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# Design of Safety Charger for Electric Vehicle

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## Abstract

**With the sharp increase in electric vehicles, fire accidents caused by electric charge explosion are also rising within the scope of all over the world. So, the safety charging for the electric vehicle has become a problem worthy of our wide attention. In this paper, a safety charger based on single chip microcomputer is designed whose working state was controlled through three control modes of temperature, current and voltage. During charging process for electric vehicle, if the battery temperature is too high or output current and voltage is abnormal, the charger can automatically cut off the charging circuit in time so as to avoid accidents and achieve the goal of security charge for battery. The simulation results show that the charger for electric car designed in this paper has stable operation, good real-time performance, and high control accuracy and can effectively reduce the occurrence of charging accidents.**

## Keywords

**Charger; Single Chip Microcomputer; Temperature Control; Electric Current Control; Voltage Control.**

## 1. Introduction

Recently, we can see electric vehicles everywhere. Electric vehicles are popular with the public for their energy saving, emission reduction, and low noise. Many electric vehicle users are accustomed to charging electric vehicles at night. Although this can effectively save time and at the same time avoid the peak electricity consumption period during the day, charging at night is also accompanied by many hidden dangers.

In this paper, a safety charger for electric vehicles with single-chip microcomputer as the core is designed. If the output current and output voltage of the charger are too high during charging, or the temperature of the battery is too high, the charger can immediately cut off the power supply to ensure the safe charging of the battery. The system uses a single-chip microcomputer as the core, selects temperature sensors, voltage sensors and current sensors to measure the battery temperature and the actual value of the charger output voltage and output current respectively, and transmits the measured data to the single-chip microcomputer. When the battery temperature is too high or the charging current and voltage fluctuate greatly, the single-chip microcomputer sends out a control signal to control the working state of the relay, and then controls the charging circuit to be disconnected.

## 2. Overall design

### 2.1. System function

(1) The basic functions that this charger can achieve are as follows:

(2) Measure the actual parameters of battery temperature and charger output voltage and output current;

(3) Judge whether the measurement parameter meets the set safety value;

(4) Control the working status of the charger (charging or power off).

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## 2.2. System module

The hardware circuit modules of this design include five modules: data acquisition circuit module, data processing circuit module, button circuit module, actuator module, and display circuit module. The composition and function of each hardware circuit module are as follows:

(1) Data acquisition module. This module mainly includes a temperature sensor, a voltage sensor and a current sensor. It collects the battery temperature, the output voltage of the charger, and the output current respectively to obtain three important data during charging.

(2) Data processing module. This module is a single-chip microcomputer, used to process the collected data and transmit it to the display; and can be compared with the preset safety value range. When the collected information exceeds the safety value range, the single-chip microcomputer sends out a control signal to control the relay Working status.

(3) Button module. This module is used to set the safety value (threshold value).

(4) Executive agency. This module is a relay circuit, and its working state is controlled by a single-chip microcomputer.

(5) Display module. This module is used to display the set safety value and collected data.

The connection form of each of the above-mentioned modules is shown in Figure 1.

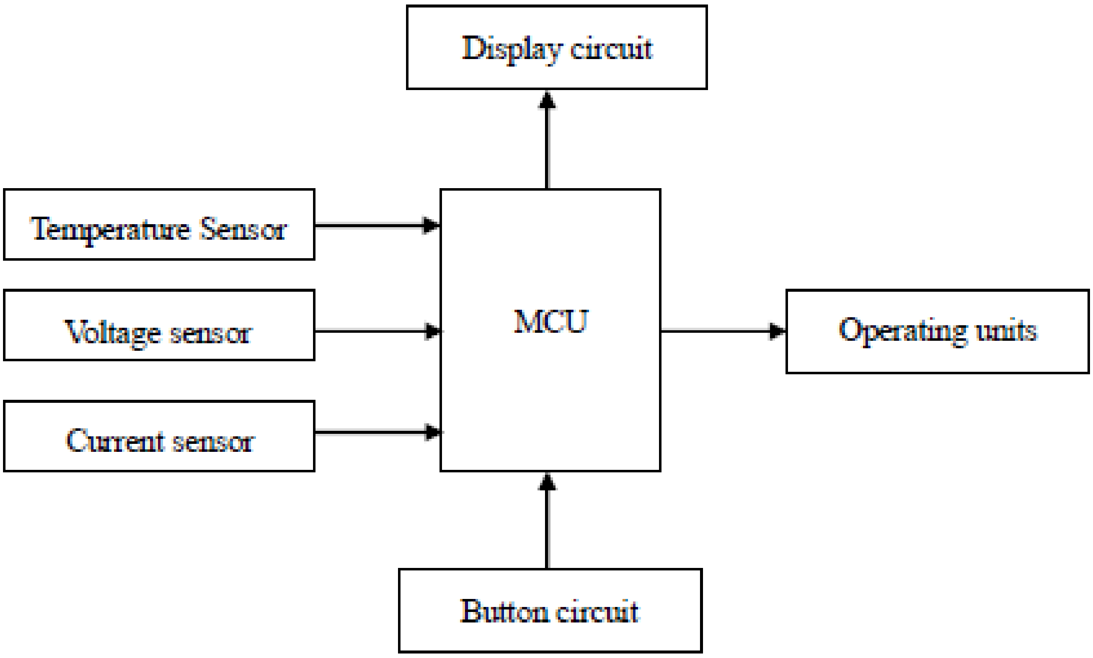


Figure 1. System hardware structure diagram

In Figure 1, the button circuit stores the preset safety value in the single-chip microcomputer, and the data collected by each sensor is sent to the single-chip microcomputer. The single-chip microcomputer sends the safety value and the collected data to the display circuit for display, and compares the collected data with the preset value. If it is higher than the preset value range, the single-chip microcomputer sends out a control signal to execute the component action.

