RESEARCH ON COMPUTER CENTRALIZED MANAGEMENT SYSTEM BASED ON THERMAL ENERGY DATA ACQUISITION AND DISPLAY

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The thesis discusses the thermal energy related theories and designs a thermal energy measurement and control system based on the AT89S52 microcontroller. Through the DS18B20 temperature sensor and DN20 flow sensor, the temperature and flow data are directly transmitted to the microcontroller. Calculate the value of heat energy consumed according to the formula, and display related information such as consumption, balance, temperature, time through the LCD display, and the system is provided with a voice warning prompt. The output signal of the one-chip computer passes the D / A, V / I circuit, and transmits the output signal to the electric regulating valve to control the opening degree of the valve to adjust the indoor temperature. Through CAN bus and non-contact IC card module to realize remote meter reading and user's prepayment function. System data is stored in the storage chip AT24C04A to prevent data loss. The prepaid heat meter cannot only solve the problem of heat consumption measurement in the heating system, but also greatly improve the accuracy and timeliness of heating billing, eliminate errors, omissions, and other issues, and provide a scientific, timely, accurate, and reasonable civilian heating system. Thermal energy billing, charging, and control provide effective tools.

Key words*: Thermal energy data collection; management system; data display; thermal energy measurement; remote meter reading*

1. Introduction

In recent years, the contradiction caused by the winter heating problem in China has been the focus of attention of all parties, mainly reflected in the inadequate pricing method and the inconvenience of paying heating fees [1]. At present, most areas in China charge by area, and the heating temperature of residents in different regions is different but fees are charged uniformly. With the continuous development and improvement of China's market economy, changing the current heating billing method from billing based on building area to billing based on thermal energy consumption is the development trend of heating billing methods. Hardware measures such as the design of new heating billing systems and the development of new heating equipment are even more necessary. As a consumer product that requires money to buy, heating energy for home heating has been recognized by consumers. In recent years, the Ministry of Construction and local construction commissions have successively promulgated relevant promotion policies, requiring the implementation of individual heating metering. However, metering and charging for heating households is still a new topic in China. It involves many issues such as policy, management, charging methods, related products, and technology. The reform of the heating charge system is one of the important components. It has become another hot issue closely related to people's lives after the medical and housing reforms. For this reason, a new type of thermal energy metering system is designed in this paper, which provides an effective tool for the scientific, timely, rigorous and reasonable thermal energy billing, payment and control of individual household heating systems.

2. System design

2.1. Thermal energy measurement method

At present, the calorimetric methods of domestic calorimeters can be basically divided into the following. The temperature difference method for determining the amount of heat used by a user is determined by measuring the heat load of the user. The method is to measure the indoor and outdoor temperature, sum the indoor and outdoor temperature differences during the heating season, and then multiply by the room constant (such as volumetric heat index) to determine the charge. The instrument is a temperature measuring instrument, which is easy to install and has a low price. However, this method requires the installation of temperature measurement equipment outside, and does not directly measure the heat supply value [2]. It is not accurate enough and is easily affected by various environmental factors. In addition, it is not conducive to long-term cumulative measurement and focuses on measuring the temperature difference. Therefore, the method is discarded. The second is the more commonly used roasting method.

$$Q=q_m\left(h_f-h_r\right)=q_r\left(C_{pf}\,p_f\theta_f-C_{pr}\,p_r\theta_r\right) \tag{1}$$

Where C_{pf} and C_{pr} are the constant pressure specific heat capacities of the inlet and outlet. q_m and q_r are instantaneous volume and mass flow. p_f, p_r are the density of the heat transfer fluid at the inlet and outlet temperatures. θ_f and θ_r are the temperatures of the inlet and outlet. This formula is simple to calculate, if it is based on the measured temperature. Look up the table to get a constant, and plug it into the formula. However, as temperature measurement accuracy improves, more data needs to be measured and calculated [3]. Moreover, for the measured temperature, an approximate calculation technique such as linear interpolation needs to be used, and the corresponding baking value is calculated by searching for the point closest to it, thereby obtaining the instantaneous heat. This method will lead to inevitable errors and inaccurate charges. Therefore, this method is discarded. The heat measurement method used in this design is the constant coefficient specific heat capacity method, which is based on the cost of heat. The formula for calculating the heat consumption Q is as follows:

$$Q=C\bullet V\bullet\Delta t \qquad \left(\Delta t=t_{\text{Water}}-t_{\text{Backwater}}\right) \tag{2}$$

