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Research Article

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Design of ultrasonic distance-measuring system using temperature compensation methods

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ABSTRACT

This document presents the principle of ultrasonic distance measurement is described, the main error sources of ultrasonic distance measurement are analyzed also. A method of improving precision of ultrasonic distance measurement in air, in which the transmission speed of ultrasonic wave if corrected by measured air temperature and the forward edge of receive wave can be determined accurately by use of the receive wave feedback—time method with the software. Based on the idea, the circuit and software of ultrasonic distance measurement system have been designed to apply digital signal processing technology. Experiment indicates that the measuring precision of ultrasonic distance measurement system is higher and its circuit is simpler.

Key words: ultrasonic, distance measurement, receive wave feedback, digital signal processing, measuring precision.

INTRODUCTION

T Ultrasonic ranging is a non-contact measurement method, which has been widely used in positioning and environment modeling occasions, such as the automotive anti-collision radar, industry control, exploration measurement, robot, etc. Ultrasonic, as a special kind of sound waves, due to its intense directivity, much lower velocity in the air than the light and transmission time easily detected, echo-feedback-time me- thud is widely used in ultrasonic ranging[1]: by computing the time ultrasonic transmitter sending ultras- nick wave through gas medium spreading to an ultrasonic receiver, i.e. echo-feedback time. Multiply the time and sound velocity in the air equals to the distance of the sound wave transmission. This article puts forward the construction phase detection based on DSP FFT links in digital signal processor echo feedback-time method calculate out of range data integration, meanwhile, analyzes and introduces basic principle of the system, hardware circuit, software design and the error, then puts forward solution method[2].

1. Working principle and correction method

Ultrasonic ranging principle is to use ultrasound in the air velocity as the known and measure the time when sound waves reach obstacles and reflect back, then calculate the actual distance. Using 8-bit single-ship controlling echo wave reflection-time ranging method is widely used, whose accuracy is not very high because of the low system clock. With reference time fixed, and the echo peak time pour push forward to testing time, or there is a threshold, makes this method problem, it is hard to do it within half a wav-length error, this problem solved the key is to establish error correction mechanism and temperature compensate measures [3].

2.1 system error correction

The designed hardware circuit has a certain delay, for example, wave filter has some microseconds' delay. And DSP, which uses the external interruption to test the echo signal, getting into the interrupt handlers and executing some

instructions that takes some time, has a few microseconds' delay. And because the piezoelectric materials is fragile, to meet the needs of seal, insulation and impedance, ultrasonic transducer is often sealed in the probe enclosure, making the piezoelectric materials and probe the surface of a certain distance, and therefore brings some error measure results[4]. For the delay time caused by designed hard- ware circuit and the distance between piezoelectric materials and probe is fixed surface, by subtracting the distance of piezoelectric materials and probe surface and adding delay time feedback function in ranging formula, when we are using software to process data, we can eliminate the ranging error because of the distance of piezoelectric materials and probe surface, and time error caused by hardware delay[5].

2.2 Temperature compensation

At present, the majority of temperature measurement and control system for temperature detection, are using the temperature sensor the temperature into electricity, through the signal amplifying circuit to the appropriate range, the structure of the circuit and then by the A/D converter converts the digital quantity to complete complex, debugging complex, affecting the accuracy of vulnerable components parameters. In view of this situation, using a digital the rmometer (integrated temperature sensor) DS18B20 and DSP controller as the main body, a multipoint digital tem-premature detection system of a high accuracy. DS18-B20 is a digital temperature sensor American DALL-AS company's new, different and thermistor temperature sensor of traditional, it can directly read the measured temperature values, and according to the actual requirements, through a simple programming, realization of 9-12 bit A/D converter. Therefore, the use of DS18B20 can make the system structure more simple and higher reliability.

The propagation speed of ultrasonic is subject to temperature, humidity and other environmental factors, among them, the temperature is a major factor. The approximation of sound velocity:

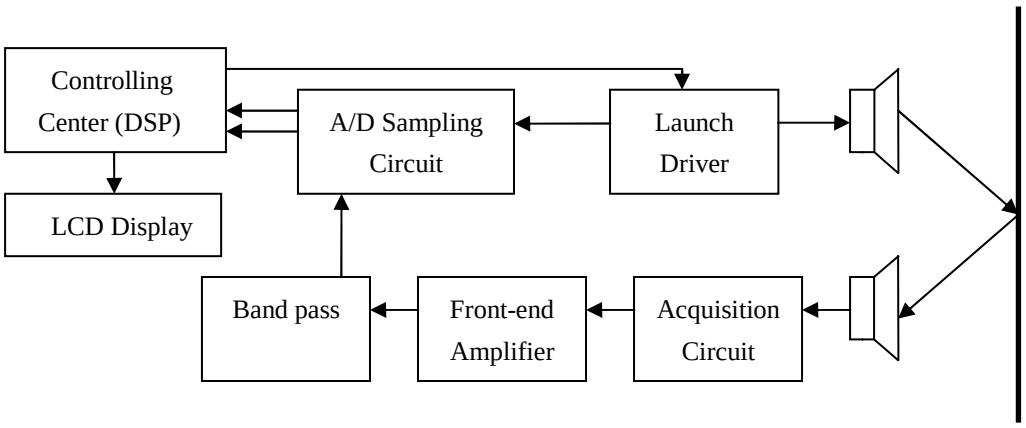

Fig. 1: Hardware circuit

$$C = 331.4 + 0.61\ T \quad (1)$$

Every 1℃'s temperature change causes sound velocity change 0.61 m/s, about 0.18%, which demonstrates sound wave velocity is greatly influenced by temperature. Therefore, precise measurement requires temperature compensation [6]. DS18B20 is used to collect temperature signal which can precisely calculate the ultrasonic velocity that is referred as variable in the design of algorithm program.

