

Design and Implementation of Water Depth Measurement and Object Detection Model Using Ultrasonic Signal System

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Abstract:- There are several ways to measure water depth without physical contact. Some devices have infrared light emitters and receivers to determine water depth. Other devices have laser-based systems which have improved accuracy and precision. Presently, the detection techniques of laser, radar, infrared ray and ultrasonic have been widely applied at the aspect of water depth measurement. The research of the water depth measurement system backing up with high ratio of capability to low price has ended at Ultrasonic Range Finder. The difficulty in measuring water depth and object detection will no longer be a complicated issue. A simple technique to determine water depth and object detection is described in this paper. In this project it is employed sensors like ultrasonic transducer. A mechanical part in the device is introduced which is a salient part for the project to measure the water depth. Ultrasonic transducers are connected in this part. Angle is measured through this mechanical part therefore it can conveniently determine water depth and object. This technique has provided a useful tool to more accurately to identify the water depth and object. The purpose of this paper is to illustrate the noble methodology for measuring water depth and object detection using Ultrasonic sounds to provide efficient and effective way. This paper provides researchers a good understanding of Ultrasonic signal and its characteristics to measure the depth of the water and object detection.

Keywords:- Ultrasonic Transducer, Object Detection, Water Depth Measurement.

I. INTRODUCTION

Water depth measurement and object detection has developed remarkably in the last few decades with the adaptation of new techniques and technologies – Ultrasonic Signal system (US) is one of them. Several methods have been studied and introduced by researchers for assessing the water depth and obstruction detection using Ultrasonic signal. Ultrasonic sounds are used in many ways, for various applications such as water depth measurement, flaw detection in metals, material characterization and other material malfunctions. The basic principle of US is ultrasound which uses the transmission of high-frequency sound waves [1]. When an ultrasonic pulse is generated in a particular direction if there is an object in the path of this pulse, part or all of the pulse will be reflected back to the transmitter as an echo and can be detected through the receiver path. By measuring the difference in time between the pulse being transmitted and the echo being received, it is possible to determine how far away the object is [2]. In the application, ultrasonic signals are used for object detection by producing a burst and detecting its reflections after they hit the object. Typically the frequency range for ultrasonic signals is in the range of 15-200 kHz. [3] This paper introduces water depth measurement and object detection by electronic means as it is very simple to produce ultrasonic signals using electronic circuitry and ultrasonic transducers. To measure the depth, angle for reflected ultrasonic signals is calculated. The number of the thread in the gear is figured out for this angle purpose. Ultrasonic signals have good directionality and they are easily reflected by solid objects [4]. Detection and measurement using Ultrasonic waves are accomplished mainly through the use of piezoelectric receivers or by optical means.

II. HISTORICAL BACKGROUND

The history of ultrasound can be traced to Lazzaro Spallanzani in the 1790's. Lazzaro Spallanzani wondered why bats could navigate at night and catch insects as they flew. He blindfolded them and they still maneuvered very well. He then plugged their ears and found that they bumped into obstacles. He concluded that their primary mode of navigation was hearing. He deduced that they must emit ultrasound waves that are inaudible to humans and listen to the echoes to determine distance and direction of objects. This idea was received by his fellow scientists with ridicule and skepticism. Spallanzani was proven right just before World War II when Griffen and Galambos, two Harvard students recorded directional ultrasound emitted by bats with a sonic detector. [5] In 1801, physicist Thomas Young worked with light and found that light waves can be shifted so two beams can either combine to become stronger or cancel each other out. Jean-Daniel Colladon a Swiss physicist/engineer discovered 'sonography' with an underwater bell in 1826. He accurately determined the speed of sound through water. However, the roots of ultrasonic technology can be traced back to research on the piezoelectric effect conducted by Pierre Curie around 1880. He found that asymmetrical crystals such as quartz and rochelle salt (potassium

sodium tartrate) generate an electric charge when mechanical pressure is applied. Conversely, mechanical vibrations are obtained by applying electrical oscillations to the same crystals. [6, 7]

