ACOUSTICS

Concept 500

White Paper

January 2017

Introduction

Q Acoustics have until now concentrated on designing and marketing loudspeakers that most would agree focussed on the budget end of the market. The objective with the Concept 500 was to concentrate on a perfect balance between art and science to produce a loudspeaker that would be stylish, contemporary, fine-sounding and accurate with less priority on price. Taking away the constraints of designing for lower price points certainly removed some pressure, but the Concept 500 still needed to be considered good value for money within its significantly higher-end target market.

The Concept 500 has been developed by Q Acoustics in collaboration with Fink Audio-Consulting and IDA with whom they have built a long-term partnership since working together on their very first loudspeaker project over 10 years ago. In the new Concept 500, this truly talented team of people have produced a beautiful loudspeaker that can be manufactured so consistently that the sound and performance of every unit will be identical from first to last.

The Loudspeaker Cabinet

Perfecting the Stereo Image

The purpose of a good hi-fi system is quite simply to enhance the musical experience of playback at home. To get something that even resembles the real thing (and whatever anyone says this is the closest the hi-fi industry ever gets) a stereo image that gives as good an impression of width depth and height as would be found at a gig or a concert is needed. Good quality drive units, a well-designed crossover and a properly constructed cabinet can achieve this, but of these the cabinet itself is absolutely paramount. The unwanted noise created by sympathetic vibrations in a loudspeaker cabinet tends to be exaggerated only at certain frequencies and is not coherent in its phase relationship with the program material. Some frequencies will be reinforced, some will cancel and it is important to realise that all this happens at a very low level where the ambient clues about time and space exist to help create the stereo image. The random noise created by poorer, noisier enclosures dramatically reduces image stability and consequently the illusion of reality.

Unfortunately most manufacturers overlook this very important area. They concentrate only on maximising dynamic range and how loud a speaker will play with respect to the affects of dynamic compression. This neglects the equally important area of how softly it can play and how silent the cabinet can be made.

Choice of Materials

High-end speaker manufacturers often espouse the exclusive use of natural wood cabinets as a superior construction material or even reject this in favour of significantly more expensive and exotic alternatives. Wooden cabinets, it is true, can bring some benefits; wood is well self-damped, is easy to cut to shape and is reasonably inexpensive. However, Q Acoustics have found that fibre boards such as MDF still have the advantage; they are even easier to cut, fit and finish but crucially, because they are not totally homogenous in their makeup, they are very well damped, avoiding high Q resonances. For these reasons Q Acoustics use these materials in preference to more esoteric alternatives which only really offer extra mass and expense for very little sonic benefit; the difference lies in how the cabinets are designed, measured and tested in order to maximise performance.

Q Acoustics P2P™ Bracing

Often, much is made by other manufacturers of having cabinets heavily supported by solid shelf-type bracing to lend extra rigidity to the loudspeaker. Shelf-type bracing can be effective, but the disadvantage is that it can also transfer noise and vibration to all the other panels thus spreading the energy to a larger surface area. This design when used indiscriminately tends to be the reserve of manufacturers who only have access to rudimentary or outdated test and measurement techniques.

Fink Audio-Consulting has evolved proprietary computer models which accurately predict ideal cabinet construction and stiffening methods in an easily repeatable manner. Through the use of Finite Element Analysis and Laser Interferometry the exact performance of the cabinet structure can be minutely and accurately analysed to reveal the exact positions which need support and those areas which do not. The resulting bracing method, known as Q Acoustics P2P™ (Point to Point) bracing, only supports the parts of the cabinet that need to be stiffened and does not spread unwanted energy randomly. The illustrations below show how effective this methodology has become. A heat map of an unbraced cabinet wall with respect to its velocity of movement at a test frequency of 545 Hz is shown in Figure 1.

