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How Speakers Work

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Speakers take electronic signals and turn them into sound. See more audio tech pictures.

Introduction to How Speakers Work

In any sound system, ultimate quality depends on the speakers. The best recording, encoded on the most advanced storage device and played by a top-of-the-line deck and amplifier, will sound awful if the system is hooked up to poor speakers.

A system's speaker is the component that takes the electronic signal stored on things like CDs, tapes and DVDs and turns it back into actual sound that we can hear.

In this article, we'll find out exactly how speakers do this. We'll also look at how speaker designs differ, and see how these differences affect sound quality. Speakers are amazing pieces of technology that have had a profound impact on our culture. But at their heart, they are remarkably simple devices.

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Sound Basics

To understand how speakers work, you first need to understand how sound works.

Inside your ear is a very thin piece of skin called the **eardrum**. When your eardrum vibrates, your brain interprets the vibrations as sound -- that's how you hear. Rapid changes in air pressure are the most common thing to vibrate your eardrum.

An object produces sound when it vibrates in air (sound can also travel through liquids and solids, but air is the transmission medium when we listen to speakers). When something vibrates, it moves the air particles around it. Those air particles in turn move the air particles around them, carrying the pulse of the vibration through the air as a traveling disturbance.

To see how this works, let's look at a simple vibrating object -- a bell. When you ring a bell, the metal vibrates -- flexes in and out -- rapidly. When it flexes out on one side, it pushes out on the surrounding air particles on that side. These air particles then collide with the particles in front of them, which collide with the particles in front of them and so on. When the bell flexes away, it pulls in on these surrounding air particles, creating a drop in pressure that pulls in on more surrounding air particles, which creates another drop in pressure that pulls in particles that are even farther out and so on. This decreasing of pressure is called **rarefaction**.

In this way, a vibrating object sends a **wave** of pressure fluctuation through the atmosphere. When the fluctuation wave reaches your ear, it vibrates the eardrum back and forth. Our brain interprets this motion as sound.

Differentiating Sound

We hear different sounds from different vibrating objects because of variations in:

- **Sound-wave frequency** - A higher wave frequency simply means that the air pressure fluctuates faster. We hear this as a higher **pitch**. When there are fewer fluctuations in a period of time, the pitch is lower.
- **Air-pressure level** - This is the wave's amplitude, which determines how loud the sound is. Sound waves with greater amplitudes move our ear drums more, and we register this sensation as a higher **volume**.

A microphone works something like our ears. It has a **diaphragm** that is vibrated by sound waves in an area. The signal from a microphone gets encoded on a tape or CD as an electrical signal. When you play this signal back on your stereo, the amplifier sends it to the speaker, which re-interprets it into physical vibrations. Good speakers are optimized to produce extremely accurate fluctuations in air pressure, just like the ones originally picked up by the microphone. In the next section, we'll see how the speaker accomplishes this.

Making Sound

In the last section, we saw that sound travels in waves of air pressure fluctuation, and that we hear sounds differently depending on the frequency and amplitude of these waves. We also learned that microphones translate sound waves into electrical signals, which can be encoded onto CDs, tapes, LPs, etc. Players convert this stored information back into an electric current for use in the stereo system.

A speaker is essentially the final translation machine -- the reverse of the microphone. It takes the electrical signal and translates it back into physical vibrations to create sound waves. When everything is working as it should, the speaker produces nearly the same vibrations that the microphone originally recorded and encoded on a tape, CD, LP, etc.

Traditional speakers do this with one or more **drivers**.

A typical speaker driver, with a metal basket, heavy permanent magnet and paper diaphragm

Making Sound: Diaphragm

A driver produces sound waves by rapidly vibrating a flexible **cone**, or **diaphragm**.

- The **cone**, usually made of paper, plastic or metal, is attached on the wide end to the suspension.
- The **suspension**, or **surround**, is a rim of flexible material that allows the cone to move, and is attached to the driver's metal frame, called the **basket**.
- The narrow end of the cone is connected to the **voice coil**.
- The coil is attached to the basket by the **spider**, a ring of flexible material. The spider holds the coil in position, but allows it to move freely back and forth.

