Design of wireless monitoring system for health diagnosis of structural engineering

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ABSTRACT: With the health diagnosis requirement increase of large-scale structural engineering, the author designed one wireless monitoring system which can be applied to different kinds of structure for health monitoring. The wireless monitoring system is a typical asteroid network, that is to say one receiver could control and receive many transmitters' action and data. One transmitter administrated one sensor. Through scan method, the receiver received signals from many sensors at the same time. Communication modules of transmitter and receiver were type of optional serial port communication module which is standard transparent serial port and supports standard intercommunication. For indoor shaking table experiments, communication module of type nRF401 can be used. The communication distance could achieve 25m and expanse of communication was very cheap. For large-scale outdoor structural engineering testing, GPRS module based on common GSM communication network can be used. This kind of module has a very good communication quality and supports long distance communication. The CPU chip was AT89C55 which is the core of the data acquisition hardware of transmitter. And AT89C55 administrated and controlled all other peripheral chips. Such as starting AD converting of chip LTC1410 which is 12bits Analogue to digital converter, saving data of one sample period in memory chip CY62256, transmitting data with the AD converting et al. Receiver was connected to computer of monitoring center through serial port. Then all the receiving data were processed at the same time by the computer. And the program has a view interface which could demonstrate all results and messages.

1 GENERAL INSTRUCTIONS

From 50's years many large-scale civil engineering were built in China. But earthquake, flood, hurricane, geological disaster destroy some of them and menace the buildings' safety. So there are so many civil engineering accidents recent years. Such as bridges broken, housing collapsed. The happen of these accidents menace the safety of people and caused economic loss. So people have to pay great attention on safe station of large-scale civil engineering. Then we must build structure health diagnosis system for large-scale civil engineering. With the help of structure health monitoring system, we can do structural performance and safety analysis. And in high intensity area, the earthquake data recorded by the monitoring system can help to adjust structural design. So data monitoring system is the base core of structural health diagnosis system. The construction and maintenance cost of the monitoring system and the running efficiency decides the performance of the health diagnosis system. Traditional health diagnosis system use cables to collect sensor's signal to data acquisition. So engineering construction complex, work quantity large, investment heavy and system maintenance expansive for the traditional monitoring system. At the same time, the traditional system is apt to fail and then can not recording data. In order to resolve these problems, research tends to wireless monitoring system for health diagnosis of structural engineering.

Four parts make up of the wireless monitoring system. There are sensors, data acquisition instrument and wireless transmit, wireless receiver, computer and central monitoring software. Although in this paper we define the communication module as wireless transmit and wireless receiver, but in fact these two modules have the function of receiving and transmitting data. First analogue data measured by sensors are converted to digital signals by digital acquisition instrument. Second the digital signals are transmitted to the computer of monitoring center after the corresponding command messages. Then monitoring software process the data and the health diagnose software analyze the data and evaluate the structural station.

2 STRUCTURAL OF WIRELESS MONITORING SYSTEM

Structural health diagnosis system can be divided into two parts, hardware monitoring devices and diagnosis software. This paper focuses on introducing hardware monitoring devices. And from the function, there are three modules, sensors, data acquisition instrument and wireless transmit, wireless receiver and centering computer, see the structural figure in figure 1. The sensors include force balance accelerometer which can measure low frequency vibration, piezoelectric accelerometer which can measure high frequency vibration, and strain sensors which can measure deformation. We can choose other type of sensors according requirement. Data acquisition instrument and wireless transmit convert the analogue data detected by sensors into digital data, and then save the data or transmit to receiver. Wireless receiver and centering computer send all kinds of control command to all data acquisition and wireless transmit. And vibration data received from each wireless transmit were input the computer through RS232 serial port. Then the computer displays monitoring data and analysis result by view picture.

