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Smart Battery Charging System Based on ATMEGA128 Microcontroller

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(Abstract) According to the problems of lithium battery, which has abroad application prospects, in the process of charging, by using of the constant current to constant voltage charging method, this paper designs a smart fast charging system based on the ATMEGA128 microcontroller and LTC4100 battery charging controller. The core modules of the MCU control and charging circuit are mainly designed to achieve the efficient and fast charging. During the process of charging, the system can automatically track the acceptable charging current of lithium battery, and monitor the charging current, voltage and temperature to realize the intelligent and precise control for the whole charging process, which can guarantee that lithium battery is neither over-charge nor less-charge.

Keywords: Lithium Battery; Smart Charging; ATMEGA128 Microcontroller; LTC4100

1. INTRODUCTION

Batteries play an irreplaceable role in various electronic equipments from the satellite and the spacecraft to mobile terminals, razors and other equipments. With the widespread use of digital products such as mobile phones, laptop computers and other products, lithium battery is widely used in such products due to its many outstanding performances [1]. Since lithium battery doesn't have the obvious memory effect, then it isn't necessary to do any discharge operation whether the charge operation is finished (discharging irregularly may damage the battery). Many practices show that the charging process of lithium battery may largely affect its life. Therefore, it is very necessary for us to investigate a fast and efficient charging system for lithium battery, which does not affect the life of the lithium battery smart charging device.

The lithium battery smart charging system designed in this paper can be able to accurately measure various impact factors during the battery charging process, such as battery temperature, the temperature of external environment, the battery current and voltage. Through a comprehensive analysis, one can effectively avoid the phenomena of less-charge or over-charge of lithium battery.

2. HARDWARE DESIGN

Figure 1 shows the diagram of the ATMEGA128 microcontroller-based lithium battery smart charging system, including the data acquisition module, ATMEGA128 microcontroller control processing module, charging circuit design module.

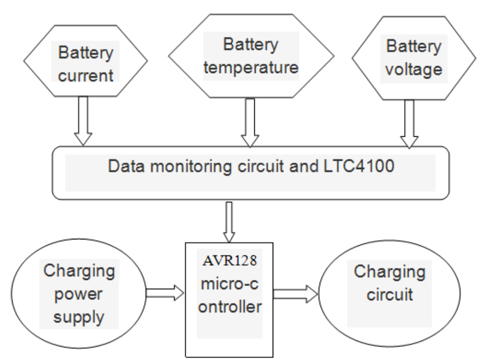
The host controller designed in this system takes full advantages of AVR chip system resources and high-speed data processing [2-3]. Because of its high rate discharge performance, wide operating temperature range, the AVR chip can complete the task of high-current pulse discharge, etc. At the same time, since it does not contain mercury, cadmium and lead, then it is safe and reliable.

The core processor of the smart charging system uses ATMEGA128 microcontroller to deal with the data collected by the data acquisition circuit. Then according to the processed data, ATMEGA128 microcontroller begins to control the charging circuit so as to realize the reasonable smart conversion of the charging module. Therefore, it naturally avoids the single charging module during the entire process and achieves the fast and efficient charging of lithium battery.

Figure 1 The diagram of lithium battery smart charging system

The basic functions of the smart charging system include:

(1) When the battery is powered on, the charging system



begins to detect the voltage and temperature of battery firstly. If the voltage and temperature of battery is below the specified threshold, then the charging system will pre-charge the battery. Otherwise when the temperature and voltage of battery reaches the specified value, the charger will automatically transfer to the module of default fast charge to charge the battery.

(2) When the detected voltage and temperature is higher than the threshold, the charging system will directly charge the battery in accordance with the method of pre-settled fast charge. The charging system can also automatically convert the status of charging according to the battery voltage and charging current, moreover, it will automatically transfer to the floating status when the battery is fully charged.

(3) During the charging process, the system can monitor several information states including the voltage and temperature of the battery and the charging current in real time, which is displayed through the LED module.

(4) The system contains a warning indicator and many monitoring circuits about the output over-voltage, over-current, short circuit and overheating, which can protect the charging devices and batteries effectively.

