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Development of Ultrasonic Rangefinder based on FPGA

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Abstract

This paper analyzes and studies the current distance measurement methods and instruments at home and abroad. From the perspective of engineering application, it proposes the current practical application of distance measurement methods and the instability of the instrument and the inability to offline analysis. It also proposes a method based on ultrasonic digitization. Measuring method, this instrument avoids the shortcomings of current engineering applications, and can realize remote real-time monitoring, data storage, and offline analysis of instrument dynamics, which greatly improves the stability of measurement and the actual requirements of engineering applications.

Keywords

Distance Measurement Method and Measuring Instrument; Ultrasonic; Offline Analysis; Digitization.

1. Introduction

With the rapid development of electronic technology, how to perform automatic measurement in complex environment and return measurement data stably in real time is an important research field at present. In engineering applications, the measurement environment of some measurement occasions is complex and changeable, which is not suitable for the on-site survey of the surveyors. In order to ensure the safety of the surveyors and provide more accurate, stable and comprehensive measurement data, domestic and foreign R&D personnel use microprocessors for remote However, this measurement method cannot realize the offline analysis application of data, and it is difficult to obtain the measured waveform data, so it is difficult to analyze the data to accurately troubleshoot the fault when the instrument fails. In response to the above problems, this paper developed a digital ultrasonic liquid level instrument, which uses FPGA system and STM32 minimum system to achieve high-precision liquid level measurement, which can realize real-time control and display functions, and can realize data storage and offline analysis and viewing functions. This system adopts digital data acquisition, therefore, a breakthrough has been achieved in the miniaturization of the instrument [1-5].

2. System Design

2.1 Principle Elaboration and Scheme Design

In some applications of the rangefinder, it is difficult for the user to operate at close range, and it is necessary to separate the man and the machine to realize remote monitoring of data and remote control of the instrument. Automatic measuring instruments play a huge role in this aspect. This section mainly introduces the system architecture and the working principle of this design. At the same time, the feasibility of the scheme is analyzed, and the overall scheme design is given. The system can export historical data for analysis when the equipment fails, and then quickly find the fault for re-operation, reducing the need for maintenance personnel to find faults on site.

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The system designed in this paper uses ultrasonic sensors for measurement. Figure 1 shows the analog schematic diagram of the digital ultrasonic range finder. In the figure, substance 2 and substance 1 are two substances with different densities. A detector is placed above the container, which includes The ultrasonic transmitting part and the receiving part, the ultrasonic wave is emitted from the transmitting device and propagates in the medium 1. When the ultrasonic wave reaches the interface of the two mediums, due to the different conditions such as the density of the two mediums, a reflection is formed. After the reflection, an ultrasonic echo is formed, and the echo passes through The medium 1 propagates to the ultrasonic receiving device and converts it into an electrical signal.

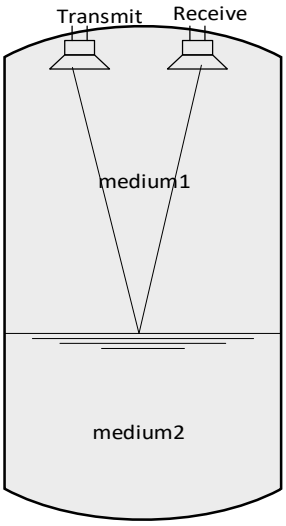

Figure 1. Principle of ultrasonic level measurement

The system scheme of this design is shown in Figure 2. The ultrasonic analog signal is converted into analog to digital, and then the digital signal collected by the ADC is passed through the fir band-pass filter to eliminate noise. According to the relevant algorithm, the highest point of the waveform is obtained, and the count starts. Counting stops when the highest point of the echo signal is received, and the count value is stored in the register and transmitted to the STM32 through SPI communication. After calculation, the height is obtained and displayed to the display device to realize the real-time monitoring function.