# 3. Introduction of key components

## 3.1. MCU

In this design, AT89C51 single-chip microcomputer is selected as the information processing unit, and after processing the information collected by the sensor, it sends out signals to control the actions of components such as relays. Its pin is shown as in Fig. 2.

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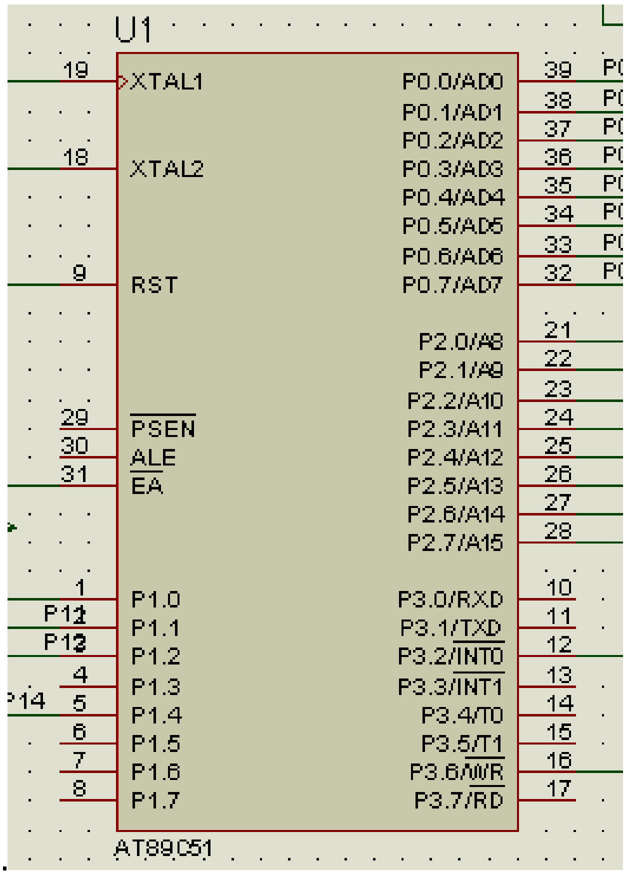

Figure 2. AT89C51 MCU pins

Pin assignment of AT89C51:

(1) Main power supply pins

40: VCC (+5V);

20: GND (ground);

(2) External crystal oscillator pins

19: XTAL1 (input);

18: XTAL2 (output);

(3) Control pins

9: RST/VPP (reset);

30: ALE/PROG (address lock enable signal);

29: PSEN (read strobe signal of external memory);

1: EA/VPP (internal and external strobe of program memory).

(4) Programmable pins

AT89C51 single-chip microcomputer has 4 groups of programmable P ports, which are P0~P3 ports. Each group of P ports has 8 bits and a total of 32 pins. In this system, the pin assignments are as follows:

11: Temperature acquisition circuit;

12: Voltage acquisition circuit;

13: Current acquisition circuit;

14, 32, 36: Button circuit;

21~28: Display circuit;

39: Actuator.

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## 3.2. Temperature Sensor

The temperature sensor of this system adopts DS18B20 digital temperature sensor, which has the characteristics of high integration and stable operation. The pin diagram is shown in Figure 3.

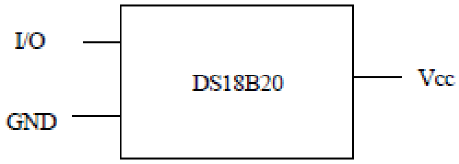


Figure 3. DS18B20 digital temperature sensor pin

## 3.3. Voltage sensor

This system selects EVS-C53 voltage sensor to collect voltage data, which has the characteristics of high accuracy, high linearity, small size, stable operation, and can adapt to different working environments. The pin diagram is shown in Figure 4.

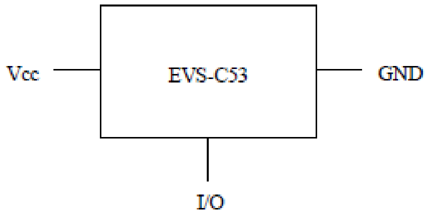


Figure 4. EVS-C53 voltage sensor pin diagram

## 3.4. Current sensor

This system uses HZIE-C4C current sensor to collect current data, which has the characteristics of high accuracy, high linearity, simple structure, stable operation, and can adapt to various working environments. The pin diagram is shown in Figure 5.

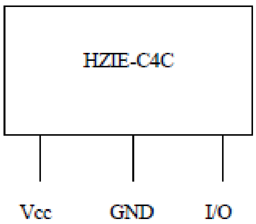


Figure 5. HZIE-C4C current sensor pin diagram

## 3.5. LED display device

This system uses four digital tubes to display data, and its pin diagram is shown in Figure 6.

