Research and Development of Dual Redundant Navigation Control Module for Unmanned Boats

Xinyu Zhu [1, a, *], Minmin Yu [1], Yunqian He [1, 2], Xinyue Du [1], Zhijie Wu [1]

[1] Taihu Laboratory of Deep Sea Technology Science, WuXi, Jiang Su 214000, China

[2] China Ship Scientific Research Center, WuXi, Jiang Su 214000, China

[a] 1002586283@qq.com

Abstract. A set of dual redundant navigation control modules has been developed to improve the reliability of unmanned boat navigation control systems, addressing issues such as poor stability, poor scalability, and difficulty in upgrading and maintaining. The module has two completely independent navigation control hardware CPUs. When one of the navigation control CPUs fails and cannot operate normally, the other can seamlessly take over, achieving hot backup redundancy switching and ensuring the stable operation of the control system. Through unmanned boat debugging, the navigation control system using dual redundant navigation control modules can smoothly achieve all preset functions and achieve the expected results.

Keyword: Unmanned boat; navigation control module; Double redundancy; CPUs; Reliability.

1. Introduction

With the rapid development of unmanned intelligent technology, the application demand of unmanned boats in military and civilian fields is becoming increasingly widespread. The navigation control system of unmanned boats is a key component of unmanned boat systems, responsible for achieving autonomous navigation, path planning, obstacle avoidance, and communication with shore based base stations.

At present, most of the navigation control modules used in unmanned boat navigation control systems have the following shortcomings:

Weak anti-interference ability. Its ability to resist external interference is weak, for example, in complex marine environments, external factors such as electromagnetic waves and changes in sea conditions may affect the control module.

2) Functional limitations. A single navigation control module may only have basic control functions, and may lack sufficient adaptability and flexibility for some complex tasks or emergency situations.

3) Difficulty in upgrading and maintaining. Upgrading and maintaining a single system may require stopping the operation of the entire unmanned vessel, which is not conducive to the continuous execution of tasks by the unmanned vessel.

4) Poor scalability. With the development of technology and changes in task requirements, a single set of navigation control modules may be difficult to expand to adapt to new functions and technologies.

5) Cost effectiveness issues. Although a single system may have cost advantages in the early stages, in the long run, the lack of redundancy and difficulty in upgrading may lead to increased maintenance costs.

6) The ability to collaborate is limited. In future maritime operations or complex mission execution, unmanned boats need to collaborate with other unmanned boats or manned vessels, and a single navigation control module may not be able to provide the necessary collaborative interfaces or protocols.

In summary, in order to improve the safety and reliability of unmanned boats and adapt to military or high-risk civilian operations, the development of dual redundant navigation control modules may become a standard configuration for future unmanned boat designs.

2. Navigation control system

The navigation control system mainly consists of dual redundant navigation control modules, A/D modules, D/A modules, D/I-D/O modules, TEMP modules, etc.

The working principle of the navigation control system is shown in Figure 1. The dual redundant flight control module runs two independent flight control programs, and two independent CPUs monitor each other's operating status through serial ports to achieve hot backup of primary and backup control. The internal modules each use dual CAN bus redundant communication and dual 24 VDC redundant power supply.

