Granary Temperature and Humidity Measurement System based on Zigbee Network

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ABSTRACT: *Aiming at the problem of intelligent monitoring in grain storage, a design plan of temperature and humidity is proposed based on ZigBee wireless network. The system integrates the SCM technology, computer technology, intelligent sensor technology and wireless communication technology, using STC89C52 microcontroller as the control chip, SHT11 as an integrated temperature and humidity sensor, and using ZigBee as the data transmission of wireless network, PC machine as the position machine to achieve human-computer interaction. Practice has proved, the wireless sensor network system overcomes the limitations of wired sensor networks, and the whole system is easy to operate, strong expansibility, realizes the intelligent management of the granary and has higher application value.*

Keywords: ZigBee Network, SHT11, SCM, Granary

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1. Introduction

As the critical safeguard mankind lives on, food has a direct effect on the security of people's life and national stability. Therefore, the safe storage of food is an important issue concerning national welfare and the people's livelihood. In order to guarantee safe food storage and prevent food mildew and contamination, it's necessary to detect the biological state of stored food[1-3]. To follow the routine way for detection, technicians have to measure the temperature and humidity of stored food at fixed periods. However, this process, with low efficiency and high labor intensity, can hardly realize the 24h/day monitoring over food status and results in the low automation level of the safety management of Chinese granary. Further technological modification and improvement is in urgent need. The development of modern information technology and sensor technology has provided new opportunities for the improvement of the automation of grain elevators; on the other hand, intelligent measure and control technology has drawn more and more public concerns. In this context, at present in China, it has become one of important issues for safe food storage to effectively monitor the biological state of stored food with automatic control system[4-7].

In order to find a better solution to this problem, considering the larger-area distribution of granaries, this paper designs a set of humidity & temperature monitoring system based on wireless sensor network. This system adopts the SHT11 integrative temperature & humidity sensor and uses the STC89C52 single chip as the control chip. Moreover, it takes ZigBee as the wireless network for data transmission and PC as the upper computer to realize man-machine interaction. With easy operation and strong expansibility, the whole system helps to realize the intelligent management of granary and is highly worth application.

2. Overall Design Scheme of the System

The granary humidity & temperature wireless monitoring system mainly consists of wireless network, field controller and monitoring host. Figure 1 shows the overall structural model of it.

The field controller and the monitoring host constitute the distributed and networked computer control system. The monitoring host connects the data terminal through interface as the upper computer. The working principle is that: each granary has a routing-capable field controller that mainly consists of humidity & temperature sensor module and ZigBee wireless transmission module to send data and receive commands from the monitoring host. The host is connected to a ZigBee coordinator as the data terminal, forming a ZigBee wireless network together with ZigBee nodes of the field controller. The ZigBee coordinator is connected to RS232 interface through the monitoring host. Status information of each granary passes through the ZigBee network and finally reaches the monitoring host to be displayed. The monitoring host coordinates and controls all processes of the whole system, provides man-machine interface, analyzes, calculates and stores all collected data. The host can also send control command to the whole network, which will be then broadcast by the Zigbee coordinator. Once the command is received, the sensing node will perform corresponding control.

There is a field controller for each granary. The controller takes single chip as the cybernetics core and has rich interfaces. It can be attached by multiple sensors according to the size of the granary and is mainly used for humidity & temperature data collecting and transmission and opening the fan. Each humidity & temperature measure station is equipped with a sensor, which can send detected humidity & temperature data to the field controller and display it on the screen. The field controller can compare the collected data with alarm threshold values. Once the data exceeds the threshold values, it will start the fan control process and give a sound-light alarm.