Among them: C is the specific heat capacity of the water ($C=0.1167kWh/L^\circ C$); V is the volume of hot water flowing through the heating equipment; t_{Water} and $t_{\text{Backwater}}$ are the two temperatures flowing through the heating equipment; according to the design requirements, the screen can display the heat consumption and the remaining temperature for a period Heat. Residual thermal energy $Q_2=Q_1-Q$ (Q_1 is the sum of thermal energy purchased by the user). The heat exchanger calculation is based on the heat balance equation and heat transfer equation as shown below.

$$Q=qm_1C_1\left(t_1'-t_1''\right)=qm_2C_2\left(t_2'-t_2''\right) \tag{3}$$

The above formula indicates the heat balance of the heat exchanger operation, that is, the principle of energy conservation. The heat Q_h (KJ) provided by the hot fluid being cooled must be transferred to the cold in addition to the heat loss to the external environment the heat Q_c (kJ/s) required for the fluid to heat up can be ignored because the proportion of heat lost is relatively small. The propagation of heat conduction in a three-dimensional isotropic homogeneous medium can be expressed by the following equation:

$$\frac{\partial u}{\partial t}=k\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)=k\left(u_{xx}+u_{yy}+u_{zz}\right) \tag{4}$$

Where: $u=u(t,x,y,z)$ represents temperature, which is a function of time variable t and space variable (x,y,z). $\partial u/\partial t$ is the rate of change of temperature at a point in space over time. Second derivative of the temperature of u_{xx}, u_{yy} and u_{zz} with respect to three spatial coordinate axes. k depends on the thermal conductivity, density and heat capacity of the material.

2.2. Overall design block diagram

The entire system works by temperature and flow sensors to detect changes in temperature and flow, and then transmits the temperature and flow signals to the single-chip microcomputer control system. The single-chip microcomputer system receives the sensor signals and drives the peripheral circuits through a software program. The peripheral circuits mainly include display and alarm drive circuit, storage circuit, clock circuit, keyboard circuit, IC card prepayment circuit, communication circuit and electric valve control circuit. Then realize the display of heat usage information, data transmission and storage, and reminders of time and cost. As shown in Figure 1.

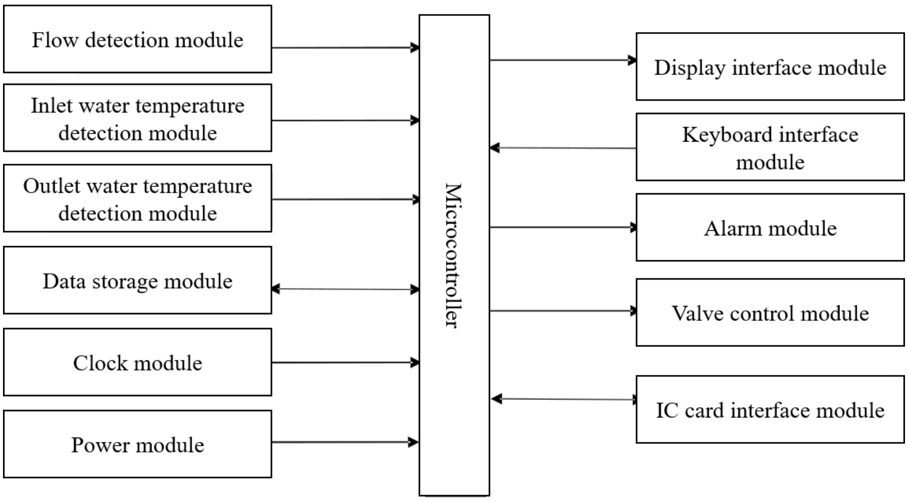

Fig.1 overall design block diagram

2.3. Selection of controller

The one-chip computer is the core of the whole system, so it is very important to choose one-chip computer. Buying a single-chip microcomputer should be considered from the following aspects: first, which resources the target system needs; second, choose the lowest-priced product according to cost control; third, you should try to choose the type of microcontroller that you are familiar with, which can shorten the development cycle; The fourth is to choose a model with ready-made development tools; the fifth is to choose a model with a high degree of collection and high reliability, which is a small system and low cost. There are 51, PIC, MSP430 and other single-chip microcomputers in the existing market. According to the knowledge they are familiar with, AT89S51, S52 microcontroller.