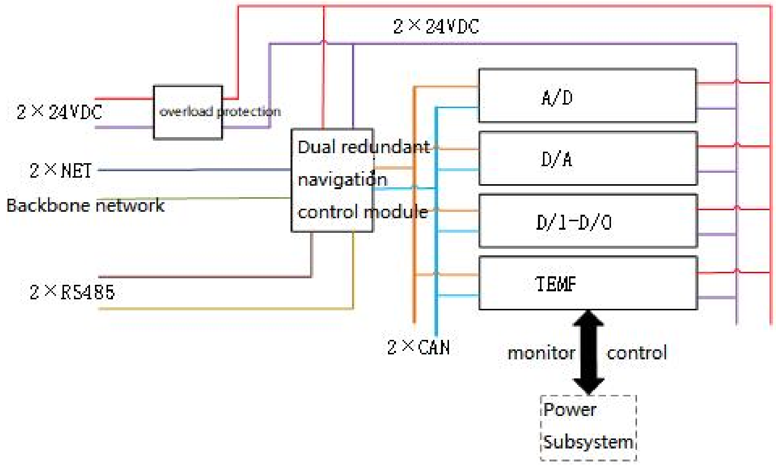

Figure 1 working principle diagram of navigation control system

Table 1 Software Development Requirements List

Serial Number	Software Name	Operating Equipment	Hardware	Software Environment	Major Function
1	navigation control software	Dual redundant navigation control module	ARM Cortex-M4	Micro real-time operating systems such as ucos III and FreeRTS	Navigation control, Ethernet communication, CAN communication, etc
2	A/D module software	A/D module	ARM Cortex-M3	Micro real-time operating systems such as ucos III, FreeRTS, or bare metal	A/D acquisition, channel self detection, CAN communication, etc
3	D/A module software	D/A module	ARM Cortex-M3	Micro real-time operating systems such as ucos III, FreeRTS, or bare metal	D/A output control, channel self-test, CAN communication, etc
4	D/I-D/O module software	D/I-D/O module	ARM Cortex-M3	Micro real-time operating systems such as ucos III, FreeRTS, or bare metal	D/I acquisition, D/O output control, channel self-test, CAN communication, etc
5	TEMP module software	TEMP module	ARM Cortex-M3	Micro real-time operating systems such as ucos III, FreeRTS, or bare metal	Temperature acquisition, CAN communication, etc

3. Redundant navigation control modules

The hardware design scheme of the dual redundant navigation control module is shown in Figure 2.

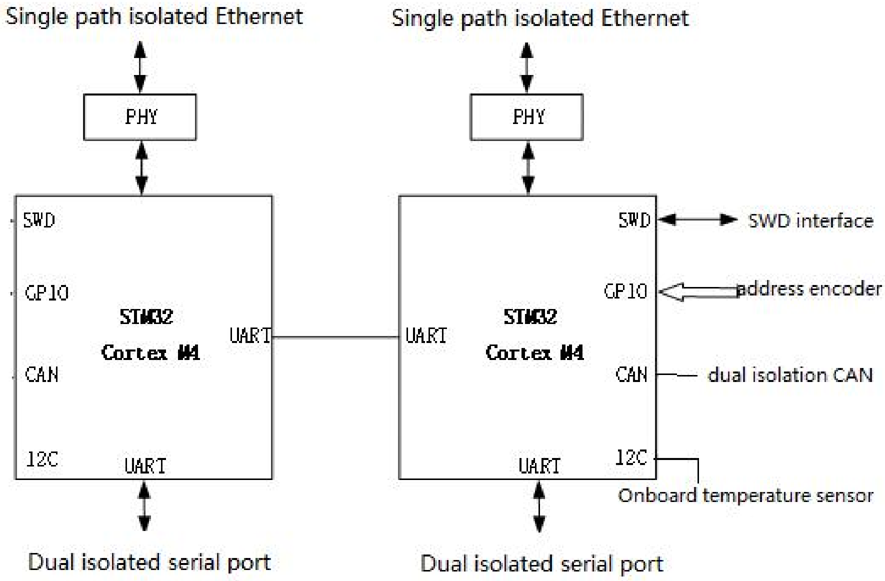

Figure 2 Schematic diagram of dual redundant flight control module

The main parameters of the dual redundant navigation control module are as follows:

Working power input: 18VDC~32VDC dual redundant, internal low voltage isolation, overload protection, overload protection, anti reverse protection, power indication;

Two redundant main control MCUs, ARM Cortex-M4 core, with a clock speed of 168M;

Two channels each, totaling four isolated CANBUS bus interfaces, achieve redundant transmission of I/O module signals and transmit/receive signal indications;

Two high/low address encoders are assigned different numbers to different I/O modules for easy identification of CAN bus IDs;

1 channel each, 2 isolated Ethernet channels, 10M/100M adaptive;

Two channels each, totaling four isolated RS232/RS422/RS485 software configurable serial ports, to enable data exchange between inertial navigation and other serial devices;

Debugging and programming of SWD interface program;

Hardware watchdog and software watchdog to prevent program anomalies;

Onboard online temperature monitoring;

SPI communication and operation status monitoring between two MCUs.

