17th World Conference on Nondestructive Testing, 25-28 Oct 2008, Shanghai, China

ARM9-Based High Speed Multi-channels Eddy Current and Ultrasonic Testing System

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Abstract

Eddy current testing and ultrasonic testing are two conventional NDT methods. Develop a new kind of NDT instrument with two methods, which shows the concept of NDT integrated technology. ARM9 integrate USB and Ethernet, it can exchange data with DSP or FPGA friendly, which is an ideal embedded processor in testing system at present. This article discuss a testing box based on ARM9 which samples the signals of Eddy Current and Ultrasonic and sends the sample data to Personal Computer through Ethernet to form the whole testing system.

Keywords: ARM9 multi-channels Ethernet

Eddy current testing and Ultrasonic testing are two major methods in nondestructive Testing. Eddy current testing has fast speed, and coil needn't direct contact with testing object, with no couplant between them, but it is only limited to detecting electric material's surface and near surface; Ultrasonic testing can detect kinds of materials, such as metal, nonmetal and Composite materials, but it also has applied limitation, for example, existing dead zone and pretreatment before detecting coarse surface of component. In many case, it is necessary to detecting objects with eddy current testing and ultrasonic testing complementally to evaluate the degree of the flaw. So develop an instrument with two methods is a trend of intelligent NDT tester.

The existing integrated instrument with two methods or single method but multi-channels instrument in market always develop as a standard card that can insert into industrial computer. This card includes the circuit of emitting eddy current signal or ultrasonic signal, the circuit of picking up flaw signal, and the circuit of sampling data, etc. And it exchanges data with CPU through ISA or PCI to form the whole testing system. This kind of instrument makes the fullest use of resource of industrial computer, but always limited by some factors such as ISA or PCI bus driving capacity, power supply, inside and outside space. Recently, there appears a new kind of multi-channels instrument in the market. It constituted by a testing box and a PC which they exchange data through parallel port or USB or Ethernet. This way can resolve the problem existing in standard card design. But this kind of instrument also has shortages such as structure complexity, low efficiency, and low integration in circuit, etc.

Since multi-channels eddy current and ultrasonic testing system has to deal with a large amount of data to meet the requirement of realtime processing and testing speed. The selection of a High-speed processor is important to the whole designing, and the quondam siglechip can't play the core role in testing system. With the development of semiconductor technology in recent years, the embedded ARM-processor series applied in numerous of commercial and industrial products. This kind of processor integrate USB, Ethernet, some high-grade chip even contain ADC, DAC and other peripheral modules. It is easy to interface with DSP or FPGA, which is an ideal embedded cyber-platform in testing instrument at present. The following will introduce the hardware and software design in making multi-channels eddy current and ultrasonic testing box, and will resolve the problem of inter-connection between the testing box and PC.

1 Introduction of System Hardware

1.1 ARM9 Feature

ARM9 family is the main embedded processors designed by British ARM Co.ltd that only design ARM kernel logic. They are high-performance, low-power 32-bit processors. At present, all well-known semiconductor companies have their own ARM9 products, such as sumsung's S3C2410, S3C2440, freescale's i.mx21, cirruslogic's EP9315 and intel's PX270. Most of processors' clock frequency is about 200MHz, some even up to 520MHz, bus' operating frequency is about 100MHz, and it integrates data-cach, instruction-cach, MMU unit in the chip. Its processing capacity is unmatched by other siglechip, which can up to 200MIPS. ARM9 is rich in integrated peripheral resources like Ethernet, USB master, USB slave, LCD controller, DMA controller, serial port, I2C and SPI and so on[2]. Linux, WinCE and VXWORK or other operating systems can run on ARM9 easily. In view of these features in hardware and software, ARM9 is an ideal embedded processor in making the testing box.

1.2 Hardware Frame of Testing System

Fig.1 shows main structure of testing system, which is composed of the testing box and PC.

