Lecture 7: Sound

What is Sound?

Sound is a wave phenomenon like light but is macroscopic and involves molecules of air being compressed and expanded under the action of some physical device. For example, a speaker in an audio system vibrates back and forth and produces a longitudinal pressure wave that we perceive as sound.

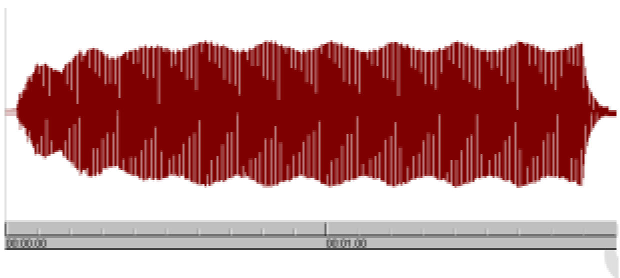
Since sound is a pressure wave, it takes on continuous values, as opposed to digitized ones. Even though such pressure waves are longitudinal, they still have ordinary wave properties and behaviors, such as reflection (bouncing), refraction (change of angle when entering a medium with a different density) and diffraction (bending around an obstacle). If we wish to use a digital version of sound waves, we must form digitized representations of audio information.

Sound involves four complex relationships:

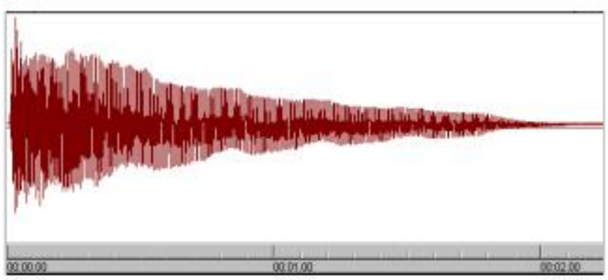
1. A vibrating object (sound source)
2. A transmission medium (usually air)
3. A receiver (ear)
4. A preceptor (brain)

Sound is measured in dB (decibel) and sound waves are known as waveforms.

Example of waveforms:

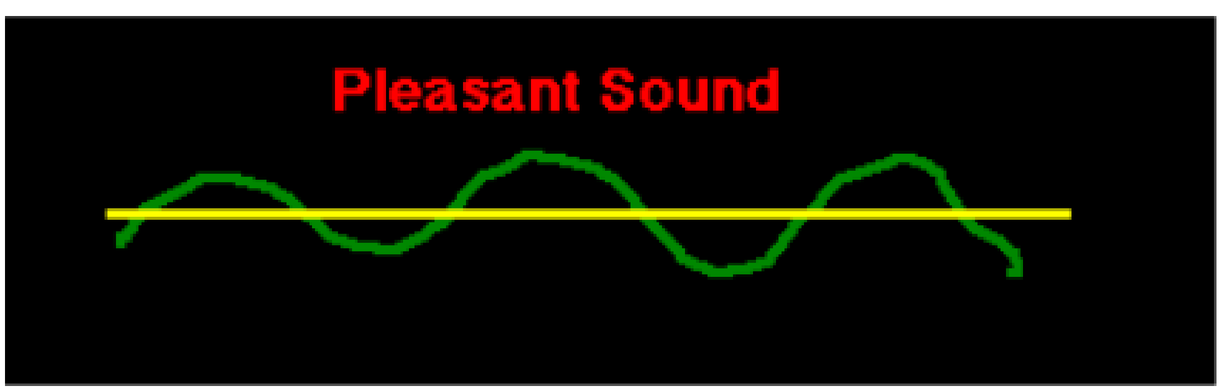


flute

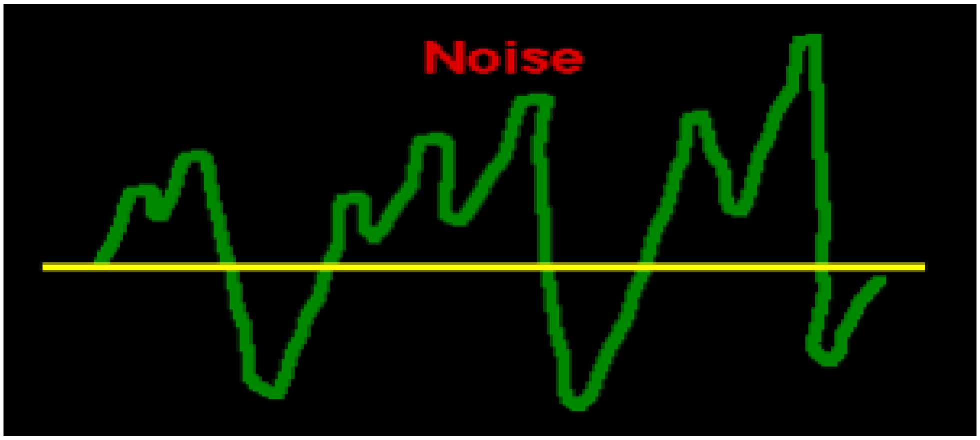


Piano

- ❖ A pleasant sound has a regular wave pattern. The pattern is repeated over and over.

