LOUDSPEAKERS 101

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MISCO Speakers is an audio industry leader using cutting-edge technology, design, and testing capabilities to continuously improve and educate. We value sharing the knowledge we've gleaned with our customers and others — from training future audio engineers to developing informational guides. Whether you're designing a sound system for a casino gaming unit, drive-thru kiosk, mass transit, auditorium, or vehicle, we're here to help you make sound decisions for your audio applications.

Only MISCO offers USA and off-shore speaker driver and amplifier manufacturing combined with full turnkey service from product design to delivery, and every step in between. From sophisticated custom audio systems to 'off-the-shelf' speaker drivers, MISCO has been saving our customers time, effort, and money for 70 years.

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The Sound of Imagination™

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What is Sound?

Sound is a variation in the local atmospheric pressure at a rate which we can hear. The rate (or frequency) of pressure variation is from about 20 Hz to 20 kHz, or from about 20 to 20,000 times per second. This pressure variation is quite small, on the order of 1/100,000th of the atmospheric pressure, so we could never see it on a barometer.

Sound has both objective and subjective attributes. Objective attributes are the things we can measure and they include:

- Amplitude or sound pressure in Pascals (Pa) or dB SPL
- Frequency in Hertz (Hz)
- The subjective attributes of sound are related to what our brain tells us about what our ears are sensing. Hearing is a percept, and what is perceived is sometimes only loosely related to objective quantities.
- Loudness (how loud or soft), in phons
- Pitch (how high or low), in mels
- Quality, which is multidimensional

For our purposes in this discussion the important thing to remember is that sound is produced by vibrations in the air.

What is a Speaker?

A loudspeaker is a *transducer*. It converts electrical energy into mechanical energy. This mechanical energy, in turn, is used to produce air movement which we hear as sound. A single loudspeaker unit is also called a driver. Multiple drivers are combined into *loudspeaker systems*.

There are several kinds of loudspeakers:

- Dynamic loudspeakers are by far the most widely used. This type of loudspeaker is MISCO's specialty. We will discuss this type of loudspeaker in detail in the coming pages.
- Electrostatic loudspeakers operate by the attraction and repulsion of electric fields. They are not commonly used except in certain specialised applications. They are usually only used for mid and high frequency reproduction.
- Piezoelectric speakers are quite common, but are limited to high frequency reproduction. They are sometimes used by MISCO as tweeters in co-axial speakers.

How a Dynamic Loudspeaker Works

Referring to the cutaway drawing on the left, and to the schematic diagram on the next page, you will see the various elements of the loudspeaker.

The basis of operation is electromagnetic. When two magnetic fields are brought near one another, if they are the same polarity (say North to North) they will repel each other. If they are of opposite polarity (say North to South) they will attract each other.

Further, when an electric current is passed through a wire, it will be surrounded by a magnetic field. This is the basis of operation of all electric motors. So to have an electric motor we at least need:

1) An electric current passing through a wire

2) A stationary magnetic field against which the field around the wire can act

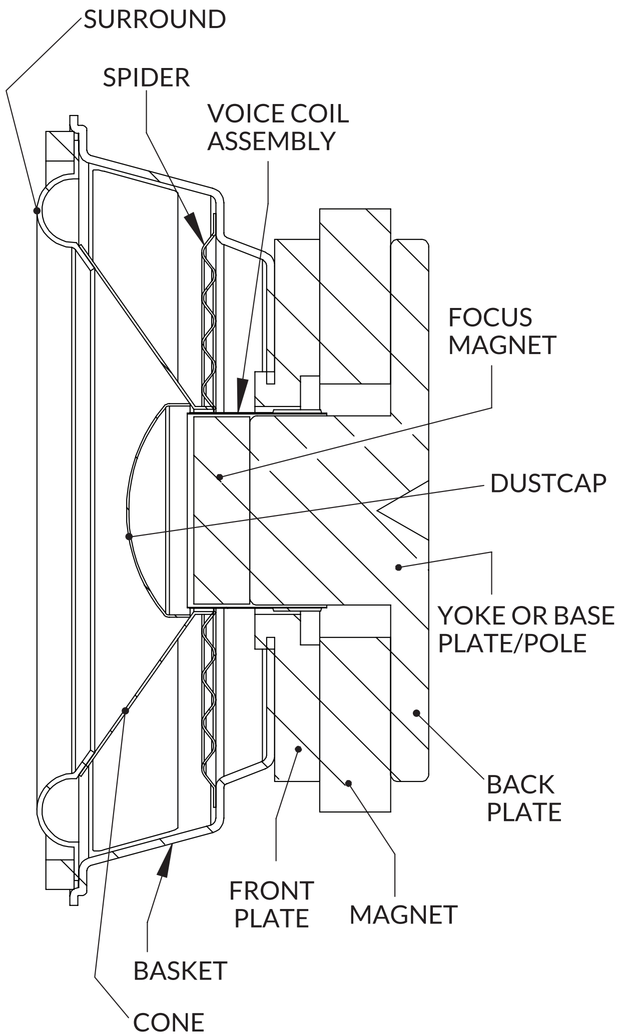
In a loudspeaker we have an electric *motor*. Its output goes back and forth in a reciprocating motion rather than turning a shaft, but it is a motor nonetheless. This is the first major subsystem of the driver. It is the part of the driver which *transduces* electric energy to mechanical energy.

The output of this motor is connected to the *diaphragm*, or *cone*. This is the second major subsystem of the driver. The movement of the cone in the air causes local variations in the pressure and *transduces* mechanical energy to acoustical energy. Acoustical energy is sound.

In order for the cone to move freely in the back-and-forth direction (axial), but to remain centered from side-to-side (radial), it is held by a suspension which is the third major subsystem. The suspension consists of the *spider* and the *surround*.

All of these parts are held in their proper relationship to each other by the chassis which is the fourth subsystem. The chassis is usually called the *basket* or *frame* in the loudspeaker business.