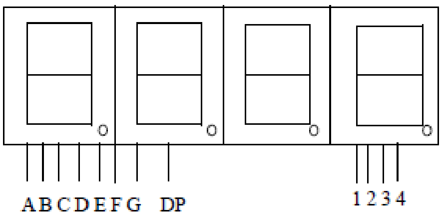


Figure 6. LED display device pin diagram

ISSN: 2710-0588 DOI: 10.29556/FSE.202105_1(2).0019

# 4. Hardware circuit design

## 4.1. The smallest system of MCU

This system chooses one-chip computer AT89C51 as the control center, its minimum system is shown as in Fig. 7.

The clock circuit itself is an oscillating circuit and an important part of the smallest system of the single-chip microcomputer. It can provide a time sequence, so that the microcontroller runs in accordance with this sequence. It is generally composed of a crystal oscillator, a crystal oscillator control chip and a capacitor, and is usually connected to the XTAL3 and XTAL2 pins of the single-chip microcomputer.

In order to prevent the system from not working properly due to various system or human reasons, this system has designed a reset circuit so that the single-chip microcomputer can run again. This circuit is composed of electrolytic capacitors, resistors and buttons.

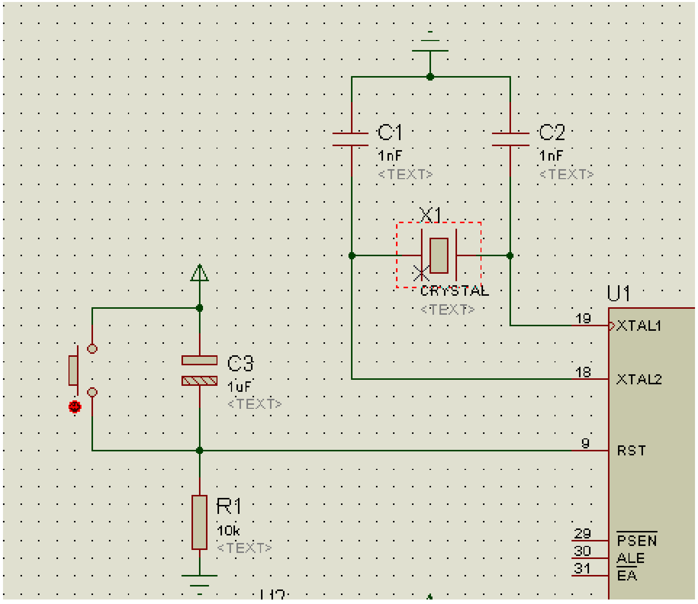


Figure 7. The smallest system of single-chip microcomputer

## 4.2. Temperature detection circuit

In order to avoid accidents caused by the high temperature of the battery during charging, the temperature detection circuit is designed in this system. The circuit sends the detected actual value to the single-chip microcomputer, and the single-chip compares the actual value obtained with the preset value. When the actual temperature is higher than the preset value, the single-chip microcomputer outputs a control signal to control the action of the relay switch contacts, cut off the charger input circuit, and stop charging the battery. The temperature detection circuit is shown as in Fig. 8.

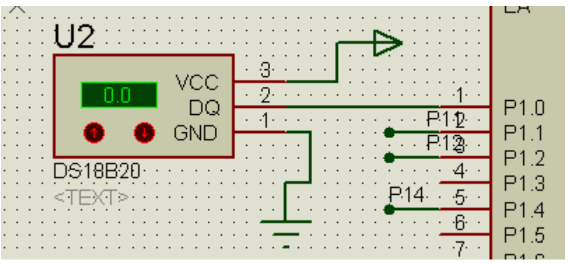


Figure 8. Temperature detection circuit

ISSN: 2710-0588 DOI: 10.29556/FSE.202105_1(2).0019

## 4.3. Voltage detection circuit

In order to prevent the charger's output voltage from being too high or too low during charging to cause damage to the battery and even cause accidents, the system has designed a voltage detection circuit. The circuit sends the detected data to the microcontroller, and the microcontroller compares the actual voltage collected with the preset value. When the actual voltage value exceeds the preset value range, the single-chip microcomputer outputs a control signal, controls the relay switch contact action, cuts off the charger input circuit, and stops charging the battery. The voltage detection circuit is shown in Figure 9.

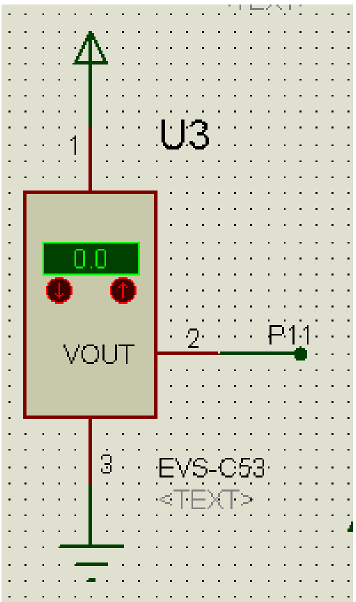


Figure 9. Voltage detection circuit

## 4.4. Current detection circuit

In order to prevent the battery from being damaged when charging is too high or too low, and even cause accidents, the system designs a current detection circuit. The circuit sends the detected data to the microcontroller, and the microcontroller compares the actual current collected with the preset value. When the actual current value exceeds the preset value range, the single-chip microcomputer outputs a signal to control the action of the relay switch contact, cut off the charger input circuit, and stop charging the battery. The electric current detection circuit is shown as in Fig. 10.

