STEPHEN BOAK

Anatomy of a Loudspeaker

A basic look at the complex design of loudspeakers.

A LOUDSPEAKER, like a microphone or a phonograph cartridge, is a transducer, or converter. It is a device that converts electrical energy into mechanical, and then acoustical, energy. Though there are many types, any speaker serves but one purpose; connecting the electrical amplifier circuits and the listener's ears.

THE ROLE OF THE LOUDSPEAKER IN AN AUDIO SYSTEM

The loudspeaker is among the simplest of audio components; yet, its design can be enormously complex. It is simple because it has relatively few parts (as compared to a tape recorder, for example) and even fewer moving parts. With very few exceptions, it is virtually impossible to alter or change one part of a loudspeaker without noticeably affecting its performance. Also, the speaker system is the only audio component whose performance is radically influenced by its environment, which is usually beyond the control of the speaker designer. Further, it is the only component in direct contact with the ear, which is far from consistent. To make matters more complicated, there are no accepted specifications which will describe the way a speaker should perform. Here, we shall try to analyze some of the variables that affect loudspeakers and loudspeaker system performance.

Before we plunge into the simple theory behind speaker operation, it would be helpful to have a small section devoted to the parts that make up a speaker. These parts are usually called "piece parts." In the average speaker, there are some twelve to fifteen piece parts, four or five of which move.

The moving parts are the surround, cone (diaphragm), dust cap, bobbin, voice coil, and spider. The cone and surround come joined together, as do the bobbin and voice coil. The stationary parts are the gasket, basket, front and back plates, magnet, and pole piece.

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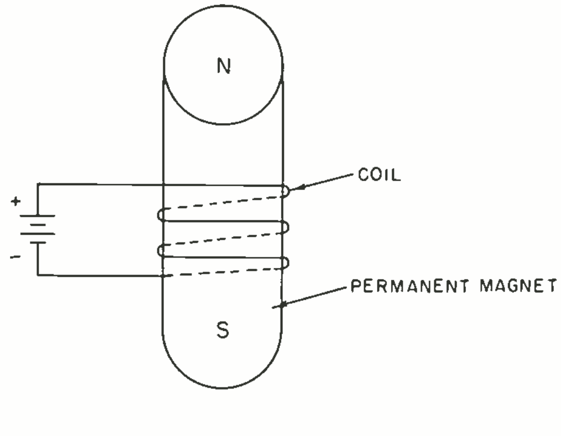
A description of some of the key pieces and their functions follows:

1. Basket—Sometimes called a frame or cone housing. The basket is the foundation for the speaker and holds all the parts. It may be made from stamped steel or cast aluminum, finished by static painting or plating.
2. Cone—Sometimes called the diaphragm or piston. The cone moves the air in front and behind it to make sound. It is usually made from a compound of paper, cloth and carbon fibre. Material for dome diaphragms range from Nylon 66 to Boron.
3. Surround—Also called the edge or anulus—part of the suspension. The surround attaches the cone to the basket. What the surround of a speaker is made of depends on the type. Woofers usually have a foam or butyl rubber edge. Musical instrument and full range types usually have a paper edge, which is just an extension of the cone. The kinds used for midranges and tweeters are too numerous to catalog here.
4. Dust Cap—Also called the center dome. Keeps foreign particles out of the air gap.
5. Spider—May be called a damper or back spider. A flexible ridged cloth disc attached to the cone and basket to keep the voice coil centered around the pole piece.

Figure 1. Current flow through the coil induces a magnetic field around the coil.



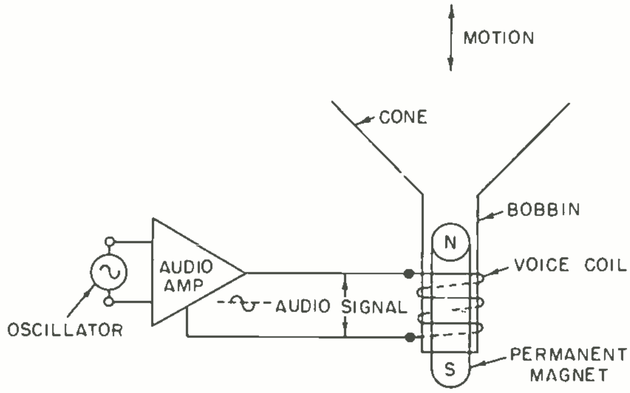


Figure 2. Basic speaker design.

