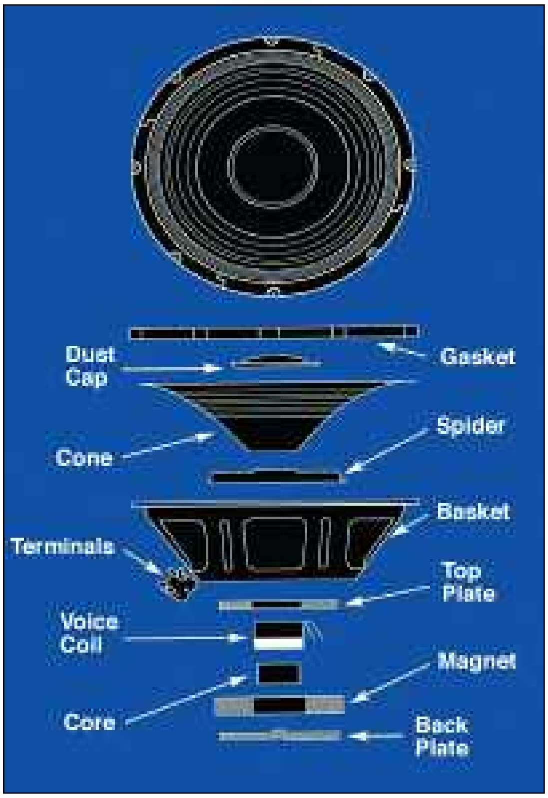
Knowing Cone Drivers

How they work, understanding data

Contributed By Eminence Speaker

Cone drivers are not overly complex. When an electrical current passes through a wire coil (the voice coil) in a magnetic field, it produces a force that varies with the current applied. The cone, connected to the voice coil, moves in and out, creating waves of high and low air pressure.



The key working components of a loudspeaker and how they fit.

The coil and magnet assembly are the "motor structure" of the loudspeaker. The movement is controlled by the loudspeaker's suspension, which comprises the cone surround and the "spider"

The surround and spider allow the coil to move freely along the axis of the magnet's core (or "pole") without touching the sides of the magnetic gap.

More important than knowing the details of how cone drivers work is the understanding of key data and what it means. Prior to 1970, there were no easy or affordable methods accepted as standard in the industry for obtaining comparative data about loudspeaker performance.

Recognized laboratory tests were expensive and unrealistic for the thousands of individuals needing performance information. Standard measurement criteria were required to enable manufacturers to publish consistent data for customers to make comparisons between various loudspeakers.

Things began changing in the early 1970s, however, when several technical papers were presented to the Audio Engineering Society (AES) that resulted in the development of what we know today as Thiele-Small Parameters.

The authors of the papers – A.N. Thiele and Richard H. Small – devoted considerable effort to showing how the following parameters define the relationship between a speaker and a particular enclosure. These parameters can be invaluable in making choices because they can tell you far more about the transducer's real performance than the basic benchmarks of size, maximum power rating or average sensitivity.

Let's have a look at the parameters defined by Mr. Small and Mr. Thiele. (And note that we listed Mr. Small first this time – bet he doesn't get that very often!)

Fs: The free-air resonant frequency of a speaker. Simply stated, it's the point at which the weight of the moving parts of the speaker becomes balanced with the force of the speaker suspension when in motion.

If you've ever seen a piece of string start humming uncontrollably in the wind, you have seen the effect of reaching a resonant frequency. It is important to know this information so that you can prevent your enclosure from 'ringing'.

With a speaker, the mass of the moving parts, and the stiffness of the suspension (surround and spider), are the key elements that affect the resonant frequency. As a general rule of thumb, a lower Fs indicates a woofer that would be better for low-frequency reproduction than a woofer with a higher Fs. This is not always the case though, because other parameters affect the ultimate performance as well.

