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Design of Automatic Curtain in Intelligent Home System

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Abstract

In recent years, with the rapid development of electronic information technology and computer technology, smart home has become a hot spot in the field of the Internet of Things, and gradually integrated into people's lives. Smart curtains are an important component of smart homes. The use of smart curtains can provide people with a suitable indoor environment and reduce the waste of electrical energy. This paper designs an intelligent curtain based on a single-chip microcomputer. The system can automatically detect ambient temperature and light conditions through the use of sensors, and control the opening and closing of the curtain according to different conditions and parameters. In addition, the curtains will automatically open and close during the specified time period. The system is cheap, convenient and easy to use, and has certain practicality.

Keywords

Intelligent curtain, microcontroller, sensors.

1. Introduction

With the development of technology, manufacturing technology, 5G and other technologies, smart home has become a hot topic of public attention. Its development is very rapid, and now many companies are involved in the production of smart homes. Home automation has three main advantages: (1) Reducing the impact on the environment: By controlling the layout of windows, utilizing natural light, ventilation, or shading, ensuring that the system is enabled only when power and light are needed, reducing the use of energy and water; (2) Improve quality of life: Intelligent homes provide appropriate heating, cooling, lighting, and watering; (3) Using automation systems in smart homes provides a sustainable indoor environment by saving electricity and water bills. In the North American market, brands such as Amazon, Google, and Apple are particularly prominent, and the main sales market is dominated by the curtain of Quoya's intelligent system. These smart curtains from Quoya are compatible with Alexa, IFTTT, Google Home, and SmartThings, providing many options when linking them to smart home control settings using your phone or the provided remote control. The curtains themselves are even touch sensitive, as long as they detect that your hand is opening or closing, they will activate [1].

The realization of smart home is mainly controlled by a microcontroller. The application occasions of different bit microcontrollers are also different. In embedded operating systems, 32-bit is commonly used [2]. The work of a single chip computer is relatively independent. The single chip computer has a RAM memory chip, while traditional microprocessors do not, and other data memories need to be connected. The combination of curtain and single-chip microcomputer has become an important direction of modern production research to make it more intelligent. Microcontrollers have also been rapidly developed and popularized. The concept of smart home in China has gradually emerged in recent years. Alibaba's Tmall Genie and Xiaomi's smart bracelet, audio, and Mijia are popular among young people. Smart curtains, as a part of smart home, have also been applied in large cities [2]. Curtain is an essential and

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familiar thing in every family. Considering people's actual life, it is necessary to design a curtain with automatic, light controlled, and wireless remote control functions, which can greatly facilitate people's lives. This design basically realizes the basic functions and automation of household intelligent curtains, and is easy to operate [3].

2. Overall design

This design is an important application in the field of the Internet of Things. Taking the microcontroller control system as the research object, a smart home system is designed. In the hardware system, STC89C52 is selected as the core design, DS18B20 sensor is used as the temperature sensor, LCD 1602 liquid crystal display is used as the display output, key input is used to set the control mode and timing, 5V voltage is used to power the system, and HC05 module is used as the Bluetooth serial communication module. ADC0832 is a dual channel A/D conversion chip. Used for digital to analog conversion connected to a photosensitive resistor. The stepping motor is a 28BYJ48 type four phase eight beat motor [4].

After turning on the power, the program initializes the LCD, serial port, input/output interface, etc. After that, the program displays information on the display, and then the program performs key detection. When receiving the signal transmitted by the button, the corresponding function will be executed to control the curtain. There are four main control methods:

(1) Manual control: Control the output signal by pressing the button to make the program control motor forward and reverse.

(2) Automatic light control: The switch of the curtain is determined by the control of the light intensity received by the sensor. When the photosensitive sensor is higher than the set initial value, the curtain will be closed, otherwise, the curtain will be opened.

(3) Time control: This function can meet the user's demand to open or close the curtain at a specified time.

(4) Bluetooth remote control: The Bluetooth module communicates with remote devices through a link, receiving signals to achieve curtain opening and closing [5].

3. Hardware of the system

3.1. Main controller

This design uses STC89C52 as the core control component of the system, which has the characteristics of low price, powerful functions, and high flexibility. Only after it can work properly can other components enter the normal working state. The 51 core microcontroller has good compatibility and does not require a dedicated emulator or or programmer. Its internal storage mode is erasable and writable, and stored data will not be lost after power failure. It is also plug and play, very intelligent and reliable, and also has a watchdog timer function [6].

