TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol.12, No.2, February 2014, pp. 1046 ~ 1052
DOI: http://dx.doi.org/10.11591/telkomnika.v12i2.4326

Research of Embedded Tower Crane Monitoring System based on FCS

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Abstract

To compensate for the lack of traditional safety limit device of tower crane, a design scheme of embedded tower crane intelligent monitoring system based on Fieldbus Control System was proposed. By this, online collection and transmission of tower crane real-time conditions were achieved, which could effectively improve the reliability and anti-interference of the system. Embedded development technology was used to build ARM-based master control platform. Embedded Linux cross-compiler environment was also built. Combining with embedded programming software, human-computer interaction interface of tower crane intelligent monitoring system was built; storage and display of tower crane's online parameters were also realized. The use of the technology has opened up a new field of tower crane condition monitoring application. The research of this paper may provide reference for tower crane safety monitoring and fault diagnosing.

Keywords: *embedded technology, FCS, tower crane, intelligent monitoring, CAN bus*

1. Introduction

With the large-scale application of tower crane in the modern engineering construction, the usage of tower crane is increasing. But as a result of tower crane were overloaded frequently and illegal operation, tower crane accidents have occurred. According to statistics, tower crane accident rate in our country is increasing year by year in recent years [1]. Traditional tower crane safety limit device has not been able to meet the operational requirements of the security of the tower crane at the construction site. Therefore, research and development of a new tower crane safety monitoring and management approach has certain theoretical significance and practical value. Compared with foreign advanced level, there is a wide gap of domestic tower crane safety monitoring system study, it also lack the necessary R&D investment of the intelligence and security warning of the tower crane [2]. To solve the problem mentioned above, the authors proposed the design of a tower crane intelligent monitoring system, which applies field bus control system (FCS), composed by CAN bus and embedded ARM technology, to realize the Internet communication between tower crane intelligent terminal nodes and embedded controller. Tower crane intelligent monitoring system is equivalent to an independent safety devices installed on tower crane, and it works simultaneously but independently of the existing traditional safety limit device. The system also has data storage capability, it could provide specific information for the afterwards accident analysis. The improvement of tower crane safety monitoring system's intelligent level is helpful to improve the technical level of monitoring and fault diagnosing of tower crane in our country.

2. Presentation of Questions

Based on the analysis of operating mode information of tower crane, this paper regards operating parameters, which reflect the overall performance and security status of the tower crane, as monitored objects, mainly including elevating capacity of the tower crane, lifting height, lifting moment, luffing displacement, rotation angle and wind speed. Due to the high requirement of reliability and flexibility this paper to the system, it is an important direction of the

Received August 4, 2013; Revised September 7, 2013; Accepted October 7, 2013

tower crane safety control technology applications to associate the intelligent node of monitoring terminal with the main controller by field bus technology.

The Controller Area Network (CAN) bus selected in this paper belongs to the field bus area and it is a serial communication network supports both distributed control and real-time control. Compared to conventional RS-485 serial communication technology, CAN bus communication has the following outstanding advantages: a) the nodes on CAN network are flexible and can be dynamically set and divided into different priorities to meet real-time requirements, b) CAN bus communication uses short frame structure, the transmission time is short and the interference is low, c) CAN protocol uses CRC error detection and other measures to ensure the reliability of data communication, d) Non-destructive bus arbitration technique applied by CAN bus could greatly save the collision arbitration time, especially in the case of heavy network load, it will not appear network paralysis. Because of its outstanding features, high reliability and unique design, CAN bus is widely used in construction machinery control field. It is especially suitable for the job requirements of tower crane safety monitoring system [3].

With the rapid development of computer technology, measurement and control technology and integrated circuit technology, embedded technology in the application of tower crane safety monitoring system has also made great progress. Hardware platform program regard singlechip AT90CAN128 as the main controller was put forward [4]. Hardware platform program regard IPC as the main controller was put forward [5]. Software design platform based on embedded operating system μC / OS-II was proposed [6, 7].

3. FCS-based Tower Crane Intelligent Monitoring System

In this paper, the design of the FCS-based tower crane intelligent monitoring system is a typical fieldbus control system, its topology diagram is shown in Figure 1. Hardware circuit of the system used modular structure, which could overcome the defects of poor flexibility of traditional security monitoring system. Plug-and-play of the system module was realized, and the cost has decreased.