The Four Main Systems of an Electrodynamic Driver



01 MOTOR

Voice Coil, Pole Piece, Front Plate, Back Plate, Magnet

02 DIAPHRAGM

Cone, Dust Cap

03 SUSPENSION

Spider, Surround

04 BASKET/ FRAME

Electrical and Acoustical Terminology

Direct Current, DC

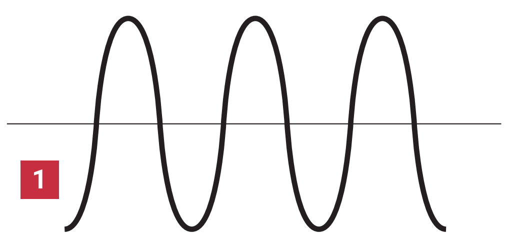
Direct current flows in only one direction. A battery is a typical source of DC. The convention for current flow is from positive to negative. There is no waveform (see below) for DC.

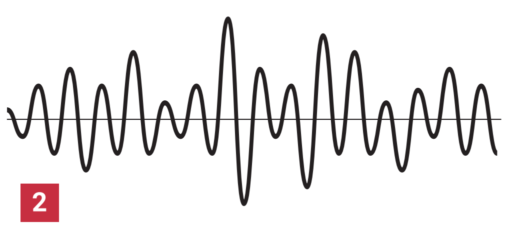
Alternating current, AC

Alternating current, as its name implies, alternates direction at a rate which is the frequency (see below). The alternation of the direction (polarity) of current flow corresponds to the alternating compression and rarefaction of the air in an acoustical signal. In the waveform diagrams below, everything above the line represents current flowing one way, and below the line the opposite direction.

Waveform

Audio engineers describe the patterns of sound vibrations as waveforms. Waveforms can be looked at using an instrument called an oscilloscope. It shows the instantaneous voltage against time. A waveform with only one frequency, at one amplitude, looks something like image 1.





Most sound is more complex, however, and is made up of many such tones at different frequencies and amplitudes summed together. A typical snippet of sound may look something like image 2.

The complexity of this second pattern gives some idea of the complexity of the cone motion in a speaker. It also shows how the same speaker can reproduce many different frequencies at the same time.

Electrical and Acoustical Terminology
continued

Frequency (Notation: f, Unit: Hertz (Hz))

Frequency is the rate at which the air is alternately compressed and rarefied. It is how many "cycles per second". High frequencies correspond to the perception of high pitch. The crests of the waves are closer together at high frequencies and farther apart at low frequencies.

Wavelength (Notation: λ, Greek letter lambda, Unit: meters (m))

Thus *wavelength* is opposite to frequency. f = 1/□. It follows that if we can hear from about 20 to 20,000 Hz, the range of wavelengths is also 1000:1. A 20 Hz wave in air is 17.25m long (56.6 feet), and a 20 kHz wave in air is .01725m long (.0566 feet or 0.679 inch).

Voltage (Notation: E, Unit: Volts, (V))

Voltage is the measure of electrical "pressure". Imagine water flowing in a pipe. The voltage is analogous to the force pushing the water through the pipe. Because the pipe may be small or large in diameter, the voltage does not, by itself, describe how *much* water is pushed through the pipe; only how *hard* it is pushed. In AC circuits, voltage is usually stated according to its RMS value, which is the correct measure of the energy.

Current (Notation: I, Unit: Amperes, (A))

Current is the measure of the quantity of electric charge. Imagine the water pipe again. Current is analogous to how big the pipe is in diameter. For the same pressure (voltage), a bigger pipe will deliver more total flow of water. In AC circuits, current is usually stated according to its RMS value, which is the correct measure of the energy.

Electrical and Acoustical Terminology
continued

Power (Notation: P, Unit: Watts, (W))

Power is the product of voltage x current. If either voltage or current is held constant, and the other is increased, the power will increase. Using the same analogy of a water pipe, power is the total amount of water which is delivered in a given period of time.

Resistance (Notation: R, Unit: Ohm, (Ω, Greek letter Omega))

Resistance is the opposition to the flow of current.

Ohm's Law

Ohm’s law relates Voltage, Current, Power and Resistance as follows:

E = I x R (and R = E/I; and I = E/R)

P = E x I (and P = E2/R ; and P = I2 x R)

Impedance (Notation: Z, Unit: Ohm, (Ω, Greek letter Omega))

Impedance is the opposition to current flow, like resistance. Strictly, resistance only applies in direct current (DC) circuits. Impedance only applies in alternating current (AC) circuits. Since all audio is AC, the term impedance will be frequently encountered.

Amplitude

Amplitude is the measure of the size of the wave, not to be confused with frequency. The units of amplitude depend on what is being described. For example:

Electrically: Volts, Amps, Watts

Acoustically: Pascals, dB SPL, Watts

Electrical and Acoustical Terminology
continued

The Decibel, dB

The *decibel* is a way of expressing amplitude.

The basic unit is the Bel, named after Alexander Graham Bell, the inventor of the telephone. The Bel is the common logarithm of the ratio of two power levels:

Bel = log10 (P1/P2)

However, in practice the Bel is inconveniently large, so the commonly used unit is 1/10th of a Bel, called the decibel, dB for short.

dB = 10 log10 (P1/P2)

If voltages (or sound pressures) are being ratioed, they must be squared, remember P = E2/R. In the log domain, exponentiation reduces to multiplication, so

dB = 20 log10 (E1/E2)

It is important to remember that the dB is always a ratio. Therefore, the term dB by itself has *no meaning*. A *reference* must be stated either in words or numbers or by a suffix. For example, dBV means dB referred to 1 Volt; dB SPL means sound pressure referred to a fixed agreed value (see below).

The reason we use logs and the dB in audio and acoustics and other fields, is because it is related to the way we hear, and also because it makes a convenient way to express large ratios which would not be intuitive on a linear scale.

