Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

The Design and Realization of High Precision Micrometric Displacement Measuring System Based on LVDT

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Abstract: This thesis introduces a kind of micrometric displacement measuring system which is based on LVDT (liner variable differential transformer) sensor. Considering the disadvantages that LVDT signal has a low precision and a large temperature drift when conditioning circuits, this thesis designs the matching hardware circuits, which mainly involves waveform generating circuit, driving circuit, wave filtering and amplification circuits, virtual value transforming circuit, and AD transforming circuit, the single-chip microcomputer will collect the AD transforming results, make digital filtering, and display them. Experimental results show that this system is of extremely high practical application.

Key Words: LVDT; micrometric displacement; signal processing

I. INTRODUCTION

LVDT linear displacement sensor has the following outstanding advantages including swift response, high definition, high linearity, good repeatability, long service life, and good environmental adaptability, etc.[1], therefore, it is universally applied to various fields such as aerospace, machinery, building, auto mobiles, and chemical industry. With the rapid development of science and technology, higher requirements are also put forward on the precision of micrometric displacement measurement by many application fields, and precision measurement technology has gradually become a significant symbol of a country′s technology level[2]. However, referring to high precision micrometric displacement measuring instruments, China, to a large extent, still depends on imported ones, and lots of domestic similar instruments are still a little inferior to those imported ones in aspects of precision and stability.

II. WORKING PRINCIPLE OF LVDT

Consisting of one primary coil, two secondary coils, one iron core, one coil framework, one housing, and other accessories, the working principle of LVDT is based on electromagnetic induction principle[3]. Its main structure is shown as Figure 1:

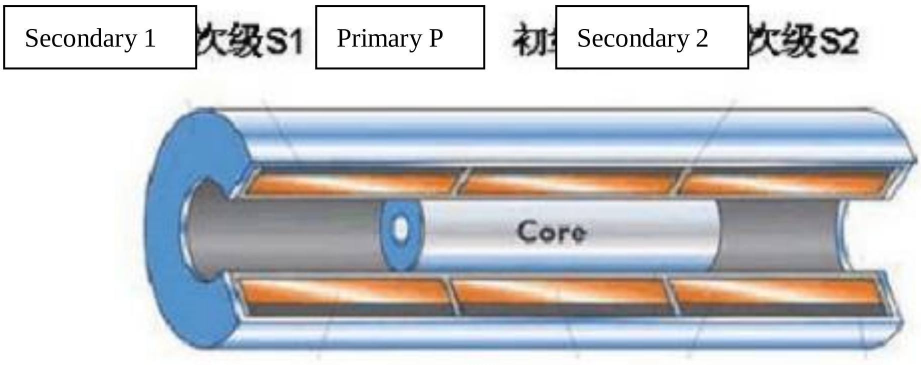

Figure 1. Structure diagram of LVDT

The primary coil is evenly winded on the central part of the framework, the two secondary coils are evenly winded on each side of the primary winding, respectively, within the coil, there is a high magnetic permeability iron core which can be linked with the measured object. If both ends of the primary coil are applied certain alternating excitement voltage, when the central point of the iron core is strictly situated on the central part of the primary winding, the two secondary coils will generate equal induced electromotive force, therefore, their differential output responses are zero; when the central point of the iron core is bias from the central part of the primary winding, the induced electromotive forces generated by the two induced coils will not be equal, moreover, their differential output and the displacement size that the iron core bias from the central part of the primary winding will appear a good linearity. The displacement size of the measured object can be achieved by measuring the differential output voltage of the two secondary coils.

III. IMPLEMENTATION OF SYSTEM HARDWARE

This system mainly consists of the circuit controlled by a single-chip microcomputer, the fundamental wave extraction circuit, the driving circuit, LVDT, filter circuit, virtual value transformation circuit, AD transformation circuit, and power transformation circuit. The structure diagram of this system is shown as follows:

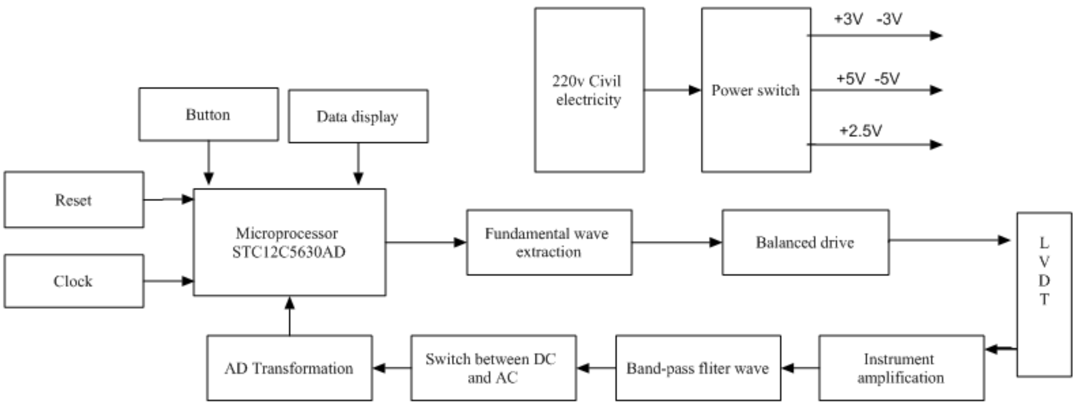

Figure 2. Structure diagram of this system

3.1 Filter Circuit And The Driving Circuit

The design thought of the high precision micrometric displacement measuring system involved in this thesis is that the 2.5KHz wave signals generated by the single-chip microcomputer multiply feeds back active filter circuit, extracts the 2.5KHz sine wave signal, input the signal into the full differential balance driving circuit, and uses the 2.5KHz differential sine wave signal with driving capability to motivate the primary coil of the LVDT sensor. The filter circuit and the driving circuit are shown as follows3:

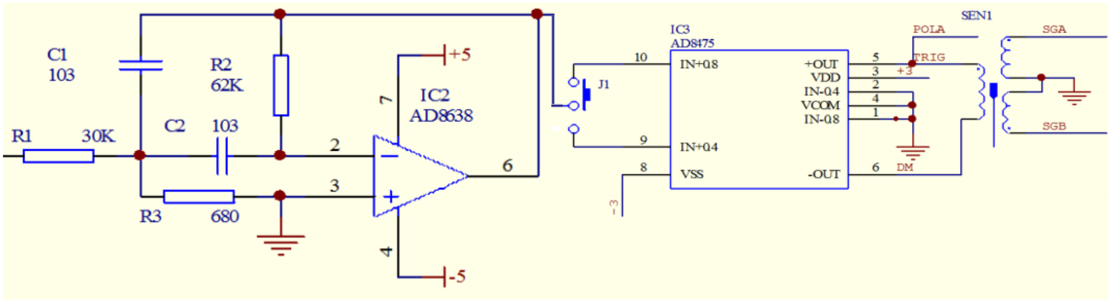

Figure 3. Filter circuit and the driving circuit

3.2 Virtual Value Transformation Circuit

Within the secondary circuits of LVDT, related output signals can be received, and these signals change with the position changing of LVDT iron core within the coil, as these output signals from LVDT secondary coils are very weak and mixed with lots of noises, these secondary output signals should be first input into instrument amplification circuit to amplify these signals, in the meantime, the common-mode noise mixed into the signals should be filtered, in order to further filter the noises, the output signals of the amplification circuit of the instrument should be input into the multi feedback active band-pass filter circuit, then the noise filtered sine wave signals should be input into virtual value transformation circuit, and the sine wave signals should be transformed into direct current signals. This system does not adopt traditional rectifier bridge to make direct current transformation, because the traditional method is of loud noise, large temperature drift, and not suitable for high precision measurement. Among these, virtual value transformation circuit is shown as Figure 4:

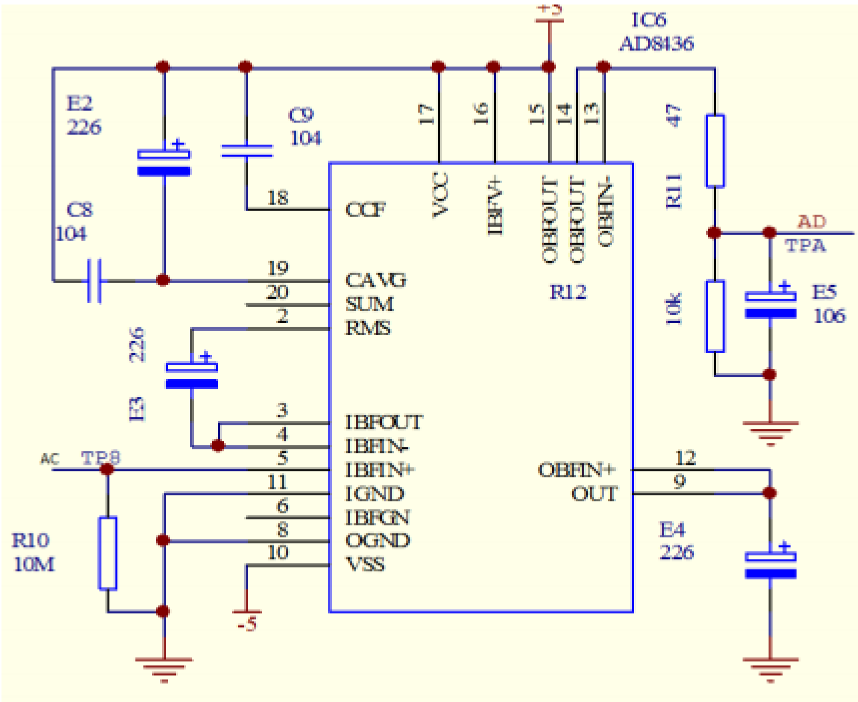

Figure 4. Virtual value transformation circuit

3.3 Single-chip Microcomputer Controlled Circuit

Input the direct current signals output by virtual value transformation circuit into AD sampling circuit and complete the transformation from analog quantity to digital quantity. In order to secure the system's measurement precision, the system has chosen the 16-bit professional high precision AD transformation chip manufactured by ADI, and read the voltage transformation results of AD transformation unit through the single-chip microcomputer's serial communication interface, further filter the noises in the signals through digital filter algorithm, then transform the voltage transformation results into displacement value of the sensor bar in the coil through theoretical formula, send them into display unit and display the results. The single-chip computer controlled circuit is shown as Figure 5:

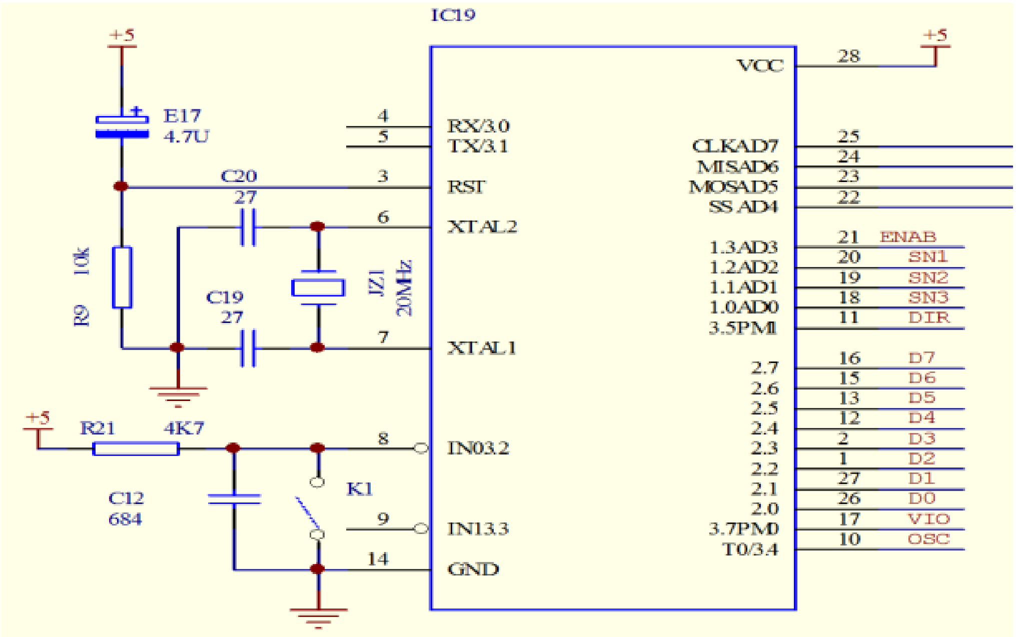

Figure 5. Single-chip microcomputer controlled circuit

IV. SOFTWARE DESIGN

The program of single-chip microcomputer mainly consists of four parts, including square wave generation, serial communication, digital filtering, and display control. The flow-chart of the systems software program is shown as Figure 6:

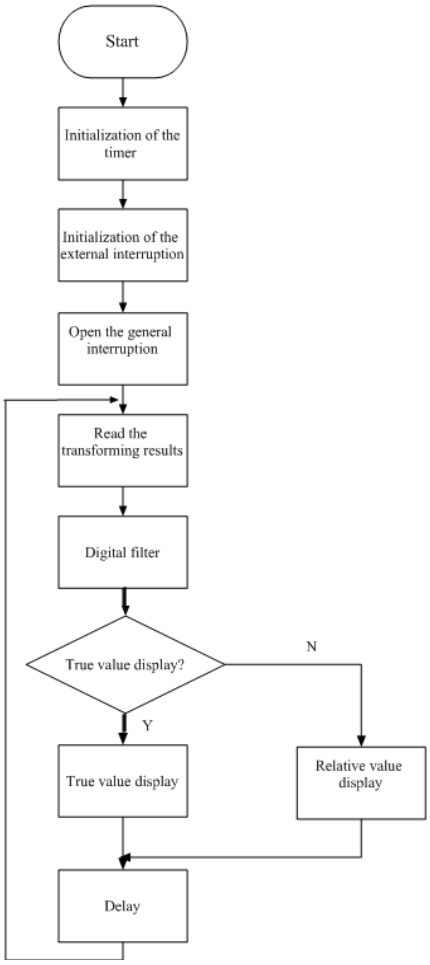

Figure 6. Diagram of the system software

After the system is powered on, first of all, initialize the timer, utilize the timer and IO port to generate 2.5Khz square wave signals, then the initialize external interruption to make preparations for using the buttons to switch the display contents. After the general interruption is started, square wave begins to generate, after a while, when the signals are stable, it begins to enter the systems main circulation, successively read AD transformed digital quantity for many times through the single-chip microcomputers serial communication port, then use digital filtering algorithm to filter the noises in the signals, after the calculation of output results by the digital filter wave and the factors set in the program, it may transform the measured voltage value into displacement value. The system has two digital display modes, namely, true value and relative value. It will display the digital results on the nixie tube according to the current display mode of the system, and these two display modes of the system can be shifted by pressing buttons. After delaying a moment, it may reread AD transformed results, make calculation and display to realize real-time measurement of the displacement.

V. EXPERIMENTAL ANALYSIS

Check the systems measurement precision by using micrometric measuring rack, firstly, adjust the micrometric measuring rack to the zero position, fix LVDT displacement sensor on the micrometric measuring rack, then connect LVDT to signal processing circuit, power on the system, and adjust LVDT, locating it on the linear working area. Press the button on the display panel of the micrometric displacement system, and adjust the display mode into relative value output mode, then the data on the panel has been cleared. Adjust the micrometric measuring rack, make the displacement value increase every 20 micrometers, and record the value of each point of the micrometric displacement system. Fit the data using the principle of least square method through MATLAB, work out the best factor through which the voltage value transformed and output by AD is transformed into displacement value, and compose the data into the program.

Adjust the micrometric measuring rack back to the zero position, record the micrometer positions of the micrometric measuring rack, 0, 10, 20, 30, 40, 50, 100, 200, and 300, and the measurement values of the micrometric displacement system, respectively. Then make a back track adjustment measurement, record the micrometer positions of the micrometric measuring rack, 300, 200, 100, 50, 40, 30, 20, 10, and 0, and the measurement values of the micrometric displacement system, respectively. Repeat this course three times, the recorded measurement data are shown as Chart 1. from the data, it can be seen that the displacement changing values measured by the system are almost the same as those measured by the micrometric measuring rack, and has achieved the predicted precision.

Chart 1. Measurement Data

Times	0	10	20	30	40	50	100	200	300
Forward track 1	0	9.9	19.9	29.8	39.9	49.9	100.0	200.1	300.1
Back track 1	0	9.8	19.9	29.8	39.7	49.8	99.5	199.8	299.8
Forward track 2	0	10.0	19.9	29.9	40.0	49.9	100.0	200.1	300.1
Back track 2	0	9.9	19.8	29.8	39.7	49.7	99.8	199.7	299.8
Forward track 3	0	9.9	19.9	29.8	49.9	49.9	99.8	200.0	299.8
Back track 3	0	9.8	19.8	29.7	49.7	49.7	99.6	199.5	299.9

VI. CONCLUSION

The unique advantage of LVDT sensor on displacement measurement is sure to make it more popular in future measuring system, moreover, this system has made full considerations on the design of both hardware and software, which has maximumly lowered the influence on the system by noise and temperature drift, and realized high precision measurement on displacement, and provided a feasible plan for lots of circumstances where high precision displacement measurement is needed.

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