Looking at Loudspeakers

The number and variety of loudspeakers — drivers and enclosures — available today can bewilder the casually interested and enthusiast alike. This article should help reduce any confusion.

ON PAPER most loudspeakers look to be terrible pieces of design. Distortion averaging 1%-2% -- and what's worse varying with frequency. Efficiency only rarely exceeding 1% — so that the vast majority of those carefully nurtured, 0.002% THD amplifier watts pumped in down those non-inductive $15 a metre cables turn into nice, safe, unmusical heat!

Of the many types and variants of speaker which have been developed, the ones we shall cover are:

1. Moving coil
2. Electrostatic
3. Isodynamic
4. Ribbon
5. Piezo-electric
6. Exotic drivers
7. Motional feedback
8. Sub-woofers

Moving Coil

The most commonly used speaker drive unit is the moving coil and, while no where near the theoretical best, it is cheap, reasonably efficient, and works.

The diaphragm of the moving coil drive unit is usually cone-shaped, with the apex secured to a cylindrical former, around which is wound a coil of wire. The coil and former assembly is suspended in a powerful magnetic field and when an electric signal is applied to the coil, the coil's magnetic field reacts against the permanent field. This moves the coil, and so the diaphragm.

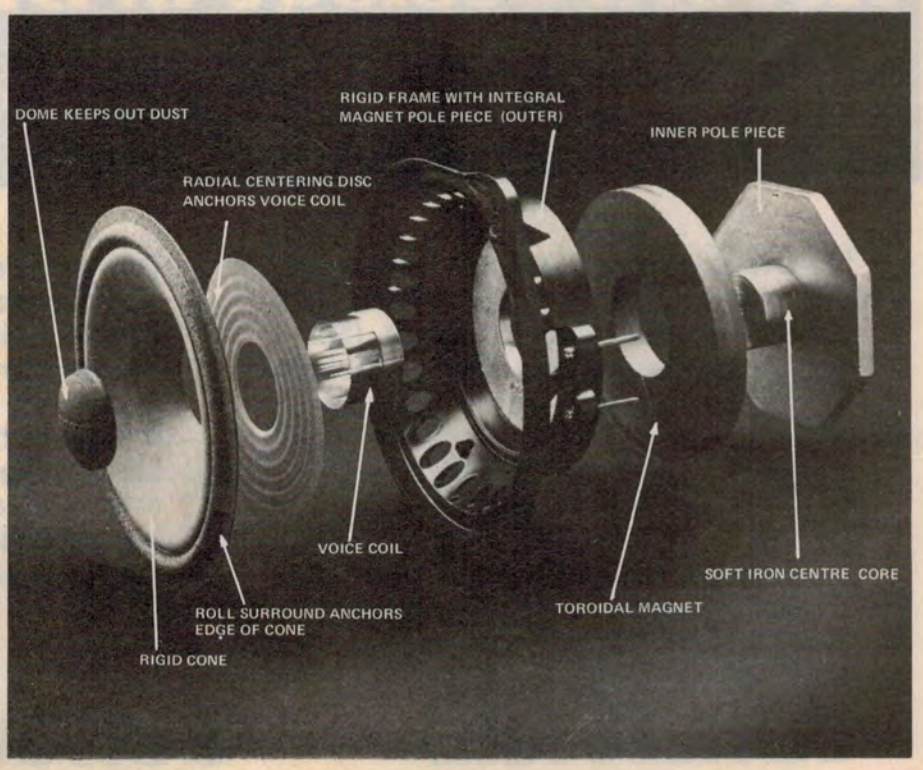
When a signal passes through the coil the force produced tries to push it out of the field in one direction or another, and this movement is transferred to the air by the movement of the cone. This movement is related more or less linearly to the input as long as the coil remains within a constant field.

If it moves out of the constant field, then the relationship will change, introducing non-linearity or distortion. For this reason large and powerful magnets are employed, which have as great a depth of field as possible.

Another solution is to use very long coils so that the number of turns of wire within the gap between the pole pieces remains reasonably constant.

The speaker chassis must be as rigid as possible, since the only reason the coil and cone move and it doesn't is that it weighs more! Any resonances present in the structure will transfer energy from the coil movement and hence distort the output.

The greatest drawback of this system is the cone itself. This is usually either doped paper or Bextrene — an ▶



An exploded view of the most common drive unit — the moving coil speaker — showing the various components in its construction (Picture: courtesy Bose).

erstwhile packing material. It should act as a piston to the air, with the entire surface moving together to produce the required air movement.

