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The design and function realization of smart socket

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Abstract

The hardware part of the design takes STM32 microcontroller as the core, and it is also assisted by the detection module, communication module, display module, alarm module and power supply circuit module. The detection module can detect the electric current and voltage in real time and calculate the electricity consumption, power, power factor and frequency. The communication module is used to send the data processed by STM32 MCU to the mobile phone client and receive instructions from the mobile phone client. The display module is used to display the data obtained by the detection module. Alarm module alarms when voltage exceeds 265V or current exceeds 3A; The power circuit module provides 3.3V DC stabilized power supply for other modules and sub-circuits. The software part uses C language as the programming language, and the client uses Android phone to complete the construction. The finished smart plug can complete the detection of current, voltage, power, frequency and power factor, and can send the data to the mobile phone client through the WiFi communication module for display through the display module. Users can also control the working status of the plug through the mobile phone client. When the detected load voltage exceeds 365V or the current exceeds 3A, the plug can cut off the circuit in the case of automatic detection of abnormality and alarm.

Keywords

SCM; Module; plug; detection.

1. Introduction

1.1. Demand

With the rapid development of Internet technology and the further improvement of living standards, consumers also put forward higher requirements for the safety of plugs and sockets. The traditional smart plug can not be connected with the mobile phone, so the power data detected by the smart plug can not be sent to the user, and the user can not control the working state of the plug through the mobile phone at the first time. In this way, the power safety is greatly threatened. With the rise of WiFi communication technology and the concept of Internet of things in recent years, plugs that can realize real-time detection of power parameters and have WiFi networking function occupy an increasing market, and the related core technologies such as MCU and WiFi communication have gradually become the research hotspot in the field of intelligent plug. The future smart plug needs to realize plug networking, power parameter detection, overload protection, alarm and other functions in close combination with MCU technology and WiFi communication technology on the premise of cost control.

Figures 1.1 below shows a smart plug which we can buy nowadays.

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Figure 1.1 smart plug

1.2. Research purpose and significance

This design is a smart plug design based on WiFi technology and single chip microcomputer technology. Through this design, it aims to create a safer and more convenient home equipment use environment for each family. Completing the design of smart plug not only has a further understanding of WiFi interconnection technology and MCU technology, but also lays a solid foundation for man-machine interconnection and home interconnection in the future, which is of positive significance to the development of smart home industry and the further improvement of people's living standards in the future.

2. Design

2.1. Function Design

Combined with the requirements and the overall framework of smart plug, the preliminary functional design is carried out. The specific function design is as follows:

(1) Under the condition of ensuring normal operation, chips and modules with relatively low working and standby energy consumption can be used. At the same time, the standby energy consumption can be further reduced by controlling the start and stop of the plug through the mobile phone. The establishment of the whole system can be completed by using the popular single chip microcomputer technology and C language programming technology.

(2) The voltage measurement circuit and current measurement circuit are used to detect the voltage and current parameters. The measured data are processed by the single chip microcomputer, and then sent to the mobile phone client by the WiFi communication module. The mobile phone client can also send instructions to the plug to control the solid-state relay to control the start and stop of the socket according to its own needs.

(3) The design of intelligent plug is based on ordinary plug. It can meet the intelligent demand and reduce the production cost without changing the original house structure.

(4) Judge the working state of the smart socket according to the state of the LED lamp.

(5) Set overload protection. The single chip microcomputer sets the alarm voltage and alarm current in advance. When the detected voltage or current parameters exceed the alarm value, the single chip microcomputer can control the solid-state relay to cut off the circuit.

2.2. Scheme selection

2.2.1 Communication scheme

WiFi is a kind of short-range wireless communication technologies,using 2.4GHz frequency band and DSSS technology.Compared with ZigBee technology, WiFi has higher bandwidth, faster transmission and wider coverage. For the monitoring system with high real-time requirements, WiFi is undoubtedly a better choice. At the same time, WiFi technology is better known and more mature than ZigBee technology. WiFi based smart plug products are more in

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line with the market development trend. Therefore, WiFi is selected as the communication scheme of smart socket in this design.

2.2.2 Detection scheme

This design uses traditional voltage transformer and current transformer to measure related parameters. Compared with the shunt resistance ,the traditional voltage and current sensors can measure the larger current and voltage, which not only saves the design time, but also makes the circuit design more convenient. The voltage and current signals are transmitted to the control module for further processing. To sum up, this design uses load series current transformer and parallel voltage transformer to detect current and voltage.

