



# Manufacture of Digital Distance Measuring Instruments Using Ultrasonic Waves

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## ARTICLE INFO

### Article history:

Received Aug 26, 2022

Revised Jun 09, 2022

Accepted Jun 30, 2022

### Keywords:

Measuring instrument,  
digital,  
Ultrasonic

## ABSTRACT

Ultrasonic sensors are widely used in various fields of application such as car alarm systems, automatic door controls, measuring the level of viscosity of liquids, measuring the tensile force on screws and others. In this study, ultrasonic sensors were applied to manufacture digital distance measuring devices that resonate at a frequency of 40 KHz above the threshold of human hearing. Ultrasonic sensors are made of piezoelectric material which has two properties, namely direct piezoelectric properties and reverse piezoelectric properties, then the sensor will change the physical quantity to electronic quantity. The principle of this tool is shooting pulses from the transmitter with the TX sensor until it hits the object to be measured until it returns to the receiver with the RX sensor. By measuring the length of time it takes for the transmitted wave to return to the sensor, then calculates the target distance using the speed of sound in the medium (air), then the conversion value will be obtained in the form of the distance. Object detection by ultrasonic sensors is influenced by several factors such as the characteristics or ability of the sensor system to reach objects, the surface area of objects and environmental conditions such as air humidity and temperature. This tool uses a seven/segment display as a display of measured distance values, with changes in distance every 0.01 meters, with the closest detectable measuring distance of 5 cm and the farthest measuring distance of 300 cm. Object detection by ultrasonic sensors is influenced by several factors such as the characteristics or ability of the sensor system to reach objects, the surface area of objects and environmental conditions such as air humidity and temperature. This tool uses a seven/segment display as a display of measured distance values, with changes in distance every 0.01 meters, with the closest detectable measuring distance of 5 cm and the farthest measuring distance of 300 cm. Object detection by ultrasonic sensors is influenced by several factors such as the characteristics or ability of the sensor system to reach objects, the surface area of objects and environmental conditions such as air humidity and temperature. This tool uses a seven/segment display as a display of measured distance values, with changes in distance every 0.01 meters, with the closest detectable measuring distance of 5 cm and the farthest measuring distance of 300 cm.

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## 1. INTRODUCTION

Measuring the distance from one object point to another object point in our daily life, we must have done it. These measurements usually use an analog measuring instrument such as a ruler or meter, but in the use of this analog measuring instrument has drawbacks, that is, sometimes we are not able to make measurements ourselves, we need someone to help. This happens because the distance of the object to be measured is far enough, this also causes the time needed in the process to take quite a long time.(SUN, nd)

In line with the rapid development of the world of electronic instrumentation, current sensor technology is also progressing. Starting from the world of industry, research, medicine to household appliances. The sensor is the sense of a tool to determine the state of the environment, namely changing physical quantities to electronic quantities(Zuhri et al., 2020). The sensor used in this study is an ultrasonic sensor, this sensor works by using sound waves as a detection medium, which resonates at a frequency of 40 KHz above the threshold of human hearing.(Mustafa, 2018), so this research will focus on making digital distance measuring devices using ultrasonic waves with various kinds of monitoring media, namely walls, wood and paper. Where the data generated from the distance measurement can be displayed on the display! seven segment as a measured distance value so visually we can immediately read it.(Noorwatha, 2020)

## 2. RESEARCH METHOD

### 2.1 Transmitter Circuit

This circuit uses two LM555 timer ICs and a 4069 inverter IC. IC 1 LM555 is an oscillator circuit that functions as a square wave generator which has high TH conditions and low TL conditions. The magnitude of the oscillation frequency obtained depends on the value of the resistor R1, resistor R2 and capacitor C used in the circuit. The output on IC 1 LM555 (third leg) is fed to an inverter IC 4069. Using this 4069 IC inverter causes the output to change from its previous state so that the high TU timer condition becomes a low 'LI timer condition, and vice versa.(Sopian et al., 2014).

