

SPEED OF SOUND

The objectives of this experiment are:

- To measure the speed of sound in air.

APPARATUS: Computer, FFTSCOPE software, PC speaker, meterstick, sound tube apparatus, thermometer, microphone



INTRODUCTION

Sound is a pressure wave that travels in a medium at a constant speed. The medium can be either a solid, liquid, or gas. Most experiences involve sound traveling through air. As it turns out the speed of sound depends on the type of gasses through which the wave is traveling. It also depends on the temperature of the gas, but not the pressure of the gas. The speed is also independent of the frequency or amplitude of the sound. An approximation (good over temperatures usually encountered) for the speed of sound, c_s , in air in meters per second (m/s) is given by the relationship:

$$c_s = (331.4 + 0.6T_C) \text{ m/s}, \quad (1)$$

where T_C is the temperature of the air in degrees Celsius (sometimes called Centigrade). If you know the temperature in the Fahrenheit system you can convert to the Celsius system by using the conversion:

$$T_C = \frac{5}{9}(T_F - 32) \quad (2)$$

A more general expression for the speed of sound in a gas is:

$$c_s = \sqrt{\frac{\gamma RT}{M}} \text{ m/s} \quad (3)$$

Where $\gamma = C_p/C_v$ is the ratio of specific heat capacity at constant pressure to specific heat capacity at constant volume (equal to 1.4 for air), R is the molar gas constant (8.314 J/mol*K), M is the molar mass (mass per mole = 28.8×10^{-3} kg/mol for air), and T is the absolute temperature (in units of Kelvin). The two equations for the speed of sound above give similar values over the usual range of temperatures.

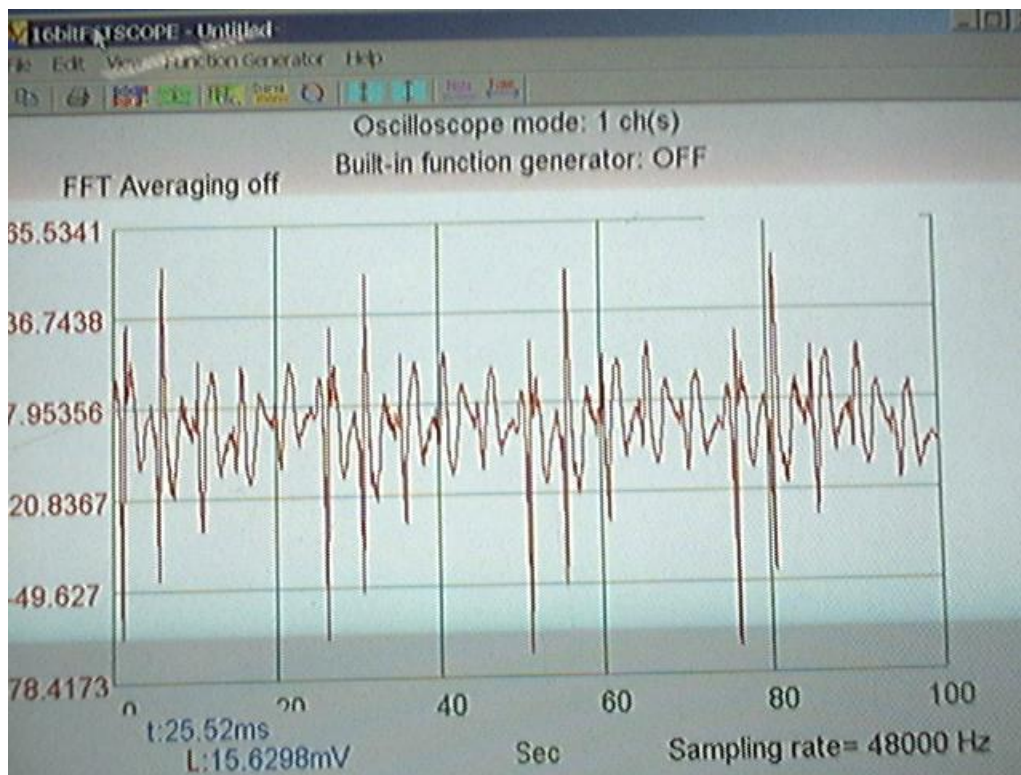
In this experiment you will use the FFTSCOPE software in oscilloscope mode to measure the time it takes a pulse (a "click") of sound to travel from a loudspeaker to a microphone. The sound pulse is controlled by the function generator option of the FFTSCOPE software which produces a series of voltage pulses that are applied to the speaker.

The sound emitted by the speaker will travel down the tube through the air to a microphone (the long white cylinder connected to the speaker by a wire) that, in turn, converts the sound pulse back into another voltage pulse. This output is displayed as voltage vs. time in oscilloscope mode of FFTSCOPE. The sound wave will propagate to the closed end of the tube and be reflected in phase. Since FFTSCOPE reads the incident pulse as a negative voltage spike, the reflected pulse will also be negative. The time delay of interest is the difference between time of the detection of the initial pulse and the reflected pulse. The distance that the sound wave traveled through the air of the tube is measured with a meterstick. So, you can calculate the speed of sound knowing the time it took the wave to travel that distance down the tube. Don't forget that the length of the tip of the microphone to the closed end of the tube must be multiplied by two to account for the fact that the sound wave is reflected before returning to the microphone.

The procedure is to click on pull down menu option "Function Generator" and select "1:100 pulse". The sound pulses are square waves of positive pressure (though as mentioned the corresponding voltage spikes detected are negative). 1:100 means that the pulse width is one one-hundredth of the period of the pulsing. So if you select "Frequency", also under the "Function Generator" menu, and set it to 40 Hz, the frequency of the pulsing is 40 Hz, its period 1/40 s, and the width of the pulse is 1/100th of 1/40 s. This is something like 25 ms which is actually observable. You can measure this 25 ms difference between incident negative voltage spikes in order to distinguish signal from noise on the trace. In other words, by measuring how far apart two negative pulses are, you can convince yourself that they represent the actual sound pulses. A frequency of 40 Hz is recommended, but anything from 20 to 50 Hz may yield optimal data.

You are to take measurements at 6 different distances of travel, determine the time intervals from FFTSCOPE, and calculate the speeds. The data for any given distance will be messy, so averaging the 6 calculated speeds is essential to arrive at a decent experimental result for the speed of sound in air. Starting with the microphone all the way in the tube (i.e. as close as possible to the speaker) is advisable because the peaks are well enough resolved to measure. The peaks will become too close together to measure when the microphone is more than half the way down the tube.

Below is a magnified view of the FFTSCOPE screen in oscilloscope mode. Note the prominent pairs of negative voltage spikes on the display. These are the incident and reflected pulses.



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LAB REPORT FORM

NAME: _____ DATE: _____

PARTNER(S): _____

In order to improve the accuracy of the experiment, make several measurements at various traveled distances. Measure the distance to the nearest millimeter. Also, measure the time differences between incident and reflected voltage spikes as accurately as possible with FFTSCOPE. Enter your data in this table and show your calculations on the back. Compare your result to the theoretical values (Eqs. 1 & 3) for the speed of sound. There should be a thermometer on the wall. If not, assume that the room temperature is 20° C.

Temperature: _____

Distance ()	Time ()	Speed ()
Average speed of sound =		

Theoretical Speed of Sound: (eq. 1) _____ (eq. 3) _____

Percent Deviation = $\frac{(\text{measured speed}) - (\text{theoretical speed})}{(\text{theoretical speed})} \times 100\%$

= _____ % (use theoretical speed from eq. 3)