3.2. Temperature module

DS18B20 is a temperature sensor with a measurement temperature range of - 55 °C to +125 °C. Due to temperature effects, its measurement accuracy varies with temperature. The temperature measurement accuracy of this module will be slightly affected in the range of -10°C to +85 °C. The DS1822 has a poor accuracy of around 2 °C. The temperature signal received by the chip is directly transmitted digitally via a "one wire bus" at the field temperature. This can significantly improve the anti-interference ability of temperature control systems, and is therefore suitable for on-site temperature detection work under harsh conditions, such as environmental management, equipment and production process management, and electronics in temperature detection. Compared to previous generation products, the new product

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supports a voltage range of 3V to 5.5V, making it more flexible and convenient in system design. And the new generation of products is cheaper and smaller in size.

The internal structure of the DS18B20 mainly consists of four parts: a 64 bit lithographic ROM, a temperature sensor, nonvolatile temperature alarm triggers TH and TL, and configuration registers. The light metering module is used to sense the intensity of light, thereby switching the curtain. This design uses a photosensitive resistor to collect light intensity signals, generate signals, and then convert them into digital signals by ADC0832 [7].

The initialization sequence of the DS18B20 starts with the initialization sequence for all transactions on the 1-wire bus. The initialization sequence consists of reset pulses sent by the bus host and presence pulses sent by the slave. After the host detects the presence of pulses, it issues a ROM command. These commands operate on a unique 64 bit ROM code for each slave device, allowing the master command to select a specific device if there are many commands on the first line bus. After using the ROM command to process the DS18B20 with which it wishes to communicate, the main line can issue one of the DS18B20 function commands. These commands allow the master server to write and read from the DS18B20's result staging memory, initiate temperature conversion, and determine the power mode [8].

3.3. Photosensitive module

This design uses our most common ADC conversion chip - ADC0832. The photosensitive resistor and the A/D converter are combined, and the light analog quantity received by the photosensitive resistor surface electrode is converted into a digital quantity through A/D, and the digital quantity information is displayed on the liquid crystal display screen through code compilation.

ADC0832 is a relatively common 8-bit resolution A/D conversion chip on the market at present, with a maximum resolution of 256 levels, which can adapt to general analog conversion requirements. The multiplexing of its internal power input and reference voltage allows the analog voltage input of the chip to be between 0 and 5 V. Chip conversion time is only 32 μ S. It is reported that dual data output can be used as data verification to reduce data errors, with fast conversion speed and strong stability. Through DI data input, channel functions can be easily selected.

When ADC0832 is not operating, its CS input should be high. At this point, the chip is disabled, and the CLK and DO/DI levels can be arbitrary. During A/D conversion, the CS enable terminal must be placed at a lower position and kept at a lower position until the conversion is completely completed. At this time, the chip starts to convert, and the processor inputs clock pulses to the chip clock input terminal CLK, while the DO/DI terminal uses the data signal selected by the DI terminal input channel function. Before the first clock pulse sinks, the DI terminal must be high to indicate the start signal [9].

3.4. Clock module

The clock chip used in this module is the DS1302, which is a trickle charging clock chip manufactured by Dallas Corporation and contains a real-time clock/calendar and 31 bytes of static RAM. It communicates with the microprocessor through a simple serial interface, providing seconds, minutes, hours, days, months, and years for the real-time clock/calendar. Automatic adjustments will be made to month end dates that have only 28 or 27 days in February, including leap year corrections. The clock operates in a 24-hour or 12-hour format and uses synchronous serial communication with AM/PM indicators to simplify the interface between the DS1302 and the microprocessor. The DS1302 uses an external 32.768KHz crystal. The oscillating circuit does not require any external resistance or capacitance to operate.

In the detailed definition of the DS1302 pin, Vcc1 is the main power supply; Vcc2 is the backup power pin. When Vcc2>Vcc1+0.2V, power is supplied from Vcc2 to DS1302, and when

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Vcc2<Vcc1, power is supplied from Vcc1 to DS1302. SCLK is a serial clock, input; I/0: bidirectional data line for three wire interface; CE: When reading and writing data, the input signal must be high. This pin has two functions: first, CE starts controlling the control logic of the word access shift register; Secondly, CE provides a method for ending single byte or multi byte data transmission. When reading (viewing time information) and writing (setting time information) data to the DS1302, it is necessary to write "0" and "1" and pass a certain conversion relationship, and then display the time information to the LCD screen through the display module [10].