We hear logarithmically. Every 10 dB change in sound pressure is perceived as a loudness difference of double (or half). **This is an important relationship to understand, because what it means is that it takes 10 times the power to produce each doubling of loudness**. 10 log10 (10/1) = 10 dB.

Electrical and Acoustical Terminology
continued

Dynamic Range

Dynamic range is the ratio between the largest and smallest signals in a system. In the system of human hearing, the dynamic range extends from the threshold of hearing to the threshold of pain. This is a range in sound pressure of about a million to one (1,000,000:1). Expressed in dB this is 120 dB between the softest sound we can hear and the loudest sound we can tolerate.

Sound Pressure Level (Notation: SPL, Unit: dB SPL)

Sound pressure level can be expressed on either a linear scale in physical units of pressure, Pascal (Newtons per square meter); or on a log scale in dB SPL.

The term dB SPL has an exact meaning. It means 20 log of the ratio between the measured pressure and a reference pressure of 20 uPa (micropascals). The reference of 20 uPa was chosen because it represents the threshold of hearing for most people. That way, on the dB SPL scale, all audible sounds will have a positive numerical value.

One decibel is the smallest perceptible change in sound level that the human ear can detect. Some examples of sound pressure levels are:

- Near total silence - 0 dB SPL
- A whisper - 15 dB SPL
- Normal conversation - 60 dB SPL
- A lawnmower - 90 dB SPL
- Passing subway train – 100 dB SPL
- A car horn - 110 dB SPL
- A rock concert or a jet engine - 120 dB SPL
- The threshold of pain is around 120 dB. SPL
- A gunshot or firecracker - 140 dB SPL

Loudspeaker and Specification Sheet Terminology

Driver

A *driver* is a single loudspeaker unit.

System

A Loudspeaker *system* is made up of two or more drivers. This is required when a wide frequency response or high acoustic output is desired. A single driver cannot cover the entire frequency range (see frequency response, below) with high power and good sensitivity. By dividing up the frequencies into two or three ranges, and using drivers designed for each range, this problem can be solved.

In a loudspeaker system as described above, the dividing-up of the frequency range is done in an electrical network called a crossover network. This crossover network is usually connected between the output from the amplifier and the individual drivers. This is called a *passive* crossover.

Sometimes, the frequencies are divided-up before the power amplifier, and a separate amplifier is used for each driver. This type of system has higher performance but is more expensive. Such a crossover is called an *active* crossover.

Woofer

A *woofer* is a driver intended to reproduce mainly low frequencies, below 500 Hz. It will almost always be 5.25" or larger but may be smaller in compact system designs. It will require a large excursion capability. Its design is generally coordinated with the design of the enclosure it will be mounted in.

Loudspeaker and Specification Sheet Terminology
continued

Midrange

A *midrange* driver handles the middle frequencies, usually from around 250 Hz up to 4 kHz – 5 kHz. This driver will not need very large excursion, but it will require frequency response which is free of irregularities.

Tweeter

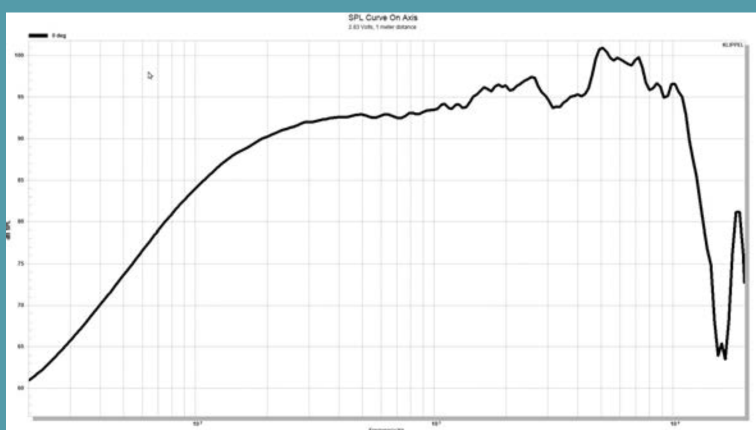
A *tweeter* is a small driver which is intended only to reproduce high frequencies, usually above 2500 Hz to 1500 Hz. It will have very little diaphragm motion, but the diaphragm must be very light in order to move quickly. Tweeters come in different sizes and types: Horn, Dome, and Electrostatic.

Frequency response

Frequency response is a measure of the uniformity of output at various frequencies. It is usually plotted as a graph, (see below) with amplitude response in dB SPL on the vertical axis, and frequency on a logarithmically plotted horizontal axis. If the frequency response is stated in words, it is of the form:

xx Hz to
xx kHz +/- xx dB

This means that from the lowest to the highest stated frequency, the output level will be within a tolerance given in dB, usually with respect to the



A typical loudspeaker frequency response curve. The X axis shows the frequency (Hz) and the Y axis shows amplitude (dB SPL).

Loudspeaker and Specification Sheet Terminology
continued

amplitude at the center of the range. A frequency response which is stated is less useful. A typical specification might read:

75 Hz to 12 kHz +/- 4 dB   -or-

75 Hz to 12 kHz +/- 4 dB re 1 kHz

Sensitivity

Sensitivity is a measure of how much sound pressure you get from a loudspeaker for a specified input. To be most correct, the input should be stated in Volts, but it is often stated in Watts. The reason for this is that the impedance of a driver is not constant at all frequencies. A nominal impedance is stated as a specification for the driver. If the input is said to be 1 Watt, that actually will be measured as a voltage equal to the square root of the power times the nominal impedance, E = sqrt(P x Z).

