World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(REVIEW ARTICLE)

Demonstration devices for measuring the speed of sound in air

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World Journal of Advanced Engineering Technology and Sciences, 2022, 06(02), 053–056

Publication history: Received on 03 June 2022; revised on 06 July 2022; accepted on 08 July 2022

Article DOI: https://doi.org/10.30574/wjaets.2022.6.2.0066

Abstract

This paper describes two simple small-sized devices for measuring the speed of sound in air. Together with a document projector, they can be used to demonstrate to students the process of this measurement.

Keywords: Physics; Demo; Device; Sound; Speed

1. Introduction

The standing wave method is used to measure the speed of sound in devices. Such waves arise as a result of the interference of two waves moving in opposite directions. The first sound wave comes from a sound source, and the second is a wave reflected from an obstacle. Waves move in a tube, at one end of which there is a sound source, and at the other is an obstacle. The interference of the incident and reflected waves forms a standing wave if the resonance condition is satisfied [1]:

$$L = n\,\lambda/2 \ (n = 1, 2, 3...),$$

Where L is the length of the tube, and λ is the length of the sound wave.

In this case, the amplitude of sound increases – the volume of the sound increases. According to the literature, the speed of sound in air at a temperature of 20^0 C is 343 m/s [2]. If we talk only about the first maxima, then for example at a frequency of $\nu = 3.0$ kHz , the first maximum is formed at a tube length of L = 5.7 cm , and the second at L = 11.4 cm. These small values allow the use of short tubes, which make it convenient to demonstrate the measurement process through a document-projector.

2. Device structures

In the first version of the device, a sound standing wave is formed in a metal tube. At one end of the tube there is a sound source – a piezoelectric emitter (buzzer). The other end is fixed on a moving plank. On this end (obstacle) there is also a small-sized electret microphone. By moving the plank, we change the position of the sound-reflecting barrier, thereby changing the length of the working part of the tube. Suppose that the microphone at a certain tube length registers the maximum sound amplitude. With a decrease in the length of the working part of the tube, the sound amplitude decreases, then again begins to increase and again reaches a maximum. Therefore, the distance between them $L(n + 1) – L(n) = \Delta L = \lambda/2$ which can be measured, is equal to half the wave length of sound. The speed of sound is equal to the product of the wavelength and frequency [1]. The speed of sound is then:

$$v = \lambda\nu = 2\Delta L\nu$$

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The electronic circuit of device is shown in Fig.1.

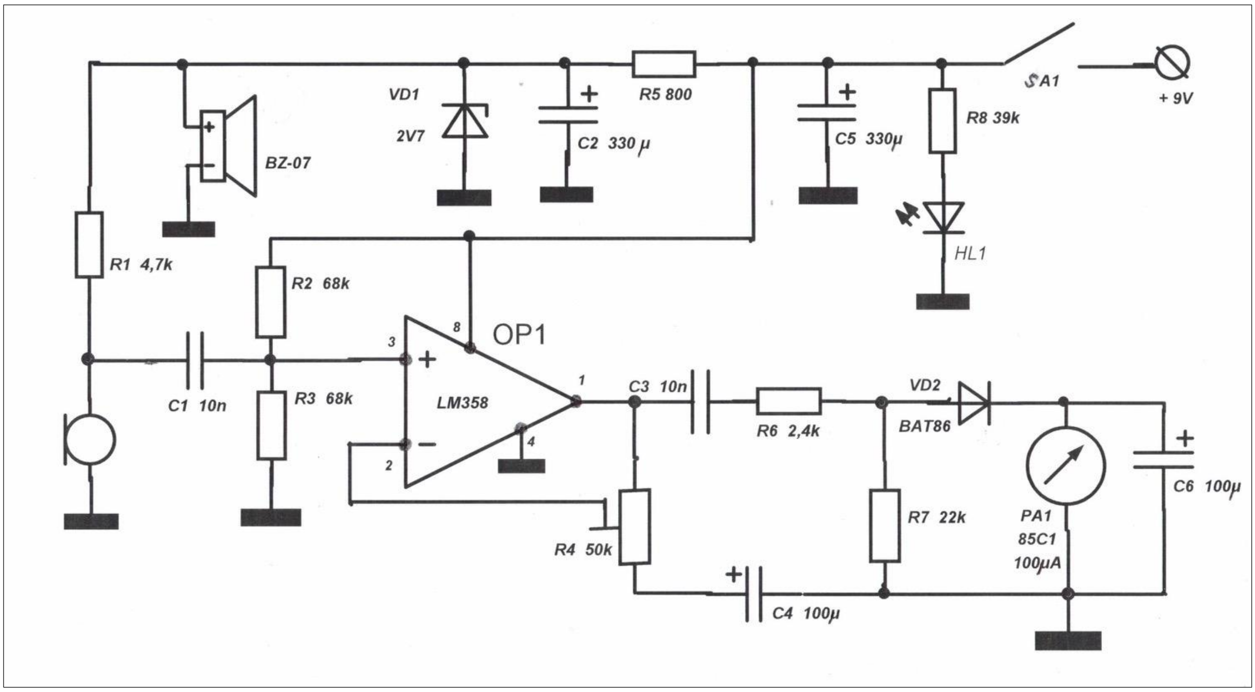

Figure 1 Electronic circuit of the first version of the device

The frequency of piezoelectric emitter is 3.46 kHz. The alternating voltage from the microphone is amplified by the operational amplifier OP1, detected and fed on the magnetoelectric microammeter PA1. The gain value is set by potentiometer R4 so that at maximum sound volume the microammeter needle does not go beyond the scale. The device is powered by 9 volt DC adapter. The speed of sound in air, measured at room temperature, coincides with the table value to within a few percent.

