Distance Measurement of an Object or Obstacle by Ultrasound Sensors using P89C51RD2

A. K. Shrivastava, A. Verma, and S. P. Singh

Abstract— **Distance measurement of an object in the path of a person, equipment, or a vehicle, stationary or moving is used in a large number of applications such as robotic movement control, vehicle control, blind man's walking stick, medical applications, etc. Measurement using ultrasonic sensors is one of the cheapest among various options. In this paper distance measurement of an obstacle by using separate ultrasonic transmitter, receiver and a microcontroller is presented. The experimental setup and results are described and explained.**

Index Terms— **Corrections in distance measurement, distance measurement, microcontroller, sewer blockage detection, sewer inspection system, robotics, and ultrasonic sensors.**

I. Introduction

Distance measurement of an object in front or by the side of a moving entity is required in a large number of devices. These devices may be small or large and also quite simple or complicated.

Such distance measurement systems are available. These use various kinds of sensors and systems. Low cost and accuracy as well as speed is important in most of the applications.

In this paper, we describe such a measurement system which uses ultrasonic transmitter and receiver units mounted at a small distance between them and a Phillips P89C51RD2 microcontroller based system. This microcontroller is equivalent to the most popular 8051 microcontroller and hence very easily available at low cost. A correlation is applied to minimize the error in the measured distance.

Ultrasound sensors are very versatile in distance measurement. They are also providing the cheapest solutions. Ultrasound waves are useful for both the air and underwater [1]. Ultrasonic sensors are also quite fast for most of the common applications. In simpler system a low cost version of 8- bit microcontroller can also be used in the system to lower the cost.

This system has been developed and tested for use in a robotic sewer inspection system under development. Sewer network is prevalent everywhere. Sewer lines may be made of circular pipes for smaller sizes or a covered masonry channel for larger sizes. Smooth working of sewer system is a present day necessity for keeping the cities clean. Generally maximum portion of sewer pipelines are underground and sewer blockages have become quite common. The blockages have become more frequent due to the dumping of polythene bags, hair and solid materials into the sewer system [2], [3].

The current methods of blockage detection are based on manual visual inspection and inspection through CCD camera based equipments. The main limitation of these systems are that sewage pipeline has to be drained out first so that visual inspection by a personnel or by a camera based equipment can work and pictures of blockage or damage can be obtained, observed and analyzed [4].

In the sewer inspection system under development and testing this system is mounted in the front portion on an automatic robotic vehicle which will move inside the fully or semi-filled sewer pipeline. The system will compute the distance of obstacle or blockage store it and also communicate the distance or location of the obstacle or blockage to the control station above ground.

II. Related Work

H. He, et al. had designed distance measurement device using S3C2410. The temperature compensation module had also been used to improve the precision [5]. Y. Jang, et al. had studied a portable walking distance measurement system having 90% accuracy [6]. C. C. Chang, et al. had studied the ultrasonic measurement system for underwater applications. It uses ultrasonic system, laser system as well as camera based system for 3-D position control of underwater vehicles [7]. A new method of timing is described by D. Webster in 1994. He used binary frequency shift-keyed signal (BSFK) which has noise immunity [8].

III. Principle

Ultrasonic transducer uses the physical characteristics and various other effects of ultrasound of a specific frequency. It may transmit or receive the ultrasonic signal of a particular strength. These are available in piezoelectric or electromagnetic versions. The piezoelectric type is generally preferred due to its lower cost and simplicity to use [5].