The correct statement of sensitivity is of the form:

xx dB SPL +/- xx dB at xxV at 1 meter --or—

xx dB SPL +/- xx dB at xxW at 1 meter

Usually the voltage is 2.83V RMS, which corresponds to 1W in 8Ω. A typical specification might read:

89 dB SPL +/-4 dB for 1 Watt at 1 meter

Note that the distance is also specified. This is very important because the SPL falls off with distance. 1 meter is the international standard measuring distance (or its scaled equivalent). In free space, the SPL falls off as the square of the distance, i.e. 6dB for every doubling of the distance. This is called the *inverse square law*. SPL $\propto$ 1/ r^2

Loudspeaker and Specification Sheet Terminology
continued

Efficiency (%)

The ratio of the acoustic power which is produced to the input of electric power is the *efficiency* of the speaker. Efficiency is extremely complicated to measure directly, so it is usually a calculated value if it is stated at all. When most people refer to efficiency, what they actually mean is sensitivity.

The efficiency of direct-radiator dynamic speakers is quite low, not because of any design shortcoming, but because of the physics of sound radiation. The highest efficiency which can be attained with a normal speaker is around 3% to 5%. What this means is that 95% to 97% of the power which is fed to the speaker goes up as heat in the voice-coil. This has major implications for the heat resistance of the motor materials in the speaker. If a big woofer can tolerate 100 Watts of input, about 95 Watts of that will be dissipated as heat. To appreciate what this means, turn on a 100 Watt light bulb for a few minutes and then try to keep your hand on it!

Resonance (fo or fs)

Every moving system, such as a loudspeaker, has a natural frequency. This is due to the mass of the system interacting with the stiffness. A good example of a natural frequency is a bell. You strike the bell any number of ways, but it always rings at the same pitch. That is because the energy of the strike excites the *resonance* of the bell.

In a loudspeaker, the mass of the cone is suspended by the stiffness of the suspension (the surround and the spider). There is, as a result, a natural frequency of oscillation, the resonance frequency. This is an important specification because it is used in many enclosure calculations, and because it is an indicator that the driver has been built right. The cone and the suspension both need to be correct for the resonance frequency to be repeatable from unit-to-unit.

Loudspeaker and Specification Sheet Terminology
continued

The resonance is normally stated at a particular drive level, for example:

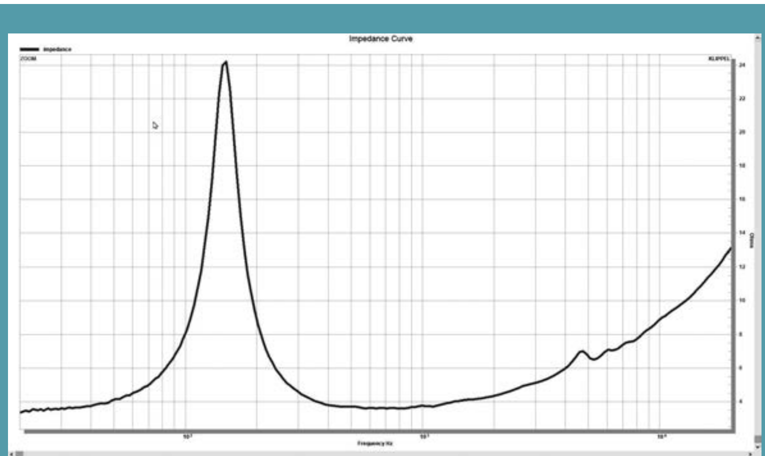
xx Hz at 1 Volt.

A typical specification might read:

Free-air resonance: 55 Hz at 1 V RMS input

If the driver is not mounted, this is called the *free-air resonance*. This is what is usually meant by resonance. The free-air resonance is notated as f_0 or fs; either is OK.

Voice coil impedance



Typical single loudspeaker impedance curve. The X axis shows frequency (Hz) and the Y Axis shows impedance (ohms).

See Impedance, above. As mentioned above, the impedance of the voice coil in a loudspeaker is not constant at all frequencies. Especially near the resonance, the impedance increases greatly. Again, at high frequencies the impedance increases. The impedance specification must include a tolerance and the frequency and input level at which it is specified: xx Ohms at xx V +/- xx% at xxx Hz

The voice coil also has DC resistance, or DCR (which is part of the impedance). This may also be stated. The impedance will always be higher than the DC resistance. A typical impedance specification might read: 8.6 Ohms+/10% at 1 kHz with 1Volt RMS input

Loudspeaker and Specification Sheet Terminology
continued

Rated Power (watts)

This is a difficult specification because a loudspeaker may be used or abused in a variety of ways. As a result, there are many official Standard methods for rating the ability of the driver to withstand input power. Two important standards are:

EIA RS-426B, (and earlier editions)

IEC 60268-5

The particular method which is used should be included with the rating. The intention of this rating is to specify how much power may be applied to the driver for a long period of time without damaging it or changing its characteristics.

The power rating of a loudspeaker is not necessarily the same as the power rating of an amplifier which would be used to operate the loudspeaker. Because normal program signals like speech and music have a peak instantaneous power level which is much higher than the average power level, it is common to use big amplifiers to avoid clipping the peaks. Within limits, these peaks do not harm the speaker, and it is the average power level which matters. For a 100 Watt amplifier reproducing music without clipping, the average power output will be 10-15 Watts. So using a 100 Watt amplifier with a speaker which has a rating of 30 Watts is not necessarily a bad idea.

Putting the Loudspeaker in a Box

Closed (Sealed) Box

A closed box is an enclosure which has no major openings except the one the driver is mounted in. It is also called an infinite baffle. In the case of a box which is small in comparison to Vas of the driver, it is called an acoustic suspension. If the volume of the box, Vb and Vas are expressed in the same units, such as litres, then α = Vas/Vb. This is called the compliance ratio. Generally, when a driver with a given fs and Qt is installed in a closed box, the resonance frequency and the Q will both rise by a factor of sqrt(α +1). Thus:

Ftc = fs sqrt(α +1)

Qtc = Qt sqrt(α +1)

A speaker enclosure is vital to the bass response. A speaker of any type not properly enclosed will yield sub-par performance.

