Design and Implementation of WSN-based Warehouse Temperature Sensor Monitoring System

Qijian WANG1, Mengqin Xia2, Yehui Chen3 and Yuting Yu*

1Department of Electronics, Anhui xinhua university ,Hefei,Anhui ,230088,China
2Department of Electronics, Anhui xinhua university ,Hefei,Anhui ,230088,China
3Department of Electronics, Anhui xinhua university ,Hefei,Anhui ,230088,China
*Department of Electronics, Anhui xinhua university ,Hefei,Anhui ,230088,China
*Corresponding author’s e-mail: yuyuting@axhu.edu.cn

Abstract: China is a large agricultural country. As an important part of the national economic foundation, the scientific storage of grain is particularly important in the process of grain production. This system uses STC89C52, nRF24L01, DHT11, etc. to form a WSN-based wireless temperature and humidity sensor monitoring system. The system monitors the humidity and temperature in the granary in real time. If the set point is exceeded, it will give an alarm. The timeliness and accuracy of environmental monitoring data on granary management will be improved, and human resources will be saved.

1. Introduction
China is a large agricultural country, every year after the grain harvest, grain storage in the granary. Grain is not only affected by humidity, but also by temperature, so the humidity and temperature in the granary should be kept within a reasonable range [1]. Grain reserve refers to a process in which grain leaves the field of production and stays in the field of circulation before it enters consumption. Grain reserve is an essential link in grain circulation. Storage of grain for a long time depends on three factors: specialized storage warehouses and complete supporting facilities; effective storage technology; scientific management methods. Traditional granary storage not only wastes manpower and material resources on a certain basis, but also cannot guarantee the safety of food [2-5].

This system mainly uses DHT11, NRF24L01 and STC89C52 to collect the temperature and humidity in the granary in real time, and displays the real time monitoring value in the LCD screen. Its core technology is wireless sensor network technology. Wireless Sensor Networks (Wireless Sensor Networks, WSN) is a distributed sensor network. Sensors in WSN communicate wirelessly. The network settings are flexible and the location can be changed at any time. WSN is widely used in military, environmental monitoring, intelligent transportation, medical and health and other fields and is developing rapidly. Wireless sensor network technology has the ability of self-organizing network, low node energy consumption, simple application, low cost, etc. The nodes are powered by batteries, which significantly improves the safety index [6-9].
2. System design principle and scheme
The system is composed of MCU minimum system (STC89C52 as the core), DHT11 circuit, wireless transmission circuit, LCD LCD display circuit, acousto-optic alarm module and power supply. The principle frame of this system is shown in Figure 1.

![System principle block diagram](image1)

Figure 1. System principle block diagram

3. Hardware design

3.1 STC89C52 minimum system
STC89C52 minimum system includes power supply, clock circuit and reset circuit. The normal voltage range of STC89C52 is 4V-5.5V, therefore, it is enough to connect 5V DC power supply to STC89C52. The clock circuit is composed of an oscillator, a capacitor and a crystal oscillator control chip; the reset circuit is completed by RESET (reset pin RST), that is, the S5 switch realizes the reset function. The smallest system of STC89C52 is shown in Figure 2.

![Single-chip minimum system](image2)

Figure 2. Single-chip minimum system

3.2 DHT11 circuit
The DHT11 sensor is connected to the P1.0 interface of the STC89C52 through Pin 2. P1.0 is the data interface for sending and receiving serial data. And DHT11 is connected to the power supply through pin 1, and DHT11 is grounded through pin 4. DHT11 pin 3 is floating. The circuit connection diagram is shown in Figure 3.

![Connect circuit diagram](image3)

Figure 3. Connect circuit diagram
3.3 Wireless transmission circuit
The wireless module nRF24L01 is used for the wireless transmission of temperature and humidity. Figure (a) is the transmitting module of nRF24L01. Data transmission is realized by connecting with the P21-P26 pins of the transmitting module STC89C52. Figure (b) is the receiving module of nRF24L01, which is connected with the P10~P15 pins of the receiving module STC89C52 to realize data transmission. The wireless transmission circuit is shown in Figure 4.

3.4 LCD1602 liquid crystal display circuit
The system uses LCD1602 LCD screen, the display capacity of LCD1602 LCD screen is 32 characters, the character size is 2.95×4.35mm, the working current of the chip is 2.0mA, the working voltage is: 4.5V~5.5V, among them, the best working voltage is 5.0V. The LCD1602 LCD screen uses a standard 16-pin interface. The circuit of LCD1602 LCD screen is shown in Figure 5.