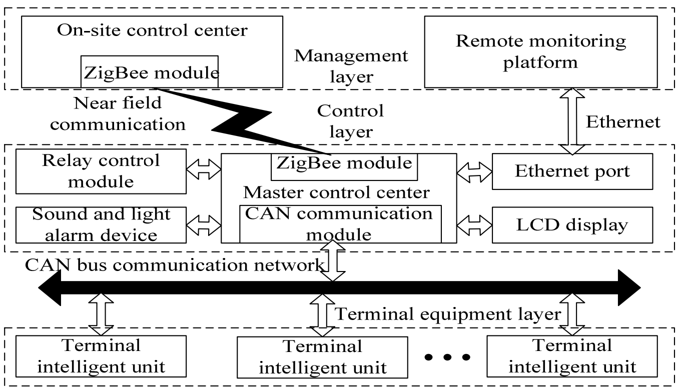

Figure 1. Topology Diagram of FCS-based Tower Crane Intelligent Monitoring System

FCS-based tower crane intelligent monitoring system delegates part of the function of traditional DCS main control layer to the terminal control unit, which completes the acquisition, processing, control algorithms and output of tower crane real-time status parameters. The system connects each terminal intelligent unit distributed on the tower crane into bus communication network through CAN bus. These units constitute the terminal device layer, which exchange information with master control platform through CAN bus. Users could check the tower crane operating conditions through LCD display installed in the driver's cab, and save the important data as a file in Flash memory. The system could also send the sound-light alarm and control the corresponding actuator by relay control mode, which reduce the risk of operations. Master control platform sends messages to the field control center and remote monitoring platform respectively through short-range wireless communications and Ethernet technology. Computers in the control room display operation status, fault and alarm status of field devices with text, diagram, curve and other forms, which provide managers with reliable and accurate real-time information, and thus realize real-time monitoring. Besides it facilitates the managers to make the best decisions to improve work efficiency.

3.1. Master Control Platform base on Embedded ARM11

Taking 16/32 bit RISC microprocessor S3C6410 as the core, the master control platform realizes the real-time display of the running state, recording and alarm of tower crane. S3C6410 is low-power, high-performance embedded SoC processor based on the ARM11 architecture. The 16/32-bit internal bus structure is composed by AXI, AHB and APB bus. Compared with the 5-stage pipeline of the ARM9, ARM11 has an 8-stage pipeline which has independent load-store and arithmetical pipeline. In the same process, the performance of ARM11 processor has increased by 40% than ARM11 processor. As system portable and wireless application, ARM11 could provide superb performance and minimize the cost and power consumption. On the basis of the embedded hardware platform, we can in-depth develop the application of embedded operating and monitoring system. The hardware system structure diagram of embedded ARM11 is shown in Figure 2 [8 -10].

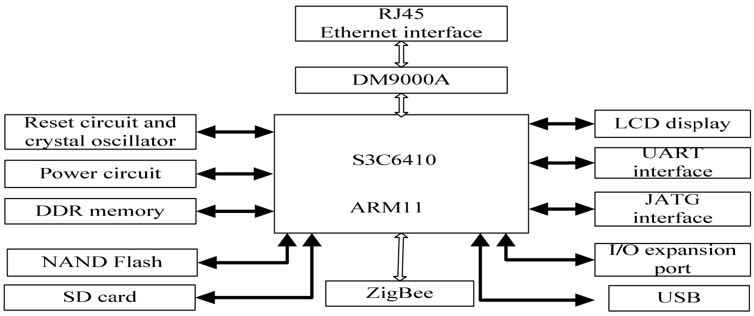

Figure 2. The Hardware System Structure Diagram of Embedded ARM11

3.2 Design of Tower Crane Intelligent Terminal Unit based on CAN Bus

Intelligent terminal unit is an important subsystem of tower crane intelligent monitoring system, including the sensor assembly, CAN communication module and intelligent data acquisition board, the system block diagram is shown in Figure 3. To prevent the reflection interference of communication signal echo, CAN bus network topology need to access to the bus terminator at bus terminal. Physically it is realized by termination resistor R that matches the characteristic impedance of the bus medium. By this the stability of the system will be improved and the system's anti-interference ability will be enhanced.

