Sensors & Transducers

Design of PZT Micro-displacement Acquisition System

[1] Qiulin Sheng, [2] Guang Yu Xu, [3] Guangya Liu
College of Electrical and Electronic Engineering, Hubei University of Technology,
Wuhan, 430068, Hubei Province, China
E-mail: sql103@qq.com, shaoyu817@163.com, whltxz@aliyun.com

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Abstract: The performance of micro-displacement acquisition device directly affects the performance of micro-positioning system and its high cost. So this paper designed a micro-displacement acquisition system consisting of detection bridge, amplifier circuit, filter circuit and SMT32F103 controller. The micro-displacement signal acquisition is achieved by using the SMT32F103 controller to complete transfer of the displacement signal and PC with LabVIEW program called dynamic link library way to complete the communication controller. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Micro-displacement acquisition system, LabVIEW, Filtering, SMT32F103.

1. Introduction

With the continuous development of science and technology, man's understanding of the nature develops from the macroscopic domains into the microscopic domains. Because the scale of the micro-nano level is extremely small, general conventional measurement techniques are no longer applicable. Therefore, many countries focused their attention on the study of nanotechnology, especially nano-operation and measurement techniques. Due to the excellent performance, Piezoelectric ceramic (PZT) driver is widely used in micro control fields and micro-positioning fields of micro-nano level. Micro-displacement acquisition system is an important part of the micro-positioning platform and its cost is high. On the condition of its own hysteresis, creep and nonlinear shortcomings the accuracy and cost of the drive will be seriously affected, nano-scale positioning. So this paper designed micro-displacement data acquisition system with high cost performance.

2. Overall Program of Acquisition System

PZT micro-displacement acquisition system consists of hard wares and software, using STM32F103 chip as a controller. The original displacement signal of piezoelectric ceramic (PZT) is detected by bridge circuit and the conditioning circuit is used to amplify weak differential signal as well as effectively reduce the interference of common mode noise. The processed signal goes through the filter circuit to filter out unwanted interference noise, and is processed into useful displacement signal by the microprocessor ARM after the digital-analog conversion, which is sent to the host computer LabVIEW program via the USB interface. The overall program of acquisition system design is shown in Fig. 1.

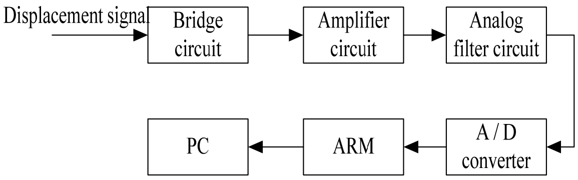

Fig. 1. Overall program of acquisition system.

3. Design of Acquisition System Hardware

3.1. Bridge Circuit

In general the measuring circuit of resistance strain sensor used the bridge circuit (Wheatstone bridge) to convert the resistance change caused by the strain to the change in voltage or current. Based on the different source of excitation, measuring bridge can be divided into two kinds: DC and AC bridge. The characteristics of DC bridge is caused by the strain of the output signal is very weak, but the output is not affected by the external electrical components and the environment, it has a strong anti-interference capability, so it needs to use a stable and high magnification amplifier to linear amplification; The AC bridge not only able to measure the change in resistance but also measure other technical indicators of circuits (Such as capacitors, conductor, etc). In principle the AC bridge circuit structure simpler than DC bridge. Thus this paper used to DC bridge to detect the resistance of the strain gauge, the structure shown in Fig. 2.

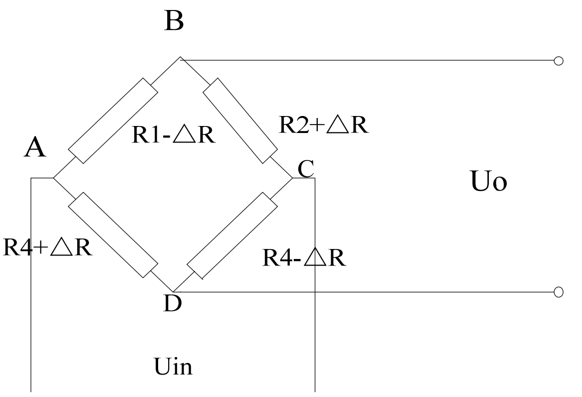

Fig. 2. The structure of DC bridge.