Re: DC resistance of the driver measured with an ohm meter, and often referred to as the "DCR." This measurement will almost always be less than the driver's nominal impedance. Consumers sometimes get concerned the Re is less than the published impedance and fear that amplifiers will be overloaded. Due to the fact that the inductance of a speaker rises with a rise in frequency, it is unlikely that the amplifier will often see the DC resistance as its load.

Le: Voice coil inductance measured in millihenries (mH). The industry standard is to measure inductance at 1 kHz. As frequencies get higher, there will be a rise in impedance above Re, because the voice coil is acting as an inductor. Consequently, the impedance of a speaker is not a fixed resistance, but can be represented as a curve that changes as the input frequency changes. Maximum impedance (Zmax) occurs at Fs.

Q Parameters: Qms, Qes, and Qts are measurements related to the control of a transducer's suspension when it reaches the resonant frequency (Fs). The suspension must prevent any lateral motion that might allow the voice coil and pole to touch (this would destroy the loudspeaker).

The suspension must also act like a shock absorber. Qms is a measurement of the control coming from the speaker's mechanical suspension system (the surround and spider).

View these components like springs. Qes is a measurement of the control coming from the speaker's electrical suspension system (the voice coil and magnet). Opposing forces from the mechanical and electrical suspensions act to absorb shock.

Qts is called the "Total Q" of the driver and is derived from an equation where Qes is multiplied by Qms and the result is divided by the sum of the same.

As a general guideline, Qts of 0.4 or below indicates a transducer well

It's vital to understand the relationship between amplifiers and drivers.

suited to a vented enclosure. Qts between 0.4 and 0.7 indicates suitability for a sealed enclosure, and Qts of 0.7 or above indicates suitability for free-air or infinite baffle applications.

Vas/Cms: Vas represents the volume of air that when compressed to one cubic meter exerts the same force as the compliance (Cms) of the suspension in a particular speaker. Vas is one of the trickiest parameters to measure because air pressure changes relative to humidity and temperature – a precisely controlled lab environment is essential.

Cms is measured in meters per Newton, and is the force exerted by the mechanical suspension of the speaker. It is simply a measurement of its stiffness. Considering stiffness (Cms), in conjunction with the Q parameters, gives rise to the kind of subjective decisions made by car manufacturers when tuning cars between comfort to carry a family and precision to go racing. Think of the peaks and valleys of audio signals like a road surface, then consider that the ideal speaker suspension is like car suspension that can traverse the rockiest terrain with race-car precision and sensitivity at the speed of a jet plane.

Vd: Peak Diaphragm Displacement Volume – in other words, the volume of air the cone will move. It is calculated by multiplying Xmax (voice coil overhang of the driver) by Sd (Surface area of the cone). Vd is noted in cc, and the highest Vd figure is desirable for a sub-bass transducer.

BL: Expressed in Tesla meters, this is a measurement of the motor strength of a speaker. Think of this in terms of how good a "weightlifter" the transducer can be. A measured mass is applied to the cone, forcing it back, while the current required for the motor to force the mass back is measured. The formula is mass in grams divided by the current in amperes. A high BL figure indicates a very strong transducer that moves the cone with authority.

Mms: The combination of the weight of the cone assembly plus the "driver radiation mass load." The weight of the cone assembly is easy: it's just the sum of the weight of the cone assembly components. The driver radiation mass load is the confusing part. In simple terminology, it is the weight of the air (the amount calculated in Vd) that the cone will have to push.
Rms: Represents the mechanical resistance of a driver's suspension losses. It is a measurement of the absorption qualities of the speaker

suspension and is stated in N*sec/m.

EBP: Calculated by dividing Fs by Qes. The EBP figure is used in many enclosure design formulas to determine if a speaker is more suitable for a closed or vented design. An EBP close to 100 usually indicates a speaker that is best suited for a vented enclosure.

On the contrary, an EBP closer to 50 usually indicates a speaker best suited for a closed box design. This is merely a starting point. Many well-designed systems have violated this rule of thumb! Qts should also be considered.

