ScienceScape Laboratory: Electrical and Audio Signals
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1 Introduction

Digital audio music is more popular than ever before. When you listen to your favorite CD, you just pop it into a CD player and hit the "play" button, but there is a vast array of technologies that makes this all possible.

To record a CD, the live music must first be converted to an electrical signal by a *microphone*. The microphone converts the sound or *acoustic energy* into electrical energy that can be transmitted over an electrical wire in the form of a *signal voltage*. The voltage increases or decreases in proportion to the amplitude or sound pressure of the acoustic signal. So a loud sound produces a large voltage while a quiet sound produces a small voltage. This type of signal is called an *analog* signal because the voltage is *analogous* to the sound pressure of the acoustic signal.

For a CD recorder, the analog signal is then converted to *digital* form for storage on the CD. This is a very complex and interesting process that we won't study today. Electrical engineers study how signals such as music and video can by efficiently stored and *transmitted* over computer networks such as the Internet, or radio waves such as broadcast television.

In order to listen to the CD, the analog electrical signal must be converted back to acoustic or sound energy. This is done using a speaker. The speaker performs the reverse function of a microphone converting large voltages into large sound pressure. You might be surprised to know that a speaker and a microphone are basically the same! However, most speakers are larger than most microphones so that they can produce large sound volumes.

2 Overview of the Laboratory

In this laboratory, you will investigate the use of analog electrical signals that either produce or are produced by sound. To do this, you will use two basic tools of an electrical engineer, a *signal generator* and a *oscilloscope*. The signal generator you will use is shown in Figure 1 and the oscilloscope is shown in Figure 3. You will also use headsets as both a microphone

and a speaker. This is possible because microphones and speakers are essentially the same. The headsets will act as speakers if you put an electrical signal into them, and they will act as microphones if we put an acoustic signal (i.e. sound) into them.

Warning: Do not put the headsets on your head or near you ears! The volume of sound produced in this laboratory can be quite large.

2.1   Hearing and viewing analog electrical signals

You will use the function generator to generate analog electrical signals of different amplitudes and frequencies. You will then use the headsets as a speaker to hear these acoustic signals, and you will use the oscilloscope to view these signals. The oscilloscope is an instrument that allows you to view an electrical signal by plotting the *voltage* of the signal versus time on a *cathode ray tube or CRT* screen. The CRT screen of the oscilloscope is very similar to the picture tube in a conventional television.

Figure 1: Function generator that will be used to generate audio signals of different frequencies and amplitudes.

First adjust the function generator to produce a 1 kHz (1 kilo Hertz) sine wave. A 1 kHz signal is a signal which repeats 1,000 times each second! In this case it is a sine wave, so the signal that is repeated is the sine function from geometry. The sine function is very smooth so it will generate a very pure tone.

Adjust the function generator as follows:

- Set switch to "line" to turn on the function generator.

- Set the dial (the larger wheel) to 10. This dial may be used to adjust the frequency of the tone you produce.

- Set the range to $100Hz$. This means that the frequency will be $10 \times 100Hz = 1,000Hz$.

- Set the "Function" to "Sine".

- Set the "DC offset" to "0".

- Make sure that the *coaxial cable* (the round black cable) is attached to the "High" output. This coaxial cable terminates in two clips. The red clip is positive, and the black clip is negative.
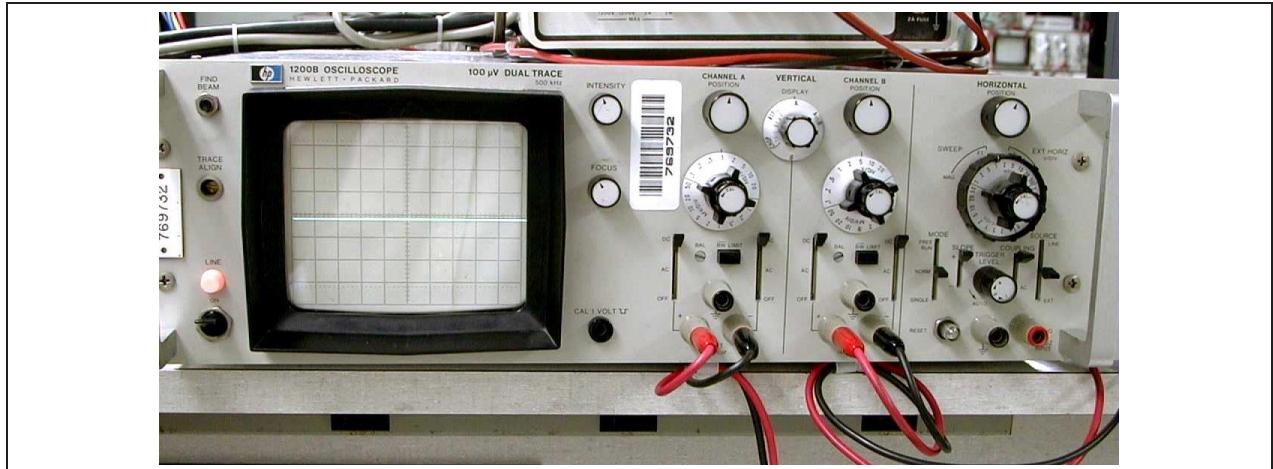
Figure 2: Oscilloscope that will be used in laboratory. Oscilloscopes are used by engineers and scientists to view electrical signals. We will use the oscilloscope to view properties of audio signals such as frequency and amplitude.