AT89C51 is a low voltage with 4K bytes of FLASH memory, high-performance CMOS8 bit microprocessor, microcontroller commonly known. AT89C51 with 2K bytes of flash memory is an erasable programmable read-only memory of the microcontroller. MCU EEPROM erase repeated 1000 times. The device fabrication techniques ATMEL nonvolatile memory of high density, it is compatible with the industry standard MCS-51 instruction set and output pins. Since the 8-bit CPU and combined in a single flash memory chip, ATMEL's microcontroller AT89C51 is a highly efficient, it AT89C51 is a compact version. AT89C51 microcontroller offers smart flexibility and low-cost solution for many embedded control systems.

In summary, in view of the system's need to measure temperature, flow rate, and other parameters, as well as keyboard input, digital tube display, communication, etc., considering the program writing space, chip performance and other issues, the AT89S52 microcontroller is selected as the system CPU.

2.4. Temperature sensor selection

In the conventional analog remote temperature measurement system, it requires a good solution lead error compensation, multi-point measuring error problem and the switching amplifier zero drift error problem and other technical problems, be able to achieve high accuracy. Further general monitoring the electromagnetic field of the environment is very bad, a variety of strong interfering signals, the analog signal is susceptible to interference temperature measurement error, affecting the measurement accuracy. Thus, in the temperature measuring system, using a strong anti-interference ability of the new digital temperature sensors are the most effective solution to these problems. In the conventional analog remote temperature measurement system, it requires a good solution lead error compensation, multi-point measuring error problem and the switching amplifier zero drift error problem and other technical problems, be able to achieve high accuracy. Further general monitoring the electromag netic field of the environment is very bad, a variety of strong interfering signals, the analog signal is susceptible to interference temperature measurement error, affecting the measurement accuracy. Thus, in the temperature measuring system, using a strong anti-interference ability of the new digital temperature sensors are the most effective solution to these problems.

2.5. Flow sensor selection

There are mainly three types of flow sensors used in heat meters on the market: electromagnetic flow sensors, ultrasonic flow sensors, and impeller flow sensors. Considering the special circumstances in China, the situation of poor water sources and many impurities, it is very easy to adsorb metal impurities during the work of the heat meter. Problems such as reduced accuracy are therefore unavoidable. Therefore, as far as the current situation is concerned, under the objective conditions of our country, the non-magnetization of the heat meter is a necessary hard condition. Therefore, in the design, when selecting a flow sensor, the first requirement is its ability to resist magnetic interference. At the same time, the actual conditions of the construction of the integrated heat meter system and the use of large quantities of users require low prices and non-industrial-level measurements that do not require particularly high accuracy; domestic heating requires small-diameter pipes; Features, design requirements for low power consumption and low cost, this system uses a non-magnetic flow sensor DN20 to measure the heating flow.

3. System hardware design

3.1. Temperature detection module design

This design uses a digital thermometer is DALLAS DS18B20 produced. DS18B20 digital temperature sensor wiring easy, after packaging to be used in many applications, such as pipe-type, screw-type, magnetic adsorption, encapsulated stainless steel, a variety of models. Mainly depending on the application to change its appearance. DS18B20 encapsulated cable channel may be used for temperature measurement, the water circulation temperature furnace, boiler temperature, room temperature, temperature measurement agricultural greenhouses, clean room temperature, ammunition depots and other non-extreme temperature temperature applications. Wear-resistant touch, small size, easy to use, packaged in various forms, for a variety of digital temperature measurement and control field devices small space. DS18B20 product features:

(1) Requires only one port can communicate. (2) In the DS18B20 Each device has a unique serial number. (3) The practical application of the need for external components to implement any temperature.

(4) Measured in the temperature range of -55oC to + 125oC. (5) Resolution of the digital thermometer user may select from 9-12. (6) Internal temperature, the lower alarm setting.

DS18B20 internal structure is a 64-bit ROM, 9 bytes of scratchpad RAM, 3-byte register EEPROM (electrically erasable nonvolatile including temperature alarm triggers TH, TL and non-volatile electrically erasable write setting register), a temperature sensor, and 8-bit CRC generator. Each tablet DS18B20 contains a unique 64-bit ROM code. Products are coded first eight, then the serial number is 48, the last 8 bits are cyclic redundancy (CRC) check code. So multi-chip DS18B20 can be connected to the same data line without causing confusion, which brings great convenience for the multi-point temperature measurements. Conversion result of the temperature sensor is stored in 16-bit two's-complement in the scratch pad memory, if the measured temperature value is above or below the temperature alarm triggers TH values of TL, the inside of the alarm flags was set DS18B20 bit indicates the temperature measured value exceeds the range. As shown in FIG. 2, the temperature sensor model for the wiring.