2.1 The Data Acquisition Module and MCU Control Module

ATMEGA128 microcontroller is a high performance embedded microcontroller with reduced instruction set collection (RISC) and FLASH memory technology. It has lots of advantages which include a power consumption, fast operation, peripheral expansion capability and so on. In addition, the ATMEGA128 microcontroller also has an integrated A / D converter module and the function of set watchdog. Design data acquisition module collection circuit (see Figure 2), the specific design ideas for: the weak voltage signal of the pressure sensor output of the two road and bridge - the power signal and the voltage signal of strain pressure (see Figure 2, IP and OP)lost to the pressure sensor signal conditioning circuit (see Figure 2), by two-way symmetrical LC low-pass filter circuit to filter out low frequency jitter caused by supply voltage signal, and then after the op amp AD8222 filtered and amplified by the dual-channel adjust able gain[4], ADS1256 differential transmission to internally adjust the gain, low-noise high-resolution 16-bit AD converter chip. ATMEGA128 microcontroller programmed to control the sampling data improve the self-correction and system calibration, and then filtered by a programmable digital filter, SPI serial data port to ARM transfer data, after transmission to the ATMEGA128 microcontroller. MCU Comprehensive analysis the processing of the acquired signal by Rate of temperature change (ΔT / Δt) method, the maximum voltage law, voltage negative growth law. The output PWM signal adjusts the frequency by changing the periodic pulse train, changing the pulse width or duty cycle adjustment voltage, and thus control the charging current.

The reset port of ATMEGA128 microcontroller is set to power-on reset, an external 4 MHz crystal. The ports (AD0-AD7) of ATMEGA128 are connected to the eight input ports of the LCD1602 that displays the process of charging temperature, voltage and current. At the same time, AD9 - AD13 and BD pin control the trickle charge mode, constant current charging mode, the constant trickle conversion mode and three different colors of light-emitting diodes, in order to avoid a single charge mode. Through the changing of diode' color, people can judge the ongoing charge mode. The BD7 pin as the partial pressure control side is used to control charge circuit.

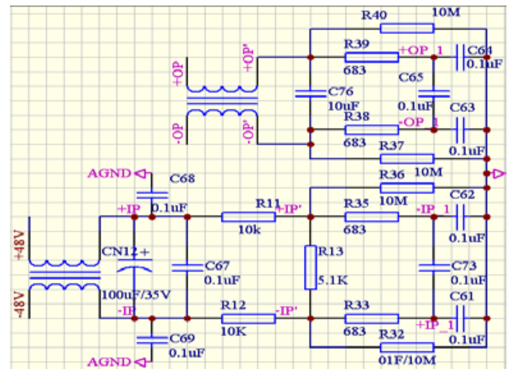


Figure 2 The collection circuit of data acquisition module

In order to reduce the ripple voltage jitter interference, the system has been designed with a 48V AC voltage to the bridge power supply, to reduce interference to increase for the pressure difference. After the AD conversion, analog and digital filtering, data is read by the ARM and stability in the full scale deviation 5V circumstances 2mV, in order to achieve high precision pressure detection.

2.2 Charging Power Supply Circuit and Charging Circuit

The core device of the charging power supply circuit, which is shown in Figure 3, is the DC-DC power module which supplies stable 5V DC-voltage. T1, D1, D2, constitute a full-wave rectifier circuit, which can convert the frequency alternating current to the pulsed DC with DC components. The diode will play the switch due to its unidirectional conductivity.

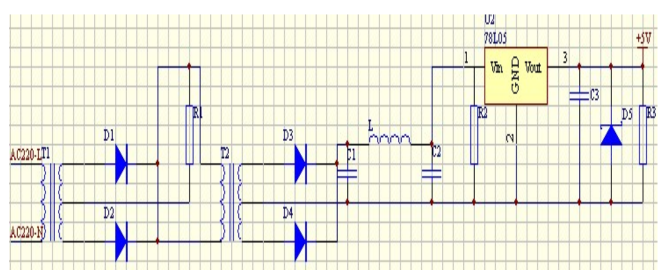


Figure 3 The charging power supply circuit

T2, D3, D4, C1, C2, L, and R2 constitute a filter circuit, which can filter out the exchange portion of the pulsed DC and increase the DC part (Here the inductors and capacitors play the role of filtering). LM7805 chip, D5, C3 and R3 constitute a regulator circuit, which can further regulator the rectified DC voltage. D5 is the diode of output protection, which is used to protect the LM7805 output stage such that it is not damaged.

