Design of Low-frequency Vibration Detection System

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Abstract: In order to improve the accuracy, feasibility and convenience of the vibration detection system, design a simple and practical low-frequency vibration detection system. This system is designed based on STM32 platform, composed of shaping circuit, the measurement of vibration signal, wireless transmission and TFT touch screen display module, μC/OS-II embedded system transplantation, miniGUI interface design, and finally realize the display of waveform and frequency of vibration signal. By testing this system, find that it is stable, reliable and real-time, basically reached the expected requirements and can be very good to meet the actual demand, which has a widespread application prospect.

Keywords: Low-frequency, STM32, Vibration detection, Vibration signal.

1. INTRODUCTION

In the rapid development of modern industry, modern detection technology has become an inevitable trend towards digital and information-oriented, and the most significant end of detection system is a sensor, which is the core of the whole detection system, is listed as sophisticated technology in the world, especially in recent years, the rapid development of integrated circuit technology and computer technology provides a good and reliable scientific technical foundation for the development of vibration sensors [1]. The development of vibration sensors change rapidly, and digital, multifunctional and intelligent is an important feature of modern sensor development [2].

Vibration detection is a key and indispensable part in industrial production line, so many foreign research institute and enterprises are vigorously study and develop the vibration detection system [3]. In China, vibration detection is also a very important research field, a lot of manpower and material resources are invested in this field, and in each Institute of Mechanics has the research team in this field. At present there have been many vibration detection systems at home and abroad, however, due to the different needs and different applications of various fields, there are still many gaps in certain specific areas [4]. The system is based on the stiffness of crane, the stiffness testing field of crane at home is still in the blank, the system is designed for the particular device, and its vibration frequency, parameter design are obtained not only through software simulation but also through repeated tests. Therefore, the development of this system has a very important significance.

2. PRINCIPLE OF VIBRATION SENSOR

The vibration sensor adopted in this research is the more common acceleration sensor of AD series piezoelectric type [5], piezoelectric type sensor, which output is related to acceleration, is widely used in all walks of life [6].

In the voltage conversion device of piezoelectric signal, a mass block is installed in the appropriate size of the force. There on the mass of a fixed nut (or spring), so that a simple model of a piezoelectric transducer can be formed. Fig. (**1**) is the mechanics model of this sensor, which is a typical piezoelectric sensor, and usually it can be simplified to a simple two order dynamics system model [7]. Mechanical model of piezoelectric type acceleration sensor is shown in Fig. (**1**).

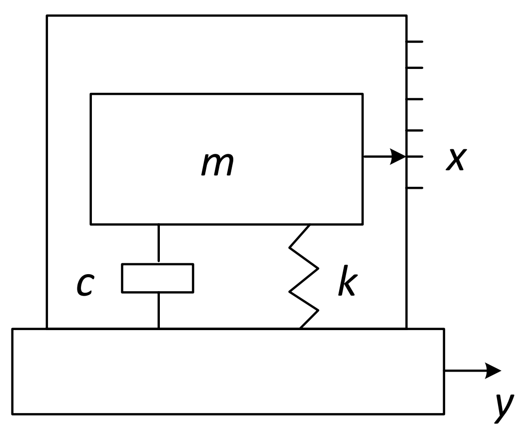

Fig. (1). Mechanical model of piezoelectric type acceleration sensor.

The work rules of install mass of piezoelectric sensor is shown in mathematical expressions:

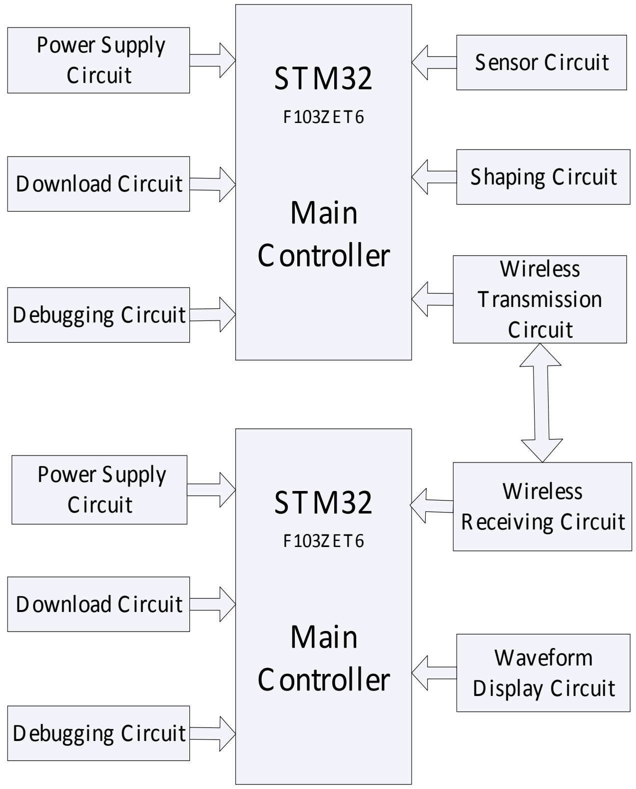

Fig. (2). Hardware design block diagram of the system.

$$m(x+y)+cx+kx=0 \tag{1}$$

Among it, m-inertial mass; c-damping coefficient; k-elastic coefficient; x-relative displacement of install mass; y-vibration acceleration, that is the bottom acceleration of sensor.

Set up the absolute displacement of sensor $y = y_0 \sin \omega t$,

Then equation (1) can be rewritten as

$$mx + cx + kx = y_0 \omega^2 \sin \omega t \tag{2}$$

Set

$$\xi = \frac{c}{2\sqrt{km}}, \ \omega_n^2 = \frac{k}{m}$$

Where ξ-dimension damping coefficient; ω_n-the resonant frequency of no damping; ω-the vibration frequency of the object.

The damping ratio ξ of piezoelectric sensor is usually very small, normally not more than 0.04, basic can be neglected. Acceleration sensor should try to improve the undammed frequency, in the $\omega_n >> \omega$, type (3) was established, that is

$$x = \frac{y}{\omega_n^2} \tag{3}$$

Which shows that the acceleration when the object vibrating is proportional to the relative displacement of the mass.

Piezoelectric sensors, under the action of inertial force on the mass block m, the charge generated by voltage conversion component on the sensor is

$$Q = d_{ij} m \ddot{y} \tag{4}$$

For each type of this sensor, d_{ij} and m are constants, type (2)-(4) shows that the output charge of acceleration sensor of piezoelectric type is proportional to the vibration acceleration. Measuring the quantity of electric charge Q with charge tester, thus realize the measurement of acceleration sensor [8].

3. THE DESIGN SCHEME FOR LOW FREQUENCY VIBRATION DETECTION SYSTEM

The design combines sensor technology, using STM32F103ZE as the main controller, mainly composed by the STM32 control circuit, sensor conditioning circuit, shaping circuit, wireless transmission circuit, wireless receiving circuit, TFT touch screen display circuit, power circuit, download and debug circuit. The system hardware design block diagram is shown in Fig. (**2**). The core of the system is the vibration sensor conditioning circuit and STM32 control circuit. Each part of the circuit is working coordinately under the control of STM32, STM32 complete the function of the central controller.

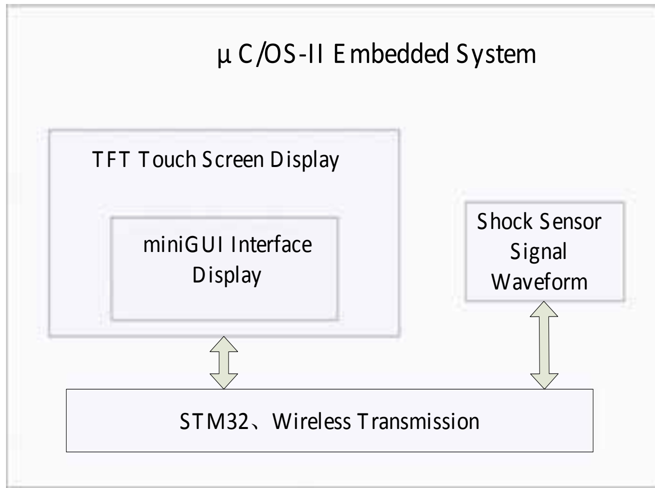

Fig. (3). Diagram of software structure.