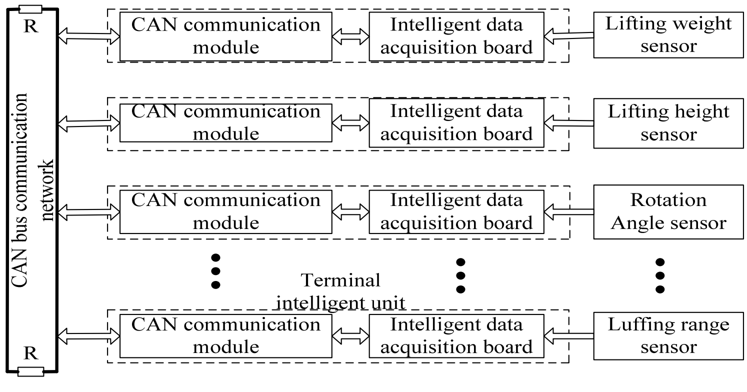

Figure 3. System Block Diagram of Tower Crane Terminal Intelligent Unit

Intelligent data acquisition board takes C8051F040 microcontroller as the core. Peripheral circuit includes signal conditioning circuit, clock circuit, and power circuit. C8051F040 internal integrates CAN controller and configures it through special function registers to read the received data as well as write the data to be sent. Intelligent data acquisition board receives the real-time working parameters collects by each sensor of the tower crane, and then, after the processing of the signal conditioning circuit, sent to the CAN bus communication network through CAN controller and CAN communication module. All protocol processing relevant to data transmission and reception filtering are performed by CAN controller without CIP-51MCU to intervention. This makes the CPU usage for CAN communication to the minimum. C8051F040 internal CAN controller block diagram is shown in Figure 4.