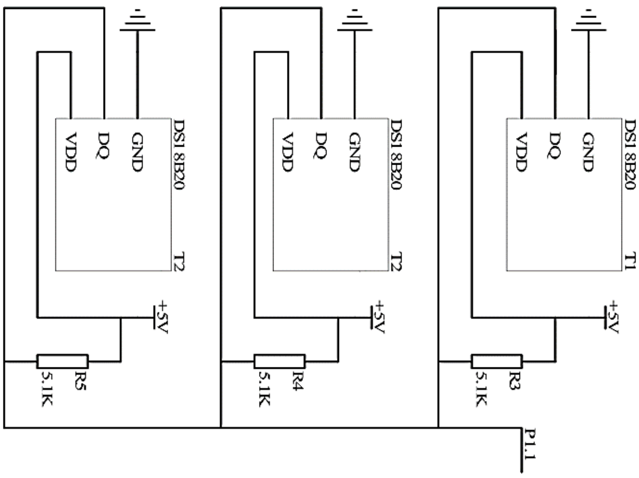

Fig.2 Temperature sensor

3.2. Data storage module design

In this design, if the information collected in time is not protected, it will cause serious consequences if it is lost. According to the design requirements and considering the convenience of connection with the microcontroller, the I²C interface is preferred. This system uses AT24C04 chip introduced by American ATEML company, and its capacity is 4KB. AT24C04 is an electrically erasable memory chip from ATEML. It uses a two-wire serial bus to communicate with a single chip computer. The voltage can be as low as 2.5V and the rated current is 1mA. And it uses 8-pin DIP package, which is easy to use. In short, AT24C02 is a chip that stores data in the event of a sudden power failure, that is, a power-down storage chip. AT24C04 has the advantages of being compatible with 400KHZ I² bus; low-power CMOS technology; write protection function; page write buffer; 100,000 program / erase cycles; can store data for 100 years. As shown in Figure 3, it is a data storage circuit.

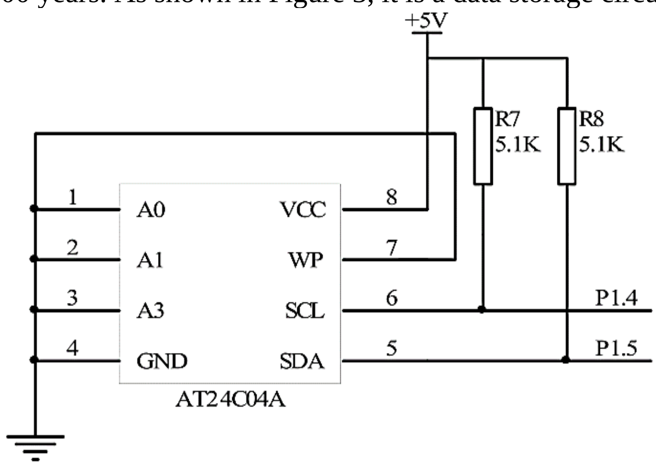

Fig.3 Data storage circuit

3.3. Control Circuit Design of Electric Control Valve

The control valve of this system uses an intelligent electric control valve to adjust the flow of the control circuit. The electric control valve is QSVP-16K. It has the advantages of high precision, advanced technology, small size, light weight, large driving force, strong function, integrated control unit and electric actuator, high reliability, convenient operation, etc. The control signal is 4-20mADC or 1-5VDC, output the valve signal of 4 - 20mADC is very convenient to use and correct. According to the digital PID formula algorithm, the relationship between the change value of the current I and the temperature change determined by it controls the opening degree of the valve. As shown in Figure 4, it is an electric valve control model based on the PID algorithm [4].

$$\Delta I = K_p \Delta T + \sum \Delta T(n) + K_D \left[\Delta T(n) - \Delta T(n-1) \right] \quad (5)$$