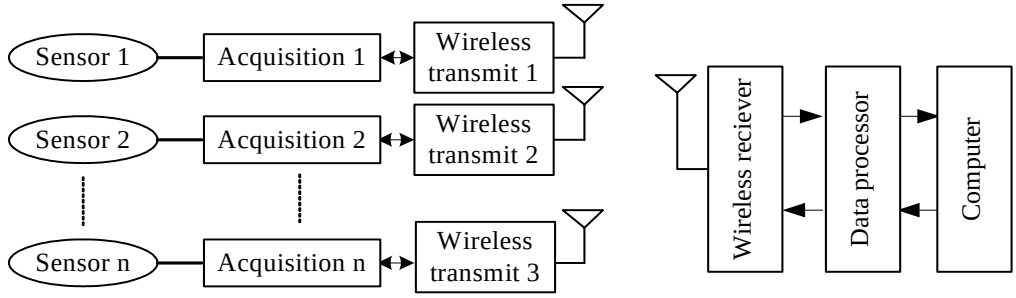

Fig.1 Block diagram of wireless monitor system

3 DATA ACQUISITION AND WIRELESS TRANSMITTING SYSTEM

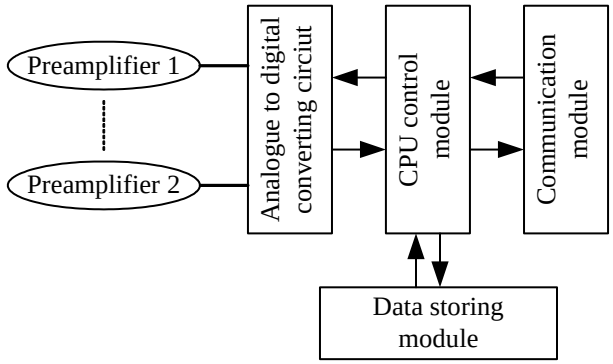

Fig.2 Wirless transmiting module

The core of wireless data acquisition module is data acquisition and wireless transmitter. And data acquisition were compose of preamplifier, analogue to digital converting circuit, data storing module, CPU control module, wireless communication module and power module, see schematic figure in figure 2. Every wireless acquisition module can measure three sensors' signal at the same time.

3.1 *Preamplifier and analogue to digital converting circuit*

Signal detected by sensor was filtered and amplitude tuned by lowpass filter and tuned circuit in Preamplifier. Then the processed signal was digitalized by AD converter. The amplifier in the prepositive circuit is high precision amplifier LF356. It has two optimal measurement scales, ±5V and ±100V. The amplifying coefficient is 0.5 and 40 for each scale. We can switch to every scale by sending scale switching command.

The analogue to digital convert chip is LTC1410 produced by Linear company. LTC1410 is a 0.65μs, 1.25Msps, 12-bit AD converter that draws only 160mW from ±5V power supply. This easy-to-use chip includes large dynamic scale, automatic sample-and-hold circuit, one precision reference and requires no external components. Two digitally selectable power shutdown modes provide flexibility for low power system. If the system in idle mode, microchip AT89C55 can give corresponding control signal and make LTC1410 go into low-power idle mode. The LTC1410 full-scale input range is ±2.5V. So the basic amplifying coefficient of prepositive circuit is 0.5.

Prepositive circuit modulates the analogue signal and output it to LTC1410. Then LTC1410 converted the signal into 12 bits parallel digital volt signal and orderly saved in 62256.

3.2 *CPU control circuit*

The AT89C55 is a low-power, high-performance CMOS 8 bit microcomputer with 20K Flash programmable and erasable read only memory. It provides following standard features: 20K bytes of Flash, 256K bytes of RAM, 32 I/O lines, three 16 bits timer/counter, on-chip oscillator and clock circuit. The AT89C55 is designed with static logic for

operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counter, serial port and interrupt system to continue function. The program language of AT89C55 is Language C. So the run speed is very fast.