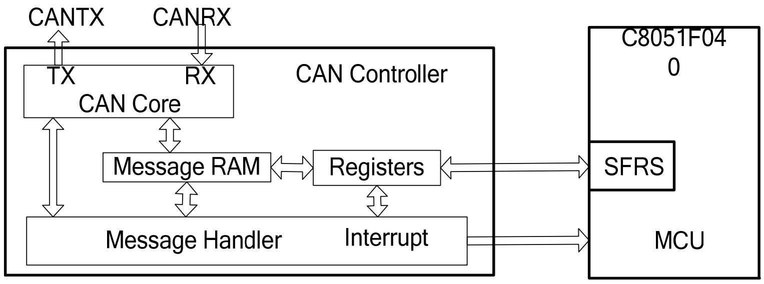

Figure 4. C8051F040 Internal CAN Controller Block Diagram

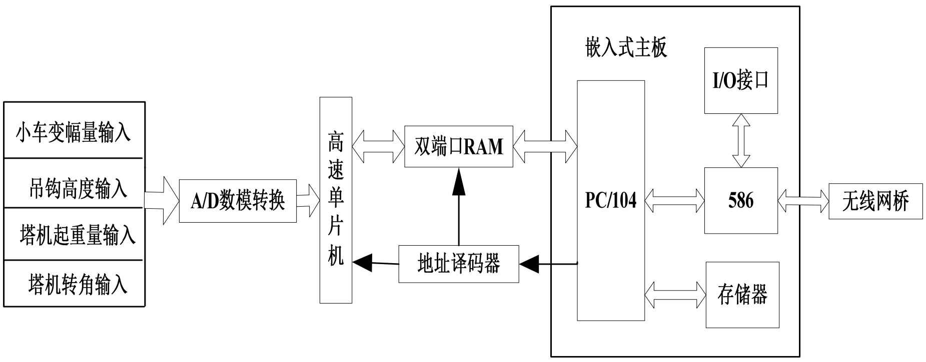

Figure 5. CAN Communication Circuit Diagram of Terminal Intelligent Unit

C8051F040 internal CAN module is just a protocol controller and can not provide the physical layer driver, so it needs for external CAN bus transceiver. Common CAN bus transceivers have PCA82C250 transceiver, high-speed TJA1050 transceiver and transceiver SN65HVD230, supply voltage of first two transceivers is 5V, while SN65HVD230 transceiver supplies voltage of 3.3V. The operating voltage of C8051F040 MCU is 2.7V to 3.6V, to simplify circuit design, CAN bus selected SN65HVD230 as the transceiver. Figure 5 is the CAN communication circuit diagram of terminal intelligent unit. To enhance the anti-jamming capability of CAN communication network, two high-speed opt coupler 6N137 was used between C8051F040 and SN65HV230. It is helpful to filter out high frequency interference in parallel two small capacitor between CANH and CANL. In series with a 5Ω resistor of each CANH and CANL pin, it could play a role of current limiting. The operating mode of bus transceiver SN65HVD230 could be altered by changing voltage on RS pin through adjusting P3.6 and JP2. In parallel resistor between CANH and CANL output pin as the termination resistor, and it works after JP2 is closed.

4. Development of Embedded Software System of Master Control Platform

The software design of master control platform applied bottom-up approach. Its keys are the correct transplantation of operating system, development of peripheral device driver and correct division and accurate scheduling of multi-tasking applications. In order to facilitate code reuse and maintenance, the entire software program applied modular and hierarchical management. Based on the instantaneity and reliability requirements of tower crane intelligent monitoring system, the master control platform, taking S3C6410 as the core, selected embedded Linux system to manage the multi-process application task scheduling. To further improve the performance of the software, multi-threading technology was used during programming, so that the main thread of the application timeshare run in parallel. The application software was divided into the following threads: the man-machine interaction module, CAN communication network data acquisition modules, wireless data communication module and management and execution module. Execution flow chart of the master control platform software system is shown in Figure 6 [11, 12].

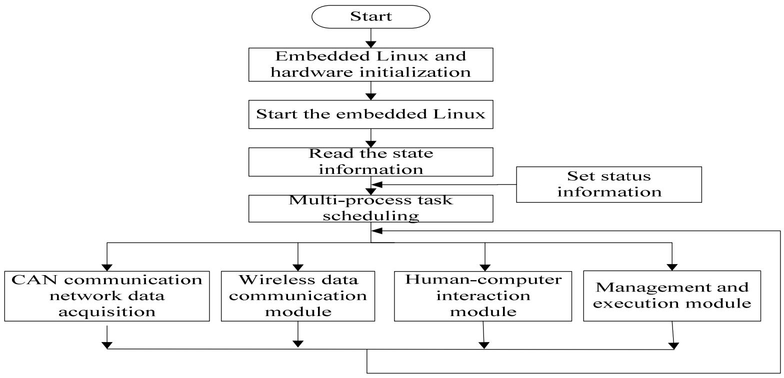

Figure 6. Execution Flow Chart of the Master Control Platform Software System

4.1. The Establishment of Cross-compiler Environment based on Linux

Due to the restricted resources, it is difficult to write software programs directly in the embedded system hardware platform. In order to facilitate the development of embedded Linux system, it is necessary to establish a cross-compiler development environment, as shown in Figure 7. Firstly, system program was written on the host. Then, the binary code format which could run on target platform was generated through cross compiling. Finally, program code will be downloaded to the target platform through the serial interface, parallel interface or dedicated hardware JTAG debugging interface.

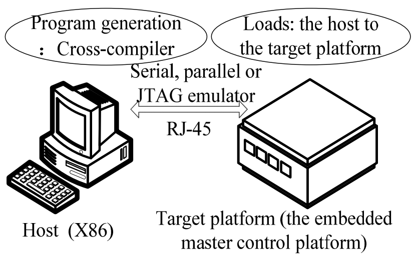

Figure 7. Cross-compiler Environment Structure Diagram of Embedded Development

In this article, embedded Linux cross-compiler environment was built through the use of VMware virtual machines. Desktop Linux operating system-Ubuntu was installed on VMware virtual machine. To make the system boot faster, it is necessary to re-compile the kernel configuration to streamline the Linux kernel based on its source code. Cross-compiler, cross-linker, C library glibc and a series of cross-tool consist of cross compiler tool chain. These cross tools are generated by configuring binary kit Binutils. In general, ARM-based Linux cross-compilers are arm-linux-gcc and cross linker arm-Linux-ld. Cross-compilation process flow chart of the system is shown in Figure 8.

