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STUDY OF INCLINATION ANGLE OF REFLECTOR OBJECT IN SIMPLE WATER LEVEL INSTRUMENT USING 40 KHz ULTRASONIC TRANSDUCER

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ABSTRACT

The simple water level instrument has been designed by using ultrasonic transducer and the inclination angle of reflector object has been studied. The hardware system consists of ultrasonic transducer, 16bits Atmega8535 microcontroller and 2x16 Liquid Cristal Display (LCD) monitor. By using a 40 KHz ultrasonic transducer, and assuming the sound velocity in air is 344m/s, the maximum theoritical resolution possible is 19.2mm for the maximum water level measured is 3.182m. The experimental obtained resolution is about 29.7mm. The minimum angle of object inclination given by factory for which the sound will not be reflected back towards the receiver is starting from 45^0, the obtained exact value of inclination angle in this research is starting from 10^0. The sensibility of system in digital bits number for the object inclination angle of 0^0 is 5143bits/m.

Keywords: *Non Destructif Method, Water Level, Ultrasonic Transducer*

1. INTRODUCTION

The water level measurement can be easily realized by destructif and non destructif methods. The transducer used in destructif method is generally a floating and potentiometer system [1 – 3]. We have also recently improved a MW22B multi-turn potentiometer which integrated to floating system for water level measurement. The range of measured water level is 0 – 2.7 m that corresponds to the potentiometer resistance ranged from 100Ω to 100 KΩ. The obtained vertical resolution of instrument is about 0.03 m and the error of system is ~1.11% [4].

The commonly used method for non destructif water level measurement is Ultrasonic (US) method [5, 6]. The ultrasonic transducer is also employed to detect obstacles on the way within a distance of two to three meters, and it will be possible to detect easily the object with the diameter of 3cm in a measurement distance of 3m [7].

The other non destructif method is the infra red sensor, it will automatically detect water level from a video signal of various river surroundings. A new approach in this research applies addition of frames and a horizontal edge detector to distinguish water region and land region [8].

The generally setup in distance measurement by ultrasonic transducer is shown in Figure 1, the transmitted signal will be reflected by object and received by receiver. The instrument presented by Danville and Martinez works on 480 – 600KHz frequency, they have deduced that the dept of water depends on the ultrasonic speed in fluid [5].

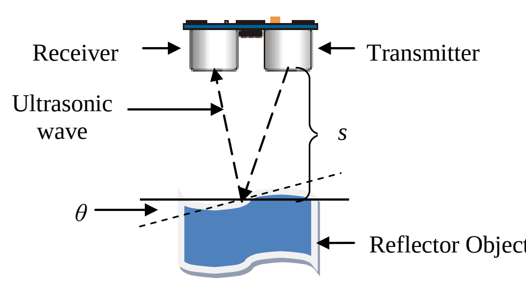

Figure 1. Distance measurement setup by ultrasonic method.

By knowing, the value of timing needed the ultrasonic pulse for going from transmitter and coming back to ultrasonic receiver, we can easily calculate the distance (*s* in meter) by using equation 1:

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$$s = \frac{v.t}{2} \qquad (1)$$

where v is the ultrasonic speed in air (344 m/s) and t is the time needed (s), where $s >> d$, d is the distance between US transmitter and receiver.

Recently, our collegues have developped the prototype of Water Level Detection System. The system is equipped with the buzzer for warning status information, it will be on active status while the real water level has just passed the reference level [9].

In this research, we have designed the simple water level detector by using the ultrasonic transducer and characterized the dependance of distance resolution to the inclination angle of reflector object.

2. METHOD

2.1. Hardware Design

The hardware designed consists of Ultrasonic Distance Sensor, ATmega8535 microcontroller and LCD as shown in Figure 2. The ultrasonic distance transducer used is 40KHz PING)))^{TM} transducer that posses theoretically the maximum measurement distance is 3m [10].

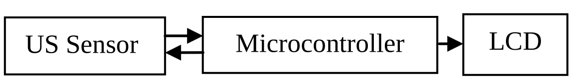

Figure 2. Design of ultrasonic water level detector.

The PING))) transducer consists of ultrasonic transmitter and receiver system. The transmitter system of transducer works by emitting the 40KHz ultrasonic pulse, it will be reflected by water surface and then come back to the receiver system of transducer (the design as shown in Figure 1). In this research, we use the 16bits Atmega8535 microcontroller as principal controller of signal, as shown in Figure 2. During this time, the microcontroller provides independently an output pulse and that will be automatically stoped when the reflected pulse is detected. Hence the total of pulse corresponds to the total time needed by ultrasonic wave for traveling from the transducer to the object and coming back to the transducer.