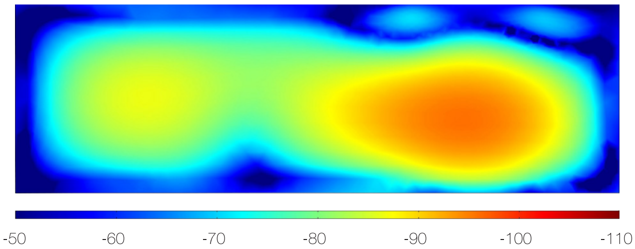


Figure 1 Heat map showing unbraced cabinet wall velocity dispersion

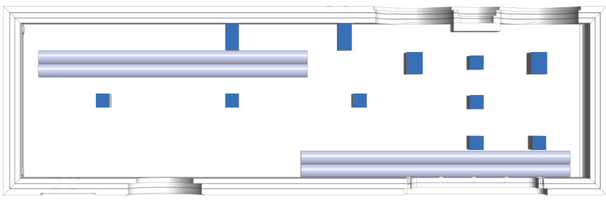


Figure 2 Position of P2P™ Bracing

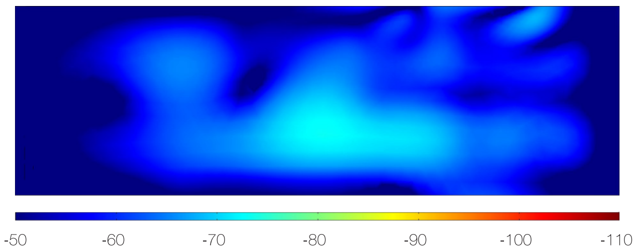
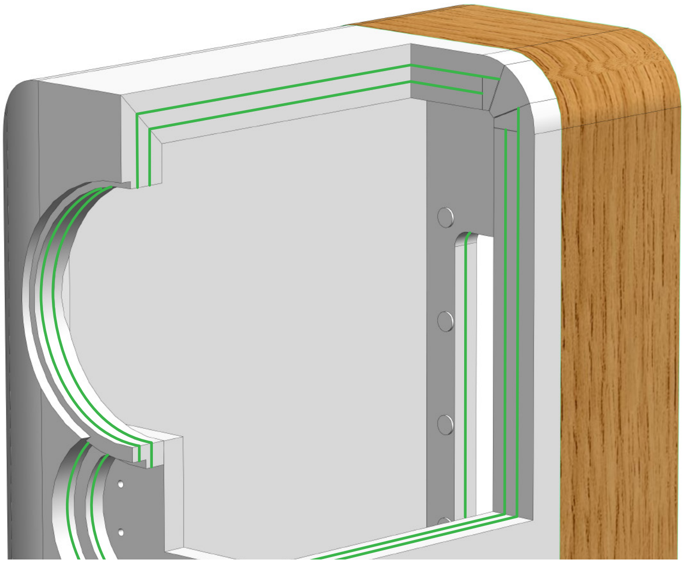


Figure 3 Heat map showing cabinet wall velocity with P2P™ Bracing

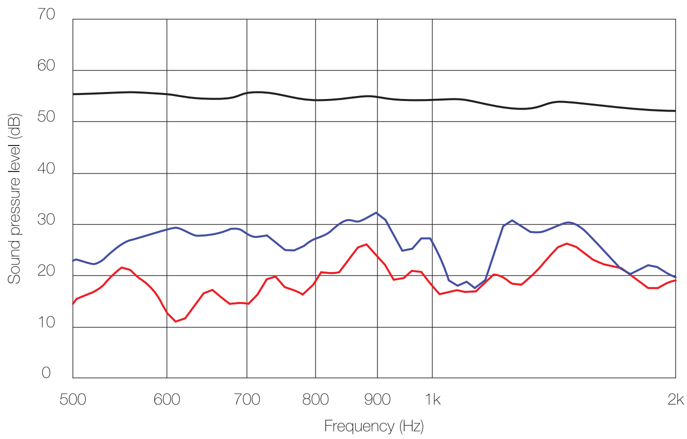
Where velocity is greatest the area is coloured towards the red end of the spectrum and where it is least it is coloured towards the blue end. You can see where a hot spot of vibration has been created at the test frequency. Conventional bracing would allow this movement to be transferred to adjacent panels but Q Acoustics P2P™ allows the design team to apply bracing only in exactly the correct places as shown in Figure 2.

When the test is repeated on the treated enclosure the heat map shows how effectively we have been able to eliminate cabinet resonances with the measurement of much lower surface velocities as shown in Figure 3.