3.5. LCD display

The LCD 1602 liquid crystal display is a widely used character type liquid crystal display module. 1602 has a specific meaning, meaning that the LCD can display 16 characters, and 02 means that the LCD requires a voltage of 5 volts and a current of 2 mA for normal operation. The normal displayed character size is 2.95mm wide and 4.35mm high. The 1602 liquid crystal display is divided into two types: non backlight and backlight, but either backlight or non backlight is invisible on the physical object, and there is no difference or impact in use. Therefore, special methods should be used to test whether backlight is present. This type of liquid crystal display generally uses an HD44780 controller 1602. The internal liquid crystal has 80 bytes of RAM, which is 16 * 2 lines. The address of the first line is 0x00H to 0x27. The second line is from 0x40 to 0x67. The address of the first line corresponds to the 16 bit characters to be displayed. Similarly, the second line corresponds to the characters to be displayed on the second line. When determining whether the system inputs a position signal or a content signal, you can use the power-on state of the RS pin. If RS is at a low level ("0"), select the command register (display position); If RS is high level ("1"), select the data register (display content).

The display module needs to set its display location and display content. It is known from the above that the LCD 1602 can display a total of 32 spaces, and to display the desired content and location on the display screen, it is necessary to use C language to connect the microcontroller and the display screen. Since only 5 bits are needed to replace 32 spaces, the highest bit can be fixed to 1. If the remaining seven bits are written to 0x01, and LCD1602 receives a message of 1000 0001, the data will be displayed in the second space, and so on. When inputting the characters you want to input, you can also use "0" and "1" to form a byte to express the characters you want to input. There are two ways to connect the LCD1602 to the microcontroller, direct control and indirect control. The two control methods are basically the same, with the difference only in the amount of data lines used. When writing content at a specified location, you must first specify the address.

3.6. Motor drive

The stepping motor used in this design is a 28BYJ-48 stepping motor. The stepping motor 28BYJ48 is a four phase eight beat motor with a voltage of DC5V-DC12V when used. When a continuous current control pulse is applied to the stepper motor, the stepper motor can continuously rotate. The inlet of a stepper motor is a pulsating sequence, while the outlet is a relative incremental or stepping motion. Under normal motion conditions, it produces a constant number of walking steps per revolution; When performing a continuous stepping motion, its speed maintains a strict relative relationship with the frequency of the input pulse, and is not affected by voltage fluctuations and load changes. ULN2003 is a product of Darlington transistor arrays, with advantages such as high voltage gain, high operating voltage ratio, wide operating temperature range, and strong load carrying capacity. It is suitable for various industrial systems that require high power drives.

Each pair of Darlingtons in ULN2003 is connected in series with a 2.7K base resistor. ULN2003 is a high voltage, high current Darlington display composed of seven silicon NPN Darlington

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tubes that can directly drive loads such as relays. At a working voltage of 5V, it can be directly connected to TTL and CMOS circuits, and can directly process data lines that initially require standard logic buffers. The ULN2003 is a seven way Darlington driver array that is an inverter with an open collector (OC) output. The maximum drive current can reach 500 mA. Typically, one end of a load stepper motor is connected to a VDD (12V) and the other end is connected to an output pin. The com terminal of ULN2003 is mainly used for two purposes. Firstly, the com terminal can be connected to the positive voltage of the power supply to reduce the amplitude of the pulse voltage, which is as low as the diode voltage drop plus the power supply voltage, so that the internal triode can withstand the minimum positive voltage pulse. Secondly, there is a diode inside the device, which is connected to the ground and is specifically used to reduce the pulse voltage of the power supply ground minus the forward voltage drop of the diode, minimizing the impact of the reverse bias voltage on the internal transistor.

4. System design

4.1. Design of hardware

4.1.1. Clock circuit

The clock circuit is the core of the microcontroller. This design uses DS1302, a digital clock chip that can provide information such as seconds, minutes, hours, days, months, and years, and also has the ability to automatically adjust software, which can improve the stability of the microcontroller.

