Intelligent Rice Cooker Control System Design

Guangyi Chen, Haoxuan Li, Ren Chen

Chengdu University of Technology, Chengdu, 610059, China.

Abstract

With the development of science and technology, the rice cooker also develops rapidly. At the beginning, mechanical heating or fixed power heating not only reduced the energy efficiency, but also made the price relatively high, and now it is difficult to meet people's growing living needs. This topic is the use of STM32 microcontroller as the main control core, the rice cooker as the control object, to low-cost, functional diversification, high energy efficiency as the design principle, design a rice cooker hardware control system; Moreover, I can independently judge the rice quantity of rice cooker, and then independently choose different heating schemes for different rice quantity. You can also achieve the appointment, memory, remote control and other functions. In terms of hardware, STM32F103VET6 single-chip microcomputer is mainly adopted as the main control core, and several circuits are added to OLED display circuit, matrix key circuit, temperature detection circuit, wireless communication circuit, heating circuit and power output circuit. The KEIL5 software is used to program the program, and the integration of each subroutine is performed in different functions and at different stages. The fuzzy algorithm is used to calculate the amount of rice; the PID adjustment is used to make the temperature of the control more accurate; the communication between the single chip and the host computer is realized by using WIFI. In the upper computer design to display and control the various functions and timing of the rice cooker. After testing, the system meets the functions required by the mission and has certain practical application value.

Keywords

Smart rice cooker; PID control; Fuzzy control; The remote control; STMsinglechip.

1. Introduction

1.1. The Purpose and Significance of the Project

With the development of science and technology, the improvement of the economy and the improvement of living standards, the requirements for diet are also getting higher and higher, and the rice cooker has become popular. At present, many rice cookers on the domestic market are heated mechanically or with fixed power, mainly using magnetic steel to temporarily lose magnetism after being heated, and the working principle of magnetism recovery after cooling to realize the control of the temperature of the bottom of the pot [1]. The price of these rice cookers is relatively high and the energy efficiency is also quite low, and now they can no longer meet people's quality of life requirements. Smart appliances have brought a lot of convenience to people today, and the modern development trend is also true. In the early part of the last century, the electronic intelligent control technology in industrial production has begun to develop, and it is developing faster and faster, followed by the development of microelectronics technology, control theory, and sensing technology, and the stability of controllable objects Performance, economy and complexity of operation have been improved. Looking back at the development history of rice cookers in China, although only a few decades, China’s rice cooker production industry has grown from weak to strong, from strong to sophisticated, and the scale of production is expanding at a high rate with an annual growth rate of not less than 30%. The content is not lower than imported products[2]. The introduction of smart rice cookers into people's lives has greatly improved people's lives. At the same time, smart rice cookers have also adapted to the development trend of the society. Therefore, they have developed a rice cooker with complete functions, high reliability and relatively low price. It has important significance[3].

1.2. Analysis of Research Status at Home and Abroad

Electric rice cooker has the name of electric cooker and electric rice cooker. It is heated by turning electric energy into heat energy by entering the heating plate. The electric rice cooker is easy to operate, clean and hygienic, and not only has one cooking function, but also Various functions such as congee and soup. Now the rice cooker is basically the most common electrical appliance in ordinary households. The invention of the rice cooker is convenient for people and saves the time spent by many families in cooking. In the 1850s, Inobu Dai of Tokyo Communications Engineering Company in Japan invented the world's first electric rice cooker.

In recent years, small home appliances have developed very rapidly, and the prospects are very promising. In the market, rice cookers are the best seller, and their retail sales are also higher than other electrical appliances. The rice cooker has a history of decades of development since its invention. From the small workshop manufacturing method at the beginning to the current assembly line manufacturing method, the products are slowly converted from simple rice cookers to current rice cookers. The original control method no longer meets the current needs, so it has gradually evolved from mechanical to Computer control. The function has also changed from the original only cooking rice to the current porridge and soup cooking[4]. The heating method is also gradually developing. The development of electromagnetic heating technology has gradually replaced the original ordinary electric heating method, which proves that the rice cooker technology is constantly improving. The design of the original rice cooker is very simple due to its inadequate technology. All functions can be completed with only one button. Computerized rice cookers have gradually replaced mechanical rice cookers. The computerized rice cooker is not limited to ordinary rice cooking functions. It can achieve multiple functions in one pot, integrating functions such as timing, cooking, porridge and soup. When cooking rice, there may be phenomena such as mashed rice, sticking to the pot, etc. This phenomenon can be eliminated by adding non-stick materials to the inner pot. In order to keep the moisture and nutrients in the food, many changes have been added to the lid of the rice cooker, and all the designs are in line with the intelligence of the current rice cooker.