The LM555 IC will continue to issue box pulses with a certain oscillation frequency without any external triggers, therefore the LM555 IC circuit in this condition is often referred to as an aslable multivibrator circuit. The time when the low TL timer is a modulating wave which will be filled with messages in the form of ultrasonic pulses, while the high Til timer is the resting time until the ultrasonic pulse is received again. Same with IC 1LM555 circuit, IC 2 LM555 circuit is a signal generator circuit to make ultrasonic pulse oscillation frequency to 40 KHz. The adjustment of the pulse oscillation frequency value is the same as in the mmus 1LM555 IC circuit. This oscillation frequency must be the same as the resonant frequency of the ultrasonic sensor specifications used(Samadikun et al., n.d.).

This is an important part before using the ultrasonic sensor. If there is no match between the oscillation frequency of IC 2LM555 and the resonant frequency of the ultrasonic sensor, then the sensitivity of the sensor will also decrease when detecting the farthest and closest distance, the magnitude of the oscillation frequency obtained can be adjusted using a VR (variable resistor). The adjustment of the sensor's resonant frequency with the oscillation frequency can be seen using an oscilloscope. The waveforms match flawlessly, indicating a match between the oscillation frequency and the resonant frequency between the output of IC 2 LM555 and the Tx sensor. This suitability can also be indicated by obtaining the modulation process that occurs between the modulating wave and the ultrasonic wave. The circuit used in this system is shown in the following figure:

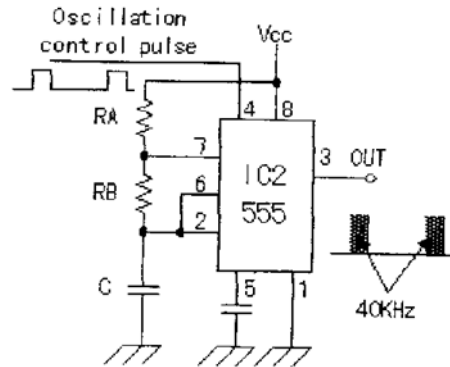


Figure 1. Signal generator circuit with an oscillation frequency of 40 KHz

## 2.2 Receiver Network

Ultrasonic waves that have been transmitted by the Tx sensor and received by the Rx receiving sensor, are then amplified by the op-amp which is cascaded twice. Op-amps that are designed without cascade have a large noise disturbance factor, such as the appearance of oscillations in the output section. By configuring the op-amp to be cascaded twice, the occurrence of these oscillations can be reduced by using the appropriate  $R_f$  (resistor feedback) value. In this circuit an inverting amplifier is used to amplify the received ultrasonic signal. The CI capacitor in the circuit has two functions. First, this capacitor will block any DC signal coming from the previous stage which is also amplified so that the circuit will be brought to an unwanted DC voltage level (not zero!) This situation can cause the amplifier to enter into saturation and distortion when given an input signal. The two capacitors help block any noise from the low frequency turrut entering the amplifier, this can be seen in the following figure

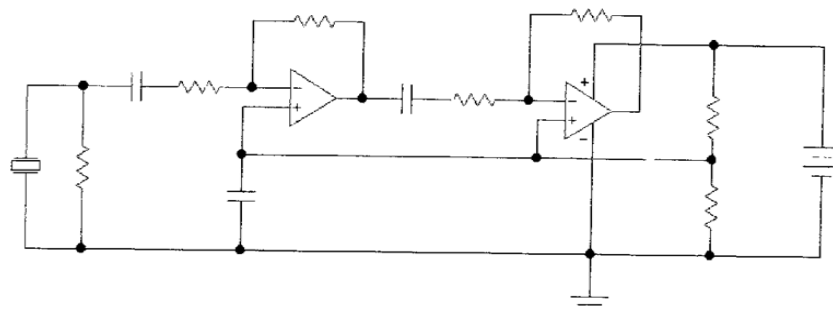


Figure 2. Ultrasonic receiver circuit

The stability of the op-amp that is used as an inverting feedback amplifier means protecting it from oscillatory disturbances, maintaining the gain according to the circuit and dampening the circuit oscillation disturbances to a minimum. The stability of the circuit is also getting better with the correct circuit layout settings. The component legs are kept as short as possible or ideally the circuit is connected directly with a short wire, because the process of connecting the wires that are not correct has an effect as an antenna. This results in unwanted incoming stray frequencies. The supply voltage supplied to the op-amp must be kept constant to obtain good stability. Most capacitors used in op-amp circuits will block any DC signal to earth that enters the circuit

