical signals. Considering the safety and cost performance requirements of the equipment, Hall sensor is selected as the key component of electrical signal monitoring. The model is TBC06-DS5 series. Its structure is shown in Fig.2 and wiring diagram is shown in Fig.3. The series of sensors can effectively isolate power buses, and their main working parameters are: supply voltage is + 5V + 5%; offset voltage is + 2.5V + 0.5%; monitorable current range is + 12A; primary inductance value is 0.013uH; primary resistance is 0.18m; insulation voltage is 2.5kV; bandwidth value is 200kHz; maximum response time is less than 500ns; maximum error of signal detection is 0.7%; signal linearity is 0.013uH. It is less than 0.1% FS and the rated working temperature ranges from - 40 to 85 C. The sensor used in electric signal monitoring is controlled by STM32 series single chip computer, and the acquisition signal range is VREF - = VIN = VREF+. If the maximum sampling current is needed, the VREF- is set to 0 and the VREF+ is set to 3.2V.

Design of temperature signal monitoring module: In addition to charging and discharging signals, temperature signals are the most important acquisition signals in the condition monitoring system. In order to ensure the safety of the system, a temperature sensor DS18B20 is connected to each single battery (its internal structure is shown in Fig.4), and multi-temperature monitoring is realized. The sensor has good reliability in intelligent identification and transmission of battery temperature detection, and can process distributed data according to different serial numbers of the sensor itself. Each sensor's ROM integrates 64-bit serial number, which can be one-to-one correspondence with a single battery.