Take the write data conversion as an example to illustrate the functional implementation. The timing chart contains two bytes, the first byte being the address/command byte, and the data byte being written to the second segment. "When the CE is at a low level, neither SCLK nor I/O can read or write data. Only when the CE is at a high level can SCLK and I/O make changes.". When CE changes from low to high, the delay time is variable, and the setting can be skipped. When the SCLK and I/O signal changes are completed, the CE signal is pulled low. In the I/O line, there is a delay time between BCs. At point C, the 1-bit signal is ready to be sent from the lowest bit, and at point D, the SCLK is pulled high. After a delay time, the 1-bit signal is sent to point E. Repeat this for a total of eight times.

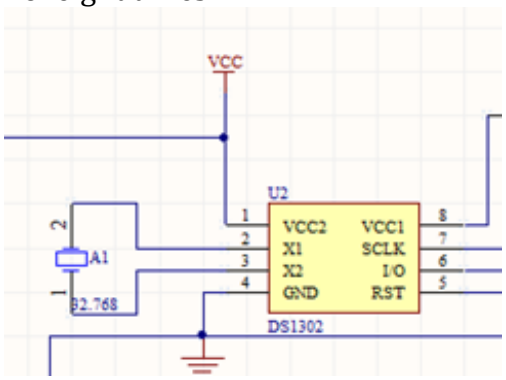

Figure 1 Clock Circuit

4.1.2. Reset circuit

Errors may occur during system operation, so a manual stop button is required. This button can prevent the reset of the single chip computer from occurring, preventing errors from continuing to occur. Errors in the operation of the single chip computer may cause serious consequences, and may cause harm to the user when the development board where the single chip computer is located is seriously damaged. Therefore, resetting the circuit is very necessary.

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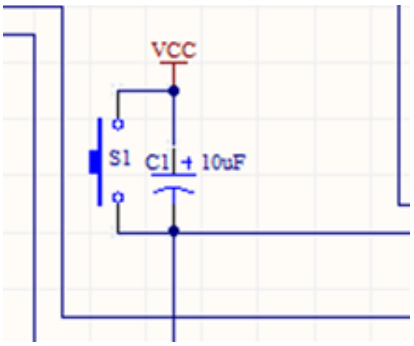

Figure 2 Reset Circuit

4.1.3. Motor drive circuit

ULN2003 is a typical integrated Darlington transistor IC. Its main features are: 500 mA rated collector current (single output), high voltage output: 50 V, compatible with input and various logic types and relay drivers. The ULN2003 has a high current gain and although it operates at a high voltage when powered on, it can be used over a wide range of temperatures, has strong load capacity, and is highly practical. When a low level is input at the input end of the Darlington tube inside the ULN2003 to turn it off, the driving element is an inductive element, so the current cannot suddenly change. At this time, a high voltage will be generated, and the Darlington tube will be broken down. Therefore, a diode is required, which mainly serves as a protective role. The input terminal can be directly connected to the pins of the MCU using TTL level control, and the output terminal can be connected to the drive circuit. See Appendix 2 for relevant codes.

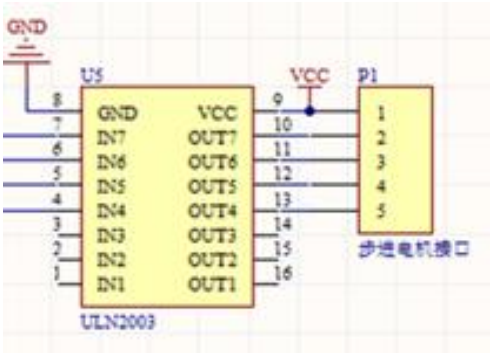

Figure 3 Motor Drive Circuit

4.1.4. Function realization of Bluetooth module

The HC05 module is a master-slave Bluetooth serial port module produced by Alientek and can also work with other intelligent terminals with Bluetooth functionality. The commonly used "automatic connection" module only converts the information received from the RxD pin into a Bluetooth wireless signal and sends it to the receiver, or transmits the received wireless signal directly from the TxD to the arduino. The AT instruction is a command applied to the connection and communication between terminal devices and PC applications. However, the AT instruction does not utilize Bluetooth wireless transmission, but only uses the TxD and RxD pins of the module to communicate with the Rx and Tx connections of the arduino. Therefore, the Bluetooth module can only accept AT instructions in AT mode and issue various AT instruction commands to the module after being turned on. Before cooperating with other Bluetooth devices, the LED on the Bluetooth module will light up once per second [15].

