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# Development of distance measurement using ultrasonic based sensors

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## Abstract

Distance had been measured in previous years using the manual method, basically using measuring tape. Though there are several ways to estimate distance to a particular point without physical contact of the obstacle. One way is the use of ultrasonic sensors, operating at 40 kHz, which is a wireless based. Ultrasonic transducers which consist of an ultrasonic transmitter and ultrasonic receiver were implemented in this work to transmit ultrasonic signals and receive the reflected signal and calculate the time it takes for a sound pulse to reach and reflect from the desired obstruction, as the reflected echo. This device calculates the distance from the transmitter to the obstacle using the speed of sound (340m/s) at 25°C-39$^0$C ambient temperature and display on a liquid crystal display (LCD) screen. Using it, we can measure distance up to 60 meters. In this work, the ultrasonic transmitter unit is excited with a 40 kHz pulse burst and expects an echo from the object or obstacle which is the intended point, whose distance we want to measure. Ultrasonic sensor measurement is among the least expensive solutions available. In this paper measurement of distance to an obstacle by using an ultrasonic transmitter and receiver and an Arduino board were presented.

**Keywords:** Ultrasonic sensors (US); Microcontroller; Liquid crystal Display (LCD); Speed of sound

## 1. Introduction

The numerical representation of an object's distance from another is called a distance. In physics or everyday use, A physical measurement of length can be referred to as distance. Optical distance measurement, electromagnetic measurements are other methods of distance measurement. In the industry distance measurement is paramount for civil engineers majorly in construction. Laser devices had also being used for distance measurement, though they are basically used to measure accurately degree of deformation and vibrations in objects [1]. An object or obstacle receives sound waves from an ultrasonic sensor and determines its distance from the ultrasonic transmitter by detecting reflected waves. In addition, ultrasonic sensors are used in robotic obstacle detection systems and manufacturing technology sensors. First generation detector arrays which are based on infrared (IR) sensors- Photon detectors were developed to improve sensitivity and response time of signals which could be applied also to implementation of distance measurement, though Robotics uses infrared sensors primarily for obstacle avoidance. Nevertheless, IR measurement devices deploy the use of measurement of the phase shift, and they offer resolution at long ranges (about 0.05m for distances up to 10m), but these are, generally expensive. The electronic based distance measurement device, which is the focus of this study, is employed to precisely calculate the distance to an object/obstacle, using ultrasonic sensors. In the industrial sector, and particularly in construction-related professions like architecture, surveying, carpentry, masonry, and locksmithing, ultrasonic distance meters are widely utilized. Based on the foregoing we can measure the

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distance to an obstacle accurately based on the formula relating distance and time based on knowledge of wave properties. Conversely, an infrared sensor, also known as an IR sensor, which can be considered for wireless distance measurement might not be suitable, based on the fact that it is an optoelectronic component that is sensitive to radiation and spectral sensitivity of this IR sensor is within the infrared wavelength range of 780 nm to 50 µm. IR sensors is now implemented in motion detectors, which are used in building services to switch on lamps or in alarm systems to detect strangers. Ultrasonic sensors are excellent tools for measuring distance without actually touching anything; they are utilized in many applications, such as measuring distance and water temperature. This is a quick and accurate way to measure tiny distances [2]. For this research, we used an ultrasonic sensor to measure the distance from the sensor to an obstacle.

