Design of Fire Monitoring System for Communities Based on NRF24L01

Qiong Wu[1], Peng Yang[2]

[1]Department of Computer Science and Electrical Engineering, Heilongjiang Oriental College Harbin, China

[2]Project Department China Resources Land (Harbin) Real Estate Co., Ltd Harbin, China

E-mail: 282977435@qq.com;5249622@qq.com

Keywords: fire monitoring; sensor;NRF24L01

Abstract: Aiming to problems that may occur in the fire monitoring system, such as electricity and signal wire damage, short wireless transmission distance, and conditions in which the situation of fire may not be transmitted due to the loss of signal, based on the Internet of Things technology, wireless sensor modules NRF24L01 is used to create a ad hoc network, designing a custom network communication mode, and transmitting sensor data. At the same time, two sets of power supply systems are used, one set supplies electricity by using an electric power system, and the other set supplies electricity by using internal batteries in an emergency situation when electricity cannot be supplied externally, to ensure the normal operation of the monitoring system. Once the fire detector in one area detects a fire, the fire control linkage will be activated so as to control the fire in time and tell the monitoring station which area has a fire. Relevant personnel will develop more effective and targeted solutions for specific situations, and to minimize the loss of personnel and property caused by fire and to protect the safety of people's life and property.

1. Introduction

With the rapid development of the social economy, low-rise residential quarters, commercial buildings, high-rise buildings, etc. have also sprung up. Today, as cluster buildings and high-rise buildings are increasing, people pay more and more attention to fire safety issues. Many types of sensors for either wired or wireless fire monitoring systems have been put into use. Fire control linkage plays an important role in detecting and extinguishing fires in a timely manner, preventing the spread of fire, and protecting people's life and property. However, because wired independent monitoring linkage equipment needs to use city power grid and wired communication facilities, when a fire occurs, it may not be able to work due to the damage of power supply line or communication line, resulting in the fire behavior not being accurately and timely reported, causing a fire spread and heavy losses. Wireless sensors have the problem of short signal transmission distance. In the event of a fire, it is more likely that the fire will not be reported in time due to poor signal.

Therefore, people's demand for building fire safety and prevention is increasing day by day. With this demand, the advent of a stable, safe and reliable sensor for fire monitoring has important practical significance for people's life and property safety [1]. At the same time, the market is also aware of this issue, and a variety of sensors for fire monitoring have emerged. In addition to their good abilities in monitoring fire and guarding safety, they also have some shortcomings. For example, if there are many monitors in a residential building, the batteries need to be replaced after one year of use. Therefore there will be a risk of not being able to detect a fire when a certain sensor has no power. Besides, replacing the batteries will increase labor costs. In addition, transmitting information to the outside world relies on wired communication. When a fire is so large to burn down the communication line, information will be not transmitted. Some monitors only have alarm function, without emergency response function. So they can only send out an alarm, but cannot effectively control the fire.

In view of this, a stable, safe and reliable monitor is what we especially need nowadays. In order

  DOI: 10.25236/icemit.2019.037

to overcome the shortcomings of existing sensors on the market and integrate all the needs, a monitor is designed in this paper [2].

2. Overall system design scheme

The fire monitoring system designed in this project is composed of a single-chip microcomputer (SCM) and other peripherals. STM32 SCM is used as the central processing unit. It has the characteristics of low power consumption and high speed. The SCM has abundant and powerful peripherals, and also has a wealth of General Purpose Input/Output (GPIO). The desired functions can be realized by programming this chip to control peripheral circuits and modules. Its architecture is shown in Figure 1.

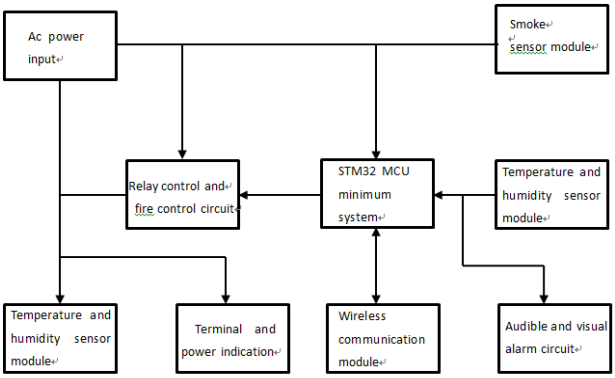

Fig.1 Structure block diagram of three-degree-of-freedom helicopter body

Functionally, the monitor has wireless communication, dual power supply, temperature and humidity detection, smoke concentration detection, acoustooptic alarm and fire fighting linkage. When two or more of the three indicators of smoke concentration, temperature and humidity in the environment are detected, for example, indicators of smoke concentration and temperature, indicators of smoke concentration and humidity, or three indicators exceed the set threshold, the system will activate the acoustooptic alarm. At the same time, this node transmits the fire information to a monitoring station through a ad hoc network, and tells the monitoring station the specific fire position. The monitor also judges that if the indicators have exceeded set thresholds for 2 minutes, the fire fighting linkage will be activated to perform fire sprinkling to timely control the fire, even extinguish the fire [3].