2.3. Design index

The parameters to be detected in this design include voltage and current. Current transformer and voltage transformer are used for detection. In order to ensure that the measurement range and accuracy meet the requirements, the parameter indicators and alarm values of the sensor need to be set. The specific design indicators are set as follows:

(1)The voltage detection range is 0 ~ 380V and the current detection range is 0 ~ 5A.

(2)The alarm voltage is set to 265V and the alarm current is set to 3A.

(3)The voltage measurement accuracy is 0.1V, the current measurement accuracy is 0.01A, and the accuracy error is less than or equal to ± 1%.

2.4. Overall system design

Figure 2.1 shows the overall design block diagram of smart plug. The hardware part of this design includes seven parts: detection module, communication module, control module, alarm module, display module, debugging module and power module.

The specific work flow is as follows: the current and voltage sensors send the collected power consumption parameters to the STM32 single chip microcomputer. After collecting and processing the data information from the voltage and current sensors, the STM32 single chip microcomputer sends it to the mobile phone client through the WiFi communication module and displays it through the LCD display module. When the smart plug detects that the voltage exceeds 265V or the current exceeds 3A, the alarm circuit will alarm. At the same time, STM32 single chip microcomputer controls the solid-state relay to disconnect the plug from the power supply. Mobile phone users can also use the mobile phone client to send instructions to STM32 single chip microcomputer through WiFi module to control the solid-state relay to disconnect the power supply of the load. In addition to the reset button in the design of the system, it is also used for resetting and debugging the system.

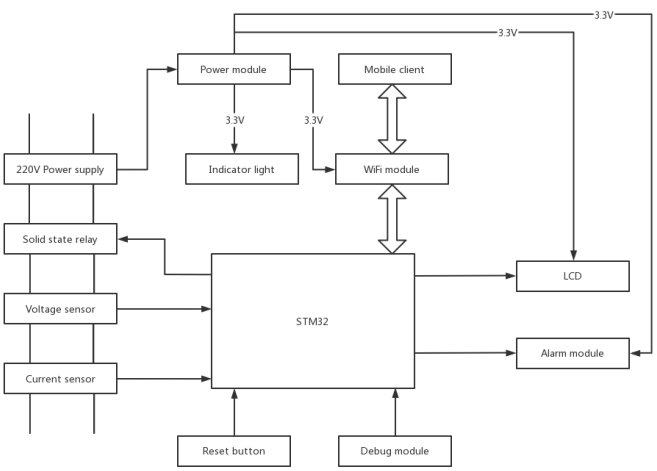

Figure 2.1 Overall design block diagram of intelligent plug

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2.5. Parameter analysis

This design uses the voltage sensor and current sensor to measure the voltage and current, the measured data will be sent to STM32, and then the parameters such as power, power factor and power consumption are calculated by STM32.Assume that the measured voltage is U ,the current value is i and the time of power consuming is t ,the active power P and apparent power S are:

$$S = Ui \tag{1}$$

$$P = Ui \times \cos\varphi \tag{2}$$

The power factor is:

$$\cos\varphi = \frac{P}{S} \tag{3}$$

The power consumption is:

$$W = Pt = Uit \tag{4}$$

3. System hardware

3.1. Control module

Figure 3.1 shows the minimum system design diagram of STM32 single chip microcomputer. The asynchronous reset pin is externally connected with the reset circuit. There are two pins boot0 and boot1 on each STM32 chip. The level state of these two pins during chip reset determines the area from which to start the program after chip reset. If you want to program the single chip microcomputer, you must meet that boot1 pin is at low level. Therefore, The method of external 10K pull-down resistance and grounding is adopted to meet the requirements. At the same time, four additional shunt capacitors are set to ensure the stable operation of the system. The above parts together constitute the minimum system of STM32 single chip microcomputer.

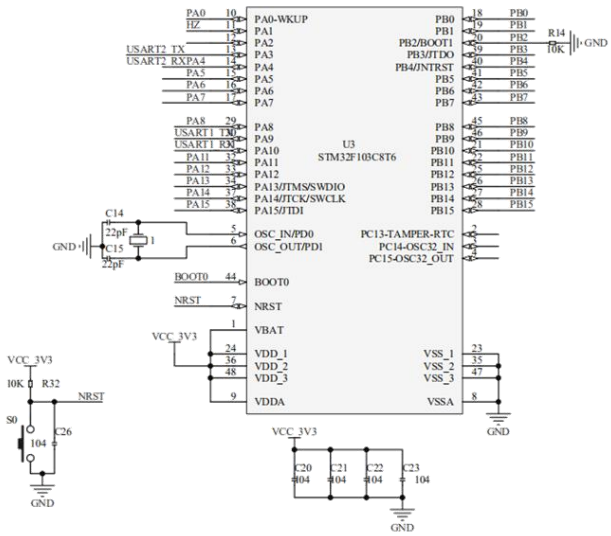

Figure 3.1 STM32 minimum system design

3.2. LCD module

Figure 3.2 shows the LCD1602,The main function of this module is to display the processed voltage, current, active power, power consumption, frequency and power factor from STM32 single chip microcomputer through LCD1602 display screen. It can display two lines of four