Mass is a consderable problem, because of inertia. With a diaphragm this means that it will try to keep going in one direction when it should be going in the other — it overshoots. The compromise between the need to maintain low mass and the need for diaphragm rigidity is very tricky, and presents speaker designers with many headaches.

Even the best moving coil system will show some signs of overshoot. In a speaker the movement caused by overshoot produces an electric current in the moving coil. This current flows to the amplifier where it is absorbed, effectively creating a brake to the diaphragm motion.

This process is known as damping and the amount of damping an amplifier can produce is called the damping factor. (The damping factor is the ratio of the speaker's impedance to the amplifier's source impedance, and a large ratio improves speaker damping.)

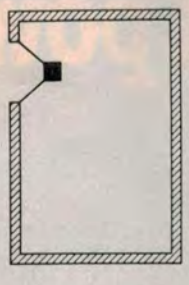
Thus the amplifier plays a very important part in the operation of the speaker, and a better amplifier will often improve the sound from a well designed speaker.

Tweeters

It is extremely difficult to make a single moving coil drive unit that will cover the entire range of frequencies (about 20 Hz to 20 kHz) needed for adequate hi-fi reproduction.

The reproduction of bass frequencies demands that a lot of air be moved relatively slowly, so a drive unit suitable for bass note reproduction has a large diaphragm that is capable of making long, fairly slow, to and fro movements.

High frequency reproduction, on the other hand, requires that fairly small amounts of air are moved very rapidly, so high frequency drive units have small, light diaphragms with very little to and fro movement.



'Acoustic suspension' or infinite baffle enclosures are totally sealed boxes (Courtesy Philips).

Two-way speakers, which are common, comprise a bass unit (commonly known as a woofer) which covers the lower frequencies and a tweeter, which takes over where the bass unit leaves off to cover the high frequencies.

All multi-way systems use a crossover network to divert the relevant frequencies to the appropriate drive units. It must be carefully designed to produce a smooth 'crossover' from one drive unit to the next, and often to compensate for differences in the sensitivity of the drive units so that the frequency bands are reproduced at the same levels.

Enclosures

Speaker enclosures are designed to counteract the tendency of the drive unit to produce an extra-loud sound at the resonant frequency.

There are basically six methods of providing a home for drive units and at the same time augmenting its performance. These are:

(i) Finite Baffle
(ii) Acoustic Suspension, (sometimes called Infinite Baffle)
(iii) Bass Reflex
(iv) Auxiliary Bass Radiator
(v) Transmission Line
(vi) Horn Loading

All of these apply primarily to moving coil units with the exception of horn loading which can be used to enhance efficiency of several types. In order then:—

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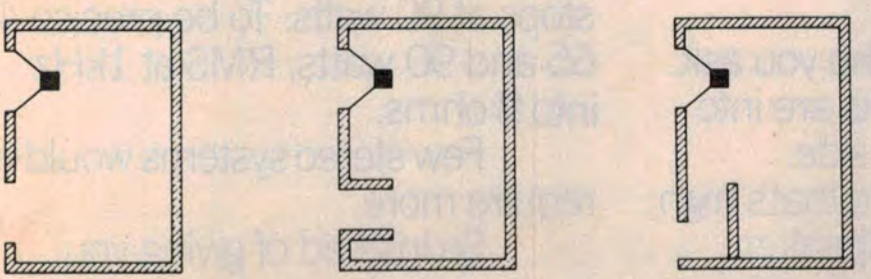
Various arrangements of a bass-reflex enclosure (Courtesy Philips).



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Finite Baffle

Since the vibrating cone is emitting sound waves in both directions, unless prevented the two waves will interact causing cancellation and reduction in output. The effect is reduced by placing the speaker in the centre of a large solid board to make it difficult for a compression produced in front to cancel the rarefaction produced behind the speaker.

Obviously, an infinitely large plane wooden sheet would prevent this entirely.. As this is a practical impossibility, a finite baffle is an attempt to do the best that can be done.

Once the sound wavelength approaches the baffle size, destructive interference takes place.