The AT89C55 is a powerful microprocessor which provides highly flexible and cost effective solution to this embedded control application. As a microprocessor in this system, AT89C55 manages other kinds of components and makes all control logic signals in the system. Then the system can control analogue-to-digital converting, data storing and wireless data transmitting. The centering software sends out command words and pre-setting words by wireless receiver. When the wireless transmitter receives the message the AT89C55 automaticly sets corresponding components.

wireless transmitter which can support about 20 meters distance. But for large-scale civil engineering, the communication distance can reach several kilometers or ten kilometers, we uses GPRS module as the communication module which based on GSM communication network. These two kinds of communication module can be connected with microprocessor serial port or computer serial port. In figure 3, nRF401 module should be connected with COM1. GPRS module should be connected with COM2. The difference is shown in figure 3.

The nRF401 is designed with stable working frequency of 433MHz, and doesn't need application license. The emission power can reach +10dBm. And it supports 1000 meters distance communication in open space. The nRF401 is an easy-to-use, cheap module.

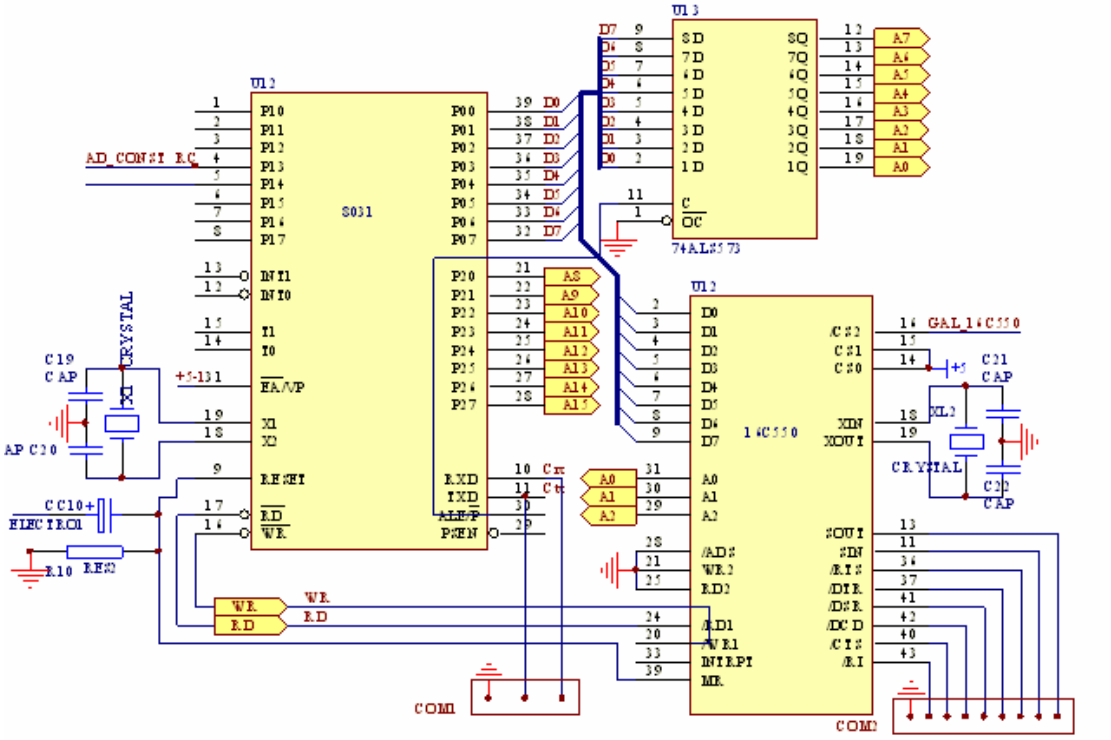

Fig.3 Schematic of CPU control electric circuit

3.3 *Data storing electric circuit*

The RAM62256 is a static RAM organized as 32,768 words by 8 bits. This device has an automatic power down feature which can reduce the power consumption by 99.9% when deselected. So it is used as data memory chip in this design.