Typically, there are three strain measuring bridge connection method, single bridge, half-bridge and full-bridge. Single bridge circuit will bring a lot of non-linear error, the full-bridge by the differential method can be better improvement to detect circuit performance, eliminate this effect. To improve the sensitivity of the sensor, eliminate all errors and to compensate circuit. So this paper uses a full-bridge circuit configuration.

3.2. Amplifier Circuit

Because the displacement signal transmitted by the resistance strain sensor is very weak and it has high resistance, but often accompanied by a high common-mode voltage, hard to be directly used for recording or the A/D conversion, it is necessary to design special signal amplification circuit to filter, amplify, linearize the original displacement signal so as to meet the input conditions of A/D converter and process the signal. In addition to amplification of the original signal can be greatly improved the noise of before A/D conversion. Typically conditioning circuit consists of an integrated measuring amplifier and external to complete this part.

In this paper use to INA333 produced by TI as the preamplifier circuit of measuring bridge, this is because it is very small noise, high linearity, lower input bias current, small offset current error and Its gain-bandwidth product, adjustable gain are very high, it can satisfy the requirements of the design. The structure is shown in Fig. 3.

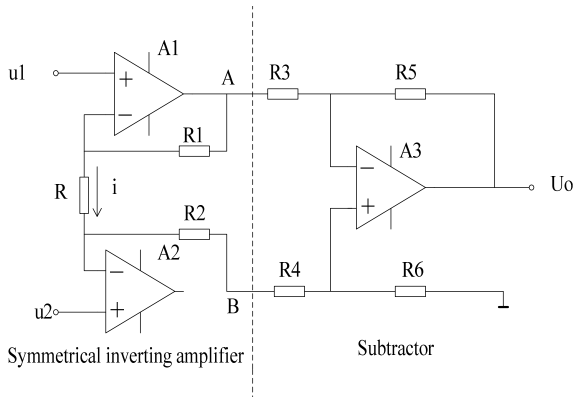

Fig. 3. INA333 Schematics.

It consists of three operational amplifiers, each op amp is characterized by low drift and low offset, etc. The input stage consists of two symmetrical non-inverting amplifiers and the output stage consists of a differential amplifier, forming a vertically symmetrical structure.

When R3 = R4 = R5 = R6, the output voltage Uo is: $U_o = U_B - U_A = -U_{AB}$.

In order to increase the input impedance of the amplifier. In the two inputs of the differential amplifier A, B, respectively accessed two voltage followers, that left part of the figure. In the case of R infinity, at this point the operational amplifier A1, A2 were composed of the two voltage follower, theoretical input resistance of the amplifier is infinite.

The following issues need to be considered is how to set and adjust the magnification of measuring amplifier. Let R3 = R4 = Ra, R5=R6=Rb, in this case by adjusting the ratio of Ra and Rb can adjust the magnification Av ,that $A_v = \frac{U_o}{U_A - U_B} = -\frac{R_b}{R_a}$.

But use of this method to adjusting the magnification, need to adjust the two resistors. For example, adjusting Rb, you need to adjust R5, R6, will inevitably result in errors. R5, R6 asymmetric error will not only affect the amplifier gain but also affect the amplifier's common-mode rejection ratio. Therefore, the practical application of this method is not used to adjust the measured gain of the amplifier, in the inverting input of operational amplifier A1, A2 inserted inverting input gain adjustment resistor R to achieve magnification adjustment.

A1, A2 in the negative feedback state, two input terminals of voltage is equal, the current through R is $i=\frac{U_1-U_2}{R}$, let R1=R2=R0, then $U_{AB}=(R_1+R_2+R)\bullet i=(1+\frac{2R_0}{R})\bullet(U_1-U_2)$, so the amplifier gain is $A_v=\frac{U_O}{U_1-U_2}=-(1+\frac{2R_0}{R})$, where R0 is constant, R is the external resistor, the magnification can be arbitrarily changed by changing R. Since the circuit is symmetrical, when adjusting the magnification, will not affect the common-mode rejection ratio.

3.3. Filter Circuit

Because it is difficult for the digital filter to filter high frequency noise of the analog signal, before performing A/D conversion, it is required to filter the input analog signal in order to filter out the high-frequency signals causing A/D converter aliasing to improve the resolution of the system.