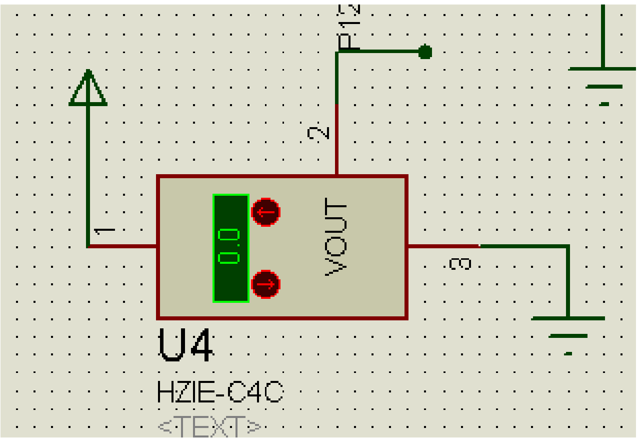


Figure 10. Current detection circuit

## 4.5. Relay control circuit

When the actual data is higher than the safe value range, the single-chip microcomputer sends out a control signal. The signal is applied to the base through a transistor. At this time, the emitter is forward biased, the collector is reverse biased, and the transistor is turned on. Then the relay coil is energized, and the relay switch contacts act. The switch of the relay determines the energized state of the contactor coil, and the switch of the contactor determines the working state of the charger. Since there are no contactor related devices in the Proteus simulation software, the system uses a bulb instead of the contactor to detect whether the single-chip microcomputer sends a control signal. The relay control circuit is shown in Figure 11.

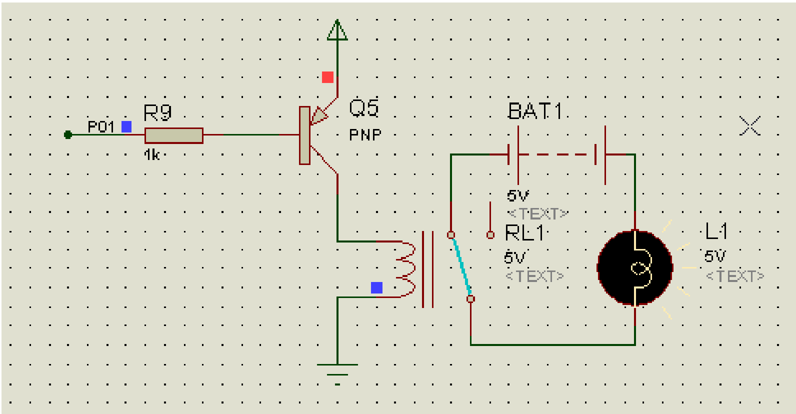


Figure 11. Relay control circuit

## 4.6. Button circuit

Figure 12 is a button circuit, used to set the threshold of each monitoring signal, and the threshold will be stored in the memory of the single-chip microcomputer at the same time. The function of the button S1 is to set the safety value, the function of the button S2 is the current value plus one, and the function of the button S3 is the current value minus 1. The setting key is used to set the highest and lowest safe values of temperature, voltage and current. Single-click is the highest value, and double-click is the lowest value. The plus one and minus one keys are used to adjust the entered value. Click the plus one key to increase the value by 0.1, and click the minus one key to subtract 0.1.

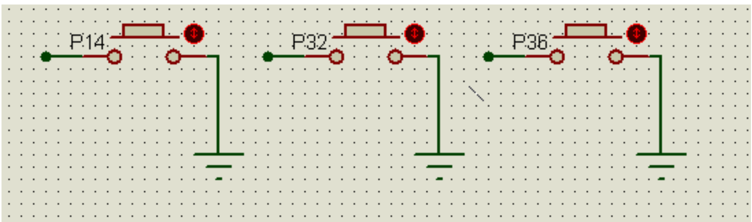


Figure 12. Button circuit

## 4.7. Display circuit

Because the safety value of the system is greatly affected by the environment, electric vehicles are in different environments, and the safety value of the system needs to be appropriately modified according to different environments, and the display circuit can display the highest safety value, the lowest safety value and the collected data set by the current user , The user can modify the threshold appropriately according to the displayed value and the environment. The display circuit is shown in Figure 13. Among them, 1, 2, 3, 4 are display interfaces, Q1~Q4 control the common terminal, and the digital tube can only display when the transistor of the common terminal circuit is energized.