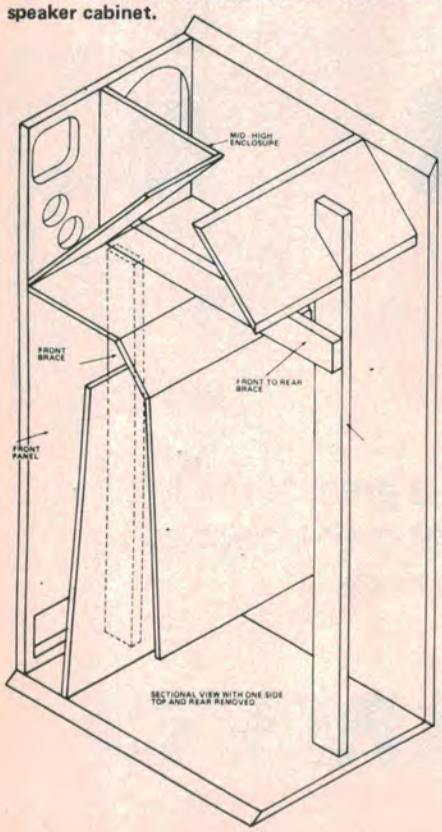
This method is responsible for those hardened enthusiasts mounting their bass units flush into walls and sides of houses!

The 'Infinite Baffle' type involves mounting a drive unit in a totally sealed box. There is no coupling between the front and rear of the cone.

Bass Reflex

The aim of this method is to raise efficiency at low frequencies and thus decrease the required enclosure size for a given bass output. This is accomplished by addition of a vent, or port, in the front panel of the enclosure.

Construction of a transmission line loudspeaker cabinet.



This allows a controlled movement of air between cabinet and room. The effect of careful design of vent dimensions and placement is to produce an effective addition to bass response below a certain frequency, such that the air moving out of the vent aids the air movement produced by the bass driver.

Above the operating frequency the vent has no effect on performance.

Transmission Lines

This is another method of 'losing' the rear radiation of drive unit, or making it think it is working into an infinitely long column. This is achieved by having a maze of woodwork inside the enclosure which is filled with graduated damping material. In this way total column length can be far greater than enclosure dimensions.

If the far end of the column is open then help is afforded to the bass performance in much the same way as bass reflex cabinets.

The design is usually for almost total absorption of the rear wave – and this leads to a gradual and smooth fall off in bass response due to the almost constant velocity working conditions for the cone.

IMF have championed the technique for a long time now as in their product transmission line bass possesses a 'solid' quality totally different to that from the other methods. It is more extended and more realistic.

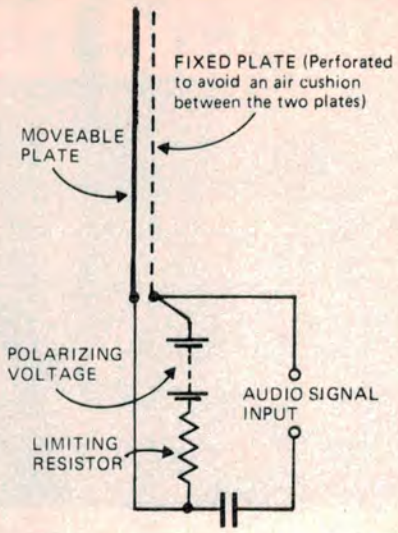
Horn Loading

A method which considerably reduces required driver excursion for a given acoustic output. The driving element is coupled to its air load by a gradually 'flaring' throat – usually exponential in cross section.

The horn converts the high pressure, low velocity sound energy present into low pressure, high velocity waves for propagation.

The advantages of this type of loading are good damping of the driver, and low distortion, but it has a limited frequency response.

To design a single horn to cover the entire audio spectrum is a confused exercise, and one yielding impractical results for domestic use, since an exponential horn to reproduce 30 Hz has a mouth of 1.5m diameter and is some 4m long! Folding the horn back and forth within an enclosure can reduce dimensions, and the American firm Klipsch market units which employ the room walls as extensions of the horn to reach lower frequencies. Usually though, the system is used to load MF and HF units within a system.



Simplified diagram of an electrostatic speaker.

Advantages of this principle are phenomenal efficiency ≈ 10% compared with 1% for bass reflex and 0.1% for transmission lines, and an attack unmatched by any other cone driver.

Electrostatics

As we have seen, the moving coil design suffers because the cone area is unevenly driven by the electrical signal. The electrostatic principle, developed by both David Tombs and Peter Walker (of the Acoustical Manufacturing Company) is an attempt to produce a unit in which the entire surface of the unit is driven by the input signal.