Some drivers have a **dome** instead of a cone. A dome is just a diaphragm that extends out instead of tapering in.

Making Sound: Voice Coil

The wire that runs through the speaker system connects to two hook-up jacks on the driver.

When the electrical current flowing through the voice coil changes direction, the coil's polar orientation reverses.

The voice coil is a basic electromagnet.

If you've read How Electromagnets Work, then you know that an electromagnet is a coil of wire, usually wrapped around a piece of magnetic metal, such as iron. Running electrical current through the wire creates a magnetic field around the coil, magnetizing the metal it is wrapped around. The field acts just like the magnetic field around a permanent magnet: It has a polar orientation -- a "north" end and and a "south" end -- and it is attracted to iron objects. But unlike a permanent magnet, in an electromagnet you can alter the orientation of the poles. If you reverse the flow of the current, the north and south ends of the electromagnet switch.

This is exactly what a stereo signal does -- it constantly **reverses the flow of electricity**. If you've ever hooked up a stereo system, then you know that there are two output wires for each speaker -- typically a black one and a red one.

Essentially, the amplifier is constantly switching the electrical signal, fluctuating between a positive charge and a negative charge on the red wire. Since electrons always flow in the same direction between positively charged particles and negatively charged particles, the current going through the speaker moves one way and then reverses and flows the other way. This **alternating current** causes the polar orientation of the electromagnet to reverse itself many times a second.

Making Sound: Magnets

When the electrical current flowing through the voice coil changes direction, the coil's polar orientation reverses. This changes the magnetic forces between the voice coil and the permanent magnet, moving the coil and attached diaphragm back and forth.

So how does the fluctuation make the speaker coil move back and forth? The electromagnet is positioned in a constant magnetic field created by a **permanent**

magnet. These two magnets -- the electromagnet and the permanent magnet -- interact with each other as any two magnets do. The positive end of the electromagnet is attracted to the negative pole of the permanent magnetic field, and the negative pole of the electromagnet is repelled by the permanent magnet's negative pole. When the electromagnet's polar orientation switches, so does the direction of repulsion and attraction. In this way, the alternating current constantly reverses the magnetic forces between the voice coil and the permanent magnet. This pushes the coil back and forth rapidly, like a piston.

When the coil moves, it pushes and pulls on the speaker cone. This vibrates the air in front of the speaker, creating sound waves. The electrical audio signal can also be interpreted as a **wave**. The frequency and amplitude of this wave, which represents the original sound wave, dictates the rate and distance that the voice coil moves. This, in turn, determines the frequency and amplitude of the sound waves produced by the diaphragm.

Different driver sizes are better suited for certain frequency ranges. For this reason, loudspeaker units typically divide a wide frequency range among **multiple drivers**. In the next section, we'll find out how speakers divide up the frequency range, and we'll look at the main driver types used in loudspeakers.


Woofer

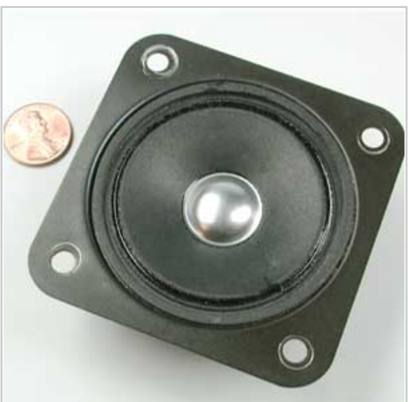
Driver Types

In the last section, we saw that traditional speakers produce sound by pushing and pulling an electromagnet attached to a flexible cone. Although drivers are all based on the same concept, there is a wide range in driver size and power. The basic driver types are:

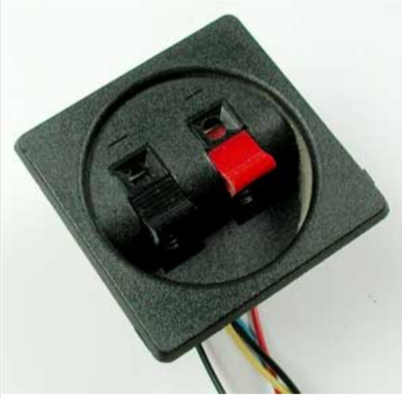
- **Woofers**
- **Tweeters**
- **Midrange**

Woofers are the biggest drivers, and are designed to produce low frequency sounds. **Tweeters** are much smaller units, designed to produce the highest frequencies. **Midrange** speakers produce a range of frequencies in the middle of the sound spectrum.