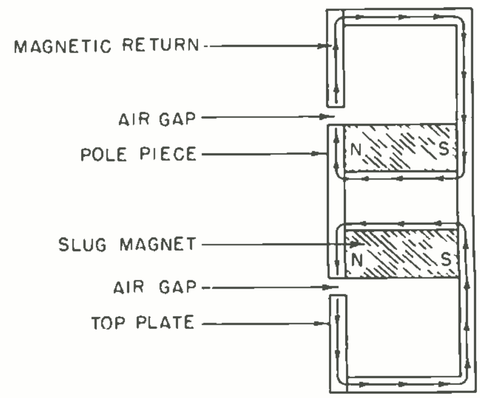


Figure 3. "Alnico" magnetic structure.

6. Voice Coil Assembly—Consists of a thin paper, cloth or aluminum tube (the bobbin) with a copper or aluminum wire coil around it.
7. Motor Structure— Front and Back Plates
   —Pole Piece
   —Magnet—popular types are Ceramic and Alnico. Ceramic magnets are a compound of clay and sintered iron. "Alnico" stands for *al*uminum-*ni*ckel-*co*balt. Other types include ferrite barium, cerium cobalt, and "Ticonal" (*ti*n-*co*balt-*n*ickel-*al*uminum).

The motor structure may also be called a "magnet pot." The motor consists of the magnet, and the magnetic return path to allow the diaphragm to move when voltage is applied to the voice coil.

TYPES OF LOUDSPEAKERS

Among loudspeakers available today, there are three basic categories (when classified by operating principle): 1. electrodynamic, 2. electrostatic, 3. piezoelectric. These classifications refer to the principle by which electrical energy is transformed into mechanical energy.

ELECTRODYNAMIC LOUDSPEAKER—BASIC PRINCIPLES

Electrodynamic loudspeakers are, by far, the most common. If it has a magnet, it's electrodynamic. When electrical current flows through wire, a magnetic field is induced around that wire. The polarity of the input voltage determines the polarity of the magnetic field around the wire. The polarity of the input signal is expressed either as a positive or a negative voltage, while the polarity of the magnetic field is expressed as north or south. Remembering high school science class, "Like poles repel, but unlike poles attract." These principles of polar attraction and the principle of induced magnetism are those upon which all electromagnetic loudspeaker designs are based.

Keeping in mind the two principles, polar attraction and induced magnetism, let's look at FIGURE 1.

The voltage from the battery will cause a current to flow through the coil, inducing a magnetic field around the coil. Because the polarity of the battery, with respect to the magnet, is positive, the polarity of the induced magnetic field will be north, causing the coil to move away from the magnet's north pole, towards its south pole.

Conversely, if we reverse the battery connections, the direction of current flow will reverse, as will the polarity of the induced magnetic field, and the coil will move in the opposite direction. If we alternate the battery connections or pass a varying signal in the coil, the direction of current flow will reverse or change with each alternation (alternating current), and the polarity of the induced magnetic field will be alternating, in turn. When this happens, the coil will move back and forth along the magnet as the direction of current flow alternates.

To convert this mechanical motion to acoustical energy, we must attach a cone or diaphragm to the coil and replace the battery with an amplifier driven by an audio signal, as in FIGURE 2. The amplifier drives the coil (now called a voice coil) with a signal of alternating potential, causing an induced magnetic field around the coil and a back-and-forth movement of the coil along the magnet. The coil is attached to the diaphragm and causes air to be moved back and forth as the coil moves back and forth. This, oversimplified, is how an electrodynamic loudspeaker produces sound.