At its most basic the design consists of two plates. The moveable plate is made to have as low a mass as possible and is so suspended that it cannot touch the fixed plate at any point in its travel. The fixed plate will usually take the form of metal 'mesh'. A high polarising voltage ≈ 5 kV is applied between the plates and the audio signal superimposed on this.

An electrostatic force – such as that which holds dust on to LPs, is thus generated between the plates and the moveable plate vibrates in sympathy with variation in the input signal.

Distortion is greatly reduced using this push-pull arrangement and can equal 0.5% in a good design.

This system first appeared on the market many, many years ago in the form of the Quad electrostatic system – which remains largely unsurpassed for lack of colouration and mid-range clarity.

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The advantage of driving the plate evenly over its whole area shows up as a linear frequency response – no rippling or 'break-up' – very low distortion and a good transient performance due to low driver mass.

However, this system does have inherent drawbacks. Consider the Quad system as an example. It is noted for its mid-range clarity and its high frequency accuracy – but also for its lack of extreme bass and its beaming of top end signals – poor vertical dispersion.

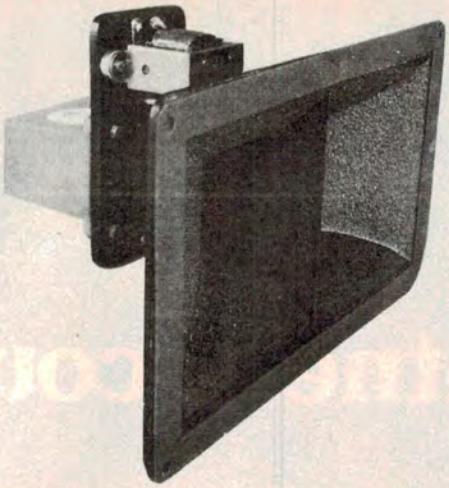
The reason for this is its physical size. Since the push-pull radiator is by nature a dipole radiator – sound emitted both front and back, some cancellation at frequencies whose wavelength exceeds the plate dimension is inevitable.

Isodynamic

With the (now-demised) Strathearn 2100 speakers, and the new Wharfedale series incorporating Isodynamic tweeters, this approach is gaining ground. It certainly has a lot of promise, which we shall undoubtedly see exploited as time goes on.

A drive unit built to this principle consists of a thin sheet of mylar, or some such material, with a conductive track bonded onto it in a pattern which covers the surface in as symmetrical manner as possible. This conductor acts as the voice coil of the speaker, and when an electrical signal is passed through it, it responds to nearby magnets by moving the diaphragm in sympathy.

Once again colouration is low, and



Decca London Ribbon high-frequency drive unit. The quoted response is 1 kHz to 25 kHz.

driver mass small – but also once again to obtain bass means large areas, and conductors capable of handling large currents. Strathearn's units covered above 500 Hz and were transformer coupled to the input. Wharfedale employ their invention in high frequency units only.

Ribbon

If we take the voice coil of moving coil speakers, and make this the active element, instead of the cone, we would do away with a lot of the causes of colouration in the process. Mass would be much smaller, break-up or rippling would be greatly reduced (if not eliminated) and thus transient handling improved.

The ribbon loudspeaker does exactly this. A very thin metal 'ribbon' is suspended between the magnet pole faces the signal passed through it. It will vibrate with the signal, and thus produce the sound output.

Acoustic output is low, and horn loading is usually employed to alleviate this problem. Once again obtaining bass is a major problem, and moving coil units will take over from the ribbon as the frequency decreases.

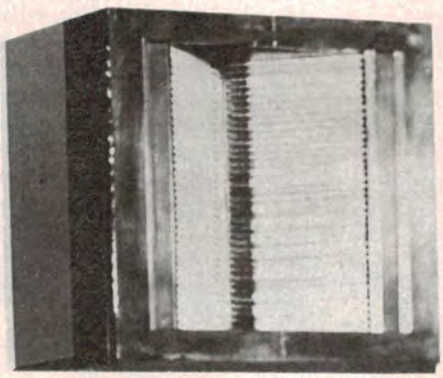
Decca market an excellent example of this principle, which operates above 2.5 kHz.

Piezo-Electric

Piezo-electrics have been around in hi-fi for a long time now in the guise of crystal/ceramic cartridges. The principle of operation is based upon the fact that when a piezo-electric crystal is stressed, a voltage proportional to the applied force is produced across its ends.