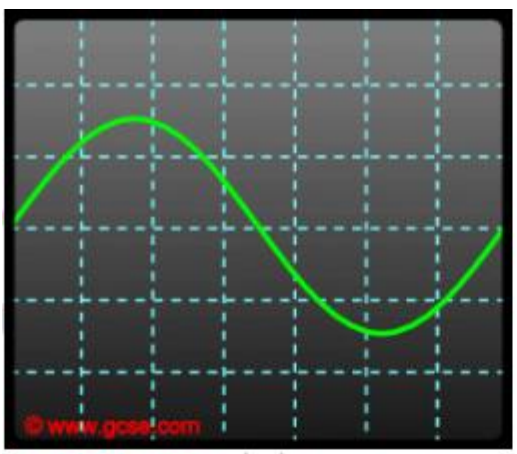


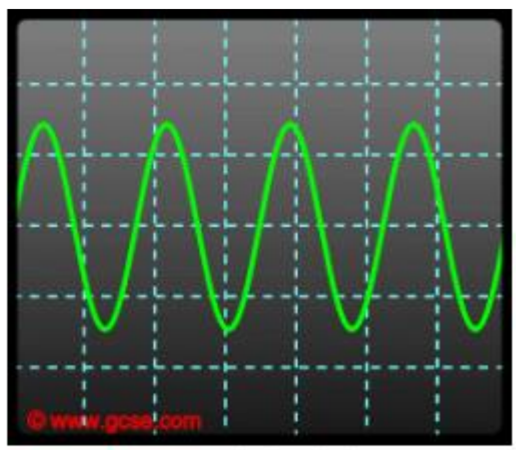
❖ But the waves of noise are irregular. They do not have a repeated pattern.



Characteristic of sound waves

❖ Frequency (or pitch): is a measure of how many vibrations occur in one second. This is measured in Hertz (abbreviation Hz) and directly corresponds to the pitch of a sound. The more frequent vibration occurs the higher the pitch of the sound.