Not only have smart rice cookers developed rapidly in China, but ordinary rice cookers abroad have basically withdrawn from the market. Smart rice cookers have spread to every household and are no longer as scarce as before. According to the top ten rice cookers nationwide in August 2018, the two brands of Midea and Supor have basically occupied two-thirds of the market in China, and these two are the winners of smart rice cookers[5].

The automatic heat preservation type is the old mechanical rice cooker, which is rarely seen in big cities now.

The timer heat preservation type is an electronic smart rice cooker, and its circuit design mainly uses a constant current source heating circuit with a temperature control system. The temperature sensor converts the measured temperature signal into a voltage signal and then inputs it to the control circuit, which drives the heating circuit to heat the heating wire set on the temperature sensor[6]. The electronic intelligent rice cooker can realize automatic reservation. This intelligent hardware mostly uses a simple automatic control system to complete the fixed set appointment time operation, and its function strength also depends on the strength of the controllable distance function[7]. Therefore, it is very necessary to develop a smart rice cooker with complete functions, low price and high energy efficiency. Combining the domestic and foreign rice cooker market conditions and research technology, it has designed and realized automatic heating, automatic heat preservation module, LCD display, appointment Timing and other functions[8].

The microcomputer-controlled rice cooker is the most technologically advanced, and the microcomputer-controlled rice cooker uses fuzzy control technology[9]. The advent of the microcomputer rice cooker can not only meet people's requirements, but also give full play to the various functions of the rice cooker. This represents that the rice cooker has promoted the development of household appliances in the direction of humanization, automation and intelligence[10]. For example, the fully automatic rice cooker based on C language has added the communication mode of wireless module to realize the remote control of the rice cooker system. The coordination work between the various parts of the system is realized through software programming[11], and artificial nerves can be added to the algorithm. Network temperature control[12]. In terms of remote control of rice cookers, there are endless solutions designed by people. For example, a smart rice cooker design solution based on mobile phone SMS remote control. This solution adopts mechatronics technology and can be remotely controlled through mobile phone text messages. The remote control module is responsible for Receiving information such as the set cooking time and meal amount remotely sent by the user's mobile phone, and the working status of the rice cooker can be fed back to the user through text messages[13]; the remote control of the rice cooker by the single-chip microcomputer also mentions the use of relays, solenoid valves, single-chip microcomputers, and electric The rice cooker, TC35I communication module, electromagnet, and water pipe are designed. When the signal sent is connected to the STC89C52 main control single-chip computer through the GSM network, it controls how long the solenoid valve opens, the amount of water in the rice cooker, and then closes the solenoid valve; The single-chip microcomputer turns on the relay to turn on the switch of the rice cooker, and the rice cooker starts to cook[14].

With the development of science and technology and society, smart rice cookers with high energy efficiency, diversified functions, and relatively cheap prices have entered people's lives and are deeply loved by people. Therefore, the future electric rice cooker will develop towards the trend of being more intelligent, easy to use, saving time and electricity.

2. System Design

2.1. System Function Analysis

The intelligence of the smart rice cooker is mainly reflected in the temperature control to make the cooked rice softer and smoother, so that the starch in the rice can be converted according to our ideas, plus some automatic control that ordinary rice cookers cannot achieve. The main workflow of the smart rice cooker is as follows:

1) Water absorption process: Use full power heating before the temperature reaches 50℃. When the temperature reaches 50℃, control the temperature and keep it between 50℃~60℃ to absorb water. Once the water temperature exceeds 60℃, the enzymes in the rice will convert and the rice will become mushy. The whole process takes about 13 minutes. The temperature is controlled by the PID control algorithm. Through this step, the rice can absorb as much water as possible, so that the cooked rice will be more delicious.