The LTC4100 Smart Battery Charger is a single chip charging solution that dramatically simplifies construction of an SBS compliant system[5]. A Safety Signal on the battery being charged is monitored for temperature connectivity and battery type information. The SMBus interface remains alive when the AC power adapter is removed and responds to all SMBus activity directed to it, including Safety Signal status (via the Charger Status command). The charger also provides an interrupt to the host whenever a status change is detected [6].

Charging current and voltage are restricted to chemistry specific limits for improved system safety and reliability. Limits are programmable by two external resistors. Additionally, the maximum average current from the AC adapter is programmable to avoid overloading the adapter when simultaneously supplying load current and charging current. When supplying system load current, charging current is automatically reduced to prevent adapter overload. During normal operation, the top MOSFET is turned on each cycle when the oscillator sets the SR latch and turned off when the main current comparator ICMP resets the SR latch. While the top MOSFET is off, the bottom MOSFET is turned on until either the inductor current trips the current comparator IREV, or the beginning of the next cycle.

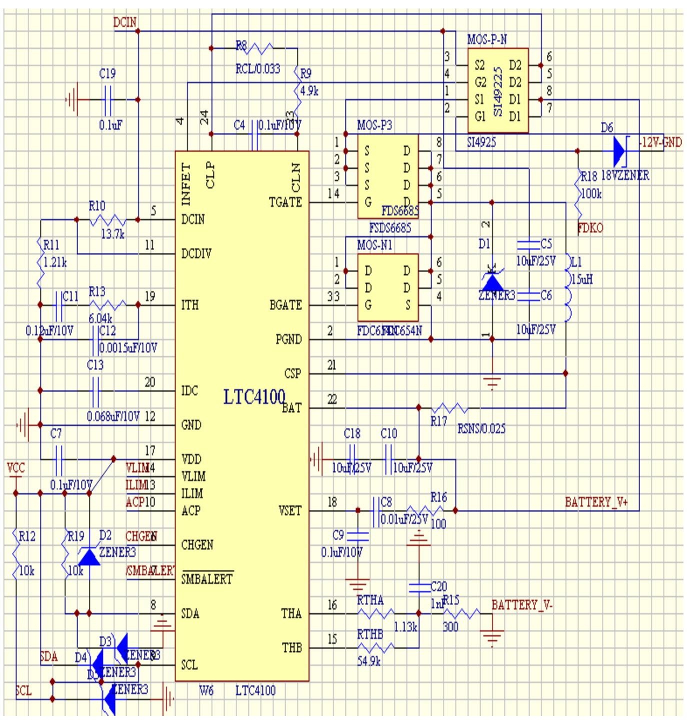


Figure 4 The design of LTC4100 circuit

After lithium battery is charging for a certain time, the voltage change is small when the battery is at the less filling state. If you continue in this way to charge the battery, lithium battery voltage will drop, resulting in charge phenomenon. Whether it is less filling or over-charge will have an impact on battery life. Set an upper limit voltage of the lithium battery in the charging process, by the ATMEGA128 MCU into trickle charge module when the upper limit voltage is reached, as shown in Figure 4, the core of the circuit chip is the Vlim pin. Since the detected terminal voltage CLP and the partial pressure off voltage BAT is a constant value. When the CLP reaches the upper limit voltage, BATGE FET turn on at this time, the relay current generates the electromagnetic effect of the road connection to enter the trickle charge mode. Charging current is set in the trickle charge stage 0.025C, timing settings, set the charge time of 60 min. Trickle charge, ATMEGA128 microcontroller control the charging switch-CHEN to end of the charge. Charging will also be disabled if CHEN is low.