And if you think about it, this makes perfect sense. To create higher frequency waves -- waves in which the points of high pressure and low pressure are closer together -- the driver diaphragm must vibrate more quickly. This is harder to do with a large cone because of the mass of the cone. Conversely, it's harder to get a small driver to vibrate slowly enough to produce very low frequency sounds. It's more suited to rapid movement.


Tweeter


Midrange



The typical crossover unit from a loudspeaker: The frequency is divided up by inductors and capacitors and then sent on to the woofer, tweeter and mid-range driver.

The typical crossover unit from a loudspeaker: The frequency is divided up by inductors and capacitors and then sent on to the woofer, tweeter and mid-range driver.

Chunks of the Frequency Range

To produce quality sound over a wide frequency range more effectively, you can break the entire range into smaller chunks that are handled by specialized drivers. Quality loudspeakers will typically have a woofer, a tweeter and sometimes a midrange driver, all included in one **enclosure**.

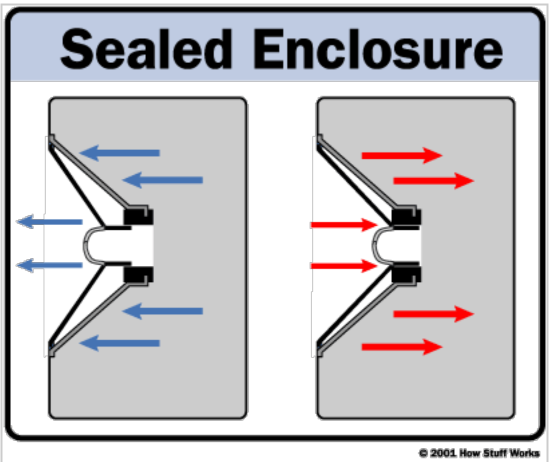
Of course, to dedicate each driver to a particular frequency range, the speaker system first needs to break the audio signal into different pieces -- low frequency, high frequency and sometimes mid-range frequencies. This is the job of the speaker **crossover**.

The most common type of crossover is **passive**, meaning it doesn't need an external power source because it is activated by the audio signal passing through it. This sort of crossover uses inductors, capacitors and sometimes other circuitry components. Capacitors and inductors only become good conductors under certain conditions. A crossover capacitor will conduct the current very well when the frequency exceeds a certain level, but will conduct poorly when the frequency is below that level. A crossover inductor acts in the reverse manner -- it is only a good conductor when the frequency is below a certain level.

When the electrical audio signal travels through the speaker wire to the speaker, it passes through the crossover units for each driver. To flow to the tweeter, the current will have to pass through a capacitor. So for the most part, the high frequency part of the signal will flow on to the tweeter voice coil. To flow to the woofer, the current passes through an inductor, so the driver will mainly respond to low frequencies. A crossover for the mid-range driver will conduct the current through a capacitor and an inductor, to set an upper and lower cutoff point.

There are also **active crossovers**. Active crossovers are electronic devices that pick out the different frequency ranges in an audio signal before it goes on to the amplifier (you use an amplifier circuit for each driver). They have several advantages over passive crossovers, the main one being that you can easily adjust the frequency ranges. Passive crossover ranges are determined by the individual circuitry components -- to change them, you need to install new capacitors and inductors. Active crossovers aren't as widely used as passive crossovers, however, because the equipment is much more expensive and you need multiple amplifier outputs for your speakers.

Crossovers and drivers can be installed as separate components in a sound system, but most people end up buying speaker units that house the crossover and multiple drivers in one box. In the next section, we'll find out what these **speaker enclosures** do and how they affect the speaker's sound quality.



In a sealed speaker setup, the driver diaphragm compresses air in the enclosure when it moves in and rarefies air when it moves out.

