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Design and Implement of Hardware Equipments of Large-scale Ship handling Simulator

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Abstract: Aiming at the disadvantage of hardware of large-scale ship handling simulator at home and abroad which has closed equipment, bad expandability, high price and so on, we design the console's frequently-used hardware equipments of the large-scale ship handling simulator based on the research strength of our college. Besides, the overall architecture of the hardware system and the hardware and software design of some equipments are also provided in detailed. The simulator follows the standards on the use of simulators of A-1/12 section of Manila amendments to the STCW Convention and meets the prescribed performance standards of China Maritime Safety Administration about "the notice of related matters on doing preparatory work for meeting Manila amendments to the STCW Convention (Sea Crew [2011] No.923)" and has broad market prospects. Now, the simulator has been applied to many domestic navigation colleges or institutions and has achieved good results.

Key words: Ship handling simulator, hardware equipments, 485 bus, design

INTRODUCTION

With the implementation of the Manila amendments to the STCW Convention as well as the continuous expansion of China's maritime education, many navigation colleges have been set up in the inland cities, therefore, to follow the standards on the use of simulators of A-1/12 section of Manila amendments to the STCW Convention, as well as to meet the prescribed performance standards of China Maritime Safety Administration about "the notice of related matters on doing preparatory work for meeting Manila amendments to the STCW Convention (Sea Crew [2011] No.923)", every navigation college or institution must be equipped with Shiphandling Simulator as a necessary equipment for training and assessing on the course of Bridge Resource Management (Jin *et al*., 2001; Jin and Yin, 2012; China Maritime Safety Administration, 2010). At present, most of the large-scale ship handling simulators designed by foreign countries have high price, bad portability, inconvenient for maintaining which can not be satisfied by the crew training for their flexible training pattern (Gan *et al*., 2012a; Gan *et al*., 2012b). Therefore, with the strong research strength of our college, we have designed a large-scale ship handling simulator with high expansibility and cost performance for users. The simulator is different from others at home and abroad which is characterized by the hardware of simulator operating table that are designed by ourselves which has got rid of the inflexibility of the communication protocol for procuring equipments from different manufacturers and lower scalable that can not be designed supporting equipment for the desires of different users. Independent research and development of hardware, will greatly enhance the flexibility and scalability and contribute to the development of the large-scale ship handling simulator (Yang *et al*., 2010; Yang *et al*., 2011).

SHIPHANDLING SIMULATOR SYSTEM ARCHITECTURE

Large ship handling simulator console contains the following equipments: Tug panel, line and anchor panel, thruster panel, steering control panel, alarm panel, navigation lights panel, radar panel, telescope panel and engine telegraph, steering wheel, compass and seven dashboards hanging on the bridge. The hardware architecture is shown in Fig. 1.

All hardware devices use a standard RS485 communication interface and all the devices are mounted on a 485 bus (Zheng and Yang, 2009). Each device is initialized in the receiving state and the host computer quests each hardware device from low to high order in accordance with a certain time interval through the established communication protocols. As the serial communication interface the host computer used is 232 interface, you need a 485 to 232 converter.

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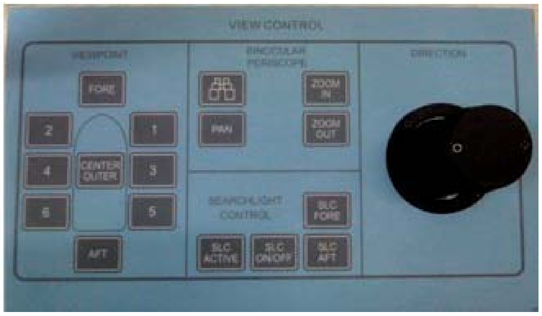

Fig. 1: Shiphandling simulator hardware architecture

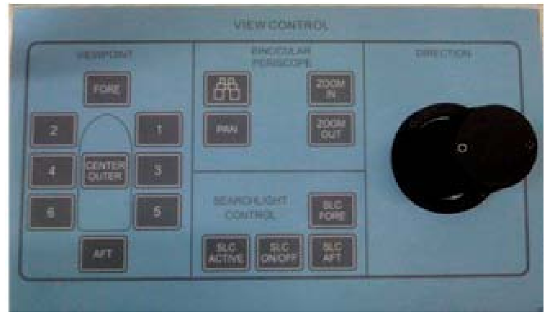

Fig. 2: The physical picture of telescope panel

DESIGN OF EACH HARDWARE MODULE OF SHIPHANDLING SIMULATOR

Hardware panel: The hardware panels are mainly consisted of tug panel, line and anchor panel, thruster panel, steering control panel, navigation lights panel, alarm panel, radar panel and telescopes panel. Due to limited space, here we just take telescope panel circuitry for analysis.

