# 1 Introduction

The first loudspeaker was invented in 1924 by Chester W. Rice and Edward W. Kellogg. Since then, speakers have evolved drastically in order to produce clearer, louder, more immersive sound. Today, modern loudspeakers vary greatly in size and shape. However, the basic process of how they produce sound has hardly changed. This document describes that process in a way that is both detailed and easy to comprehend.

# 2 Sound

In order to understand how a speaker works, we must first understand how sound works. Sound is created when an object, such as a string or surface, vibrates back and forth at a high speed. This vibration moves the air around the object, creating pressure waves in the surrounding air molecules that move similarly to waves in the ocean. Our ears detect these pressure waves and register them as sound.

The speed at which an object vibrates is known as the frequency of the wave. This frequency is what determines the pitch of the sound. The faster an object vibrates back and forth, the higher the pitch. The strength of the sound (how loud it is) is determined by how far the vibrating object fluctuates back and forth. The larger the vibration, the louder the sound. This measurement is known as the “amplitude” of the wave. By carefully manipulating vibrations of specific frequencies and amplitudes, speakers can create the organized sound that we hear.

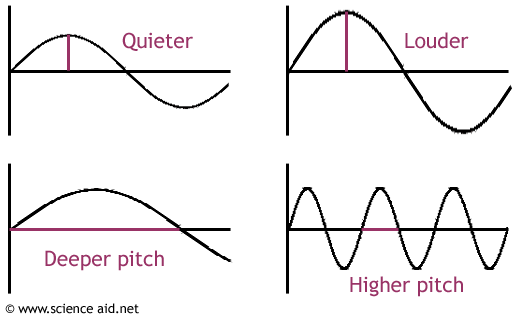


Figure 1: Examples of how different sound waves produce different pitches and volumes.

# 3 Components

Speakers utilize four main components in order to produce sound. These components include the magnet, voice coil, suspension, diaphragm. In this section, we will describe each component, its function, and its interaction with the rest of the system.

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| Figure 2 | Cutaway of a Loudspeaker Bass   1. Magnet 2. Voice Coil 3. Suspension 4. Diaphragm |

## 3.1 Magnet

Speakers contain a magnet which serves to assist the voice coil. The magnet’s strength roughly corresponds to the volume the speaker can produce; a strong magnet is capable of driving a much louder speaker. The magnets used in speakers are typically ferrite or neodymium, the latter being much stronger.

## 3.2 Voice Coil

The voice coil is a cylindrical coil of wire which is attached to the diaphragm, as shown in   
figure 1. Electric current in the wire induces a magnetic field parallel to the hole in the coil. This induced magnetic field reacts to that of the physical magnet. This reaction translates the electronic signals into voice coil movement, which moves the diaphragm and produces sound. The voice coil’s motion (and subsequently, the diaphragm’s movement) is controlled by changes in electrical current.

As current in the voice coil changes, the induced magnetic field alternates between attracting and repelling the magnet, creating linear back-and-forth movement of the diaphragm. The strength of the field is manipulated by the amount of current running through the coil and the design and size of the coil. More current leads to a stronger magnetic field in the voice coil, larger movements of the diaphragm, and louder output from the speaker.

## 3.3 Diaphragm

The diaphragm (sometimes called a radiator) is a cone-shaped component that is seen on the front side of the speaker. The main purpose of the diaphragm is to amplify the vibrations coming from the voice coil. In order to do this, the diaphragm must be constructed out of a material that is both stiff and lightweight in order to produce clean and controlled sound without requiring too much energy. The material also must be well damped so that vibrations don’t continue to resonate longer than desired. The materials most commonly used include plastic, metal, and paper.

Different diaphragm shapes and materials produce a variety of sounds. A soft material such as paper produces warm tones, but dampens very quickly. To contrast, a hard material like aluminum creates sharp tones, but may resonate or ring longer than desired. The most common diaphragm shape is a cone. Other shapes such as domes or rings produce sound that better represents different frequencies. For example, dome diaphragms are often used to produce clearer high-frequency tones.

## 3.4 Suspension

The diaphragm is typically held in place by two firm but flexible suspension components: the *surround* and the *spider*. The respective components serve as outer and inner bounds to the diaphragm’s movement. The suspension system also serves as a centering device for the diaphragm, constraining it to linear back-and-forth movement and dissuading movement left or right. It isn’t necessary to have both suspension components for all diaphragm types, so the information below refers to their functions with respect to cone-shaped diaphragms.

The surround (the black ring in figure 2) is the exterior suspension component and acts as an outer "bound" for the diaphragm. It is attached to the basket (speaker housing). The surround’s job is to dampen the diaphragm's movement and to create an outer seal for the loudspeaker. The surround is made of a rigid, non-porous material, often a resin-saturated linen. It is sealed with a rubber-like “damping dope” which prevents extends the life of the surround and prevents cracking.