The ultrasonic signal received by the receiving sensor is amplified 1000 times the input voltage by the op-amp with 2 state levels. The state of the first level uses a resistor  $R_f$  (resistor feedback) 1 Mohm and  $R_{in}$  (input resistor) 10 Kohm, so the gain is  $A_v = -R_f / R_{in}$ . So that the first gain is 100

times, for the second level amplifier resistors  $R_f$  100 Kohm and  $R_{in}$  10 Kohm are used, so the gain is 10 times. If directly given amplification of 1000 times using an op-amp, it is likely that oscillations will occur at the output of the op-amp.

### 3. RESULTS AND DISCUSSIONS

#### 3.1 Observation Results of the System Section

Testing and analysis of the tools made includes testing on the following parts: transmitter, receiver including testing of op-amp circuits, comparators (comparators), detectors, time measurement gate circuits, pulse count oscillators, counters, decoders and seven displays segments:

##### a. NE555 ICI Oscillator Circuit

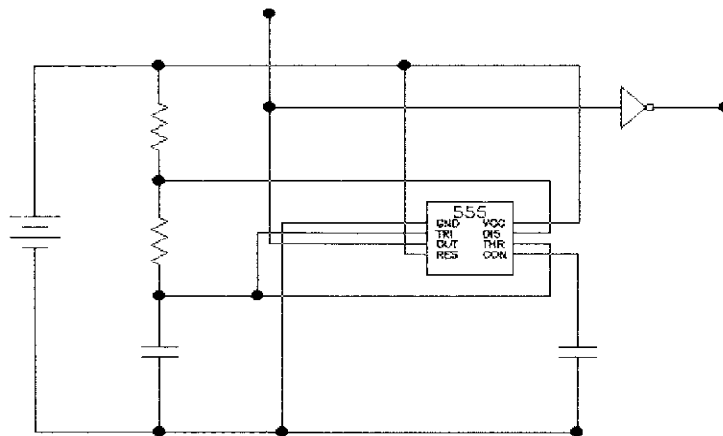


Figure 4. Measurement point of the ICI NE555 oscillator circuit

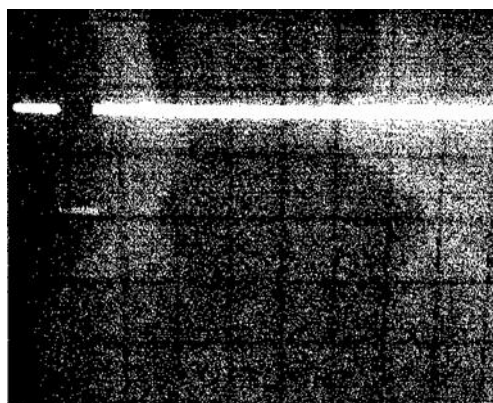


Figure 5. Oscilloscope signal display at the observation point (point I)

IC 1 NE555 in Figure 4.1 is used as a square wave generator that functions as a modulating signal. From the signal image 4.2 it is known:

Time/Dive = 0.1 ms

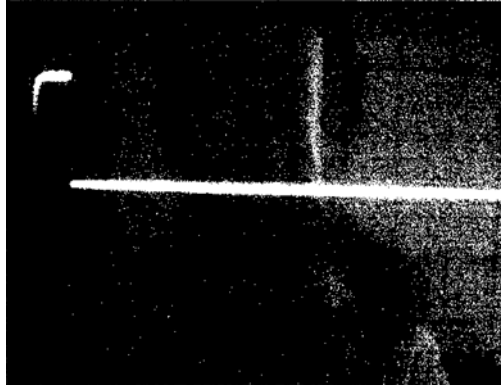
Volts/Dive = 5 Volts

Signal period  $T = \text{Time/Dive} \times \text{pulse width}$

$$= 0.1 \times 0.6$$

$$= 0.06 \text{ ms}$$

$$\begin{aligned}
 \text{Signal frequency } f &= 1/f \\
 &= 1 / 0.06 \\
 &= 16.7 \text{ KHz} \\
 \text{Peak to Peak Voltage } V_{pp} &= \text{Volts/Dive} \times \text{pulse height} \\
 &= 5 \times 1.8 \\
 &= 9 \text{ Volts}
 \end{aligned}$$

