

Jacquard Control System of Warp Knitting Machine Based on Embedded System

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Abstract: In order to improve the control precision and speed, jacquard control system of warp knitting machine is designed using Embedded System. Based the overall design of the jacquard control system, the hardware and software are designed respectively. Industrial Ethernet is used to complete the data transmission in the system, aiming to improve the capacity and reliability for high speed data transmission. The synchronous control of the yarn guide pin is based on the distributed clock algorithm. The designed control system can simultaneously control multi-jacquard with faster speed and higher stability.

1. Introduction

With the deepening restructuring of the textile industry, warp knitting machine is developing towards high speed, intelligence and networking[1]. At present, the control system of warp knitting machine mostly adopts SCM or PLC processor. The advantage of SCM is relatively low cost, while the disadvantages are poor anti-interference capability, complex wiring, high failure rate, limited number of jacquard controlling and long development cycle. Compared with SCM, PLC has its advantages in anti-interference ability, working environment, development and maintenance. But its cost is relatively high, which restricts the application in efficient algorithm and intelligent control.

For Jacquard control system of warp knitting machine, the demands of real-time, reliability and data transmission speed are continuously raising. SCM and PLC are difficult to meet the requirements of machining accuracy. Here, system design is based on the embedded microprocessor, and the Linux operation system is used to control the jacquard. The embedded system has flexible clipping property of hardware and software, making it possible to integrate special platform for hardware and software, which results in good real-time, high reliability and low power consumption. For data communication, the industrial Ethernet EtherCAT bus is used. Industrial Ethernet has been widely used in the field of industrial automation, it has high response speed, low CPU occupancy rate and good synchronization performance.[2]Using EtherCAT's distributed clock mechanism, the clock synchronization accuracy between each slave node less than 1 μ s can be realized,[3][4] which is very important to the synchronizing action of the guide needle.

The integration of micro processing technology, communication technology and automatic control technology can improve the processing speed of the control system, shorten the development cycle of the system, make the system have better real-time and stability, faster speed, stronger anti-interference ability, lower power consumption and higher scalability. The level of information and automation of the warp knitting machine is improved.



2. Overall design of the control system

Based on the analysis of the control requirements and working environment, the overall design of the piezoelectric jacquard control system is completed. As shown in Figure 1, the jacquard control system includes IPC, jacquard controller, jacquard repeater, jacquard driver and piezoelectric jacquard guide needle. Considering the large quantity short offset interval and high frequency of the yarn guide needle,[5] the whole control system adopts embedded technology and EtherCAT bus, and distributing clock synchronization algorithm mechanism is used to realize the real-time control, providing high reliability, real-time and anti-jamming capability, large data packet capacity and high transmission speed. which meets the requirements of the high-speed stability of the jacquard control system and can adapt to a poor working environment.

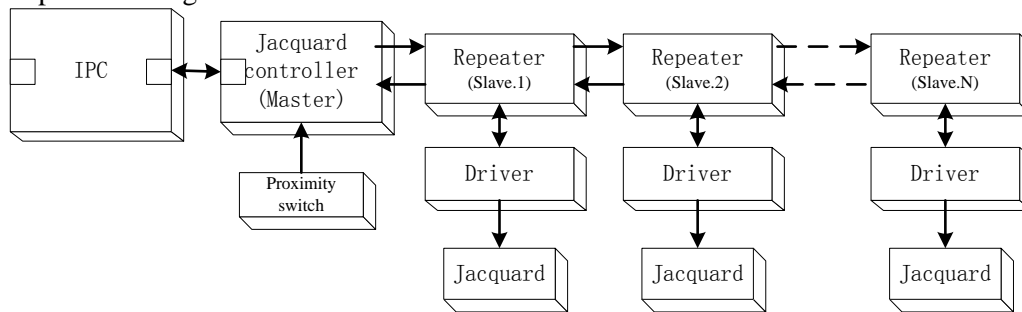


Figure 1. Jacquard control system

In the system, IPC realizes data transmission, parameter configuration, debugging and real-time control of jacquard controller. Master-slave mode is adopted between jacquard controller and repeater. The controller downloads the process data from the industrial control machine and transfers the process data to each jacquard repeater. The repeaters insert the data while extracting, so that the controller can monitor each repeater in real time. The repeater passes the received data to the jacquard drive after analyzing, and the real-time control of the piezoelectric jacquard is realized through the driver. The system uses EtherCAT to complete the bus communication from the industrial field layer to the management layer, which can replace the existing complex bus systems in the industrial control industry. While improving the transmission rate, the number of wires is reduced, and failures due to complicated wiring can also be reduced, contributing to less jacquard errors by malfunctions.

3. Hardware design of the control system

3.1 Design of the controller

The hardware of jacquard controller is mainly composed of processor, memory, communication interface and power supply. The hardware structure is shown in Figure 2. In the control system, the jacquard controller is the main communication station in the entire EtherCAT communication system, so the high performance industrial application processor AM3359 is adopted to meet the high requirement of jacquard controller. AM3359 is a 32-bit ARM core processor based on the ARM Cortex-A8 core developed by TI. The main communication module of the controller is implemented by two Gigabit Ethernet interfaces. The physical layer is connected by AR8031 chip using RGMII interface.