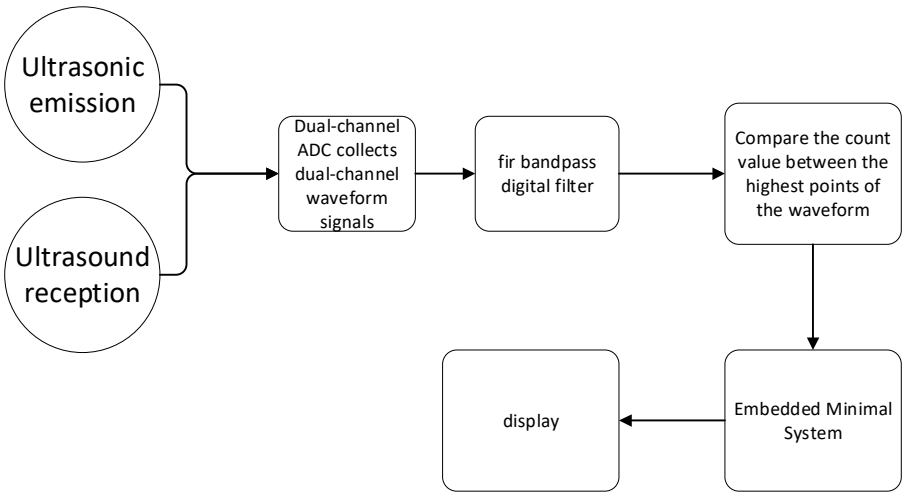

Figure 2. System design diagram

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2.2 Hardware Circuit Design

The hardware of the digital distance measuring instrument consists of a power supply module, a signal conditioning module, ADM9226 dual-channel ADC, FPGA minimum system and STM32 minimum system. The hardware implementation block diagram is shown in Figure 3.

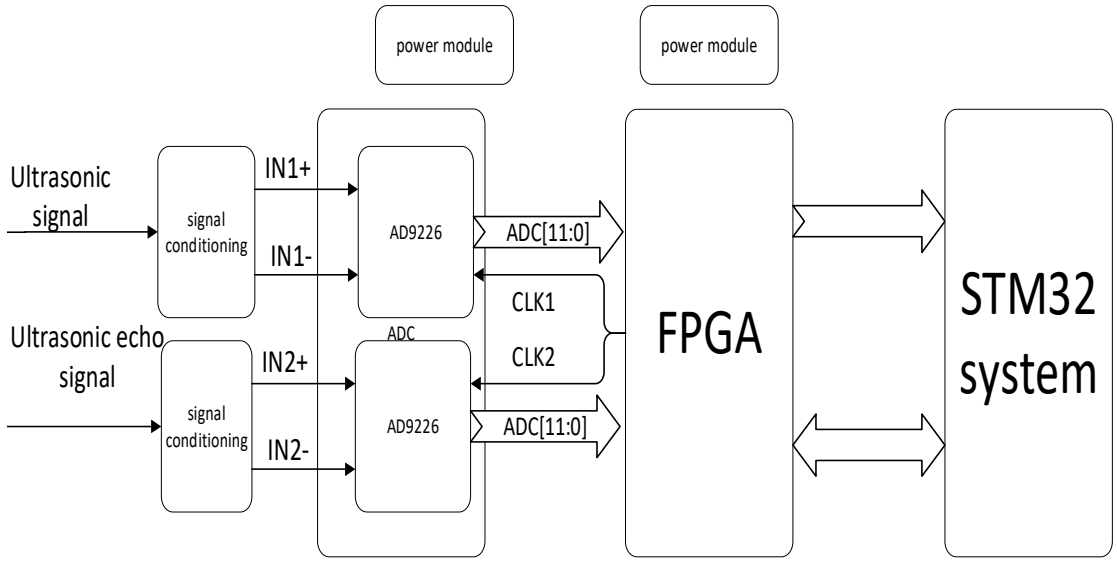

Figure 3. Hardware Design Block Diagram

Ultrasonic sensor is a waterproof sensor in industrial production. It is suitable for on-site measurement of liquid level under high temperature, steam and foam. It can effectively complete the measurement in complex environment; due to the complexity of the measurement environment and the distribution of impurities in the liquid , so the ultrasonic signal will generate a certain noise signal. In order to measure the data accurately, a signal conditioning circuit is required to complete the function of removing noise. The signal conditioning module is mainly composed of a band-pass filter and a signal amplification circuit; the innovation of this design is It is the digitization of the measurement signal, so a digital-to-analog converter is needed to digitize the analog signal. The ADM9226 dual-channel ADC is a 65M digital-to-analog converter for waveform acquisition and digitization of analog waveforms; FPGA has a great deal of signal processing. Speed advantage, so FPGA is used as the signal processing system, which is used to digitally filter the digital signal collected by ADC and obtain the time interval between echoes after algorithm processing, and send the obtained count value to the embedded device through the SPI communication protocol. The STM32 is more convenient and concise in human-computer interaction and data calculation, and has great advantages. Therefore, the STM32 embedded minimum system is used to process the data processed by the FPGA to obtain the distance data and display it on the display interface.