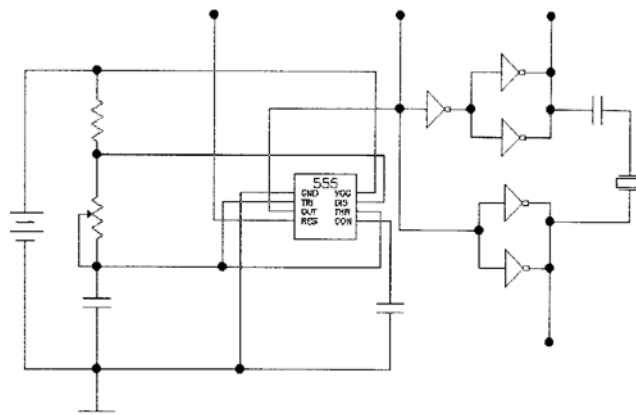


**Figure 6.** Oscilloscope display at the observation point (point 3)

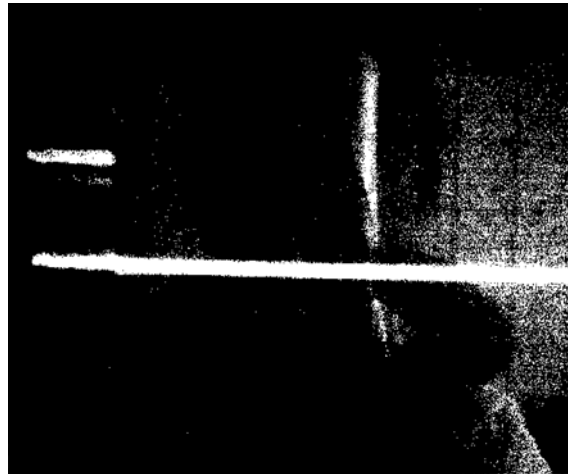
From Figure 4.3 IC3 4069 functions as a signal inverter by not increasing the peak-to-peak voltage value and its period. The value of the period  $T_{11} = 0.06 \text{ ms}$  is used as a modulating wave and a clock signal generator to determine the closest distance value that can be measured by the sensor. According to equation 2.1. then the distance is:

$$\begin{aligned}
 S &= \frac{(V \times T)}{2} \\
 &= \frac{(340 \text{ m/s} \times 0.06 \text{ ms})}{2} \\
 &= 1.02 \text{ centimeters}
 \end{aligned}$$

### 3.2 IC2 NE555 Oscillator Circuit



**Figure 7.** The measurement point for the 2nd oscillator and inverter circuit



**Figure 8** Oscilloscope display at the observation point (point 3)

From Figure 4.6 there is a signal mixing process between the 16.7 KHz modulator signal (IC1 NE555 output) and the 40 KHz carrier signal (IC2 NE555 output), where the high TH timer time period of 0.06 ms will be filled with a message in the form of a 40 KHz ultrasonic pulse. which will then be fed to the 4069 inverter IC.