3.4 *Communication module*

According to different kinds of tests, we provide two different kinds of communication modules according the transmitting distance. For indoor structural experiment or small engineering experiment, nRF401 is the core module of wireless receiver and

GPRS wireless module is data transmitting device and remote monitoring terminal device which based
on GSM/GPRS communication network. And it has many merits, such as supporting long distance communication, reliable stability and seamless communication overlay. GPRS wireless module is designed with standard RS232 interface, true transparent operation, stable 20~40Kbps data transportation. Compared with nRF401 wireless module, the merit of GPRS wireless module is long communication distance, the demerit of this module is need considerable run expense.

In working state, first analogue signal detected by sensors were converted into digital signal. Second

the digital signal was saved in RAM62256. When the microprocessor of the wireless transmit received the command message, through chip 16C550 data stored in RAM62256 were transmitted bit by bit serially. The transmitting stop until the microprocessor received stopping transmitting command. The wireless receiver receives the data and disposes them.

4 WIRELESS RECEIVING SYSTEM

The principle and designed method of wireless receiver is same with wireless transmit. But the wireless receiver doesn't need AD converter. It works as a digital data collector and transmission instruments. So it is relatively simple device, see figure 4. Wireless receiving system is designed with microprocessor AT89C55, serial communication chip 16C550 and wireless receiving module. For the wireless receiving module is a separate module, we does not draw it in figure 4. For a normal size structural monitoring system, its' normal nodes can achieve more then ten. We can plug one multi-serial ports card in computer and use the card to read multi-channels signals at the same time.