The telescope panel appearance is shown in Fig. 2. It can simulate the nautical telescope of bridge and control the telescope view to zoom in or out by manipulating the corresponding joystick. Meanwhile, we can switch the telescope view by combining with the corresponding buttons in the panel.

The circuit is shown in Fig. 3. It is mainly composed of five parts: The analog-to-digital conversion interface, a 485 communication interface, the main controller, matrix keyboard scanning module, LED control module.

Analog-to-digital conversion interface is used to collect internal potentiometer voltage value of the rocker. When the crew manipulate the joystick which will cause the internal potentiometer of the rocker voltage values change, so that the master controller can identify the joystick direction and shaking amplitude. The interfaces has three degrees of freedom to identify left and right directions, up and down direction and the direction of rotation which has greatly improved the flexibility of signal acquisition, enhanced the real sense of manipulation in Crew Cab.

485 communication module establishes a link between each hardware devices to PC. As all the hardware devices shared a 485 bus and the situation is very complex, there exists high common-mode voltage between each hardware devices. Though RS-485 interface uses differential transmission, has a certain resistance to common mode interference, when the common-mode voltage exceeds the limit of RS-485 receiver voltage that is greater than +12V or less than -7V which will lead to the incapable communication, even burn chip and the other hardware. Therefore, we adopt the DC-DC power supply to isolate the system power and RS-485 transceiver power, besides, a TLP521 chip as well as two 6N137 chips have been used to constitute a photoelectric isolation circuit for signal isolation which has completely eliminate the impact of the common-mode voltage to guarantee 485 network communication stability.

The matrix keyboard scanning module is used to identify the buttons operation for user on the operation panel, Here we mainly adopt a reversal scan mode to improve the execution efficiency.

LED control module is mainly used to control the color and brightness changes of LED inside the panel buttons, so that the users can verify the accuracy of the operation by observing the color change of LED during the operation,. The module uses a MAX7219 chip control which is an integrated serial input/output common-cathode display driver and it can not only control 8 digital tube display but also 64 independent LED. Besides, it can be used n chip MAX7219 cascaded to drive 8*n-bit digital tube display. It also has an external register to set each LED segment current and control the brightness of the LED. It uses a convenient four-wire serial interface (SCLK, DATA, LOAD, DOUT) to connect to the main controller chip. When the host controller chip sends data to the MAX7219, it can separate dynamic scanning display, without being intervened by the main controller chip.

The master controller is constituted of an STC microcontroller. The microcontroller not only has dual serial ports, but also has 8-channel 10-bit AD converter, 2 channel PWM function and so on. It not only has to capture the voltage value of the joystick potentiometer to proceed analog to digital conversion but also identify the user's operation through the matrix keyboard scan and doing logical judgment and control of a series LED inside the panel. Finally, it will send all data of user operation to the PC through 485 bus and PC will deal with the data sent