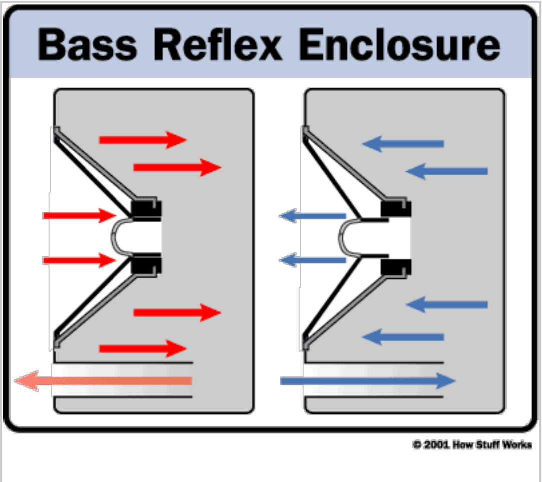
Sealed Speaker Enclosures

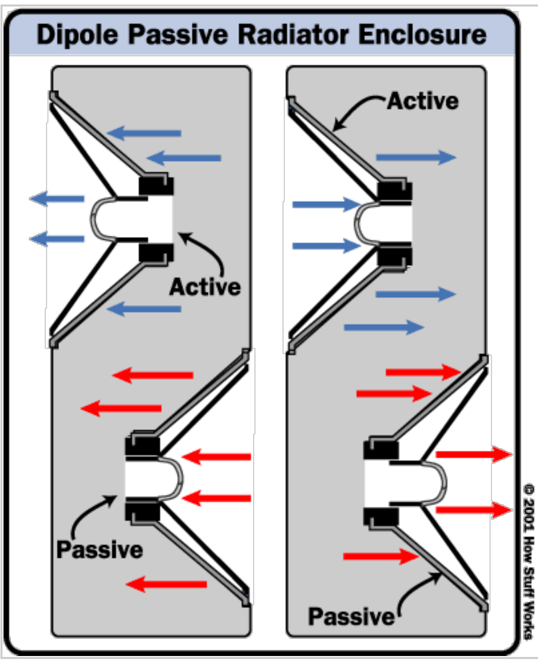
In most loudspeaker systems, the drivers and the crossover are housed in some sort of **speaker enclosure**. These enclosures serve a number of functions. On their most basic level, they make it much easier to set up the speakers. Everything's in one unit and the drivers are kept in the right position, so they work together to produce the best sound. Enclosures are usually built with heavy wood or another solid material that will effectively absorb the driver's vibration. If you simply placed a driver on a table, the table would vibrate so much it would drown out a lot of the speaker's sound.

Additionally, the speaker enclosure affects how sound is produced. When we looked at speaker drivers, we focused on how the vibrating diaphragm emitted sound waves in front of the cone. But, since the diaphragm is moving back and forth, it's actually producing sound waves behind the cone as well. Different enclosure types have different ways of handling these "backward" waves.

The most common type of enclosure is the **sealed enclosure**, also called **acoustic suspension enclosure**. These enclosures are completely sealed, so no air can escape. This means the forward wave travels outward into the room, while the backward wave travels only into the box. Of course, since no air can escape, the internal air pressure is constantly changing -- when the driver moves in, the pressure is increased and when the driver moves out, it is decreased. Both movements create pressure differences between the air inside the box and the air outside the box. The air will always move to equalize pressure levels, so the driver is constantly being pushed toward its "resting" state -- the position at which internal and external air pressure are the same.

These enclosures are less efficient than other designs because the amplifier has to boost the electrical signal to overcome the force of air pressure. The force serves a valuable function, however -- it acts like a spring to keep the driver in the right position. This makes for tighter, more precise sound production.