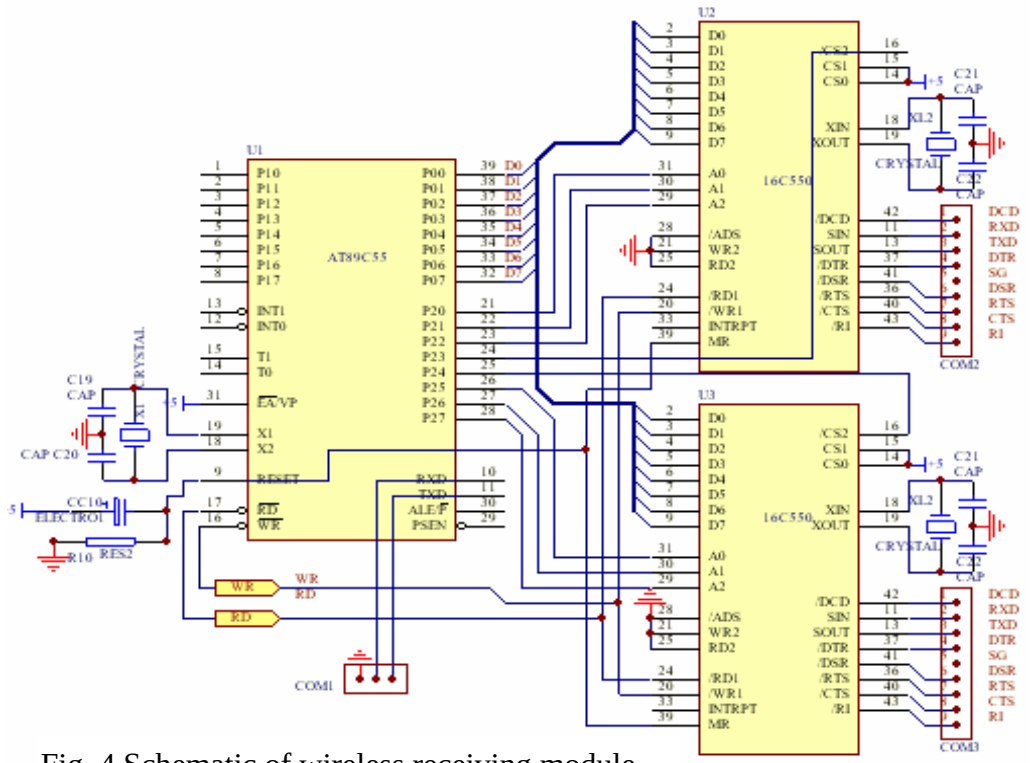

Fig. 4 Schematic of wireless receiving module

5 DESIGN OF VIBRATION MONITORING AND ANALYSIS SOFTWARE

Vibration monitoring and analysis software that base on Visual C++ was designed for the healthy monitoring system. Every suit of devices stands for one measurement points and all of them were included one big networks in the software. The software can manage many devices at the same time, or control devices one by one. It reads multi-channels vibration data through scanning every serial port.

There are interfaces for user to sends all kinds of commands to wireless data acquisition, such us start real time acquisition and transmission, data storage, power down acquisition, acquisition parameter setting, trigger mode setting, trigger parameters setting, et al. When wireless acquisition working in trigger mode, it first use low frequency filter to filter the data, then it start the trigger computation program. The vibration data which achieve trigger condition come into being trigger records and saved. At the same time the wireless acquisition sends trigger alarming message to wireless receiver. When working in real time acquisition mode, vibration data collected by each device were transmitted to wireless receivers synchronization. The computer in monitoring center displays the vibration data with view picture. And through the software analysis module, user can do many kinds of filtering dispose with the data, such as low frequency filter, high frequency filter, FFT et al.

6 DESIGN OF VIBRATION MONITORING AND ANALYSIS SOFTWARE

We have made some experiments on a simple steel truss model with the wireless monitoring system. The sensor includes strain gauge, PVDF sensors and force balance accelerometers. In figure 5 and figure 6, there are waveforms of some sensors.

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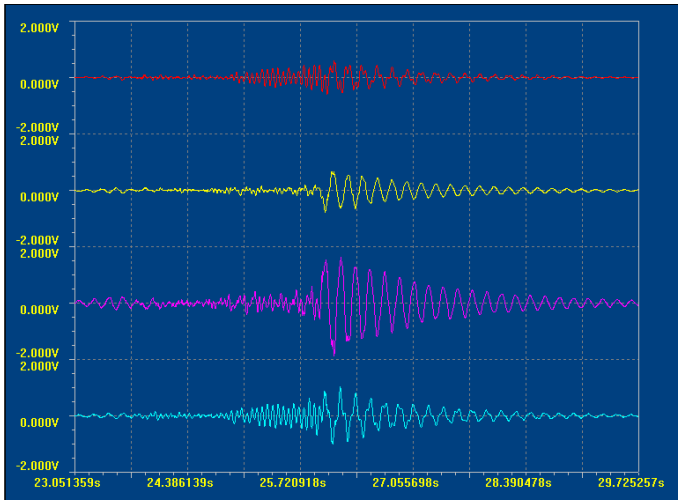

Fig. 5 Output of force balance accelerometers

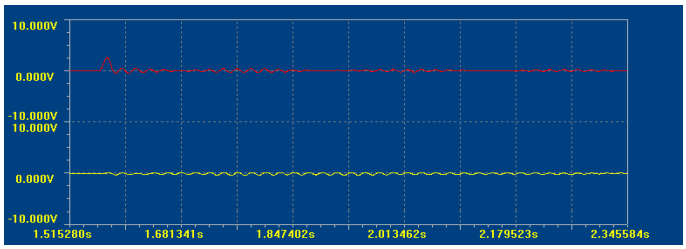

Fig. 6 Output of two strain gauges

7 CONCLUSION

Structural health diagnosis is a hard job. The setup of structural health monitoring system is only the basis of the system. As time go on, we will accumulate much more data which contains the structural information. We should make use of these data and data mining methods, build a effective fault recognize methods, that is the core of structural health diagnosis.

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