City, University of London

Department of Electrical and Electronic Engineering

LAB - MANUAL

EE3600 / EE3700 Design - III

Measure the Distance Using Ultrasonic Sensor- HC SR04

T1 LAB - 3

1.0 Introduction

In this mini-project we are going to use the HC-SR04 Ultrasonic sensor with Arduino. The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats do. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package. It comes complete with ultrasonic transmitter and receiver modules.

2.0 Required Components

- 1 x Arduino UNO
- 1 × Breadboard
- 1 × LCD 2004A Display
- 1 × Ultrasonic Sensor (HC-SR04)
- Connecting wires

3.0 Component Description

3.1 Ultrasonic Sensor (HC-SR04)

The HC-SR04 Ultrasonic distance sensor consists of two ultrasonic transducers. The one acts as a transmitter which converts electrical signal into 40 kHz ultrasonic sound pulses. The receiver listens for the transmitted pulses. If it receives them, it produces an output pulse whose width can be used to determine the distance the pulse travelled.

Figure 1: HC-SR04 sensor front and rear view

On the front of the ultrasonic range finder are two metal cylinders. These are transducers. *Transducers convert mechanical forces into electrical signals*. In the ultrasonic range finder, there is a transmitting transducer and receiving transducer. The transmitting transducer converts an electrical signal into the ultrasonic pulse, and the receiving transducer converts the reflected ultrasonic pulse back into an electrical signal. If you look at the back of the range finder, you will see an IC behind the transmitting transducer labelled MAX3232. This is the IC that controls the transmitting transducer. Behind the receiving transducer is an IC labelled LM324. This is a quad Op-Amp that amplifies the signal generated by the receiving transducer into a signal that is strong enough to transmit to the Arduino.

Here are complete specifications:

Operating Voltage	DC 5V
Operating Current	15mA
Operating Frequency	40kHz
Max Range	4m
Min Range	2cm
Ranging Accuracy	3mm
Measuring Angle	15 degree
Trigger Input Signal	10µS TTL pulse
Dimension	45 x 20 x 15mm

The sensor is small, easy to use in any robotics project and offers excellent non-contact range detection between 2 cm to 400 cm (that is about an inch to 13 feet) with an accuracy of 3mm. Since it operates at 5 volts, it can be hooked directly to an Arduino or any other 5V logic microcontroller platform.

The timing diagram of HC-SR04 is shown in Fig 2. To start the measurement, Trig of SR04 must receive a pulse of high (5V) for at least 10us, this will initiate the sensor to transmit out 8 cycles of ultrasonic burst at 40kHz and wait for the reflected ultrasonic burst. When the sensor detects the ultrasonic signal from receiver, it will set the ECHO pin to high (5V) and wait for a period (width) which is proportional to distance. To obtain the distance, measure the width (Ton) of the Echo pin.

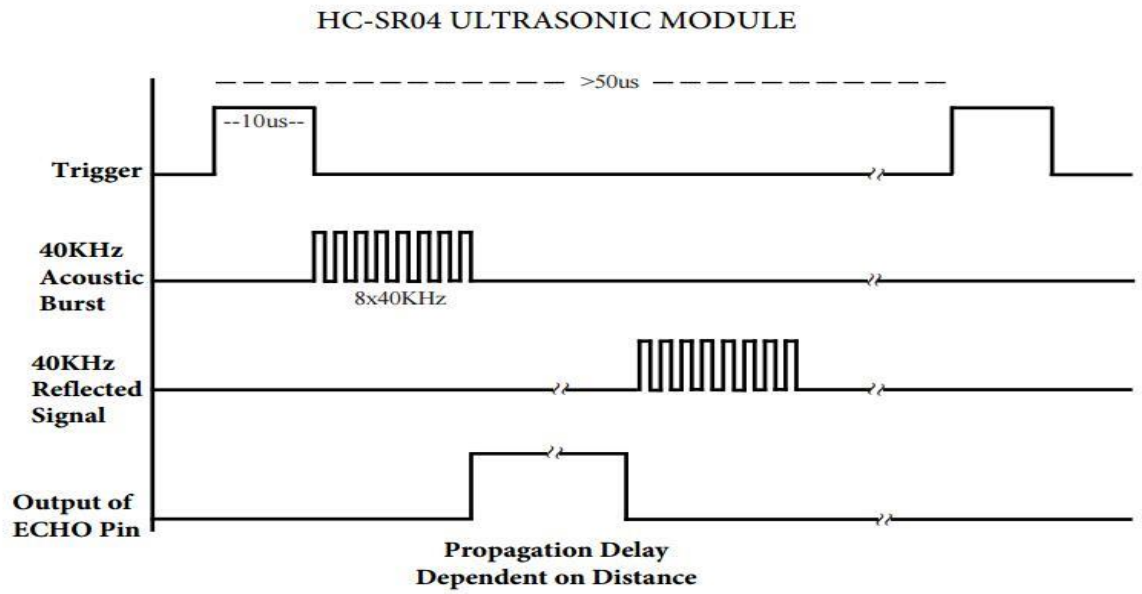

Figure 2: Timing Diagram

Time = Width of Echo pulse, in us (microsecond)
Distance in centimetres = Time / 58
Distance in inches = Time / 148