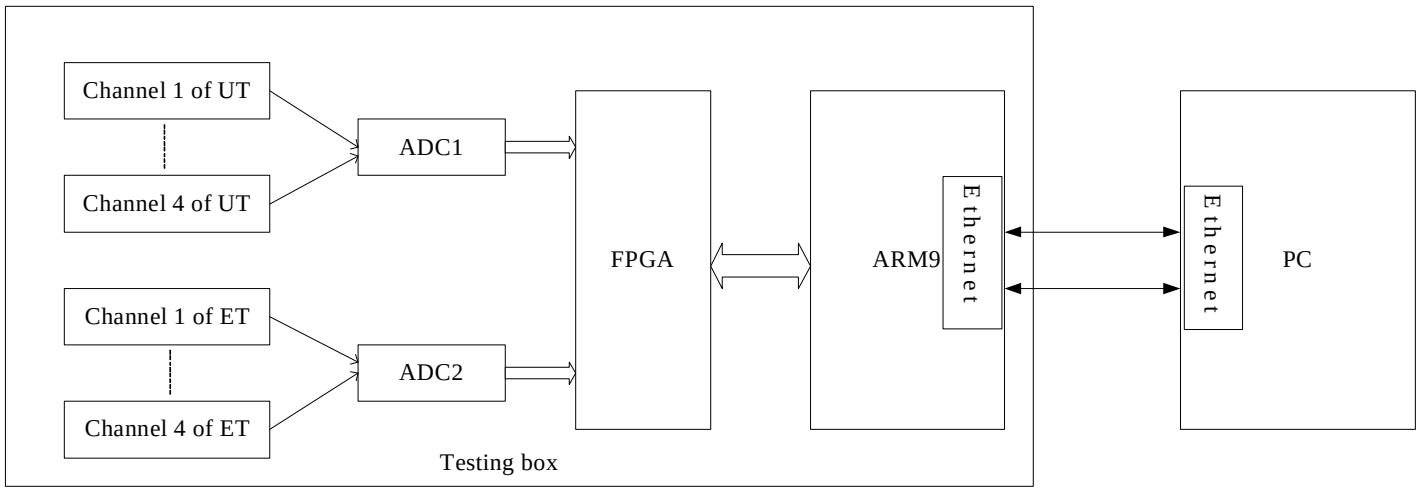

Fig.1 Hardware frame of testing system

The testing box is in charge of sampling, controlling and pretreatment of eddy current and ultrasonic' signals. At here we explain the testing box of 4-channels ultrasonic and 4-channels eddy current for example.

Each channel of ultrasonic includes the circuit of emission, receiver, preamplifier and voltage-controlled amplifier. Four channels ultrasonic are sampled by the ADC1 in time-sharing mode. Each channel of eddy current has the same circuit configuration as ultrasonic. Four channels eddy current are sampled by the ADC2 in time-sharing mode. Take the two signals' frequency into account, two ADC are used here, and the sample rate of ADC1 is higher than ADC2. This kind of design is not only favorable for controlling two signals' independently, but also can avoid cross-interference. FPGA resources divides into two parts, one part is responsible for ultrasonic channel's switching, collecting, filtering, coding, the other part doing corresponding work of eddy current. ARM9 is the core controller of the testing box. It interfaces with FPGA through address bus, data bus, control bus, and assigns FPGA hundreds mega-bytes memory space for exchanging the data of ultrasonic and eddy current. Meanwhile it connects to PC through 10M/100M adaptive Ethernet for exchanging data. ARM9 receives parameter from PC and sends it to ultrasonic part or eddy current part of FPGA, it also receives ultrasonic data or eddy current data from FPGA, after pretreatment, alarm, data compressing, then sends to PC. PC is responsible for human interface, such as display flaw, keyboard, storage, analysis and other works.

1.3 Network Topology of Multi-channels Instrument

The testing box and PC exchange data through Ethernet, so multi-testing boxes can interconnect to form the testing network. As Fig.2 shows, 4 testing boxes with different IP addresses, all connect to a hub that connect Client PC to form the testing system. This system has 16 channels eddy current testing and 16 channels ultrasonic testing. PC sends detecting start signal and each channel's parameter to corresponding testing box, and receives the testing data from each testing box by turns. PC also analyses the testing data, displays flaw, alarms with sound and stores corresponding data. Take this system as a testing unit, and organize multi-units