Dual Gelcore™

Whereas Q Acoustics P2P™ bracing deals with low frequency panel vibrations, higher frequency cabinet noise is dealt with by the use of Dual Gelcore™ which is a development of the same Gelcore™ technology used to great success in the Q Acoustics Concept 20 & 40 loudspeakers. The speaker cabinet is constructed in three separate layers rather like a room within a room and the resulting interstices are completely filled under pressure with a compliant form of non-setting gel. The two constrained layers effectively damp the walls of the speaker cabinet by converting higher frequency vibrations into heat, which is then dissipated harmlessly within the damping gel. The graph of Figure 4 below shows how the cabinet performs in the mid-band frequency area from 500Hz to 2kHz. The blue line shows the amount of unwanted sound energy produced by the wall of a conventional loudspeaker cabinet. Any erroneous boost or cut in level at this frequency can affect the perception of musical timbre and contribute to listener fatigue. You can see from the trace of the red line how the addition of Dual Gelcore™ technology significantly reduces the ability of the speaker cabinet to interfere with the accurate reproduction of the source material.



Input (——), Conventional cabinet (——), Dual Gelcore™ (——)

Figure 4 SPL v Frequency for Gelcore™ treated / untreated cabinet wall

Helmholtz Pressure Equalisation

Tall loudspeakers all tend to suffer from what is often known as organ pipe resonance. A rather dramatic term used to describe areas of high and low pressure within the enclosure. Q Acoustics engineers designed a Helmholtz Pressure Equaliser (HPE™) to be positioned inside the cabinet to assist in balancing pressure irregularities. The HPE™ tubes convert pressure into velocity reducing the overall pressure gradients within the enclosure.

Figure 5 below shows the pressure differential inside a conventional loudspeaker cabinet, modelled at 155Hz by Finite Element Analysis.

Areas of high pressure are coloured red and areas of low pressure are coloured blue. Compare this to the same cabinet incorporating HPE™ technology shown in Figure 6. The high pressure areas have been reduced significantly thus increasing the low frequency linearity.

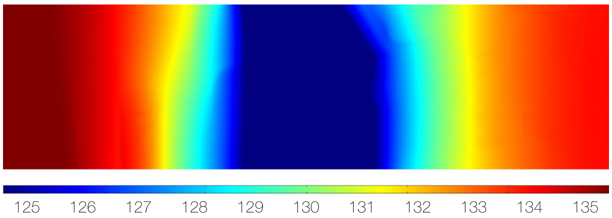


Figure 5 Pressure differential inside speaker cabinet without Q Acoustics HPE™

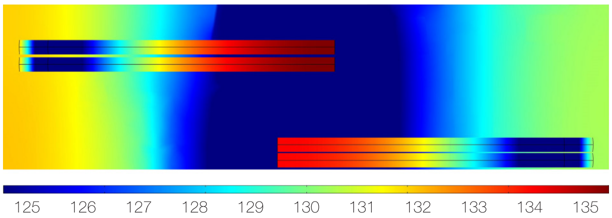
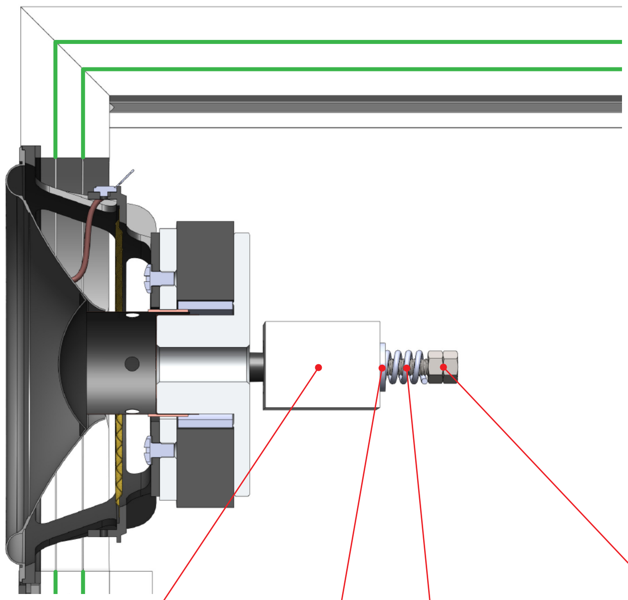


Figure 6 Pressure differential inside speaker cabinet with Q Acoustics HPE™



Drive Unit Mounting

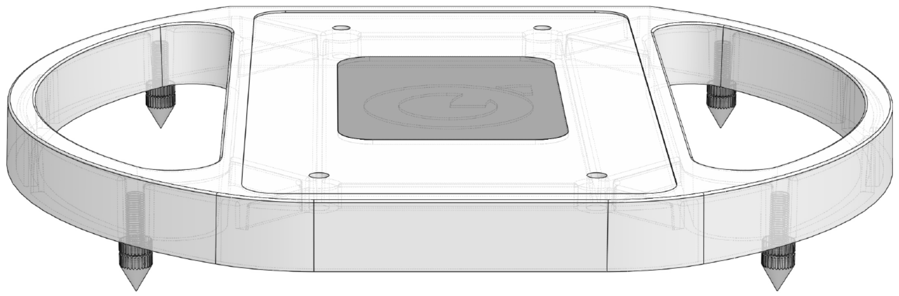
There are two additional aspects of loudspeaker cabinet design which are so obvious that they are often overlooked completely and they both revolve around drive unit fixing.

