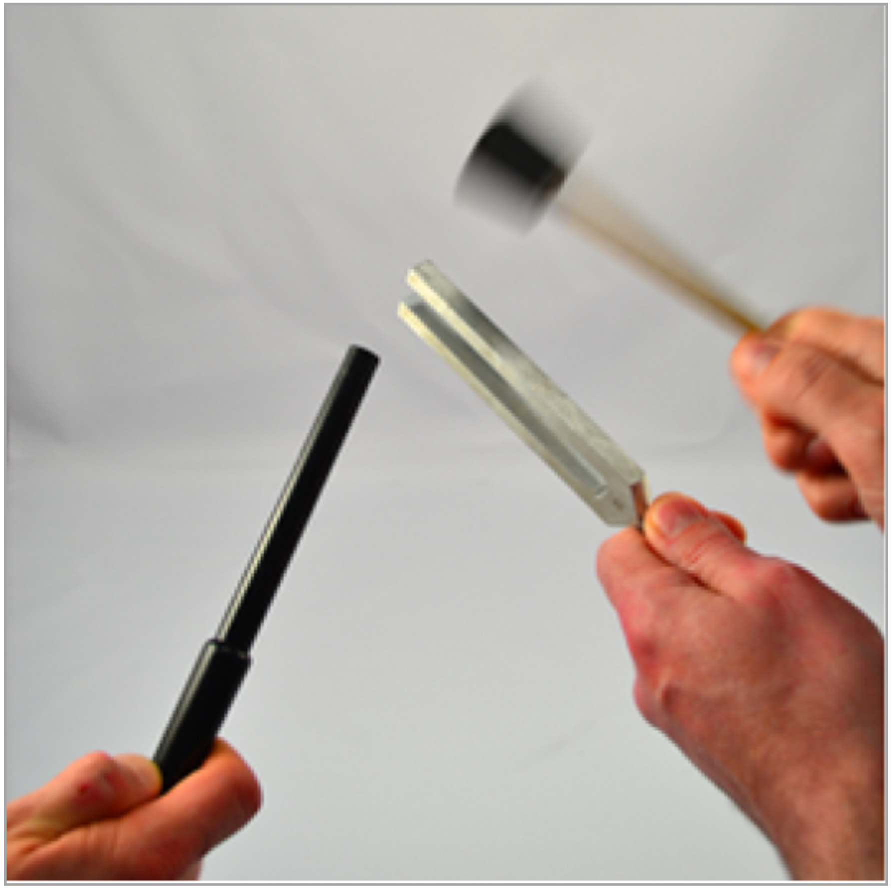
Introduction to FFT Analysis



Prelab

LR Write experiment title, your name and student number at top of the page.

LR **Prelab 1:** Write the objective of this experiment.

LR **Prelab 2:** Write the relevant theory of this experiment.

LR **Prelab 3:** List the apparatus and sketch the setup.

! Have these ready to be checked by lab staff at the door on the day of your lab.

Introduction

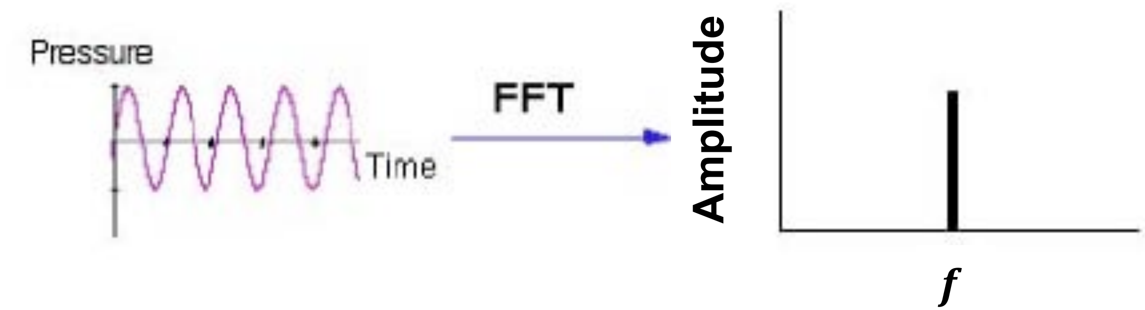
In today's experiment, you will examine the frequency information contained within sound by using fast Fourier transform (FFT) analysis. In particular, we'll use the sound created by tuning forks as our source by recording their sound with a microphone and studying those signals.

Tuning forks are used exactly as the name implies: They are most often used by musicians as a reference sound, as the tuning fork is designed to produce a single frequency, sine wave sound-source. We'll use these to gain familiarity with FFT information as an introduction to basic signal processing and learn more about sound composition and its properties.

Fast Fourier Transform (FFT)

Sound waves in air travel as pressure variations caused by motion of the air molecules. Taking the Fast Fourier Transform of a sinusoidal wave shows the frequency of that wave.

EXAMPLE: A single-frequency, sinusoidal pressure wave as is shown below.



