LOUDSPEAKER

Definition

A **loudspeaker** is an electromechanical transducer that converts an electrical signal into sound.

Basics

A **loudspeaker**, which is also called a speaker, is a device that is used to create the sound in radios, television sets, and electric musical instrument amplifier systems.

How it works

Loudspeakers use both electric and mechanical principles to convert an electrical signal from a radio, television set, or electric musical instrument into sound. For a loudspeaker to produce sound, the signal from the radio, television set, or electric musical instrument needs to be connected to an electronic amplifier.

Loudspeakers are usually built by using stiff paper cone, a coil of thin copper wire, and a circular magnet. The cone, copper wire, and magnet are usually mounted in a rectangle-shaped wood cabinet. The coil of copper wire moves back and forth when an electrical signal is passed through it. The coil of copper wire and the magnet cause the rigid paper cone to vibrate and reproduce sounds.

Types of loudspeakers

Some loudspeakers are designed for lower-pitched sounds, such as woofer loudspeakers or subwoofer loudspeakers. Other loudspeakers, which are called tweeters, are designed to reproduce high-pitched sounds (such as the sound of a whistle or a bird singing).

Loudspeakers for electric musical instruments are usually much stronger and heavier than loudspeakers for radios or television sets.Loud speakers main function is to convert electrical signals given to it into sound signals.

History

Alexander Graham Bell invented the first loudspeaker in 1876. Bell invented the loudspeaker because he needed a device that would amplify sound for the telephone. In 1878, Ernst Siemens from Germany invented an improved type of loudspeaker.

Topics of Interest

A **loudspeaker, speaker**, or **speaker system** is an electromechanical transducer that converts an electrical signal into sound. The term loudspeaker can refer to individual devices (or drivers), or to complete systems consisting of an enclosure incorporating one or more drivers and additional electronics. Loudspeakers are the most variable elements in any audio system, and are responsible for marked audible differences between otherwise identical sound systems. Loudspeaker performance (i.e., their accuracy in reproducing a signal without adding distortion) is significantly poorer than that of other audio equipment. For example, harmonic distortion in a typical loudspeaker can be 100 to 1000 times greater than that in amplifiers. The frequency response of a loudspeaker is often referenced as being within ±3 dB of perfect linearity (though many speaker designs fall far outside this range), whereas an amplifier may vary less than 0.1 dB.

To reproduce a wide range of frequencies, most loudspeaker systems require more than one driver, particularly for high sound pressure level or high fidelity applications. Individual drivers are used to cover different frequency ranges. The drivers are named subwoofers, for very low frequencies; woofers, for low frequencies; squawkers, for middle frequencies; tweeters, for high frequencies; and supertweeters, for very high frequencies. An electronic filter called a crossover separates the incoming signal into different frequency bands appropriate for each driver. A loudspeaker system with 'N' separate frequency bands is described as "N-way speakers": a 2-way system will have woofer and tweeter speakers; a 3-way system a combination of woofer, tweeter, and mid-range speakers, and so on.

History

Alexander Graham Bell patented the first electrical loudspeaker as part of his telephone in 1876, which was followed in 1878 by an improved version from Ernst Siemens. Nikola Tesla reportedly created a similar device in 1881, but was not issued a patent. During this time, Thomas Edison was issued a British patent for a system using compressed air as an amplifying mechanism for his early cylinder phonographs, but he ultimately settled for the familiar metal horn driven by a membrane attached to the stylus. In 1898, Horace Short patented a design for a loudspeaker driven by compressed air, then sold the rights to Charles Parsons, who was issued several additional British patents before 1910. Several companies, including Victor and Pathe, produced record players using compressed-air loudspeakers. However, these designs were significantly limited by their poor overall sound quality and their inability to reproduce sound at low-volume. Variants of the system were used for public address applications, and much more recently other variations have been used to test space equipment for resistance to the very loud sound levels launch rockets produce (ca, 165 dB SPL).

The modern design of moving-coil drivers was established by Oliver Lodge in (1898). The moving coil principle was patented in 1924 by Chester W. Rice and Edward W. Kellogg.

These first loudspeakers used electromagnets because large, powerful permanent magnets were generally not available at a reasonable price. The coil of an electromagnet, called a field coil, was energized by current through a second pair of connections to the driver. This winding usually served a dual role, acting also as a choke coil filtering the power supply of the amplifier to which the loudspeaker was connected. AC ripple in the current was attenuated by the action of passing through the choke coil; however, AC line frequencies tended to modulate the audio signal being sent to the voice coil and added to the audible hum of a powered-up sound reproduction device.

The quality of loudspeaker systems until the 1950s was, by modern standards, poor. Continuous developments in enclosure design and materials have led to significant audible improvements. The most notable improvements in modern speakers are improvements in cone materials, the introduction of higher temperature adhesives, improved permanent magnet materials, improved measurement techniques, computer aided design and finite element analysis.

