PM-3 : LOUDSPEAKERS
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A single article may only be able to scratch the surface of a topic as complex as loudspeakers, but it can pose useful questions about the market stereotypes we all tend to take for granted, and highlight some of the assumptions which deserve closer examination.

The task of the loudspeaker is to take the electrical version of the music signals which our sources supply and amplifiers amplify, and use it to try and recreate the original acoustic signals the musicians made and the microphones captured.

A loudspeaker can therefore be seen as a microphone in reverse. Indeed, some microphones would make perfectly adequate, er..., headphones. A microphone capsule can produce enough acoustic power to drive the ear canal directly, but the analogy starts to break down when you try to generate enough power to drive a whole room. The microphone is an inherently inefficient device which merely has to respond in a linear fashion to the sound vibrations it picks up. The loudspeaker has the much more onerous task of replicating - admittedly at a rather reduced scale - the original sound made by musical instruments, many of which have a much larger radiating area than the domestic loudspeaker.

To mimic the microphone, the intuitive solution is perhaps a single full-range drive unit, large enough to deliver sufficient power. In practice this poses all sorts of engineering and acoustic problems. In the first place it's virtually impossible to construct a device that's able to cover the full 20Hz-20kHz three-decade (or ten-octave) span of the audio range in anything like a linear fashion.

Even more problematic is the way in which sound waves are propagated from a vibrating (typically conical) diaphragm. At low frequencies (those whose wavelength exceeds the diaphragm diameter), the sound is radiated omni-directionally, while above that point the sound waves start to be thrown forward or 'beamed', into an increasingly narrow arc as the frequency rises.

One practical consequence is that a typical open-frame main driver won't generate any appreciable bass output on its own, because the output from the front will cancel the out-of-phase output from the rear through the omni-directional part of the spectrum. Simply, in order to prevent this low frequency cancellation, the driver is mounted in an enclosed box.

Although a handful of single-driver systems do exist and have a following, even their protagonists will acknowledge that this approach involves substantial compromise. To avoid the problem of high frequency beaming, most loudspeaker systems pass the higher frequencies on to a smaller tweeter drive unit.

The two-way speaker is by far the most popular solution, partly because of its cost-effectiveness, but also its simplicity. The stereotype two-way uses an open-frame cone main driver to cover the seven octaves below 2.5kHz, plus a sealed-back dome tweeter for the top three octaves.

Perhaps 'two-way' is not quite the right term, as in practice most designs also use a reflex port or similar arrangement The port acts as a Helmholtz resonator, usefully inverting the phase of the energy coming off the rear of the driver over a narrow band (less than an octave), so that it arrives in phase with the main driver. This may augment the system's total bass extension, and can also help control the main driver excursion at peak power, depending on the tuning of the various elements.

CONFIGURATION COMPROMISES
There's no such thing as the 'right' way to design a loudspeaker. Rather the designer is confronted by a series of compromises, so that an advantage in one respect is invariably accompanied by a disadvantage in another.

The single full-range driver approach may have all sorts of difficulties in maintaining a linear amplitude response, especially at the top and bottom extremes of the audio range. But it still provides the most accurate option in terms of phase reproduction, simply by avoiding any form of crossove network. That said, even a single driver will have significant phase anomalies, due to its inherent electrical and mechanical filter characteristics.

Add a tweeter to handle the high frequencies, and it's necessary to use crossover circuitry to protect its delicate moving parts from large low frequency signals. That involves placing at least a single capacitor in series with the tweeter, which in turn phase-shifts the incoming signal by 90 degrees. More complex crossover networks can provide better control over the system amplitude response, and a more precise transition from main driver to tweeter, but at only the expense of greater phase perturbation. By the same token, adding a reflex port might usefully augment the bass output of a speaker system, but again with some compromise in phase linearity.

Even in a two-way system, the main driver represents a serious compromise between its extension and loudness capability at the bottom of its working range, and its ability to maintain coherent, linear output with wide directivity at the top of its operating range. The two-way speaker system with a small main driver is likely to have superior midband voicing, but only at the expense of reduced bass extension, dynamics and loudness capability.

