Research on PTC Electric Heater Detection Bench

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Abstract. PTC electric heating is widely used in the air conditioning system of electric vehicles. This paper studied the PTC electric heater detection bench. First, introduced the research background and three keys of the detection bench control system: PWM board, serial port protocol, design of database. Then, elaborated the three key points respectively, including board structure, analysis of serial port protocol and design ideas of database. Finally, the detection bench was set up and tested repeatedly. The results of experiment shows that the bench achieved expected goals.

1. Introduction
PTC electric heating is a commonly used heating method in electric vehicle’s air conditioning systems today. PTC electric heater consists of PTC ceramic heating element and aluminum tube with low thermal resistance and high heat transfer efficiency. It is an automatic constant temperature, power saving electric heater. It overcomes the shortcomings of wire heating such as spontaneous combustion, short service life etc [1]. Well-known domestic heater manufacturers include Hebei Hongye, Hebei Nanfeng, and Beijing Jingwei. They have designed different PTC electric heaters for different models, but there is no R & D input in the automatic detection of PTC electric heaters. But foreign veteran heater manufacturers such as Weibo Stone, Eberspacher has perfect detection bench, their electric heating products are well controlled, well known and well feedback from users.

Based on this situation, this paper makes a thorough study on the detection bench of PTC electric heater. The painful point of PTC electric heating intelligent detection bench lies in data acquisition and storage under normal working condition of PTC electric heater device [2, 3]. Data acquisition includes voltage, current, output power, insulation resistance, leakage current and PWM signal of PTC electric heater controller. Voltage, current and other parameters can be measured by instrument and sent to industrial computer through serial port. This paper focuses on the PWM signal, which involves fault information of PTC electric heater [4], and MYSQL database is used for storage and analysis of the detected data.

2. System structure
The detection bench studied in this paper is divided into two parts: hardware and software. Hardware includes power supply, bar code scanning gun, industrial computer, measuring instrument, PWM board and so on. Software includes analysis of serial port protocol, PC software and MYSQL database. Power supply is used to supply working voltage for the device to be tested. Bar code scanning gun is used to scan the bar code of the device to be tested and send it on the industrial computer. Industrial
The computer is responsible for reading data by the measuring instrument through the serial port, displaying and storing them in the MYSQL database. PC software controls the PWM board to collect and send control signals to the controller of measuring device. This paper mainly studies the design of PWM board, the analysis of serial protocol and the design of database. System structure diagram is shown in Figure 1.

![System structure of the PTC electric heater detection bench](image)

**Figure 1.** System structure of the PTC electric heater detection bench

2.1. **PWM board design**

The PWM board designed in this paper is based on the MC9S12P128 one-chip computer of Freescale series. The board includes BDM debugging module, reset circuit module, crystal oscillator circuit module, LED debugging module, serial level conversion module and PWM signal interface circuit module. Figure 2 shows the structure of the PWM board.

![Structure of the PWM board](image)

**Figure 2.** Structure of the PWM board

1) BDM debugging module
   ① Download the user program to the target chip or read out the data from memory;
   ② Send BDM command to modify working mode and resource allocation register of MCU;
   ③ Read or write MCU memory and internal registers.

2) Reset circuit module
   Using capacitor charging and discharging to reset target MCU, and ensure that the original state can be restored when SCM program run away.

3) Crystal oscillator circuit module
Consists of two 10pF capacitors and a 4M crystal, provide accurate clock signal to ensure the normal operation of MCU.

4) LED debugging module

Consists of eight LED, mainly used to display the program error phenomenon, the PWM fault information and the operation status of the PWM card when debugging program.

5) Serial level conversion module

Based on MAX232 chip, converted TTL signal into serial level and communicated with industrial computer.

6) PWM signal interface circuit module

Mainly responsible for communication between PWM board and PTC electric heater controller. The PWM interface circuit of this system used photoelectric coupling elements to separate the signal of PWM board and controller of PTC electric heater, avoid damaging devices due to voltage difference between two sides of the circuit. The PWM interface module is shown in Figure 3.

The PWM board designed in this paper mainly completes two tasks: receiving PTC controller signal and sending control signal to PTC controller. In this paper, the receiving module of PWM pulse signal is designed based on TIM timing module of MC9S12P128. TIM timing module has eight pins: IOC0-IOC7. These eight pins can complete input capture and output comparison function, furthermore the IOC7 can also be configured as input pin of pulse accumulator. The output signal of PTC controller is a series of pulse signals, which indicate the current working state of PTC electric heater. The IOC7 pin of MC9S12P128 can be used as the acquisition terminal of the pulse accumulator. Through TCxH and TCxL register, numbers of captured pulses can be read out and apply to the detection of PTC electric heating state (Fault detection) [5]. The fault types are shown in Table 1.

| Numbers of pulses | Fault type                  |
|-------------------|-----------------------------|
| 1                 | Working normally            |
| 2                 | Over current detection      |
| 3                 | Over voltage detection      |
| 4                 | Under voltage detection     |
| 5                 | Excessive internal temperature |
| 6                 | Heating element overheating |
| 7                 | IGBT fault                  |
| 8                 | SRS signal                  |

For sending PWM signal to PTC electric heater controller, it is based on the PWM module of MC9S12P128. The PWM module has eight independent PWM channels, each channel has an independent timer, which can be divided into eight 8-bit channels, or can be combined into four 16-bit channels. The polarity of the output waveform can be set by the PWMPOL register. The period and duty cycle of the output waveform can be set by the registers of PWMPERx and PWMDTYy (x stands
for the channel number of 0-7). By configuring these registers, the waveform of the output signal can be controlled.