The spider (the yellow component in figure 2) is located on the interior side of the diaphragm. Its inner diameter is attached to the diaphragm or voice coil, and its outer edge is fixed to the basket. The spider limits the diaphragm’s movement, creating an inner bound to its oscillations. It must be made out of a rigid, non-porous material to create a firm bound. The concentric ridges strengthen the spider while giving it slight flexing capabilities. Unlike the surround, the spider’s material is not sealed because it must allow heat to escape; voice coil temperatures often exceed 400° F within seconds of start-up (Jones, 8:32).

## 3.5 Drivers

A driver is simply an assembly of the components mentioned above. Drivers convert electrical energy into kinetic energy via the magnet and voice coil. The diaphragm’s motion then turns kinetic energy into sound waves. Drivers take many different shapes and sizes to reach different frequencies and reach wider pitch ranges. Drivers containing small diaphragms vibrate at high frequency and make clear treble tones, while drivers with large diaphragms vibrate at low frequencies and create rich bass tones. Typical loudspeakers contain several drivers to cover a wide range of the sound spectrum. Four common driver types, from high to low frequency, are tweeters, mid-range drivers, woofers, and subwoofers.

### 3.5.1 Tweeter

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| Figure 3 | Cutaway view of a dynamic tweeter with acoustic lens and a dome-shaped diaphragm.   1. Magnet 2. Voice coil 3. Diaphragm 4. Suspension |

The driver capable of producing the high audio frequencies is called the tweeter. Tweeters are designed for frequencies from 2,000 Hz to 20,000 Hz; it got the name tweeter from the high-pitched “tweets” birds make. The tweeter is typically the smallest driver. Tweeters usually have dome-shaped or horn-shaped diaphragms. Old tweeters were just smaller woofers. There are two types of domes: soft domes and hard domes. Three criteria for a good dome are low mass, high stiffness, and good damping.

### 3.5.2 Mid-range

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| Figure 4 | Cutaway view of a dynamic midrange speaker.   1. Magnet 2. Cooler (sometimes present) 3. Voice coil 4. Suspension 5. Diaphragm |

The mid-range driver (sometimes called a squawker) is designed for audio frequencies from 250 Hz to 2,000 Hz. These audio frequencies make up a significant part of the audible sound spectrum.The speakers found in T.V.s and other electronics are usually mid-range ones as the audio frequencies on T.V.s rarely leave the mid-range spectrum. Mid-range drivers are usually cone-shaped but are sometimes dome-shaped.

### 3.5.3 Woofer

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| Figure 5 | Picture of typical Woofer |

The woofer is capable of producing low frequencies of sound. To reduce cost, the woofer is sometimes used to cover all or part of the ranges of the mid-range (up to 5,000 Hz) or subwoofer (as low as 20 Hz), at the cost of reduced performance. The woofer is typically larger than the other drivers, excluding the subwoofer, though advancements in speaker technology have reduced this over time.

### 3.5.4 Subwoofer

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| Figure 6 | Picture of a typical Subwoofer |

The subwoofer is capable of producing very low frequencies of sound, even below that of the woofer. It is typically used in the range of 20 Hz to 100 Hz. Higher quality systems are constrained to a lower range, typically below 80 Hz. The frequencies produced by a subwoofer are able to vibrate and travel through most materials, and they must be built solidly to prevent “cabinet rattle”, a phenomenon where loose materials are vibrated by these frequencies and rub against each other, producing unwanted noise.

Subwoofers are commonly installed separate from other components. One of the properties of low frequencies means it does not particularly matter where the subwoofer is located within a room, or which way it is facing. In addition, subwoofers tend to be much larger than the other components.

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# 4 Application

Loud speakers are used in a variety of locations, here are some examples:

Night clubs, known for loud music, use loud speakers of all size, some night clubs even have speakers hidden in the ceiling. The loud speaker set ups in nightclubs will incorporate all the different types of drivers: tweeter, mid-range, woofer, and subwoofer in order to get the widest range of frequencies. The more frequencies available the better the sound quality will be and good sounding music is a driving force in nightclubs.

Stadiums, specifically outdoor ones, use large and weather resistant loudspeakers. The usage of stadium speakers is a mix between spoken word such as live commentary and music, in between innings for baseball and in between plays during football as examples. The speaker setups for stadiums are more focused on covering a large area than having all the possible frequencies; therefore, most stadium speakers are mid-range. That is the reason bands and performers bring their own speaker setups when they perform in stadiums — to cover the rest of the frequencies.

Schools, even public ones, need to be able to address all those on campus. Loud speakers in every room and hallway allows for this to happen. The main usage of school speakers is spoken word such as morning announcements, fire drills, and calling students to the principal’s office. Mid-Range speakers are the best choice for the needs of school. So the ones in the ceilings are usually the dome shaped variety to be less invasive.

Homes, depending on what kind of experience is wanted, can be outfitted with any and all kinds of loudspeakers. The speakers found in houses could be for a home theatre, a garage band, or a simple bluetooth, recently in home devices such as Alexa and Google Home have incorporated speakers. The sound bar is a popular speaker type to have in the home it has bluetooth connectivity, most have good sound quality for the price, and the bar shape is perfect for the home setting.