ISSN: 2710-0588 DOI: 10.29556/FSE.202105_1(2).0019

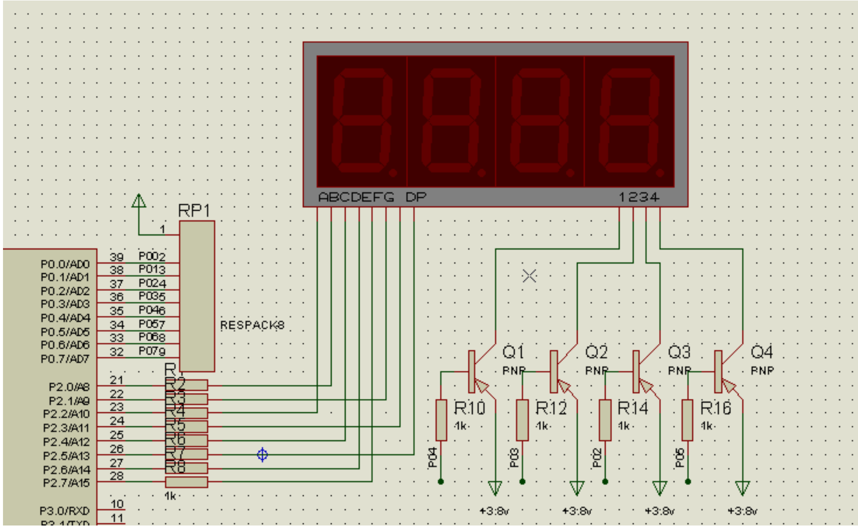

Figure 13. Display circuit

## 5. Software design

When starting to run the program, you must first run the initialization program of each module, and then set the preset value, after finishing it, enter the main loop. In the main loop program, first. First, the sensor collects the actual parameters of temperature, voltage, and current, and displays them on the display, and then compares the actual value with the preset value. When the actual value exceeds the preset value, the single-chip microcomputer outputs control signals to control the working status of the actuators. The main program flow chart is shown in Figure 14.

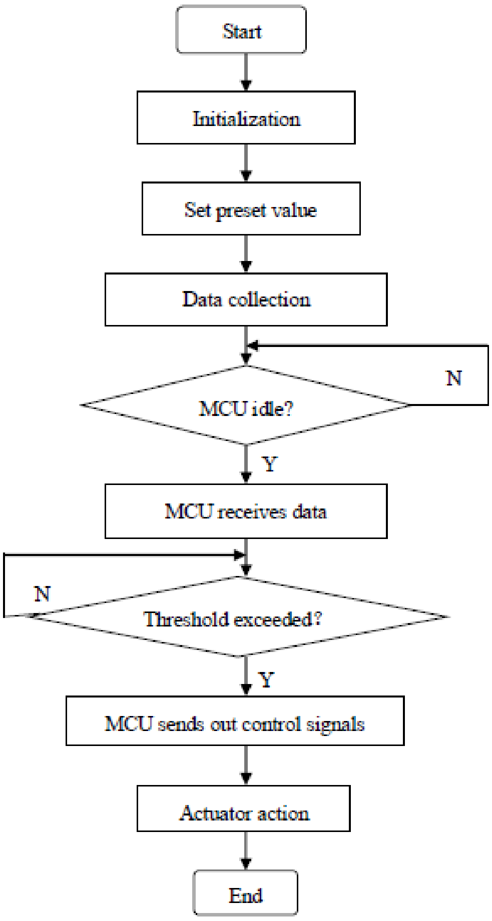

Figure 14. Main program flow chart

ISSN: 2710-0588 DOI: 10.29556/FSE.202105_1(2).0019

During the charging process, the temperature sensor detects the temperature of the battery at all times and transmits it to the single-chip microcomputer. The microcontroller compares the actual temperature value with the preset value. When the actual temperature is lower than the safe value, the single-chip microcomputer outputs a low level, the relay normally open switch is opened, the contactor normally closed switch is closed, and the charger is charged; when the actual value is higher than the safe value, the single-chip microcomputer outputs a high level and the relay normally closed switch When closed, the normally closed switch of the contactor is opened, and the charger is immediately cut off.

In the charging process, the voltage sensor detects the real-time value of the output voltage of the charger at all times and sends it to the single-chip microcomputer. The microcontroller compares the actual data with the safe value. When the actual voltage is within the safe value range, the single-chip microcomputer outputs low level, the relay switch does not act, the contactor normally closed switch is closed, and the charger is charged; when the actual value exceeds the safe value range, the single-chip microcomputer outputs high level, the relay switch acts, and touches When the normally closed switch of the charger is disconnected, the charger will be powered off immediately.

During the charging process, the current sensor collects the real-time value of the output current of the charger at all times and transmits it to the single-chip microcomputer. The microcontroller compares the actual data with the safety value. When the actual current is within the safe value range, the microcontroller I/O outputs low level, the relay switch does not act, and the contactor normally closed switch is closed. Charge the charger; when the actual value exceeds the safe value, the microcontroller I/O outputs high level, the relay switch acts, the contactor normally closed switch is disconnected, and the charger is immediately powered off.

## 6. Simulation results

This design uses proteus software to simulate. First, import the HEX file of the pre-written program into the microcontroller, and then start the simulation. First click the setting button to set the highest safety value and the lowest safety value, press the plus one key and minus one key to adjust the value. Here, in order to show the simulation results more concisely, the three data of temperature, voltage and current are simulated separately. Since there is no contactor in Proteus, in the simulation of this system, the contactor is replaced by a light bulb, and the on and off of the light bulb represents the on-off of the contactor switch.

### 6.1. System temperature control simulation results

After consulting the relevant information of electric vehicle batteries, we can know that for general lead-acid batteries, when the temperature is higher than 70°C, it will affect the service life of the battery and even cause safety hazards. Therefore, here, the system sets the highest safety value to 70.0°C. When the actual temperature is 10.0°C, because within the safe value range, the single-chip microcomputer outputs a low level, the relay switch is turned off, and the light bulb is off, which means that the contactor normally closed switch is closed and the charging circuit is energized. When the battery temperature is within the safe value range, the simulation result is shown in Figure 15.