2) Heating stage: In this stage, the rice filled with water is heated to boiling with high power. At this stage, it is necessary to calculate the amount of rice by measuring the time for the top of the pot to reach 53°C, and automatically select the corresponding Heating scheme.

3) Boiling stage: At this stage, the temperature in the rice cooker is mainly maintained at about 100°C, and the water is gradually evaporated to dryness.

4) Rice braising stage: When the temperature in the pot reaches 102°C, it proves that most of the water in the pot has evaporated. According to the selected taste, use the appropriate power to heat for a while.

5) Insulation stage: This stage is mainly to keep the rice at about 70°C and wait for it to enter the insulation mode.

2.2. Overall Scheme Design

According to the design requirements of the subject, two options are proposed:

The first is that the main control chip uses 51 series single-chip microcomputers, the data acquisition uses NTC thermistor, LCD is the display, and GSM is the wireless communication module to realize the function.

The second is that the main control chip uses a 32-bit single-chip microcomputer, the DS18B20 digital sensor is used for data collection, the OLED12864 is used as a display, and the ESP8266 is a wireless communication module to realize the function.

After comparison, 32-bit single-chip microcomputers have more I/O ports than 51 series single-chip microcomputers and realize more functions. Compared with DS18B20, the NTC thermistor has one more voltage divider circuit, which increases the design workload. OLED has a large enough advantage on the display because it saves more power and conforms to current environmental protection concepts. The ESP8266 module is more convenient to use than the GSM module, and the data is easier to observe. So this design chooses the second set of plans.

3. Hardware Design

Hardware circuit design is an important part of this design. Whether the hardware circuit design is reasonable or not directly affects the performance of this system. The hardware circuit of this design includes functional modules such as the single-chip minimum system, button circuit, display circuit, temperature detection circuit, power output circuit, wireless communication, etc. Every detail in the design process may become the key to design success or failure.

3.1. Button Circuit Design

The key circuit of this design adopts the matrix keyboard form, uses 2 column lines as the keyboard output to connect to the microcontroller, and 4 row lines as the keyboard input to connect to the microcontroller. The I/O ports connected to the microcontroller are PC0~PC5. First set all the input terminals to high level, and set all the outputs to low level, which means that no key is pressed, and which key is pressed is detected by the line scan method.

3.2. Display Circuit Design

The OLED liquid crystal display has 4 pins, which are VCC, GND, SCL, and SDA. VCC and GND are respectively connected to the power and ground terminals of the microcontroller, and SCL and SDA are respectively connected to the PD6 and PD7 ports according to the definition in the program port.

3.3. Detection Circuit Design

DS18B20 temperature sensor adopts the probe form, and its temperature measurement range is -55℃~+125℃, and the measurement accuracy is ±0.5℃ when it is -10℃~+85℃. When using the DS18B20 probe, the voltage divider circuit or the transmission circuit required by the thermistor can be omitted, saving expenses. The sensor connects a resistor in parallel between the VCC and the signal line, and then the signal line is connected to the PC12 port of the single-chip microcomputer to realize temperature collection.

3.4. Power Output Circuit Design

The power output circuit is mainly composed of a single-chip microcomputer, a relay and an electric heating plate. The single-chip microcomputer is responsible for generating the control signal, the relay is responsible for receiving the control signal and making corresponding actions, and the electric heating plate is responsible for receiving. Because the electric rice cooker uses 220V alternating current which cannot be directly controlled, a relay is used. The input terminal of the relay is connected to the PB5 port and GND port of the single-chip microcomputer, and receives the PWM wave output by the single-chip microcomputer from the PB5 port to control the on-off and control the heating and non-heating modes of the rice cooker.

3.5. Wireless Communication Method Design

This time, the VCC and GND of the ESP8266 module are respectively connected to the +3.3V interface and the ground interface of the microcontroller. TXD and RXD are connected to the microcontroller according to the interface defined in the program, here is the defined serial port 2, so TXD and RXD are connected to the PA3 and PA2 ports respectively. Through the ESP8266 module to realize the communication between the single-chip computer and the remote device.

