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# Digital Audio

## 5.1 What is Sound?

Sound is a physical phenomenon caused by vibration of material, such as a violin string or a wood log. This type of vibration triggers pressure wave fluctuations in the air around the material. The pressure waves propagate in the air. The pattern of this oscillation (see Figure 5.1) is called **wave form**. We hear a sound when such a wave reaches our ears. Sound in the audio sonic frequency range is primarily important for multimedia systems. The waves in the audio sonic frequency range are also called **acoustic signals.**

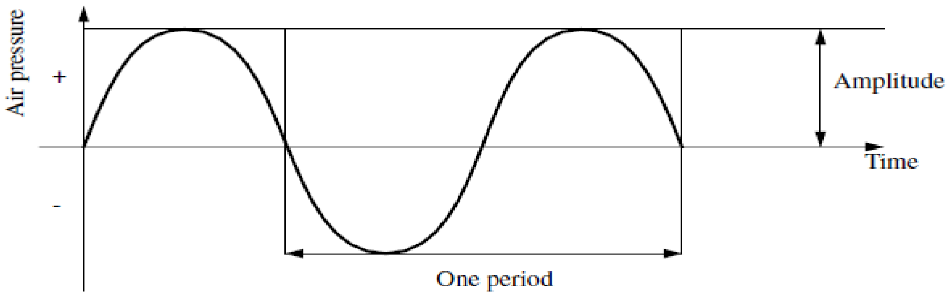


Figure (5.1): Pressure wave oscillation in the air.

**The important of sound in multimedia:**

1. Sound is the best way to **attract attention**.
2. Often audio provides the effective way to **convey an idea**, elicit an emotion, or dramatize point.
3. Sounds also can be combined in a multimedia presentation to provide information and **enhance the other media being presented**.

### 5.1.1 Source Generates Sound

1. Air Pressure changes
2. Electrical: Microphone produces electric signal
3. Acoustic: Direct Pressure Variations

**Destination — Receives Sound**

1. Electrical: Loud Speaker
2. Ears: Responds to pressure hear sound

### 5.1.2 Frequency

A sound's **frequency** is the number of periods per second and is measured in hertz (Hz) or cycles per second (cps) see (Figure 5.2). A common abbreviation is kilohertz (kHz), which describes 1,000 oscillations per second, corresponding to 1,000Hz. Sound processes that occur in liquids, gases, and solids are classified by frequency range:

- Infrasonic: 0 to 20Hz
- Audiosonic: 20Hz to 20kHz
- Ultrasonic: 20kHz to 1GHz
- Hypersonic: 1GHz to 10THz

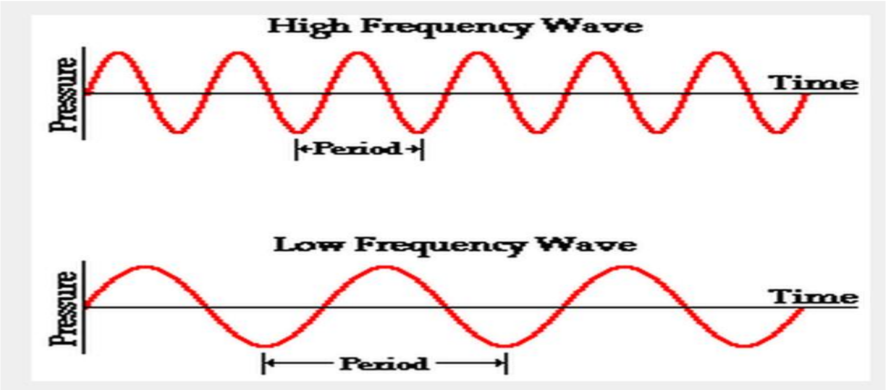


Figure (5.2) wave frequency

Speech is the signal humans generate by use of their speech organs. These signals can be reproduced by machines. For example, music signals have frequencies in the 20Hz to 20kHz range. We could add noise to speech and music as another type of audio signal. Noise is defined as a sound event without functional purpose.

