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Study and design on industrial Ethernet switch

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ABSTRACT

With the rapid development of computer network technology, Ethernet technology has been widely used in the field of industrial control. Industrial Ethernet switch is the most ideal and direct products of the industrial control field in upgrading network speed, and it not only can be used as high performance Gigabit LAN access equipment, but can also be used as a convergence layer switch at the department level. In this paper, starting from the market demand it is expounded in detail to development and design on industrial Ethernet switch that satisfies the special field of industrial control applications in the aspects such as environmental adaptability, electromagnetic compatibility, safety and stability etc..

KEYWORDS

Gigabit LAN; Industrial Ethernet switch; Design.

Due to the rapid development of computer network technology, Ethernet technology has been widely used in various industries[1,2]. But in the field of industrial control, due to the requirements such as certainty and real-time in communication as well as adaptability[3], stability and safety in field environment, it put forward higher requirements on the performance of equipment, and has to satisfies the requirements of industrial field in aspects in material selection[4], product strength, applicability, real-time, interoperability, reliability, anti-interference and intrinsic safety etc.

FUNCTIONAL REQUIREMENTS OF INDUSTRIAL ETHERNRT SWITCHES

In addition to complete access convergence exchange function of ordinary switches, the industrial Ethernet switch needs to have the following several aspects of the management function[5].

① Support for network security. It mainly includes the protection of user data (unicast packets) security, isolation of broadcast packets carrying user information, preventing broadcast storm blocking switching equipment, and preventing key equipment being attacked and so on[6,7].

② Support for QoS. It can provide multi-services to meet the different needs of different types of business service quality.

③ Support for multicast technology. It can make effective utilization and saving network bandwidth, and a copy of the data can be sent simultaneously to a number of members of the same group to improve the real-time and reliability of network.

④ administration of networks. It includes the management of network equipment and user management.

DESIGN OF INDUSTRIAL ETHERNET SWITCH

This paper studies the design of the switch for Gigabit managed industrial grade switch. It owns the functions of network management[8], VLAN management, priority management of service quality, port stack management and the others, and provides two layer switching function in stable and reliable working[9,10]. It not only can be used as access equipment of high performance Gigabit LAN, and can also be used as a convergence layer switch at the department level[11,12].

Main performance index and the external interface

The main performance index of the designed switch in this paper includes the following aspects.

① The two layer switching performance. Its exchange capacity is not less than 24Gbps (fast), the L2 address table is not less than 4K, and it adopts on chip cache package.

② Support for VLAN. It accords with VLAN specification of 802.1Q, and supports at least 4096 VLAN.

③ Support for Multicast. It supports IPV4/IPV6 multicast, IGMP snooping and IP multicast filtering.

④ Support for QoS. There are at least two priority queues per port, and it supports the source / destination address filtering. The definition of priority can adopt available VLAN Tag field or port priority.

⑤ Support for flow control function. It supports the full duplex IEEE 802.3X flow control and the half duplex anti pressure flow control.

⑥ Suppression ability of broadcast storm. It can set up the prevented occurrence of broadcast storm.

⑦ Support for network port security. It makes the binding of port and MAC address, and supports the port access control (ACL) of IEEE 802.1X

⑧ Support for link aggregation of a group of ports (IEEE 802.3ad), and load balancing.

⑨ Support spanning tree protocol. It supports IEEE 802.1d or IEEE 802.1w or IEEE 802.1s.

⑩ Support for SNMP.11, it can expand and support uplink or stack.

There are 24 10/100/1000Mbps electric interface in the external interface of a switch, in addition, the switch also supports 2 1000Mbps optical interface, and therefore, it can be convenient for different user interface.

Electrical interface adopts the RJ-45 connector or Y50DX-0804 aviation socket and UTP-5 line, and it can carry out self-negotiation for 10/100/1000Mbps speed and duplex mode. When the RJ-45 connector is adopted the working model is auto negotiation for 10/100/1000Mbps, and it can be compatible with the original 10/100M Ethernet, and in which the maximum distance of 1000Base-T is 100 m. Optical interface adopts SFP and single mode optical transceiver module (1000Base-LX), and the maximum transmission distance is 5000 m. According to different needs it can select the appropriate interface to form flexible networking scheme. Ethernet interface owns indicating lamp, and it can respectively indicate the link state (Link), data transmission state (Act) and transmission speed (10／100／1000Mbps). Management control interface includes a support RS-232 protocol DB9 (Y50X-1010) interface, by means of 24 electric interface or 2 optical interface, it can make remote management control through Telnet, and at the same time, the system supports SNMP management based on Web.