## 2. Related Works

Previous work done in this field related to distance measurement will be briefly presented in this section. As suggested by [3], "The advent of Electronic distance measurement (EDM) equipment has revolutionize completely all surveying steps which caused a shift in focus and methods since it is now possible to estimate distance precisely regardless of the state of the terrain. This was actually based on the use of laser radiation which travels with speed of electromagnetic waves and distance to the obstacle was calculated based on the time taken to travel to the obstacle and be reflected back to the measuring instrument. With this method some corrections were still made based on environmental factors. It was observed that digital system measurement using ultrasonic as proposed by [4] cannot measure more than 5meter (500cm) due to some constraints. The authors in [5] develop ultrasonic sensor for distance measurement in automotive applications. In their design an ultrasonic sensor which is piezoelectric based and has ambiguity of 1mm with stumpy speed sends out a pulse signal and the reflected pulse signal from the obstacle is effortlessly captured by a comparator and compared against standard reference value. The sensor works at a speed of up to 30 m/s, although at higher uncertainty. Also the use of ultrasonic sensor for distance measurement was studied by [5] wherein an integrated system that measures the ambient temperature and an ultrasonic sensor that measures object distances between 2 and 400 centimeters was implemented. In this work the speed of sound was calculated based on the temperature of the surrounding air and the distance from the measuring device to the target object is computed based on this measured temperature. Ultrasonic distance measurement was also proposed by [6] in which ultrasonic sensors estimate the time duration between the signal sent and receiving the echo to determine the distance to an object, based on the time taken in seconds for the to and from travel of sound waves from an obstacle; using velocity of 330 m/s, the distance in centimeters is displayed on the LCD Module after the computations are completed, but this device can only measure from 0.5m up to 4 m with an accuracy of 1 cm. [7] designed a model which is based on the use of infra-red (IR) sensor based on the principle of light intensity back-scattered from objects and measures distances of up to 1m. Based on this method the target object is recognized and modelled, and the distance from the device to the target object is determined by subsequent measurements. This device can measure distances from a few centimeters to one meter, with minimal errors. [8] proposed a method for measuring distance that uses ultrasonic waves and an Arduino interface. Precisely an ultrasonic sensor interfaced with an arduino board was implemented to estimate the distance of an obstacle to the distance measuring device. The design was implemented such that it can provide 0.02m to 4m non-contact measurement function with range accuracy of 3mm. Also as suggested by [9], he used an ultrasonic sensor which that can generates frequency sound waves of 310 kHz and receives the echo which is received back from the target object. The sensing range is between 50 – 400 mm while its unusable range is 0–50 mm and the response time is less than 50 ms. In order to calculate the distance to an object, the sensor can measure the time delay between transmitting a signal and getting an echo. In this work changes in ultrasonic sensor readings was used to obtain the information on distances to obstacle, it was discovered that the ultrasonic sensors could provide a pretty accurate depiction of the item position by obtaining numerous readings at varied distances. However, it had trouble handling items that were spherical in form [10]. In this paper an ATMEGA32 microcontroller interface to an ultrasonic transmitter and receiver sensors using a comparator circuit was proposed for distance measurement using the assumed speed of sound in air at between 25$^{o}$C- 35$^{o}$C.The device was able to measure distance range of 1m-10m (1000cm).

## 3. Methodology

The block diagram of the model for our proposed design is shown in fig.1, which is an ultrasonic based sensor distance measuring device.

