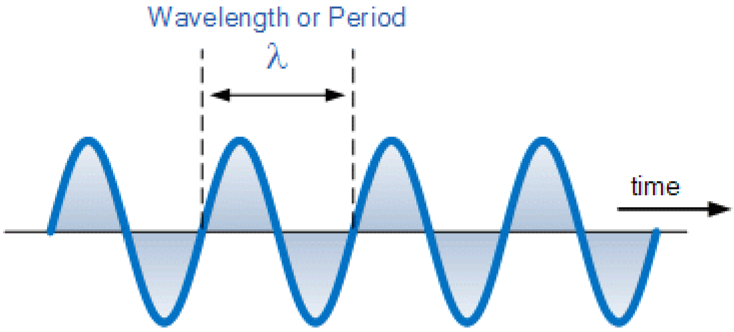


Sound Transducers

Sound Transducers use electrical energy to create mechanical vibrations to disturbe the sourrounding air producing sound whether of an audible or inaudible frequency

Sound is the generalised name given to "acoustic waves". These acoustic waves have frequencies ranging from just 1Hz up to many tens of thousands of Hertz with the upper limit of human hearing being around the 20 kHz, (20,000Hz) range.

The sound that we hear is basically made up from mechanical vibrations produced by an **Audio Sound Transducer** used to generate the acoustic waves, and for sound to be "heard" it requires a medium for transmission either through the air, a liquid, or a solid.

Also, the actual sound need not be a continuous frequency sound wave such as a single tone or a musical note, but may be an acoustic wave made from a mechanical vibration, noise or even a single pulse of sound such as a "bang".

Sound Transducer

Audio Sound Transducers include both input sensors, that convert sound into and electrical signal such as a microphone, and output actuators that convert the electrical signals back into sound such as a loudspeaker.

We tend to think of sound as only existing in the range of frequencies detectable by the human ear, from 20Hz up to 20kHz (a typical loudspeaker frequency response), but sound can also extend way beyond these ranges.

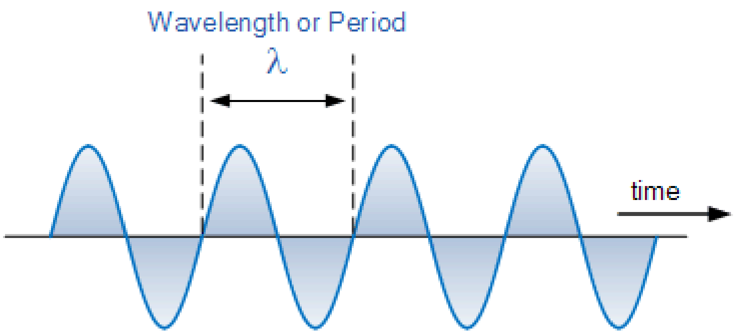
Sound transducers can also both detect and transmit sound waves and vibrations from very low frequencies called *infra-sound* up to very high frequencies called *ultrasound*. But in order for a sound transducer to either detect or produce "sound" we first need to understand what sound is.

What is Sound?

Sound is basically a waveform of energy that is produced by some form of a mechanical vibration such as a tuning fork, and which has a "frequency" determined by the origin of the sound for example, a bass drum has a low frequency sound while a cymbal has a higher frequency sound.

A sound waveform has the same characteristics as that of an electrical waveform which are **Wavelength** (λ), **Frequency** (f) and **Velocity** (m/s). Both the sounds frequency and wave shape are determined by the origin or vibration that originally produced the sound but the velocity is dependent upon the medium of transmission (air, water etc.) that carries the sound wave. The relationship between wavelength, velocity and frequency is given below as:

Sound Wave Relationship



$$\text{Frequency}, (f) = \frac{\text{Velocity}\,(m/s^{-1})}{\text{Wavelength}\,(\lambda)} \text{ in Hertz}$$

Where:

Wavelength – is the time period of one complete cycle in Seconds, (λ)

Frequency – is the number of wavelengths per second in Hertz, (f)