When the actual temperature value is 71°C, because it is higher than the safe value, the single-chip microcomputer sends out a high-level control signal, the relay switch is closed, and the light bulb is on, which means that the contactor normally closed switch is disconnected and the charging circuit is disconnected. When the battery temperature is higher than the safe value, the simulation result is shown in Figure 16.

ISSN: 2710-0588 DOI: 10.29556/FSE.202105_1(2).0019

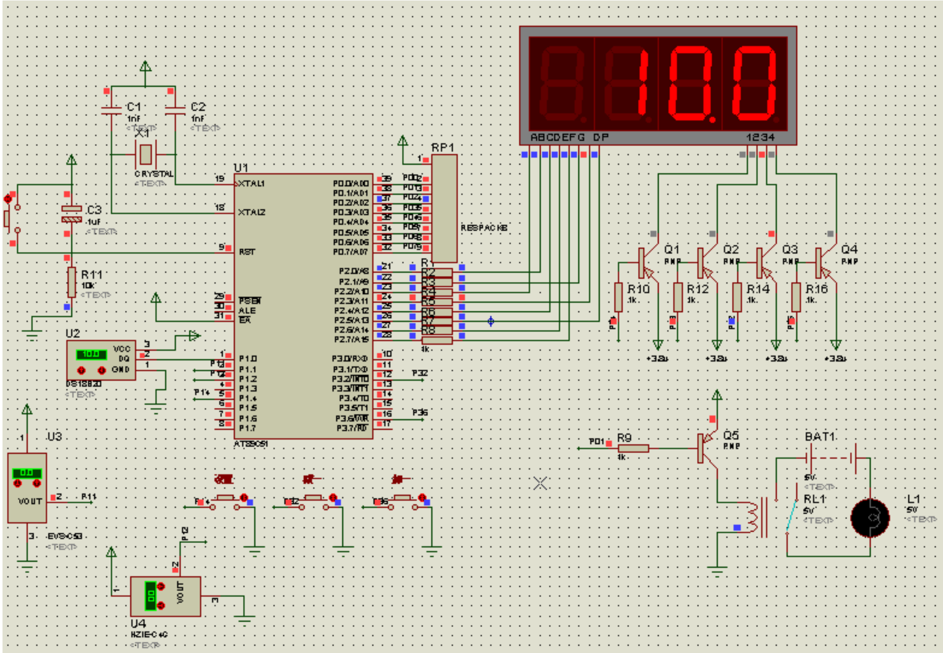

Figure 15. The battery temperature is within a safe range

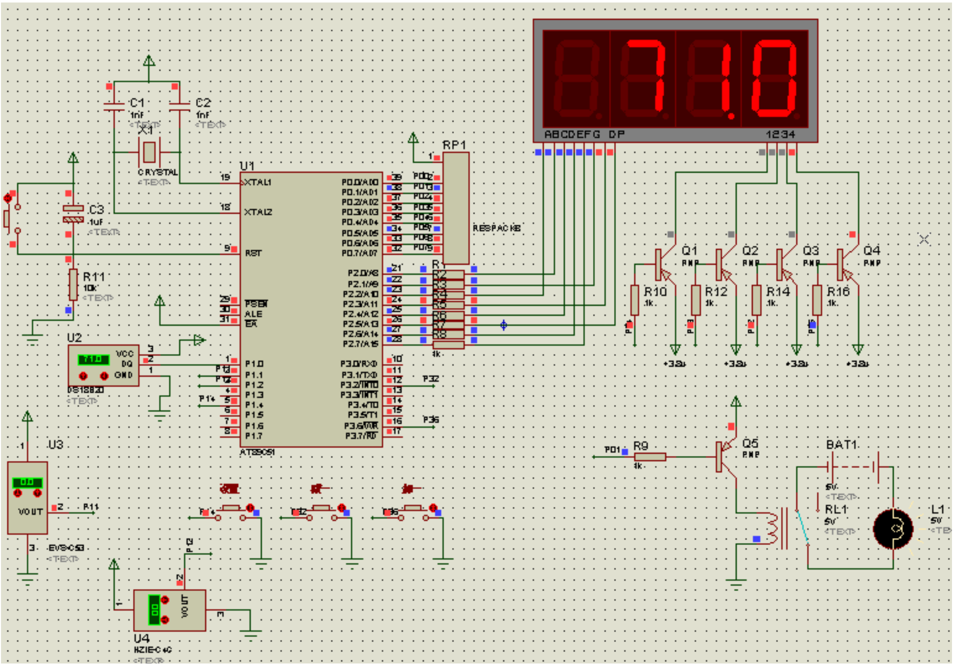

Figure 16. The battery temperature is higher than the safe value

## 6.2. System voltage control simulation results

Take an electric vehicle with four batteries as an example. Its rated voltage is 48V, and the safe output voltage of its charger is 57.6V~60.0V. If the charging voltage is too high or too low, the service life and safety of the battery will be reduced. Therefore, in this simulation experiment, the system sets the highest safety value to 60.0V and the lowest value to 57.6V. When the actual voltage value is 58.0V, because within the safe value range, the single-chip microcomputer sends out a low-level control signal, the relay switch is turned off, and the light bulb is off, which means that the contactor normally closed switch is closed and the charging circuit is energized. When the actual voltage is within the safe value range, the simulation result is shown in Figure 17.