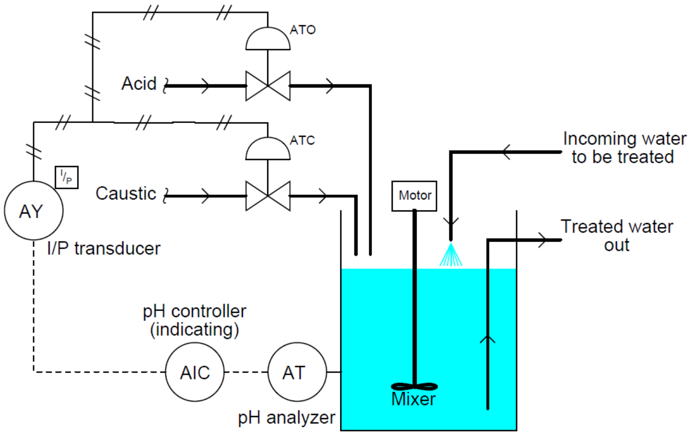

Fig.4 Electric valve control model of PID algorithm

D / A converter has two kinds of output forms, one is the voltage output form, namely input to the D / A converter is a digital quantity, and the output is a voltage. The other is the current output form, that is, the output is current. In practical applications, for current output D / A converters, if an analog voltage is needed, a current / voltage conversion circuit composed of an operational amplifier can be added to its output end to convert the current output into a voltage output. Since the D / A converter requires a certain time, the digital quantity at the input of the D / A converter should remain stable during this time. Therefore, a latch should be set in front of the digital input of the D / A converter to provide Data storage function. The main technical indicators of D / A converter are resolution and accuracy of settling time. Resolution refers to the change of the analog output caused by the change of the unit digital input to the D / A converter, and it is a description of the sensitivity of the output to the change of the input [5].

It is usually defined as the ratio of the output full-scale value to 2n (n is the number of binary bits of the D / A converter). Obviously, the more binary digits, the higher the resolution, that is, the higher the sensitivity of the D / A converter to changes in the input quantity. Settling time is a parameter describing the conversion speed of the D / A converter and is used to indicate the conversion speed. Its value is the time required from the input digital quantity to the output reaching the final value error ± (1/2) LSB. The conversion time of the output form is short, while the converter of the output form is voltage. Since the delay time of the operational amplifier to complete the I / V conversion is added, the settling time is longer. The fast D / A converter has a settling time of less than 1 μs. Figure 5 shows a D / A conversion circuit.

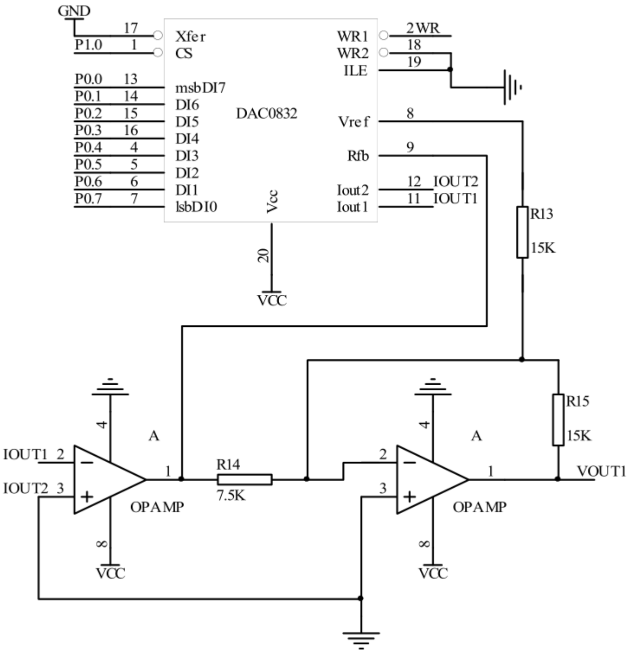

Fig.5 D / A conversion circuit

3.4. Flow Detection Module Design

The electrode-type non-magnetic flowmeter DN20 produced by Beijing Huijingtong Technology Co., Ltd. was selected for this system. Features of this non-magnetic flowmeter: a. Wide voltage, low power consumption design, under normal conditions, the working voltage is 3.5-5.5V, the current is a dynamic value, and the minimum flow rate is 9uA. b. The use of pulsed excitation signals in metal damped undamped oscillation technology, which can avoid the disadvantages of magnetic steel fouling of traditional base watches. c. The use of multi-beam technology guarantees higher accuracy and stability and a wider range. d. The sensor adopts non-magnetic detection technology, which has a compact structure and is easy to install and maintain. e. Intelligent self-diagnosis and error correction functions to ensure the normal operation of the instrument. The f interface is simple, which can facilitate the establishment of reliable pulse signal output with the microcontroller. g. When the power supply voltage VCC is higher than 3.6V, the optical signal can be used for signal isolation. When VCC is 3.0-3.6v, it can directly receive the pulse signal without the need for optical coupling isolation. h. The pulse is 512us, which is a high-level pulse signal [6].