Firstly, unattractive screws or bolt heads need to be hidden and conventionally this requires solidly fixed decorative trims which at the same time need to be easily removable should servicing be required.

Secondly and more importantly is a problem that besets most loudspeakers – that of drive unit mounting bolt torque stability. Over time most conventional screws or bolts can loosen due to vibration in the loudspeaker cabinet.

A performance improvement can usually be achieved by regularly tightening the drive unit screws (maybe every six months) to the designer prescribed torque. The problem is that most hi-fi owners don't have a torque adjustable screwdriver and the degradation in sound quality is so slow and gradual that one barely notices.

The Concept 500 solves both the above problems in a simple and elegant way. The drive units are held in place *from behind* by strong spring tensioned retaining bolts, keeping the torque constant and obviating the need for decorative trims.



Cabinet Plinth

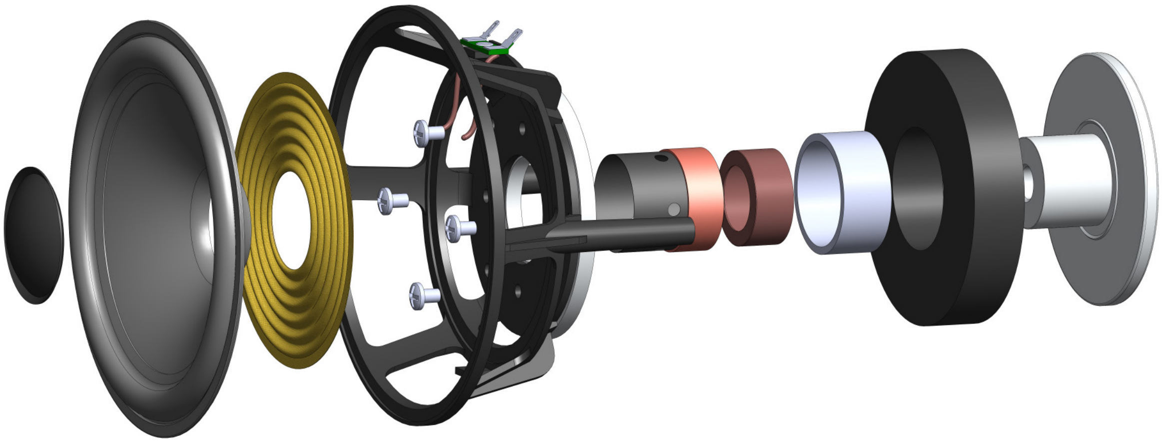
A speaker that doesn't sit solidly on the floor – one that rocks on its base – will not be able to deliver its ultimate performance because the speaker cone energy will not be transferred to the surrounding air in a completely linear way. The cast aluminium base supplied with the Concept 500 is securely mounted to the bottom of the cabinet. It can be fitted with four sharp spikes or ball-end feet to immovably couple the loudspeaker to a variety of domestic flooring surfaces. It allows excellent adjustability to enable complete rigidity on sloping or uneven floors. Because the plinth is designed without large flat areas and is simply chrome plated without additional adornments it does not encourage the deleterious effects of unwanted acoustic reflections – the music will rock, the loudspeaker will not.

What do all these cabinet benefits amount to?

Signal to Noise Ratio really has become the forgotten specification in loudspeaker design. The ratio of effective mid / bass cone size to cabinet surface area on a floorstanding loudspeaker is quite large, so cabinet vibrations, although small, can still be easily audible. On poor cabinets as little as 30dB difference between music signal and cabinet noise can be measured. The scientific engineering approach adopted by Q Acoustics to the problems outlined above has resulted in a *30dB reduction* in the power of unwanted cabinet radiation and noise across the board.