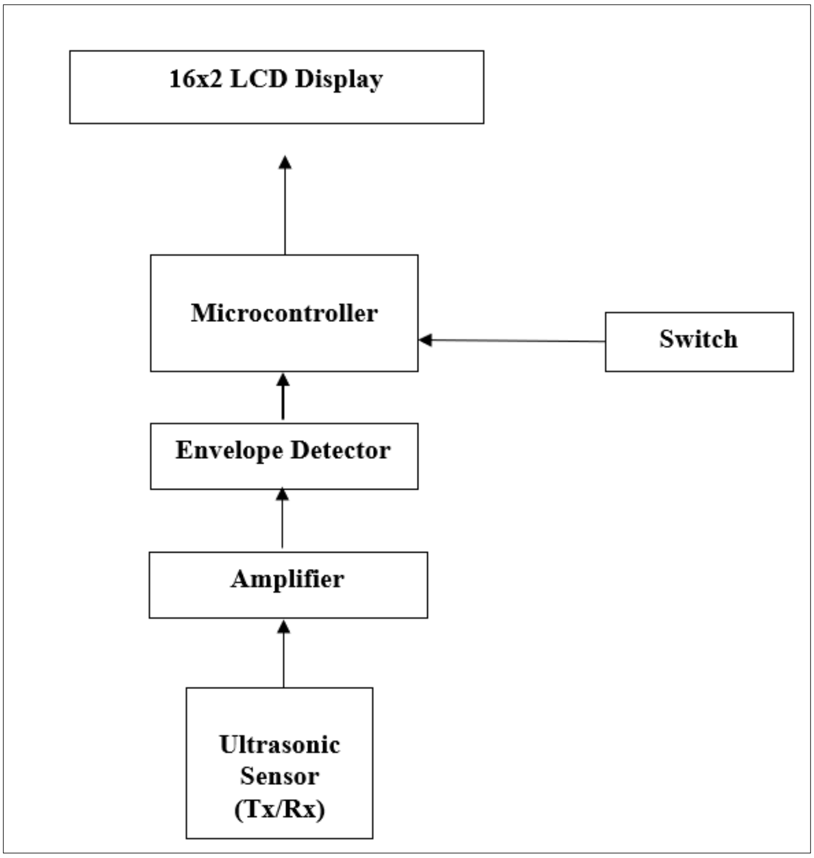


**Figure 1** Model of an Ultrasonic distance measurement device

The major components in the model in Figure 1 include The AVR ATmega 32 Microcontroller, Transmitter Driver, Ultrasonic Receiver, Amplifier Circuit, Ultrasonic Transmitter, Envelop Detector, Comparator (embedded in the microcontroller module) and LCD. The envelope detector, amplifier and the comparator all embedded on an arduino board. The Microcontroller is the heart of the system which is configured to use a passive component to create a 40 kHz electrical signal that is supplied to the transmitter. Following the generation of the signal burst, the ultrasonic transmitter receives the electrical signal at 40 kHz and generates ultrasound waves. As these waves travel through the atmosphere, any obstruction causes the signal waves to be reflected back to the receiver. The reflected ultrasound is to electrical signals of the same 40 kHz frequency by the receiver. However, these can be weak signals that require processing and amplification before they can be used, the amplification is carried out by an embedded amplifier which receives the weak signals. Direct current signal is accomplished by an envelope detector connected to the amplifier. This signal is transformed into square wave form by a comparator. The output from comparator alternates from low level to high level. This output is fed to microcontroller, the amplitude of the signal is compared with equivalent value of distance to be displayed on the LCD screen, based on the code written on the microcontroller, which calculates the time for the signal to travel to and from the target object, and determines the distance of the obstruction. The distance is displayed in LCD. The displayed distance is calculated based on the general equation (1)

$$x = \frac{v * t}{2} \quad (1)$$

Though the distance measured is computed based on an average of three consecutive values, such that the values of $x$ in equation (1) is computed three times to obtain the average value, that is:

$$x_n = \frac{v_n * t_n}{2} \quad (2)$$

Where $1 \leq n \leq 3$

$$x_{actual} = \frac{x_1 + x_2 + x_3}{3} \quad (3)$$

Where $x_{actual}$ is the actual measure distance between the ultrasonic device and target object in meters, $t$ is the time taken for the signal to travel to and reflected back from the object or obstacle in seconds and $v$ is speed of sound at 340m/s. The signal amplification is assumed to have a gain of 1000, so the amplified signal is three times higher than the received signal, this account for higher sensitivity. A flow chart that describes the operation of this device is shown in fig.2.