Xmax/Xmech: Short for "maximum linear excursion." Speaker output becomes non-linear when the voice coil begins to leave the magnetic gap. Although suspensions can create non-linearity in output, the point at which the number of turns in the gap (see BL) begins to decrease is when distortion starts to increase.

Xmax is voice coil height minus top plate thickness, divided by two, while Xmech (as expressed by Eminence) is the lowest of four potential failure condition measurements times two: Spider crashing on top plate, and/or voice coil bottoming on back plate. Voice coil coming out of gap above core; physical limitation of cone.

Take the lowest of these measurements then multiply it by two. This gives a distance that describes the maximum mechanical movement of the cone. (For Eminence transducers, half the Xmech value represents the one-way excursion-limit that if exceeded would cause permanent damage.)

Sd: This is the actual surface area of the cone, normally given in square centimeters.

Zmax: Represents the speaker's impedance at resonance.

Usable frequency range: Manufacturers use different techniques for determining this, and most are recognized as acceptable in the industry. However, they can arrive at different results.

Technically, many speakers are used to produce frequencies in ranges where they would theoretically be of little use. As frequencies increase, the off-axis coverage of a transducer decreases relative to its diameter. At a certain point, the coverage becomes 'beamy' or narrow like the beam of a flashlight.

See the **chart** at right – it demonstrates at what frequency this phenomenon occurs relative to the size of the transducer. If you've ever stood in front of a guitar amplifier or speaker cabinet, then moved slightly to one side or the other and noticed a different sound, you have experienced this phenomenon. Clearly, most two-way enclosures ignore the theory and still perform quite well.

Charting Frequency Range

Speaker Diameter (Inches)	Theoretical Maximum Frequency Before Beaming (Hz)
0.75	18,240
1	13,680
2	6,840
3	5,472
5	3,316
6.5	2,672
8	2,105
10	1,658
12	1,335
15	1,052
18	903

Power handling: A transducer needs to be capable of handling the input power it's provided. (*For more about this topic, see Tech Topic by Pat Brown, beginning on page 46 of this issue.*)

The general rule of thumb is that a power amplifier, when reproducing any program source, "provides" long-term-thermal power that is approximately 1/8 its maximum rated output before clipping (rap music excluded). This is why even UL testing for power amps is done, and listed for on the back of the amp, at 1/8 the rated output power of the amp.

Typically, a speaker will handle somewhere between 6 dB to 10 dB higher peaks than its long-term-average power rating, particularly in the case of the conservative EIA-426A standard used by several manufacturers. This means that if a speaker is rated for 100 watts long-term-average power, the amp driving it should be rated between 400 and 1000 watts – if the user does not compress the source signal. Once compression is used, all bets are off.

Generally speaking, the number one contributor to a transducer's power rating is its ability to release thermal energy. This is affected by several design choices, but most notably voice coil size, magnet size, venting, and the adhesives used in voice coil construction. Larger coil and magnet sizes provide more area for heat to dissipate, while venting allows thermal energy to escape and cooler air to enter the motor structure. Equally important is the ability of the voice coil to handle thermal energy.

Mechanical factors must also be considered when determining power handling. A transducer might be able to handle 1000 watts from a thermal perspective, but would fail long before that level was reached from a mechanical issue such as the coil hitting the back plate, the coil coming out of the gap, the cone buckling from too much outward movement, or the spider bottoming on the top plate.

The most common cause of such a failure would be asking the speaker to produce more low frequencies than it could mechanically produce at the rated power. Be sure to consider the suggested usable frequency range and the Xmech parameter in conjunction with the power rating to avoid such failures.

Sensitivity: One of the most useful specifications published for any transducer, it's a representation of the efficiency and volume you can expect from a device relative to the input power.

Manufacturers follow different rules when obtaining this information – there is not an exact standard accepted by the industry. As a result, it is often the case that loudspeaker users are unable to accurately compare the sensitivities of different products. ■

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