Research on Ship Fire Monitoring and Alarm System

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Abstract—This paper analyzed the application status of land fire protection system and the characteristics of ship fire protection, and analyzed the functional requirements of ship fire protection system according to the ship special environment with crowded escape routes and complex structure. Using distributed intelligent control mode and modular structure design, a monitoring and alarm system composed of sensor acquisition module, microprocessor, central server, audible and visual alarm module, liquid crystal display module and CAN bus communication is constructed. The designed system has simple structure, stable performance and high cost performance, and has certain application and promotion value.

1. Introduction

With the rapid development of economic globalization and shipping industry, water transportation accounts for an increasing proportion in national trade. As the main means of water transportation, ships undertake 90\% of foreign trade cargo transportation every year. Ship safety has gradually become the focus of attention [1]. With the development of science and technology, modern ships have more and more functions, more and more advanced technology and more complex internal environment. There are working cabin, living cabin, engine room, cargo cabin and various fuel bunkers on the ship. Fire is a common and harmful ship accident, which poses a great threat to the safety of the ship. Due to the ship special environment with crowded escape routes and complex structure, the moving ship can not get timely and comprehensive rescue like the buildings on land. It is very difficult to evacuate and transfer the personnel and goods on the ship, or even can not be transferred. Therefore, ship fire is much more harmful than land fire. Ship fire accidents will cause huge losses to the safety of personnel and cargo property on board [2,3].

Based on the above background, higher requirements are put forward for ship fire protection system. It is necessary to design the fire protection system, which is required to quickly respond to the fire, achieve the integration of monitoring and alarm, and improve the accuracy of fire monitoring and the timeliness of alarm.
2. CAN Bus

CAN bus, fully known as controller area network, is a widely used fieldbus technology. This technology can realize data transmission between a variety of industrial equipment in the industrial field environment. These industrial equipment can be called nodes. All nodes are distributed on the Fieldbus to form an interconnected network structure [4].

The sensors or controllers in different compartments of the ship can be connected through CAN bus. The signal transmission adopts serial communication, and the transmission speed reaches 1M/s. Due to CAN bus can meet the interconnection between different nodes, it is very suitable for building distributed ship fire monitoring and alarm system, especially for large ships. Large ships have many cabins, equipment and goods, so the monitoring range is naturally much larger. The CAN distributed bus structure can well solve the problem of data transmission [4]. Because of its outstanding characteristics, unique design and high reliability, CAN bus was widely used in the interconnection of field monitoring equipment such as shipbuilding industry and industrial automation. It was also one of the most promising fieldbuses.

3. System Hardware Design

3.1. Overall Scheme Design

The ship fire monitoring and alarm system connects all subsystems through microprocessor, which can collect sensor data, judge fire by using data fusion algorithm, drive sound-light alarming and LCD, and communicate through CAN bus [5]. The whole system is an embedded system integrating CAN bus communication, information acquisition, analog control, data fusion and judgment. The microprocessor adopts STC8A8K64S MCU, which has an ultra-high speed 51 single chip microcomputer core (1t), and is about 12 times faster than the traditional 51 single chip microcomputer. It has built-in PWM, ADC, UART and other functions. In the system, it can not only complete the information collection of various sensors, but also ensure the information transmission requirements at all levels. When designing the whole system, we should not only complete the required functions, but also consider small volume, high cost performance, safety, reliability and convenient development.

The hardware structure frame diagram of the system is shown in Figure 1.

![Figure 1](image)

**Figure 1** System hardware structure frame diagram.

The hardware structure of the system is mainly composed of central server, STC8A8K64S MCU minimum system (oscillation circuit and reset circuit), CAN controller and drive module, sensor module, sound-light alarming module and LCD module. In practical application, due to wired communication transmission data is more stable, most fire protection systems adopt wired communication, but the limited space and special environment on the ship require higher requirements for fire monitoring and alarm system. With the rapid development of wireless network, the fire monitoring and alarm system using wireless network communication will gradually replace wired network, especially CAN bus, which has perfect development, strong anti-interference ability and wide application. The designed system combines the advantages of CAN bus and adopts CAN bus communication mode [6].
3.2. CAN Bus Interface Circuit Design

