Low cost intelligent household design based on Modbus/RTU protocol

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Abstract. Concerning about the fact that the quality of citizen’s daily life is improving in recent time, the construction of smart home has become as mainstream. We designed the intelligent household control system which achieved the multi-device communication through Modbus/RTU protocol, including the master device (AT89C51 singlechip), and the slave device. The master device took interrupt mode to send and receive data and realized the function that the slave device could receive, process, framing and send out the messages by adopting modular programming. The conflict of electrical level because of multi-device communication was solved effectively by designing the matched communication interface according to the Modbus protocol. This system has been tested to be useful and stable in basic control for intelligent household device. It can be easily achieved, duplicated and transplanted due to its minimal and low cost design.

1. Introduction
In recent times, with the unprecedented development of social economy, the living standard of citizens has a dramatic improvement, thus, safe home system receives more and more favor. Intelligent Household, also known as home LAN (local area network), takes the home-building as fundamental platform and has information and intelligence of residence, network, and household appliances. This system has many advantages such as high efficiency, comfort, safety, convenience, environmental protection, and combines structure, management and service. Intelligent Household has a breakthrough which solves the issue that traditional housework is always completed by human and the single exchange of information between people and home devices. Intelligent Household is already being tried and has been the trend of the future in this increasingly automated society.

Most of the traditional Intelligent Household adopt the structure based on wired connection, which only realizes the simple interconnection of the home system. However, there are no communication protocol which can be used to uniformly control all home appliances, the solution does not have extension which need designer to come up with specific solutions to actual situation of customers. These disadvantages immensely hinder the widespread of intelligent household and the ease of use.

This article aims at achieving communication control system for household appliance and researches a measuring and control device for reading and modifying the state of a household device that retains the control communication port, based on single-chip microcomputer. By designing minimum unit controller, I adopt single-chip microcomputer, AT89C51, as main control unit to implement multi-device and distributed controlling. On account of the programmable full duplex serial communication interface inside the standard 51 single-chip computer, this system without adding...
another hardware resources enables Modbus protocol to apply to muti-device communication module, and design integrated regulation of communication.

2. Modbus communication protocol and setting

2.1. Modbus protocol specification

The communication formats of Modbus protocol mainly contains ASCII, RTU, TOP and so forth. The RTU (Remote Terminal Unit) format is adopted widely because less numbers are needed for the same information and RTU formats have larger data traffic at same communicate speed. Every byte in message of RTU format contains two four-digit hexadecimal characters. An integrated data of Modbus RTU consists of 1 address bit, 8-digits data bits, 1 parity check bit, 1 stop bit and 1 error checked bit.

This protocol apply to conventional devices such as RS-232, RS-422, RS-485 and Ethernet [4]. The data communication of controller adopts the technology of one master with muti-slaves. Each device only has unique device’s address in the same communicate network. When the host sends message to ask for messages, the slave device will give corresponding reactions according to the messages from the master. The master computer not only can communicate with the a slave, but also can communicate with all the slaves by broadcast. For a separate communication, the slave responds certain message to the master. If inquired by broadcast, the slaves don’t give any response. The RTU format of Modbus communication protocol are displayed in Table 1.

| start bits | address codes | function codes | data area | CRC codes |
|------------|---------------|----------------|-----------|-----------|
| T1-T2-T3-T4 | 8bits         | 8bits          | n×8bits   | 16bits    |

2.2. Serial communication protocol

Serial communication format contains 1-digit start bit and 8-digits data bit, 1 stop bit; The traffic rate is 9600 bit/s; communication mode applies one-to-one model (or one-to-many) master/slave mode; communication protocol is Modbus RTU. The address codes are the addresses of the slaves. Setting single-chip microcomputer(C8051F) as 01, PC (personal computer) as 02, command words are functions performed by the slave. Single-chip microcomputer waits for response after sending address codes, and sends command codes after receiving the answering signals. When single-chip microcomputer collects all data, such as the length of verification does not match the length of the uploaded data, it indicates that the data is inserted incorrectly or lost due to interference during data transmission. Consequently, the frame of data should be discarded and be asked to resend.