2.2. Analysis of Serial Port Protocol

Serial port is the communication interface of each component. The system hardware interface studied in this paper adopts RS232 serial port and uses RTU transmission mode of MODBUS protocol to communicate [6]. The MODBUS protocol information frame includes four partial: address field, function field, data field and error checking field, shown as Table 2.

| Address | Function | Data | Check |
|---------|----------|------|-------|
| 8-Bits  | 8-Bits   | N*8-Bits | 16-Bits |

Address field: composed of 8 bits, representing the address of slave equipment. Address range is 1-247, address 0 is the broadcast address. The host finds the slave by slave address, and the slave responds, then analyzes functional field.

Functional field: represents what functions are performed by the addressed terminal device, with an effective range of 1-255. For example, the 01 code represents the read coil state, which is used to obtain the current state of a set of logical coils (ON/OFF).

Data field: Contains data needed by the terminal to perform specific functions or data collected by the terminal in response to queries. If no error occurs, the slave machine responds to the request data from the host. When an error occurs, the slave response data contains an abnormal code.

Error Check field: CRC verification of transmission data using 16-bit cyclic redundancy method to ensure that the host or terminal does not respond to the erroneous data in the transmission process.

When the host computer sends a frame of RTU message, the slave device with the corresponding address receives the message and analyzes the message. If the message passes the CRC check, it continues to complete the task of function code and sends the result back to the host computer. The result called return messages include address codes, function codes for executing actions, data and error checking codes. If there is an error, no information will be sent. Return messages will be analyzed and displayed on the host computer.

2.3. Design of database

The database is the core of the system. The original intention of designing database is to facilitate data storage and processing [7]. In order to ensure the rationality of database, three normal forms of database should be followed: ○1First normal form: database table fields are indivisible atomic data items; ○2Second normal form: on the basis of the first normal form, each instance or row of the data table must be uniquely identified; ○3Third normal form: on the basis of the second normal form, each non-principal attribute does not depend on other non-principal attributes.

The design of database tables is related to the parameters detected by the detection bench, so it is necessary to do an all-round demand analysis for the measurement parameters [8]. The PTC electric heater is mainly detected by two instruments: Electrical parameter measuring instrument measures input voltage, input current and output power; Insulation measuring instrument measures insulation resistance, power frequency, withstand voltage and leakage current. Number information of PTC electric heater can be read by bar code scanning gun, and fault information of PTC electric heater can be collect by PWM board. According to the above analysis, the fields of database tables should include the following parts: input current, input voltage, output power, insulation resistance, power frequency withstand voltage, leakage current, product number and fault information etc. The design of database tables is shown in Table 3.
Table 3. Design of database tables

| Number | Name             | Type            | Description | Primary key |
|--------|------------------|-----------------|-------------|-------------|
| 1      | ID               | Varchar(10)     | Not NULL    | Yes         |
| 2      | Fault message   | Int             | NULL        | No          |
| 3      | Input current   | Float           | NULL        | No          |
| 4      | Input voltage   | Float           | NULL        | No          |
| 5      | Output power    | Float           | NULL        | No          |
| 6      | Insulation resistance | Float   | NULL        | No          |
| 7      | Withstand voltage | Float      | NULL        | No          |
| 8      | Leakage current | Float           | NULL        | No          |

3. Analysis of experimental results

According to the research of PWM board in hardware part, this paper completed the design of PWM board and tested sending PWM signal, receiving PWM signal. Test results of sending PWM signal is shown in Fig.4 and Fig. 5. Test data of the received signal is shown in Table 4.

Fig.4 and Fig. 5 show that four groups of pulse signals with frequency of 100 Hz, 1 KHz, duty cycle of 50 and 60 are measured by oscilloscope channel 1 and channel 2. It is proved that the PWM board can generate pulse signals with adjustable frequency and duty cycle.

In addition, in order to verify normal operation of the experimental bench, some important parameters of a certain type of PTC electric heater are tested and stored in the database according to the design format of the database table. Experimental results are shown in Table 4.
Table 4. Detection bench experimental results

| Number | ID     | Fault message | Output power | Leakage current       |
|--------|--------|---------------|--------------|-----------------------|
| 1      | EW150727 | 1             | 15.03KW      |                       |
| 2      | EW150728 | 1             | 15.01KW      |                       |
| 3      | EW150729 | 5             | 16.52KW      | 0.20mA                |
| 4      | EW150730 | 1             | 14.92KW      | 0.15 mA               |
| 5      | EW150731 | 4             | 14.20KW      | 0.83mA 0.47mA 0.27mA 0.22mA |
| 6      | EW150732 | 1             | 15.00KW      | 0.16mA 0.20 mA        |
| 7      | EW150733 | 1             | 15.08KW      |                       |
| 8      | EW150734 | 1             | 14.95KW      |                       |

According to table 4, it can be seen that bar code scanning gun can correctly read type information of equipment, PWM card can correctly receive fault information from the PTC controller, electrical parameter measuring instrument and the insulation testing instrument can read data through serial port and the testing bench designed by the system can run normally. It proves that the detection bench designed by this paper can run normally.

4. Conclusion
This paper analyses the detection bench from the hardware and software parts. The hardware part mainly studies the design of PWM board and the software mainly studies the design of database tables. Finally, according to the characteristics of bench, experiments are carried out. Results show that the detection bench can complete the PTC electric heater detection work better, and also can complete data storage, analysis functions.

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