Vented Box

A vented box in its simplest form has two openings. One is where the driver is mounted, and the other connects the air volume inside the box to the outside. The purpose of the second opening is to try to use some of the energy at low frequencies which is simply wasted in the closed box. A vented box is also sometimes called a ported enclosure or a bass reflex enclosure. The vent turns the box into what is called a Helmholz resonator. The resonant frequency of the box is coordinated with the fs of the driver in a systematic way to produce a frequency response which is a little flatter (more uniform) to a lower frequency than would happen with a closed box.

In a vented box, the unity load volume (Vas Qt^2) can be used to predict the response. If the volume of the box, Vb, is about equal to 7x the unity load volume, the flattest response in the smallest box will be obtained.

Putting the Loudspeaker in a Box
continued

The vent usually takes the form of a tube or a duct. The length and the cross-sectional area of the vent are calculated to resonate with the air volume in the box to cause the box frequency fb to be about equal to 0.39fs/Qt.

There are many other kinds of vented box arrangements. The math to describe them is fairly complicated and this subject should be studied separately from this paper if you are interested in doing so.

Passive Radiator

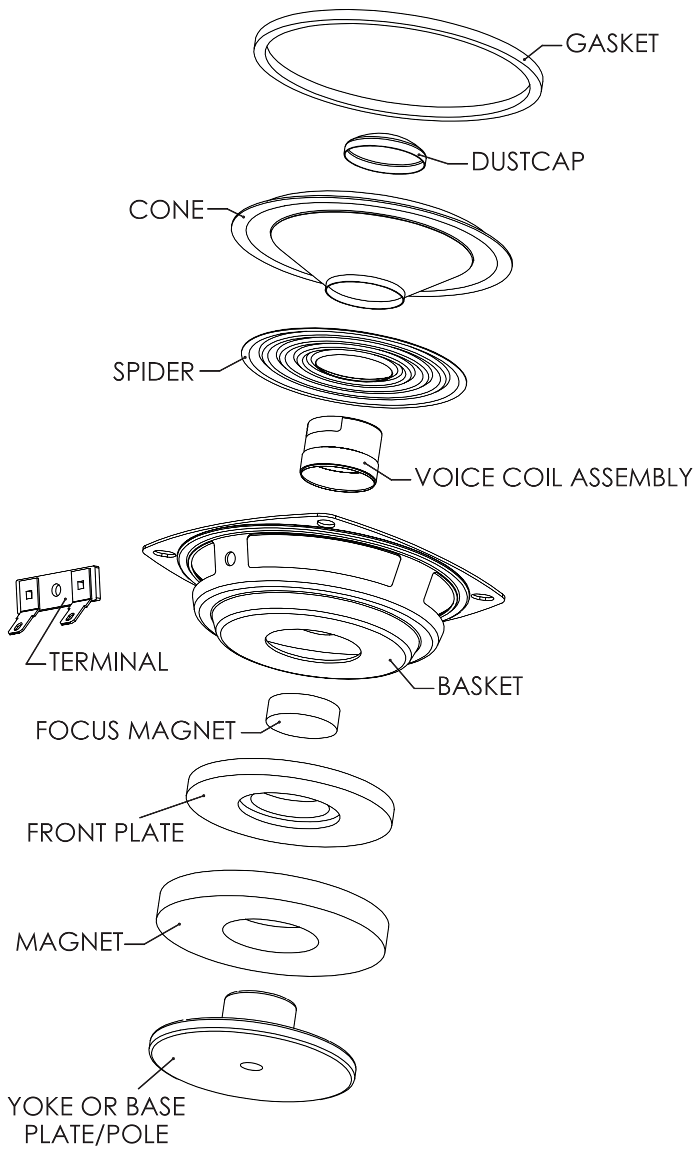
A box with a passive radiator operates exactly the same as a vented box. The passive radiator usually looks like a driver from the outside, but it has no motor. The purpose of the passive radiator is to substitute for the mass of the air in a normal vent. The reason for this is that often the vent needs to be very large in order to have enough air mass. A passive radiator uses the "lumped" mass of its diaphragm in place of an air mass.

Passive radiators can replace tuned ports in vented, bass reflex enclosures especially when the box is not deep or large enough to accommodate the proper port size.

The Parts of the Loudspeaker

The diagram at the right shows the principal parts of a standard dynamic loudspeaker driver. Recall from the introduction that there are four main systems to the driver:

- The motor
- The diaphragm
- The suspension
- The frame



The Parts of the Loudspeaker
continued

Motor

The motor is the system which converts electrical energy into mechanical energy, or force. The motor of a loudspeaker is like any other electric motor, except that its mechanical output is in the form of reciprocating motion rather than the familiar rotation motion of a motor shaft.

Motor: The Magnet

The *magnet* is the source of power in the driver. It is made from either ferrite (ceramic), alnico (aluminum, nickel, cobalt), or neodymium (neodymium, iron, boron). It is correctly called a permanent magnet, which means that at some point in its existence it was “charged” with magnetic energy which it stores like a battery. Unlike a battery, it doesn’t run down. As we refer to polarity in electricity as (+) and (-), so a magnet has “poles” which are referred to as North and South. Magnetic *flux* exists between the poles of the magnet. In the picture, the magnet is in the form of a ring which we see sideways. It is magnetized from left-to-right in the picture.

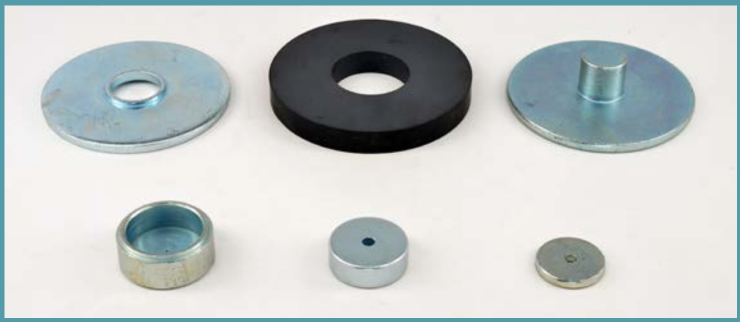
There are many types of magnetic materials used in loudspeakers: ferrite, neodymium (rare earth), and alnico are the most common.