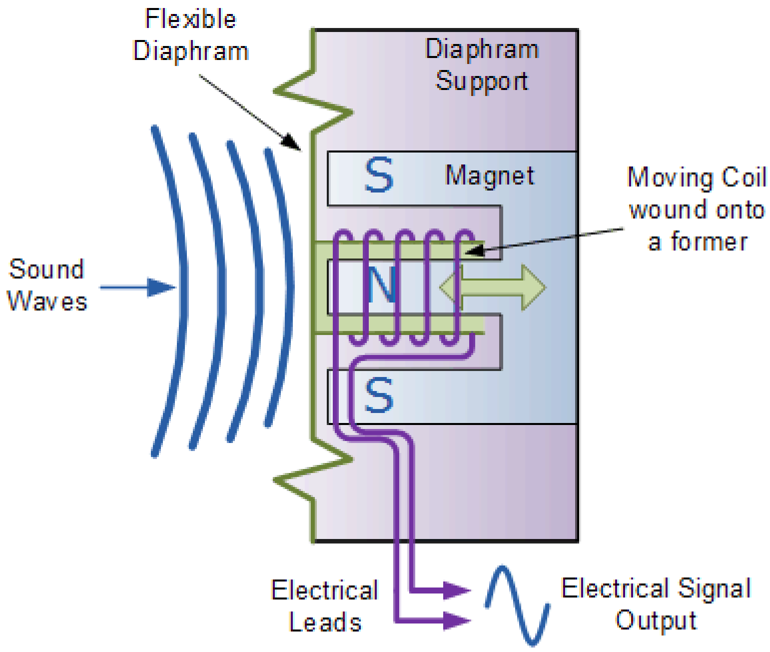
Velocity – is the speed of sound through a transmission medium in m/s^{-1}

The Microphone Input Transducer

The **Microphone**, also called a “mic”, is a sound transducer that can be classed as a “sound sensor”. This is because it produces an electrical analogue output signal which is proportional to the “acoustic” sound wave acting upon its flexible diaphragm. This signal is an “electrical image” representing the characteristics of the acoustic waveform. Generally, the output signal from a microphone is an analogue signal either in the form of a voltage or current which is proportional to the actual sound wave.

The most common types of microphones available as sound transducers are *Dynamic*, *Electret Condenser*, *Ribbon* and the newer *Piezo-electric Crystal* types. Typical applications for microphones as a sound transducer include audio recording, reproduction, broadcasting as well as telephones, television, digital computer recording and body scanners, where ultrasound is used in medical applications. An example of a simple “Dynamic” microphone is shown below.

Dynamic Moving-coil Microphone Sound Transducer



The construction of a dynamic microphone resembles that of a loudspeaker, but in reverse. It is a moving coil type microphone which uses electromagnetic induction to convert the sound waves into an electrical signal. It has a very small coil of thin wire suspended within the magnetic field of a permanent magnet. As the sound wave hits the flexible diaphragm, the diaphragm moves back and forth in response to the sound pressure acting upon it causing the attached coil of wire to move within the magnetic field of the magnet.

The movement of the coil within the magnetic field causes a voltage to be induced in the coil as defined by Faraday's law of Electromagnetic Induction. The resultant output voltage signal from the coil is proportional to the pressure of the sound wave acting upon the diaphragm so the louder or stronger the sound wave the larger the output signal will be, making this type of microphone design pressure sensitive.

As the coil of wire is usually very small the range of movement of the coil and attached diaphragm is also very small producing a very linear output signal which is 90^{o} out of phase to the sound signal. Also, because the coil is a low impedance inductor, the output voltage signal is also very low so some form of "pre-amplification" of the signal is required.

As the construction of this type of microphone resembles that of a loudspeaker, it is also possible to use an actual loudspeaker as a microphone.

Obviously, the average quality of a loudspeaker will not be as good as that for a studio type recording microphone but the frequency response of a reasonable speaker is actually better than that of a cheap "freebie" microphone. Also the coils impedance of a typical loudspeaker is different at between 8 to 16Ω. Common applications where speakers are generally used as microphones are in intercoms and walki-talkie's.