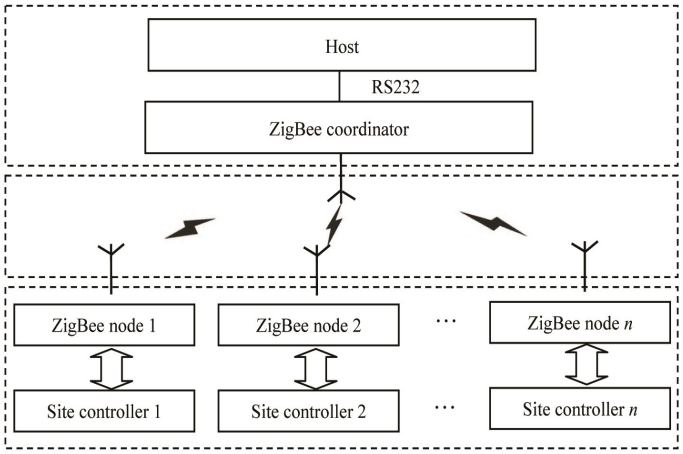


Figure 1. The overall structure of system

3. Hardware Design of the System

Hardware of the granary humidity & temperature monitoring system mainly includes node field-controller module and data terminal module. The field controller therein mainly consists of supply circuit, clock circuit, microcontroller module, sensor module, sound-light alarm module, wireless transmission module, display module, keys and control module. The structure is shown in figure 2.

3.1 Microcontroller and Clock Circuit

The field controller uses single chip STC89C52 (produced by Shenzhen Hongjing Technology) as the processor. It is an enhanced high-performance CMOS microprocessor with 8K-byte internal programmable memorizer and 512-byte SOC RAM. The instruction code and mount structure are fully compatible with the conventional 8051. STC89C52 has three 16-bit timers: T0, T1 and T2, falling-edge interrupted or low-level triggered circuit. Four of the circuits can be interrupted. It also has the unique Watchdog function. A universal 8-bit CPU and ISP Flash storage unit are embodied on the chip. No special programming unit or emulator is necessary to download program, because user program can be downloaded directly onto the chip through interface.

Therefore, it provides effective solution for the development of a great number of control systems. Figure 3 shows the minimal-configuration system circuit. Y1 is a 12MHz crystal oscillator; K1 is the circuit reset key; C1 and C2 are 30PF capacitance.

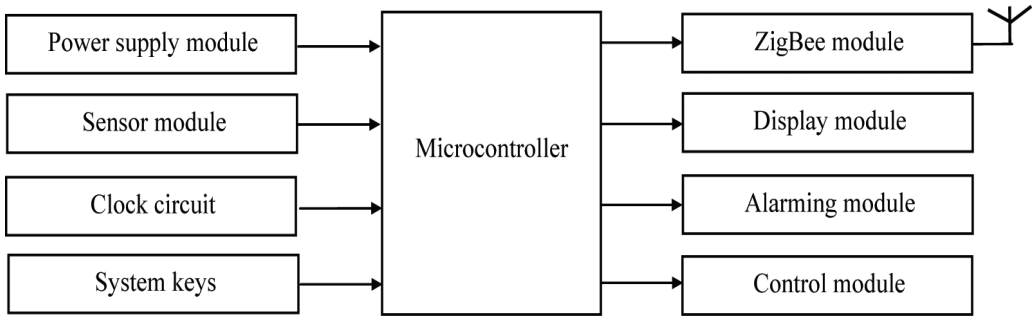


Figure 2. Structure of site controller

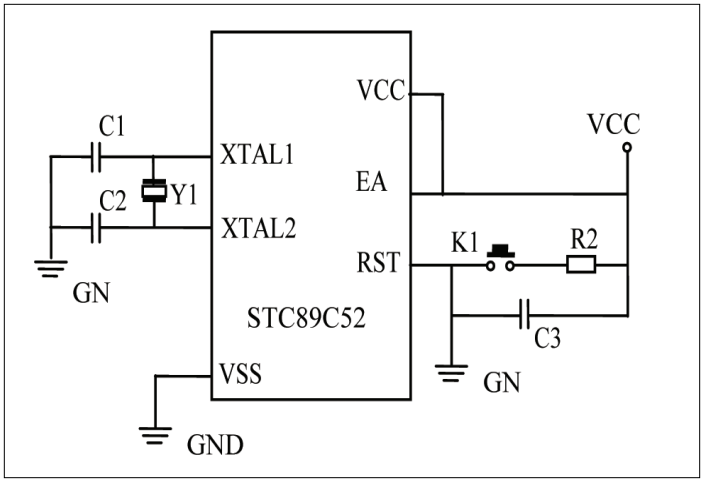


Figure 3. The smallest MCU system

3.2 Power Supply Module

Since the working voltage of single chip STC89C52 is 3.8-5.5VDC and the granary circuit provides 220V alternating current, it's necessary to transform the voltage with a potential transformer and then convert the voltage through a rectification capacitor filter circuit into 5V fixed voltage for output. Figure 4 shows the conversion circuit. The circuit uses the 7805 three-terminal voltage regulator. The encapsulation style is T0-220 with regular linear voltage dropping DC-DC convertor. This convertor provides 1.5A output and has overheating protection. When appropriate external component is connected to it, the convertor allows different voltages and currents to pass through.