One of the first applications for ultrasonic wave was sonar (an acronym for sound navigation ranging). It was employed on a large scale by the United States Navy during World War II to detect enemy submarines. Sonar operates by bouncing a series of high frequency, concentrated sound wave beams off a target and then recording the echo. Because the speed of sound in water is known, it is an easy matter to calculate the distance of the target. Prior to World War II researchers were inspired by sonar to develop analogous techniques for medical diagnosis. For instance, the use of ultrasonic waves in detecting metal objects was discussed beginning in 1929. In 1931 a patent was obtained for using ultrasonic waves to detect flaws in solids. Japan played an important role in the field of ultrasonic's from an early date. For example, soon after the end of the war, researchers there began to explore the medical diagnostic capabilities of ultrasound. Japan was also the first country to apply Doppler ultrasound, which detects internal moving objects such as blood flowing through the heart. In the 1950s researchers in the United States and Europe became increasingly aware of the progress that had been made in Japan, and they began work on additional medical applications. The late 1960s and early 1970s were referred to as the sonic boom, according to Baker. During this period, 2D echo was introduced by Klaus Bom. In 1966, Don Baker, Dennis Watkins and John Reid developed pulsed Doppler, which enabled the detection of blood flow from different depths in the heart. Don Baker also was a member of the engineering teams that later developed color Doppler and duplex scanning [8]. Real-time ultrasound started to appear in the early 1980s. With this development, "Ultrasound became more believable because those not used to using it could recognize what they were looking at" Baker said. In the 1990s, the field went one step further with 3D and even 4D images that the public could interpret [9].

The first ultrasonic instruments displayed their results with blips on an oscilloscope screen. That was followed by the use of two dimensional, gray scale imaging. High resolution, color, computer-enhanced images are now common. Ultrasonic's technology is now employed in a wide range of applications in research, industry and medicine [10].

The depths of the ocean have been charted since the early days (1872-1876) of sailing using a method called sounding. A sounding line (a rope that has a weight attached) is lowered over the side of the ship. When the weight hits the seafloor, the line goes slack, and is marked at the water's surface. The weight is pulled back up and the distance from the surface mark to the weight is measured. This length equals the depth of the ocean at that point. This method of seafloor mapping is very time consuming, especially when charting deep water.

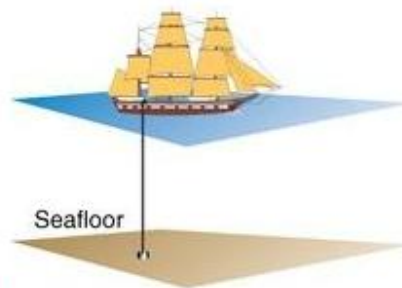


Fig 1: Old Process of Depth Measurement.

The invention of sonar changed the way that the seafloor is mapped. A combined transmitter and receiver, called a transducer send a sound pulse straight down into the water. The pulse moves down through the water and bounces off the ocean bottom. The transducer is able to pick up the reflected sound. This method of seafloor mapping is called echo sounding. Echo sounders (early 20th century) can use different frequencies of sound to find out different things about the ocean. Water depth is typically measured by echo sounders that transmit sound at 12 Kilo Hertz (KHz). Lower frequencies (3.5 KHz) can be used to look at the layers of sediments below the seafloor while higher frequencies (200 KHz) can be used to identify fish and plankton that are in the water column.

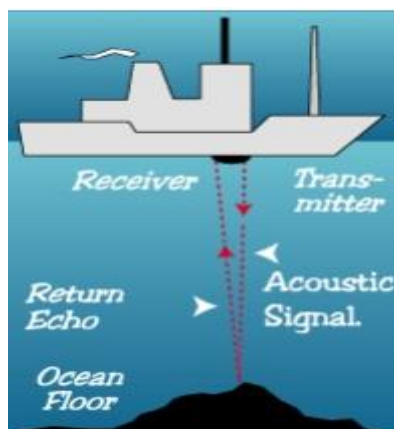


Fig.2: Echo-sounders calculate water depth.