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DOI: 10.29556/FSE.202105_1(2).0019

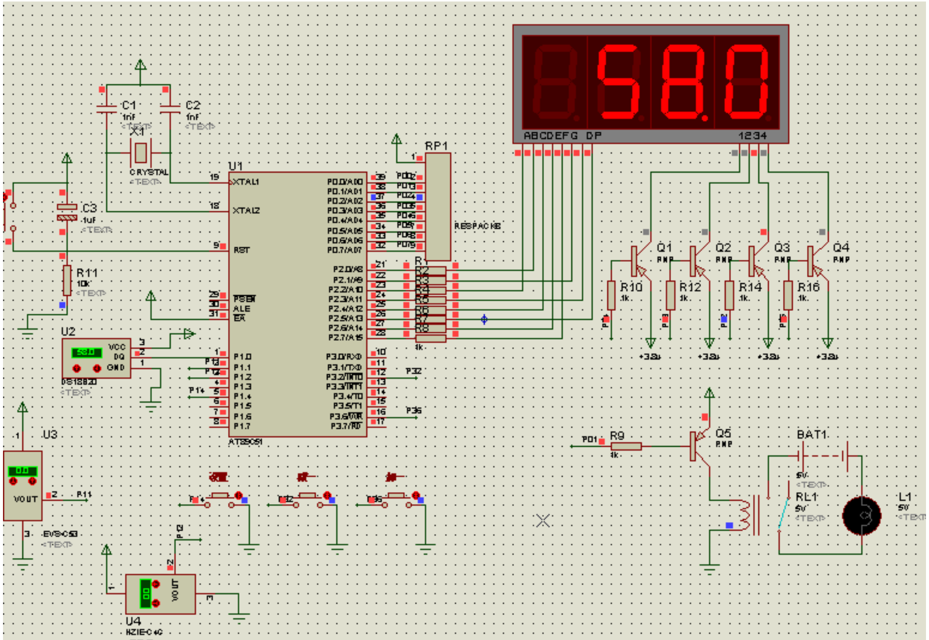


Figure 17. The actual voltage is within the safe value range

When the actual voltage value is 61.0V, because it is higher than the highest safe value, the single-chip microcomputer sends out a high-level control signal at this time, the relay switch is closed, and the light bulb is on, which means that the contactor normally closed switch is disconnected and the charging circuit is disconnected. When the actual voltage exceeds the safe value range, the simulation result is shown in Figure 18.

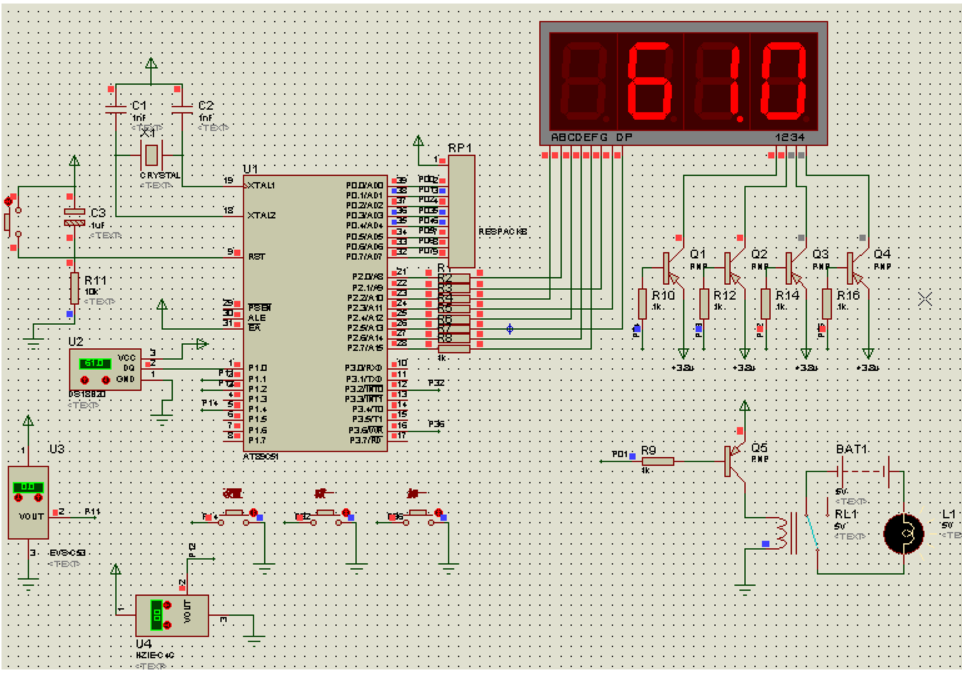


Figure 18. The actual voltage exceeds the safe value

## 6.3. System current control simulation results

When the electric vehicle is charging, if the charging current is too large, the battery liquid will heat up, which will affect its life, even explode, and cause an accident. Therefore, the most suitable charging current for electric vehicle batteries is one-tenth to one-twentieth of the

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battery capacity. Since the batteries currently on the market are generally 20AH~30AH, the safe charging current is 1A~3A. When the actual value is 2.0A, because it is within the safe value range, the single-chip microcomputer sends out a low-level control signal, the relay switch is turned off, and the bulb is off, which means that the contactor normally closed switch is closed and the charging circuit is energized. When the actual current is within the safe value range, the simulation result is shown in Figure 19.