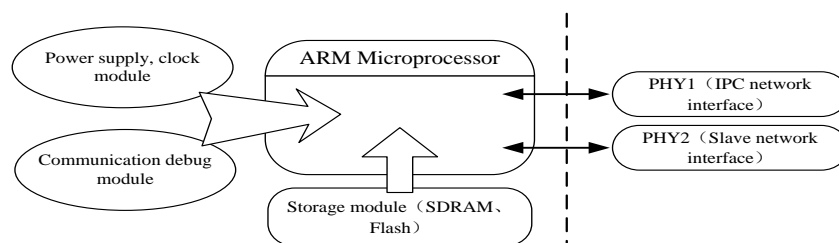


Figure2. Jacquard controller hardware structure

3.2 Design of the repeater

Jacquard repeater is used as the slave station of communication system. Due to the large amount of system data and high communication rate, the jacquard repeater hardware adopts ARM+FPGA architecture. The ARM processor mainly processes EtherCAT data frames, and sends the location instructions and pattern data to FPGA. The output control is realized through FPGA. Figure 3 shows the hardware structure of the jacquard repeater.

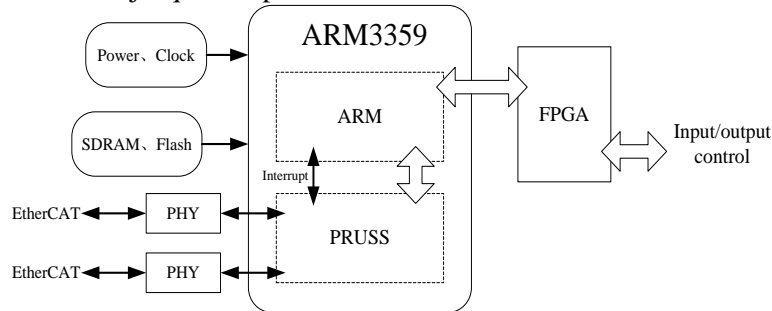


Figure 3. Jacquard repeater hardware structure

Slave processor also chooses AM3359 chip. The microprocessor chip has independent running clock with good application flexibility, and has programmable real-time unit subsystem PRU separated from ARM unit. TI provides PRU-ICSS-based EtherCAT slave routines for free.

FPGA uses the Cyclone III series EP3C16Q240C8N chip produced by Altera Corporation. It combines high performance and low power consumption with relatively low cost. It can also realize high-speed communication and control with multiple jacquard drives at the same time.

ARM and FPGA are connected by 16 bit data bus, three-way control signals and four-channel GPIO. Because ARM chip and FPGA adopt different clock signals, asynchronous FIFO can be used to realize fast real-time data transmission conveniently. Compared to serial bus interface, parallel bus of data transmission can realize high-speed data transmission[5][6]. The three-way control signals include write enable signal (W_EN), read enable signal (R_EN) and chip select signal (NGCS5). The four-channel GPIO can be used as a control command signal for FPGA to realize the control of FPGA state.

4. Software design of the control system

4.1. Design of the master station

As the main station of the system, the jacquard controller completes the analytical communication protocol, and manages the whole communication. The software architecture of jacquard controller is mainly divided into three parts: network device module, application program and master station module, user management module. The software architecture of the master station is shown in Figure 4.

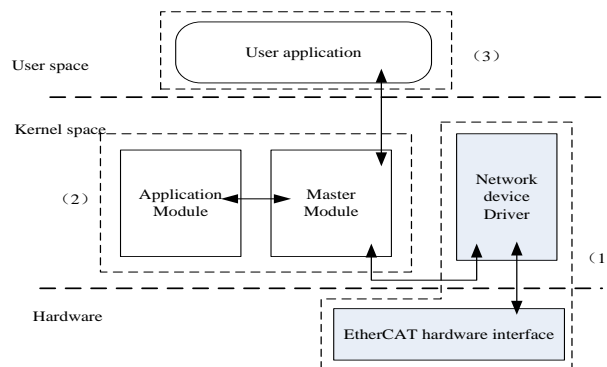


Figure 4. Software architecture for master station of control system

The functions implemented by each module are as follows:

(1) Network device module. EtherCAT's network communication function can be realized through common network devices. In kernel layer, it is difficult to realize EtherCAT protocol by common network device driver, so a universal network card driver provided by the open source EtherCAT protocol stack is adopted, which can support EtherCAT master communication without modifying existing drivers.

(2) Application program and master station module. In order to ensure the real-time performance of the controller, both the application and the master module are in the kernel layer. The EtherCAT master module analyzes the protocol, completes the task scheduling, and provides the function interface for the network device and the application program.[7] The application program module is written according to the control request of jacquard repeater, thus realize the automatic control of repeater.

(3) User management module. A variety of commands that can be run at the Linux user tier is provides, enabling direct access to jacquard repeaters and setting.