III. CIRCUIT DESIGN

Schmitt wave generator is used to drive the Ultrasonic transducer. The transmitter is built with two NAND gates of the four found in 4093 group which are used here wired as inverters and in the particular circuit they form a multi vibrator the output of which drives the transducer. The trimmer Vr adjusts the output frequency of the transmitter and for greater efficiency it should be made the same as the frequency of resonance of the transducers in use. To receive the desired signal a receiver circuit is implemented that contained gain amplified buffer. Our ultrasonic receiver connected with gain amplifier circuit which converted the mechanical vibrations that penetrate through the material into electrical energy. These gain amplifiers contained voltage divider biasing with AC bypass capacitor. The standard voltage divider circuit AC feedback caused by resistor R₄ reduced the gain. This can be avoided by placing a capacitor (C₃) in parallel with R₄, as shown in figure-5. As the signal was relatively weak from the gain amplifier hence it was buffered by using single supply op-amp buffer circuit. A 12V DC single supply was used for the buffer circuit. Single-supply applications have inherent problems that dual-supply op-amp circuits often overcome. The fundamental problem is that an op amp is a dual-supply device, so it is a must to employ biasing using external components to center the op amp's output voltage at mid supply. This approach allows the maximum input and output voltage swing for a given supply voltage.

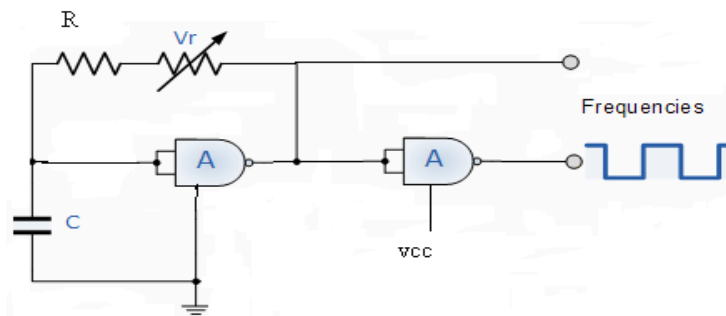


Fig. 3: Wave Generators and Output.

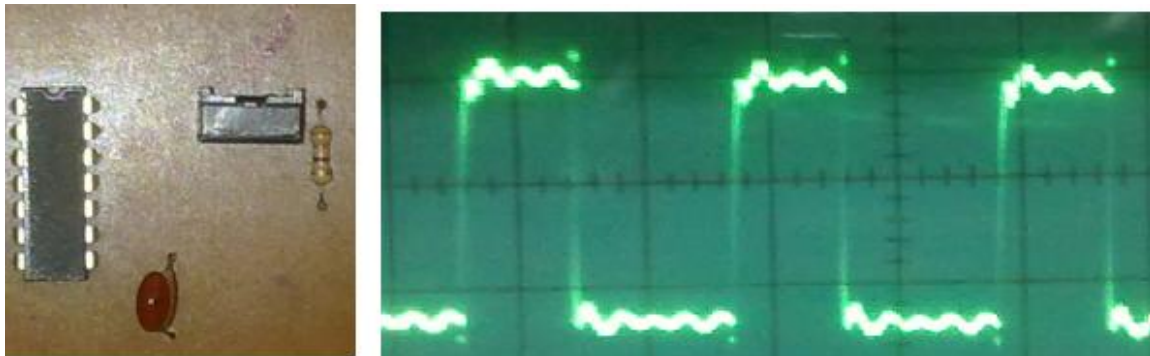


Fig. 4: Project Signal Generation and Output for Ultrasonic Transmitter.