4. Software Design

In addition to the hardware circuit design in a system, it is also inseparable from the system software design. In the software design of this system, the single-chip microcomputer is used to receive the instructions issued by the upper computer or mobile phone, complete the program design of the required functions such as rice cooking on the single-chip, generate PWM output to the relay to control the temperature, and upload it to the upper computer for display through the WIFI module . The software mainly includes the design of the single-chip microcomputer system, buttons, display, temperature acquisition, wireless communication, power output, PID algorithm, heating scheme, fuzzy control algorithm and timer interrupt module.

4.1. The Main Program Design of the Microcontroller System

The main program mainly realizes the supervision and management of the entire system, completes the initialization of DS18B20, buttons, OLED, timer interrupt, PWM, ESP8266, and calls DS18B20, buttons, OLED, ESP8266, PID, PWM and other subprogram modules. This control system is mainly divided into several sections, namely temperature acquisition module, key scanning module, display module, WIFI communication module and PWM output module. By programming each module separately, each module can successfully complete its corresponding work and functions. Finally, comprehensive debugging is carried out to finally realize the functions required by this design.

The program first includes stm32f10x, DS18B20, buttons, OLED, ESP8266, PID and other header files, and then the initialization of DS18B20, buttons, OLED, timer interrupt, PWM, ESP8266, etc. that need to be used, because only the initialization is successful can the following step. Then call the subroutines of each module in the main loop to coordinate their work.

4.2. Button Programming

This design uses 8 buttons. They are ① "rice cooking soft key" ② "rice cooking hard key" ③ "appropriate rice cooking button" ④ "porridge cooking button" ⑤ "soup button" ⑥ "time minute + 30 button" ⑦ "time minute + 1 button" ⑧ "OK button". First, initialize the matrix buttons, and then scan the buttons. Before scanning the buttons, you need to set 4 input terminals to high level, 2 output terminals to low level, and then one input terminal to low level

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to detect specific Which button was pressed. When the key is detected, the corresponding function will be executed.

4.3. Display Programming

In the software design of the OLED12864 module, it is necessary to first use some character dot matrix data according to the design needs, and use the special modulus software to convert the characters into codes and put them into the program for calling. Then initialize the I/O port in the OLED_Init function, and use the macro definition OLED_MODE to set the IO port to be used. Then clear the video memory, so that the last display data will not continue to be displayed, because the OLED does not want to need a backlight so there will be a black screen, but this is normal. After setting the horizontal and vertical coordinates where the displayed data is placed, the data can be observed on the OLED. There is a difference here from LCD1602. OLED_ShowCHinese can be used to display Chinese characters, but 1602 cannot. It cannot display Chinese characters and can only display characters.

4.4. Temperature Detection Program Design

DS18B20 is a digital sensor, it can read the temperature to be measured without conversion. The operating voltage of the sensor is 3-5.5 V, and its system design is very flexible due to the use of a variety of packaging forms. DS18B20 has 6 types of write 0, read 0, write 1, read 1, response pulse and reset pulse. These signals are basically synchronous signals sent by the host, but the response pulses are different. And the data and commands sent are the low order of the byte first. Since the collected temperature is not an accurate temperature and needs to be converted, its conversion relationship is:

$$\mathrm{Temp} = \mathrm{temp} \times 0.0625 \tag{1}$$

As the temperature needs to be optimized, digital filtering is needed. Digital filtering is the use of digital computers to process digital signals, and the processing is to perform calculations in accordance with pre-programmed programs. The 10 data collected this time remove the highest value and take the average value.

4.5. Program Design of Wireless Communication Module

After hardware comparison, the wireless communication module selected in this design is the ATK-ESP8266 module of Punctual Atom. This module mainly uses mobile phone hotspots to establish communication with the server, and realizes the functions of receiving data and issuing instructions from the server through programming . The server used in this design is the OneNet platform, which is the open platform of China Mobile Internet of Things. In the program, you can connect to the platform by writing the device number and APK code on the platform, and writing the name and password of the current hotspot.

Many settings need to be configured in the subroutine of ATK-ESP8266, such as initializing the serial port and a series of initializations. Now the ESP8266 subroutine is called in the main program, otherwise the connection will not be successful. To realize the sending and receiving functions, the ESP8266_Wait_RecData() and OneNET_SendData() statements are needed to realize the MCU sending data to the platform and instructions sent by the platform to the MCU.