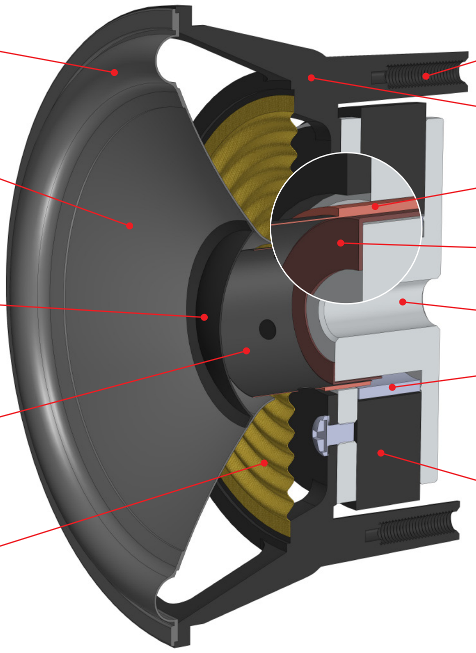
That's a real 30dB increase in signal to noise ratio, or to put it more simply, that's a lot more music and a lot less noise.

Drive Units



Drive Unit Design Overview

The partnership with Fink Audio Consultancy has granted access to skills and techniques that alone would have taken years to develop. It has also brought unparalleled contact with the world's best loudspeaker manufacturers and suppliers of specialist components. Together this has led to the design and production of a proprietary range of drive units which are used to create loudspeakers that are far better than their price tag might indicate.



Mid / Bass Driver

From the outset, in keeping with a policy of proprietary development, the 165mm mid / bass drive units were designed exclusively for the Concept 500 project so that each aspect of the design was tailored to Q Acoustics precise requirements.

The cone is precision formed from impregnated and coated paper and is teamed with a newly developed low-hysteresis rubber surround, which helps to reduce unwanted cone resonances. The voice coil has an uncommonly large diameter of 35mm. This allows increased 'shove' and higher power handling, as well as reduced dynamic compression. Instead of Kapton® or aluminium, the voice coil former is made of glass fibre which delivers the required stiffness but without the unwanted effects of eddy currents within the former.

The voice coil uses an unusual 2+2 copper clad aluminium winding (CCAW) configuration. The two dual layers of CCAW conductors are wound in parallel, which gives the voice coil increased force for a given current input compared to a normal dual layer winding, *without adding extra mass.* Higher distortion can sometimes be caused by this arrangement but it is eliminated by adding an aluminium inductance compensation ring to the motor system and a copper cap to the top of the pole piece.

The key drive unit elements from a measurement point of view are good Force Factor symmetry and a very low inductance variation, during both the full range of speaker excursion and varying coil current. Force Factor is a measure of the force exerted on the voice coil for a given current and should be exactly symmetrical in both directions of coil excursion as shown in Figure 7a. Similarly Figures 7b and 7c show how the coil inductance remains essentially the same with varying coil excursion and coil current respectively. Having a driver with parameters which measure this well significantly reduces mid-band and intermodulation distortion with the added benefit of attenuating the modulation effect on the crossover. The 'spider' features a symmetrical and progressive stiffness characteristic that has been optimised for use in large reflex enclosures like the Concept 500 as evidenced by the parabolic curve shown in Figure 7d.