The design of hardware circuit is mainly the circuit between CAN communication controller and MCU, and the circuit between CAN bus transceiver and physical bus. Each CAN bus needs to be matched with a master controller. There are two common controllers: one is an independent can controller, such as SJA1000, 82C200 and Intel 82526/82527, and the other is a can controller with chip, such as 16 bit microprocessor 87C196CA/CB and P8XC582. However, SJA1000 has high compatibility and applicability, so it is selected as the system CAN bus controller to be responsible for the interpretation of bus protocol.

There is also a special interface between the CAN bus and SJA1000 to realize the connection between the physical layer in the CAN bus and the master controller. The transceiver control chip produced by Philips is widely used in the domestic market, so the 82C250 chip of Philips is selected as the information transceiver of CAN bus.

CAN bus communication is the core of ship fire monitoring and alarm system. Its core circuit is the master controller SJA1000 and its peripheral circuit. It mainly realizes the CAN bus communication protocol through each interface circuit in the line. In addition, the control of some external factors (such as system anti-interference ability, system thermal protection ability, bus protection ability, communication distance and other factors) is also realized through the 82C250 transceiver of CAN bus communication [7].

The designed interface circuit diagram is as follows:

![Interface circuit frame diagram.](image)

3.3. Sensor Detection Module Design

The sensor detection module is a unit circuit that makes corresponding induction according to the characteristic parameters of the fire site and can independently send fire signals. Temperature, smoke, CO, flame, smell, combustion products, combustion sound can be used as characteristic parameters of fire. The sensor detection module detects these characteristic parameters through sensitive elements, converts them into electrical signals through A/D, then processes these electrical signals and compares them with the preset threshold. If the threshold is exceeded, it will make corresponding further response.

According to the characteristics of ship fire, the four characteristics of temperature, smoke concentration, CO concentration and flame are selected as ship fire detection parameters. The temperature sensor detection module adopts DS18B20 temperature sensor, the smoke concentration sensor detection module adopts MQ-2 smoke sensor, the CO concentration sensor detection module adopts MQ-7 gas sensor, and the flame sensor detection module adopts Flame-1000 PIR Sensor [8].

The four sensor detection modules are connected with STC8A8K64S MCU to form the fire monitoring device of the system, which can directly transmit digital signals and connect with external PC to realize accurate monitoring, and also meet the requirements of high detection accuracy and simple communication circuit of ship fire protection system.

The following figure shows the circuit schematic diagram of the smoke concentration sensor in the sensor detection module.
3.4. Sound-light Alarming Module

If the temperature change, smoke concentration and CO concentration signals collected by the sensor are judged to have a fire after corresponding A/D conversion and data processing, the sound-light alarming shall be started immediately. The sound-light alarming circuit is composed of NE555, speaker and LED.

The sound alarm signal of the speaker is controlled by STC8A8K64S MCU. If the control signal sent by MCU is high level, the speaker plays treble; if the control signal is low level, the speaker plays bass; the program design can realize the alternating alarm of different frequencies of speaker treble and bass. The on and off of LED is also determined by the control signal sent by MCU. If the control signal is high level, the LED is on; if the control signal is low level, the LED is off; through program design, the LED can flash alternately on and off [9]. The circuit diagram of the designed sound-light alarming module is as follows:

4. System Software Design

According to the actual needs of ship fire protection, the system software is designed and developed from three modules: system monitoring module, system alarm module and system management module to ensure that the requirements of fire monitoring and alarm are met. The system monitoring module consists of temperature monitoring, smoke concentration monitoring, CO concentration monitoring and flame monitoring; system alarm module is composed of fire alarming and fault alarming; the system management module consists of user management and operation status management [7].

The software framework diagram of ship fire monitoring and alarm system is as follows:
Figure 5 System software framework diagram.

Through the program design of MCU, an automatic and orderly working mode is formed between each module of the system and between each module and CAN bus, so as to realize the intelligent operation of the whole monitoring system.