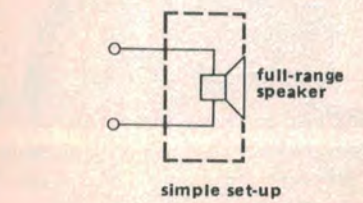
Conversely if we apply a varying voltage across the ends of the crystal, mechanical deformation occurs, sympathetic to that voltage. No magnets are required, and no coil is used.

In a Motorola design two thin

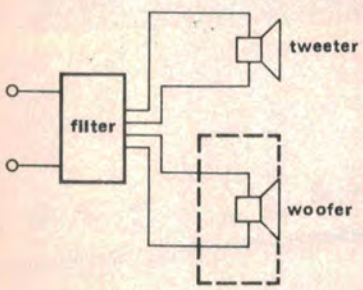


The Heil Air Motion Driver – a sort of cross between a speaker and a concertina.

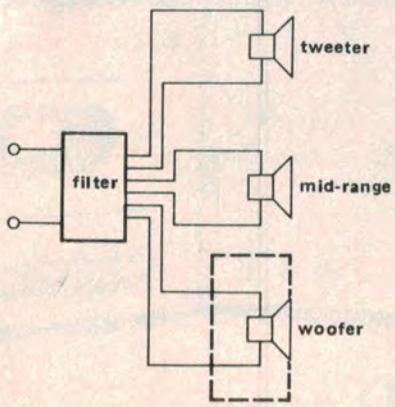
slices of ceramic material are epoxied onto a brass separator, and nickel electrodes deposited on for electrical connection.



simple set-up



two-way system



three-way system

There are several methods used to cover the audio spectrum using a variety of drive units. The filter is generally referred to as the 'crossover network'. Dotted lines around the woofer denote the enclosure.

EXOTICA:

Walsh Driver

Looking something like a naked dalek, the Walsh driver is made up of progressively larger cone sections of titanium, aluminium and paper. A voice coil at the small end drives the device, while the large end is held in place by a surround. Sound is radiated by the side of the cone in a plane. The disadvantage is low efficiency.

Planar Magnetic

This is the equivalent of an electrostatic speaker but it uses a magnet and coil.

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A sheet of insulating material with conductive tracks bonded to it is suspended between two perforated magnets. A current passed through the tracks causes the sheet to move in a similar way to a conventional voice coil.

Again, inefficiency is the major drawback.

Heil Driver

The Heil 'Air Motion Transformer' is a bit like a planar magnetic driver – a sheet with conductive tracks is the diaphragm but in this design it is folded like an accordion and suspended in a uniform magnetic field.

Audio frequency current through the tracks makes the 'accordion' squeeze and expand creating compression and rarefaction waves in the air in sympathy with the audio applied.

'Massless' Driver

In this highly unusual design helium is mixed with air and then ionised by a high voltage discharge. Audio current passed through the plasma causes it to expand and contract.

This system requires a bottled helium supply and a fanaticism not usually found even in hi-fi!

Motional Feedback

Although this is perhaps only a modification of earlier systems, the performance gains at LF are such that it warrants a closer look.

Motional feedback is a form of feedback control of the driver cone in moving coil systems. The power amplifiers are mounted within the enclosure, a separate amp for each drive unit, and signal is fed from a pre-amplifier. The system is marketed by Philips.

The main advantage of this extra complication lies at the bottom end of the range where the output for given enclosure volume is considerably enhanced. The complication lies in the sensor fitted onto the driver.

This is mounted on a small PCB and is a ceramic acceleration sensor. This generates a signal proportional to the actual driver output, and this is compared electronically to the incoming audio. Correction is applied to remove any errors present. Crossover is carried out at small signal level, and active filters with all their inherent superiority are applied.

Sub-Woofers

Nothing to do with old sea-dogs, these devices represent a very clever approach to the problem of speaker size in small rooms.

At frequencies below about 100 Hz, although sounds can still be heard it's very difficult to say where they're coming from. Why bother then with two gigantic bass units to give a stereo image at 20-100 Hz? They only take up space and cost money. Why not make do with one?

This single bass source is called a sub-woofer and makes the overall speaker configuration something like this: Two smallish medium/high frequency units in the room corners, as per normal, with one dirty great sub-woofer serving as a coffee table in the middle of the room. The only disadvantage is that it rattles the cups.

Sub-woofers usually have built-in power amplifiers and connect to both speaker outputs. The low frequencies are separated from the rest and both channels are added. ●