You will only be using the *Channel A* input of the oscilloscope; so you will need to set the "Channel A position" and "Horizontal position" controls. Adjust the oscilloscope settings as follows:

- Flip switch to "on"

- Channel A settings:

    - Attach two *banana plug wires* to the "+" and "-" inputs. Use a red wire for the "+" input, and a black wire for the "-" input.
    - Set the dial to a scale of 1 volt.
    - Set both input switches to "DC" (direct current).
    - Set "BW limit" to the out position.

- Vertical settings:

    - Set vertical mode to "A".

- Horizontal settings:

    - Do not attach any wires to inputs under horizontal mode.
    - Set the outer dial to "Sweep" and "X1".
    - Set the time resolution dial to 1 millisecond.
    - Set the inner dial marked "← cal" to the maximum counter-clockwise position.
    - Set the "mode" to "normal".
    - Set the "slope" to "+".
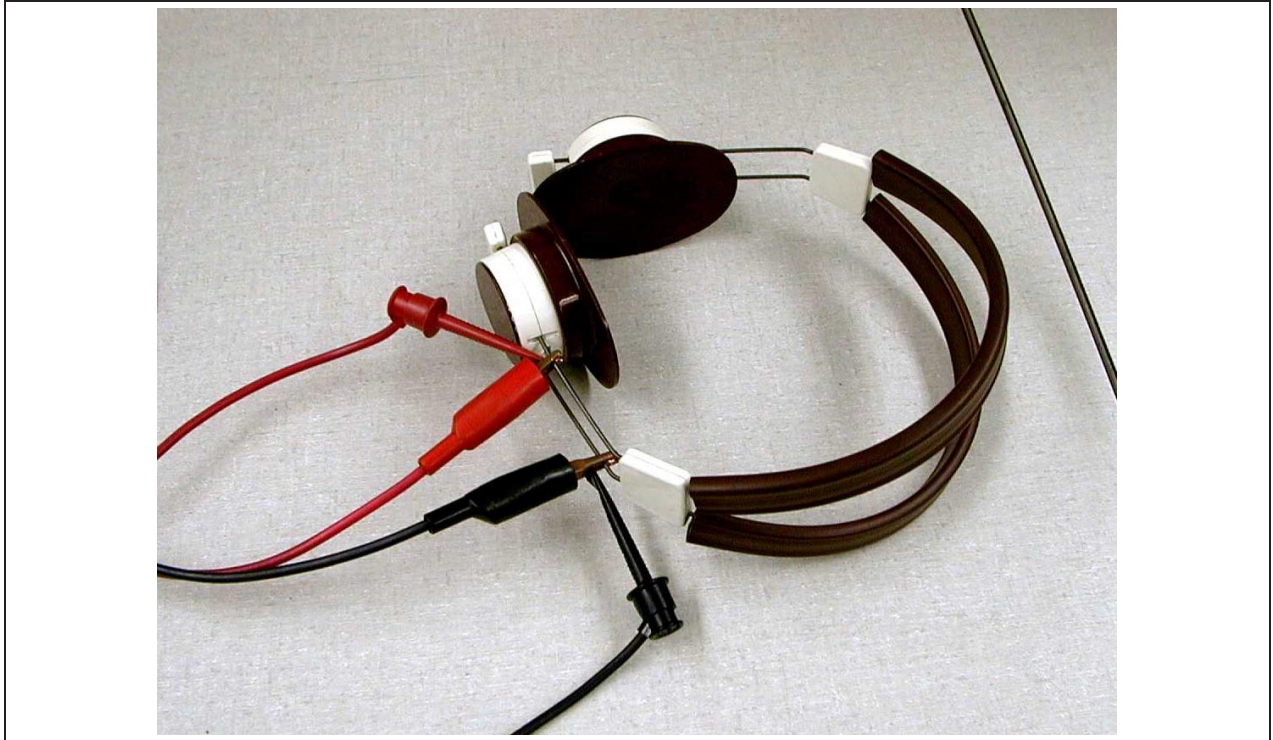   - Set the "source" to "int" (internal).

Figure 3: A picture of the headphones that will be used in the laboratory. Notice that the wires from the signal generator and the oscilloscope are clipped to the two thick wires coming from a single side.

You will use the headsets as speakers so that you can listen to the sound generated by the $1kHz$ tone. Attach the headsets and the oscilloscope to the function generator as follows.

- Attach the red clip from the function generator to either of the thick metal wires coming out of a signal headset speaker. Then attach the black clip to the other metal wire. At this point, you should hear a high pitch tone. You may want to adjust the amplitude of the tone by adjusting the "output level" knob on the function generator.

- Attach the red and black clips for the oscilloscope inputs to the red and black clips from the function generator. Be careful to leave the clips attached to the headsets so that you can still hear the sound produced by the signal.

2.2   Experimenting with electro-acoustic signals

Now that you have the function generator and oscilloscope attached to the headsets, you can listen and see how the electrical signal behave.

1. Change the amplitude of the signal by adjusting the output level.

    - How does the signal you are listening to change?
    - How does the signal on the oscilloscope change?

2. Change the frequency of the signal by adjusting the large dial for output frequency.

    - How does the signal you are listening to change?
    - How does the signal on the oscilloscope change?

3. What is the highest frequency you can hear?

    - People can only hear sounds up to some maximum frequency. This maximum frequency is different for different people, but most people can not hear sounds above $20kH$. Most young people can hear higher frequencies than older people because their hearing is better! Experiment with different frequencies and see who has the best hearing.

2.3 Generating acoustic signals

Next you will see what your own voice looks like as an electrical signal. To do this, simply disconnect the function generator from the headsets, but be careful to leave the oscilloscope connected.

1. Speak into the headset and view the signal on the oscilloscope.

    - You may need to adjust the "scale dial" and the "time resolution" dial on the oscilloscope to get the best view of your signal.

2. Try to produce a pure sine wave signal.