Time/Dive =- 0.5 ms

Volts/Dive - 5 Volts

Period TH = Time/Dive x pulse width

-0.5x 1.2

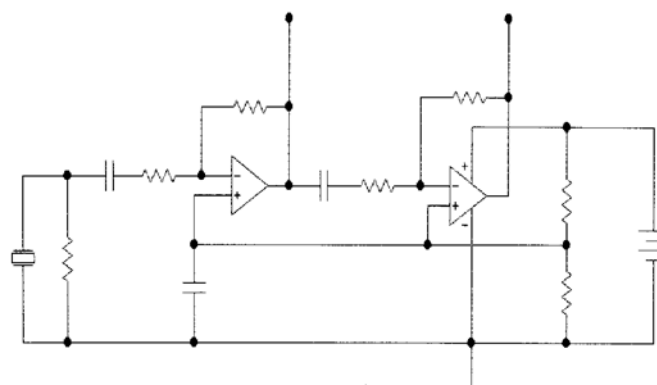
- 0.06 ms

Peak-to-peak voltage Vpp - Volts/Dive x pulse height

-5x1.8

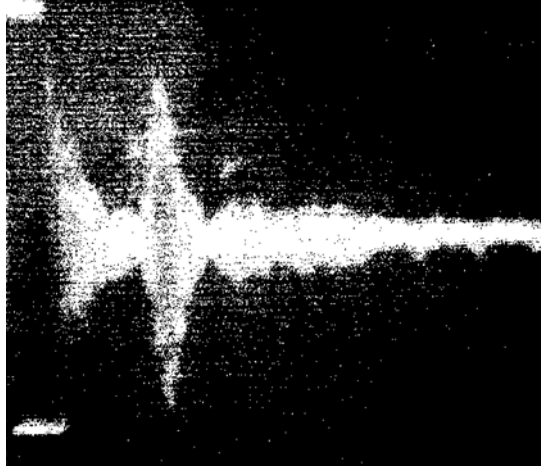
- 9 Volts

### 3.3 Receiver Network



**Figure 9.** Measurement point of the ultrasonic receiver circuit

In Figure 4.9 the signal to be amplified is in the form of AM (Amplitude Modulation) waves where the amplitude of the high frequency signal will vary according to the amplitude of the low frequency signal. The peak-to-peak voltage (Vpp) of the signal varies, this is due to the effect of the distance being measured. If the distance of the object being measured is close, the Vpp voltage will be large and if the distance to the object being measured is far enough, the Vpp voltage will be smaller.



**Figure 10.** Oscilloscope display on the RX sensor

Time/Dive = 0.1 ms

Volts/Dive = 10 mV

Period TH - Time/Dive x pulse width

- 0.1 x 0.6

= 0.06 ms

Peak-to-peak voltage  $V_{pp}$  ^ Volts/Dive x pulse height

- 0.1ms x 6

- 0.6 inVolt

At the RX ultrasonic sensor receiver, the received input voltage is still very small at 0.6 mV volts, this is done at a measurement distance of 5cm. To obtain the maximum voltage gain, an op-amp is needed.

### 3.4 Observation of System Performance

To find out how well the design of the tool that has been made responds to a distance, observations are made by providing a variable distance between the ultrasonic sensor and the object (reflective media), the test is carried out by changing every 1 centimeter distance, until it reaches a maximum distance of 300 centimeters.

**Table 1.** Measurement results with wall reflecting media

N0	Actual distance(cm)	Tool readable distance (cm)	Difference (cm)	Error percentage (%)
1	5	5	0	0
2	6	6	0	0
3	7	7	1	0
4	8	9	0	4.42
5	9	9	1	0
6	10	11	0	4.42
7	11	11	0	0
8	12	12	0	0
9	15	15	0	0
10	25	25	0	0
11	30	30	0	0
12	100	100	0	0
13	150	150	0	0
14	183	183	0	0
15	200	202	2	10.23
16	210	210	0	0
17	220	221	1	4.42
18	252	252	0	0
19	273	275	2	10.23

20	298	298	0	0
21	300	301	1	44.42

This difference can be caused because the construction of the materials of each reflecting medium is not the same, so that the reflection of sound waves (ultrasound) is also different. The magnitude of the difference in the average distance difference in measurements can be calculated by the formula:

$$X = \frac{\text{Total difference in overall distance}}{\text{Number of measurements}}$$

#### 4. CONCLUSION

Making this digital distance measuring tool can detect changes in distance every 1 cm. The shortest distance that can be displayed on a seven segment display is 5 cm and the farthest distance that can be displayed on a seven segment display is 300 cm. The difference in distance in each measurement is 1 cm to 1 cm. The difference in distance that occurs in the reflecting media (walls, paper and wood) is due to the construction of the materials of each reflector which are different in response to sound waves (ultrasonic). Adjustment of the oscillation frequency obtained in each part of the system cannot be equated with mathematical calculations. Then the adjustment of the oscillation frequency needs to be done again using one of the oscilloscope testing instruments. Adjustment of the sensor resonant frequency needs to be done with the oscillation frequency of the signal generator circuit. Both must match at a frequency of 40 KHz so that the sensor can be more sensitive when detecting the farthest and closest distances.

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