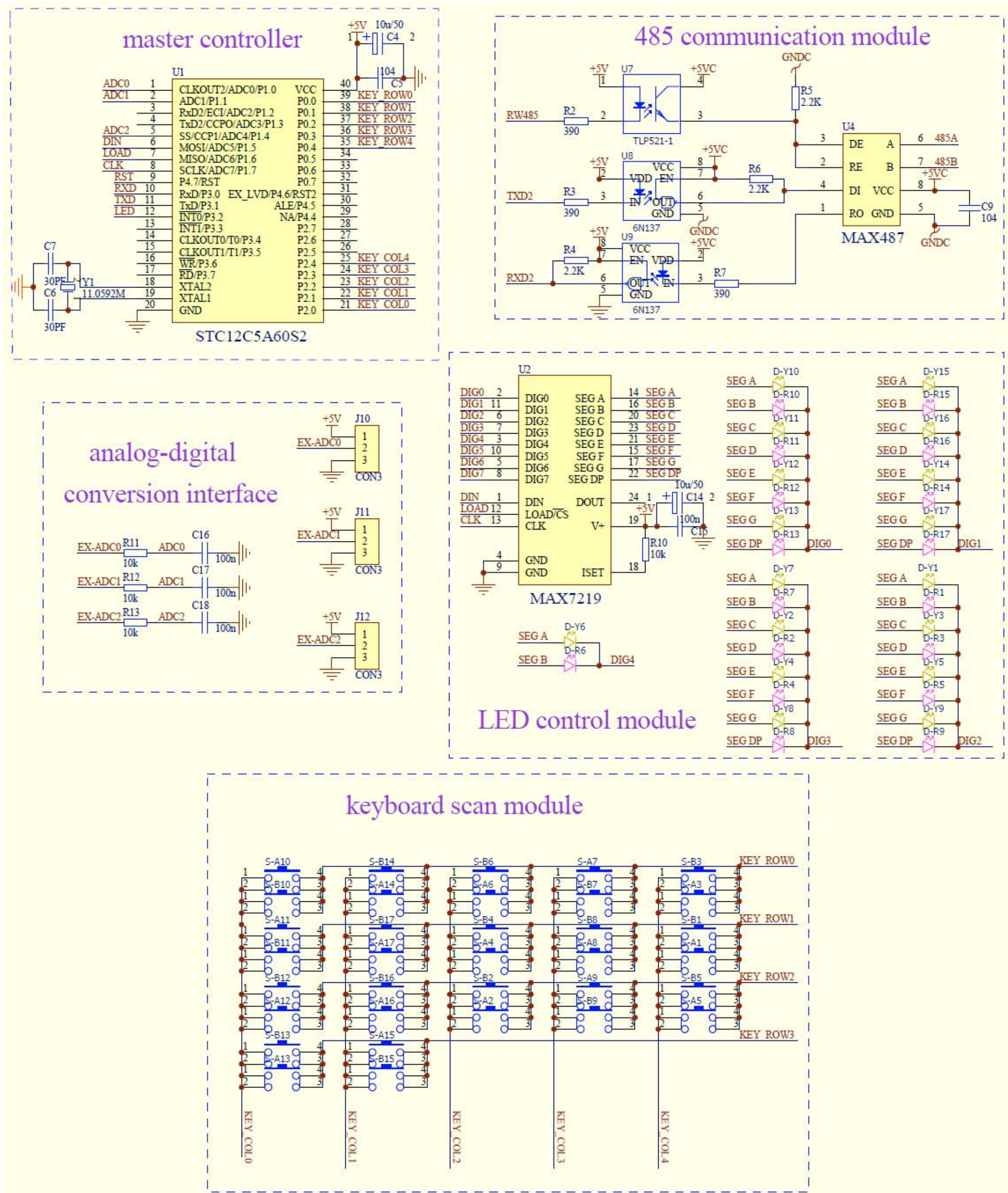

Fig. 3: The circuit of telescope panel

from the master controller combining with the appropriate software values for displaying by view or matching software.

Engine telegraph, compass, steering wheel: Engine telegraph, compass, steering wheel are three indispensable parts of ship handling simulator. Former simulators use true engine telegraph, true compass and true wheel, but they have high price and low scalability because we have to rely on the own definition communication protocols and interfaces of manufacturers. Therefore, the main function of engine telegraph, compass and steering wheel are all simulated; their appearances are life-size; the structure, main function, operation mode, display panel and data are nearly the same with real equipments. Due to limited space, this paper only describes the compass circuit.

The compass is used to indicate the ship course in the ship handling simulator. The object is shown in Fig. 4. Taken into account the machining process of internal compass as well as the compass accuracy, we designed the compass primarily as a single circle compass.

The compass circuit is mainly composed of five parts: stepper motor driver module, 485 communication interface, the host controller interface, zero finding interfaces, brightness control module of LED. Here we mainly introduces the stepper motor driver module and zero finding interface.

The stepper motor driver module is controlled by a ULN2803 chip which is a high-voltage, high-current Darlington transistor array products. With many features such as high current gain, high operating voltage, wide temperature range, it is suitable to be used to drive a stepper motor. The stepper motor is 42BYG series, four-phase eight-shot high-torque hybrid stepper motor, with step angle of 0.9 degrees, even can be 0.45 degrees by dividing into two frequencies, it is fully meeting the accuracy requirement of the compass in the simulator . In addition, taking into account the extension of double ring compass, we have set aside four interfaces to drive another stepper motor which offers the possibility of extension for the double ring compass.

A critical problem for analog compass to be solved is the finding zero. We mainly use a slotted opt couplers. The notch has two ends: one end is the infrared emitter; the other is the infrared receiver. In this case, the dial is painted with a certain width of the black at the edges when machining and got rid of a gap in the zero-scale. By specific machining the dial is able to rotate droved by the stepper motor while the black side of the dial is still blocking infrared emitter. At this time, when the zero-side of dial is turned to infrared emitter, the other end of the infrared receiver is able to receive infrared at once because of the notch in the zero-scale and generates a falling edge output which will be sent to the external interrupt pins of the master controller chip by corresponding circuit and then triggers the host controller chip to generate an external interrupt. Therefore, the compass has finished finding zero.