2.3 System Software Design

The innovation of this design is to digitize the ultrasonic signal, improve the stability of the measurement, and realize the miniaturization of the measurement tool. In addition, data storage and real-time transmission are carried out, so as to realize historical data playback and remote troubleshooting. In this paper, FPGA is used as the data processing module. In the design of the FPGA software module, the functions implemented by each module are shown in Figure 4. Due to the functional characteristics of the FPGA, each module realizes parallel operation, and is written in the hardware code Verilog HDL language. , to realize data transmission between various modules. The main task of the high-speed counter module is high-speed timing or counting. Its main function is to sample the pulse data between the time difference between the ultrasonic drive signal and the return signal of the echo signal, which is a prerequisite for the ranging operation. The more accurate the

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arrival time, the higher the ranging accuracy. The main function of the FIR digital filter module is to filter out the noise signal mixed with the ultrasonic signal to prevent the measurement error caused by false triggering. The ultrasonic signal measured in the experiment is about 100KHz. Therefore, the filter used is a band-pass filter with a center frequency of 100KHz. This design directly calls the IP core of FIR, and the parameters of the band-pass filter are generated by MATLAB; the main functions of the transmit and echo ADC acquisition modules are: Reading the digital signals collected by the ADC and accurately obtaining the relative time between the two signals in real time is the key to the stability and reliability of the system; the main function of the communication module is to transmit the count value obtained by the high-speed counter module to the STM32.

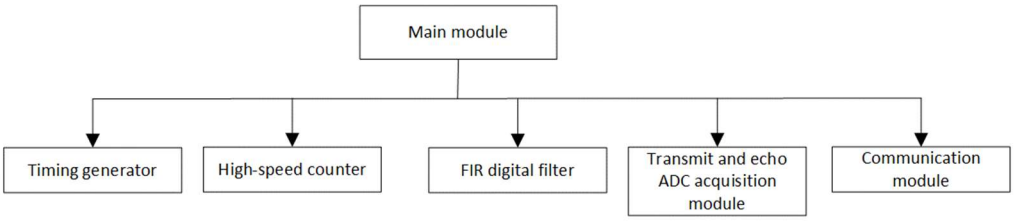

Figure 4. Hardware program flow chart

3. Experimental Results

By testing the experimental equipment, the size of different distances can be measured. The measurement process is to obtain real-time measurement data by moving the hand-held detector. According to the comparison between the data measured by the instrument and the actual distance data, a set of measurement data tables are obtained to reflect the measurement data of the instrument. The size of the error that exists. to see if the instrument meets industrial needs.

Table 1. Experimental measurement results and errors

Data Name	Display Data(cm)	Measurement results(cm)	Error size(cm)
Group 1	37	35	2
Group 2	45	42	3
Group 3	54	52	2
Group 4	65	63	2
Group 5	76	73	3

4. Conclusion

The digital ultrasonic distance meter realizes the real-time measurement and monitoring of distance data, and the digitalization of instrument measurement realizes the miniaturization of the measurement instrument, integrates the detector device with the measurement system, and improves the stability of the measurement system at the same time. This measurement system realizes digital acquisition, measurement and calculation, and stores the data in the measurement process to realize the offline analysis of the data, which can not only find the equipment fault through offline data analysis, but also provide reference value for later scientific research.

References

[1] Cai Guangzhao,Hong Yuanquan,Zhou Yongming.Design of ultrasonic speed and distance measurement system based on STM32[J].Modern Electronic Technology, 2014(24).

[2] Wang Rongyang,Qian Zhenhua,Yin Yonghui. FPGA-based cross-correlation and crosstalk-free ultrasonic ranging system [J]. Computer Engineering, 2013(08).

ISSN: 2414-1895 DOI: 10.6919/ICJE.202208_8(8).0135

[3] Zuo Baoshou,Design and Implementation of Digital Ultrasonic Level Gauge[D]. North China Electric Power University, 2017.

[4] Si Chunning.Research and application of distance measurement system based on ultrasonic[D].Donghua University,2009.

[5] Wu Junhe. Research on ultrasonic liquid level meter based on DSP[D].Zhejiang University,2012.