Magnetism, like electricity, is always trying to neutralize itself; in this case, by trying to reduce the energy potential between one pole and the other. It is this principle that permits the electrodynamic loudspeaker to operate. FIGURE 3 shows a close-up view of an Alnico-type magnetic structure. The magnetic energy flows through the magnet pot, top plate, and pole piece to get the opposite pole of the magnet. To accomplish this, it must "jump" between the pole piece and top plate. This area is called the air gap. Just how much energy (called "flux density") is allowed to cross the gap, is a function of the size and type of magnet as well as the types and masses of materials used in the magnetic return circuit. The amount of magnetic energy, or flux, that crosses the gap is one of the major determing factors in the sensitivity of the loudspeaker to the input signal.

Types of magnets. As mentioned earlier, there are two popular types of magnets used in electrodynamic loudspeaker designs: Alinco (slug type) and ceramic (ring type). Magnet manufacturing methods dictate the shapes into which the magnets can be formed. The difference between the two is that the magnet slug is the pole piece in the Alnico design. In the ceramic design, the magnet surrounds the voice coil and the pole piece. Each structure has its own advantages and disadvantages.

Although both magnets are relatively efficient, the Alnico design has a better concentration of flux, thereby permitting relatively lighter structures when compared to ceramic designs. The basic drawback to the Alnico design, is that the magnet is inside the voice coil. If the coil is a high-power type, sustained amounts of high input power can actually result in a partial demagnetization of the magnet, which will alter the loudspeaker's performance. In the ceramic design, this is avoided. The ceramic design, however, has its own disadvantages. Because the

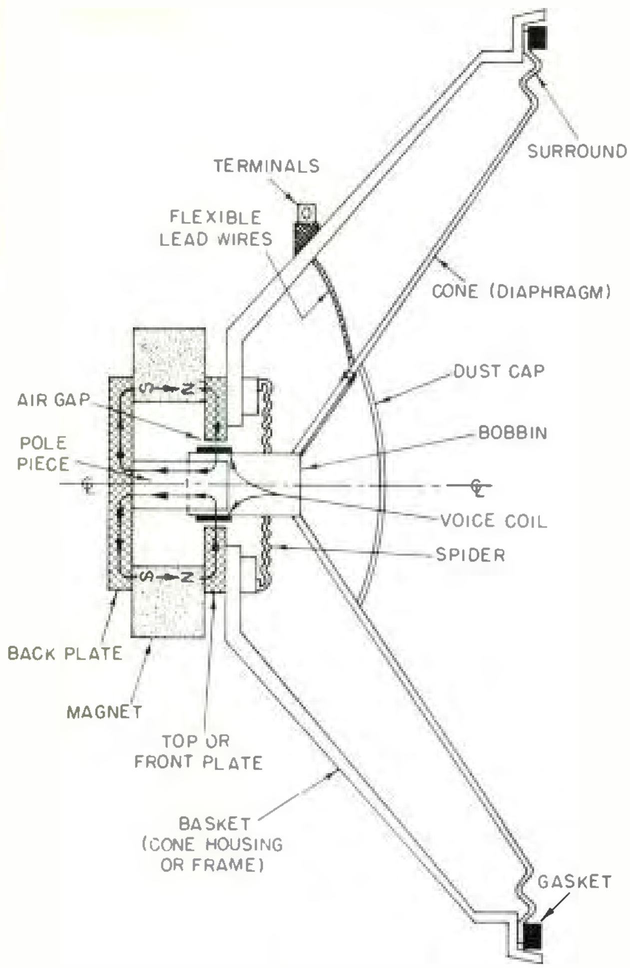


Figure 4. Parts diagram for a ceramic magnet-electrodynamic loudspeaker.

