Design of Multi-channel high capacity synchronous digital strong-motion recorder

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Abstract One multi-channel high capacity synchronous digital strong-motion recorder (MCSMR) was designed for the Digital Strong-motion Monitoring Plan of China Earthquake Administration. The multi-channel strong-motion recorder was designed with all essential functions that three-channel strong-motion recorder has. And its' upper limit channel number is sixty-four. Building structural array of strong-motion monitoring with the multi-channel recorder will save a lot of money and can fulfill central monitoring and communication.

Keywords： strong-motion observation, analog-to-digital convert, real-time clock, trigger-mode storing;

1 Introduction

With the economic development in the world, commercial manufacture and living of human go into era of large-scale. There are more and more large-scale infrastructure, super large-scale structural engineering in cities. Such as large-scale chemical plants, nuclear power plants, reservoirs, large bridges, high-rise buildings, et al. But the frequent earthquake can cause serious damage and destroy of these large-scale structures. And the earthquake will cause more and more severe economic loss in today large-scale economic era, especially the strong earthquake. The strong earthquake caused not only large numbers of death but also serious secondary disasters. In recent years, in order to protect the economic development, many countries pay more attention to strong-motion observation of typical structures and earthquake resistant methods for reducing disaster. Now structural strong-motion observation not only belongs to professional seismology research, but also becomes part of disaster mitigation, fast-report of city earthquake intensity, strong-earthquake pre-alarm of city and large-scale engineering, structural health diagnosis of structural engineering. All these research promotes the development of strong-motion observation and its' relative work. Such as the manufacture of strong-motion observation instruments, the construct of strong-motion observation network, the disposal methods of strong-motion observation data.

Before 2001, there are about 488 strong-motion observation apparatuses in China strong-motion observation network. About half of them are analog or magnetic tape strong-motion observation apparatuses. And most of them were distributed in southwest and northwest of China remote area. Small amount of strong-motion observation instruments were installed in economic developed cities of east area in China. The strong-motion recorders which were managed by provincial Earthquake Administration are very old. Some recorders set up by large enterprises are

not effectively used. These data collected from these recorders seldom is used. With the startup of Digital Seismological Observation Network, a large number of digital network recorders will be used. And the recorders should be designed with powerful functions, such as huge capacity memory, automatic earthquake trigger, automatic alarm, local serial port communication, remote modem dialing communication, remote IPv4 or IPv6 network communication. All these designs make data record, data storage, and data transmitting possible.

2 Multi-channel high precision strong-motion recorder

The dynamic range of strong earthquake signal is very wide and its' up limit can achieve to 120dB. So high precision strong-motion measurement apparatus should has large dynamic range to accurately measure the strong earthquake signal. Now most seismic sensors' dynamic range exceeds 120 dB. If we want to get accurate seismic signals, high precision seismic recorders that with over 120dB dynamic range should be used. Many apparatus researchers managed to get improvement in strong-motion recorder design.

In recent years, equipped with 24 bits delt-sigma analog converter, the specifications of strong-motion recorders are greatly improved. So this kind of strong-motion recorder can be used to fulfill measurement of seismic signal which dynamic range larger than 120dB. Because Chinese engineers still use 16 bits analog-to-digital converting technology to design strong-motion recorders, these recorders can not achieve large dynamic range. So now we didn't own wide dynamic range, high performance strong-motion recorders. In order to change the situation, our team spent more than one year on two kinds of strong-motion recorders design, 3-channel portable strong-motion recorder and multi-channel high precision strong-motion recorder. In this paper, we mainly focus on the design of multi-channel high precision strong-motion recorder.

The multi-channel high precision strong-motion recorder (MCSMR) contains many components. The main component parts are analog-to-digital converting board, data sampling mainboard, industrial computer mainboard, keyboard, displayer and other necessary elements. Figure 1 is the principal picture of the multi-channel high precision strong-motion recorder. Among them, two key circuit boards are designed by us. They are analog-to-digital converting board and data sampling mainboard. The analog-to-digital converting board is in charge of analog-to-digital conversion. Through data bus, the digital data were transmitted to the data sampling mainboard. Then these data were transporting to industrial computer mainboard and finally be deposited in storage meory. The following paragraphs will introduce the design and specifications of the MCSMR in detail.