3.5. IC card interface module design

Currently on the market are many kinds of contactless IC card, such as ATMEL Corporation TEMIC series, TI's TAG-IT series, the Swiss company EM EM series. But the most representative of the two RF card technology, is the Netherlands PHILIPS company's technology and MIFARE1 Swiss company KABA LEGIC technology. LEGIC technology in the early development of China's market had a lot of possession, even now in terms of its high degree of security and flexibility are other cards can not match. However, due to LEGIC's market position is high-end users card market, which have high requirements for safety certification, but is currently in the country has been more widespread MIFARE1 technology promotion and application. MFRC522 use of advanced modulation and demodulation concept completely integrated passive contactless communication methods and protocols at all types of 13.56MHz. Support ISO14443A of multi-tier applications. Its internal transmitting portion may drive a communication antenna and reader ISO14443A / MIFARE cards and transponders, and no additional circuits. As shown in Figure 6, it is an IC card interface circuit diagram.

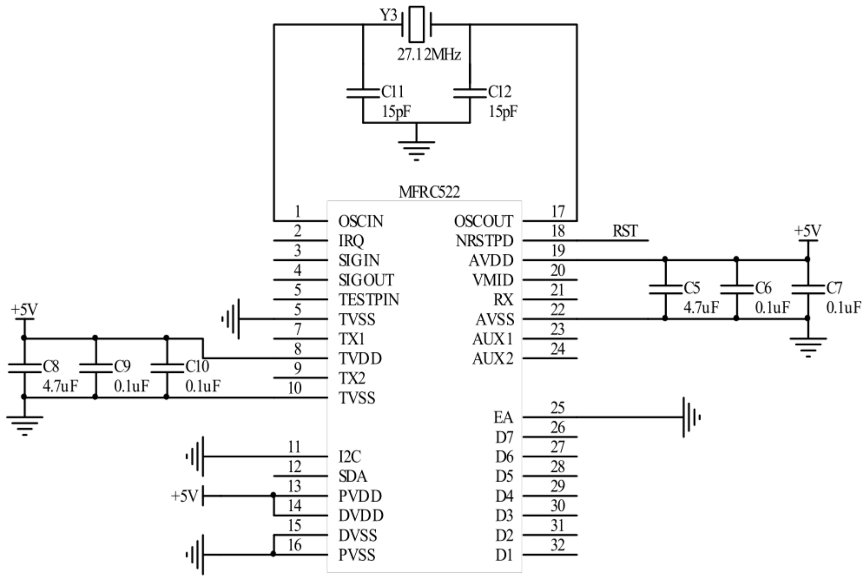

Fig.6 IC card interface circuit diagram

3.6. Display Module Design

In a single-chip microcomputer system, an LCD digital display is usually used to display the control process and operation results. Because it has the advantages of clear display, high brightness, low use voltage, long life, simple structure, and cheap price, it is widely used. It consists of several light-emitting diodes. When the light-emitting diodes are turned on, a corresponding dot or stroke is illuminated. By controlling the conduction of different combinations of diodes, various characters can be displayed. For the heating billing system display screen, various prompt information needs to be displayed, such as heat, accumulated flow, water supply temperature, return water temperature, accumulated working time, purchased heat, and the remaining amount of the heat meter. Considering the low power consumption requirements of this system, a liquid crystal display is used here. The LCD is small, light in weight, and low in power consumption. This system uses a model LCD1602.