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data on each page. The whole display module needs to display six parameters in total, so it needs to be divided into two pages for display. The specific display content and unit of each page are shown in table 3.1.

Table3.1 Display content and measuring unit

	Data 1	Data 2	Data 3	Data 4
Page one	Consumption/Kwh	Frequency	Voltage/V	Current/A
Page two	Voltage/V	Current/A	Power factor	Power/W

Figure 3.2 LCD1602 module

3.3. Detection module

Figure 3.3 is the detection module of this design. The whole detection module includes three parts: current transformer, voltage transformer and electric energy metering module. Im1281B electric energy metering module is selected as the electric energy metering module. The module adopts the circuit design of complete isolation, which solves the safety problems caused by incomplete isolation between digital circuit and strong current, and can be easily embedded into various equipment that need to measure power consumption. In this design, the module is used to detect the current and voltage consumption of household appliances using 220V AC.

Figure 3.3 Im1281B detection module

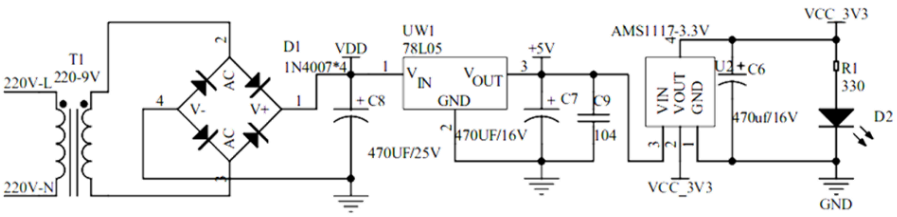

Figure 3.4 the design of power supply module

3.4. Power supply module

Figure 3.4 shows the design of power supply module. The specific work flow is as follows: firstly use DB-5VA transformer to convert 220V AC into 9V AC, then convert it into DC through bridge rectifier circuit, and then use AMS1117-3.3V chip to obtain 3.3V DC through secondary voltage reduction and stabilization.

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4. System software

4.1. System main program design

The following figure 4.1 shows the main program flow chart of this design, The main function first executes a series of initialization functions, which configure the I/O pins and microcontroller resources used by each module. Then the program executes subroutines such as communication program and display program. For example, LCD1602 module will execute from the initialization program first. When the system initialization is completed, enter the if judgment statement. After the system is powered on, the program will always execute the if function. When the statement is true, execute the statement, otherwise skip the statement. Continuously refresh the detection of voltage and current parameters throughout the cycle.