2.3. Communication interface design

The data acquisition system based on single-chip microcomputer, AT89C51, takes responsible for receiving the data from Real Time Monitoring System, and inputs the information to FLASH chip K9F1GU0b and stores these information forever, and achieve the transmission of data between the FLASH and PC, after receiving the request made by the higher-level software.

C8051F takes charge of collecting and storing the data from home appliance status, the further data-processing and classification are achieved by PC, that is, the match host computers communication software takes the data, displays, and processes the database report and trend chart and prints these off finally.

Single-chip microcomputer AT89C51, the master computer, C8051F and PC as the slaves both take the serial ports of single-chip computer. However, there is only one receive and send duplex serial ports, lead to communication conflict between the host and subsidiary computer. This device adapts
several communication protocols as the method for solving the issue, and develops corresponding electric circuit of computer hardware interface. Finally, it achieves the point-to-point communication between the single-chip computer and the subsidiary computer, by developing the softwares and hardware.

Single-chip microcomputer, AT89C51, provides good conditions for RS-232 asynchronous communication. The communication interface circuit between PC and C8051F displays in figure 1. This circuit takes driver chip MAX232 conform to the standard of RS-232 to serial communication.

![Figure 1. PC and C8051F communication interface circuit design](image)

3. Communication process
The host program mainly achieves the setting of serial ports’ communication and another two functions. The content of the master’s communication is made up of several parts, communication initializing for Modbus, the message changed into frames, sending messages, receiving messages, processing messages and so forth. The detail of it displays concretely in figure 2.
After the communication test of the master is correct, the master has been waiting for a request from the PC. If receiving the PC port state detection command, the master computer sends command to
C8051F, the state data of household appliances are collected by the 12 bits AD module of C8051F. After receiving all data, the master will check, if correct, the data input the Flash of the master, or send the resend command to C8051F to recollect. Making sure that the collected data is stored in Flash, and the collected data are transmitted by the master to PC. If receiving a status setting command from the PC, the master take data from PC, and it will be stored in the master’s Flash after passing the inspection. Then send it to C8051F, and the 12-digits DA module is converted and sent to the control module of household appliances.

The slave communication is similar with that of the master which process of communication includes receiving messages, processing messages, the message changed into frames, sending messages and so forth. Receiving and sending both adopt the interrupt mode.

After initiating the serial ports, waiting for command, after judging the beginning character, starting receiving the address characters. If the address is not local, it will not be appropriate, if not, the local address replies with a response message, parses command code and perform different functions.

4. Device and field tests
After taking this system to test the prototype of air conditioner, we could read three temperatures from room temperature sensor, external tube temperature sensor and external temperature sensor, by inputting request status monitoring on PC terminal port wizard. When PC terminal port wizard inputs state settings and setting values, the setting values can be written to slave by the master, transmitting through the air conditioning control module external connection serial communication port to the air conditioning control circuit. Increasing household equipment to three air conditioners, by testing, this system runs steadily without communication interrupt or accidental shutdown. In normal operation, in the face of a sudden stop or disconnect on the slave, these will not affect other devices’ normal communication on the communication network. When devices go back to normal, the system will be reinitialized, waiting for new command to continue working.

5. Conclusion
This article adopts Modbus communication protocol RTU messages format and corresponding interface design to achieve the muti-device communication which take single-chip microcomputer, AT89C51, as the master, other single-chip computers as the slaves. It minimizes the cost of data transmission and communication in Intelligent Household systems. The device designed in this article includes RS-232 communication interface. We can monitor part of household appliances through RS-232 port by laptop computers or desktop computers. It can realize the function of real-time calling, real-time reading and real-time setting, and it can extend to 247 home appliances. In the future, this Intelligent Household system also can take smart phones instead of PC as the host computers to interact with people and adopt a wireless communication method which has a lower and lower cost to replace the RS-232 wired serial communication module between the master and the slave.

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