Driver design

Cut-away view of a dynamic loudspeakerThe most common type of driver uses a lightweight diaphragm connected to a rigid basket, or frame, via flexible suspension which constrains a coil of fine wire to move axially through a cylindrical magnetic gap. When an electrical signal is applied to the voice coil, a magnetic field is created by the electric current in the coil which thus becomes an electromagnet. The coil and the driver's magnetic system interact, generating a mechanical force which causes the coil, and so the attached cone, to move back and forth and so reproduce sound under the control of the applied electrical signal coming from the amplifier. The following is a brief discussion of the individual components of this most common type of loudspeaker.

The diaphragm is usually manufactured in a cone or dome shaped profile. A variety of different materials may be used, but the most common are paper, plastic and metal. The ideal material would be stiff, light and well damped. In practice, all three of these criteria cannot be met simultaneously, and thus driver design involves tradeoffs. Paper is light and well damped, but not stiff. Metal can be made stiff and light, but it is not well damped. Plastic can be light, but typically the stiffer it is made, the less well-damped it is. As a result, many cones are made of some sort of composite. This can either be a sandwich construction or simply a coating to stiffen or damp a cone.

The basket or frame must be designed for rigidity to avoid deformation, which could cause the voice coil to rub against the magnet structure. Baskets are typically cast or stamped metal, although molded plastic baskets are becoming common, especially for inexpensive drivers. The frame plays a secondary role in conducting heat away from the coil.

The suspension system keeps the coil centered in the gap and provides a restoring force to make the speaker cone return to a neutral position after moving. A typical suspension system consists of two parts: the "spider", which connects the diaphragm or voice coil to the frame and provides the majority of the restoring force; and the "surround", which helps center the coil and allows free movement. The spider is usually made of a corrugated fabric disk. The surround can be a roll of rubber or foam or a corrugated fabric, attached to the outer circumference of the cone and to the frame.

The voice coil wire is usually copper, though aluminum, or rarely silver, may be used. Voice coil wire can be round, rectangular, or hexagonal, giving varying amounts of wire volume coverage in the available magnetic gap. The coil is oriented coaxially inside the gap, a small circular volume (a hole, slot, or groove) in the magnetic structure within which it can move back and forth. The gap establishes a concentrated magnetic field between the two poles of a permanent magnet; the outside of the gap being one pole and the center post (a.k.a. pole-piece) being the other. The center post and back-plate are sometimes a single piece called the yoke.

Modern driver magnets are almost always permanent and made of ceramic, ferrite, Alnico, or, more recently, rare earth. The size and type of magnet and the magnetic circuit differ depending on design goals. A current trend in design, due to increases in transportation costs and a desire for smaller, lighter devices (as in many home theater multi-speaker installations), is the use of rare earth magnet instead of ferrite types.

Driver design, and the combination of one or more drivers into an enclosure to make a speaker system, is both an art and science. Adjusting a design to improve performance is done using magnetic, acoustic, mechanical, electrical, and material science theory, high precision measurements, and the observations of experienced listeners. Designers can use an anechoic chamber to ensure the speaker can be measured independently of room effects, or any of several electronic techniques. Some developers eschew anechoic chambers in favor of specific standardized room set-ups intended to simulate real-life listening conditions. Some of the issues speaker designers must confront are lobing, phase effects, off axis response, crossover complications, and psychoacoustics.

Most loudspeaker drivers are currently manufactured in China. The fabrication of finished loudspeaker systems is segmented, depending largely on price point and on shipping costs and weight limitations. High-end speaker systems, often heavier than economic shipping allows outside local regions, are usually made in the same area as their target markets and can command prices of $10,000 or more per pair. The lowest-priced speaker systems are mostly manufactured in China or other low-cost manufacturing locations. Although the manufacture of drivers has become essentially commoditized, the fabrication and subsequent sale of finished speaker systems still carry high profit margins. Partly for this reason, manufacturers are increasingly combining power amplifier electronics (a typically lower profit item) with finished speaker systems to create "powered speakers" with an overall higher market value.

Loudspeaker system design

Crossover

Used in multi-driver speaker systems, the crossover is a device that separates the input signal into different frequency ranges for each driver. Each driver, therefore, will receive the frequency range it is designed for, so that the distortion in each driver, and interference between the drivers, is reduced. The ideal crossover would have no overlap in the signal sent to different drivers, but this is not achievable in practice with standard analog filters.

Crossovers can be passive or active. A passive crossover is an electronic circuit using a combination of one or more non-polar capacitors, resistors, and inductors. These parts are connected after the amplifier and divide the signal into individual frequency ranges before it is delivered to the speaker drivers. A passive crossover requires no external power. An active crossover is an electronic filter circuit that divides the signal into individual frequency ranges before the amplifier, requiring one amplifier for each bandpass.

Passive crossover are generally installed inside speaker boxes and are by far the most common type of crossover for home and low power use. In car audio systems, passive crossovers are often in a separate box due to the size of some of the passive components used. Passive crossovers convert part of the amplifier power they handle into heat, so when high power output is needed, active crossovers are often used. Active crossovers allow more precise alignment of phase and time between frequency bands; equivalently tight adjustment using only passive components is a difficult engineering problem in part because of part tolerances.