The Parts of the Loudspeaker
continued

Motor: The Magnetic Structure

The magnetic structure consists of:

- The front plate
- The back plate
- The pole piece



Most loudspeaker magnet assemblies – whether ferrite or neodymium consist of three primary parts: The magnet, a T or U yoke, and a top plate.

The purpose of the magnetic structure is to provide a path for the flux between the poles, and to concentrate the flux into a narrow *gap* where it can be acted upon by the voice coil. Often the back plate and the pole piece are combined in a single piece of steel. This is called a *yoke*. The front plate is sometimes referred to as the *top plate*. The pole piece does not always have a vent hole through it. In a structure using an alnico magnet, the magnet forms one pole and the pot the other pole. In a structure using neodymium, a pole tip is often added to the magnet to form one pole. As in an alnico structure, the pot forms the other pole. The concentration of the magnetic flux in the gap is expressed as *flux density* (measured in Gauss, G or Tesla, T; 1T = 10,000G).

The loudspeaker voice coil is designed to provide the correct impedance of the speaker and must be able to handle the heat created when the speaker is operating. High temperature wire, adhesives, and form materials must be carefully selected and specified.

Motor: The Voice Coil

The *voice coil* is the part of the motor which moves and is often referred to as the "heart" of the loudspeaker. It is a coil of wire which is wound onto a *former*. The former may be made of paper, aluminum or a high temperature film such as polyimide. The wire in the voice coil is usually copper (Cu) but is sometimes aluminum (Al). The wire is coated with insulation and a high temperature adhesive. Around the

The Parts of the Loudspeaker
continued

top side of the coil is a *collar*, which is normally made of Nomex, Paper, or other fibrous materials. The collar helps to position the wires as they come out from the windings. It also serves as a bonding surface for attaching the voice coil to the spider and cone.

Current from the amplifier is connected to, and passes through, the wire in the voice coil. The current produces a magnetic field. This magnetic field, which varies, is acting against the magnetic field in the *gap*, which is stationary. The current is AC, which means that it changes direction on each half-cycle of the signal (see above). When the current flows in one direction, the coil is pushed forward, when the current reverses direction, the coil is pulled backward. The force with which the voice coil is pushed and pulled is proportional to the amplitude of the current. The rate (or frequency) at which the coil is pushed and pulled is the same as the frequency of the current. The voice coil former is connected to:

The Diaphragm

The diaphragm is more commonly called the **cone**. It converts the *mechanical force* from the motor into *acoustical energy*, which we call sound.

The cone is simple in one way. It is a very rigid shape which is good because we want the cone to move as a single piece with the voice coil, or as a *piston* in the air. The inherent rigidity of the cone as a geometric shape is why it almost always used a diaphragm in dynamic speakers. Flat diaphragms have been tried, but they tend to flex and flap and not behave as a piston unless driven in a particular way.

Cones are usually round, oval or oblong. Cone bodies are typically made of paper, polypropylene, carbon fiber, treated cloth, Kevlar or aluminum.   The flexible surround material can be foam, natural rubber, synthetic rubber, cloth or even just paper.

The Parts of the Loudspeaker
continued

The cone is most commonly made of felted paper, but many other materials are also used such as plastic, glass fiber, carbon fiber, aluminum and various combinations of these in layers. The reason for all this variation is that, while the cone always operates as a piston at low frequencies, it unavoidably “breaks up” at higher frequencies. Different materials are used by speaker designers to promote various "breakup modes” which will affect the tone quality of the driver. This aspect of the cone is very important in midrange and tweeter drivers.

Dust caps not only protect the area inside the voice coil but they can also be an important part of the high frequency component. They come in many sizes & shapes depending on the application.

The center of the cone usually has a **dust cap** glued onto it. This is because the apex of the cone must be open during assembly of the driver, but leaving it open would allow dirt and dust to enter the gap. The dust cap prevents this. A special type of dust cap, called a *whizzer,* provides the protection of a dust cap but also allows better high frequency.

The Suspension

The purpose of the suspension is to hold the cone and the voice coil so they are centered laterally (side-to-side) but are still free to move axially (back and forth). There are two parts to the suspension, the **surround** and the **spider**.

The *surround* connects the edge of the cone to the basket. Sometimes the surround is just a corrugated extension of a

The spider is most often corrugated cloth or a synthetic blend of polypropylene and cotton. It's pattern of rolls varies depending on the required excursion of the driver.

The Parts of the Loudspeaker
continued

mylar, paper, or cloth cone, but usually it is a separate piece made of specially treated fabric, rubber, synthetic rubber (Santoprene) or foam which is glued to the edge of the cone.

The *spider* supports the cone toward its apex, usually close to where the cone joins the voice coil. The spider is a circular corrugated piece which is almost always made from specially treated cloth, Nomex, or a Polypropylene/cotton blend.. In the early days of speakers, this support was in the form of flexible rods which looked like spider legs, which is why it is still referred to as a spider.

In addition to supporting the cone and voice coil, the suspension provides restoring force. If no current is flowing in the voice coil, the moving parts must rest in a defined location. The stiffness of the surround and the spider restore the cone and voice coil to the center of their range of axial motion when they are at rest. The stiffness of the spider is often specified as by its deflection in inches when a 50 or 100 gram weight is hung from it. From the same spider die, many different deflections can be made by using different materials and treatments.

The Frame

The frame or chassis of the loudspeaker is usually called the **basket**. It forms the supporting structure for the entire speaker. It holds the motor parts, the cone and the suspension all in the correct relationship to each other. The flange at the outermost diameter permits mounting to a panel. The basket is usually square or round, but oval (or elliptical) speakers are also made. This is usually to accommodate cramped mounting locations.