3.5 Acousto-optic alarm circuit
This system uses NPN type S8550 transistor drive, The P16 port of STC89C52 outputs low level. The collector of the triode is counter-biased, and the emitter is positively biased. When the triode is saturated, the light-emitting diode will emit light. The buzzer sends out sound to realize the function of acousto-optic alarm. When the P16 port of STC89C52 outputs high voltage, the triodes is cutoff, the buzzer and the light-emitting diode stop working. The acousto-optic alarm circuit is shown in Figure 6.
4. System software design

4.1. Flow chart of wireless transmission
Initialize the I/O interface and SPI register of STC89C52, so that it can communicate with nRF24L01 normally. The system configures the RF chip to enter the correct working mode. When it transmits data, it is set to transmit mode, that is, the TX-ADDR (target address) and TX-PLD (data) of the data to be transmitted at the sender end are written into the buffer, and the transmission is delayed by 130μs. The flow chart of wireless emission is shown in Figure 7.

![Figure 7. Wireless transmission flow chart](image)

4.2 Flow chart of wireless reception
When the system receives data, it is configured to receive mode. The receiving state is then delayed 130μs. When the valid address and CRC are detected, the packet is stored in the receiving stack, and the interrupt flag bit RX_DR in the status register is set high to generate the interrupt to lower the IRQ and notify STC89C52 to obtain the data. The wireless reception flow chart is shown in Figure 8.
4.3 Flow chart of LCD1602 liquid crystal display

The digital tube temperature display adopts bit-by-bit scanning. LCD display code input is P1.0-P1.7 port, corresponding to LCD a~g and dp in turn, LCD bit selection input is P3.4~P3.7 port, corresponding to H1~H4 in turn, H1 is the lowest Bit, H4 is the highest bit. When the P3.7 port outputs low level and P1.0~P1.7 are also low level, the highest position of the LCD display is lit, and the LCD1602 liquid crystal display flow chart is shown in Figure 9.

![Flow chart of LCD1602 liquid crystal display](image_url)
The following are the debugging results of the hardware and software of the temperature and humidity sensor. When the humidity exceeds the set range, the LED will be lit up and the buzzer will alarm. As shown in figure 10.

Figure 10. Test pattern

5. Conclusion
This system uses temperature and humidity sensor DHT11 technology and wireless transceiver nRF24L01 technology to form a wireless temperature and humidity sensor monitoring system based on WSN to complete the monitoring of granary. The sending part is based on STC89C52, and the temperature and humidity conversion chip of DHT11 is used to collect the temperature in real time. The collected temperature is transmitted to the receiving part wirelessly through the radio frequency chip nRF24L01. Finally, it is displayed on the digital tube at the receiving end.

Acknowledgments
Foundation item: 2019 Provincial Teaching and Research (2019JYXM0499)
Provincial Teaching Research Project of 2020(2020JYXM0809)
University-level first-class undergraduate construction site (2020YLZYX01)

References
[1] Sun Z.Q. (2019) Realization of Temperature and Humidity Monitoring System of Grain Barn with Wireless Sensor Network Facilities. Journal of Jilin University of Chemical Technology, 36(09):86-90.
[2] Liang S. (2019) ZigBee-based WSN Measurement and Control System for Rosa Rosa Seedling Greenhouse. Automation Technology and Application, 38(07):60-64.
[3] Song W.W., Li M., Yang Y.J. (2019) Design of remote greenhouse monitoring system based on WSN and PLC. Journal of Anhui Agricultural Sciences, 47(02):246-249.
[4] Du C.Z., Tang S.T., Yang K.M., Wang Y.C., Wang S.L. (2018) Study on Influence of Temperature Change on Temperature and Moisture Migration of Grain Dumps under Continuous Ventilation Condition. Journal of Henan University of Technology (Natural Science Edition), 39(05):96-101.
[5] ZHANG G. (2017) Discussion on the application of intelligent robot in grain depot. Food Safety Guide, 36:32.
[6] Liang Y.Q., Li H.B., Luo Y., Kang Y.C., Liu S., Liu Z.L., Chen L.W. (2020) Development of intelligent mobile monitoring system for facility agriculture based on WSN. Computer Technology and Development, 30(07):164-168.
[7] Song W.W., Li M., Yang Y.J. (2019). Design of remote greenhouse monitoring system based on WSN and PLC. Journal of Anhui Agricultural Sciences, 47(02):246-249.

[8] Zheng Z.H. (2019) Application of WSN in greenhouse environment monitoring. Journal of Qiqihar University (Natural Science Edition), 35(01): 43-50.

[9] Xiong Q. (2017) Autonomous positioning and navigation design of fruit and vegetable picking robot——Based on the fusion of RFID and WSN information. Journal of Agricultural Mechanization Research, 39(10): 223-227.