Design and Implementation of the Control System of the Internet of Things Washing Machine Based on STM32

Qianqian Duan1, Yulin Zhang*

1 School of Information Science and Engineering, University of Jinan, Jinan, Shandong, 250001, China
*Corresponding author’s e-mail: ise_zhangyl@ujn.edu.cn

Abstract. With the development of science and technology, household appliances continue to develop in the direction of automation and intelligence. The emergence of the Internet of Things has promoted the development of intelligent household appliances. Washing machine is one of the indispensable household appliances for people nowadays. This article mainly introduces the design and realization of the control system of the Internet of Things washing machine based on STM32. The software and hardware of the control system were designed according to the specific requirements of the project. In terms of hardware, this control system uses STM32F103C8T6 as the main control chip, and the main controller is the core of the entire control system, responsible for communication with external devices. The washing machine main board reserves a serial communication interface for connecting to the DTU module, and the DTU module is used to realize the wireless communication between the washing machine main board and the server. In the software, the ucosii operating system is transplanted to improve the stability of the entire system to achieve the overall performance of the system.

1. Introduction
The Internet of Things is to connect things to things through network infrastructure, so as to exchange and communicate information, to realize the intelligent management of things. The Internet of Things washing machine is an extension of the smart home. This control system uses ST's STM32F103C8T6 chip as the main control chip. STM32F103 is an enhanced series of chips with low power consumption and high performance. The chip has a wealth of peripheral interfaces. This article introduces the selection of communication module equipment, the design of the communication program between the washing machine motherboard and the communication module, and the hardware and software design of the control system.

2. System structure
The controller of this system uses the STM32F103C8T6 chip. The main function of the controller is to act as a control center to control the communication between the motor and the server. The motor driving the washing machine is a series-excited DC motor, which has the advantages of mature control technology, low cost, and easy speed adjustment. The main control board reserves a serial communication interface when designing, and the controller uses the DTU module to communicate with the server. The structure diagram of this control system is shown in Fig.1.
3. Hardware design of control system

3.1. Power circuit design
In this control system, the series-excited DC motor needs 220V DC voltage, so 220V AC power needs to be converted into DC power through a rectifier filter circuit. In the design of the step-down circuit, a step-down module is used to convert the high voltage of 220V into a low voltage of 12V. The 12V DC voltage outputs 5V through the TPS54331 step-down chip, and then outputs 3.3V through the LM1117 to power the STM32 chip. The schematic circuit diagram is shown in Fig.2 and Fig.3.

Figure 1. System structure diagram

Figure 2. DC 220V to DC 12V circuit.

Figure 3. DC 12V to DC 3.3V circuit.
3.2. Serial communication circuit design
The washing machine main control board needs to communicate with the server. In this design, a serial communication interface is reserved on the washing machine main control board. The data is transmitted to the DTU module through the serial port. The DTU module is embedded with the TCP/IP protocol, and the DTU module transmits the serial data Convert into TCP/IP data packet for transmission. In this design, UART3 is used as the interface for data transmission between the washing machine main control board and the DTU module. The circuit schematic diagram is shown as in Fig.4.

![Serial communication circuit](image)

Figure 4. Serial communication circuit.

3.3. Water level detection circuit design
This system uses a resonant water level sensor. The water level detection circuit converts the water level signal collected by the water level sensor into the signal required by the washing machine controller MCU. The water level sensor is composed of inductors and capacitors, and forms an LC oscillating circuit with the water level detection circuit, which converts the change of the inductance signal into a frequency signal to facilitate the collection of the controller chip. In this design, the sine wave output by the water level sensor is inverted, amplified, and reshaped by the 74HC04 six-way inverter to form an ideal square wave [1]. The function of the capacitor C45 in the circuit is to block direct current and filter. The resistor 103 is connected in parallel at the input and output ends of the inverter to form a feedback bias circuit. At this time, the inverter is in the linear amplification zone, so that the signal is amplified. The main control chip judges the water level by detecting the frequency of the square wave. The circuit schematic diagram is shown as in Fig.5.