2. Overall design

3.1 hardware circuit design

Way as a means of realization. To make sure that the digital signal processor successfully starts A/D conversion to send A signal and echo signal FFT inspection phase, the control circuit driver and to launch ultrasonic algorithm based on timing measurement results [7]. When timing is accomplished, start A/D launch signal and echo signal sampling, and carries on FFT phase-detecting, circuit acquisition, frontend amplifier and band pass filters in the form of pulse after return to A/D sampling circuit and digital signal processor, and get their phase difference[8], which is accurate measurement and displayed on the 128 * 64 LCD display.

3.2 system software design

Through FFT phase-detecting module driving ultrasonic transducer, sending out optimized ultrasonic signal, and handling the echo signal with error correction and temperature compensation, we can get ultrasonic feedback time, then the exact distance value. Thus, the whole measuring process of system software design is controlled by DSP,

after sampling FFT signal phase-detection, FFT data processing, receiving signal scattered FFT spectrum, through selected specific sampling frequency and FFT calculation will base wave signal to determine the sequence of fixed position of FFT imaginary part numerical and real part of the ratio of the value is the base wave anyway cut phase [9]. In order to receive computational speed and make advantages of DSP instructs system, the design adopts TI's FFT program, selecting with time, base for 2, transform phase-detecting process to FFT libraries call. The design of the software process is as follows:

(1) Rearrange the N input signal data by diverse order of bit-code. Void FFTC-brevl(int * SRC, int * DST, int size)function is used in this step, SRC is signal sampling for data storage space after the start of the pointer, DST for on-site calculation data buffer beginning pointer, size is FFT size;

(2) The imaginary part of zeroed complex number sequence of input signal, call form as FFT. Calc (& FFT);

(3) Proceeding plural number FFT calculate of N Base point as 2, call form as FFT. Calc (& FFT);

(4) Design temperature compensation son function: formula (1) provides appropriate algorithm, call form as FFT. tep(&ftt);

(5) Takes the corresponding unit output of complex number sequence, call mathematical library "math. H" cut the anyway that base wave function phase signal in a single cycle and the whole cycle of value, the sampling base wave real part and imaginary part respectively in the third, storage four units in. If for multi-periodic sampling, fundamental wave real part and imaginary part storage units come by sampling rate [10]. The whole process is automatically finished, meeting the requirements of real-time and automation.

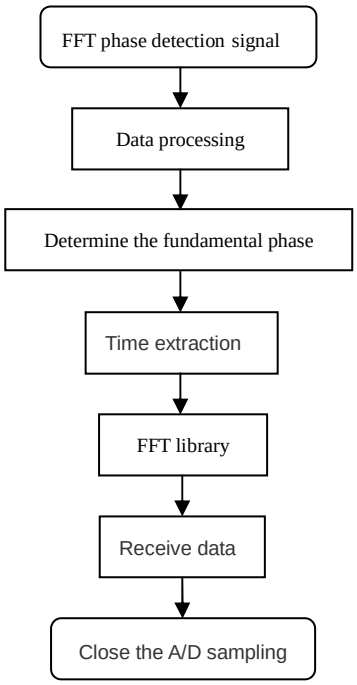

Fig.2: The program flow chart

Accordingly, can the program flow shown in Figure 2 are.

The ultrasonic frequency adopted is 36.8 kHz, closely to 40 kHz. The ultrasonic sensor range was limited between 0.06m and 1.00m, which is working well in a dust, smoke, strong magnetic fields environment of variable interference. Using128 * 64LCD display mode makes ranging fast, convenient and easy real-time control. As we can get from table 1, the accuracy of ultrasonic ranging device is high from 0.1 to 0.4m. With the increase of distance, error has increased. But as a result of the error correction mechanism and temperature compensation measures, the measurement error was in allowing range. In addition, DSP's powerful digital signal processing power and complete use of algorithm, makes the average measurement error to be △S= 0.001 m. After the correction, the measurement accuracy of the system can reach + /-0.02m, enough to ensure that the measurement system's superiority.

3. Results of designing system

A lot of experiments were carried out with the ranging device designed according to the above method. Table 1 is part of the experimental data.

Table1:Test data units: m

No.	readout value	actual value	No.	readout value	actual value
1	0.068	0.061	8	0.353	0.381
2	0.103	0.101	9	0.408	0.436
3	0.149	0.150	10	0.455	0.478
4	0.194	0.202	11	0.508	0.532
5	0.244	0.251	12	0.599	0.627
6	0.285	0.302	13	0.671	0.699
7	0.326	0.353	14	0.875	0.898

CONCLUSION

Considering the defects of traditional ultrasonic sensor based on single pulse, we design a new type ultrasonic ranging method using embedded DSP as the core of the devices, respectively, using phase-detecting by FFT, sampling circuit, front-end amplification, band pass filters and 128 * 64 LCD module circuit to achieve. Correct the transmission speed through the method of temperature compensation, and ensure high measuring accuracy and quick response. As the needs of auto-ranging by search and rescue robot, navigation system and level detection and micro-topographic structure, automatic ranging accuracy becomes very important. So the research and development of this project is of practical significance.

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