The Loudspeaker Output Transducer

Sound can also be used as an output device to produce an alert noise or act as an alarm, and loudspeakers, buzzers, horns and sounders are all types of sound transducer that can be used for this purpose with the most commonly used audible type output sound actuator being the "Loudspeaker".

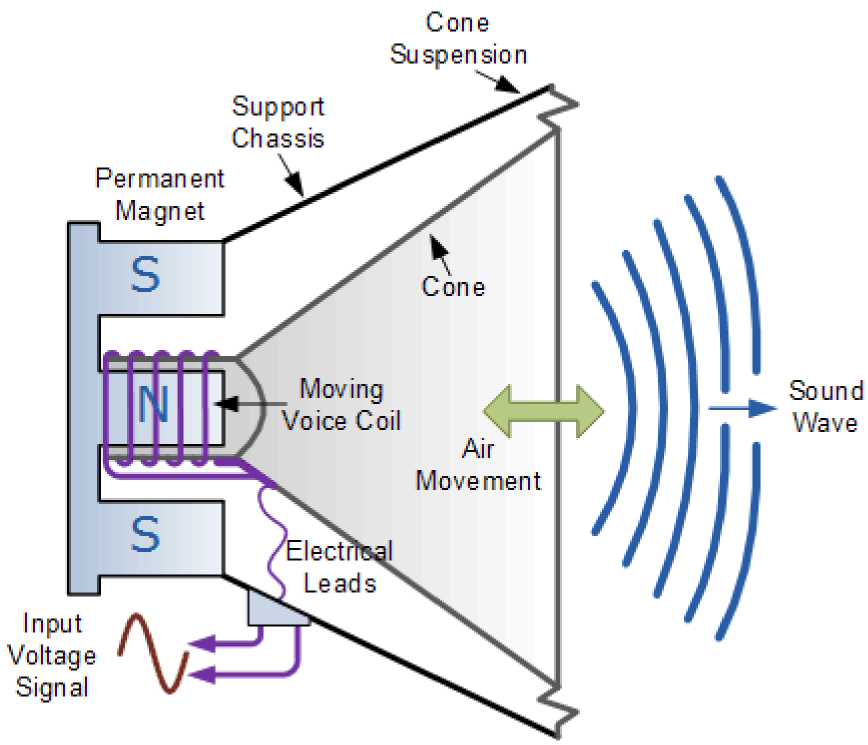
Loudspeakers are audio sound transducers that are classed as "sound actuators" and are the exact opposite of microphones. Their job is to convert complex electrical analogue signals into sound waves being as close to the original input signal as possible.

Loudspeakers are available in all shapes, sizes and frequency ranges with the more common types being moving coil, electrostatic, isodynamic and piezo-electric. Moving coil type loudspeakers are by far the most commonly used speaker in electronic circuits, kits and toys, and as such it is this type of sound transducer we will examine below.

Loudspeaker Transducer

The principle of operation of the **Moving Coil Loudspeaker** is the exact opposite to that of the "Dynamic Microphone" we look at above. A coil of fine wire, called the "speech or voice coil", is suspended within a very strong magnetic field, and is attached to a paper or Mylar cone, called a "diaphragm" which itself is suspended at its edges to a metal frame or chassis. Then unlike the microphone which is pressure sensitive input device, this type of sound transducer can be classed as a pressure generating output device.

The Moving Coil Loudspeaker



When an analogue signal passes through the voice coil of the speaker, an electro-magnetic field is produced and whose strength is determined by the current flowing through the "voice" coil, which in turn is determined by the volume control setting of the driving amplifier or moving coil driver. The electro-magnetic force produced by this field opposes the main permanent magnetic field around it and tries to push the coil in one direction or the other depending upon the interaction between the north and south poles.

As the voice coil is permanently attached to the cone/diaphragm this also moves in tandem and its movement causes a disturbance in the air around it thus producing a sound or note. If the input signal is a continuous sine wave then the cone will move in and out acting like a piston pushing and pulling the air as it moves and a continuous single tone will be heard representing the frequency of the signal. The strength and therefore its velocity, by which the cone moves and pushes the surrounding air produces the loudness of the sound.