The Ultrasonic wave propagation velocity in the air is approximately 340 m/s at 15°C of air or atmospheric temperature, the same as sonic velocity. To be precise, the

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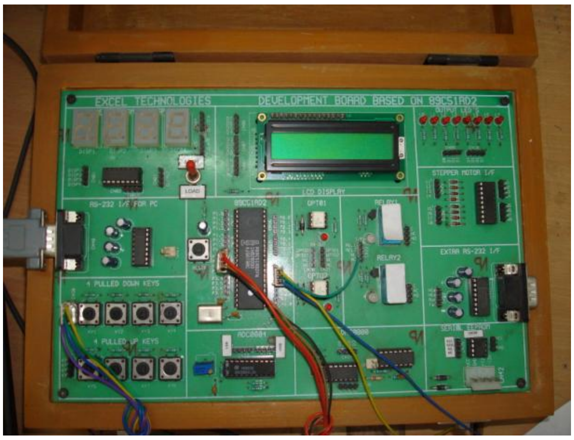

Fig. 1: System Development Kit

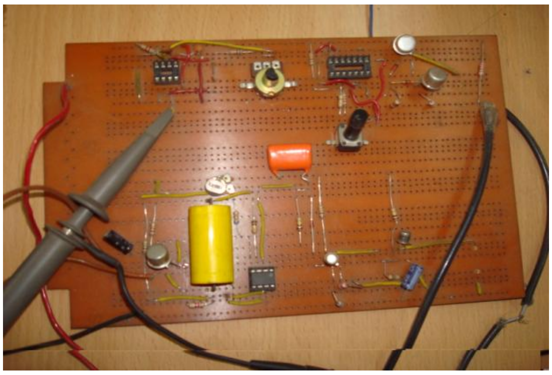

Fig. 2: Transmitter Module

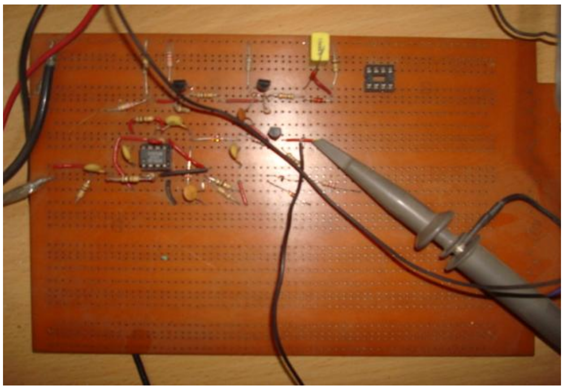

Fig. 3: Receiver Module

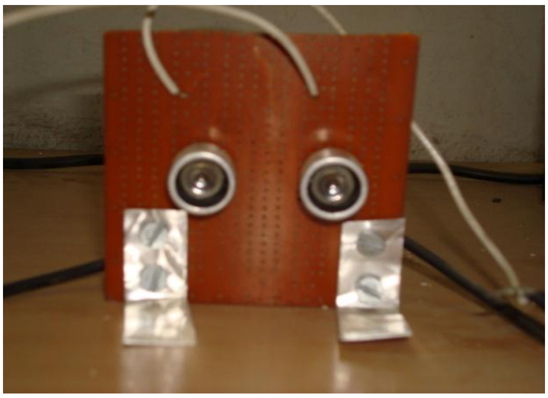

Fig. 4: Sensor Module

ultrasound velocity is governed by the medium and its temperature hence the velocity in the air is calculated using the formula below (1).

$$V = 340+0.6(t-15) \text{ m/s} \quad (1)$$

t:temperature, °C

In this study, a room temperature of 20°C is assumed; hence the velocity of ultrasound in the air is taken as 343 m/s. Because the travel distance is very short, the travel time is little affected by temperature. It takes approximately 29.15µsec for the ultrasound to propagate waves through 1cm distance; therefore it is possible to have 1cm resolution in the system [6].

IV. Experimental Setup

The system consists of a transmitter and a receiver module controlled by a microcontroller P89C51RD2. A microcontroller development kit has been used for testing of the system (Fig, 1). 40 KHz ultrasound sensors have been used for the experiments. Fig. 2 & Fig. 3 show the photographs of the transmitter module and the receiver module, Fig. 4 shows the photograph of ultrasonic transmitter and receiver sensors. The block diagram of the system is shown in Fig. 5.

In the Fig. 5, an interrupt INT1 signal initiates the system. When the interrupt INT1 signal is received, MCU (microcontroller unit) starts the timer1 and simultaneously generates the controlled 40 KHz burst pulse having a train of specific number of pulses. These pulses are applied to the amplifier circuit and after amplification; the ultrasound transmitter transmits the 40 KHz ultrasound pulses in the air in the direction of the object. These ultrasonic pulses are reflected from the object and travels back in different directions.

