

# Embedded Voice Announcement Ultrasonic Distance Meter and University Lab Teaching Reformation

Yu ZHANG<sup>1,a</sup>, Xinyu JIN<sup>2,b</sup> and Huizhong LI<sup>3,c</sup>

<sup>1,2,3</sup>Information Science & Electronic Engineering College, Yuquan Campus, Zhejiang University,  
Hangzhou, Zhejiang, China, 310027

<sup>a</sup>zangwill@zju.edu.cn, <sup>b</sup>jinxy@zju.edu.cn, <sup>c</sup>lihz@zju.edu.cn

**Keywords:** Ultrasonic, Distance Meter, Embedded System, Lab Teaching

**Abstract:** A voice announcement ultrasonic distance meter with temperature compensation based on embedded MCU has been designed. This distance meter project has been introduced into the electronic design lab course teaching in Zhejiang University. Some teaching method reformation measures have been taken, which arouse the enthusiasm and creativity of the students greatly, and improve the lab course teaching effects.

The ultrasonic distance meter is a practical electronic system. In many universities, it's also a common design project in the electronic system design lab course and the electronic design contest. In the Information Science and Electronic Engineering College of Zhejiang University, the ultrasonic distance meter has been adopted as a lab project. In this paper, the whole design of a voice announcement ultrasonic distance meter based on embedded MCU has been presented, and some lab course teaching reformation measures have also been presented to improve the teaching effects. This 5V single-supply meter can measure a distance up to 600mm, with measurement error less than 5mm, and it has the functions of LCD display and voice announcement.

## System Architecture

There are many techniques to fulfil the ultrasonic distance measurement, such as Phase Detection, Sonic-Wave Magnitude Detection, and Flight Time Detection. Phase Detection technique has high measurement precision, but the measurement range is limited. Sonic-Wave Magnitude Detection technique is susceptible to the reflection media. Flight Time Detection technique can be realized easily, and it has low cost and wide measurable range, but it has a little blind zone in the short distance range [1].

In this paper, Flight Time Detection has been adopted. At one time, the ultrasonic emitter emitted the ultrasonic signal, and then the echo signal reflected from the measured object was received by the ultrasonic receiver. After the time period between the emitting and the echo receiving was calculated, and the sonic transmission speed in the media was known, then the distance under detection could be calculated.

In this system, 40kHz PWM signal was generated firstly by the embedded MCU, which brought the resonance and produced the highest transmission power efficiency. Then the magnitude of the PWM signal was amplified by the drive circuit to increase the transmission power, and then the PWM output entered into the ultrasonic transducer. In the receiver, because the voltage signal derived from the echo signal by sonic-electronic conversion was in mV level, with fairly high noise interference, so the signal must be amplified, filtered and voltage compared and then it became the trigger signal for the MCU.

In order to increase the measurement precision, and decrease the environment temperature influences, the DS18B20 temperature sensor has been used to measure the temperature, and then get the corresponding sonic speed, and add to the final distance computation. In order to realize voice announcement, the ISD1760 voice module has been used in this system.

The system architecture is shown in Fig. 1.

## Hardware Design

### Emitter circuit

40kHz pulse was generated by MCU, and the performance of the MCU's PWM signal output is very good. The MCU can be TI MSP430 or ARM STM32.

The piezoelectric ultrasonic transducer NU40C12T/R-1 was used. But the current and power of the pulse signal directly from MCU were limited. So a drive circuit using TLV3501 high-speed comparator

was designed to drive the transducer [2-5], which can generate 5Vpp square wave. This comparator has a 5V single-supply. Its input is the PWM signal. Its reference voltage is derived from 5V supply.

### Receiver circuit

In order to receive the high low levels for the MCU easily, the signal received should be reshaped, that was to output after another TLV3501 comparator circuit. The reference threshold voltage of the comparator could be set properly according to the magnitude of the received signal.

As the distance increased, the ultrasonic wave's attenuation increased too. So there's the weak signal to be amplified. For the opamp's power supply is 5V, the opamp's output is nearly 4.8V. Then the slew rate of the opamp can be calculated to be 1.2V/us in 40kHz. So the precision opamp OPA211 was used to build the amplifier circuit [2-5].