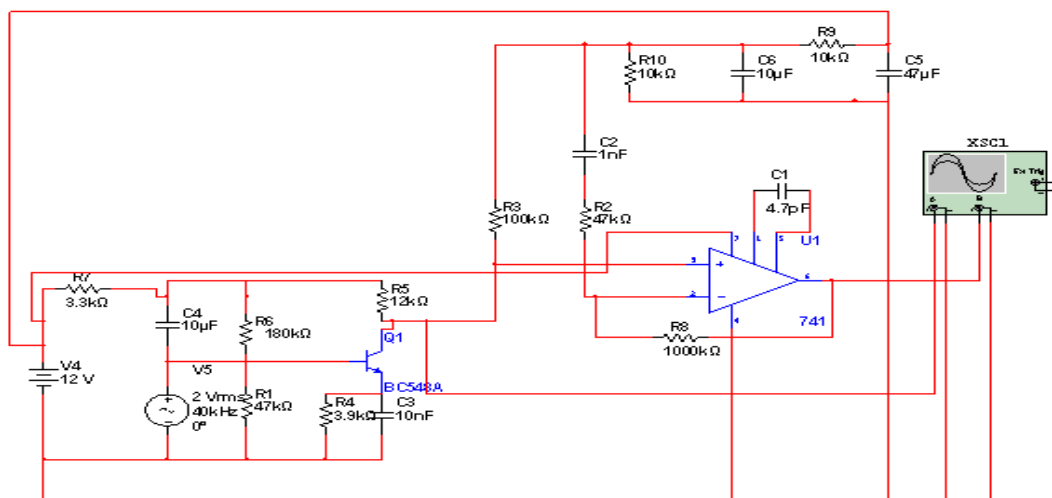


Fig. 5: Ultrasonic Transducer Receiving Circuit.

The mechanical part of this project contained three gears, consists of one driving gear and two main gears. Main gear mechanically contains 26 threads and two secondary gears mechanically contain 260 threads. This system is calibrated at the highest peak (strongest signal). The rotational gear will be rotate in clockwise direction, so that the main spool rotates anticlockwise. This type of construction made the project reliable to get the perfect angle. If the main gear rotates 360 degrees, then both the secondary gears rotate 35.9996 degree because of their thread configuration. A gear mechanism consisting of two mutually sliding gears of diameter 7 inches, fitted with the transmitter and a receiver at their centers, forms the main structure for focusing the ultrasonic wave and receiving the same in a co-plane.

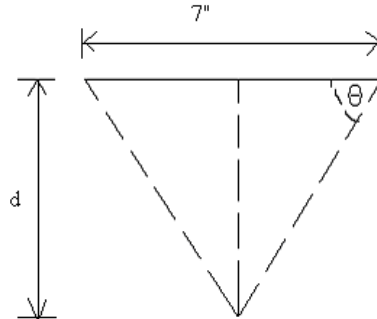


Fig. 6: Distance between two gears fitted with the transmitter and receiver.

A driving gear of diameter 0.7 inch (ratio 10:1) has been used to rotate the main gears manually. The ratio between big and small size of the gear=260:26=10:1 and total rotation of the gear=360 degree.

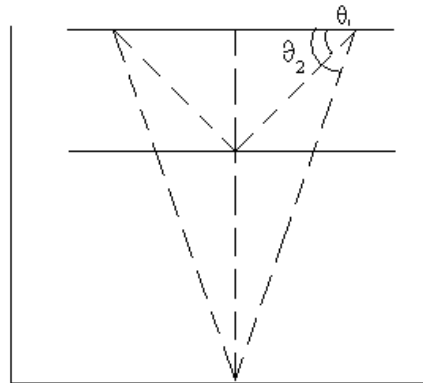


Fig. 7: Focusing angle on the water-surface and water-bed.

The mechanical view of the model is illustrated below for better understanding of the whole work.



Fig. 8: Mechanical part of the project.

From this setup, the first maximum amplitude was due to the reflection in the water surface. In second case the signal was totally lost due to noise reflection which is due to water bed. For that purpose few parameters were introduced to measure the water depth.