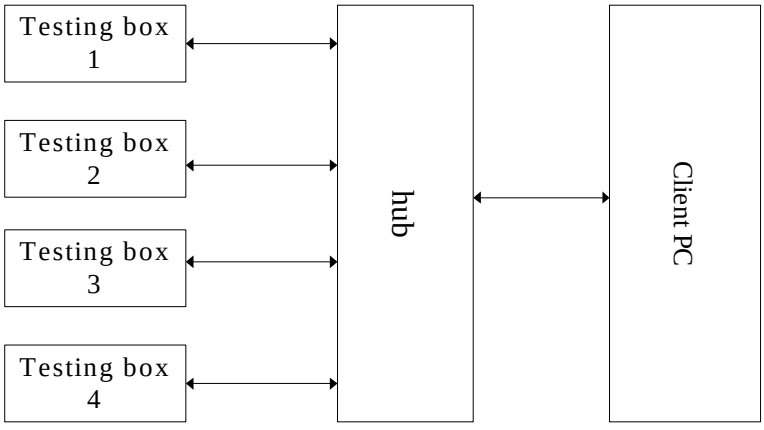

Fig.2 Network topology of 16 channels testing system

to form testing workstation through network. Every user on each client PC can communicate with email or real time information in workstation, and also can share printer、display plotter and other facilities which can connect each client PC, even can share application files[1] .

2 Software Design

System-software includes two parts: ARM-software and PC-software. They communicate with each other through the TCP/IP network protocol. The PC's operating system is WINDOWS, and the ARM's operating system is LINUX. Although the operating systems are different, they all provide the socket that is standard network programming interface, it provides an easy way to access the protocol of TCP. The software interface under the WINDOWS is shown in Fig.3, you can choose program between 4-channels eddy current testing procedure and 4-channels ultrasonic testing procedure, and you can access the network port under two procedures. Due to the introduction to TCP under WINDOWS is too much, the following will introduce ARM-software designing and network communication on server under Linux.