Design scheme and chip selection

The design scheme is based on the integration of exchange engine and CPU, adopts the structure of SoC (Switch on a Chip), and it means that CPU and exchange module are integrated on a chip. Due to the high degree of integration, it results

in simpler in external module, and can reduce the number of chips and the area and layer number of the PCB. It reduced the amount of hardware and connection, improved the stability and reliability of the switch, and therefore, the cost is reduced. In the aspects of improving performance of the working group, expanding network bandwidth and increasing network node, it provided great flexibility, and it has the characteristics of being simple in use, convenient in installation, advantageous in performance and high in cost performance etc. SoC chip selects BCM56224 pushed-off by Broadcom company, in which it is a 24 port of two layer Gigabit Ethernet switch chip, and the structure diagram is shown as in Figure 1.

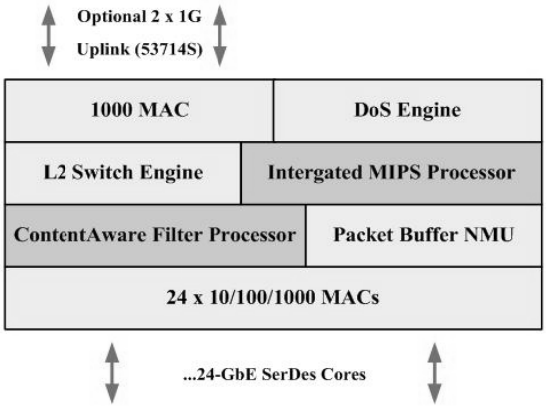

Figure 1 : The structure for BCM56224

BCM56224 has 24 Gigabit interface, and in which, there are four of the most high-speed 2.4Gbps interfaces that is the uplink interface. These Gigabit interface is used in SGMII/SerDes standard, and can be connected with the PHY chip or is connected with the optical module SFP. BCM56224 supports 4096 VLAN (IEEE 802.1q), and Spanning tree protocol IEEE 802.1d, IEEE 802.1w and IEEE 802.1s. In which, There are 4 priority queue in supporting QoS accorded with IEEE 802.1p, and supports the Link aggregation of IEEE 802.3ad, broadcast storm control and access list control IEEE 802.1x as well as 1.392MB cache, 8000 MAC address table, 8000 IPv4/IPv6 multicast address, and all the speed is up to 34Gbps. BCM56224 is with UART interface, supports for Web network management, it has an integrated MIPS processor, and therefore, it can save the external CPU module and at the same time implement the complex system management.

Design of hardware system

Structure of switch hardware system is shown as in Figure 2. The system takes BCM56224 as the core, and in which, it concludes the switching engine, CPU module and auxiliary function module etc.

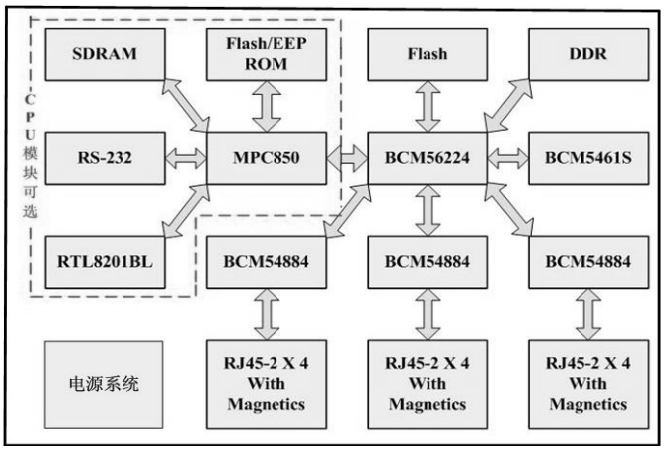

Figure 2: Structure of switch system

Exchange engine module

BCM56224 integrated the exchange engine, CPU system and several kinds of interface. The interface of BCM56224 and PHY is SGMII / SerDes, and it can be directly connected with the SFP module of optical module, or PHY electric port, Or directly connected with photoelectric multiplexing interface of supporting Combo formation of PHY. The BCM56224 has a total of 8 interfaces, and each port can be connected with the electric RJ45 with Maganetic connected by CAT5 line. At the same time, it can be connected with optical interface SFP, namely the Combo, and BCM56224 chip can automatically detect the interface which is connected to the electric interface or optical interface.

