EEN G18020 Ultrasonic Lab
Week 1 - Characterisation

1 Introduction

In this project you will design an ultrasonic distance measurement device. The laboratory experiment will contain 8 sections to be finished within 7 weeks and leave one week for presentation. The laboratory sheet contains the instructions for all tasks you have to perform, and the appendix contains relevant background knowledge to this laboratory. After finishing each section, make sure you show all your work to a laboratory demonstrator.

To measure distance we use the time-of-flight technique. The measurement process can be summarised as follow:

1. send out an ultrasonic signal.
2. the signal will be reflected back by the surface of any object.
3. a receiver will receive the reflected signal.
4. the micro-controler calculates the time difference between the sent and received signals (time-of-flight).

By knowing the speed of sound and time-of-flight, the distance can be easily measure by the following equation:

$$d = c.t \tag{1}$$

where

d= distance travelled (round trip)

c = Speed of the wave propagation

t = time-of-flight

In this project, you will be using ultrasonic transducers to transmit and receive ultrasonic signals.You will be required to build circuits to: generate, amplify, send and receive these signals, and program a micro-controller to control the transmitter and process the received signal in order to measure the distance. An overview of the system is shown in Figure 1.

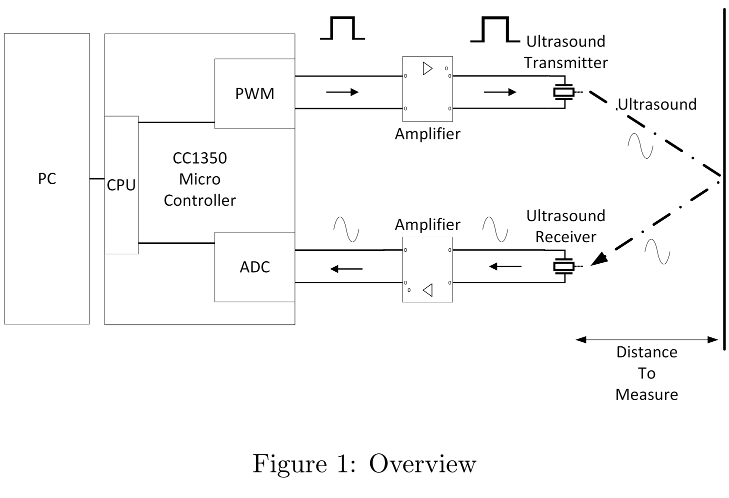

Figure 1: Overview

2 Characterising Ultrasonic Transducer

An ultrasonic transducer is a device that converts between electrical energy and kinetic energy (sound). It receive an input signal and only produce a output at a certain frequency, known as *fundamental* frequency. We must feed the transducers with a frequency close enough to its fundamental frequency to produce a significant output. Your first task is to characterise the given transducers and find their fundamental frequencies.

At the fundamental frequency, the impedance of the transducer will be close to zero, therefore we can find the frequency by constructing an impedance-divider (like a normal voltage divider, but frequency-dependent) using the transducer and a resistor, as shown in Figure 2. We can calculate the frequency response of the system as

$$\frac{V_{out}}{V_{in}} = \frac{Z_T}{Z_T + Z_R}$$

where Z_T is the impedance of the transducer and Z_R is the resistance of R. At the fundamental frequency when Z_T is low, the amplitude of V_{out} will also go low, therefore a minimal value of V_{out} will give us the right frequency. To find the frequency, we perform a frequency sweep and measure the amplitude of V_{out} at each frequency.

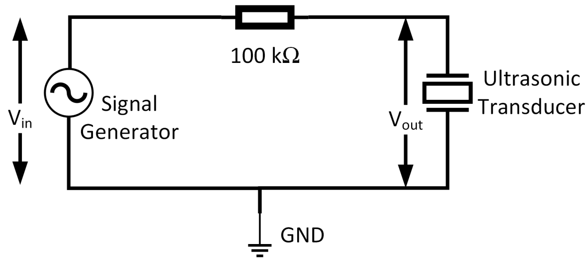

Figure 2: Circuit for characterising one transducer

Task 1: Use signal generator to generate a sinewave, with amplitude 10V peak-peak (10 Vpp), frequency changing from 35kHz to 45kHz, note down the amplitude of V_{out} and V_{in} at each frequency. Plot a diagram of the frequency response ($\frac{V_{out}}{V_{in}}$ verses frequency) and find the fundamental frequency.

3 Characterising the Second Transducer

In order to separate the transmitted and the received signal we will use two transducers: one for send and one for receive. Therefore, to make sure the two transducers are matched we need to characterise them. As the response of a transducer is the same regardless of whether it is converting from sound to voltage or vice-versa, we can use the same characterisation method for both. .

Task 2: Characterise the second transducer in the same way you did the first. Note down if there is any difference in the fundamental frequencies between the two.

4 Characterising the Combined System with Both Transducers

As our system will be utilising two transducers, the input signal will be attenuated by both transducers from input to output, as well as by the medium through which the ultrasonic waves travel (the air). Hence, we will need to characterise the combined attenuation and obtain the resonant frequency of the combined system.

We first assume the two transducer are cascaded together, i.e. the ultrasonic signal produced by the transmitter will be transmitted to the receiver directly without considering the distance in between, then the characteristic function of the combined system would be simply multiplying the frequency responses of the two systems.

Task 3: Multiply the obtained frequency responses together to get a cascaded frequency response, plot it on a graph. Interpolate to find the resonant frequency.

Connect the transmitting transducer to the signal generator, connect the receiving transducer to the oscilloscope, as shown in Figure 4. Place a reflective object at a relatively close distance (e.g: 30cm) in front of both transducers, so the ultrasonic signal bounces off and arrives at the receiver. Calculate the gain of the system as the output voltage (measured from the receiver) divided by the input.

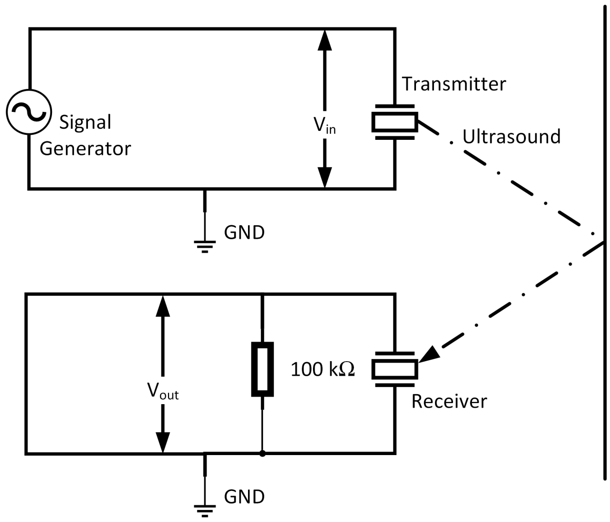

Figure 3: Circuit for characterising both transducers

Task 4: Use signal generator to produce a sine wave, with amplitude 10Vpp, use a frequency sweep to determine the frequency response of the combined system. Plot the frequency response and determine the resonant frequency. How close is it to the cascaded approximation?

Task 5: Increase and decrease the distance between the object and the transducers, determine the change in the frequency response. Based on the change in the frequency response, what is the nature of the air when modelled as an electrical component (resistor, inductor, capacitor, resistor-capacitor, etc.)?