At the same time, the dual power supply will play a role in two kinds of emergencies. One is a normal situation in which there is a sudden power failure, and the system will automatically and immediately switch to standby power supply to ensure that the monitor can continue to work. When the power is restored, the monitor automatically switches back to using AC power. Meanwhile, the standby power supply is recharged normally[4]. Another situation is a sudden fire. The fire will damage electric power system. And the monitor will then immediately switch to the standby power supply, and wirelessly transmit the fire position to a monitoring station. One of the purpose of the dual power supply design is to deal with emergencies, and the other is that there is no need to replace the battery so as to avoid non-timely fire reports due to lack of electricity, as well as reduce labor costs.

3. Technology used in design

The core controller of this design adopts STM32F103C8T6 single-chip microcomputer; wireless communication adopts an ad hoc network based on NRF24L01 module to communicate; temperature and humidity sensor adopts a sensor AM2302 whose measurement accuracies of humidity and temperature are higher than that of commonly used DHT11; The commonly used smoke sensor module MQ-2 characterized with long life, low cost and high sensitivity, is used for smoke concentration detection. The core technology of this design is to use wireless communication module

NRF24L01 for large-scale, multi-node ad hoc networks. Each node is both a host and a slave. Each node has the capability to serve as a terminal node to communicate with the upper computer. Another key design element of this design is the usage of dual power supply (both AC and backup power supply) to power the system to ensure the continuous and stable operation of the monitor.

4. System hardware design

4.1 Design of Wireless Communication Module

The NRF24L01 is a single-chip wireless transceiver chip developed by NORDIC, working in universal ISM band of 2.4-2.5GHz. Its highest operating rate is 2Mbps with high efficient GFSK modulation and strong anti-interference ability, especially suitable for industrial control occasions. It supports 125 channels to meet the needs of multi-point communication and frequency hopping communication. It includes built-in hardware CRC error detection and point-to-multipoint communication address control. With low power consumption, operation voltage is 1.9-3.6V. Current is 22uA in standby mode and 900nA in power down mode. The module has a built-in 2.4Ghz antenna and a compact size (15mm*29mm) [5]. An address can be set through software, and the data is output only when the local address is received (providing interrupt instructions). The module can be directly connected to various single-chip microcomputers, and the software programming is very convenient. With a built-in voltage stabilizing circuit, using a variety of power supplies has a good communication effect. The module is easy to use, with 2.54MM spacing interface and DIP package. Working in Enhanced ShockBurst mode with automatic packet handling, auto packet transaction handling, optional built-in packet response mechanism, the module greatly reduces the packet loss rate. The unit has a very low current consumption: with 9mA when the transmit power is -6dBm while working in transmit mode; with 12.3mA while working in receive mode. And the current consumption is even lower in power-down mode and standby mode. The pin diagram of NRF24L01 is shown in Figure 2.

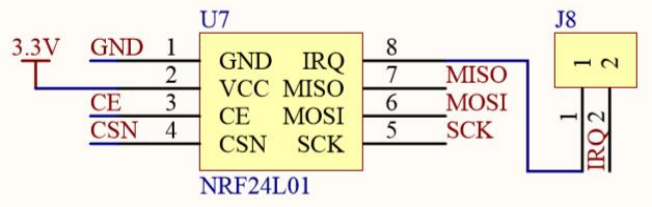

Fig.2 NRF24L01 application

4.2 Design of Temperature, Humidity and Smoke Detection

The temperature and humidity sensor adopts a digital temperature and humidity sensor AM2302, which is a complex sensor for temperature and humidity outputting with calibrated digital signal. The sensor uses dedicated digital acquisition technology and temperature-humidity sensing technology. Digital signal has stronger discreteness and stronger ability of anti-interference than analog signal with weak continuity, ensuring the product has strong reliability and stability. It contains an NTC temperature measuring element and a capacitive humidity sensor, and is connected to an eight-bit microcontroller. Each sensor is calibrated in a precision humidity calibration chamber. The calibration coefficients are stored programmatically in the OTP memory, and these calibration coefficients are called internally during the processing of the detection signal. The sensor has a small size, low power consumption and a signal transmission distance of up to 20 meters.