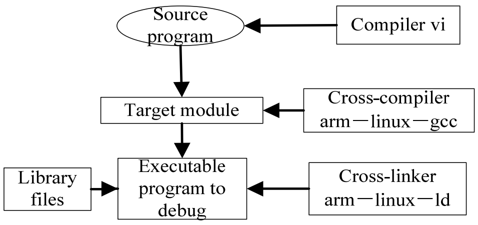

Figure 8. Cross-compilation Progress Flow Chart of the System

4.2. The Development of Linux-based Device Driver

The hardware device driver of master control platform is part of the core design driver in the Linux environment, and it can only rely on Kernel function to design drive program in the Linux environment. Figure 9 shows the hierarchical structure of device driver of master control platform in the Linux environment. Linux supports three types of hardware devices: character device, block device and network equipment. Main written device drivers include UART serial port driver, the master control platform NAND Flash storage device driver, LCD display driver, touch screen interface driver, USB driver and network control chip driver.

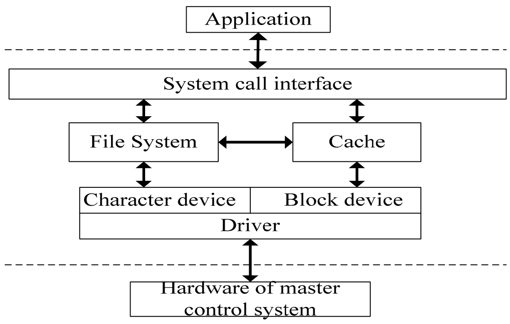

Figure 9. The Hierarchical Structure of Device Driver of Master Control Platform

4.3. The Development of the Embedded Master Control Platform Application Software System

In order to invoke multiple tasks, Round-Robin scheduling policy based on the priority was applied to the development of embedded application software. Real-time requirements of each task are different, through prioritization, real-time requirements of high priority tasks to be scheduled to ensure the system's real-time requirements. According to the control requirements of tower crane intelligent monitoring system, a number of different priority control tasks could parallel time-sharing run on embedded Linux system. For tower crane intelligent monitoring system, scheduling of on-site control center determines its system settings. So it needs to assign the task of receiving on-site control center scheduling to the relatively highest priority. Other tasks were allocated to the corresponding priority based on the relative importance and order of execution. From high to low, they were respectively receiving scheduling of on-site control center, receiving control commands of users, collecting parameter information of intelligent terminal units, controlling output devices, displaying state parameters of the tower crane, send data to the on-site control center and storing the construction information. Figure 10 shows he functional flow diagram of the embedded master control platform application software system.

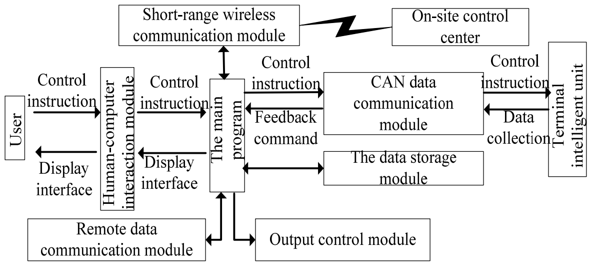

Figure 10. Functional Flow Diagram of Embedded Master Control Platform Application System

5. Conclusion

This paper researched the application of CAN Bus and ZigBee technology in wireless monitoring and control system of tower crane. Wireless monitoring system based on CAN bus and ZigBee technology was designed and its software/hardware circuit design was achieved. Compared with the traditional tower crane safety monitoring system, this system specified the standardization of data transmission and improved the information integration. The innovation of this paper was to use modular structure in both hardware and software design, which facilitated program modification and system upgrade, so as to improve the flexibility and applicability of the system. In the long run, the system has a certain economic practicality and a very good application prospects. In this paper, hardware and software design of the intelligent monitoring system based on CAN bus was provided. Taking the high-performance embedded ARM microprocessor and embedded Linux operating system as the core, coupled with stable CAN bus technology, intelligent monitoring system of tower crane based on FCS was established. It could ensure the high reliability and real-time of the system and meet the condition monitoring needs.

Acknowledgement

The authors are grateful for the assistance provided by the Natural Science Funds of Liaoning Province under grant NO. 20102184.

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