3.7. Communication module design

The CAN bus communication module is used in this design. The CAN bus uses a low-cost and easy-to-install twisted pair as the communication medium, connecting each node into a network system. The CAN controller SJA1000 acts as the core and implements the CAN protocol, including framing and de-framing of data, and transmission and reception of frames. Due to the limited bus drive capability of SJA1000, it is connected to the physical bus through the CAN transceiver PCA82C250 chip. The CAN transceiver converts the logic level signal from the CAN controller into a logic level signal suitable for transmission on the CAN bus and can be received by the CAN transceiver, which resists instantaneous interference and radio frequency interference, increases the communication distance and protects the bus. And other effects. The CAN controller and the transceiver cooperate to complete the communication protocol functions of the physical layer and the data link layer in the CAN protocol. The microprocessor STC89C52 controls the functions of the SJA1000, including initialization, monitoring and management, data transmission and reception, and application-layer functions. When a node (station) on the CAN bus sends data, it broadcasts to all nodes in the network in the form of a message. For each node, whether it is sent to itself or not, it receives it. The first 11 characters of each group of messages are identifiers that define the priority of the messages. This message format is called a content-oriented addressing scheme. The identifier is unique in the same system, and it is not possible for two stations to send messages with the same identifier. This configuration is important when several stations are competing for bus reads at the same time.

4. System main program design

The main program is mainly responsible for controlling the work flow of the entire system. In the main program, the first thing to consider is the initialization of each module of the system. After the one-chip computer is initialized, the data memory is reset and needs to be initialized, including the stack pointer, interrupt entry address, and interrupt control. After the initialization is completed, the keyboard subroutine is called to set the data after the interrupt is turned on. If there is no setting, the default setting is enabled and the D / A conversion subroutine is started to monitor and display the data to keep the system stable and automatic operation.

The design system consists of initialization module, data acquisition module, metering module, data storage module, display module, IC card module and other modules. To achieve data collection, thermal energy measurement, display information, remote meter reading and other functions. Modular programming and structured programming are used to complement each other. The function of the heat meter requires a large number of effective programs to implement. So many tedious programs need to adopt a modular programming method. That is, a large program is divided into several small modules, and each module maintains relative independence. In this way, Each program module can be designed separately, so that it is easy to debug, modify and maintain the program. In addition, when the program is large, different people can write different modules at the same time. The main block diagram is shown in Figure 7. The main program is the normal entry point for the operation of the heat meter. It is mainly to mobilize various interrupt subroutines to complete the functions of the system. The main block diagram is initialized first, and then enters the main loop program, determines whether there is a metering interrupt, an IC card interrupt, and performs protective processing again, then enters STOP mode and waits for the interrupt to wake up the CPU.

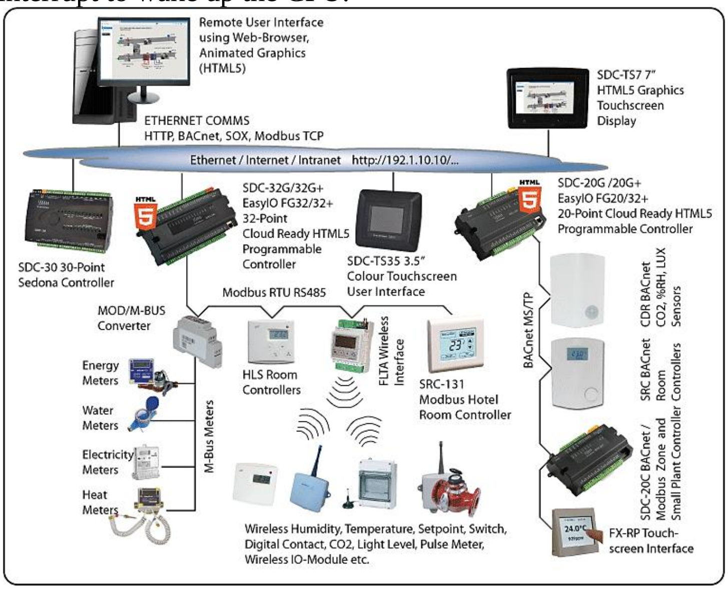

Fig.7 Main flowchart

5. Conclusion

This design applies sensor technology, electronic measurement technology, and remote communication technology to urban winter heating charges. Taking various parameter indicators in urban heating as the measurement object, the flow measurement adopts advanced non-magnetic measurement technology, which solves the problems of blockage and the decrease in power consumption caused by the adsorption of iron filings in the past when there was magnetic flow measurement. The design of the temperature measurement circuit was completed. On the premise of reducing costs, the circuit structure was simplified as much as possible to meet the requirements of specified accuracy and power consumption, and the complexity of the circuit was reduced. Use non-contact IC card communication to complete the system's prepayment and monitoring functions. Compared with contact cards, non-contact cards have the advantages of long service life and higher reliability. By setting cards with different roles in the system, the functions of the system are improved, ensuring the security of the entire payment process and the fairness of the interests of users and suppliers.

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