Considering the noise frequency here is not near 40kHz, a passive bandpass filter circuit [2,6] with R and C was used to filter the noise. The cut-off frequencies of the highpass and lowpass part of the filter are calculated in Eq. (1), where  $f_{hp}$  is for the highpass part and  $f_{lp}$  is for the lowpass part:

$$f_{hp} = 1/(2\pi \times 510 \times 10n) = 31.2kHz; f_{lp} = 1/(2\pi \times 220 \times 10n) = 72.4kHz. \quad (1)$$

### Temperature compensation

The sound speeds differ in the different environments. To decrease the measurement error, temperature compensation was made for the ultrasonic transducer. The relationship between the temperature and the sound speed is shown in Eq. (2), where  $ss$  is the sound speed in m/s and  $temp$  is the temperature in °C:

$$ss = 331.45 + 0.061 * temp. \quad (2)$$

So in order to satisfy the ultrasonic distance measurement accuracy, the temperature compensation is needed. The environment temperature was measured using DS18B20, and then calculate the accurate sound speed now using Eq. (2), and finally calculate the distance value.

### Voice announcement

ISD1760 module was used in this design for the voice announcement, which communicated with the MCU using the simulated SPI interface from the I/O port of the MCU. From the datasheet of ISD1760, it can be found that the SPI protocol used by ISD1760 is different from the common

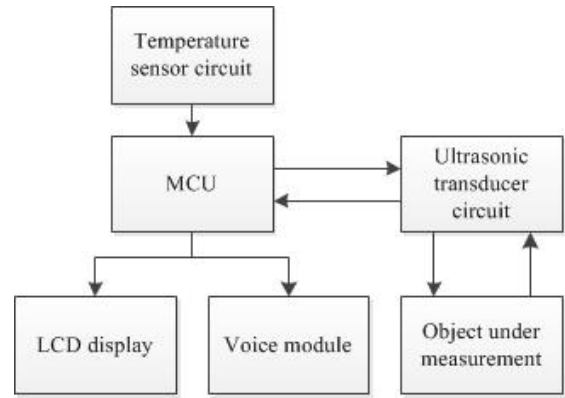


Fig. 1 System Architecture Diagram

SPI. Its special SPI protocol should be realized and programmed according to its sequence chart.

After the SPI configuration, the functions such as reset and play were realized in the MCU referring to the instruction set. For the record file saved in ISD1760 was positioned by the pointer, so when an audio file was to be played, only the pointer should be set, and reset after the play.

### Power supply module

With the increase of the measurement distance, the sine wave magnitude received also decreased. To amplify the signal better to ease the reshaping afterwards, the precision opamp with higher power supply should be used. So at first the boost converter LM2733 was used to convert 5V to 12V as the power supply.

### Software Design

40kHz PWM signal generation was controlled by the MCU programs. And the echo output detection in the receiver part was realized using input capture by the MCU programs. During one measurement, MCU transmitted the PWM signal, and start the timer, until that the 40kHz echo output has been detected in the receiver. Then the PWM signal transmission was closed, and the ultrasonic transmission time was calculated to get the final distance value measured finally. The distance result was displayed in LCD12864, and voice announced in ISD1760. The software flowchart is shown in Fig. 2.

### System Testing

#### Testing Instruments

SDS 1102X Oscilloscope, F05A DDS Signal Generator, UT803 Digital Multimeter.

#### Testing Data

The testing data is shown in Table 1. From Table 1, it can be found that this distance meter can meet the precision design target (<5mm) in 600mm.