Many new loudspeaker designs have begun incorporating active crossover circuitry and onboard amplification. Such designs typically require AC power and need low level signal inputs instead of high level amplifier output connections. Ideally, this approach offers the advantages of close alignment of phase between frequency bands, active protection circuits to protect drivers, and virtually no loss of amplifier power in long cable runs or passive crossover components. Self-powered loudspeakers are being used in many applications such as small-scale computer sound (for one listener) and large-scale concert sound systems (for large halls full of listeners). Self-powered concert loudspeakers provide the additional benefit of improved predictability in sound quality; the touring concert sound engineer need not worry about customized crossover settings in each venue changing the characteristics of a loudspeaker.

Enclosures

Most loudspeaker systems consist of drivers mounted in an enclosure, or cabinet. The role of the enclosure is to provide a place to mount the drivers and prevent sound waves from the back of a driver from meeting those from the front-- which causes interference, cancellation and significantly alters the level and quality of low frequencies.

The simplest mounting is a flat panel (baffle) with the drivers mounted to it. However, in this design, frequencies with a wavelength longer than the baffle dimensions are canceled out because the antiphase radiation from the rear of the cone interferes with the radiation from the front. With an infinitely large panel interference could be entirely prevented. A sufficiently large sealed box can approach this behavior.

Since panels of infinite dimensions are impractical, most enclosures function by containing the rear radiation from the cone. A sealed enclosure prevents transmission of the sound emitted from the rear of the loudspeaker by confining the sound in a rigid and airtight box. Techniques used to reduce transmission of sound through the walls of the cabinet include thicker cabinet walls, lossy wall material, internal bracing, curved cabinet walls or more rarely visco-elastic materials or thin lead sheeting applied to interior enclosure walls.

However, this rigid enclosure provokes internal reflection of sound which can then be transmitted through the loudspeaker cone, again resulting in degradation of sound quality. This is reduced by internal absorption through the use of absorptive materials (often called "damping") such as fiberglass, wool, or synthetic fiber batting within the enclosure. The internal shape of the enclosure can be designed to reduce this by reflecting sounds away from the loudspeaker where they may then be absorbed.

Other enclosure types alter the rear radiation so it can add constructively to the output from the front of the cone. Designs that do this (including bass reflex, passive radiator, transmission line, etc...) are often used to extend the effective low frequency response of the driver.

To make the transition between drivers as seamless as possible, system designers have attempted to time-align or phase adjust the drivers by moving one or more drivers forward or back, so that the acoustic center of the drivers is in the same vertical plane. This may involve tilting the face speaker back, or providing separate enclosure mounting for each driver, or, less commonly, using electronic techniques to achieve the same effect. These attempts account for some unusual cabinet designs.

A speaker cabinet will cause diffraction, causing peaks and dips in the frequency response. This is usually a problem at higher frequencies where wavelengths are similar to, or smaller than, cabinet dimensions. The effect can be minimized by rounding the front edges of the cabinet, using a smaller or narrower enclosure, strategic arrangement of the drivers, or using absorptive material around a driver.

Specifications

Speaker specifications generally include:

- **Speaker or driver type** (individual units only) – Full-range, woofer, tweeter or mid-range.
- **Rated Power –** Nominal (or continuous) power, and peak (or maximum short-term) power a loudspeaker can handle (ie, maximum input power before thermally destroying the loudspeaker. It is not the power the loudspeaker produces). A driver may be damaged at much less than its rated power if driven past its mechanical limits at lower frequencies. Tweeters can also be damaged by amplifier clipping or by music, or sine wave input, at high frequencies. Both situations pass more energy to a tweeter than it can survive without damage.
- **Impedance –** typically 4 Ω (ohms), 8 Ω, etc.
- **Baffle or enclosure type** (enclosed systems only) – Sealed, bass reflex, etc.
- **Number of drivers** (complete speaker systems only) – 2-way, 3-way, etc.

and optionally:

- **Crossover frequency(ies)** (multi-driver systems only) – The frequency boundaries of the signal division between drivers.
- **Frequency response –** The measured, or specified, output over a specified range of frequencies for a constant input level varied across those freqencies. it often includes a variance limit such as within "+/- 2.5 dB".
- **Thiele/Small parameters** (individual drivers only) – these include the driver's Fs (resonance frequency), Qts (a driver's Q (or damping factor) at resonant frequency), Vas (the equivalent air compliance volume of the driver), etc.
- **Sensitivity –** The sound pressure level produced by a loudspeaker, usually specified in dB, measured at 1 meter with an input of 1 watt or 2.83 volts, typically at one or more specified frequencies. This rating is often inflated by manufacturers.
- **Maximum SPL –** The highest output, short of damage or not exceeding a particular distortion level, the loudspeaker can manage. This rating is often inflated by manufacturers and is commonly given without reference to frequency range or distortion level.

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