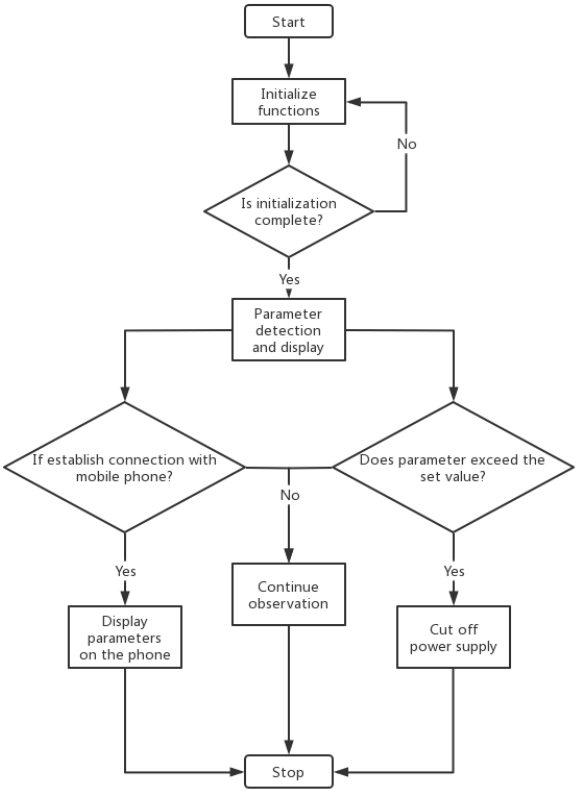

Figure 4.1 the main program flow chart of smart plug

4.2. Communication subroutine

The communication module of the system is used to receive the data from STM32, and send the received data to the mobile phone client. First, the WiFi module is initialized, and then the data is sent through the phone client to establish a connection with it. When the connection is established, the data sent by the WiFi module will be displayed through the phone client. As long as the connection exists, the data of the WiFi module will be sent to the mobile client, and the mobile client, when acting as the instruction sending end, is similar to the receiving end. After the connection is established, when the mobile client has instructions to send, the instruction is executed until the next instruction is sent. The subprogram flow diagram of the communication module is shown in figure 4.2.

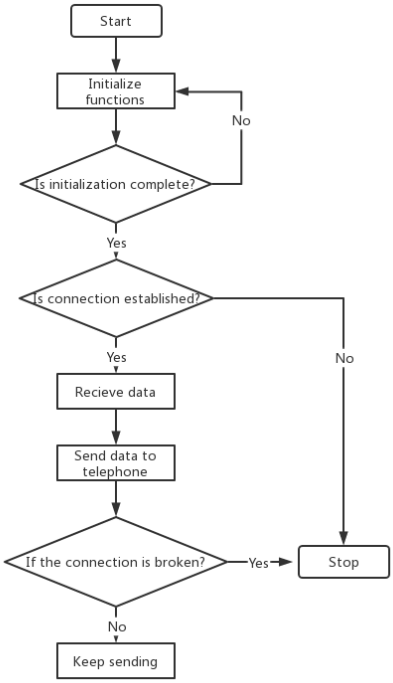

Figure 4.2 the flow chart of communication subroutine

4.3. Alarm module subroutine

The subroutine of the alarm module needs to set the voltage and current alarm value ahead of time for the STM32 mcu. When the current detected by the detection module exceeds 3A or 265V, the STM32 mcu sends the signal to the alarm circuit, the buzzer of the alarm circuit starts to give an alarm until the parameters return to normal before stopping the alarm. The flow chart of the alarm module is shown in figure 4.3.

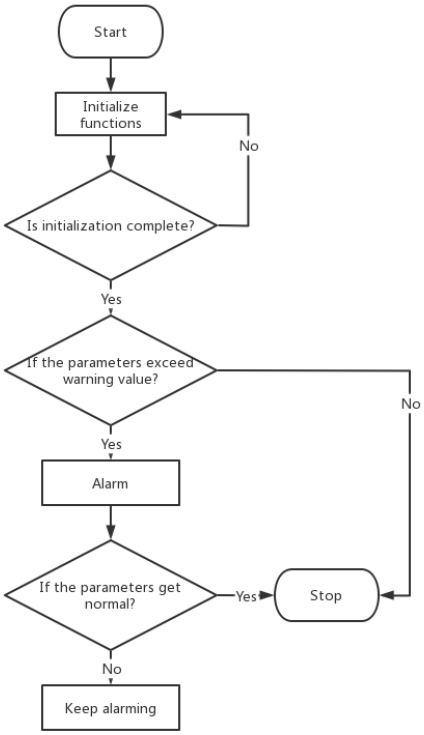

Figure 4.3 the flow chart of alarm module subroutine

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5. System function test

5.1. Communication Test

The steps to establish communication between the phone client and the WiFi module are: turn on the smart plug switch and the WLAN option in the Android smartphone settings, select the wireless network called USR-WIFI232-T to connect, as shown in Figure 5.1.

Figure 5.1 select the wireless network of WiFi module to connect

Open the network debugging assistant app, select the TCP client option, and enter the IP address 10.10.100.254 and port number 8899 of the WiFi module in the interface. After entering, click open, and the IP address and port information input interface is displayed as shown in Figure 5.2.