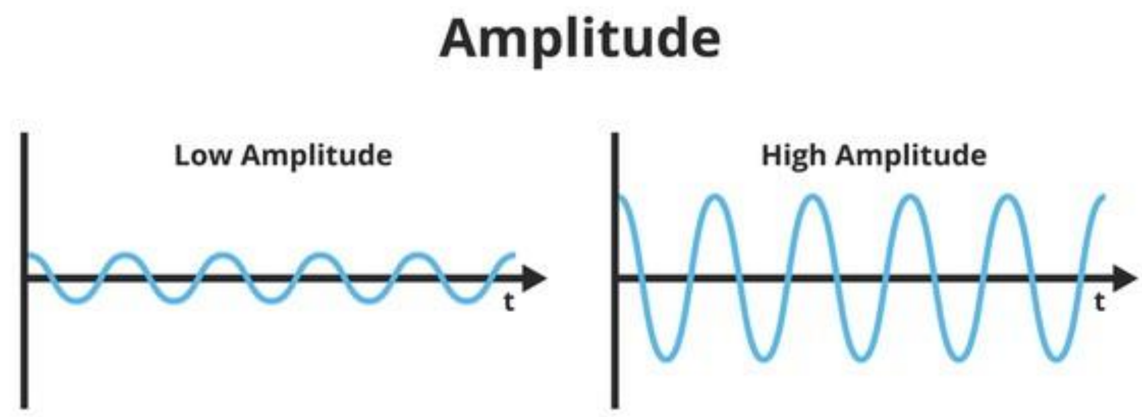


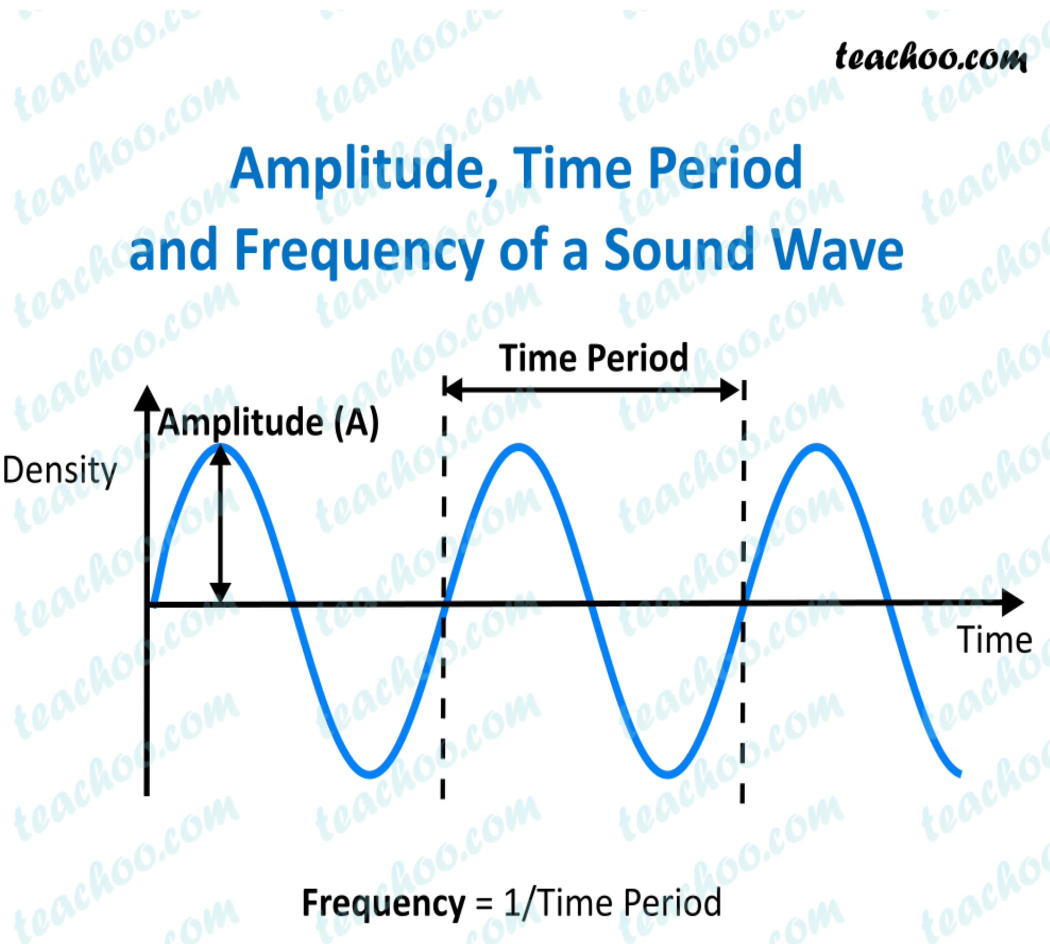


Low Frequency Hight frequency

Optimally, people can hear from 20 Hz to 20,000 Hz (20 kHz), sounds below 20 Hz are infrasonic while sounds above 20 kHz are ultrasonic.

❖ Amplitude (or loudness) is the maximum displacement of a wave from an equilibrium position. The louder a sound, the more energy it has. This means loud sounds have a large amplitude.

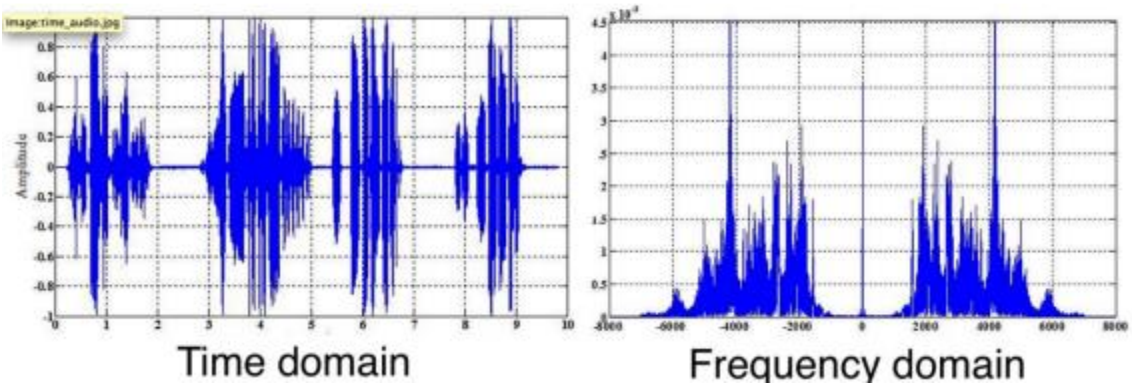




Representations of Sound: Time and Frequency Domains

- **Time domain**: shows the amplitude of a signal at different points in time. When we are examining an audio signal in the time domain, the X-axis is time. So the value of the Y-axis depends on the changing of the signal with respect to time. Usually examining an audio signal with respect to time is only useful when we need to find out the amplitude of a signal, because this is the only information that is shown in the time domain.
- **Frequency Domain**: is much more useful in examining audio signals. The X-axis is frequency, and the value of the Y-axis depends on the changing of the signal with respect to frequency.

