College Physics II

Lab 2: Oscilloscope: Superposition of Waves

Peter Rolnick with Taner Edis

Spring 2017

Introduction

A sound wave can be transformed into an electric signal by way of a microphone, and an electric signal can be transformed into a sound wave with a loudspeaker.

Though we have not studied electric signals yet, we are going to use oscilloscopes to look at them—first as a way to qualitatively study sound waves from musical instruments using a microphone, and then to quantitatively look at interference between two electric signals, each of whose shape, frequency and amplitude you can control. An oscilloscope is an electronic instrument that displays electric signals graphically and allows you to easily combine one electric signal with another and display the resulting superposition of the two signals.

You will also use a signal generator, which is a device that makes periodic electric signals with adjustable amplitudes and frequencies. It can generate three shapes: a sine wave, square wave, and a sawtooth (triangle) wave.

In this lab you will:

- Learn the basics of how to use an oscilloscope and a signal generator, both of which will be used in future labs;

- Examine sounds from different instruments visually using a microphone and an oscilloscope, noting the differences and similarities between the sounds from different instruments. (If you have an instrument you'd like to play, please bring it to the lab!)
- Quantitatively study superposition of waves (consult section 16.7 in your textbook) by adding together electric signals of known frequency and looking at the resulting superposition on the oscilloscope.

Activity 1: Musical Instruments

The whole lab section will do this together. We will play tuning forks and various instruments (if available) into a microphone, and then look at the electric signal from the microphone on an oscilloscope. In the process, you will learn the basics of oscilloscope use. As we look at the signal from each sound, we will ask two questions:

1. How recognizable is the periodicity of the signal—can you see a clear pattern which repeats itself?
2. How like (or unlike) a sine wave is the signal?

When a signal is not a pure sine wave—and the signal from most musical instruments is not—that means that it is a superposition of many sine waves: the fundamental tone plus many weaker overtones. The combination gives the unique timbre (and uniquely shaped signal) for each instrument.

To hand in for activity 1

- A list of all the instruments we looked at and, for each instrument, a picture showing what the signal qualitatively looked like.
- A comment pointing out which signals looked most like a pure sine wave.
- A brief discussion of any connection you noticed between the sound of an instrument and the shape of the signal from that instrument.

Activity 2: Signals and Superposition

First, you will find out how to hook up two signal generators to the oscilloscope, and how to look at signal one alone, signal two alone, or at the linear superposition of the two signals. Once you have become comfortable with the equipment, do the following:

1. Look at a sine wave in channel one, and measure its amplitude (in volts), then measure its period T (in seconds). Check to see if $1/T$ is equal to the frequency setting on the signal generator.
2. With the same signal as before, switch to a square wave and a sawtooth wave, and see what they each look like. When you are done, switch back to a sine wave.
3. Using the other signal generator, set up another sine wave with a frequency of about 10 times that of the original signal, and with a noticeably smaller amplitude. Look at it in channel two. Then look at the superposition of the two sine waves. **Note:** "Superposition" means the addition of the two waves—*not* picturing the two waves on the screen simultaneously.
4. Set up two sine waves with approximately—but not exactly—the same frequency, and with the same amplitudes. Look at the linear superposition of the two signals: you should see beats. (Consult section 16.7 in your textbook.) To see the beats clearly, you will probably find it useful to compress the time scale (that is, increase the rate at which the beam sweeps across the screen. Adjust one of the frequencies and observe what happens to the observed beats. For a setting of frequencies such that the beats are clearly observable, estimate (from the oscilloscope screen) the period of the beats and from that calculate the beat frequency. Compare it with the difference between the frequencies of the two signals. **Note:** It will be *hard* to get a decent, stable beat pattern on your oscilloscope screen. Keep trying, and use the best you can get even if it is imperfect.
5. Do at least one other superposition of two signals, letting at least one of the signals be a square or sawtooth wave.

To hand in for activity 2

- For part 1:
  - the frequency setting of the signal generator,
  - the measured amplitude (from the oscilloscope),
  - the measured period (from the oscilloscope),
  - the calculated frequency (from your measurement of period above),
  - a comparison of the frequency setting on the signal generator with that obtained from the oscilloscope measurement.
- For part 3:
  - a picture of each of the two sine waves,
  - a picture of the superposition of the two sine waves.
- For part 4:
  - the frequency of each of the two signals (from the signal generators) and the expected beat frequency $|f_1 - f_2|$,
  - the estimated beat period (from the oscilloscope) and the resulting beat frequency,
  - a comparison of the expected beat frequency (using the signal generator values) and the observed beat frequency (using the oscilloscope estimate of beat period).
- For part 5:
  - a picture of each of the two signals,
  - a picture of the superposition of the two signals.