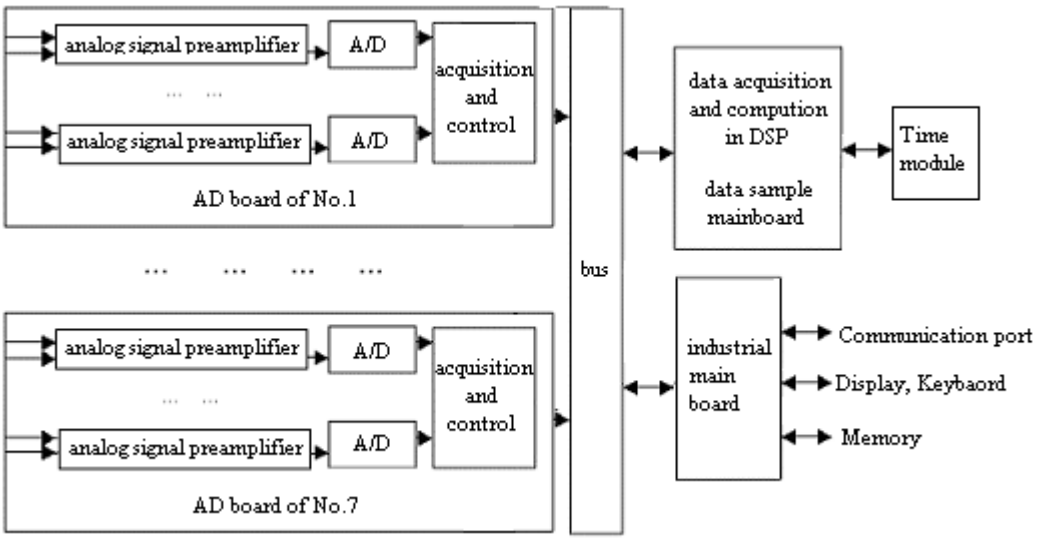

Fig. 1 Schematic diagram of multi-channel strong-motion recorder

2 analog-to-digital converting board

The 24 bits MCSMR has a large measurement range and super sensitive measuring circuit. It's easy to couple interference signal [1]. Some methods must be taken when designed the preamplifier circuit, such as isolation, anti-interference, shield and et al. For example, the preamplifier circuit should be designed with electrostatic shielding case. And the analog power and digital power were completely isolated in preamplifier circuit. One analog-to-digital converting board has 9 analog-to-digital channels. For setup one MCSMR with 64-channel (including one time channel) needs seven piece of analog-to-digital converting boards. Each analog-to-digital converting board includes two parts, preamplifier circuit and analog-to-digital circuit. We will give detailed information of the design and the power supply circuit in next two paragraphs.

2.1 preamplifier circuit

One MCSMR with 64-channel can measure sixty-three analog signals in synchronism. All measurement channels are designed in the same way, but each channel completely isolated from the others [2,3]. Figure 2 is principal diagram of one measurement channel's pre-processing circuit. In figure 2, node 1 is the input signal port and the signal ranges from -5V to 5V. The input signal plusing one 5volt reference voltage forms one positive voltage which effective range is from 0volt to 10volt. First, the output positive voltage was processed by the positive amplifier circuit with one magnification times. Then through a two-order low pass filter, we can get an effective output voltage $+V_{in}$ at node 2. The voltage signal directly output to input pin of analog-to-digital converter. In order to keep the normal working state of the converter, one 2.5Volt reference voltage from node 3 was output to pin $-V_{in}$ and pin V_{REF} of analog-to-digital converter.

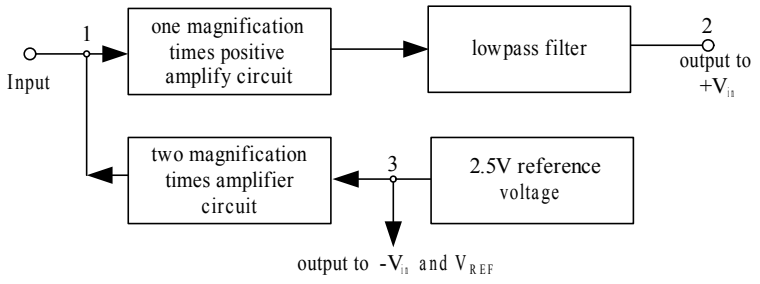

Fig.2 Preamplifier circuit

2.2 AD Conversion circuit

In MCSMR, chip ADS1252 with Δ-Σ structure was used as an analog-to-digital conversion component. ADS1252 is one high precision, wide dynamic range, 24 bits resolution, single +5V power supply analog-to-digital chip. One chip ADS1252 can complete one channel's 24 bits analog conversion and there is no missing code. The relative design circuit about chip ADS1252 is very simple. With two signals, clock signal to pin CLK and serial shift output clock signal to pin SCLK (figure 3), ADS1252 can convert an analog signal into an digital signal of 24 bits. There are 384 clock periods in one data conversion period. Among these periods, 36 periods are for DRDY, 348 periods are for DOUT. Figure 3 is the data conversion sequence picture. You can get further information about conversion from it. During the periods of DOUT, 24 bits binary data were output one by one from pin DOUT of ADS1252. By using three piece of chips 74HC595, these 24bits serial data were transformed into three 8 bits parallel data and output.