Below is a graph of an audio signal in both the time and frequency domain:



Furthermore, we can convert a specific signal or function between the frequency and time domains with transforms. A perfect example of a transform is the Fourier transform. Which converts a time function (time domain) into an integral of various frequencies (frequency-domain). However, as the name implies, the inverse Fourier transform converts the frequency-domain function back to the time function.

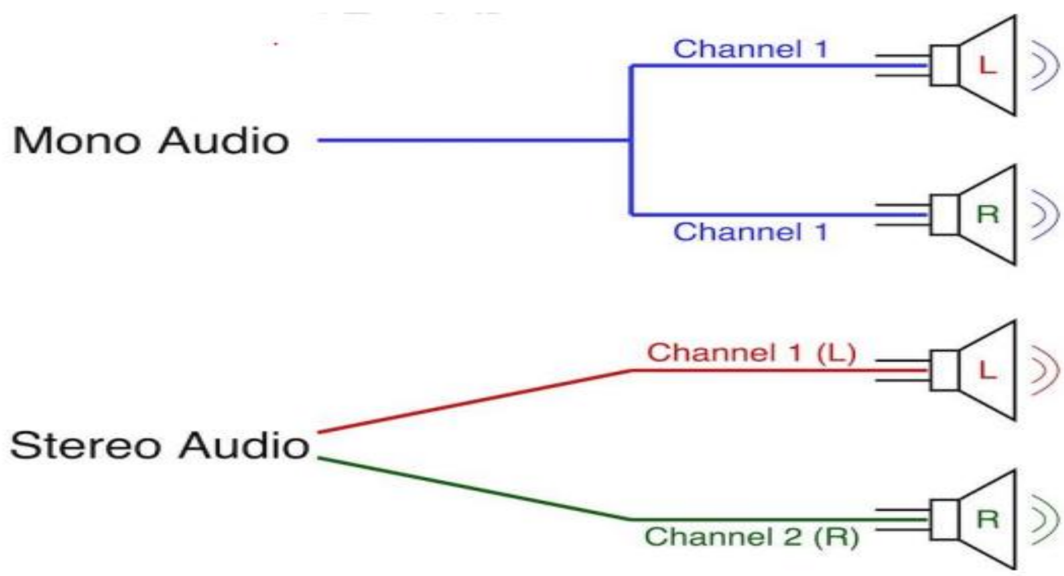
Main types of audio or sound:

There are three types of sound (audio), understanding each type help as have an improved listening experience:

1. **Monophonic sound**: is created by one channel or speaker and is also known as monaural or high-fidelity sound.

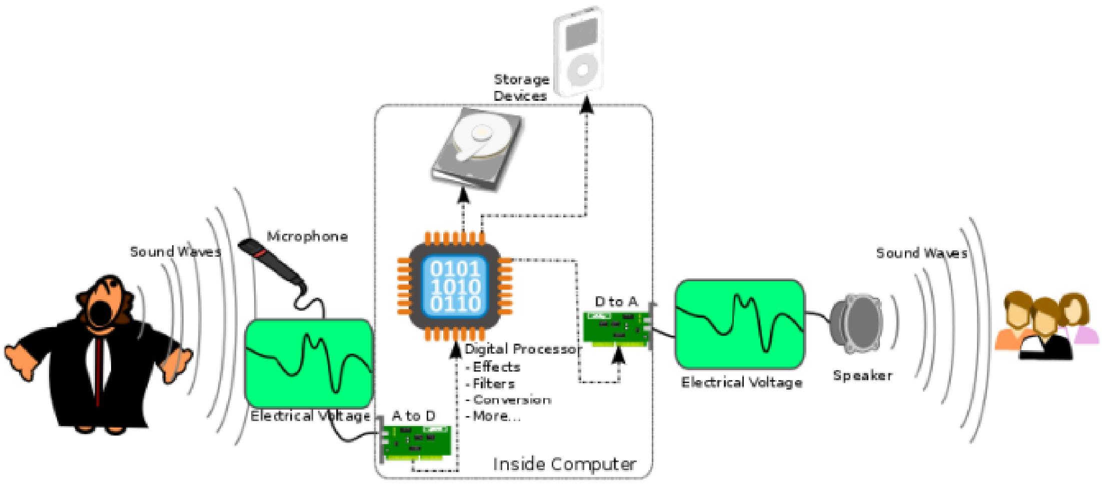
2. **Stereophonic Sound**: is created by two independent audio channels or speakers and provides a sense of directionality because sounds come from different directions.