### 5.1.3 Amplitude

A sound has a property called amplitude, which humans perceive subjectively as loudness or volume. The amplitude of a sound is a measuring unit used to deviate the pressure wave from its mean value.

## 5.2 Digitizing Sound

Microphone produces analog signal and computers understands only discrete (digital) entities. This creates a need to convert analog audio to digital audio using specialized hardware, which perform **sampling process**. Before the continuous curve of a sound wave can be represented on a computer, the computer has to measure the wave's amplitude in regular time intervals. It then takes the result and generates a sequence of sampling values (samples). Figure (5.3) shows the period of a digitally sampled wave.

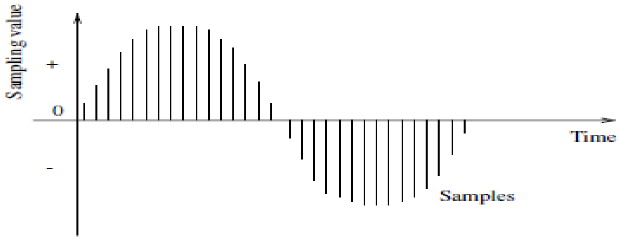


Figure (5.3) Sampling a wave.

The digitization process requires two steps. **First** the analog signal must be sampled. The **second** step involves quantization.

### 5.3.1 Sampling Rate

The sampling rate refers to the number of times per second that an audio signal is measured (or "sampled") when converting an analog audio signal into a digital format. It is measured in hertz (Hz) or kilohertz (kHz), where 1 kHz equals 1,000 samples per second. The sound wave is sampled at regular intervals. Each sample represents the amplitude (loudness) of the sound wave at a specific point in time. The range of (bandwidth) frequencies humans can hear is 20 Hz-20,000 Hz, which equal to 19,980 Hz and refers to the frequency range of human hearing. The sampling rate determines the frequency range that can be accurately reproduced. According to the Nyquist Theorem, to faithfully reproduce a sound wave, the sampling rate must be at least twice the highest frequency you want to capture.

$$\text{sampling rate} = 2\, f_{max}$$

$$\text{Nyquist frequency} = \frac{\text{Sampling rate}}{2}$$

The Nyquist frequency is half of the sampling rate and represents the frequency that can be accurately captured. For example, to capture audio up to 20 kHz, the sampling rate needs to be at least 40 kHz, which is why 44.1 kHz is commonly used for CDs.

### 5.3.2 Quantization

The quantization process consists of converting a sampled signal into a signal that can take only a **limited number of values**. An 8-bit quantization provides 256 possible values, while a 16-bit quantization in CD quality results in more than 65,536 possible values. Figure (5.4) shows a 3-bit quantization.

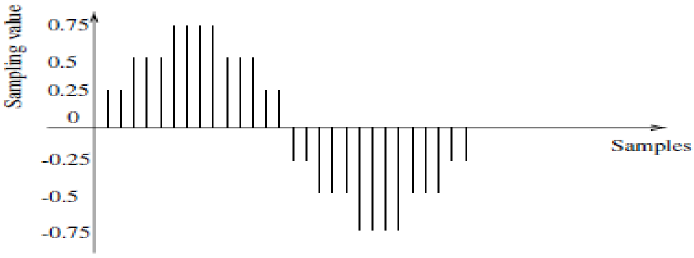


Figure (5.4) 3-bit quantization.

## 5.3 Play Digital Audio

In order to play digital audio WAVE file, "Wave form Audio File Format", file extension for a WAVE file is "**.wav"**, we need a card with a Digital to Analog Converter (DAC). This means that the **Digital-to-Analog Converter (DAC)**, which converts the digital audio signals (binary data) into analog signals, is connected to the **Line Out jack** of the audio card. The Line Out jack then outputs these analog signals to external audio devices such as **speakers**, **headphones**, or **amplifiers**, allowing the digital sound stored or processed by the computer to be heard as audible sound waves. Playback process is almost an exact reverse of the recording process.

Note: (**Line Out jack** connection is commonly used to connect audio devices to external speakers, amplifiers, or audio recording equipment. It allows you to play audio from your device through larger speakers or integrate it with a professional sound system).