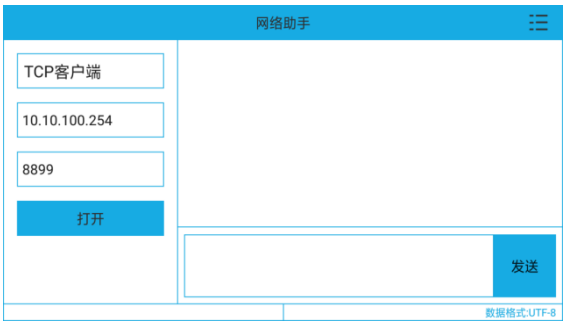

Figure 5.2 IP address and port number to be entered in the user interface

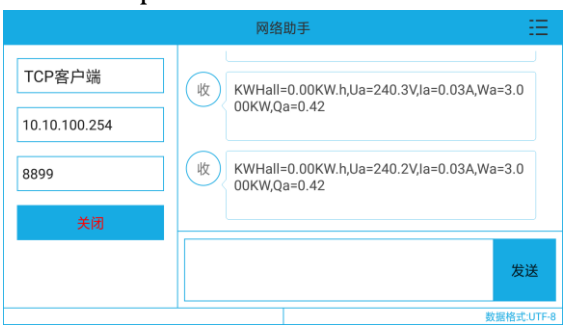

Figure 5.3 display of mobile client page after successful connection

If the connection is successful, the app interface will continue to display the data information sent by the WiFi module. If you want the smart plug to stop working, enter 2 in the input window and click send. If you want the smart plug to resume working, enter the number 1 in

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the input window to restart working. The interface after successful connection is shown in Figure 5.3.

5.2. Joint testing

After completing the mobile client test, then conduct joint test.

Power on the plug, press the switch, the LCD1602 display screen will display data, and the power circuit indicator will light up, as shown in Figure 6.1.

Figure 6.1 status of plug when the load is not connected

After the load is connected to the plug and the mobile phone is connected to the WiFi module, the power, current and other parameters displayed on the LCD1602 display screen change significantly, and the WiFi module indicator is lit, as shown in Figure 6.2. The mobile client page is shown in Figure 6.3.

Figure 6.2 status of plug when load and mobile phone are connected

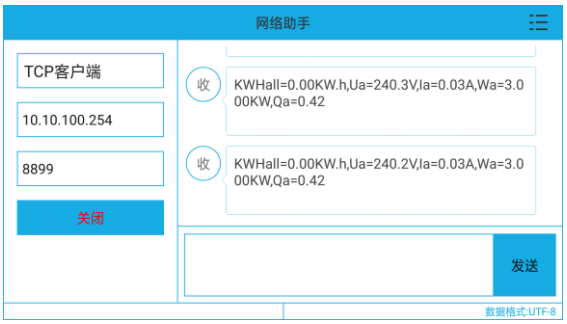

Figure 6.3 mobile phone client interface when accessing load and establishing connection with plug

Press the page turning button, and the type of data information displayed on the LCD1602 display screen changes to power factor and power, as shown in Figure 6.4.

Figure 6.4 status of plug after pressing page turning button

After pressing the power reset button, the power displayed on LCD1602 screen will be reset. As shown in Figure 6.5, the mobile client interface is shown in Figure 6.6.

Figure 6.5 status of plug after pressing power reset button

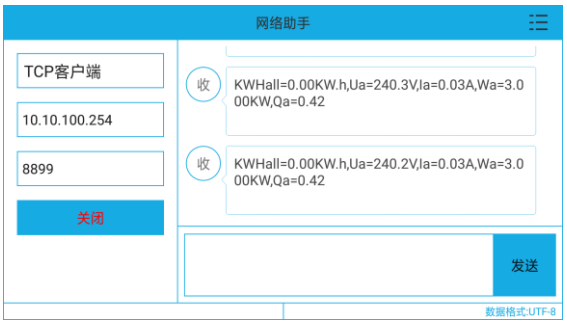

Figure 6.6 mobile phone client interface after pressing power reset button

6. Summary and outlook

6.1. Summary

(1) The standby energy consumption can be further reduced by controlling the start and stop of the plug through the mobile phone. The establishment of the whole system can be completed by using STM32 single chip microcomputer technology and C language programming technology.

(2) The voltage and current parameters can be detected. The measured data can be sent to the mobile phone client by the WiFi communication module. The mobile phone client can also send

instructions to the plug to control the solid-state relay to control the start and stop of the plug according to its own needs.

(3) It can meet the intelligent demand and reduce the production cost without changing the original house structure.

(4) Judge the working state of the smart plug according to the state of the LED lamp.

(5) When the detected voltage or current parameters exceed the alarm value, the single chip microcomputer can control the solid-state relay to cut off the circuit.

6.2. Outlook

(1) On the basis of data transmission, the data storage function is realized.

(2) Better integrate the Internet of things technology, and the data can be sent not only to the mobile client, but also to the cloud.

(3) Realize ultra long distance information transmission and instruction sending.

(4) Further reduce the size of the socket.

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