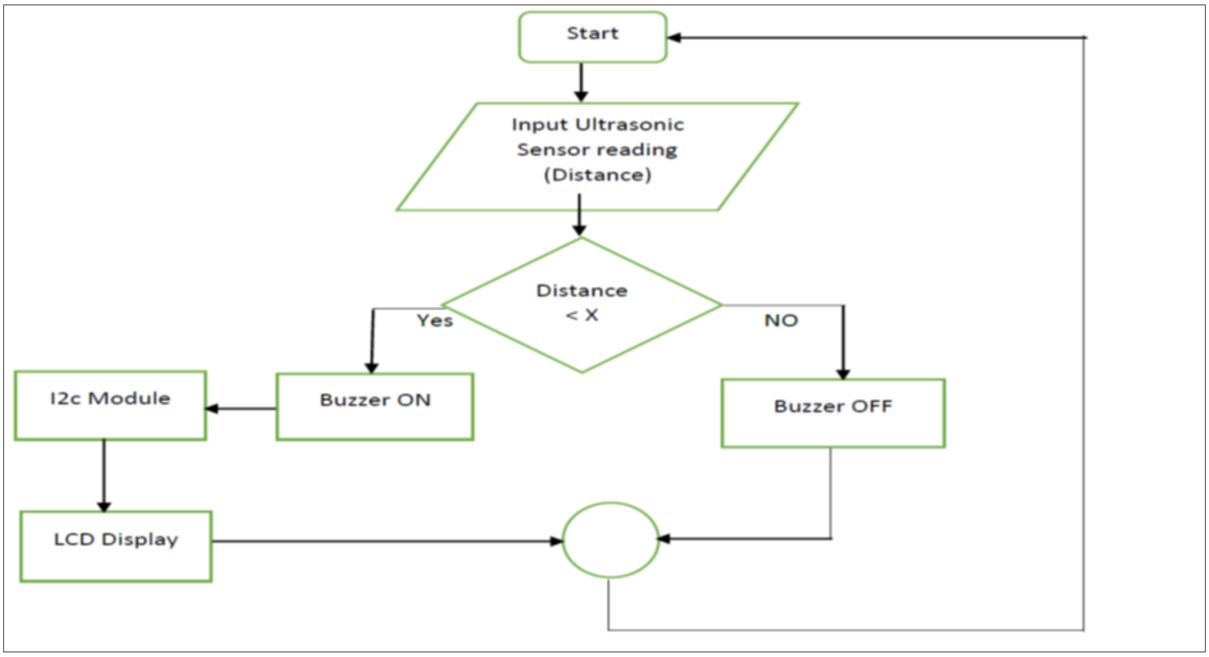


**Figure 2** Flowchart for the ultrasonic distance measurement device

It is observed that from the flow chart, the maximum distance that the ultrasonic device can measure is set by the value of x in the algorithm and that the value of x be computed three times and average value produced as an output.

## 4. Results and Discussion

The result obtained using ultrasonic distance measurement meter is tabulated in table I below, for a maximum distance of 10m. The exact distance was measured using a measuring tape, while the measured distance was carried out using the ultrasonic device. Also, the difference between the exact distance and measured distance was tabulated.

**Table 1** The difference between exact distance and the measured distance

| Exact distance x (m) | Measured distance y(m) | Difference between x and y (m) | Percentage error difference/exact)*100 ((%) |
|---|---|---|---|
| 1.0 | 1.05 | 0.05 | 5.00 |
| 1.5 | 1.55 | 0.05 | 3.33 |
| 2.5 | 2.58 | 0.08 | 4.00 |
| 3.0 | 3.05 | 0.05 | 1.67 |
| 5.0 | 5.08 | 0.08 | 1.60 |
| 6.5 | 6.59 | 0.09 | 1.39 |
| 8.5 | 8.58 | 0.08 | 0.94 |
| 9.0 | 9.57 | 0.07 | 0.77 |

Also the result in table I was compared with another result obtained by [11], displayed in table II , it was observed that our percentage error was small when compared, which invariably assumes better accuracy in our coding. The graph of table I is displayed in Fig. 3.

**Table 2** The difference between Exact distance and the measured distance

| Exact distance x (m) | Measured distance y(m) | Difference between x and y (m) | Percentage error difference/l)*100 ((%) |
|---|---|---|---|
| 0.075 | 10.05 | 0.05 | 33.33 |
| 0.10 | 0.09 | 0.05 | 10.00 |
| 0.15 | 0.13 | 0.025 | 17.20 |
| 0.17 | 0.15 | 0.01 | 11.76 |
| 0.25 | 0.22 | 0.027 | 12.00 |
| 0.26 | 0.24 | 0.02 | 7.69 |
| 0.29 | 0.27 | 0.02 | 6.90 |
| 0.36 | 0.34 | 0.02 | 5.56 |
| 2.15 | 2.03 | 0.12 | 7.69 |

The graph of table I is shown in fig.3, it was observed from fig.3 that the graph is almost a linear graph which means an almost linear relationship between exact distance measured against measured distance.