Here,

The number of thread for water surface level = N_s
The angle between the thread of the small size of gear,

$$X = 360/260 = 1.3846$$

Distance between transmitter and receiver, $D = 3.5$ inch
Therefore, the focusing angle, $\theta_1 = L_s * X$
So, water surface level, $L_s = D * \tan \theta_1$

Now whole depth of the water from the reference point has been calculated by using the following formula.

The number of thread for whole depth of the water from reference point = N_r and other equations remain same.

Therefore, the focusing angle, $\theta_2 = N_r * X$

So, whole depth of the water from reference point depth of the water, $L_r = D * \tan \theta_2$

From the above two formula it is possible to find the desired water depth.

The desired water depth,

$$D_w = (\text{whole depth of the water from reference point} - \text{water surface level}) = L_r - L_s$$

IV. RESULT

The experiment was done with a bucket of water to measure its depth. The bucket placed in front of the mechanical gears. For getting the maximum signal the same alignment of both transmitter and receiver are positioned. The first work is to measure the surface of the water by adjusting the ultrasonic radar signal that gives the maximum reflection. Then rotating gear is adjusted to find that minimum amplitude which will demonstrate the whole depth of the water from the reference point. Then, subtracting the surface level from the whole depth of the water gives the desired water depth value. Figure-9 shows the water depth measurement setup using ultrasonic transducer which is connected with mechanical part of the model. Figure-10 gives the whole depth of the water from reference point waveform while figure-11 represents the surface level waveform.



Fig. 9: Water Depth Measurements.

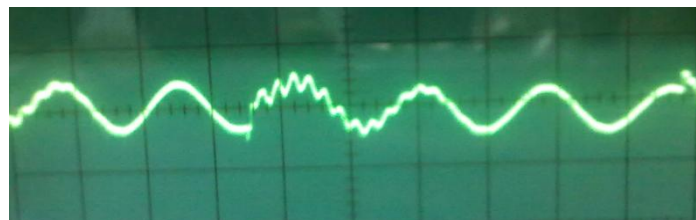


Fig. 10: Whole depth of the water from reference point wave.

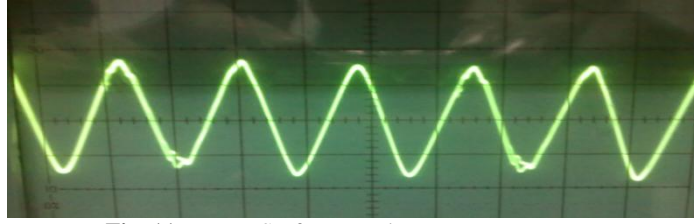


Fig. 11: Water Surface Level Measurement Wave.

In order to measure the water surface small gear has been configured until it gives the maximum value. Then the number of threads is calculated.

Here,

$$\begin{aligned} N_s &= 26 \\ X &= 1.3846 \\ D &= 3.5 \text{ inch} \end{aligned}$$

Therefore, the focusing angle, $\theta_1 = N_s * X$

$$\begin{aligned} &= 26 * 1.3846 \\ &= 35.996 \end{aligned}$$

So, water surface level,

$$\begin{aligned} L_s &= D * \tan \theta_1 \\ &= 3.5 * \tan (35.996) \\ &= 2.5429 \text{ inch} \end{aligned}$$

Again to measure the water bottom surface the small gear has been configured until it gives us minimum value and the corresponding number of threads is calculated.

At this point,

$$\begin{aligned} N_r &= 47 \\ X &= 1.3846 \\ D &= 3.5 \text{ inch} \end{aligned}$$

Therefore, the focusing angle,

$$\begin{aligned} \theta_2 &= N_r * X \\ &= 47 * 1.3846 \\ &= 65.0762 \end{aligned}$$

So, whole depth of the water from reference point,

$$\begin{aligned} L_r &= D * \tan \theta_2 \\ &= 3.5 * \tan 65.0762 \\ &= 7.5319 \text{ inch} \end{aligned}$$

So, the water depth,

$$\begin{aligned} D_w &= L_s - L_w \\ &= (7.5319 - 2.5429) \text{ inch} \\ &= 4.989 \text{ inch} \end{aligned}$$