The design of stack port adopts that it takes four interfaces of 10/100/1000/2500Mbps converge into 2x5Gbps interface to make the heap for convenience to form an annular or chain shaped topological structure. Here, two interfaces of four 10 / 100 / 1000 / 2500Mbps interfaces would be converted to optical interface.

In addition to the realization of the basic frame of exchange, the exchange engine also supports VLAN management and other functions such as spanning tree protocol, QoS and flow control, Link aggregation, broadcast and multicast control, port mirroring, address learning and aging, stack, Web network management etc.

The following discusses the selection of the other peripheral chips in the exchange engine module.

Firstly, BCM56224 memory interface is a DDR standard, and here's a selection of Micron company's MT46V64M16TG-75IT memory chip of working voltage 2.5V. The system is based on 32Mxl6bit structure, namely data is a 16 bit， and address space is 32M.

Secondly, nor Flash with ROM is selected, the interface is selected as the parallel, and the capacity is 128Mbit. Here's a selection of Spansion company's S29GL256N80TAI chip, the working voltage is 3.3V and no external pressure to write operation. Due to the nor Flash with ROM, the system can directly be started from the Flash. Boot loader is stored in Flash ROM, the configuration information etc of system is stored in the other area, and the system adopts 16Mx8bit structure.

Thirdly, the last is to select some auxiliary system on chip.

RS-232 interface chip of UART interface selects Intersil company's icl3243cb, its working voltage is 3.3V. Through the RS-232 interface, the user can complete the update of system software and manage the configuration system and so on.

JTAG interface accords with IEEE 1149.1, and it is used for connecting simulator to make the software and hardware debugging. It is currently the most conveniently embedded debugging method, and its debugging function is much powerful than UART.

The SPI interface is worked in the master-slave mode, it can make the peripheral equipment communication accorded with the standard interface, and therefore, it can expand the system.

The system clock signal is generated by a 125MHz high precision crystal oscillator, and then, it generates the multiple clock signals through the clock Buffer chip. Here, IDT's ICS551M chip is selected, and its working voltage is 3.3V.

The reset signal adopts Maxim company's MAX811TEUS-T, and its working voltage is 3.3V. When the system power is on, it generates a reset signal to start the system, and makes the system back to foreseeable state. In addition, the system is also connected with a manual reset system.

The CPU module

BCM56224 not only supports the built-in MIPS processor system, but also it can be connected with external CPU module. The switch design uses a built-in MIPS processor system, and therefore, it does not make the description for external CPU module.

Ethernet PHY module

Because the interface of BCM56224 and PHY layer is SGMII/SerDes, as long as the PHY chip is selected according to the standard interfaces. The switch selects the BCM5488S chip that supports electric interface..

BCM5488S interface is SGMII／SerDes. When it works in 1000BASE-T mode, it can be connected with MAC only adopting two of the differential, and greatly simplifies the interface. Auto-negotiation module mode of BCM5488S can automatically detect the link state to determine the chip working state.

The chip has three kinds of working mode. The working mode from SerDes interface of MAC to five kinds of line, it only supports 1000M BASE-T. The working mode from SGMII interface of MAC to five kinds of line, it supports 10 M BASE-T,100 M BASE-T and 1000 M BASE-T. The working mode from SGMII interface of MAC to 100 M BASE-FX. The switch design selects the working mode from SGMII interface of MAC to five kinds of line.

There are a variety of ways in the configuration of the system. ① Set the internal registers via the MIIM interface. ② The chip corresponding CMODE pins connected in series with the corresponding resistance. ③ By reading the external EEPROM configuration. The switch design adopts a relatively simple way ② to configure the system, and at the same time, it can configure the address of PHY chip. MDI interface for each port has four pairs of differential is used for connecting transformer, then it connects the RJ45 interface and five kinds of line to to make the communication. BCM5488S has the function of automatic detection on line, and according to the conditions of the line, it can decide the work at which rate.

BCM56224 makes communication with PHY through MIIM management interface. MIIM interface has two signal lines, one is a clock signal line, and the other is the line of data input and output. Connecting all the MIIM interfaces of PHY with BCM56224 interface, BCM56224 can distinguish that which PHY is by means of the address configuration of PHY.