When these waves arrive at receiver, the signals received by the receiver is amplified and processed by the receiver module. The receiver module also generates an interrupt signal; INT2 at the instant the first pulse of the burst is received. Interrupt INT2 stops the timer1, and MCU calculates the time period between the generation of the wave and reception of the wave, which is proportional to the distance travelled by the waves. Using the formula, MCU calculates the distance of the obstacle and displays it or transfers it to the part of the total system where it is to be used for further control.

V. Experimental Results

A recording of the transmitted and received waveforms of the ultrasonic signal as displayed on a Digital Storage Oscilloscope, is shown in Fig. 6.

The transmitted wave is shown on the upper part of the Fig. 6 and the received wave is shown in the lower part of the same figure.

Measurements of travel time have been taken for a number of distances at intervals of 5 cm. Three measurments have been made for each distance. The results of the measurement are shown in Table I. The table shows the average of the three travel time measurements.

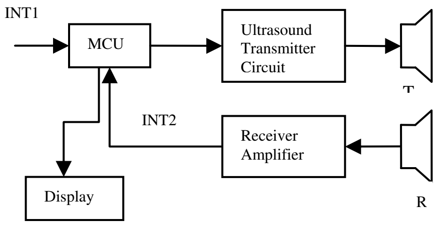

Fig. 5: Block Diagram of the System

The maesured distance is calculated on the basis of travel time. The formula to calculate the distance is shown below (2)

$$\text{Distance (cm)} = (\text{Travel Time}*10^{-6} * 34300) / 2 \qquad (2)$$

The ultrasonic waves travevelled to and from the object hence the whole distence is divided by two.

Table I: Experimental Results

S.No.	Actual Distance (cm)	Travel Time (µSec)	Measured Distance (cm)	% Error
1	5	400	6.86	37.20
2	10	690	11.83	18.34
3	15	1050	18.01	20.05
4	20	1250	21.44	7.19
5	25	1650	28.30	13.19
6	30	1930	33.10	10.33
7	35	2180	37.39	6.82
8	40	2400	41.16	2.90
9	45	2700	46.31	2.90
10	50	3000	51.45	2.90

The experimental results for the distance measurement are shown in Table I. Fig. 7 shows the graph between actual distance and measured distance. We observe that there is considerable error in the measured distance as compared to the actual distance. The %error column also shows similar results. The error is specially large at lower distances of the obstacle. The same error is also observed in the graph of Fig. 7 between actual distance and measured distance.

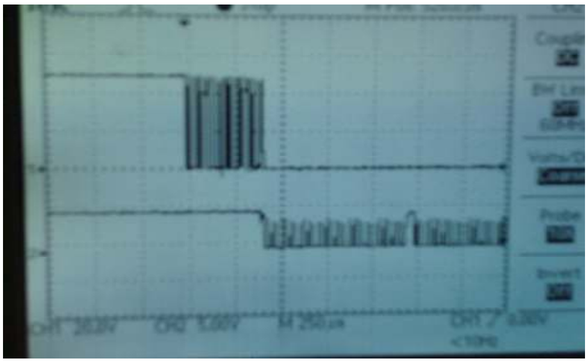

Fig. 6: Waveforms of Transmitted & Received Waves

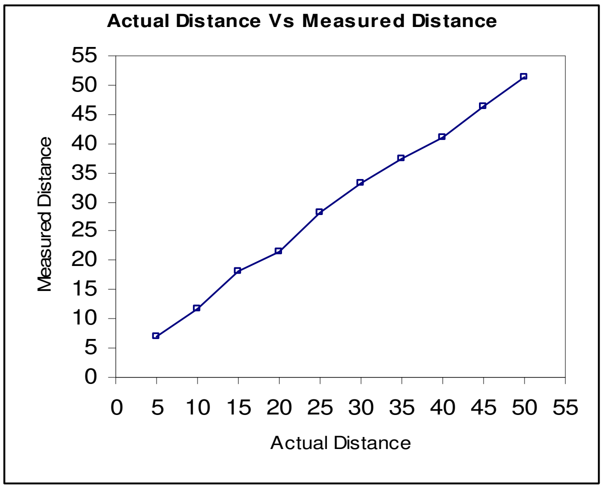

Fig. 7: Graph between Actual Distance and Measured Distance

VI. Corrections in the Measurement

The observed errors in the measured distance are due to many factors. One important factor is the inclusion of generation and processing times of the burst pulse signals. These are as follows:

1. Time period between the starting of the timer1 and actual time of the transmission of the first pulse of the burst pulse train by the ultrasonic transmitter. This happens due to two delays, first the time taken by the microcontroller to start generating the burst pulses and second the time delay introduced by the amplifier.
2. The reflected signal received by the ultrasonic receiver sensor is passed on to the receiver amplifier, which amplifies it and generates the interrupt signal INT2. This is applied to the microcontroller.

The above time periods are also included in the measured travel time. Hence these time periods have been calculated and their sum deducted from the measured travel time. This has been shown as corrected travel time in Table II, which shows the corrected experimental results.

Table II: Corrected Experimental Results

S. No.	Actual Distance (cm)	Travel Time (µSec)	Correc. Time (µSec)	Correc. Measured Distance (cm)	% Error
1	5	400	335	5.75	14.91
2	10	690	625	10.72	7.19
3	15	1050	985	16.89	12.62
4	20	1250	1185	20.32	1.61

5	25	1650	1585	27.18	8.73
6	30	1930	1865	31.98	6.62
7	35	2180	2115	36.27	3.64
8	40	2400	2335	40.05	0.11
9	45	2700	2635	45.19	0.42
10	50	3000	2935	50.34	0.67

From the Table II, it is observed that corrected measured

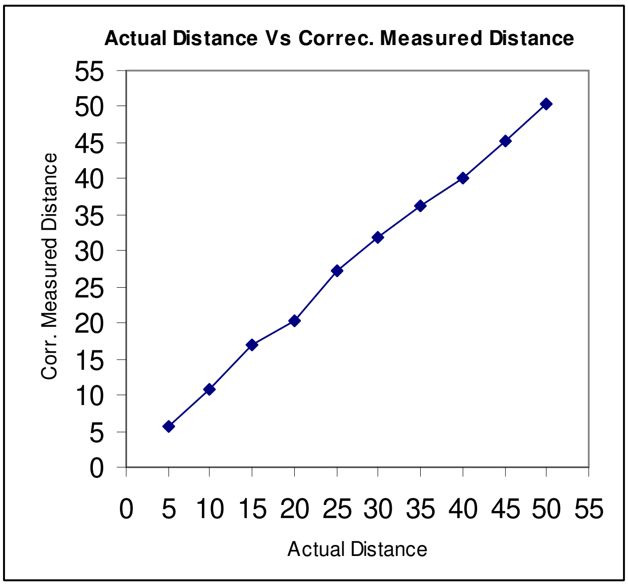

Fig. 8: Graph between Actual Distance and Corrected Measured Distance

distance comes very close to the actual distance. The corrected measured distances have also reduced the %error to small levels for long distances.

The graph for the corrected measured distance versus actual distance is shown in Fig. 8. It shows that the plotting of the graph for corrected measured distance and actual distance is almost linear.

I. Conclusion

The results show that the results for measured distance is satisfying for use in the sewer inspection system being developed. It can also be used for other devices requiring distance measurement of an object or obstacle.

As shown, the system is implementable in the robotic sewer blockage detection system. The distance of the blockage from a specified entry point in the sewer pipeline can be calculated by adding travelled distance by the robotic vehicle and the distance of the blockage from the robotic vehicle. The accuracy of distance of blockage will be sufficient for normal practical uses.

The system can be easily implemented in other devices and systems requiring the measurement of distance of an object or an obstacle from stationary or moving observation point where the ultrasonic sensor will be located.

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