Functional of each module of the hardware circuit are as follows:

●Entire detection system is controlled by STM32F103ZET6, the main controller take the signals collected from vibration sensor for AD conversion, and measure the waveform frequency, then the processed data is transmitted over the wireless receiving circuit to each other.

●We use the AD100T vibration sensor, which is an acceleration sensor to obtain a signal by measuring the vibration acceleration. The conditioning circuit of this part is to amplifier the collected vibration signals through appropriate operational to get the signal waveform.

●Shaping circuit is put the original waveform magnified four times, and then set a threshold, reshape the amplified wave into a square wave, which is convenient for us to measure the frequency. Here we set the threshold for 1.6V, which is the result of many experiments and calculated.

●The wireless transmission module mainly completes the data transmission, which data is handled data, namely amplified data after reshaping.

●The wireless receiving module mainly completes the data receiving, transmitted to the main controller.

●Display module, we use TFT touch screen in 7 inches. This screen is a capacitive screen, its touch sensitivity is very high and its display is also very clear. We will process the data which received from the wireless module such as calculation, anchor point and drawing line, and display the data in the TFT screen.

●Power supply circuit supplied normal power for STM32, and its power supply voltage is 5V, while the voltage of the vibration sensor is 24V, constant current 2 mA.

●Download and debug circuit is shared JTAG, in order to perform online simulation the JTAG port is added so that it is convenient for online debugging and simulation on the test.

4. THE SOFTWARE DESIGN OF THE SYSTEM

The design of the system software is completed in the real-time multi task operating system μC/OS-II. The first step of software design to be achieved is how to put the μC/OS-II transplanted to STM32, this is a problem for most of us. However, in the study we found that, we don't require a lot of changes for some of the underlying code, as long as to modify some files associated with the processor such as the header files, the C file and assemble language file. Transplantation is the basis of other software design, then design the miniGUI after finished. MiniGUI is also the important part of software, and the display effect can be achieved good results by miniGUI design.

4.1. The Transplantation of μC/OS-II Embedded Systems

What the Fig. (**3**) shows is μC/OS-II system structure. It's known from file of μC/OS-II system that, we only need to modify the code associated with micro in transplantation. That including a header file OS_CPU.H, a compilation file OS_CPU_A.ASM and a C file OS_CPU_C.C. Next, we modify each file.

4.2. The System Main Program

This system uses STM32 as the core, completed the acquisition, transmission and display of the vibration signal through wireless transmission on the C/OS-II real-time system platform. After wireless data acquisition terminal powered on, control the AD converter to vibration signal digital conversion, implement equal time interval sampling. After each successful acquisition, start the wireless protocol process, transfer data, while recording data and operation data. At the Interactive terminal, the C/OS-II real-time system will start automatically, and call the window display and other tasks after powered on. Each task is dispatched and executed by the system uniformly. When the wireless device receives the data, breaks bale and stores data including vibration signal data and vibration frequency

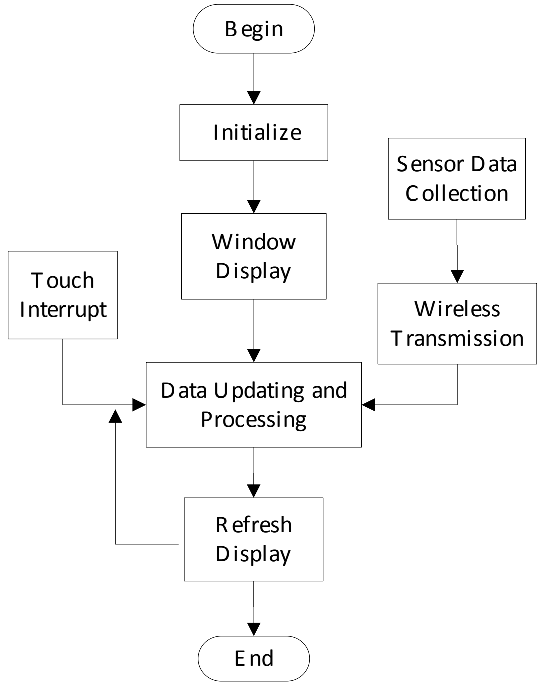

Fig. (4). Flow diagram of the main program.

Table 1. Experimental data table.