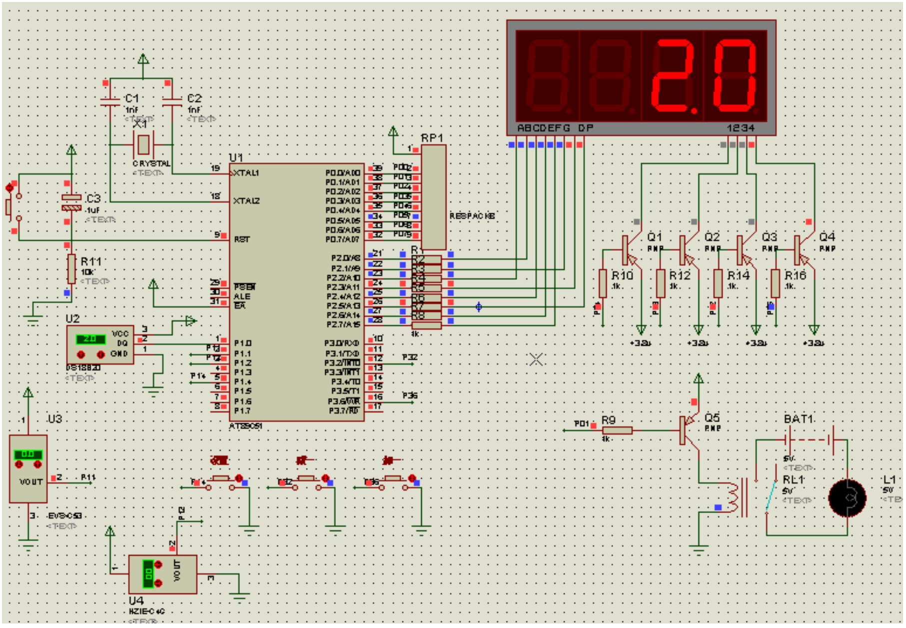


Figure 19. The actual current is within the safe value range

When the actual value is 4.0A, because it is higher than the safe current, the single-chip microcomputer sends out a high-level control signal, the relay switch is closed, and the bulb is on, which means that the contactor normally closed switch is disconnected and the charging circuit is disconnected. When the actual current exceeds the safe value range, the simulation result is shown in Figure 20.

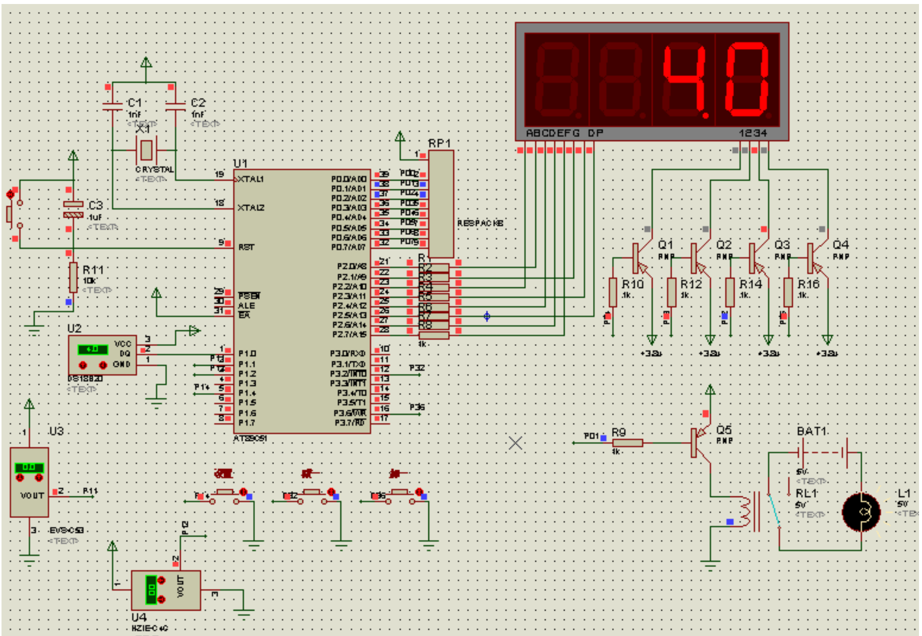


Figure 20. The actual current exceeds the safe value

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## 7. Conclusion

According to the current problems caused by high battery temperature, excessive charging voltage and excessive charging current in the charging process of electric vehicles, this paper designs a safety charger for electric vehicles based on a single-chip microcomputer. This system uses a cost-effective digital temperature sensor to automatically monitor the battery temperature, and uses a voltage sensor and a current sensor to detect the battery charging voltage and charging current. According to the actual situation of the battery working, the corresponding temperature, voltage and current safety values can be set. When the system detects that the measured data reaches a certain setting area, the single-chip microcomputer will immediately send a signal to control the working state of the relay. In order to facilitate the debugging of the system during the design process, this design adopts a modular design, including data acquisition, data processing, display, buttons, and actuators. From the final simulation results, it can be concluded that the system can basically realize the safe charging of electric vehicles. Compared with traditional control systems, this system has the characteristics of good stability, high control accuracy, good real-time performance, and easy operation.

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