The core function of the monitoring and alarm system is to receive the fire signal collected by each sensor from the monitoring site, send out the fire sound-light alarming after being processed by the microprocessor and peripheral circuit, and display the specific location of the fire through the LCD module, so that the ship workers can take fire-fighting measures in time.

In addition, if the system fails, it can also send out fault sound-light alarming, so that the ship workers can eliminate the fault and reset in time. The system program flow chart is as follows:

Figure 6 System software framework diagram.

System working principle: first initialize the system and the controller SJA1000. In the normal operation mode, the system is always in the state of patrol and monitoring. If a fire signal or fault signal is sent, it is transmitted to the microprocessor through CAN bus communication, and then the microprocessor will judge whether it is a fire signal or a fault signal.
If it is judged that it is a fire signal, it will start the fire sound-light alarming and LCD display the fire alarm position, and timely remind the ship workers to take corresponding fire extinguishing measures. If it is judged that it is a fault signal, start the fault sound-light alarming until the fault is eliminated and reset. In this process, the system is still in the state of patrol and monitoring. If a fire signal is detected, give priority to the fire information according to the system priority and give corresponding alarm [10].

Priority judgment of fire and fault signals:
1) When fire and fault signals occur at the same time, the control unit shall give priority to transmitting fire signals.
2) When the fault alarm is in progress, if a fire signal is suddenly detected, the system will immediately shield the fault alarm and start the fire alarm. After the fire alarm is eliminated, the fault alarm will be restored immediately.

5. Conclusion
With the continuous improvement of ship automation development, the requirements for fire monitoring and alarm are higher and higher. The ship fire monitoring and alarm system studied in this paper is a distributed system based on bus communication mode. CAN bus communication technology is used for information transmission, which makes the system more intelligent and automatic.

In this paper, STC8A8K64S MCU is selected as the microprocessor to be responsible for information collection and transmission at all levels. In the design of CAN bus interface circuit, SJA1000 is selected as the CAN bus controller and the 82C250 control chip is selected as the information transceiver of CAN bus.

The hardware part of this design is mainly composed of the following modules: the minimum system in MCU and the control module in CAN system. It mainly designs the system framework, MCU oscillation circuit and reset circuit, CAN bus interface circuit, sensor detection module, sound-light alarming module.

The system software design part of this paper mainly carries out software design and development from three modules: system monitoring module, system alarm module and system management module, so as to ensure that it can meet the requirements of fire monitoring and alarm.

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References
[1] Z. Yan, “Research on cabin fire prevention monitoring system based on CAN bus,” China water transportation (the second half of the month), vol. 20, no.2 pp. 82-83, 2020.
[2] J. Jia, S. Lu, “Study on fire risk analysis method of ship cabin,” Journal of safety and environment, no. 3, pp. 132-137, 2014.
[3] J. Li, Z. Huang, “Fire and explosion risk analysis and evaluation for LNG ships,” Procedia Engineering, no. 45, pp. 70-76, 2012.
[4] H. Min, “Application of distributed bus communication module in ship fire monitoring and alarm system,” Ship science and technology, vol. 40, no.6, pp. 145-147, 2018.
[5] J. Qi, “Design and implementation of fire alarm system based on CAN bus,” Xi'an University of architecture and technology, 2009.
[6] H. Yang, Wan Zhengquan, “Application of CAN bus in ship structure safety monitoring system,” Journal of electronic measurement and instruments, vol. 28, no.5, pp. 553-559, 2014.
[7] Y. Yang, “Research on ship fire monitoring automation system,” Qilu University of technology, 2019.
[8] C. Zhang, “Ship fire early warning technology based on multi-sensor data fusion,” Harbin Engineering University, 2017.

[9] S. Qiu, “Design of an audible and visual alarm system based on single chip microcomputer,” Digital technology and application, vol. 36, no.12, pp. 158-159, 2018.

[10] B. Wang, “Research on automatic fire detection, alarm and automatic fire control system of new intelligent ship,” Dalian Maritime University, 2008.