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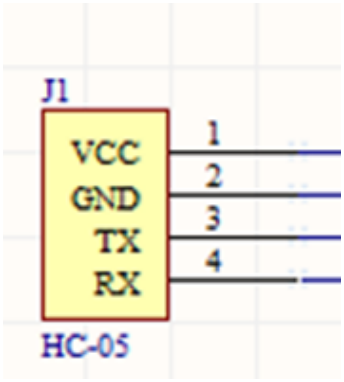

Figure 4 Bluetooth module circuit

4.1.5. Crystal oscillator circuit

The crystal oscillator in integrated circuits is also known as a quartz crystal vibrator, which is a structure composed of thin slices cut from the surface of quartz crystals. When an alternating current is applied to a crystal, the crystal will form thermodynamic vibrations and alternating electric fields. When the current changes to a specified value, the amplitude of the crystal will increase. Because quartz crystal vibrators have excellent high-frequency stability and the ability to resist external disturbances, quartz crystal vibration devices can be used to form a reference frequency spectrum. Use a reference frequency to control the accuracy of the spectrum in the circuit. The crystal oscillator circuit can also provide an accurate clock signal and clock frequency for the system, facilitating the synchronization of all parts and facilitating the synchronization of all parts. The maximum capacitance used in this integrated circuit is 30pF, while the crystal frequency is 12MHz.

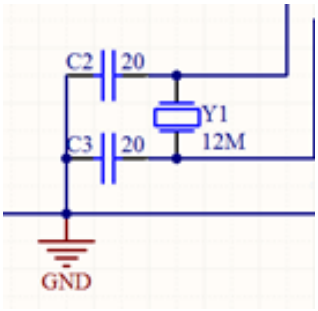

Figure 5 Crystal oscillator circuit

4.2. System programming

Based on the consideration of the usage scenario, the implemented functions are divided into multiple modules to be implemented one by one. After integrating the design logic sequence, programming is performed using C language and keil software, protel performs rendering, simulation debugging, and running the program, checking and correcting errors, and production begins after integrating the designs of others.

After the system starts running, it is necessary to initialize the LCD 1602 and memory, and then the clock circuit starts working. After reading the clock circuit time, it is displayed on the LCD. If a key signal is input, the corresponding command is executed and the mode is displayed on the display. The main function of the timing program is that the microcontroller can receive an interrupt signal at a set time to control the opening and closing of the curtain. The clock sends a fixed clock signal, which is sent to the microcontroller and the counter counts. However, after the count within the unit reaches 24 hours a day, the counter fills up and transfers the value to the designated unit in the storage unit. The subroutine for motor rotation is mainly used to control pulses and determine whether the forward and reverse rotation of the pulse sequence and the number of transmission steps have been completed.

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The count of DS18B20 is accumulated based on the preset base of the counter. When the counter 1 receives low temperature, the counter decreases. When it decreases to 0, the value of the temperature reading register increases by one, and the counter restores the preset value. When the value of the counter 2 is also 0, the count is stopped. At this time, the value of the temperature register is the measured timed weather temperature. Read the temperature, initialize the DS18b20, and start a temperature conversion command. Converting the temperature requires time, so it needs to be delayed appropriately. Initialize the temperature sensor again, read the register command, place the read temperature in the lower eight bits of value, convert the temperature value, and return the read temperature value. When the temperature exceeds the setting in the microcontroller, it will automatically alarm.

The photosensitive module mainly uses the resistance characteristic of the photosensitive resistor to achieve light control. The resistance value of the photosensitive resistor decreases as the light intensity increases. This relationship is used to determine the input voltage value corresponding to the light intensity, compare it with the reference voltage, and then send a signal to the microcontroller to change the operating direction of the electric machine. When the light is weak, the photosensitive resistor is high resistance, and the single chip is high level. The system controls the motor to reverse and the curtain is closed. Conversely, when the light intensity is high, the curtain is opened.