The PCB of the dual redundant navigation control module is shown in Figure 3. The external dimensions are 185mm *108mm.

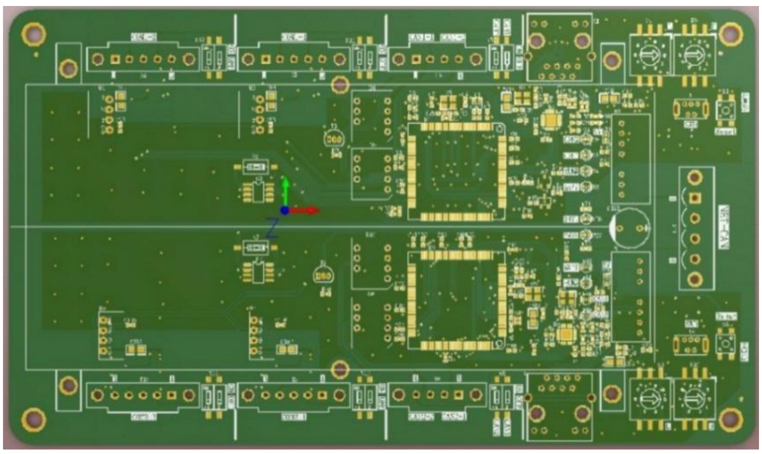

Figure 3 Double redundant flight control module PCB board

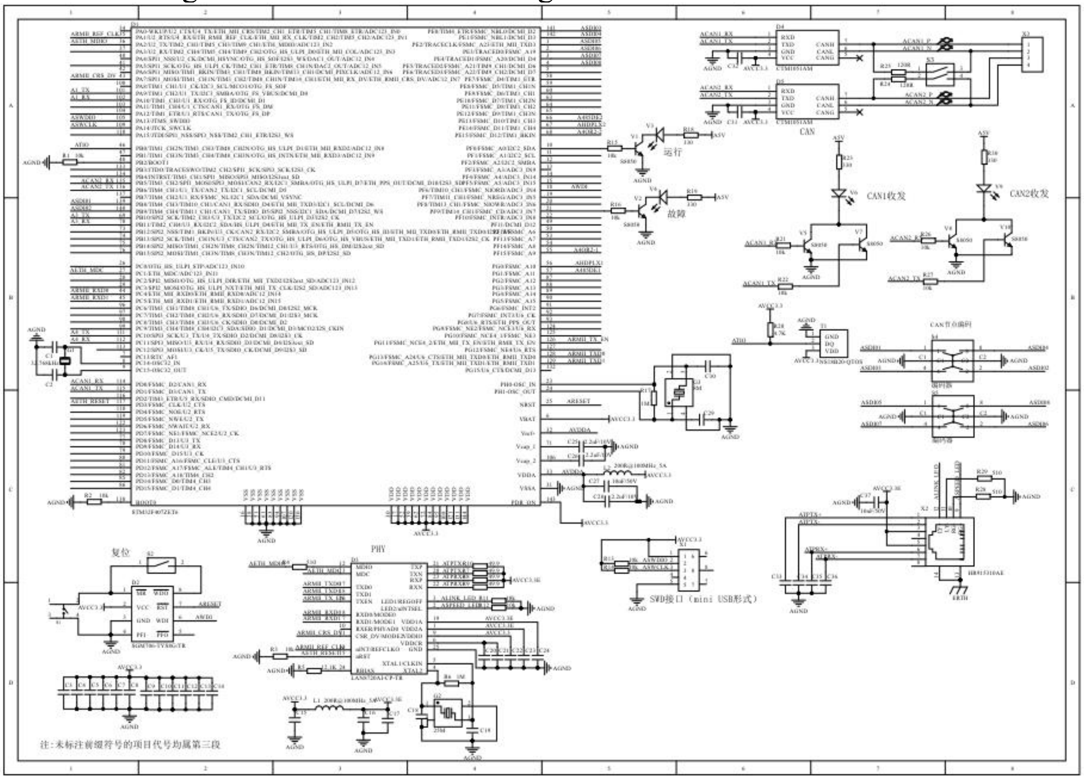

Figure 4 Circuit diagram of navigation control module

The localization rate of its components is over 95%, and it is designed with high reliability channel isolation. It has multiple switch input modules for dry and wet contacts, multiple switch output modules for relays and transistors, multiple range analog input and output modules for voltage and current, multi-mode temperature acquisition module, and integrated communication gateway module for serial/CAN/Ethernet. It can achieve signal loop self detection, online temperature detection during operation, and dual redundant power supply operation. Adopting dual redundant field CAN bus communication. The issuance of control instructions for the dual redundant flight control module and the monitoring of the operating status of the executing mechanism are achieved through dual redundant CAN communication.