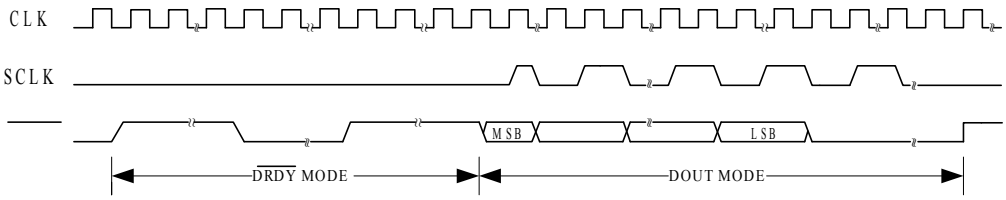

Fig.3 Timing diagram of data conversion

2.3 power processing circuit

In order to get high measuring precision and avoid power supply interference, analog power and digital power were completely isolated in circuit design. And the power supply of the pre-processing circuit and analog-to-digital conversion were separated. Isolated regulated power supplies provide power for all amplifiers in preamplifier circuit. Another isolated +5V regulated power supply provides power for all analog-to-digital converters in the same board. Every power supply must be filtered through necessary filter circuits. Figure 4 is the filter circuit of power supply for analog-to-digital conversion circuit.

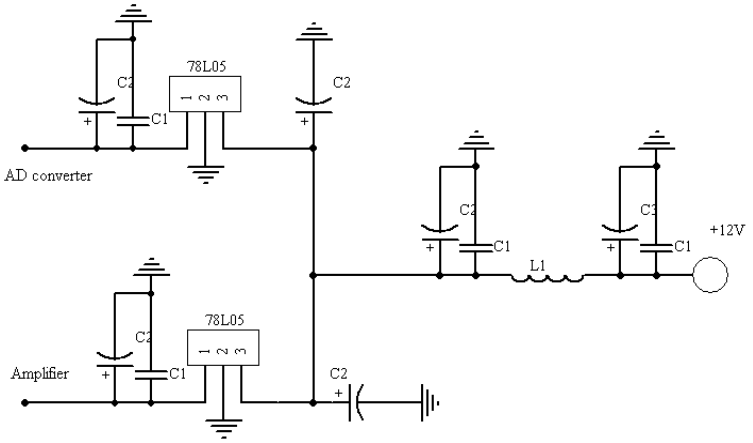

Fig.4 filter circuit of power supply for analog-to-digital conversion

3 sample mainboard

For the MCSMR, sample mainboard is one of key circuit boards that are designed by us. The

sample mainboard takes charge of logic control between different components of the strong-motion recorder. The logic control includes start-up and stop of analog-to-digital conversion, reading and transmitting of all channel's conversion result, data filtering and computing, reading time from two kind of clock modules, revising time of real-time clock, communication between sample mainboard and computer mainboard, data transmitting. The sample mainboard was composed of three parts, CPU control circuit, time service circuit, data saving module and logic control circuit. These three circuits were under the control of microprocessor TMS320VC33 which work as the CPU in the sample mainboard.

3.1 Time service circuit

The time service circuit with high precision real-time clock is the necessary part of the strong-motion recorder. Figure 5 displays block diagram of the time service circuit designed with high precision and high velocity. Microprocessor (CPU chip), real-time clock, GPS module and programmable chips form the time-service circuit. Through two different ports, microprocessor can read two pieces of time information from two different chips. Through serial port, we can get the GPS time data. While through parallel port, we can get the real-time time data from the real-time clock chip. All the time data were wrote into the FIFO chip.

After startup of the MCSMR and the successful location of the GPS module, the strong-motion recorder will automatically get time information from GPS module, load it into the memory of DS12887 and complete time calibration. The most important character of the strong-motion recorder is that the time calibration can not be done during the data acquisition. For the time delay caused by time operation will make the data processing collapse.