3. **Multichannel Surround Sound**: also known as surround sound, is created by at least four and up to seven independent audio channels or speakers placed in front of and behind the listener that surround the listener in sound. We can enjoy multichannel sound on DVD music discs, DVD movies, and some CDs.



Digitization

Digitization is the process of converting an analog signal to a digital one. To digitally record sound, samples of a sound wave are collected at periodic intervals and stored as numeric data in an audio file. A digital file can be identified by its type or its file extension, such as Thriller.mp3 (an audio file). The most popular digital audio formats are: AAC, MP3, Ogg, Vorbis, WAV, FLAC, and WMA.



Lifecycle for capture and playback of digital audio

A sound is recorded by making a measurement of the amplitude of the sound at regular intervals which are defined by the "sample rate". The act of taking the measurement is often called "sampling" and each measurement is called a "sample point".

Audio Toolbox in MATLAB:

It provides tools for audio processing, speech analysis, and acoustic measurement. It includes algorithms for processing audio signals such as equalization and time stretching, estimating sonic signal metrics such as loudness and sharpness, and extracting audio features. It also provides advanced machine learning models, including i-vectors, and pre-trained deep learning networks, Toolbox apps support live algorithm testing impulse response measurement and signal labeling.

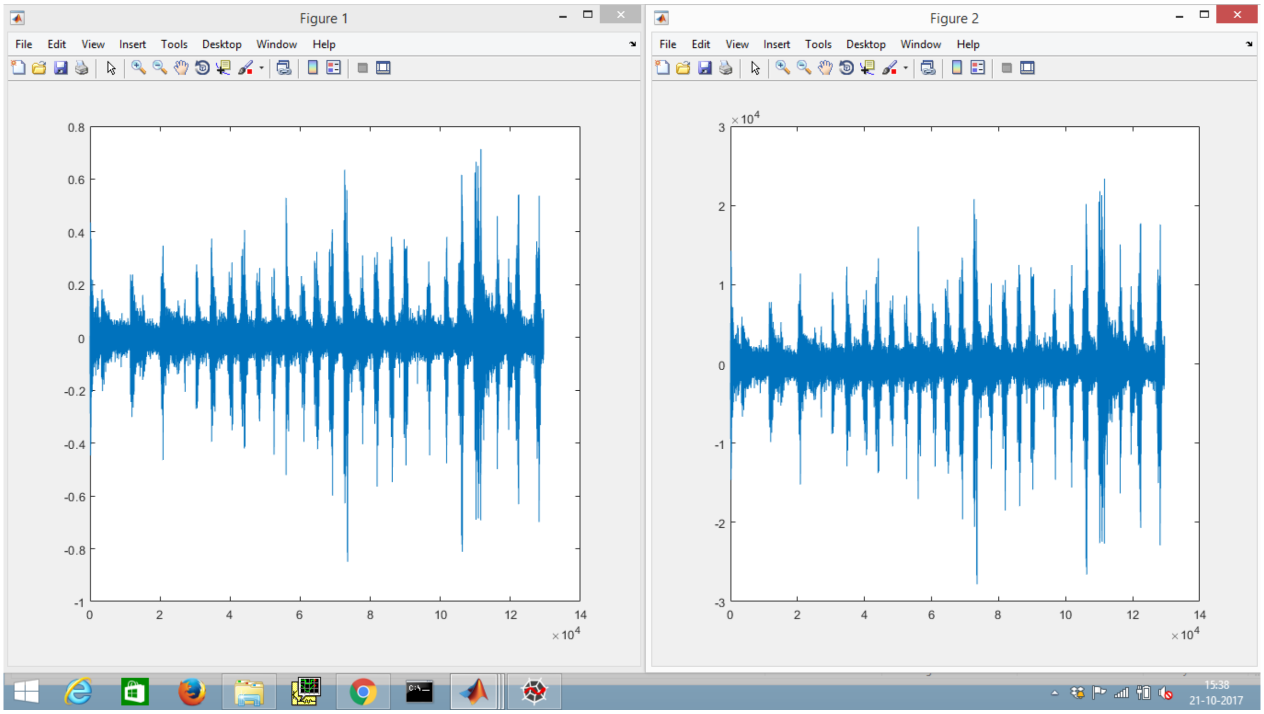

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Figure 2
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