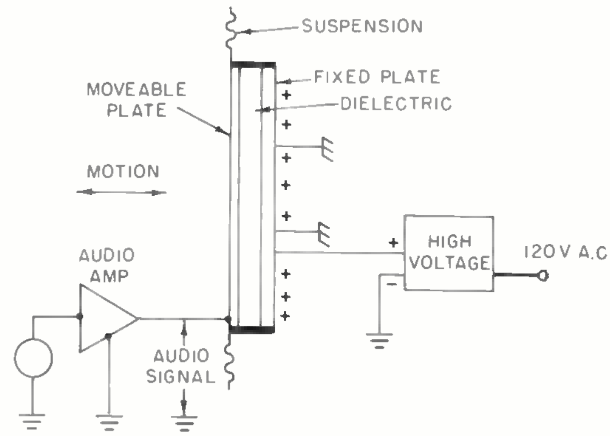


Figure 5. Electrostatic driver circuit.

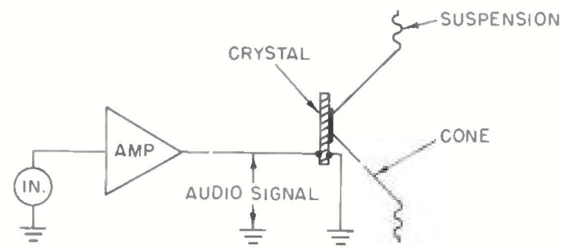


Figure 6. Piezoelectric driver circuit.

ceramic design requires that the magnet edges be exposed, a greater degree of fringing (lack of flux concentration) occurs, as compared to the Alnico design. This results in proportionately less flux being transferred to the air gap, requiring proportionately larger (than Alnico) magnets to perform a given job. This excess weight increases the chance of the magnet structure shifting, if the speaker is subjected to a sharp jolt. The ceramic magnet is also more susceptible than Alnico structures to being fractured, due to its material composition. FIGURE 4 shows the parts and assembly of a typical ceramic magnet electrodynamic loudspeaker.

ELECTROSTATIC OPERATION

Electrostatic designs, although not as common as electrodynamic designs, do occupy a very important position in the world of high fidelity. Although these designs tend to have excellent frequency response and transient response abilities, they do have limitations which are more severe than electrodynamic designs. In the areas of total acoustic output and power handling capacity they are deficient; they also lack good low frequency response and user convenience (for example, they require an extra power supply, which must be located near the speaker).

The electrostatic speaker operates in a similar fashion to an electrodynamic unit; that is, it derives its motion from the attraction of unlike charges. At the risk of being redundant, however, the charges are electrostatic, not magnetic.

FIGURE 5 indicates the basic parts of the electrostatic driver. A fixed high voltage is applied to a fixed plate. An amplified audio signal is applied to a movable plate. The two plates are separated by a dielectric (a special type of insulator). As the audio signal varies, the charge to the movable plate—which has the same polarity as the charge on the fixed plate—causes the movable plate to move away from the fixed plate. (Remember, like charges repel). Conversely, as the audio signal becomes more negative or less positive, the direction of motion is reversed because the movable plate is attracted to the charge on the fixed plate (unlike charges attract). This mechanical motion moves the air mass around it and produces sound.

PIEZOELECTRIC OPERATION

The third basic operating principle is the piezoelectric type. Loudspeakers of this design are sometimes referred to as solid state drivers.

As the name implies, this type of driver operates on the principle of piezoelectricity. It is also called a solid state driver because its operation is based on crystal, which is the basis for today's transistorized circuits.

The principle of piezoelectricity states that a crystal, when squeezed by a mechanical force, will emit a proportional electrical voltage. The earliest microphones worked this way. A diaphragm was attached to a crystal. The diaphragm would receive sound waves and push against the crystal. The crystal would emit a proportional electrical current which could then be amplified. The piezoelectric loudspeaker works in just the opposite way of the crystal microphone. It is shown in FIGURE 6.

An amplified audio signal is applied to the crystal. This causes a squeezing motion by the crystal. A diaphragm, connected to the crystal, moves with it, causing the air mass to move at the same rate, producing sound.

Because of the limited size of the crystals available, current piezoelectric designs have been restricted to high frequency reproducers only. These units are sometimes referred to as piezoelectric or solid state tweeters. ■