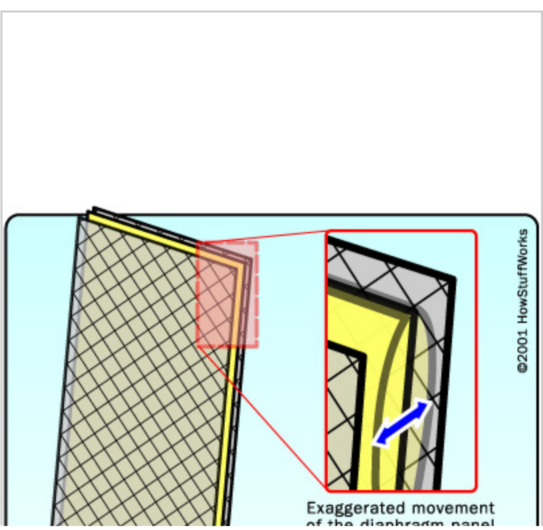
Other Speaker Enclosures

Other enclosure designs redirect the inward pressure outward, using it to supplement the forward sound wave. The most common way to do this is to build a small **port** into the speaker. In these **bass reflex** speakers, the backward motion of the diaphragm pushes sound waves out of the port, boosting the overall sound level. The main advantage of bass reflex enclosures is efficiency. The power moving the driver is used to emit two sound waves rather than one. The disadvantage is that there is no air pressure difference to spring the driver back into place, so the sound production is not as precise.

Passive radiator enclosures are very similar to bass reflex units, but in passive radiator enclosures, the backward wave moves an additional, **passive** driver, instead of escaping out of the port. The passive driver is just like the main, **active** drivers except it doesn't have an electromagnet voice coil, and it isn't connected to the amplifier. It is moved only by the sound waves coming from the active drivers. This type of enclosure is more efficient than sealed designs and more precise than bass reflex models.

Some enclosure designs have an active driver facing one way and a passive driver facing the other way. This **dipole** design diffuses the sound in all directions, making it a good choice for the rear channels in a home theater system.

These are just a few of the many enclosure types available. There are a huge range of speaker units on the market, with a variety of unique structures and driver arrangements. Check out this page to learn about some of these designs.

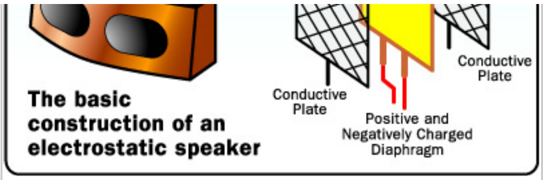


Alternative Speaker Designs

Most loudspeakers produce sound with traditional drivers. But there are a few other technologies on the market. These designs have some advantages over traditional **dynamic** speakers, but they fall short in other areas. For this reason, they are often used in conjunction with driver units.

The most popular alternative is the **electrostatic speaker**. These speakers vibrate air with a large, thin, conductive diaphragm panel. This diaphragm panel is suspended between two stationary conductive panels that are charged with electrical current from a wall outlet. These panels create an electrical field with a positive end and a negative end. The audio signal runs a current through the suspended panel, rapidly switching between a positive charge and a negative charge. When the charge is positive, the panel is drawn toward the negative end of the field, and when the charge is negative, it moves toward the positive end in the field.

In this way, the diaphragm rapidly vibrates the air in front of it. Because the panel has such a low mass, it responds very quickly and precisely to changes in the audio signal. This makes for clear, extremely accurate sound reproduction. The panel doesn't move a great distance, however, so it is not very effective at producing lower frequency sounds. For this



The diaphragm is alternately charged with a positive current and a negative current, based on the varying electrical audio signal. When the diaphragm is positively charged, it fluctuates toward the front plate, and when it is negatively charged it fluctuates toward the rear plate. In this way, it precisely reproduces the recorded pattern of air fluctuations.

reason, electrostatic speakers are often paired with a woofer that boosts the low frequency range. The other problem with electrostatic speakers is that they must be plugged into the wall and so are more difficult to place in a room.

Another alternative is the **planar magnetic** speaker. These units use a long, metal **ribbon** suspended between two magnetic panels. They basically work the same way as electrostatic speakers, except that the alternating positive and negative current moves the diaphragm in a magnetic field rather than an electric field. Like electrostatic speakers, they produce high-frequency sound with extraordinary precision, but low frequency sounds are less defined. For this reason, the planar magnetic speaker is usually used only as a tweeter.

Both of these designs are becoming more popular with audio enthusiasts, but traditional dynamic drivers are still the most prevalent technology, far and away. You'll find them everywhere you go -- not only in stereo setups, but in alarm clocks, public address systems, televisions, computers, headphones and tons of other devices. It's amazing how such a simple concept has revolutionized the modern world!

For more information on speakers and related topics, check out the links on the next page.

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