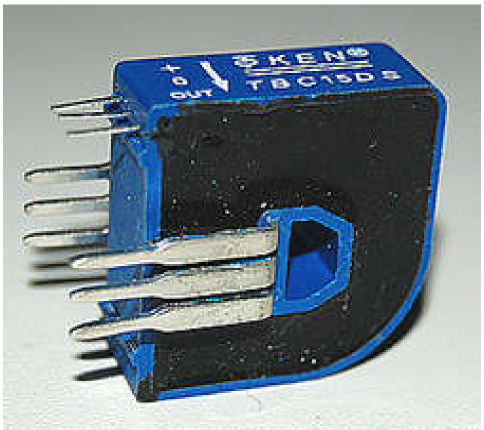

Fig. 2. Current hall sensor

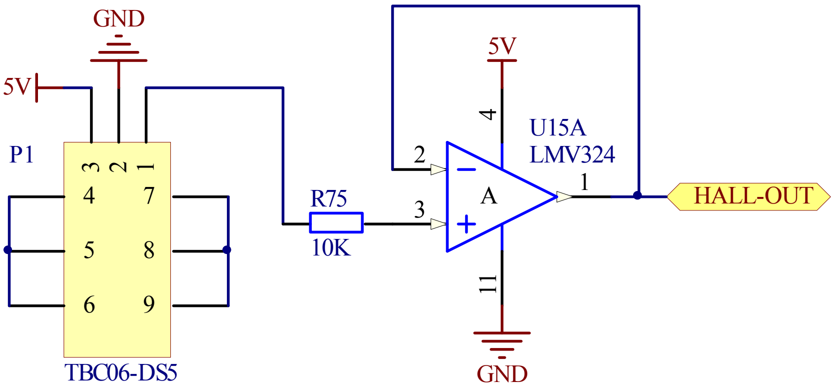

Fig. 3 Sensor wiring diagram

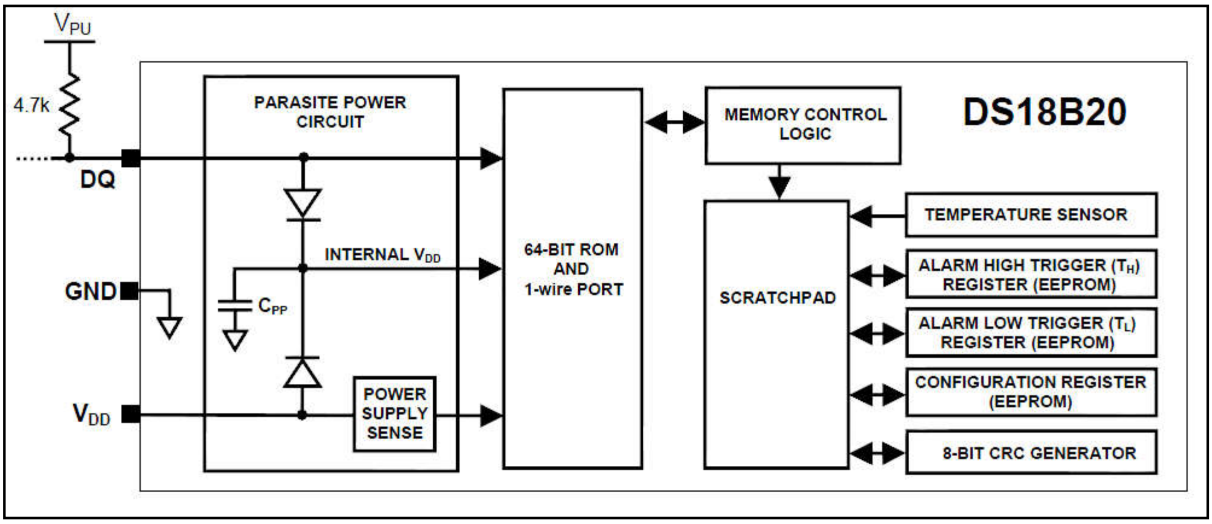

Fig. 4. 18B20 internal structure diagram

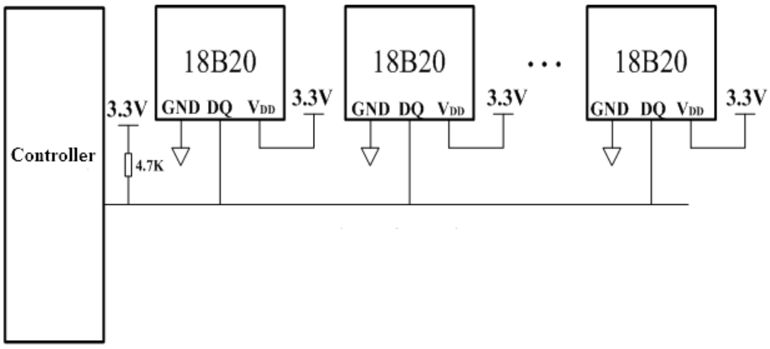

Fig. 5. 18B20 temperature detection circuit

For data reading, the search mode is adopted, that is to say, only the corresponding serial number can be exactly corresponded to the subsequent operation. In order to simplify the circuit of the whole temperature detection system, the connection structure of the sensor is designed as shown in Fig.5. The DQ port of the temperature sensor DS18B20 is directly connected with the I/O port of the main controller, which is beneficial to the direct control of the system. At this time, the access voltage of each sensor is 3.3V. The battery pack of the system consists of eight single batteries, so it is necessary to connect eight temperature sensors corresponding to series numbers. Because the sensor reads accurately and works reliably, there is no need to design the maintenance circuit separately.

Design of communication module: In terms of communication, the system adopts CAN bus transmission mode, and PCA82C250 series chips are selected as the control core. The chip can be directly connected to the physical bus, so it can effectively determine the working position and working state of the bus. The isolation circuit of CAN bus communication in the system is shown in Fig. 6, which can achieve good common mode signal suppression effect. In addition, the protection function is also very significant. The high-speed optocoupler used in the control module is 6N137 series, which has strong anti-interference ability and can display the working state through LED when receiving and sending signals.