In this paper used MAX7410 filters, it is a fifth-order Butter-worth switched capacitor filter, the pass-band of filter is very smooth and the transition time is shorter than Bibeisaier and Chebyshev. The filter pass band must be very smooth is the most important thing in this design, only in this way the magnification of system will be stable under normal operating conditions.

There are two methods to set the corner frequency of filter. First, through the external clock frequency to set the corner frequency of the filter. The formula is: $f_c=f_{CLK}/100$. f_c is the frequency of the inflection point, f_{CLK} is clock frequency.

Another way is though add a capacitor between CLK and GND, achieve internal crystal to shock. The oscillation frequency is $f_{OSC}=30\times10^3/C_{OSC}$.

When using the first method is required to design an external clock circuit of chip, such a high frequency clock will cause interference to analog signal, so this paper uses the second method show in Fig. 4.

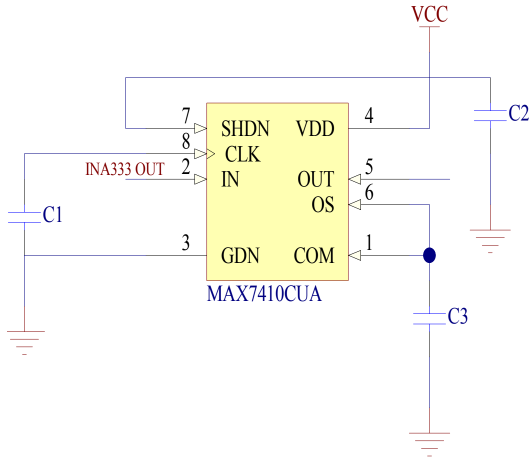

Fig. 4. Low-pass filter circuit.

3.4. Control Circuit of ARM

ARM controller uses the ST Micro-electronics (ST) produced STM32F103 chip, its function is to micro-displacement signal is processed through an integrated A/D converted into digital signals and transmitted to the PC via USB. The structure shown in Fig. 5.

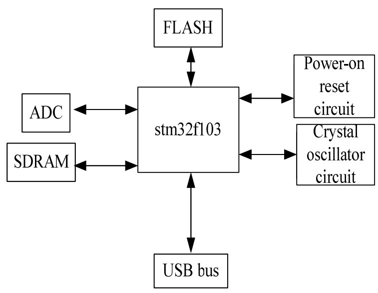

Fig. 5. Control block of ARM.

4. The Software of Acquisition System Design

4.1. The Firmware of Controller

Firmware controller design is mainly set it's A/D module and USB module. It is consist of initialization, acceptance and recognition instruction and instruction execution. The flow chart shown in Fig. 6.

The purpose of initialized to the controller is setting the relevant register, ensure that the controller is working properly. First, the controller receives control instructions from PC and store it in the SRAM, finally judgment and execution it.

To communicate with the host computer, according to the STM32 firmware library for setting the USB function module package, this is greatly save the time of writing program. Program flow chart shown in Fig. 7.

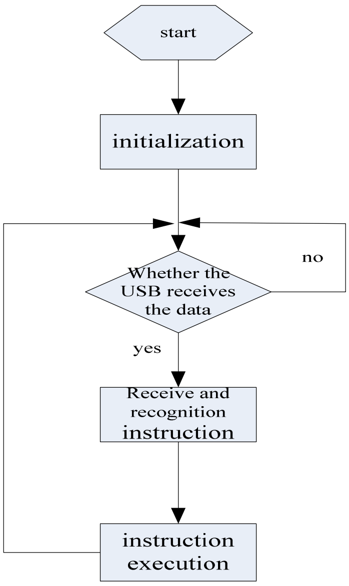

Fig. 6. Firmware flowchart of controller.