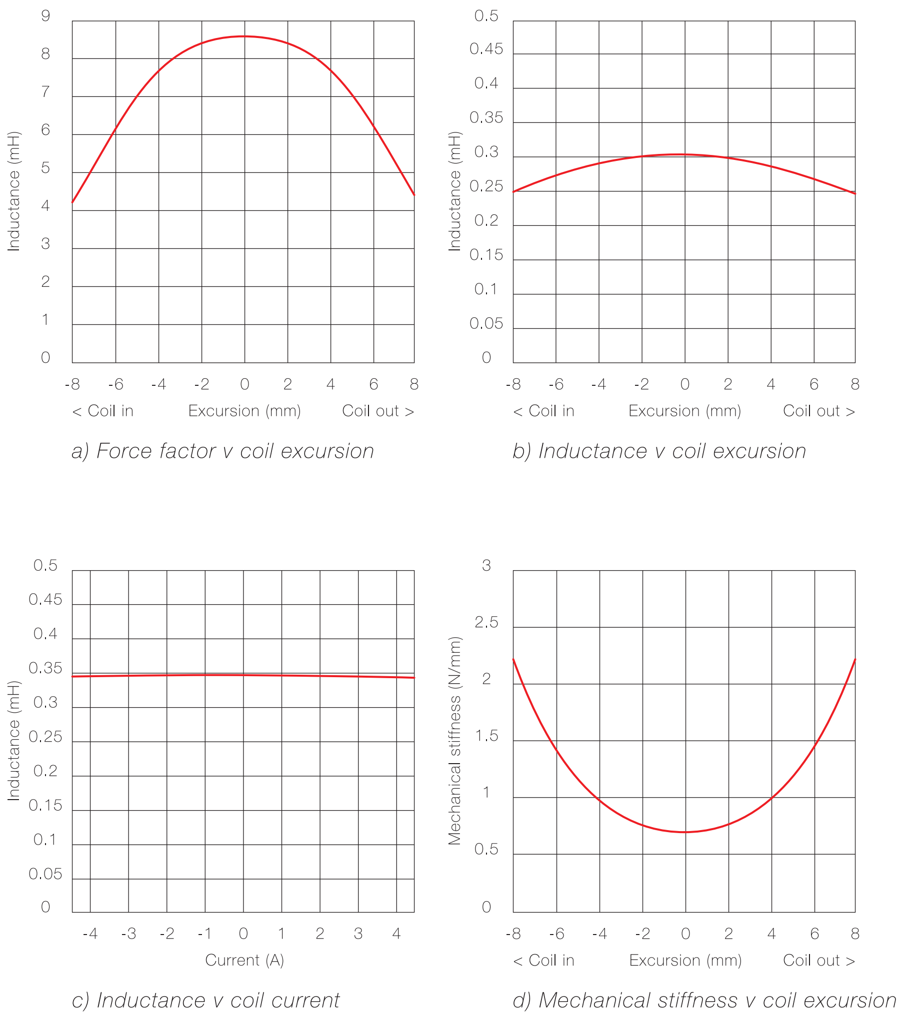


Figure 7 Mid / bass driver voice coil parameters

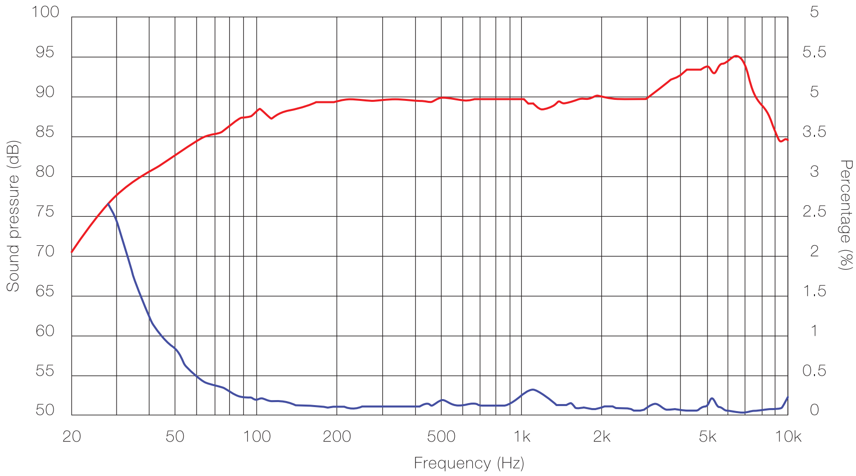
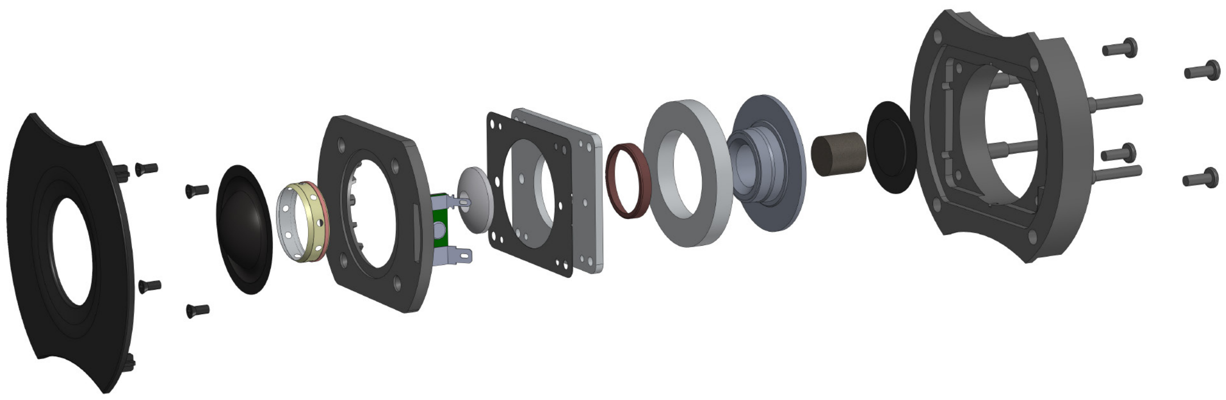