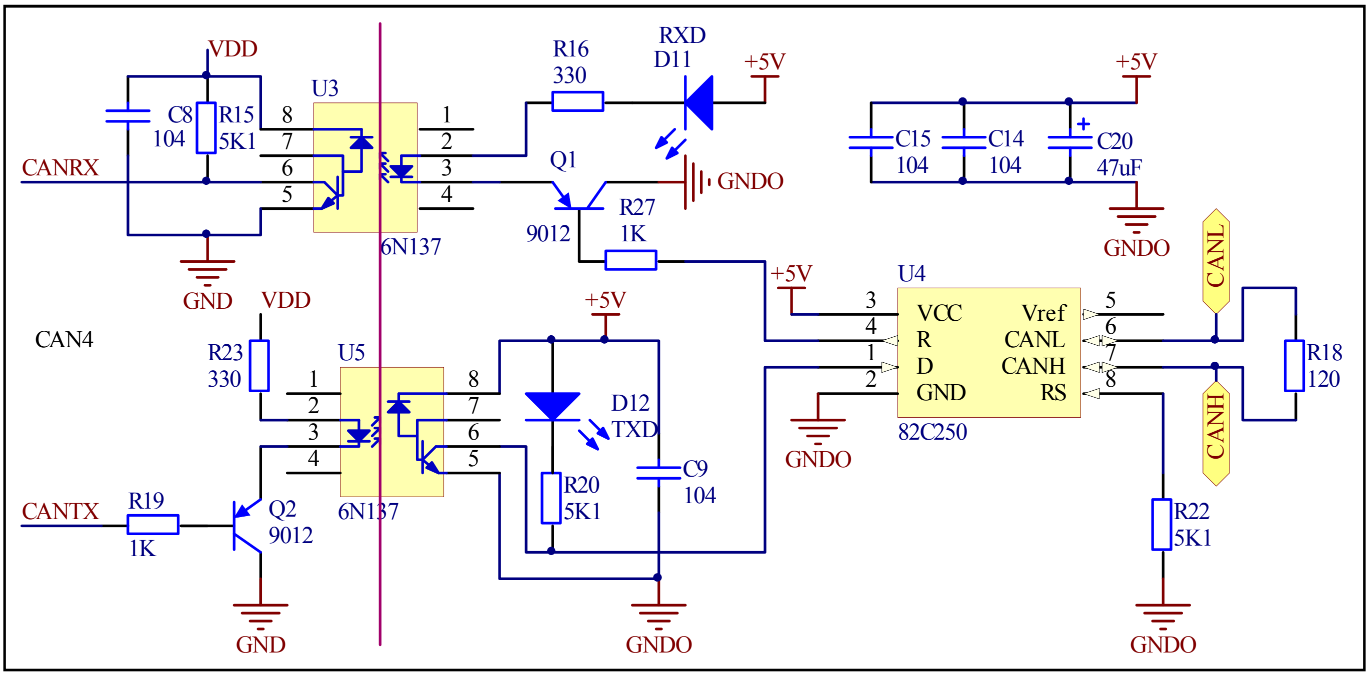

Fig. 6. Isolation circuit for CAN bus communication

System debugging and testing: To further ensure and verify the performance and stability of the state monitoring system for lithium battery packs designed in this paper, the hardware modules are wired and debugged. In the process of debugging and testing, signals are collected by different signal collectors, and voltage waveforms are obtained by signal processing module. For the comparative test of circuit voltage, high precision multimeter is used. The results show that the balance deviation between the system monitoring signal and the multimeter acquisition signal is less than 1%. This shows that the system has very high detection accuracy and reliability, and is suitable for intelligent control of lithium battery packs.

Acknowledgement

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Conclusions

According to the working requirement of tram, the function design of lithium battery control system is completed, including charge and discharge signal monitoring, temperature signal monitoring, discharge maintenance, charge equalization and corresponding protection functions. In structure, a distributed MCU control scheme is adopted. Each single cell has its own control sub-unit, and data transmission is realized by CAN bus. The main hardware design of the system is completed, including the main controller, charge and discharge maintenance circuit, monitoring module of electrical signal and temperature signal, communication module and so on.

The debugging and testing results show that the deviation between the voltage signal detected by the system and the measurement results of the multimeter is less than 1%.

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