After the SCM sends a start signal to the AM2302, the AM2302 switches from the low-power mode to the high-speed mode. After the start signal sent by SCM ends, the AM2302 sends a response signal, transmits 40-bit data, and triggers a signal acquisition [6]. The data read by the SCM from AM2302 is the last measured value. The timing diagram of AM2302 start signal is shown in Figure 3.

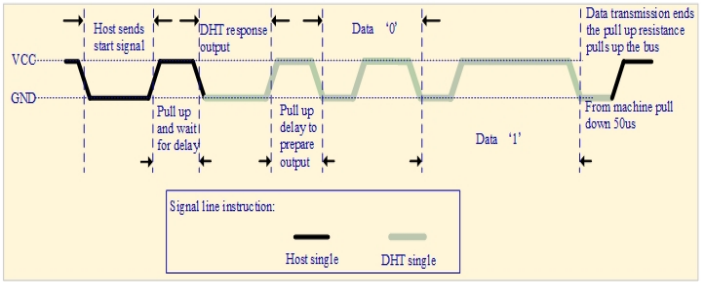

Fig. 3 AM2302 start signal timing diagram

Smoke Sensor MQ-2 is a common gas detection sensor for detecting gases such as liquefied gas, methane, propane, butane, alcohol, hydrogen and smoke. It has high sensitivity in detecting liquefied gas, natural gas and city gas. In this design, the smoke sensor is used to detect whether there is gas leakage and smoke or not, and then combined with temperature and humidity data to detect whether there is a fire[7].

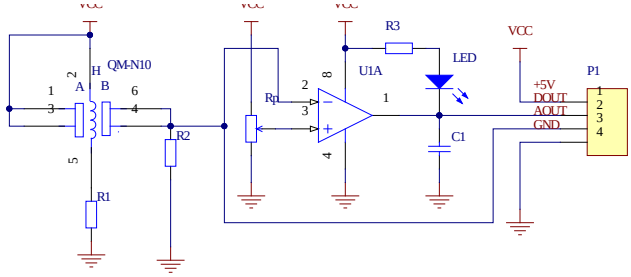

Fig.4 Mq-2 module schematic diagram

As can be seen from Fig. 4, the MQ-2 sensor has both digital and analog outputs. In this design, the digital output is used. During the installation and debugging process, the voltage at analog output terminal is adjusted to 1.2V as the standard by adjusting the potentiometer, and then the digital output is used as a system response.

4.3 Design of Acoustooptic Alarm Section

The designed circuit of the acoustooptic alarm adopts the commonly used transistor amplifier circuit. In this circuit, the transistor operates either in saturated conduction state or cut-off state. In this design, a S8550 transistor (PNP) is used. When the base is at a low level, the emitter and collector are conducting. The 5V active buzzer is used in this design. Since the active buzzer is an inductive component, a freewheeling diode is connected inversely at the ends of the buzzer to prevent the buzzer from generating a counter electromotive force after the power is turned off and thus from interfering the system. The light-emitting component is a 5mm high-brightness red LED with a operating voltage of 1.9-2.1V, using red light warning and ensuring luminous intensity.

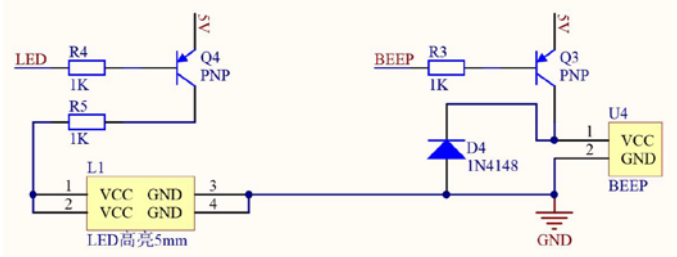

Fig.5 Acoustooptic alarm circuit

4.4 Design of interface for power supply, charge and discharge control and fire fighting linkage

AC power input adopts PB5N-2025 AC-DC module, which is a high-and-low voltage isolated constant voltage power supply with functions of over current protection and short circuit protection. It has a wide voltage input range of AC 85V-265V, optional input frequency of 50Hz or 60Hz. , 3W output power, stable 5V output voltage, and 600mA working current, but without peripheral

components. The module has the advantage of small size, only 25*20*15mm, can be directly welded on the Printed Circuit Board (PCB). It is convenient to convert 220V AC to 5V DC to supply power for the system[8].