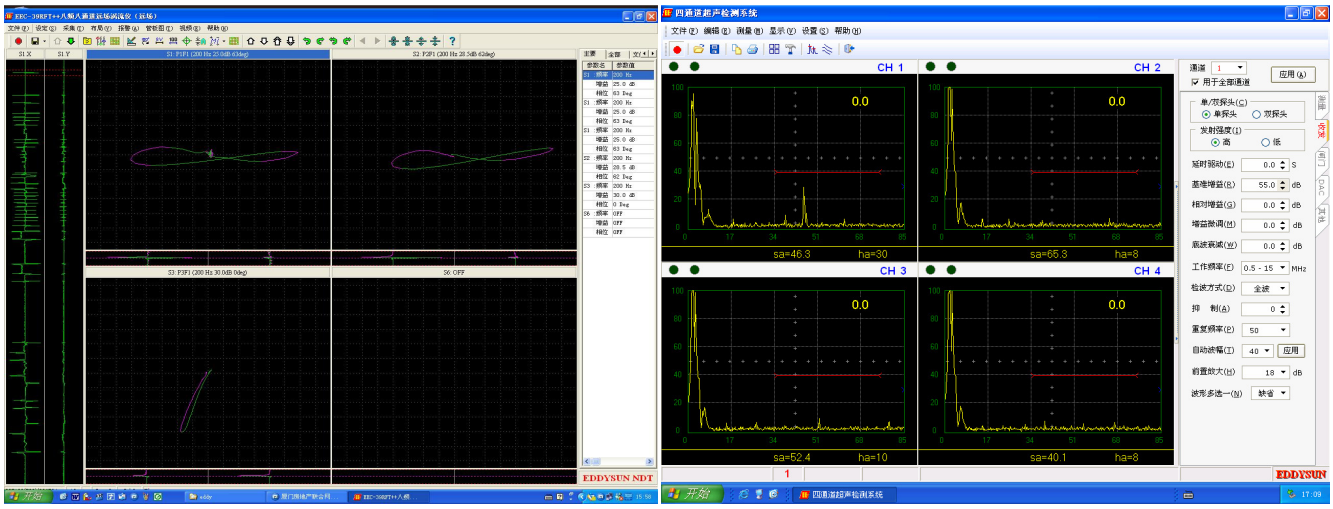

Fig.3 Software interface of 4-channels eddy current and 4-channels ultrasonic

2.1 ARM-Software

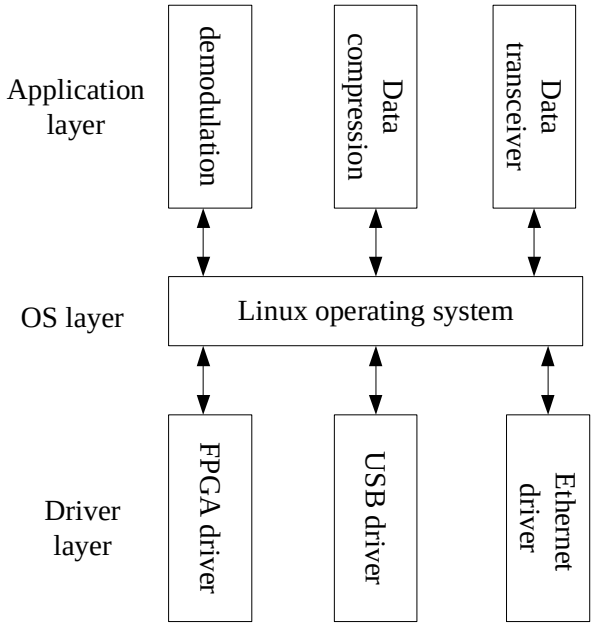

Fig.4 Software frame on ARM9

As shown in Fig.4, ARM-software includes three parts. They are the device driver layer, the operating system layer and the application layer[3]. The kernel version of the LINUX is 2.4.18, it's better to select the used option and cancel the no used that just to meet system requirement. The device driver layer includes FPGA driver, USB driver and ethernet driver. The system assigns hundreds mega-bytes memory space to the eddy current and ultrasonic separately, and abstracts them into two character devices in FPGA driver; The USB driver and the ethernet driver can be transplanted from the development board[5]. The application layer is divided into three processes: demodulation process, data compression process and data transceiver process. The demodulation process receives data from eddy current device or ultrasound device, and picks up flaw eigenvalue from these data. The data compression process compress eigenvalue and location information to reduce data stream. The data transceiver process is in charge of receiving parameter from PC and sending detecting data to PC. And all three processes communicate with each other through the signals.

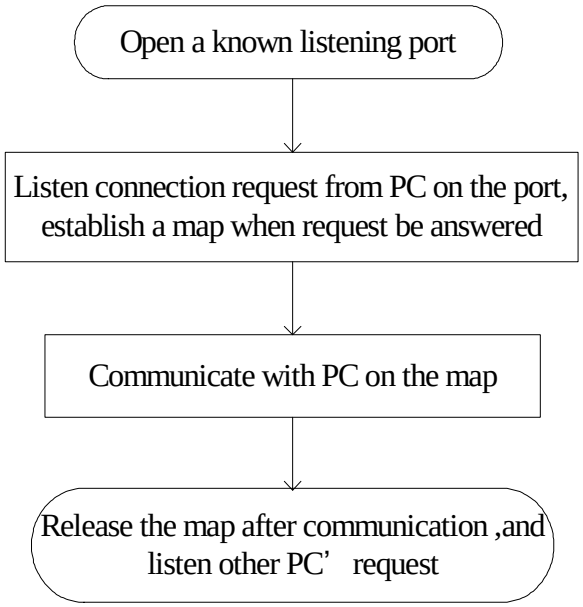

Fig.5 The flow chart of Ethernet on testing box

2.2 Network Communication on Server under LINUX

The network communication in system built on the base of the client-server model, and treats the testing box as a server, PC as a client. Under the mode of communication oriented to connection, the testing box opens a known listening port, and listens the request of connection from PC on network. It will establish a map to PC when answered the request signal, then they communicate with each other[4]. The network communication program runs on the testing box that as a server is shown in Fig.5. The program mainly relate to several functions Under LINUX, such as socket(), bind(), listen(), accept(), recv(), send() and close(). There are some introductions as follows:

(1) socket(): the function will return the Socket descriptor, which relate to a port on server, the function such as bind(), listen() will use it in the program.

(2) bind(),listen() and accept(): They built a connection to client PC, and the second parameter of bind() function includes local IP address and port's number pointer.

(3) recv(),send(): They are receiving and sending data respectively oriented to socket(). The parameters in the recv() include the pointer of receiving data buffer, the data's length, the signs, etc.; and the parameters in the send() include the pointer of sending data buffer, the data's length and the signs.

(4) close(): It will release associated socket so as to stop all operations on the Socket after finishing communication.

3 Conclusion

Due to the resource restriction of industry computer when making multi-channels instrument base on PCI or ISA, and there appears new configuration of multi-channels instrument that constituted by a testing box and a PC in the market. In view of the speed of ARM9 and its resources, we choose ARM9 as the processor in making the testing box. And the testing box exchanges data with PC through Ethernet, thus forms the 4-channels eddy current and 4-channels ultrasonic integrated testing system. The testing system also relies on the PC's powerful data-processing, it also can enlarge more channels through ethernet, it meets the requirement in making trend of NDT integrated instrument.

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