A. Error Calculation

Error is always an endemic of any sort of experiment. Although several precautionary steps were taken but due to some limitations for introducing noise, temperature of the environment, distortion of signal etc. it was observed marginal errors during the experiment.

$$\begin{aligned} \text{Error Calculation} &= \frac{\text{Theoretical Depth} - \text{Measured Depth}}{\text{Theoretical Depth}} \times 100\% \\ &= ((5.1 - 4.989) / 5.1) * 100\% \\ &= 2.18 \% \end{aligned}$$

The value of error in terms of inch for this experiment is,

$$\begin{aligned} \text{Error} &= \text{Known Value} - \text{Experimental Value} \\ &= (5.1 - 4.989) \text{ inch} \\ &= 0.111 \text{ inch} \end{aligned}$$

V. APPLICATIONS

There are several areas where this model can fit and contribute. Water level measurement equipment is becoming increasingly important for the implementation of water conservation programs in irrigation districts, water transporting systems, sea levels detection, earthquake alarms etc. This setup is very useful in the following sectors.

- Measurement of water levels upstream or downstream of canal check structure.
- Measurement of water levels at key remote monitoring points such as regulating reservoirs and tail end canal pools of a Hydro-electric power plant.
- Measurement of water levels on “critical flow” measurement devices in irrigation district canals, such as flumes or weirs.
- Measurement of water levels for water transporting system such as ships, boats. Failure or inaccuracies of the sensing equipment in this application can have catastrophic results such as collision between ships.
- Measurement of water levels on rising sea levels. Flooding caused by more frequently occurring storm surges is an indication of rising sea levels.
- Measurement of water levels as an indicator of Climate and Global Change.
- Measurement of water levels as an earthquake alarm. Changing water levels in deep wells is recognized as a significant precursor to earthquake. An accelerated lowering of water levels (rate often exponential) in the final few months or weeks preceding the earthquake.
- To dredge the river, lake etc it can be used. It can be used also vehicle alert system when the distance between two or many vehicles are in shortest way. Thus it alerts the driver of the vehicle and prevents the road accident.
- It can be used as security alert system in the commercial place or Industrial place and made them restricted region.

VI. FUTURE WORK

The future work of this model lies in the overcoming the limitations and adding important features to maximize the safety purpose. It will be a great challenge to make the circuit water proof so that no hindrance could be caused by the weather. Secondly, other type of distance measurement sensor could be used. Such as laser type distance measurement sensor. Moreover, a DC motor controlled servo mechanism could be implemented to run the system automatically making the system more versatile and offering it new dimensions. However, to achieve higher precision in depth measurement the latest technology like DSP can be applied. This type of solution will filter the received wave form more accurately and remove the parasite reflection from the surrounding body. Furthermore, the distance measuring circuit can be modified also. The 15-20 KHz signal cannot travel for a longer distance. For a fair distance 40 KHz signal would be a better solution. Last but not the least, the quality of the ultrasonic transducer was not high enough for such precession application. The ultrasonic wave might have scattered around causing error in tending the actual surface of reflection. This added more error in calculation. However, still this model stands alone a great setup where it embedded almost all of the parameters and ended up with a result including slightly more than 2% of error only.

VII. CONCLUSION

The paper demonstrates the measurement and implementation of the depth of water and object detection using ultrasonic signal where it is focused on the angle. The angular precision technology is preferred to measure depth of the water than the time precision. The system represents the angular precision technology (using mechanical gears) that differs from other kinds of sensor. It is also made using the conventional rules by which anyone can achieve their goal by using this apparatus that it offers. The construction and operation of the circuit is simple. It is also economical for the simplicity it offers. When measuring water level in sealed tanks in a wide temperature interval the propagation of ultrasonic signals needs to be improved. It is also required to increase the range of ultrasonic signals to measure the deep depth of different water sources. If all the future works can manipulate to the device then it will be an excellent in case measuring the depth of water and object detection.

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