Instrument panel: Instrument panel is used to display all kinds of navigation data in ship handling simulator. It is mainly constituted of several instrument panels: wind direction and speed, water depth, ship speed, main engine rotate speed, rudder angle, rate of turn. The objects are shown in Fig. 5.

The instrument panels are needle indicator except the wind direction and speed panel which is displayed with digital and driven by the DC voltage. The driving voltage range has two types, one is 0 to 5V, the other is-5V to 5V. However, the data of the instrument panel sent from the host computer is a digital signal in ship handling simulator. It is therefore, the digital signal must be translate into voltage signal to drive the instrument panel

Fig. 4: The physical picture of compass

Fig. 5: The physical picture of instrument panel

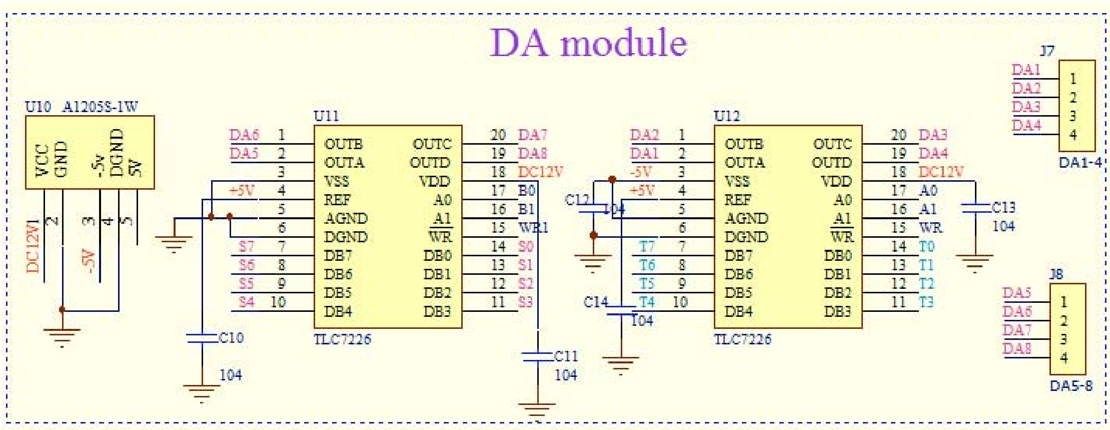

Fig. 6: The part of schematic diagram of drive circuit for instrument panel

by digital-to-analog converter. At the same time, taking into account the two types of driving voltage, we need two DA converter chips Here we use the converter chips named TLC7226 (Sheng and Huang, 2004). It includes 4-way 8-bytes voltage output, has output buffer amplifiers and interface logic on a single chip. Data is sent to the one of data registers through the public eight TTL/CMOS compatible (5V). Each channel DAC can supply output current up to 5 mA and supports unipolar and bipolar output. The unipolar output range is 0 to 5V and the Bipolar output voltage range is -5V to 5V which are enough to meet the requirements of drivering the instrument panel. The circuit schematic diagram is shown in Fig. 6.

The software design of hardware system in shiphandling simulator: The software design of the system includes system software protocol and hardware modules.

System software protocol: As majority of hardware devices of shiphandling simulator (including all hardware panels, engine telegraph, compass, steering wheel, instrument panels etc.) are mounted on a 485 bus, the host computer quests each hardware unit in order. The 485 bus are half-duplex, so when the host computer quests one hardware, the other equipments should be in the receiving state, otherwise there will be communication garbled. Therefore, we designed the following communication protocols.

Each hardware device has its own address and they are all initialized in the receiving state. The host computer quests each device from low to high order in accordance with the address. If there is some data form the quested device to be sent, then the device will change to the sending status and sends a message .The protocol format of the message is defined as follows:

$(1)(2)*hh<CR><LF>

where, “$” is string head; (1) is the address of the device; (2) is a key value, whose range is determined by the number of buttons on the panel. “*” is end of the string; “hh: is check code; <CR> is carriage-return characters; <LF> is newline control characters.

There are some nixie tube display on some hardware panel , while the digital display values are derived from the host computer, it is therefore, in order to avoid displayed data collision on the multi-panel nixie tube, the protocol is defined as follows:

@(1)(2)(3)(4)*hh<CR><LF>

where, the @ is string head; (1) is the address of the device; (2) is the key sequence number (taking into account some panel multiple keys have shared a nixie tube and they are needed to be distinction), the range of values is determined by the keys of the panel; (3) is the sequence number (taking into account a panel has many nixie tubes and in order to avoid display conflict we make the definition); (4) is a parameter value, 4 bytes and the value is range from 0-9999, “*” is the end of the string; “hh” is the check code; <CR>is carriage-return characters; <LF> is newline control characters.