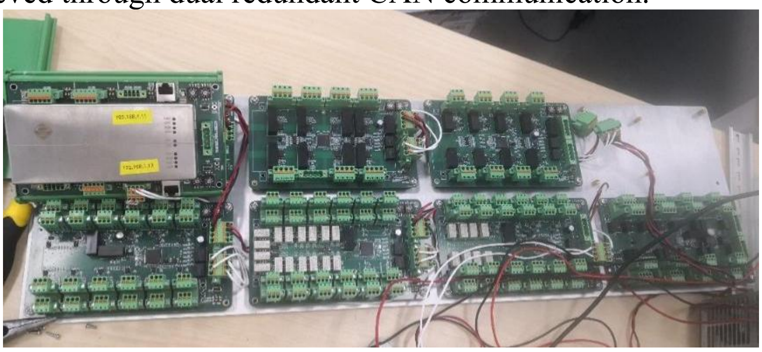

Figure 5 Navigation Control Module

4. Debugging

Debugging of the navigation control module was carried out in the unmanned boat debugging room, and the process record is shown in Table 2. When the system is running normally, one set of flight control modules can be disconnected, and the other set can be immediately taken over to continue executing tasks such as issuing control instructions. The dual redundant navigation control system of unmanned boats can smoothly achieve all preset functions on unmanned boats and achieve the expected results.

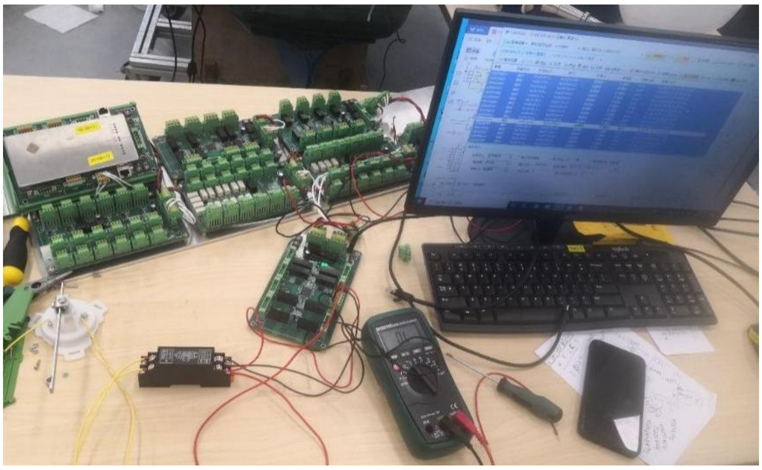

Figure 6 Debugging conducted in the unmanned boat debugging room

Table 2 Debugging Test Records

Serial Number	operate	Feedback situation	condition assessment	Manipulating people
1	Hardware connection and inspection	The interface connections of each module are correct	normal	Xinyu Zhu
2	Software Settings	The flight control module is connected to the control system software, and the communication parameter settings are correct	normal	Xinyue Du
3	System self-test	After starting the flight control module, the system self-test is normal	normal	Minmin Yu
4	Communications Test	The communication connection between the navigation control module and the shore based upper computer system is stable	normal	Yunqian He
5	Redundancy function testing	Cut off the connection of one set of air control modules, and the other set can be immediately taken over	normal	Minmin Yu

5. Conclusion

By designing dual redundant flight control modules, redundant backup of the flight control system has been achieved, improving system stability. The next step is to use a dual redundant navigation control system for the transformation of a 7-ton unmanned boat, and conduct lake and sea trials to test the stability and reliability of the system in different test scenarios. And according to the subsequent experimental scenarios and task requirements, more functional modules will be integrated to improve the practical value of the system.

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