Table 1. Distance Measurement Results of the Meter

Real Distance (mm)	100	150	250	300	350
Distance Measured (mm)	102.8	151.5	246.3	305.0	346.4
Error (mm)	2.8	1.5	4.7	5.0	3.6
Real Distance (mm)	400	450	500	550	600
Distance Measured (mm)	401.2	446.8	495.6	547.3	602.1
Error (mm)	1.2	3.2	4.4	2.7	2.1

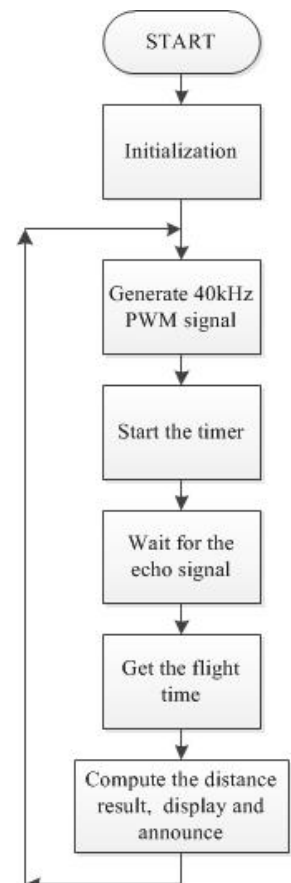


Fig. 2 Software Design Flowchart

### Lab Teaching Reformation

In the *Electronic System Innovation Design Lab* course of the Information Science and Electronic Engineering College of Zhejiang University, in order to improve the teaching effects, arouse the initiative and enthusiasm of the students, the following four teaching method reformation measures have been carried out:

1). Autonomic, Diversified, Innovative Lab Project Selection:

From the newest National Undergraduate Electronic Design Contest Project Questions, after

many discussions, some lab project questions have been chose by the teachers, which are provided to the students to autonomously select their own lab project tasks. The above ultrasonic distance meter is one of the selected projects.

#### 2). Autonomic, Diversified, Flexible Lab Project Design:

The selected lab projects have no fixed procedures and ready-made answers. After the student selected one project, he could choose the design scheme and design tools freely, from the several newest MCU and PLD development boards and their related design software provided by the teachers, according to his own situation and the course knowledge that he has learned. The students can design freely under the teachers' guidance and suggestions. In the above ultrasonic distance meter project, the students can choose STM32 or MSP430 as the MCU, and choose ISD1760 or WT588D as the voice module, or even choose HC-SR04 ultrasonic module, after the discussions between the students and the teachers.

#### 3). Lab Progress Inspection Form:

In order to reinforce the process monitoring and process evaluation of the lab course, a Lab Progress Inspection Form was designed by the teachers and provided to every student group to fill, in which the group leader should allocate the tasks for the partners, and every group member should fill in his own task progress. Every student could be evaluated and graded precisely.

#### 4). Lab Project Design Check Presentation:

In the final phase of the course, the lab project design check and presentation meeting has been implemented. Every teacher and student of the lab course attended the meeting. Every group presented their design achievement publicly. The lab course scores of the group would be graded from the teachers' evaluations and the other students' mutual evaluations.

The above measures strongly aroused the learning enthusiasm, creativity and imagination of the students. They said they have a lot of harvests from the lab course. After the lab course, some of the best students have been selected to participate in the National and Provincial Undergraduate Electronic Design Contest, and some of them won the National 2nd Prize or the Provincial 1st Prize, which firmly proved that the lab course teaching effects are obviously improved.

## Conclusion

An ultrasonic distance meter has been designed for the university electronic system design lab course and the electronic design contest, in which the temperature compensation and voice announcement functions were added. This distance meter has reached the measurement distance and precision design targets. And some lab course teaching reformation measures have been taken, which have got the obvious education improvement effects proved by the excellent student contest achievements.

## Acknowledgements

This work was financially supported by the Higher Education Class Teaching Reformation Program of Education Department of Zhejiang Province (kg2015025).

## References

- [1] Xiaoting He: *Electronic System Design (5th Edition)* (Zhejiang University Press, 2015)
- [2] Bruce Carter: *OP Amps for Everyone (4th Edition)* (Elsevier, 2013)
- [3] Sergio Franco: *Design with Operational Amplifiers and Analog Integrated Circuits (3rd Edition)* (McGraw-Hill, 2002)

- [4] Toshiaki Enzaka: *Measurement Electronic Circuit Design – Analog* (CQ Publishing, 1997)
- [5] Texas Instruments (Shanghai) University Plan: *TI High Performance Analog Device University Application Guide – Signal Chains and Power Sources* (Texas Instruments, 2015)
- [6] Toshiaki Enzaka: *Measurement Electronic Circuit Design – Filter* (CQ Publishing, 1998)