3. SYSTEM SOFTWARE DESIGN

The system software is developed by C language, using a modular structure. It is mainly constituted by the main program, interrupt service routines and subroutines that is used to accomplish each function. The interrupt service routine is used to accomplish some tasks with higher real-time, which mainly include tracking the change of voltage and current, detecting various information variables.

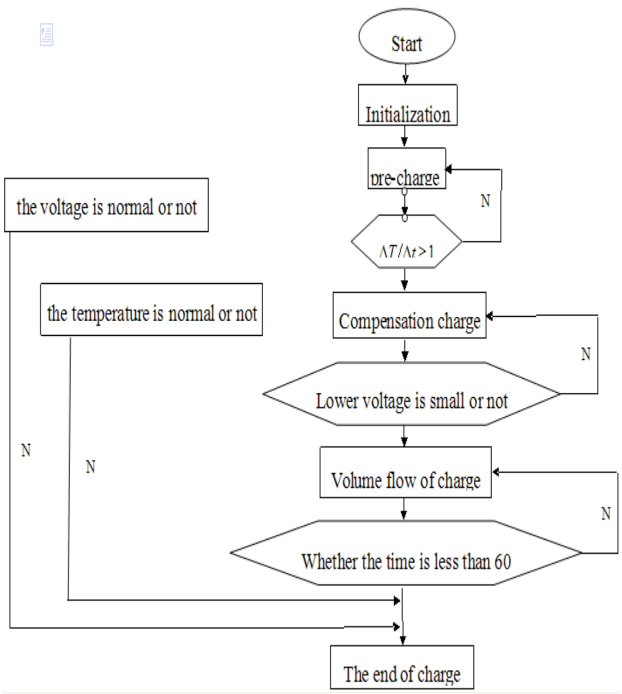
3.1. Charging Algorithm Selection

According to the battery charging characteristics, in order to ensure the safe use of the battery and prolong the battery's life, one must select some appropriate charging algorithms. The general charging control algorithms can be classified into the following categories accordance with different control objects[8]: timing control, current control, voltage control, temperature control to terminate the charging. The general control methods of constant current, constant voltage and the highest temperature are simple and easy to implement, but they may cause the less-charge or over-charge, affecting the battery life.

The charging system designed in this paper applies the constant current to constant voltage control method for lithium battery. In detail, under the stage of constant charging, the system begins to test constantly the battery terminal voltage. When the battery voltage reaches the saturation voltage, the constant current charging status will be terminated and automatically transferred to the constant voltage charging status. If the charge current drops to 1/7 of the charge current in constant current condition, then the constant voltage charging status will be terminated. In addition, in order to improve the safety performance of rechargeable batteries, the longest constant voltage charging time and the highest temperature control threshold is also designed.

3.2. Lithium Battery Charging Procedure

The ATMEGA128 control software is developed by C language in the IAR environment [7]. When designing the system, we must firstly initialize the system including A / D conversion, setting the IO ports and so on. The battery charging process is divided into pre-charging, fast charging, the compensation charge, trickle charge. In the previous three charging processes, we should set the charging time and charging current. When the fast charging is finished, lithium battery can be recovered to the original storage. If $\triangle T / \triangle t \geqslant 1$(i.e., the battery temperature of the charging circuit increases 1° C per minute as shown in Figure 5), the fast charge should be terminated immediately. When the fast charge is finished, we use a negative voltage method to detect the battery voltage and then stop the compensation power immediately if the battery voltage is slightly lower. We settle the charge time for trickle charging to ensure the battery is not



less-charge and over-charge. The charging software process is shown in Figure 5.

Figure 5 Software processes of the charging system

4. CONCLUSIONS

The battery charging system designed in this paper can improve the battery life effectively. We take both the system's functionality and designing cost into account, and strive to achieve the highest letter bid. A combination of a variety of analytical methods for smart charging of the battery is applied such that the system performance is not only stable but also easy to be used. On one hand, the charging battery is neither be less-charged nor over-charged, which extends the life of the lithium battery, on the other hand, the designed cost is significantly reduced, which leads to the associated reduction of the environment pollution.

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