We can utilize the speed of sound, since it is known that sound travels through air at about 344 m/s (1129 ft/s), we can take the time for the sound wave to return and multiply it by 344 meters (or 1129 feet) to find the total round-trip distance of the sound wave. Round-trip means that the sound wave travelled 2 times the distance to the object before it was detected by the sensor; it includes the ‘trip’ from the sonar

sensor to the object AND the 'trip' from the object to the Ultrasonic sensor (after the sound wave bounced off the object). To find the distance to the object, simply divide the round-trip distance in half.

$$Distance = \frac{speed\ of\ sound\ x\ time\ taken}{2}$$

The time variable is the time it takes for the ultrasonic pulse to leave the sensor, bounce off the object, and return to the sensor. We divide this time in half since we only need to measure the distance to the object, not the distance to the object *and* back to the sensor (i.e. flyback). The speed variable is the speed at which sound travels through air.

The speed of sound in air changes with temperature and humidity. Therefore, to accurately calculate distance, we'll need to consider the ambient temperature and humidity. The formula for the speed of sound in air with temperature and humidity accounted for is:

$$C = 331.4 + (0.606\ x\ T) + (0.0124\ x\ H)$$

Speed of the sound at 0^o C and 0% humidity - 331.4 m/s
T – Temperature in 0^o C
H - % of Humidity (relative humidity)

For example, at 20 °C and 50% humidity, sound travels at a speed of:

$$C = 331.4 + (0.606\ x\ 20) + (0.0124\ x\ 50)$$
$$C = 344.02\ m/s$$

The accuracy of Ultrasonic sensor can be affected by the temperature and humidity of the air it is being used in. However, for these tutorials and almost any project you will be using these sensors in, this change in accuracy will be negligible.

It is important to understand that some objects might not be detected by ultrasonic sensors. This is because some objects are shaped or positioned in such a way that the sound wave bounces off the object but are deflected away from the Ultrasonic sensor. It is also possible for the object to be too small to reflect enough of the sound wave back to the sensor to be detected. Other objects can absorb the sound wave all together (cloth, carpeting, etc), which means that there is no way for the sensor to detect them accurately. These are important factors to consider when designing and programming a robot using an ultrasonic sensor.

4.0 Working of the Project

4.1 Using the ultrasonic sensor HC-SR04 to measure distance and display the results in the serial monitor

The HC-SR04 ultrasonic range finder has four pins: Vcc, Trig, Echo, and GND. The Vcc pin supplies the power to generate the ultrasonic pulses. The GND pin is connected to ground. The Trig pin is where the Arduino sends the signal to start the ultrasonic pulse. The Echo pin is where the ultrasonic range finder sends the information about the duration of the trip taken by the ultrasonic pulse to the Arduino board.

We can make the connections as shown on the schematic below.

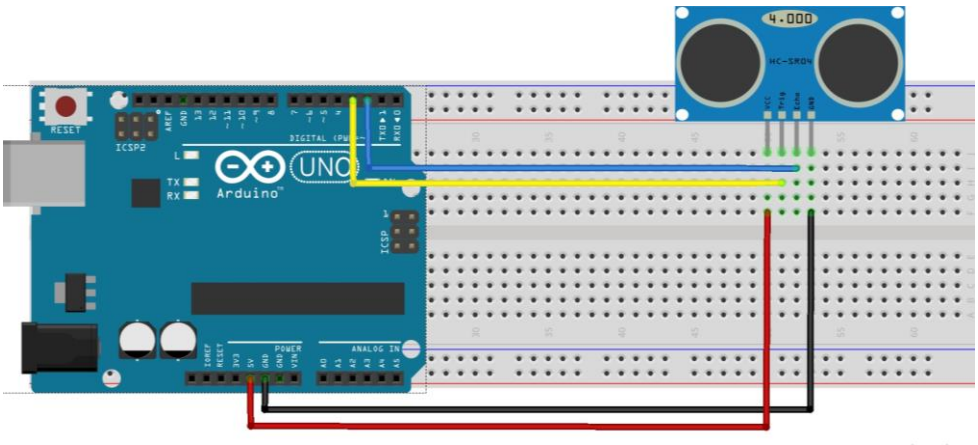

Figure 3: Arduino and HC-SR04 sensor schematic

Coming to the design, the pins of the HC-SR04 sensor configuration as follow:

No	HC-SR04 Pins	Connection to Arduino Pins
1	**GND**	**GND**
2	**VCC**	**5V**
3	**Trig**	**2**
4	**Echo**	**3**

4.2 Using the ultrasonic sensor HC-SR04 to measure distance and display the results in LCD 2004A display

We can make the connections as shown on the schematic below

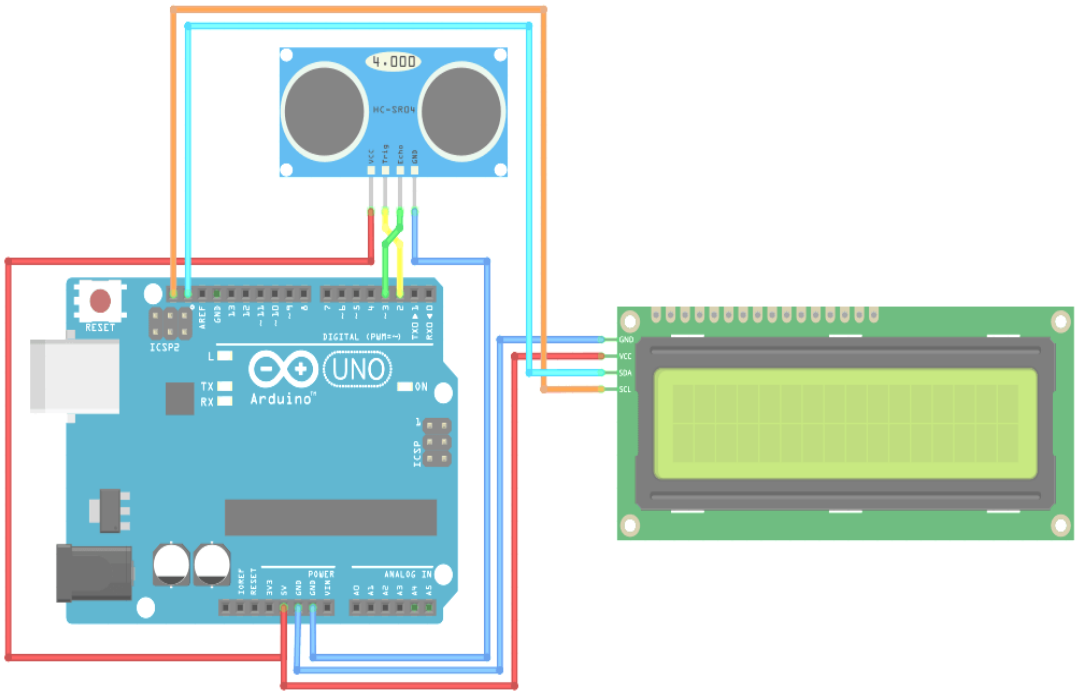

Figure 4: Arduino, display, HC-SR04 sensor schematic

Also, we can use, what we have learnt in **Lab-2** to construct the above circuit.

5.0 Code

Following the hardware setup, we need to write a program that will take care of the operation. There are special libraries available for the sensors. These libraries will help us to reduce the length of the coding and reduce the amount of time spent in writing the coding.

The program will make the Arduino to automatically read the data from the sensor and display the measured distance in the screen.

6.0 Tasks

1. Understand the overall concept of this design,
2. Familiarise yourself with the Hardware setup,
3. Understand the given sketch for this design (**for Section 4.1**),
4. Modify the provided sketch to display the results on the LCD (**for Section 4.2**),
5. Your measured value should be displayed on LCD in **centimetres** and **inches** in two different lines,
6. Future improvements and implementation of this design. **At least one of your suggestion must be linked to the Lab-2 design**.

7.0 Marking Scheme

Description	**Marks**
Total marks for this project	**10**
Hardware Design (10+20)	**05**
Oral (each member of the group will be accessed)	**05**

8.0 Sample MCQs for Quiz

8.1) Which 2 pins in the Ultrasonic sensor transfer the data to Arduino board?

1) V_{cc} and Trig
2) Trig and GND
3) Trig and Echo
4) Echo and V_{cc}

8.2) What is the baud rate (bits per second) set in given sketch for the Lab-3?

1) 38400
2) 19200
3) 4800
4) 9600

8.3) What is the operating frequency for the Ultrasonic Sensor **HC-SR04**?

1) 14 kHz
2) 24 kHz
3) 40 kHz
4) 44 kHZ

8.4) What is outcome of **delay(500) command** in the Arduino program***?***

1) Delay an operation by 500 minutes
2) Apply the delay to pin 5 without any time delay
3) Delay an operation by 8.33 seconds
4) Delay an operation by 500 milliseconds

End of Lab - 3