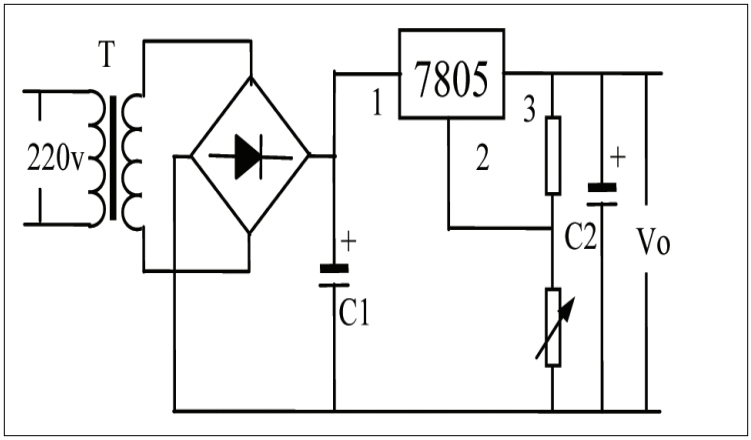


Figure 4. The power supply circuit

3.3 Sensor Module

Since temperature and humidity are the main parameters for describing the status of food, this paper finally chooses SHT11 as the sensor considering the range and accuracy requirement. Produced by Sensirion (Switzerland), it is an integrated humidity & temperature sensor with I2C-bus single-chip all-calibration digital signal output. The sensor has 14-bit output resolution of humidity and 12-bit output resolution of temperature, which can also be set as 12-bit and 8-bit respectively in programming. Supported by the unique CMOSens TM technology, it has the characteristic of digital output, debugging-free, calibration-free, peripheral-circuit-free and all-conversion. It is small in size and low and power consumption, 550μA when measured, 28μA by the average and 3μA in sleeping mode. It runs stably and chronically if powered by battery. SHT11 can reach an accuracy of ±3.5% (20%-80%RH) when measuring the relative humidity. Meanwhile, with a temperature measuring range between -40^{o}C to +120^{o}C and a corresponding accuracy of ±0.5^{o}C, it can totally satisfy the needs of actual measurement. Figure 5 shows the connection between SHT11 and the single chip.

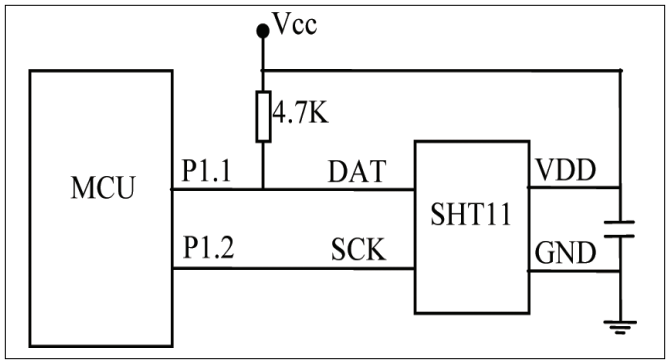


Figure 5. The interface of SHT11 and MCU

3.4 ZigBee Wireless Communication Module

The configuration of the wireless network of the system is supported by the Zigbee technology. There is a reliable communication between the granary field and the monitoring center of the system. This technology, featured with low power consumption and low cost and mainly applied to electronic devices with low efficiency of data transmission and close transmission distance, is very suitable for industrial control and parameter collection. In order to reduce the development cycle, the DRF2617A module (Dingtaike Electronics) is directly adopted by this system. This module is developed by TI based on the latest ZigBee SOC chip, the CC2530F256; with the 256KBFLASH, it is endowed with all the functionalities mentioned by the ZigBee2007/PRO protocol. In the mode of receive and transmit, the current loss is below 25mA and 34mA, respectively. An external stabilized power provides this module with 5V voltage to guarantee the long-term and stable operation of it. DRF2617A can be connected to the single chip through RS232 serial ports. Users are allowed to change the channel following serial port instructions. The visual communication distance of the outdoor/wireless RF can reach as high as 1,600m. Figure 6 shows the junction circuit of the module and the single chip.