Applying FFT analysis changes time to frequency. For a single frequency source, only a single peak is displayed, meaning, there is only one frequency present in that signal.

If a sound wave is composed of many frequencies, the FFT will show many peaks of **all frequencies** present in that sound.

Apparatus

The following equipment has been provided:

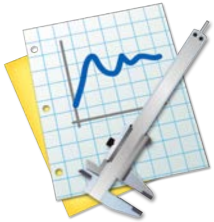
- Microphone
- Mallet
- Two tuning forks

The active element of the microphone (transducer) is the 9 mm diameter disk located on the end of the plastic case. To detect sound, point the end of the microphone directly at the sound source.

The microphone should be plugged into the CH1 socket on the LabPro.

Experimental Method

Click the icon to launch Logger Pro.



It should open with two graphs: **pressure versus time** and **amplitude versus frequency** (**FFT**).

The **top graph** of pressure and time is called the **waveform** and displays the wave shape as recorded.

The **bottom graph** of relative amplitude vs frequency is the **FFT**, showing the frequency content of the waveform. Any peaks would indicate the those frequencies are relatively higher in amplitude (louder!) than other frequencies.

Recording Sound

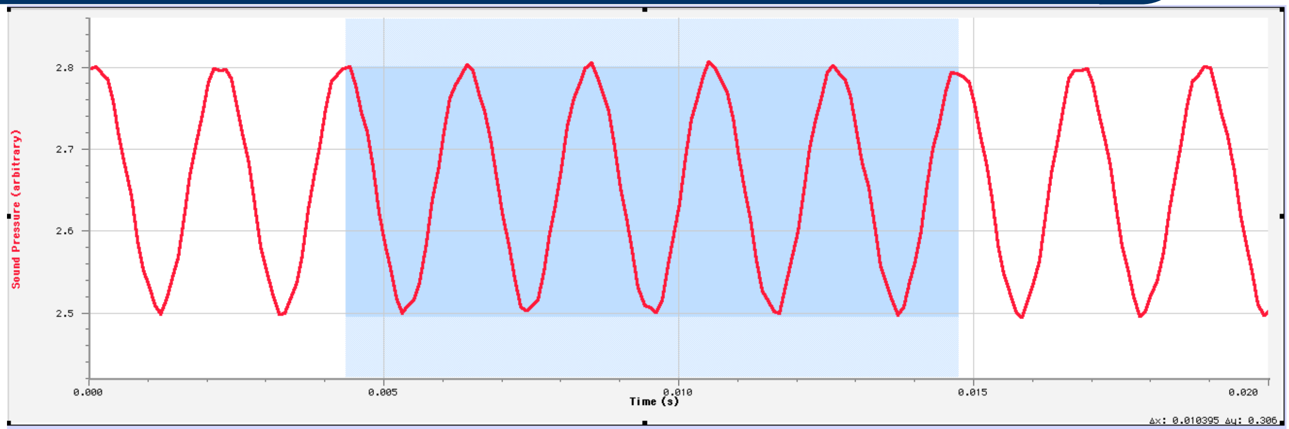
To collect a sound recording, we need to remember some details. The microphone must be pointed at, and in close proximity to the sound you wish to record. We also must think about what it is we are trying to record.

For example, to collect the sound of the tuning fork, it works best to hit the tuning fork with the rubber mallet **AWAY** from the microphone, and once the fork is ringing, then point the microphone into the forks. You DO NOT want to record the sound of the mallet hitting the fork, only the sound of the ringing fork itself.

Click Collect in Logger Pro to ready the software. Ring a tuning fork and then move near the microphone.

Only strike the tuning fork with the mallet!

Understanding the FFT



The waveform produced by the tuning fork, should look similar to the one shown above. You can adjust the scale of the x-axes by double-clicking the whitespace and setting the left and right values to get a clear picture of the waveform.

Highlight the peak-to-peak region for five oscillations of your waveform. The amount of time highlighted is displayed in the corner of the waveform plot as Δt:.

Analysis

LW **Lab Report 1:** Record the Δt for five oscillations and use this value to determine the frequency of this wave. Include uncertainty.

Click the FFT graph to activate it and select **Analyze** and **Examine** from the drop-down menu at the top of the screen. This function allows the value of the data at the position of the mouse cursor to be displayed in a small pop-up box on screen.

LW **Lab Report 2:** Identify and record the frequency value from the FFT of the tuning fork. Include uncertainty estimate.