Bluetooth functionality requires the use of a mobile app for control, and there are many options for software design, such as app inventor and Android studio. Due to lack of familiarity with Java and C language development software, app inventor is used. This software is relatively simple to start with, and its fully visible operation makes the appearance and logic of the program more intuitive and clear. First, create a start interface, and add a layout on this interface. Select a horizontal layout and a vertical layout to add buttons to display information labels and control methods, respectively. You can also use custom backgrounds and fonts. Then, logical blocks are placed in the work panel to splice logical functions, and logical blocks can share logical blocks. The logical design option sets the label to correspond to the content and dialog boxes invoked during runtime and keystrokes. After that, you can click to download the APK file to your computer to package and install it.

5. Commissioning

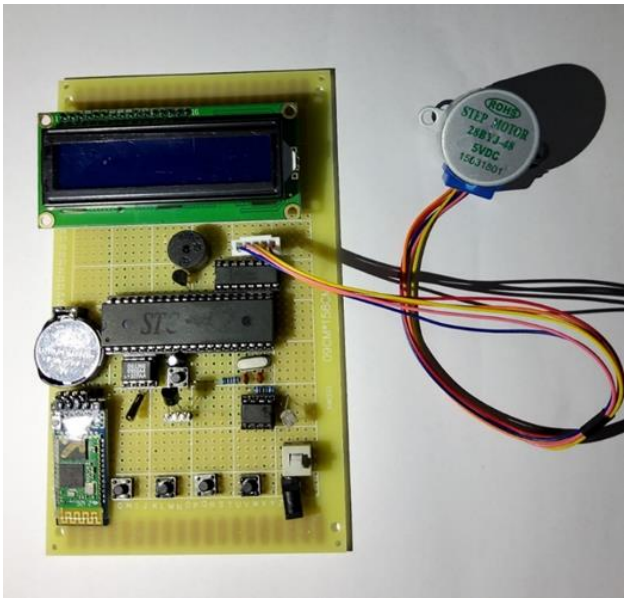

Figure 6 Physical diagram of the system

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After welding is completed, use a burner to insert the pins, check whether the com port is connected, and use the burning software to download and burn the program into the physical object. Turn on the power and the buzzer will sound. After the system is started, LCD 1602 displays the current date, temperature, light intensity, and other information. The current mode of the system will be displayed in the upper left corner of the LCD 1602. The default time control mode of the system is also the user-defined time control mode. Users can manually open or close the curtain by selecting the time after the curtain is opened or closed through the button circuit. Only in this mode can the current time and date be prompted and adjusted. The two time settings are not related to each other. This means that even after the user has set the curtain opening time, they can continue to set the curtain closing time, and this time can be set many times. At the same time, the button circuit can also change the mode and switch to the timing module. By setting the timing module's time, it is also possible to adjust the time between opening and closing the curtain. The key circuit can adjust the mode and switch to the timing mode. In manual mode, press the key to control the operation of the motor, and then press the button again to stop the motor. The system time, timing time, percentage of light intensity in light mode, and temperature can be set in the setting button (the first one measured on the right in the figure). In light mode, the curtain switch will determine whether the light intensity lux received by the photosensitive resistor is higher than the set initial value. When the light intensity of the photosensitive resistor is higher than the set value, the curtain will close. Otherwise, the curtain will be pulled open, enabling automatic operation during the day and night, and the temperature can be set by pressing the button. When the light is strong, the photosensitive module presents a low current, the stepper motor controlled by the program rotates forward, and the curtain is opened. The output current of the microcontroller terminates, and the stepper motor stops rotating. When the light intensity decreases again, the opposite motor opens the curtain. When pressing the button in the Bluetooth module, select HC05 in the Bluetooth module and connect it. After the terminal program is connected to the Bluetooth module, it sends a signal to achieve the remote control of the curtain switch. The corresponding buttons enable the function. The plus/minus and minus keys control the rotation and stop of the motor. The setting keys set the time, date, and light intensity. The mode selection button can control the mode of the smart home system on the interface.

6. Conclusion

This design takes the single-chip microcomputer control system as the research object, and designs a smart home system. In the hardware system, the popular STC89C52 single chip microcomputer or other single chips are used as the controller chip, and the light sensor and motor are configured outside the chip. The program code is optimized and compiled through the Keil software environment, realizing the function of automatically turning on and off according to the light and different time periods.

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