The JTAG interface of BCM5488S chip is in accordance with IEEE 1149.1, and it can make the debugging.

The PLL module makes frequency multiplication to the input reference clock frequency. LED Interface is used for indicating the port working state, and there is the serial and parallel mode. The serial mode needs an additional serial parallel conversion chip, so the design selects the parallel mode. The indicator light indicates the port working state, when data connecting, it often shows to be bright and flashing, different colors also represent different speed, and when disconnection it is not bright. So it only needs just 26 state indicating lamps plus a power indicator. In order to better display the working status of the machine, the indicating lamp are installed on the front panel of the machine, and the corresponding interface of switching system is connected on the system board.

Photoelectric conversion module

The photoelectric conversion circuit is mainly composed of a peripheral circuit and optical fiber transceiver module HFCT-5911ALZ, and it is used to realize the conversion between 1000Mbps signals and optical signals. The principle block diagram is shown as in Figure 3.

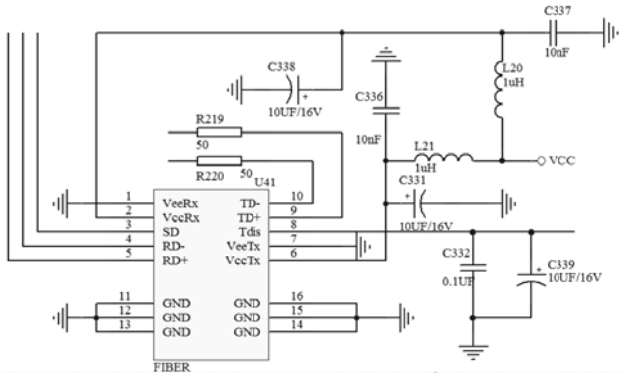

Figure 3 : Block diagram of the photoelectric conversion principle

Power-supply module

Using the DC-DC transform, the DC24V voltage can be transformed into the external power supply voltage 5V, and then through the LTC3728EG chip on the motherboard it can be transformed into 1.0V, 2.5V, 1.25V, 2V voltage needed. Each power supply adopts the transformation way of switching power supply. Because the system is built by a lot of digital circuit, when the digital circuit adopts the high speed switch, the current changes a lot, and therefore, the use of switching power supply can adapt to such kind of changes.

System software architecture

The system software mainly completes the configuration management of the exchange module, including the configuration management of PHY. The CLI interface provides through UART interface can make the initial configuration of the system, and moreover it can also configure management through Web at any time. The system software adopts the layered modular method to design, and it is shown as in Figure 4.

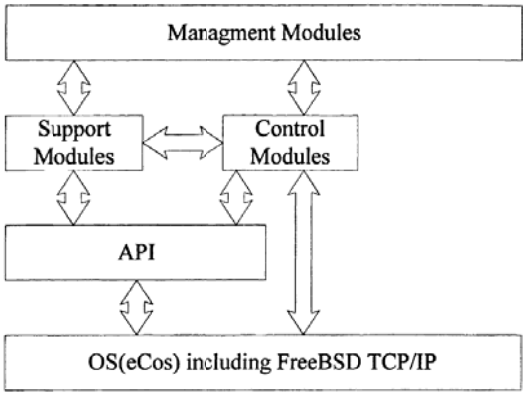

Figure 4 : Block diagram of software design

The operating system of the switch adopts embedded configurable operating system to implement. It is the product of RedHat and a real-time operating system of configurable, transportable and oriented to embedded application of open source code, and the agreement also includes TCP／IP of FreeBSD.

The API layer provides lots of programming interface, and it is very convenient to software development for third party. In addition, API also provides the switching chip and PHY chip interface etc.

Support Modules provide a variety of system service.

Control Module provides a management interface for management module, and it can control the work of exchange control chip and store the configuration information and so on.

Management Module provides the user interface. The user manages the switch through the module, and it can manage switch by means of two ways of CLI and Web.

CONCLUSION

Starting from meeting the functional requirements of Ethernet switch in industrial control field, this paper makes a detailed research and analysis on design scheme, chip selection, system hardware structure and software architecture etc. of industrial Ethernet switch. In the paper, it designs and develops a kind of Gigabit Ethernet management switch that owns the functions of network management, VLAN management, priority management of service quality, and port stack management, and provides the two layer switching function. The design and implementation is fully combined theory and practice, and the switch provides a reference platform for application of the Ethernet switching technology in industrial control field.

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