As the speech or voice coil is essentially a coil of wire it has, like an inductor an impedance value. This value for most loudspeakers is between 4 and 16Ω and is called the "nominal impedance" value of the speaker measured at 0Hz, or DC.

Remember that it is important to always match the output impedance of the amplifier with the nominal impedance of the speaker to obtain maximum power transfer between the amplifier and speaker. Most amplifier-speaker combinations have an efficiency rating as low as 1 or 2%.

Although disputed by some, the selection of good speaker cable is also an important factor in the efficiency of the speaker, as the internal capacitance and magnetic flux characteristics of the cable change with the signal frequency, thereby causing both frequency and phase distortion. This has the effect of attenuating the signal. Also, with high power amplifiers large currents are flowing through these cables so small thin bell wire type cables can overheat during extended periods of use, again reducing efficiency.

The human ear can generally hear sounds from between 20Hz to 20kHz, and the frequency response of modern loudspeakers called general purpose speakers are tailored to operate within this frequency range as well as headphones, earphones and other types of commercially available headsets used as sound transducers.

However, for high performance High Fidelity (Hi-Fi) type audio systems, the frequency response of the sound is split up into different smaller sub-frequencies thereby improving both the loudspeakers efficiency and overall sound quality as follows:

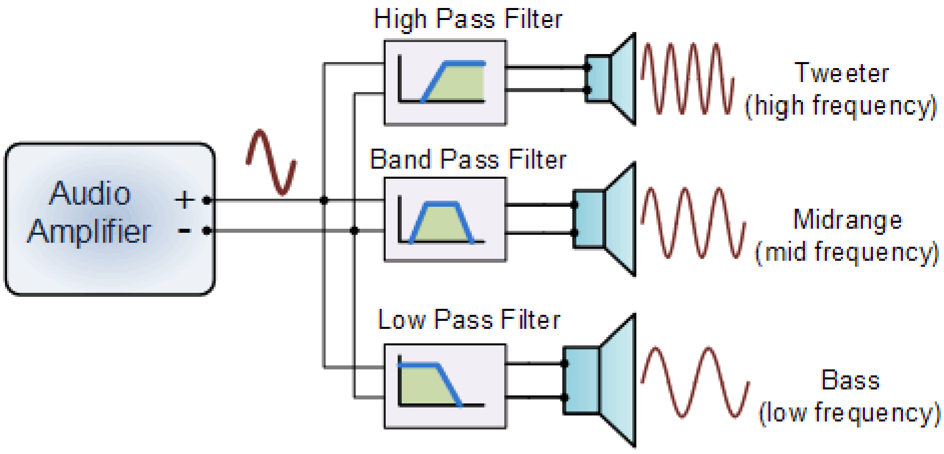
Generalised Frequency Ranges

Descriptive Unit	Frequency Range
Sub-Woofer	10Hz to 100Hz
Bass	20Hz to 3kHz
Mid-Range	1kHz to 10kHz
Tweeter	3kHz to 30kHz

In multi speaker enclosures which have a separate Woofer, Tweeter and Mid-range speakers housed together within a single enclosure, a passive or active “crossover” network is used to ensure that the audio signal is accurately split and reproduced by all the different sub-speakers.

This crossover network consists of Resistors, Inductors, Capacitors, RLC type passive filters or op-amp active filters whose crossover or cut-off frequency point is finely tuned to that of the individual loudspeakers characteristics and an example of a multi-speaker “Hi-fi” type design is given below.

Multi-speaker (Hi-Fi) Design



In this tutorial, we have looked at different **Sound Transducers** that can be used to both detect and generate sound waves. Microphones and loudspeakers are the most commonly available sound transducer, but other lots of other types of sound transducers available which use piezoelectric devices to detect very high frequencies, hydrophones designed to be used underwater for detecting underwater sounds and sonar transducers which both transmit and receive sound waves to detect submarines and ships.