Figure 8 On-axis response curve mid / bass unit without crossover

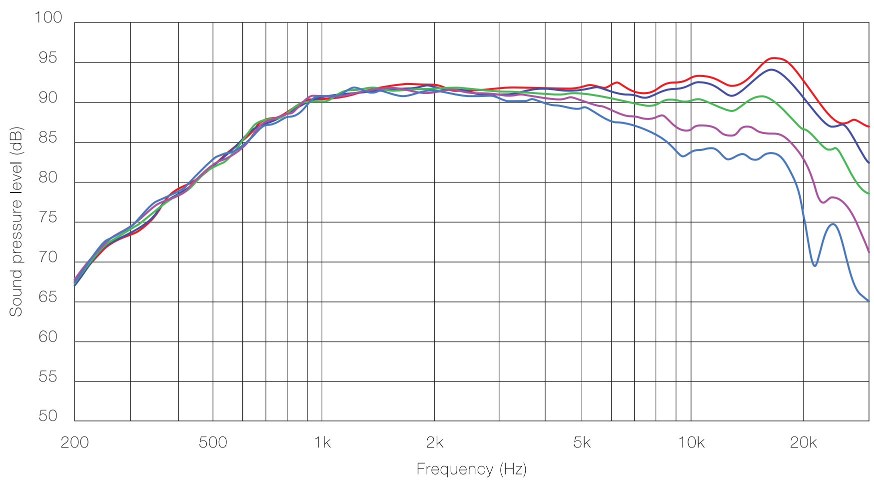
Optimisation of one parameter to the detriment of others is to be avoided because the essential element of every good drive unit design is achieving proper balance. As an example, optimising cone termination – dominated by the surround material and shape – can produce a very low colouration drive unit with perhaps an ideal looking response outside of the useable band, but this can make it sound dead and slow with little 'get up and go'. That is not to say that the opposite approach should be taken – resulting in something that is super excitable, requiring an enormously complex crossover in order to tame it. It's all about balance, as the on-axis response curve of the mid / bass drive unit in Figure 8 shows. Here, the in-band response of the driver measured without a crossover is extremely flat but the unit retains its lively character with a controlled rise in the response outside the useable band where the high frequency driver takes over.



High Frequency Drive Unit

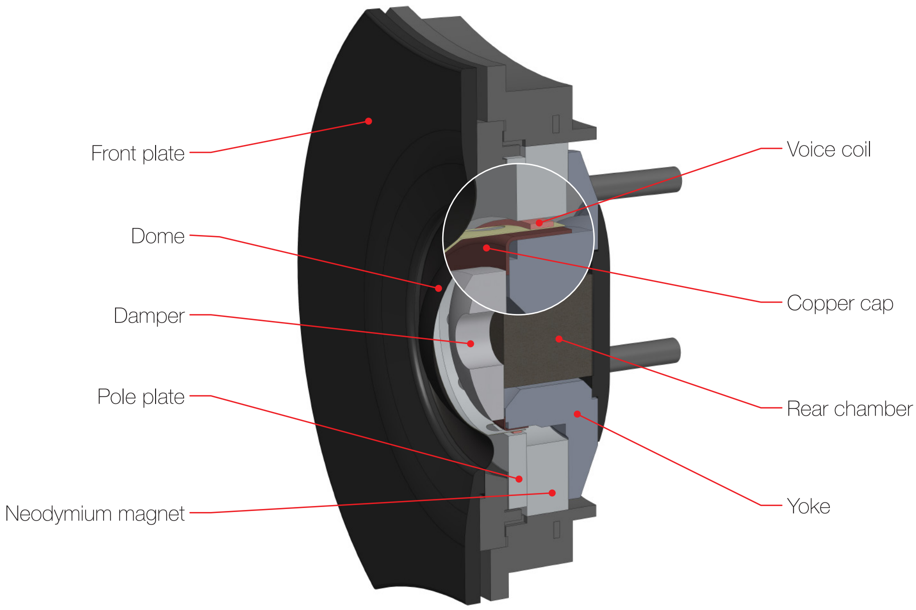
To design and build a truly excellent high frequency drive unit is not an easy task. In comparison, the precision required in manufacturing a good mid / bass unit is much more straight-forward. The moving mass of a high frequency unit is so small that even the mass of the adhesive used becomes significant. The main task is to develop a design and implement a build process that is repeatable over thousands of units – not just a few specially selected samples.