The microcontroller (PB0) will send the high pulse to the ultrasonic transducer and making it in activ condition (Figure 3). In the same time, the sensor will transmitt the 40kHz ultrasonic pulse, then the microcontroller send the pulse by 200 μs of width. While the reflected signal has been received by the receiver, the PING))) transducer sends the high pulse to the microcontroller, and automatically the pulse counting will be stoped. The total of pulse will indicate the total time needed for transducer as principal calculation in distance measuring, this process will be affected by the microcontroller. The calculation result of microcontroller will be shown on LCD.

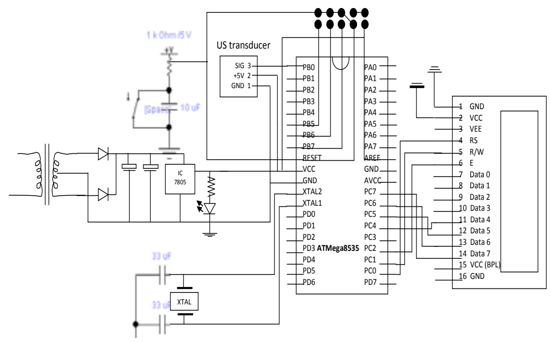

Figure 3. The realized circuit.

The method used in studying the resolution and object inclination angle is shown in Figure 1. During the ultrasonic transducer transmits the ultrasonic pulse to the reflector object in fixed distance, the reflector object will be turned slowly, and the receiver pulse will be read as a function of reflector object angle (θ). The sensiblity of system is obtained by displacing the distance of the reflector object without angle inclination.

2.2. Software Design

The software design in this research is destined to control the PING))) transducer works, to process the internal signal and to show the output signal to the LCD monitor in water level value. The used software is the CodeVisionAVR based on C compiler software.

3. RESULTS AND DISCUSSION

3.1. Calibration of System

The calibration of system is very important in order to easily calculate the real distance shown on LCD monitor. During the calibration of system the angle of reflector object is fixed in 0^0. The result of calibration is shown on Table 1, the time given on table 1 is the time needed for going from

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transmitter and coming back to receiver. The real distance (s) is directly measured as calibrator value, s' is the value of calculated distance and the s'' is the distance shown in LCD monitor of realized instrument. For the calibration system, we use equation 1 and the value of distance average error shown on LCD monitor is 2.27%.

Table 1. The results of distance calibration.

No	s (10^{-2} m)	t (μs)	s' (10^{-2} m)	s'' (10^{-2} m)
1	5	299	5.14	5
2	10	624	10.58	11
3	15	915	15.05	15
4	20	1206	20.74	21
5	25	1533	25.58	26
6	30	1860	31.22	31
7	35	2168	35.69	36
8	40	2487	40.85	41
9	45	2786	46.01	46
10	50	3104	51.79	52
11	55	3385	54.95	55
12	60	3715	60.46	60
13	65	3988	64.93	65

The limited distance measured is determined by angle formed between transmitter and receiver as shown in Figure 4.

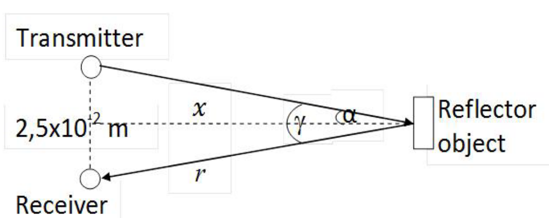

Figure 4. the angle formed by transmitter and receiver transducer in small distance.

The real reflected object distance is marked by x, when the value of x is too far (x >> d) where d= $2.5x10^{-2}$ m, the angle of γ will be very small and the $\alpha \approx 0^0$, $\cos\alpha = 1$ then $r \approx x \approx s$. In this condition, we can use directly the equation (1). If the distance of reflector object is very close, the angle value of γ will be important. The value of α and γ are also be able to be found by using:

$$\tan\alpha = \frac{d}{x} \qquad (2)$$

In this research, the minimal distance of rfkector object (x) is $5x10^{-2}$ m, so by using the equation 2, we have $\alpha = tan^{-1}\, 0{,}25 \approx 14^0$. If $\gamma = 2\alpha$, the value of γ will be 28^o.

The characterization of transducer as a function of object inclination angle is shown in Figure 5 for difference distances. According with the value of bits number as a function of real distance in Figure 6, the distance measured in Figure 4 is ranged from 0.05 – 0.09m. The line charts shown in figure 4 shows that in small distance, the value of transducer respond gives the average error is ~20%. This high error value is caused by the importance influence of reflector inclination angle for small distance measured as shown on Figure 4.

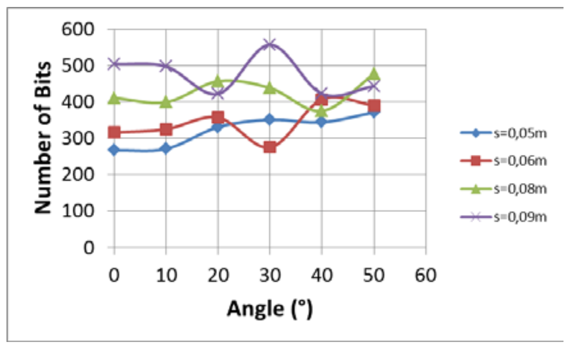

Figure 5. The number of bits counting as a function of object inclination angle for difference distances.