No.	Vibration Source (Hz)	Measured Value (Hz)	Error (Hz)
1.	1.0	1.05	0.05
2.	1.3	1.32	0.02
3.	2.5	2.53	0.03
4.	3.4	3.42	0.02
5.	4.8	4.86	0.06
6.	5.2	5.17	-0.03
7.	6.6	6.59	-0.01
8.	7.9	7.94	0.04
9.	8.0	7.99	0.01
10.	9.5	9.53	0.03

into memory. The amount of vibration data meets the requirements which usually be a screen of points, start GUI drawing program, draws a screen of waveforms and updates the vibration data at the same time. All the human-computer interaction functions can be completed in touch control. The flow-process diagram of main program is shown in Fig. (**4**).

5. EXPERIMENTAL RESULTS AND ANALYSIS

We test the frequency on a standard vibration source by using the system (low frequency within 20Hz), experimental data as shown in Table **1**:

Experiments show that the maximum value of data error is 0.06 Hz, the average error is 0.03 Hz. It can be seen that the measuring accuracy of the system is higher from the experimental results.

The running result of the system is shown in Fig. (**5**). The system can display the vibration waveform and frequency value, the system runs well, and its performance is stable.

CONCLUSION

This system uses the wireless radio frequency communication technology, combined with the advanced embedded

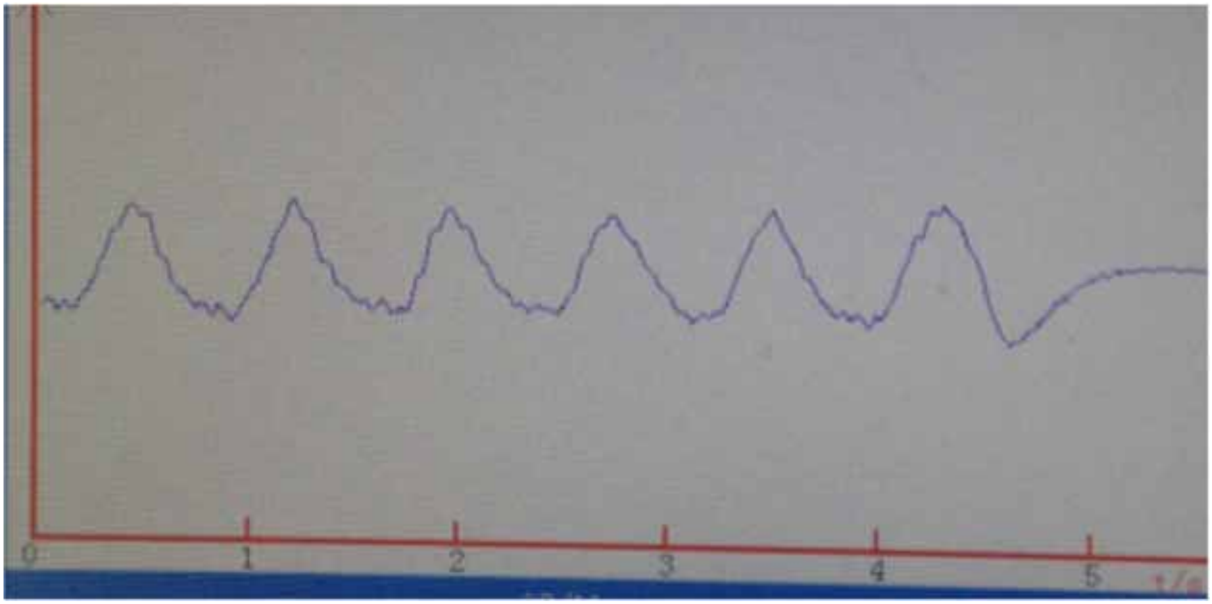

Fig. (5). System debugging results (f=1.32Hz).

solution, realizes the collection, transmission, processing and display of vibration signal. The system uses a small piezoelectric acceleration sensor, combined with the constant current driving and amplifying and conditioning circuit, realizes the acquisition of vibration signal, transfer data through the wireless radio frequency module to overcome the difficulties in the space layout. Then schedule multi task on μ C/OS-II real-time system platform, and operate procedure. Experimental and operational results show that, this system has high measuring accuracy, the stable system performance, able to solve a class of measuring problems on engineering vibration, and has good application value and market prospect.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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