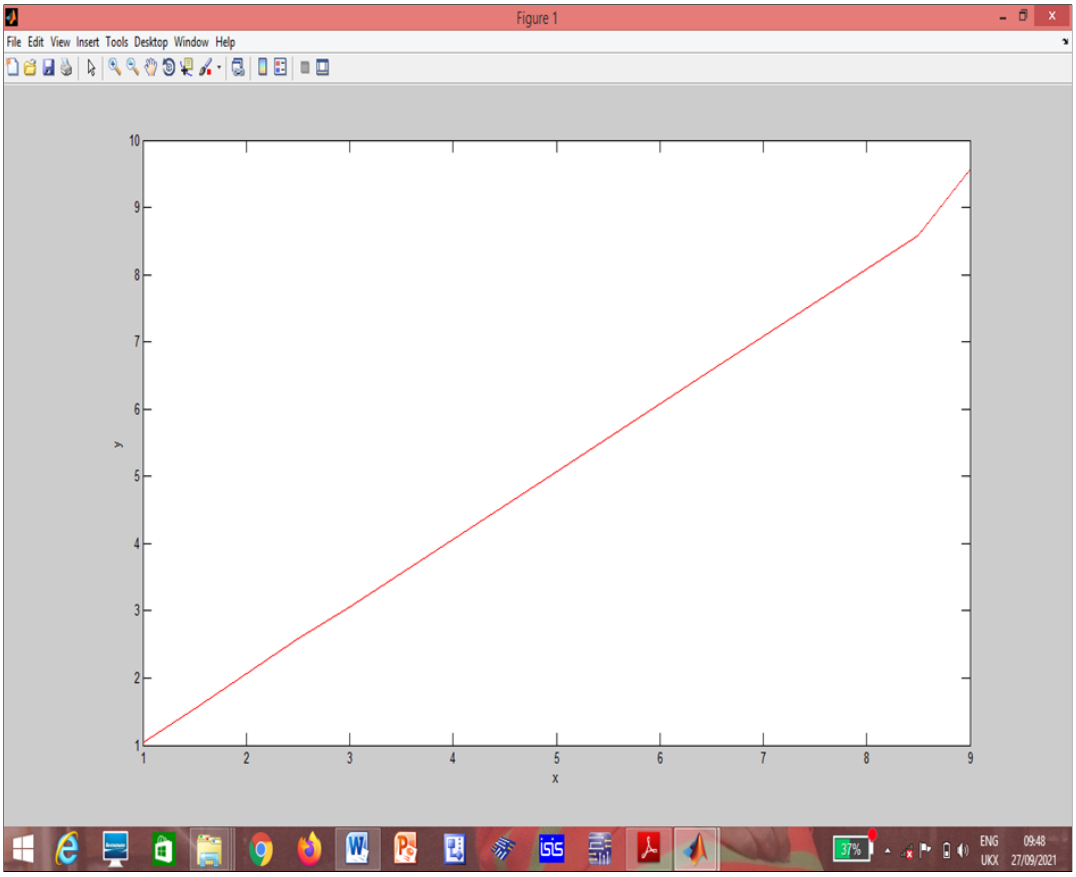


**Figure 3** Graph of measured distance (y) against Exact distance (x)

## 5. Conclusion

In this work an ultrasonic distance measurement system was developed successfully, implemented using an ATmega32 microcontroller. Distance ranging from 100cm to 1000cm can be measured using an HC-SR04 ultrasonic distance sensor. In other to enhance the accuracy of the measurement, an on-board sensor for temperature compensation, was incorporated into the work, to enhance its accuracy due to the fact that changes in temperature affect the speed of ultrasonic waves. As it is observed from the result, the use of temperature compensation device increases the accuracy of the designed system and minimizes error in measurement of the distance.

## Compliance with ethical standards

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### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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