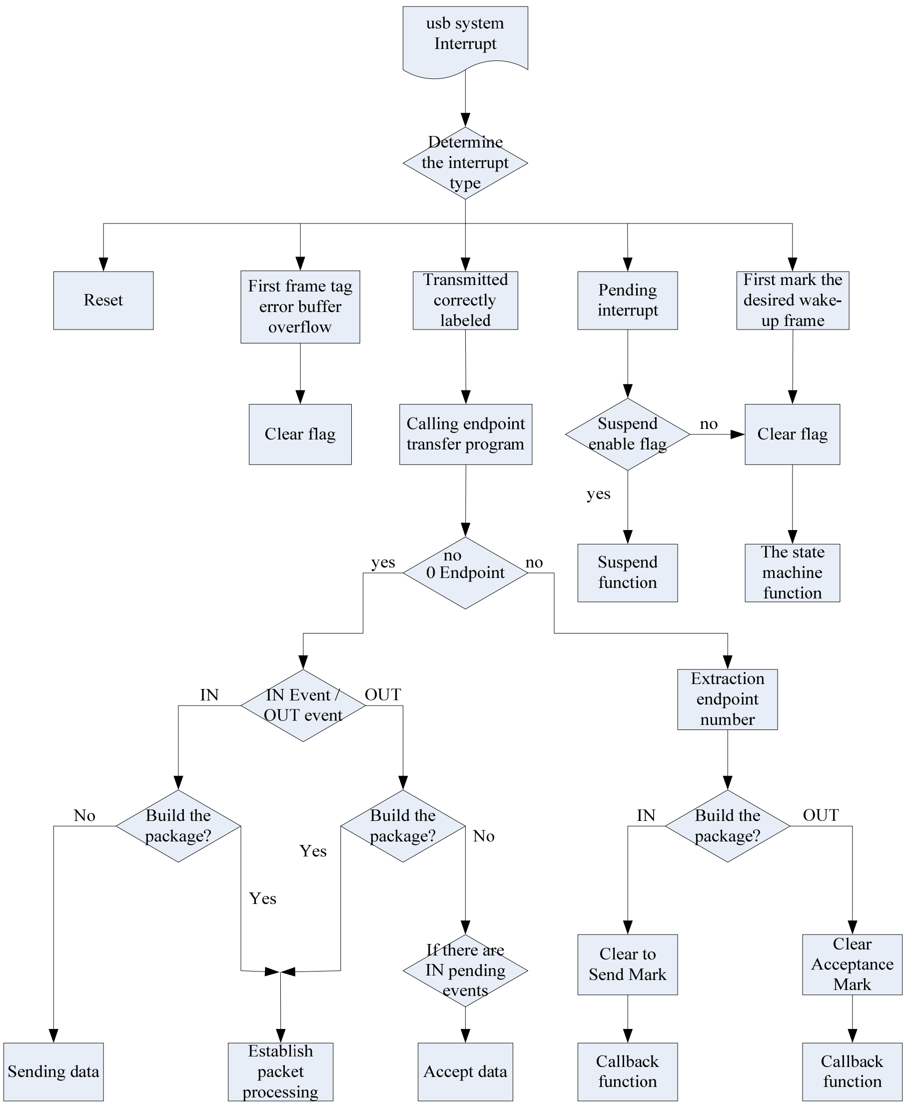

Fig. 7. USB communications firmware flowchart.

Because of the need to use A/D signal acquisition module for displacement, Therefore they need to be set to achieve the above functions, Program flow chart shown in Fig. 8.

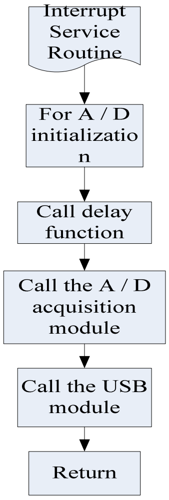

Fig. 8. A/D firmware flowchart.

4.2. LabVIEW Program

During development of the system will encountered with the collection device and PC communication problems, LabVIEW platform has a strong advantage in the application of this area. To take full advantage of other programming languages, in this paper, the way is called a dynamic link library (DLL) to the PC and collecting device communication problems.

Dynamic Link Library that can be shared by other applications program modules, it encapsulates some of the routines can be shared and resources, generally the suffix extension is DLL. It is functionally very similar to the executable file, The main difference is that although the DLL file contains an executable program, but can't execute independently, must be called in order to use the program either directly or indirectly through under Windows. In LabVIEW, use the library function node can more easily achieve the call to the DLL, thus improving the efficiency of the development process. Using the call library node, you can call the standard Windows dynamic link library, you can also call the user-compiled DLL. program interface shown in Fig. 9.

5. Performance Testing of Collecting Systems

In order to test the performance of the acquisition system, here the amplitude of the piezoelectric ceramics is 24 μm input control signals and the frequencies are different (Fig. 10). Through micro-displacement acquisition system can be observed, displacement signal and the actual output to its acquisition still exist certain errors, this is mainly due to the nonlinear characteristic of the piezoelectric ceramic and the external interference caused by the acquisition system (Such as vibration of air and the electromagnetic of outside world).