Cinemas invest in very extensive, high quality sound setups. They typically have many speakers embedded in multiple locations in front of, behind, and above the audience. The speaker systems are calibrated and software coordinated to reproduce audio as if it is in a specific location, a feat achieved by varying the intensity of the audio broadcast from each speaker independently. Dolby Atmos is commonly used in theatres, and claims the ability to reproduce up to 128 sounds in varying locations at any point in time (*Dolby Cinema: The Total Cinema Experience)*.

Mobile devices typically do not need to deliver outstanding audio performance. The speakers are therefore relatively weak, and usually unable to broadcast more than a few feet. In addition, due to their small size, mobile speakers are often quite bad at producing low sounds, and usually do not include many separate drivers to save on cost and space. Modern flagship devices do have quite high audio quality, and some even have advanced features like surround sound.

Headphones, similar to mobile devices, use miniaturized speakers. However, they are often required to produce very high audio performance. These higher end devices will include multiple drivers for different ranges and are much more accurate than those used in mobile devices as a result. There are many types of headphones, primarily divided into three categories: in-ear, on-ear, and over-ear, in order from smallest to largest. In-ear headphones are much smaller than the other two, however they are more convenient because of this. On-ear and over-ear headphones are larger, but can provide a higher quality listening experience and often include extra features like noise-isolation and noise-cancelling.

# 5 Conclusion

A loudspeaker is a device which converts electricity into sound. It houses multiple drivers which produce different frequencies, or pitches, of sound. Each driver has four components: a magnet, a voice coil, a diaphragm, and a suspension. Changing electrical current runs through a cylindrical wire winding called a voice coil. The current induces a magnetic field which attracts or repels the permanent magnetic field of the magnet. The diaphragm, connected to the voice coil, oscillates and produces pressure waves in the air, also known as sound waves. Lastly, the surround and spider comprise the suspension system which limits the movement of the diaphragm.

Since its invention, there have been some discoveries that led to improvements in sound quality from a loudspeaker. Material choice for each of the components may affect loudness, clarity, or frequency range. The shape of the diaphragm or suspension will have an impact as well. There are many factors that can play a role, but at its roots, the general technology inside a modern loudspeaker is surprisingly similar compared to an early loudspeakers. Once the basics are understood, the process by which a loudspeaker creates sound is simple to understand

# 6 Bibliography

Svjo. *File:Loudspeaker-Bass.png*, Wikimedia Commons, 25 Dec. 2013, 18:15:46, commons.wikimedia.org/wiki/File:Loudspeaker-bass.png.

Svjo. *File:Midrange-Speaker.png*, Wikimedia Commons, 20 Mar. 2014, 13:06:27, commons.wikimedia.org/wiki/File:Midrange-speaker.png.

Svjo. *File:Tweeter.png*, Wikimedia Commons, 8 Jan. 2014, 12:33:15, commons.wikimedia.org/wiki/File:Tweeter.png.

Jones, Andrew. “ELAC’s Andrew Jones on the Art of Speaker Design.” *Youtube,* uploaded by  
 Steve Guttenberg Audiophiliac, 15 Mar. 2018, www.youtube.com/watch?v=  
 wcXvIfQfy8Q&

“Sound.” *Merriam-Webster*, Merriam-Webster, www.merriam-webster.com/dictionary/sound.

“How Loudspeakers Work.” *Explain that stuff,* 4 July 2018, www.explainthatstuff.com/loudspeakers.html

Contributors, HowStuffWorks.com. “What's a Voice Coil on a Speaker?” HowStuffWorks, HowStuffWorks, 27 July 2011, electronics.howstuffworks.com/voice-coil-speaker.htm.

Reccius, Matias. *File:Woofer.jpg*, 17 June 2006, commons.wikimedia.org/wiki/File:Woofer.jpg.

Herzog, Christian. *File:Final12hw6.Jpg*, 2009, commons.wikimedia.org/wiki/File:Final12hw6.jpg.

“The Total Cinema Experience.” *Dolby Cinema: The Total Cinema Experience*, www.dolby.com/us/en/platforms/dolby-cinema.html.

“PROFESSIONAL SOLUTIONS.” *Nightclub | HARMAN Professional Solutions*, ro.harman.com/  
 applications/clubs-bars/solutions/nightclub.

“Stadium Speakers.” *Pro Acoustics*, www.proacousticsusa.com/commercial-sound-equipment/  
 commercial-audio-speakers/stadium-speakers.html.

“School Sound Systems.” *Pro Acoustics*,   
 www.proacousticsusa.com/complete-sound-systems/school-sound-systems.html.

“Home.” *JBL*, www.jbl.com/home-audio/.

“'Dome Tweeter' in Patent Application Approval Process (USPTO 20190098412)." Journal of   
 Engineering, 15 Apr. 2019, p. 7271. Gale Academic Onefile, link-gale-com.proxy.lib.  
 iastate.edu/apps/doc/A582306609/AONE?u=iastu\_main&sid=AONE&xid=ef1d4227.

Ballou, Glen, and Safari, an O’Reilly Media Company. *Handbook for Sound Engineers*, 4th   
 Edition Ballou, Glen. 4th ed., 2013.