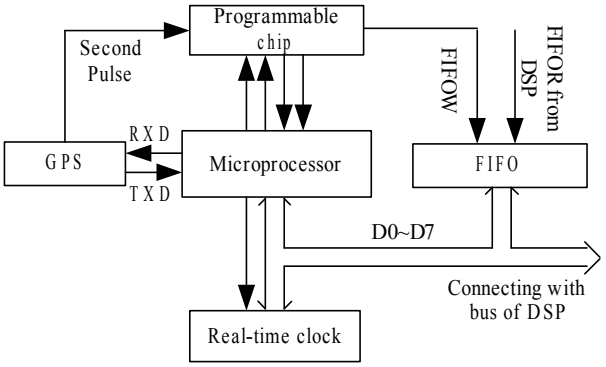

Fig.5 Block diagram of time service circuit

3.2 CPU control circuit

In order to increase the data sample rate and running rate, decrease the power consumption, one 32-bit floating-point DSP processor TMS320VC33 was used as a CPU of the data sample mainboard. It has 13ns instruction cycle time, 150 millions floating-point operation per second. It supports 32-bit instruction words, 24-bit addresses, two 32-bit clocks, four external interrupts and one serial port. TMS320VC33 also supports two kinds of low-power running mode. In circuits, DSP processor control the start and stop of the analog-to-digital convert, serially read the sampling data from every channel and write them into FIFO, read data from FIFO, transmit command data and sampling data through the BAB bus between data sample mainboard and industrial mainboard.

3.3 Data saving circuit and logic control circuit

In MCSMR, vibration data and time information were deposited in the same memory, chip FIFO. The data saving sequence is, first time data, next the first channel data, second channel data,

and the last one is the last channel data. Data write and read operations of FIFO are both controlled by logic control circuit. Real-time clock circuit of the DSP data sample mainboard, CPU control and data transmitting are all controlled by the logic control circuit and interrupt system. The general logic scheme is displayed in figure 6.

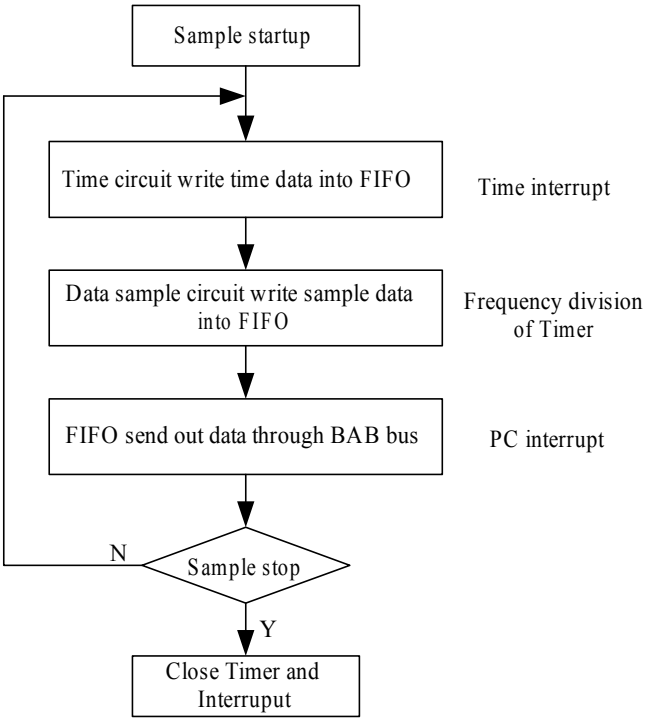

Fig.6 Logic control chart of data sample mainboard

4 Specifications of MCSMR

There are some main specifications of the strong-motion recorder.

1) Sixty-three sampling channels, one time channel, all channel data are synchronously sampled.

2) Analog-to-digital converter has 24-bits resolution.

3) Measurement range is -5V~+5V.

4) Four sample frequencies, 100 Hz, 200 Hz, 500 Hz and 1000Hz. Program control.

5) Multiple data saving methods, including continuous saving, manual saving, trigger saving. Trigger saving includes threshold trigger, time trigger, short-window and long-window difference, short-window and long-window ratio. The upper limit of trigger sensitivity is 0.0001g.

6) Saving memory is hard disk with IDE interface. Its' volume ranges from 1G to 80G.

7) Two isolated clock modules are embedded. One is real-time clock, the other is GPS module.

8) With two RS232 serial ports, one standard Modem interface, one network interface.

9) Includes one liquid displayer, one keyboard and one mouse. It is an independent instrument.

5 Conclusions

This paper introduced one high precision wide dynamic range multi-channel strong-motion recorder. The recorder is designed with high precision Δ-Σ analog-to-digital converter. So it can achieve 18.5 effective resolutions. All channel data were converted synchronously. The sample channel numbers in one recorder can reach 64.

Fig.7 Picture of Multi-channel strong-motion recorder

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