The logical step would seem to be to move from a two-way to a three-way, using a larger driver to give plenty of bass drive, weight and power handling, plus a smaller unit to cover the midband. What sounds convincing enough in theory has proved surprisingly difficult to put into practice. Although the three-way configuration can be made to work effectively, the extra complexity involved, especially in the considerably more elaborate crossover network, makes it a far, far more difficult design proposition, much more expensive to make, and a significantly more complex load for the amplifier to drive too.

Two alternative approaches which fall somewhere between the two-way and three-way have become increasingly popular, because of their compatibility with the slim floorstanding enclosures which are currently in favour. One retains a two-way mode of operation but uses two main drivers instead of one - invariably placed above and below the tweeter in the so-called d'Appolito arrangement.

The other arrangement - sometimes referred to as a 'two-and-a-half-way' - also uses two main drivers, but the lower one is rolled off much earlier than the upper one, so that it's only active through the bass region, and its location in the array is less critical.

Both these avoid the complex crossover network of the three way. A modest size main driver gives good lateral distribution and hence better matching to the tweeter, while adding a second driver doubles the bass radiating area, which seems like the best of both worlds, despite a less welcome increase in acoustic complexity.

LOUDSPEAKERS AND ROOMS

Loudspeakers come in a wide range of different sizes - far wider than any other hi-fi component. To some extent it's generally understood that smaller loudspeakers suit smaller size rooms, but little attempt has been made to formalise this in any way, and choice is far more likely to be made on the basis of appearance than acoustic compatibility.

It is easy to overlook the fact that a pair (or multi-channel quintet) of loudspeakers do not operate in isolation, but actually interact strongly with the characteristics of the listening room, especially at low frequencies. Take a decent quality pair of speakers out into the open air, and they will sound distinctly basslight - even if they're placed close to a wall. Move them back into a typical room, and interaction with the room modes will provide substantial low frequency reinforcement.

Room standing wave modes are very complex, creating reinforcements and cancellations at various points throughout a room, though their underlying structure is basically derived from the fundamentals and harmonics of the prime room dimensions. Irregular shaped rooms, or regular ones where the the main room dimensions avoid any harmonic relationship with each other, will tend to give good results. A cube-shaped room is most undesirable, because all the room modes will coincide and reinforce each other.

The larger the room dimensions, the lower the pitch of the main modes. The floor-to-ceiling height is usually the smallest room mode, and for a typical room is likely to provide reinforcement in the 50-70Hz midbass region. Close-to-wall siting also provides mid-bass boost (50-100Hz), and the combination of these two factors explains why a pair of small 7litre port-loaded miniatures can give effective in-room bass extension down to 50Hz. (Reproducing the region below 40Hz is a lot more difficult.)

Although it would be nice to be able to apply a simple formula to help select the right size loudspeaker to match a given room size, in practice there are too many variables. Different building construction methods and materials will affect the structure's ability to absorb or sustain the bass. And the actual bass alignment of the speaker will vary considerably between different models.

Although the main or bass driver size can provide clues, the tuning of reflex ports can vary dramatically, in both frequency and Q. Then there's the relationship between bass extension and sensitivity to consider, which effectively amounts to a straight trade-off one against the other.

Indeed, any attempt to compare loudspeakers purely on the basis of paper specifications is likely to be misleading. One obvious trend over the past few years has been a steady rise in sensitivities. This would seem to be beneficial, taken in isolation, making life that much easier for the driving amplifier. In practice, however, the rise in sensitivities has been paralleled by a drop in impedances, which in turn means the amplifier must supply more current to achieve the same voltage. The steady rise in sensitivity (as distinct from genuine efficiency) is therefore largely mythical in true power input terms - and in fact loudspeaker manufacturers have forced each other into the strategy in order to 'sound as loud' on the showroom shelf.

Loudspeakers are all about choosing between conflicting compromises, and there are far too many variables involved to predict the outcome in advance. The underlying quality can only be properly determined through extensive listening tests, using a wide range of material and variety of conditions.

CHART

FREQUENCY (Hz)	WAVELENGTH (m)	WAVELENGTH (ft)
10	34	111.5
20	17	55.8
40	8.5	27.9
80	4.3	14
160	2.1	7
320	1.1	3.5
640	0.50	1.75
(kHz)	(mm)	(ins)

1.28	250	10.5
2.56	125	5.3
5.12	63	2.6
10.24	31	1.3
20.48	16	0.7