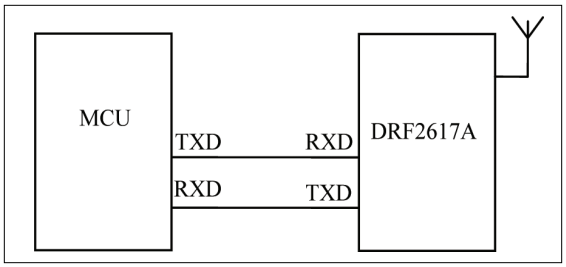


Figure 6. The connection circuit of ZigBee module and MCU

3.5 External Device Control Circuit

The ventilation device of granary uses the on-off control system. Port P1.7 of the single chip STC89C52 is the output control port. The output signal passes through the amplifying circuit to realize the on-off control of the ventilation device to regulate the relative humidity of the granary. The ventilation device must be controlled by heavy current, and the switching value of the output of the single chip system is TTL level, which cannot directly drive external devices in general situation; on the other hand, the fan causes strong electromagnetic interference in the switching process, and system error or damage might be caused if no isolation measure is taken. Therefore, in the interface design, this system uses optoelectronic isolator for the optoelectronic isolation.

4. Software Design

Software is an important part in the design of humidity & temperature monitoring system. Modularized designing method is employed to develop the software design of this system. The programming is based on C language. The software mainly includes field controller testing program and man-machine interface program of the monitoring center.

4.1 Program Flow of Field Controller

According to the working principle of humidity & temperature sensor and the communication protocol of the ZigBee module, all the interfaces between components and single chips should be provided with strict time-control. Once the system is powered on, single chips, SHT11, corresponding I/O of the ZigBee module and relevant registers begin to initialize and the wireless network is established. Based on the sent commands, the field controller starts the data transmission, humidity & temperature data collection and then displays it on the screen. If the humidity or temperature exceeds the threshold value, the control device will be started and a sound-light alarm will be given; if the data-collection commands sent by the monitoring host are received this moment, it will be sent to the monitoring center through the ZigBee module. Figure 7 shows the program flow.

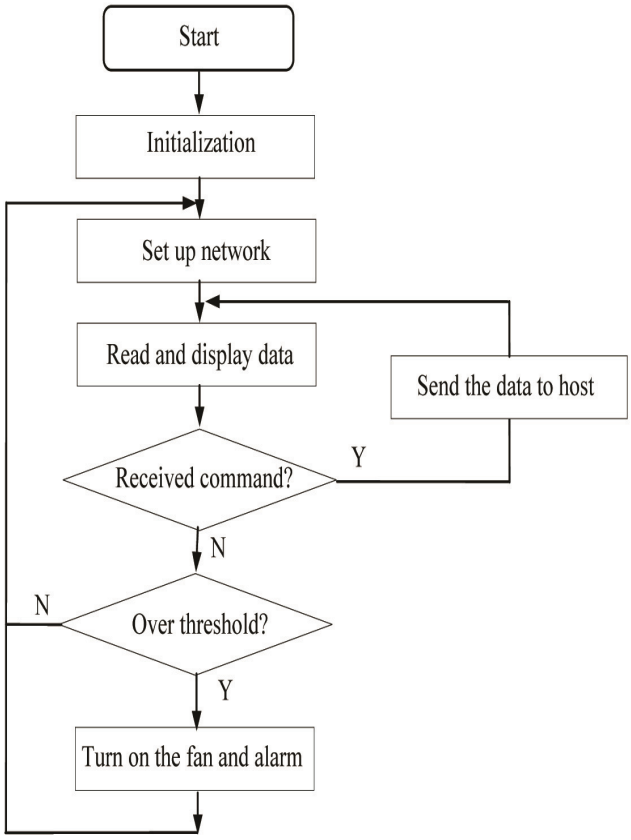
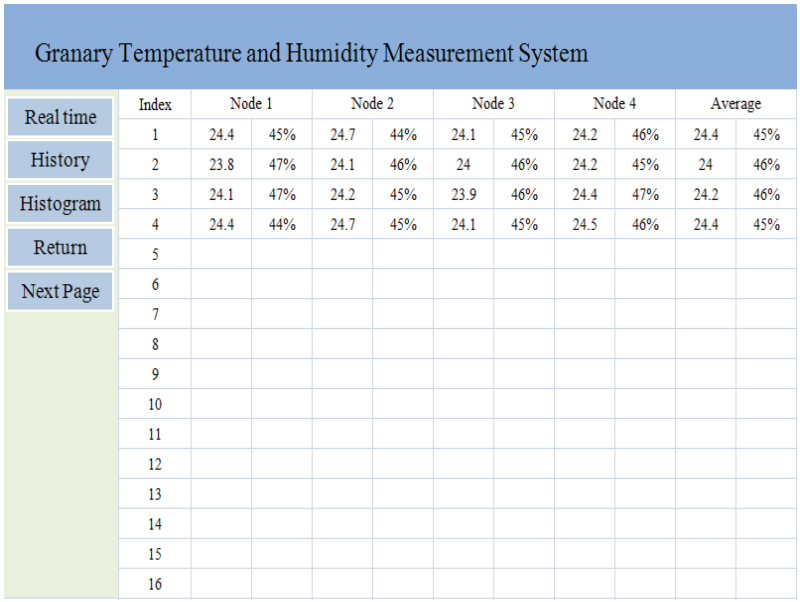