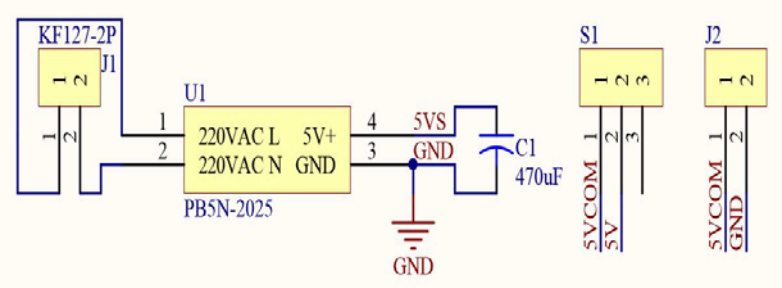

Fig.6 AC power circuit

This design uses a lithium battery charging board charging lithium ion battery up to 4.2V with 5V input voltage. Through a relay control circuit, the charging timing and charging period of a 14500 lithium-ion battery are controlled by the SCM. When there is a failure in the AC 5V external supply power suddenly, through the relay control circuit, the 14500 lithium-ion battery will be switched into the circuit and supply power to the system by a booster board converting 3.7V input voltage to 5V output voltage. When the external power supply is restored, it will be switched into the circuit and the lithium-ion battery will be charged at regular time.

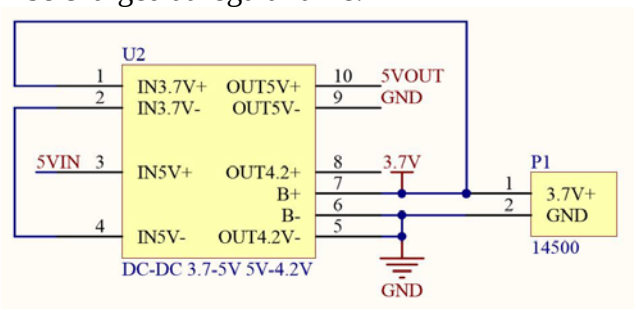

Fig.7 Charge and discharge control circuit

5. Conclusion

Today, fire monitoring is an important field related to nature and national production and life. It has great responsibilities, with rigid demand, good market prospects, and rapid development and application. Fire monitoring system is of great significance for forest-fire prevention and protection of people's life and property. The product designed in this study have a wide range of applications. It can be used in residential buildings, shopping malls, warehouses and other buildings. Because of its compact size, it's installation is convenient. With its powerful functions, there is no need to lay dedicated signal lines. Thus, it has a high price performance. The monitor studied in this project has two sets of power supply systems, which can cope with unexpected situations. The daily temperature and humidity information of each area can be transmitted to monitoring stations by monitors. They can detect harmful gases and smokes, and automatically give an acoustooptic alarm and perform fire fighting linkage. Simultaneously, the monitors transmit information about fire behavior and fire position to monitoring stations.

The fire monitoring system designed in this paper uses STM32F103C8T6 SCM as the controller, combined with wireless communication module, smoke sensor, temperature and humidity sensor and power module, etc., realizes a simple fire monitoring system. The system continuously carries out all-weather monitoring on data of temperature, humidity and smoke concentration, so as to protect people's life and property. Because of its powerful functions, excellent performance, high reliability, wide network coverage, convenient installation, maintenance free and other advantages, it can be widely used in buildings, warehouses and other environments, and has a broad application prospect.

Acknowledgment

Scientific Research Project of Heilongjiang Oriental University in 2018 (Numbering: HDFHX180112)

References

[1] H.J.Wang. Fire monitoring system based on Iot technology. Suzhou university, 2012:3.

[2] Y.H.Sun . Research and implementation of fire monitoring system in wireless sensor network. Heilongjiang university, 2012:3.

[3] Y.L.Zhu.Design of wireless multi-point temperature transmission system based on nRF24L01 .IEEE conference paper, 2011.

[4] L.N.Zhang. Design of new wireless composite fire automatic alarm system. Fire science and technology, 2016, (6) : 825-826.

[5] Juck. Research on the design of fire monitoring system based on ZigBee technology. Anhui agricultural science, 2014,42 (17) : 5689-5690.

[6] Z.Z.Li. Design of intelligent controller for high-voltage isolation switch based on ARM. Xi 'an university of engineering, 2012:96.

[7] H.Gao. Design of the temperature signal wireless receiver and display system on polishing interface in chemical mechanical polishing .Procedia Engineering,2011:417-421.

[8] G.H.Chen. Design of simple intelligent home control system based on STC12C5A60S2. Design and application of electronic technology, 2016, (5) : 45.