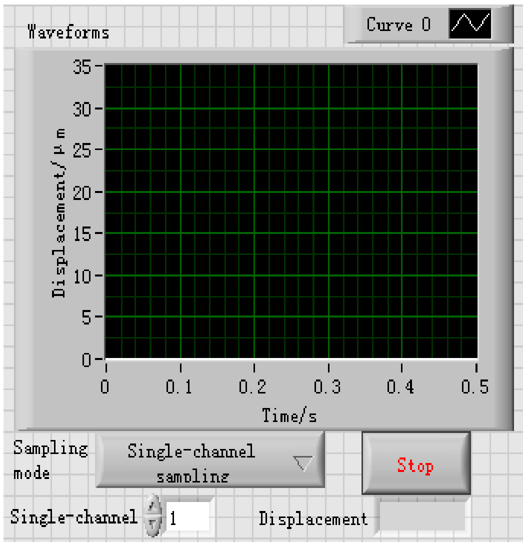

Fig. 9. User interface of data acquisition system.

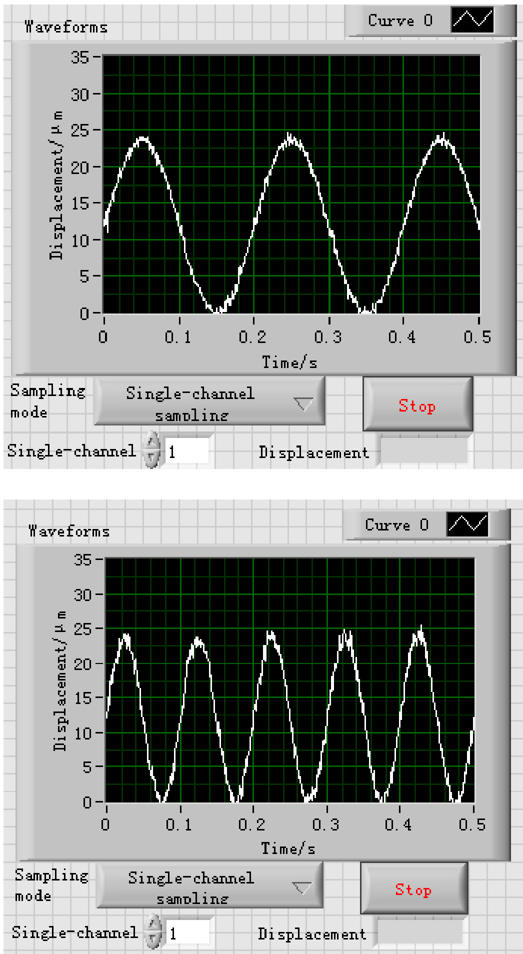

Fig. 10. Performance testing of collecting systems.

6. Conclusions

This micro-displacement acquisition system consists of detection bridge, amplifier circuit, filter circuit and stm32f103 controller. It transfers the displacement signal by the controller. PC using LabVIEW program called dynamic link library way to complete the communication with controller and achieve the micro-displacement signal acquisition. The performance test proved that the micro-displacement acquisition system is suit to the places of less precision, with high practical value.

Acknowledgements

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References

[1]. Hanyu Sun, Design of Nano Displacement Sensor's Signal Acquisition and Processing System for PZT Actuator, *Dissertation, University of Science and Technology of China*, Hefei, 2011.
[2]. Renbing Chen, Research of Nano-micro Displacement Sensor's Signal Acquisition and Processing for the AFM, *Dissertation, University of Science and Technology of China*, Hefei, 2010.
[3]. Tang Wei, Yu Ping, Li Zhenghui, A Multi-channel USB Data Acquisition System Based on STM32F103x, *Microcontrollers & Embedded Systems*, No. 8, 2009, pp. 39-45.
[4]. Xu Yueqing, Design of Multi-function Data Acquisition and Control System Based on STM32F0, *Journal of Anhui Vocational Collage of Electronics and Information Technology*, No. 6, 2012.
[5]. Behzad Razavi, Design of analog CMOS integrated circuits, *Jiaotong University Press*, Xi'an, 2003.
[6]. You Li Hua, Test technology, *Machinery Industry Press*, Beijing, 2006.
[7]. Marc T. Thompson, Intuitive Analog Circuit Design, *Elsevier*, Singapore, 2009.