4.6. PID Algorithm Program Design

PID is an algorithm control that uses proportional, integral, and differential to adjust. PID algorithm is an indispensable part in process control. Its parameters are simple to change, and its structure is relatively simple and portable. It is often used to adjust temperature and pressure. In the PID control algorithm, the proportional coefficient mainly controls the response speed. The larger the parameter, the faster the response time, but it may also make the system unstable; integral can eliminate the steady-state error of the system, but it may make the system unstable; Reduce the overshoot of the system and reduce the adjustment time, but it will reduce the system adjustment accuracy [17]. The most important part is proportional control. Measure the actual value of the current temperature in the pot, compare it with the set temperature value, and use this deviation to calculate, thereby adjusting and controlling [18]. What is used this time is the integral separation PID algorithm, the formula is:

$$\mathrm{u}(k) = K_P\left\{e(k) + \frac{T_d}{T}[e(k) - e(k-1)]\right\} \tag{2}$$

5. System Debugging

5.1. System Hardware Debugging

There are many hardware modules used in this design, so when debugging, each one needs to be debugged successfully. One shared the following hardware modules: (1) matrix button module; (2) OLED display module; (3) wireless communication module; (4) temperature acquisition module; (5) relay module, etc.

(1) OLED display module: The OLED display module is the most commonly used in hardware debugging, because the easiest and most direct way to determine whether the operation can be successful is to display it on the display when designing and debugging. The hardware debugging of the OLED display module is relatively simple. Download the routine to observe whether it can be displayed normally, and if it can, it proves that the interface is correct.

(2) Button module: Because this design uses a row of unchangeable interfaces, but the sequence of the I/O ports on the microcontroller is not a row, so two rows of pin headers need to be welded on a hole plate for connection The matrix keyboard is interfaced with the microcontroller. If there is a response when the button is pressed, the module is considered to be successfully applied.

(3) Wireless communication module: Connect the module and the single-chip microcomputer according to the connection method in the instruction book, observe the power light and signal light of the module, if the power light is blue and the signal light flashes, the module is successfully connected.

(4) Temperature collection module: Connect according to the instructions, display the temperature value with OLED, compare the collected temperature with the temperature measured by the thermometer, if the difference is small, the installation is considered successful.

(5) Relay module: Connect the positive pole of the input terminal of the relay to PB5 of the microcontroller, and the negative pole to GND. The output terminal is connected to the live wire of the power cord of the rice cooker. If the indicator light of the relay is bright, the connection is considered correct.

5.2. System Software Debugging

After the hardware module is debugged, the software is debugged after confirming that the wiring is correct. In software debugging, it is mainly through program debugging to achieve the desired function of the design. Software debugging and hardware debugging are both step-by-step debugging and module debugging. The following is the software debugging part of the module or platform.

(1) OLED display: change the program and control the OLED to display different letters or Chinese characters by pressing the buttons, such as displaying the currently collected temperature value, and displaying the cooking modes "soft cooking", "hard cooking", and

"cooking" The meal is right" and so on. If the above words are displayed, the debugging is successful.

(2) Matrix buttons: Write the program to use the "line scan method" to detect button presses, and print the characters that the corresponding buttons need to display on the screen. If the desired words can appear, it means that the debugging is successful and then write other function programs. .

(3) WiFi module: write ESP8266 subroutine, write the name and password of the mobile phone hotspot, call it in the main program and download it to the microcontroller to observe whether it can be connected to the mobile phone hotspot. If you cannot successfully connect to the mobile phone hotspot, you need to open the serial port debugging assistant to debug to find out the problem and solve it.

(4) Acquisition module debugging: Write the subroutine of the temperature sensor DS18B20. Since the collected temperature is not an accurate temperature, it needs to be converted to display the accurate temperature.

(5) Onenet platform: When debugging the onenet platform, it mainly receives data and sends data. To receive data, you need to package the data that needs to be sent to the platform in the program and upload it to the platform, otherwise the data stream cannot be found on the platform. Sending data on the platform needs to use control elements, and write the elements that need to be controlled in a logical language.

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