4.2. Design of the slave station

In the system, jacquard repeater is set as slave station. The entire software architecture of the secondary station will be divided into three layers: the driver layer, the EtherCAT protocol layer and the user application layer. The standard interface function is used to complete the connection between each layer. The driver layer includes all hardware drivers for initialization and operation of PRU, power, memory and corresponding interfaces. Among them, PRU driver includes configuring PRU-ICSS register program, reading and writing the cache function. The EtherCAT protocol layer mainly includes EtherCAT state machine, Mailbox Communication and Process Data Communication for processing EtherCAT communication. The FPGA control and data interaction are realized through the user application layer. The overall architecture of the slave software is shown in Figure 5.

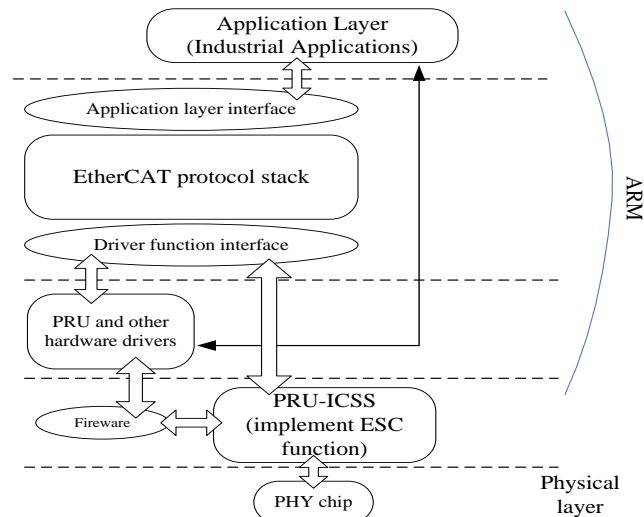


Figure 5. Control System Slave Software Architecture

4.3. Design of the distributed clock and periodic synchronization controlling

The control system is used to synchronize the guide pins, and the precise synchronization control is a critical part of the system. EtherCAT bus has been widely used in industrial control field because of its excellent real-time performance[8]. The distributed clock algorithm can be used to achieve synchronous output control of the jacquard repeaters.

The distributed clock mechanism synchronizes all jacquard repeater to a reference clock. The first repeater with the distributed clock function connected by the jacquard controller is choosed as a reference clock to synchronize the clock of other devices and controllers. The distributed clock

synchronization algorithm consists of three parts: transmission delay measurement, offset compensation and clock drift compensation.[9][10] The implementation process of the distributed clock algorithm is shown in Figure 6.

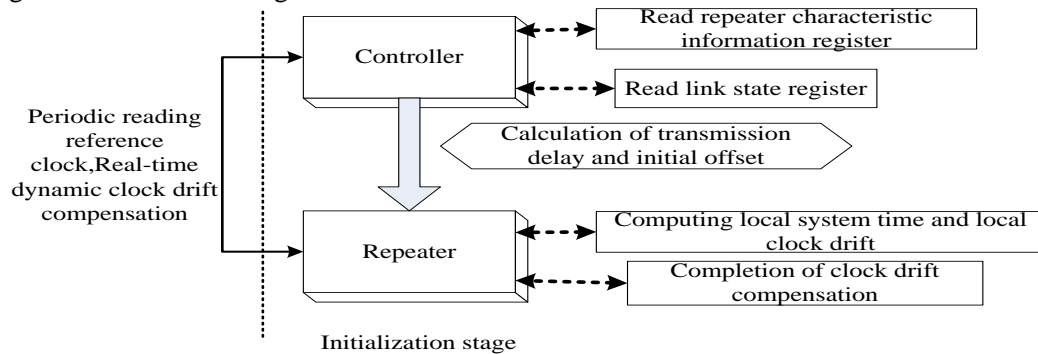


Figure 6. Distributed clock algorithm implementation flow

As shown in Figure 6, the controller initializes the distribution clock synchronization function by reading and writing some configuration registers of the repeater. According to the running stage of the EtherCAT state machine, the controller completes the reading and writing of the repeater corresponding register in the initialization state, making the repeater support the distributed clock and configure the distributed clock related registers. During the configuration process, it is necessary to measure and calculate the transmission delay and the initial clock offset. Under safe running state, the controller begins to synchronize the clock of all repeater, and sends the message to every repeater by sending order addressing command. Through reading current system time from the reference clock repeater and writing the time in other devices, the speed of the local clock is adjusted based on time control loop. In the running state, the controller can periodically send sequential addressing commands along with the process data. By reading the system time of the first repeater and writing to other devices, the dynamic clock drift compensation on the other repeaters can be realized in real time.

5. Conclusion

The system applies embedded control technology. The data transmission and information collection are completed through industrial Ethernet EtherCAT bus. The overall scheme of the control system is given, and the software and hardware design of jacquard controller and jacquard repeater are carried out respectively. The control system has faster transmission speed, larger packet capacity, stronger anti-interference capability and better function expansion. At the same time, the distributed clock mechanism is adopted to meet the speed and accuracy requirements of the control system, and the speed and intelligence level of the warp knitting machine control system are improved.

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