The display value of nixie tubes of some panels can be changed by buttons, so the changed value should be sent immediately to the principal computer in order to keep synchronism to the software interface, it is therefore, the protocol is defined as follows:

&(1)(2)(3)*hh<CR><LF>

where “&” is the string head; (1) is the address of the device; (2) is the key sequence number; (3) is the parameter value, 4 bytes ,values is range from 0 to 9999, “*” is the end of the string; “hh” is check code; <CR> is carriage-return characters; <LF> is newline control characters.

In addition, there are reset protocol and initiation protocol and so on. Here we will not describe that.

The software design of hardware module: The software designs of hardware module include eight hardware panels, engine telegraph, compass, steering wheel and instrument panel drive. All the system are based on the C programming language. As the logical relationship of each hardware device is complex, here we take the software design of the telescope panel for analysis.

First, the telescope board is initialized, including working setting, the AD conversion mode, channel select setting, the initialization setting of MAX7219 chip, baud rate parameter setting and interrupt enable register setting and so on (Yu *et al*., 2008).

Secondly, we adopt the reversal mode to scan the matrix keyboard. If there is a button trigger, the board record the key immediately after identifying it is the real trigger, then judge the logic for the button lights of the panel and control them to change the color or extinguish according to the protocol developed by the telescope panel which tells the user the actual operation of the button.

After key scan the rocker start to be scanned, i.e. the voltage value of internal rocker potentiometer start to be analog-to-digital converted. As the rocker has three degrees of freedom, it requires three analog to digital conversion interfaces. The board will judge whether the three values collected this cycle is different from the ones of last scan cycle after the analog-to-digital conversion, ,and if so, then record it , otherwise, proceeds to the next scan cycle.

As the host computer scan each hardware device by 485 bus, when the host computer is not scanning the telescope panel, the device should be in the receiving state, even there is action trigger, it can not be sent immediately until the host computer quests the telescope panel. Then the data will be packaged into the format the protocol defined and sent to the host computer through the 485 bus by calling the serial communication module. After the data has finished sending, it will immediately turn into the receiving state for the next scanning cycle. The program flow chart of telescope panel is shown in Fig. 7.

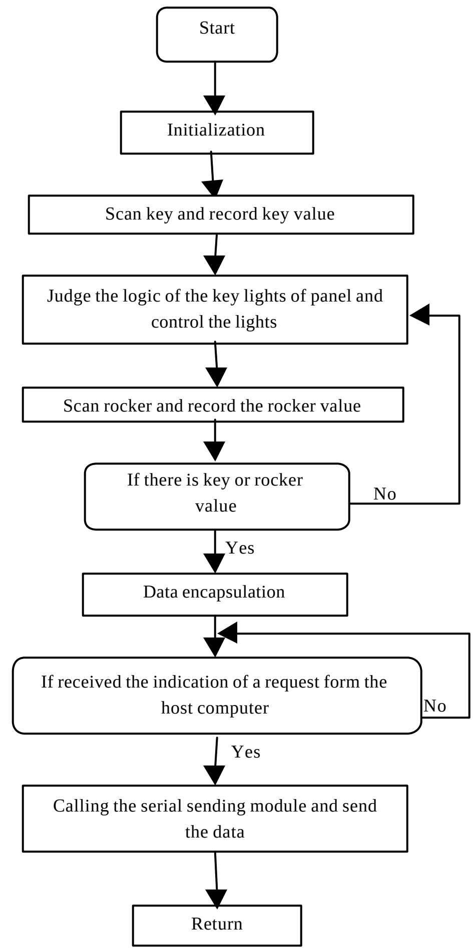

Fig. 7: The program flow chart of telescope panel

CONCLUSIONS

This study discusses the design of the large-scale shiphandling simulator hardware and details the overall design of the hardware and the hardware and software design of some hardware devices. The system has been put to a number of large and medium-sized domestic maritime colleges. After a continuous run and test as well as the reflected situation of the user, the work state of the simulator hardware is stable and high fidelity which can comparable to a number of large domestic and foreign shiphandling simulators. Meanwhile, as the hardware devices are all independent designed which is avail for expanding future performance and reducing maintenance costs. And it will lay a solid foundation for the second generation of a large-scale shiphandling simulator and greatly accelerate the development process of the shiphandling simulator.

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