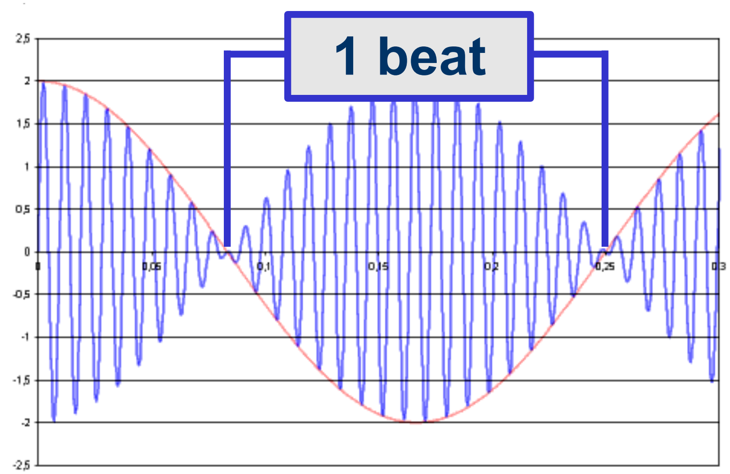
LW **Lab Report 3:** Compare your values of frequency from the waveform and the FFT with the frequency stamped on the tuning fork itself. Comment on their agreement with one another.

Beat Frequency

Sound is a pressure wave in air (typically) and hence, when more than one wave is present they interference with one another. This interference can manifest in many different ways.

Beats occur when two sounds are present and are relatively close in frequency. They are perceived commonly as a periodic fluctuation in loudness (amplitude) and the rate is the difference between the frequencies, namely

$$f_{beat} = |f_1 - f_2|\,.$$



Source:Wikipedia (en.wikipedia.org/wiki/Beat_(acoustics))

Beat Data Collection

Record the sound of two tuning forks ringing simultaneously to study the beats produced.

This works best by clicking **Collect** in Logger Pro while holding two tuning forks in one hand. Ring the forks in quick succession with the rubber mallet, and move them quickly near the microphone.

This may take a few tries to be successful. It may be helpful to know that the spacebar also triggers the collect button.

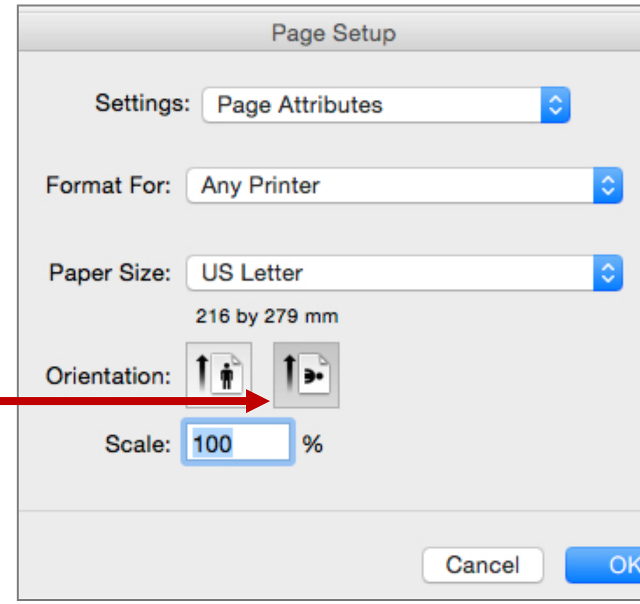
Autoscale the waveform.

CP

Have an instructor check your data and initial your lab report.

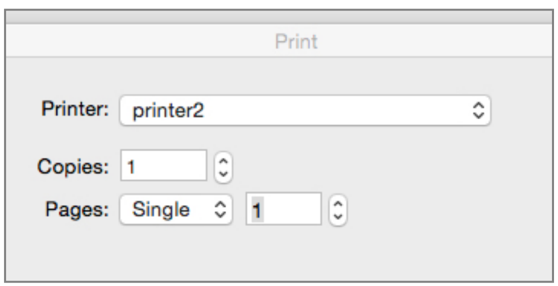
Print Beat Data

Click **File** then **Page Setup** and choose the landscape orientation.



Click **File** then **Print**.

To select the only necessary page:
Click Pages and choose Single.



Include your printed waveform and FFT with your report

Data Analysis

Using the waveform in Logger Pro, highlight one complete **beat period**, meaning the time for one complete beat.

LW

Lab Report 4: Record the period for one beat and determine the beat frequency for the waveform of two tuning forks. Include uncertainty. Identify the region used on your printed data.

LW

Lab Report 5: Use the examine function on your FFT to determine the beat frequency of the sound. Include uncertainty estimate.

LW

Lab report 6: Calculate the beat frequency using the frequency values stamped on each of the tuning forks. Compare the values of beat frequency and comment on their agreement.

Data Collection

As a comparison, try an open-mouth hum into the microphone and recording this sound.

When humming into the microphone, try not the blow directly into the microphone as this can distort the recording. Hold the microphone close, but to the side of your mouth, so as to not blow into the transducer element.

LW

Lab Report 7: Describe the differences in the FFT between the sound of humming and the tuning fork. Provide a simple sketch of the FFT and use this as reference to your description.

Summary & Conclusion

LR **Lab Report 8**: Briefly summarize your experiment, in a paragraph or two, and include any experimental results.

LR **Lab Report 9:** List any sources of experimental uncertainty and classify them as random or systematic.

! **Include your prelab, printed data, and all analysis with your report.**