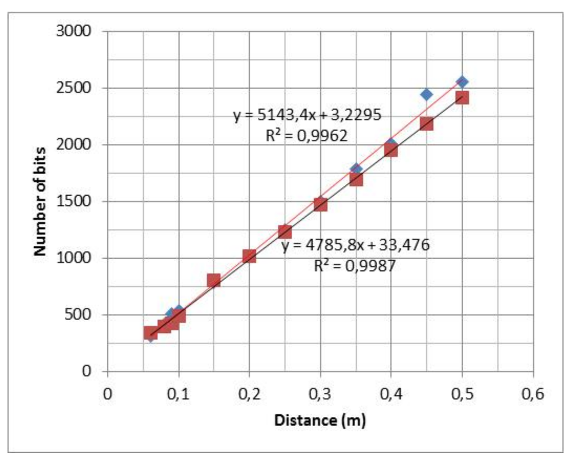

Figure 6. Number of bits as a function of real distance for 0^0 (blue points) and for 10^0 (red points) of object inclination angles.

By using the sound velocity in air is 344m/s, the maximum theoritical resolution possible is 19.2mm for the maximum water level measured is 3.182m.

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The angle of object inclination will give the significant respons if the object inclination angle is more than 10^0, the value given by factory is 45^0 [10]. For the inclination angle between 0^0 to 10^0 the resolution of system is relatively constant and starting from 20^0, the sensibility will be disordered as shown in Figure 4. The sensibility of system for the object inclination angle of 0^0 is 5143bits/m as shown in Figure 6.

3.2. Software Analysis

As we have discussed before, the software used is CodeVisionAVR C Compiler, and the principal software design is destined to control the PING))) transducer in active or off function, to calculate the real distance, and to show the real distance on LCD monitor.

The first step of software design is to control the active condition of PING))) transducer by sending the high pulse to transmitter, as given by this step:

```
counter=0;
dirsig=1;
sigout=1;
delay_us(5);
sigout=0;
dirsig=0;
sigout=1;
while (sigin==0) {}
while (sigin==1) {counter++;}
```

The fourth line, the microcontroller sends the high pulse to make an active status in delay time of 5 µs. The transducer will transmitt the ultrasonic pulse by giving the high value to ultrasonic transducer as shown in seventh line. In the same time, the counter will start to count the number of 1µs pulse during the ultrasonic wave will be reflected back towards the receiver and the counting will be stoped by giving the low signal.

To obtain the water level, the principal statement is given below:

```
 //water level measurement
distance=counter/(2*100);
dist=distance*344;
jrk=dist/100;
h1=300-jrk;
```

In this research, we use the maximum distance is $300x10^{-2}$m and the value of ultrasonic speed is 344m/s. We use the cm unit for water level in our system because the resolution of realized instrument is 19.2mm. The measured distance given by instrument as a function of real distance is given in Figure 7. The last line of software indicates that the maximum level is 300 cm, and the water level is given by substracting this value by the distance measured by ultrasonic transducer (h1=300-jrk).

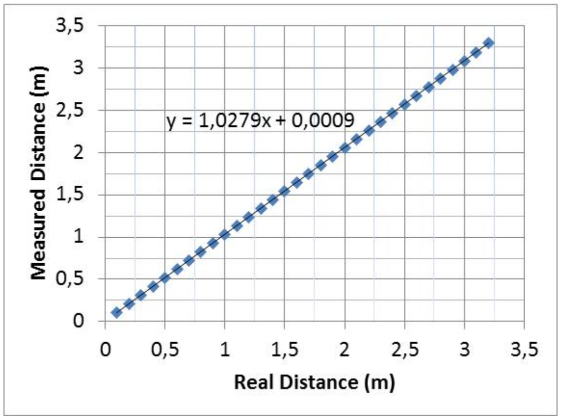

Figure 7. Measured distance as a function of reel distance obtained by inserting the calibration equation to the microcontroller software.

By using a 40 KHz ultrasonic transducer, and assuming the sound velocity in air is 344m/s, the maximum theoritical resolution possible is 19.2mm for the maximum water level measured is 3.182m. The practice obtained resolution is about 29.7mm.

4. CONCLUSION

It has been designed the simple water level instrument by using the 40KHz ultrasonic tranducer, the system possess the sensibility in bits number of 5143bits/m. The minimum angle of object inclination is more than 10^0 for which the pulse will not be reflected back towards the receiver. The obtained resolution of system is 29.7mm and the value of distance average error shown on LCD monitor is 2.27% for the distance range up to 3.182m.

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