Somewhat better results were shown by an improved device, the electronic circuit of which is shown in Fig.2.

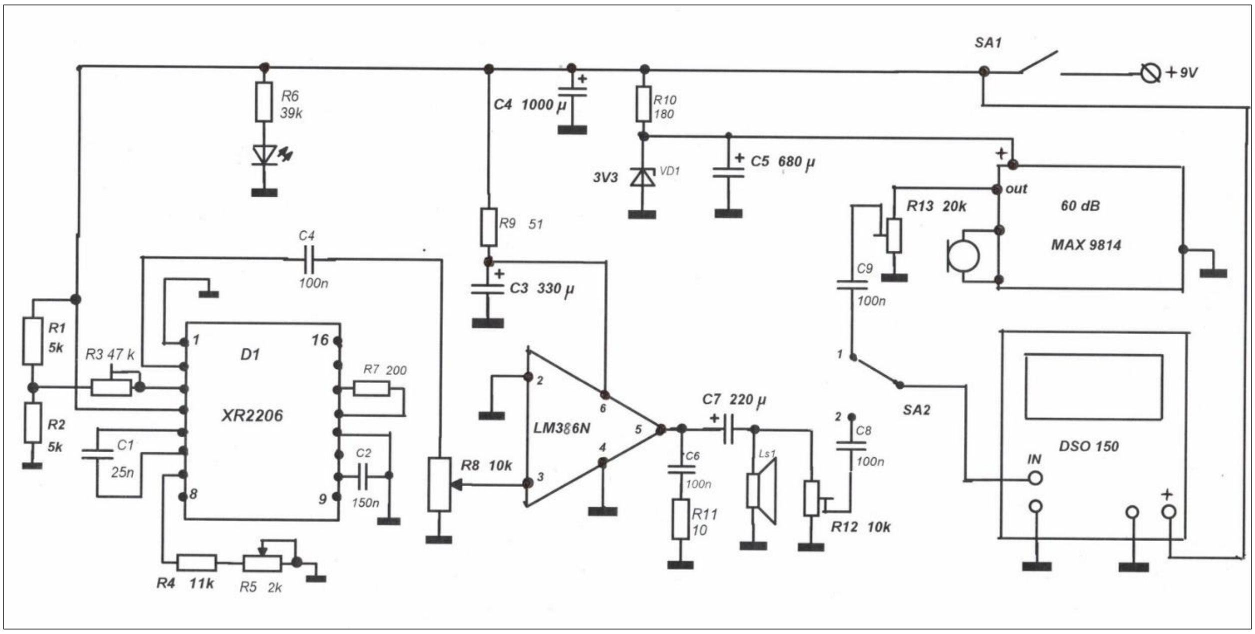

Figure 2 Electronic circuit of the second version of the device

In this version, a miniature oscilloscope DSO 150 was used to determine the maximum amplitude of the sound and measure the frequency of the used sound oscillations. From a generator built according to a well-known electronic circuit on a XR2206 chip. An alternating voltage is supplied to a power amplifier assembled on a LM386N chip. Oscillation frequency can be selected using potentiometer R5 in the range of 2.7 … 3.2 kHz. Power amplifier loaded onto a miniature speaker with an impedance of 8 Ω.

As a tube in which a standing sound wave is formed, a plastic medical syringe with a volume of 30 ml is used. In this capacity he showed very good results. Using it, it is convenient to change the length of the working part of the tube by moving the forcer which serves as a barrier that reflects the sound wave. The end of the syringe, on which the needle is attached, is completely cut off. A gap of approximately 5 mm is left between the speaker and the tube inlet. MAX 9814 sound amplifier module with electret microphone is located on the side of the tube inlet. From the output of the module, an alternating voltage is supplied with the switch SA2 in position «1» to the input of the oscilloscope. Position «2» of the switch is for measuring sound frequency with an oscilloscope. To register the difference in the lengths of the tube of the first and second maxima, a millimeter scale is used, which is a segment of a metal ruler. The appearance of the second device is shown in Fig.3.

Figure 3 Appearance of the second version of the device

At a sound frequency of 3 kHz, and a sound speed equal to 343 m/s, the sound wavelength is 0.114 m = 114 mm. The distance between the maxima of the standing wave to be measured is half as small – that is, 57 mm. If the main contribution in the error of the measured speed of sound is made by the error measuring scale (2 x 0.5 div. = 1 mm), then the relative error E will be:

$$E = 1 \text{ mm} / 57 \text{ mm} = 0.0175 \approx 1.8\%$$

This is confirmed by experience. The speed of sound determined by careful measurement differed from the value of 343 m/s by no more than 2%

3. Conclusion

Experiments carried out with these small-sized devices have shown that measurements of the speed of sound in air can be made simply, quickly and fairly accurately. This suggest that these devices can be successfully used in lectures in the process of teaching physics.

Compliance with ethical standards

Acknowledgments

The author acknowledges the contribution of the assistant who prepared this manuscript for publication.

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