Baskets are made in many sizes and shapes, typically between 1" and 21". They can be square, round or oval and made stamped steel, stamped aluminum, injection molded plastic, or die cast aluminum.

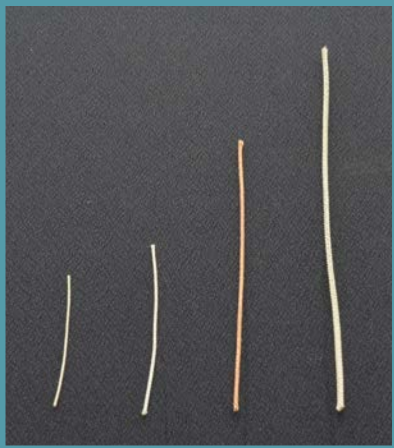
The Parts of the Loudspeaker
continued

The frame also holds the *terminals* (also called terminal strip or solder lugs) where the flexible lead wires (also called tinsel leads) from the voice coil are connected to the external wires coming from the amplifier or crossover network. Different types and sizes of lugs on the terminal strip accommodate different customer needs for connections using quick connects or solder type connections.

Other Key parts of a speaker

Lead wires (also called tinsel leads)

Lead wires connect the voice coil wires to the terminal strip. These wires are normally made of copper or silver wire wrapped around a cotton or Nomex core. Each lead wire has multiple strands of this wire. While small speakers may only have three strands, larger speakers may use as many as twenty. These different sized wires accommodate the amount of electrical current the speaker must handle during operation. In addition, these wires must be flexible as they vibrate along the cone. Lead wires which are too short or too stiff will eventually break, just as a paper clip will break when flexed many times.



Tinsel wires are typically woven of multiple stands of both conductor and support material depending on current carrying capacity required and then cut to length for the proper speaker excursion.

The Parts of the Loudspeaker
continued

The top gasket or pad ring has a similar shape to the basket and made of many materials - chipboard, plastic, rubber, cork or foam.

Gasket (also called pad ring or clamp ring)

The gasket does not usually have a role in the performance of a speaker. It can be made of chipboard, plastic, or rubber. It's purpose is usually one of the following: to clamp the cone in place during assembly; to serve as an isolation gasket to prevent vibration noise or as spacer when a speaker is "rear mounted" onto a grille or surface; for cosmetic purposes.

Adhesives (also called glue or cement)

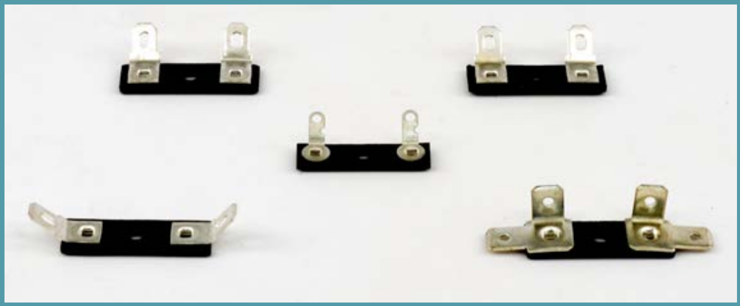
The correct choice and application of adhesives on every speaker is critical. Nearly all of the parts of a speaker are attached using glue. Each glue joint requires a unique adhesive designed for the materials and stresses involved in that joint. In addition, manufacturing considerations for cure time and application method must also be considered. Glues often used are: Cyanoacrylates (also called CA or super glue), epoxy, structural acrylics, and many varieties of solvent based glues. In addition, various types of primers and accelerators are also used for better or faster curing. The most common glue joints in a speaker are:

- Magnet structure
- Spider to basket
- Voice coil to spider and cone
- Cone to basket
- Gasket to basket and cone
- Voice coil wires to cone
- Dust cap to cone or voice coil

The Parts of the Loudspeaker
continued

Rivets and eyelets

Rivets are used to attach most terminal strips. Eyelets are used to attach solder lugs in closed basket speakers. Eyelets are also used as a junction point on top of the cone where the voice coil wires and tinsel lead wires can be joined together and soldered.



Speaker terminals allow a location of the incoming signal wire to be connected either by solder or by quick connect style lugs. Most speaker lug sizes accommodate connectors between 0.110" and 0.250".

Workmanship

Because of the close tolerance of the voice coil travel, the variety of materials being used, and interrelationships of the key systems of a speaker, precision workmanship is a must. Most loudspeaker users have extremely high expectations in regards to the sound quality and the appearance (cosmetics) of each and every unit they use. This requires speaker designs that are easy to assemble, work instructions that are detailed, and the thorough training of each person involved in the assembly operation.

Common Manufacturing Defects in a Loudspeaker

An important part of product quality is an in depth understanding of possible manufacturing defects and their causes or quickly diagnosing any field failures. The failure analysis process drives continuous improvement of both product design and manufacturing quality.

Possible problems when the speaker is **Open** or **Intermittent**:

- The voice coil lead wire is broken
- The voice coil lead wire is not connected to the eyelet
- The voice coil windings are bad
- There is bad soldering at the eyelet/terminal

Possible problems when there are **rubs, buzzes,** or the voice coil is "**frozen**" (locked in place):

- The shim was left in.
- The voice coil has a bad winding.
- The magnet assembly is off center.
- There is a burr on the front plate.
- The pole piece or pole tip is off center.
- The spider is glued to the front plate.
- There is glue or epoxy between the voice coil and pole piece.

Possible problems when there are **chips** (loose particles) in the magnetic air gap:

- There are magnet chips
- There are front plate chips

Common Manufacturing Defects in a Loudspeaker
continued

Possible problems when there is **low output**:

- There is partial or no magnetism.
- There is insufficient cone treatment causing an air leak through the cone or cone surround.
- There is a short in the voice coil.
- There is a bad tweeter (in coax models).
- The leads to the basket were shortened.
- The tinsel leads are too short causing restricted cone motion.