![Water level detection circuit](image)

Figure 5. Water level detection circuit.
4. Communication system design

4.1. DTU module

DTU is a wireless terminal device that uses the public network of mobile operators to convert serial data into IP data or IP data into serial data, and provides users with wireless data transmission through wireless communication networks [2]. The internal TCP/IP protocol is embedded in the DTU module, which can encapsulate the serial port data through the internal embedded processor and then encapsulate the data through the wireless network. When using the DTU module, the user needs a SIM card, insert the SIM card into the DTU module. After powering on the DTU module, log in to the GPRS network, and the network center will assign a dynamic IP address to the DTU module to establish communication. As long as the communication between the two parties is established, the communication will be maintained.

4.2. System communication protocol

The main board of the washing machine communicates with the DTU module through the serial port, so it is necessary to customize the communication protocol format. The protocol is formulated with reference to the MODBUS communication protocol. The washing machine main board and DTU module adopt asynchronous half-duplex communication, and the receiving method adopts serial port interrupt. The signal sent by the DTU module to the washing machine main board is defined as a downstream signal, and the signal sent by the washing machine main board to the DTU module is defined as an upstream signal.

(1) The washing machine main board sends the collected data to the DTU module through the serial port. The format of the upstream frame is:

| Frame header | Frame length | Command code | Data field | CRC check | End of frame |
|---------------|--------------|--------------|------------|-----------|--------------|
| 2 bytes       | 1 byte       | 1 byte       | n bytes    | 2 bytes   | 2 bytes      |

(2) The monitoring center sends control commands to the DTU module through the GPRS network. The DTU module encapsulates the control commands and sends them to the washing machine main board through the serial port. The format of the downstream frame is:

| Frame header | Frame length | Command code | Data field | CRC check | End of frame |
|---------------|--------------|--------------|------------|-----------|--------------|
| 2 bytes       | 1 byte       | 1 byte       | n bytes    | 2 bytes   | 2 bytes      |

The two-byte frame header is a fixed value: 0XA5A5, and the two-byte frame tail is a fixed value of 0XFFFF. All data formats are hexadecimal, with big endian first and little endian last.

4.3. Communication system programming

The program design of the system communication part is mainly the data transmission process after the communication is established successfully. The wireless communication between the washing machine main control board and the cloud server is established on the DTU module. The communication between the washing machine main control board and the DTU module and between the cloud server and the DTU module is established, so as to realize the data exchange between the washing machine main board and the cloud server.

5. The main program design of the control system

The ucosii operating system is transplanted in the software design of the control system. The ucosii operating system is a tailorable, portable, and deprived multi-task operating system kernel. The Ucosii operating system only needs to modify the core files related to the CPU type during transplantation. They are os_cpu.h, os_cpu_a.asm, os_cpu.c. After the system is powered on, the OSInit() function is called to initialize the operating system kernel, and the OSStart() function is called to start the ucosii
operating system. After the system is started, the task is managed and scheduled by the operating system [2]. Create various tasks according to the requirements of the project, such as motor control tasks, serial communication tasks, washing machine process control tasks, and fault monitoring tasks. The operating system assigns a task stack and task priority to each task. Each task runs independently, and the operating system performs task scheduling according to the priority of the task. The main program flow chart is shown as in Fig.6.

![System Programming Flowchart](image)

**Figure 6. System programming flowchart.**

### 6. Conclusions

This article analyzes and designs the control system of the Internet of Things washing machine based on STM32. The system software part is transplanted with the ucosii operating system, and the programming is realized by IAR. The hardware circuit is mainly designed and implemented by Cadence software. This design has been able to achieve stable wireless control of the washing machine. The physical diagram of the system and the output waveform of the system are shown in Fig.7 and Fig.8.
Figure 7. System physical diagram.

Figure 8. System output waveform.

References
[1] Petrov., M., Ganchev., I., Taneva, A. (2002) Fuzzy PID control of nonlinear plants Intelligent Systems, First International IEEE Symposium., 9: 30-35.
[2] Bertil., S., M., Granborg. (2007) Speed Control of Series Motors By Means of Thyristor Bridges, IEEE/ASME Transactions on Mechatronics., 12: 428-434.
[3] Yan., B., Xu., Y., (2011) Study of combined control strategies for Switched Reluctance Motor, International Conference on Mechanic Automation & Control Engineering., 163: 51–59.
[4] Joachim von Zitzewitz, (2007) Michael Bernhardt and Robert Riener, A Novel Method for Automatic Treadmill Speed Adaptation, IEEE Transactions on Neural Systems and Rehabilitation Engineering., 3: 401-408.