Figure 7. Program flowchart of control node

4.2 Software Design of Monitoring Host

Monitoring software of the host mainly includes serial port communication module, man-machine interface and database. The lower computer collects all the obtained data, including port number, humidity & temperature data and status information to the PC. The application platform of the monitoring software is Microsoft WindowsXP. The client application program is the interactive interface between operating personnel and database. All queries, modifications and other operation of the database are done through the client application program. The primary function of the database application program is humidity & temperature data storage, data search and statistics out of the database to get all kinds of information (various charts and graphs). The application programs of a complete database can be divided into four categories according to function: database, application form, query and statistics, charts and graphs. Figure 8 shows the final interface of this system.



Index	Node 1		Node 2		Node 3		Node 4		Average	
1	24.4	45%	24.7	44%	24.1	45%	24.2	46%	24.4	45%
2	23.8	47%	24.1	46%	24	46%	24.2	45%	24	46%
3	24.1	47%	24.2	45%	23.9	46%	24.4	47%	24.2	46%
4	24.4	44%	24.7	45%	24.1	45%	24.5	46%	24.4	45%
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Figure 8. The Human-computer interface

5. Experimental Test

In order to verify the system performance, we conducted black-box testing and white-box testing experiments. The black-box testing mainly focuses on the system function, while the white-box testing focuses on the internal logic. Repeated tests and pilot runs indicate that the system host and field controller nodes perform quite well, and the expected function has been stably realized. Major experimental projects include:

(1) Data collection of the sensor: a field controller is able to finish multiple-spot data collection. The humidity & temperature measuring error is less than 0.6 ! and the relative humidity error is less than 3%.
(2) Display and alarm function: multiple-spot data from the granary field can be displayed; an alarm will be given if the data exceeds the threshold value.
(3) External device control: the field controller can start and close the ventilation device through the relay.
(4) Wireless communication test: the lower computer receives commands from the upper computer and smoothly transmits it to the monitoring host as required.
(5) Interaction between the monitoring host and man: operating staff can set the control parameter and timely display the measured data; they can also analyze the historical data through charts and graphs.

To sum up, by processing the collected data stably and timely and detecting the status of food stored in granaries effectively, the monitoring system realizes the intelligent environment control.

6. Conclusion

Focusing on the intelligentization of food storage, this system is designed to provide effective and practical environment monitoring system for the safe of stored food. This system overcomes the limitations of wired sensor network with the wireless sensor network constructed based on the ZigBee technology, so hat to improve the collecting accuracy, save the labor force and accelerate the upgrading of the existing automatic measuring and controlling technology. This monitoring system, with the advantage of high detection accuracy, simple application, low cost, stable reliable operation and so on, can not only be applied to the granary's environment measurement and control, but also can be further promoted to the greenhouse vegetable planting, wireless meter reading and other fields. The application prospect is promising.

Acknowledgement

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