The speaker **bottoms too soon**:

- There is a depressed spider.
- There is glue under the spider.
- The moving soft parts of the speaker bottoms (hits) too soon against the back or magnet assembly.

Possible problems of a **miscellaneous** physical nature:

- There is bad glue around the dust cap, cone or gasket.
- The leads are short.
- There is bad soldering.
- The basket is bent.
- The plating is bad.
- The cone eyelets and terminals are misaligned.
- The cone is torn or warped.
- The gasket is torn.
- The washer under the solder lug is missing.
- The magnet is chipped or broken.
- There is an incorrect terminal or solder lug.
- There is a loose pot or magnet assembly

Small Signal Parameters

The small signal parameters (or Lumped Parameter Measurements- LPM) of a loudspeaker are part of loudspeaker terminology, but we have given them a special section because of their importance and particularly technical nature. These parameters are a way of describing the fundamental physical properties of a loudspeaker so that they may be conveniently applied to the proper design of enclosures for low frequencies. These parameters are often incorrectly called the Thiele-Small parameters. They were originally devised by Neville Thiele of Australia. His work was elaborated by Richard Small, but Thiele referred to these parameters as small-signal. That's the important thing to understand about these parameters: they are only accurate at small inputs to the speaker. At higher inputs they will almost always shift, so they should not be used to describe the driver at high input levels.

There are also large-signal parameters (Large Signal Indicators - LSI) for a speaker, but they are not well standardized. They pertain to power handling capabilities, maximum linear excursion of the motor assembly, suspension, coil inductance and mechanical damage from overdrive. The most common large-signal parameter is called x-max. It defines how far the cone can travel in either direction from rest with linear force applied by the motor. This parameter is used to determine how much low-frequency output can be obtained, since that is where the cone movement is the greatest. Large signal parameters can be directly correlated to driver distortion.

The small signal parameters given in MISCO data sheets are measured generally in accordance with IEC 60268-5 using Klippel analyzers.

Fundamental free-air resonance, f_s or f_0 (Note: all parameters with subscripts are pronounced "f sub s" or "f sub o" or by some as "fs" or "fo")

This has already been discussed above, but it is the first of the small-signal parameters. It is stated in Hz, usually to a resolution of 1 Hz.

Voice coil DC resistance, R_e

Small Signal Parameters
continued

This is simply the DC resistance of the voice coil, measured very carefully. Small errors in this measurement will cause serious errors in the calculated values of Q. The unit of R_e is Ohms

Quality Factor, Q

The quality factor of any resonant system describes how lossy it is. Q is the inverse of damping (d = 1/Q). There are three aspects to Q in a dynamic speaker:

Qm is the mechanical Q. It represents the damping of the fundamental resonance by the mechanical energy dissipation in the parts of the loudspeaker, mainly the suspension (see below). It is the ratio of the resonant frequency to the bandwidth at which the open-circuit impedance is 3 dB below the impedance at resonance. The frequency above resonance which is –3dB is f_h; and the frequency below resonance which is –3dB is f_L. Thus $Qm = f_s / (f_h - f_L)$. Q is a ratio of Hz to Hz and is therefore dimensionless (has no units).

r_0, spoken "ratio naught" is the ratio of the impedance magnitude at the fundamental resonant frequency to the DC resistance of the voice coil. It is a ratio of Ohms to Ohms and therefore dimensionless.

$r_0 = Zmax / R_e$

Qe is the electrical Q. It represents the damping of the fundamental resonance by the braking action of the motor. This parameter assumes that the speaker will be driven from an amplifier with constant voltage output. Qe is found by dividing Qm by r_0-1, thus $Qe = Qm / (r_0 - 1)$.

Qt is the total Q. It represents the damping of the fundamental resonance by all causes. It is the parallel combination of Qm and Qe. $Qt = Qm / r_0$. This is the value of Q which is most important for system designers to know.

It is important to understand the relationship among the aspects of Q. Qm is mainly due to the elastic elements of the driver, the spider and surround. These are the

Small Signal Parameters
continued

most difficult to control in production. Qe, on the other hand, is due mainly to the motor, which is easily controlled to high accuracy. High performance drivers with large motors will show a large ratio of Qm to Qe. This means that Qt will be almost completely controlled by the motor.

Vas, Compliance Equivalent Volume,

This parameter describes the stiffness (or inversely, compliance) of the suspension of the driver. The mechanical compliance of the driver can be stated directly in meters/Newton, but this is not convenient for an enclosure designer. What Vas does is to express the compliance of the driver as if it were an enclosed volume of air. Therefore, the units would be cubic meters (m^3), but this is a little inconvenient so Vas is usually stated in litres (l). 1 m^3 = 1000 litres.

Vas x Qt^2 Unity Load Volume

It was stated earlier that Qm is susceptible to variations in the spider and surround. This is also true for Vas and for f_s. The unity load volume factors these things together as Vas x Qt^2. Some algebra will show that if this hybrid parameter remains constant, the performance of the driver in the box will also remain constant, even if the individual parameters drift somewhat. This is an important bit of information which is usually overlooked. It depends mainly on the motor strength which is one of the most precisely controllable aspects of speaker manufacturing.

BL, Force Factor,

The product of the flux density in the gap times the length of voice coil wire in the gap is the force factor, also known as the Bl product. The dimension is stated either as Tesla-meters (T m) or Newtons per Ampere (N/A). The latter is more intuitive because it states exactly what happens: Current passes through the voice coil and produces force on the cone. It is a direct measure of the motor strength. Some algebra will show that Tesla-meters and Newtons per Ampere are exactly the same thing.

Need help selecting a loudspeaker driver or designing one for your application?

Talk to the MISCO Speakers team at MISCOspeakers.com.

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