Finite Element Analysis was used to model the acoustic performance of the soft dome and surround for optimal axial dispersion. Too narrow a high frequency dispersion characteristic means the speaker will not drive the room well, making it sound flat and uninteresting unless the listener is sitting in the exact 'sweet spot'. The extra wide high frequency drive unit surround contributes to the dispersion of upper frequencies, adding extra energy off-axis. As can be seen by the axial response curves shown in Figure 9, the sound pressure level at 45 degrees off-axis is only 6dB lower at 15kHz, compared to the on-axis level.



On and off-axis SPL @ 1W/1m: 0°(——), 15°(——), 30°(——), 45°(——), 60°(——)

Figure 9 Axial response curves SPL v frequency

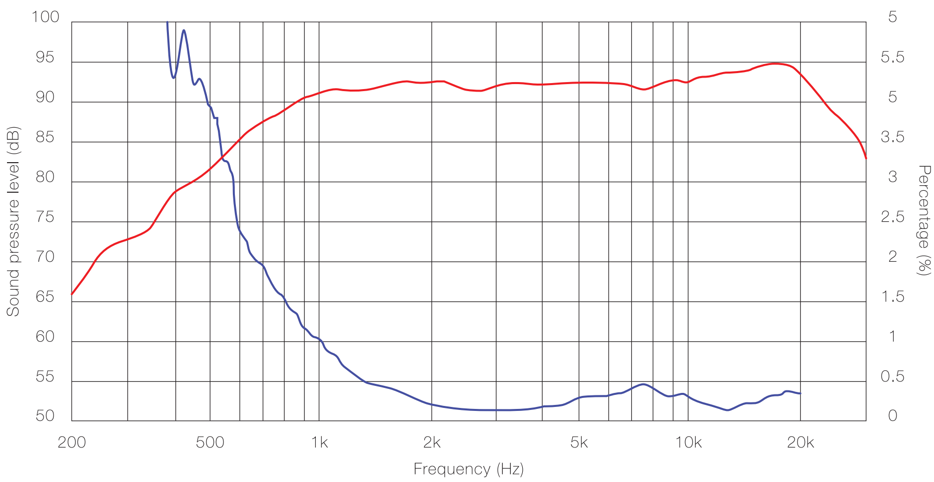


The high frequency unit is mechanically decoupled and mounted in a specially designed rubber gasket developed to isolate the driver and speaker cabinet from reciprocal vibrations that otherwise would be transmitted between them.

The 28mm voice coil and larger than average one-piece coated-microfibre dome with its wide surround give excellent power handling capability, lower dynamic compression and hence, lower distortion – especially at the lower end of the frequency range. In addition, the pole piece includes a copper cap to further reduce distortion.

The front plate incorporates a very gentle horn shaped profile to facilitate acoustic impedance matching with the surrounding air without introducing horn resonance that would add unnatural character to the sound.

The internal volume of the dome has been carefully optimised using Thermo-Acoustic Finite Element Analysis to minimise the detrimental effects caused by coupled cavity resonances between the various sub-cavities.

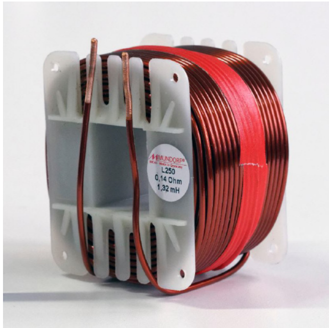


On-axis SPL @ 1W/1m (——) and THD @ 90dB/1m (——)

Figure 10 On-axis response curve high frequency drive unit without crossover

In common with all Q Acoustics drive units, the final design is the culmination of years of experience combined with precision modelling and measurement, confirmed of course by critical listening. If proof were needed, the blue line in Figure 10 shows how distortion has been reduced to below 0.5% across the useable band.

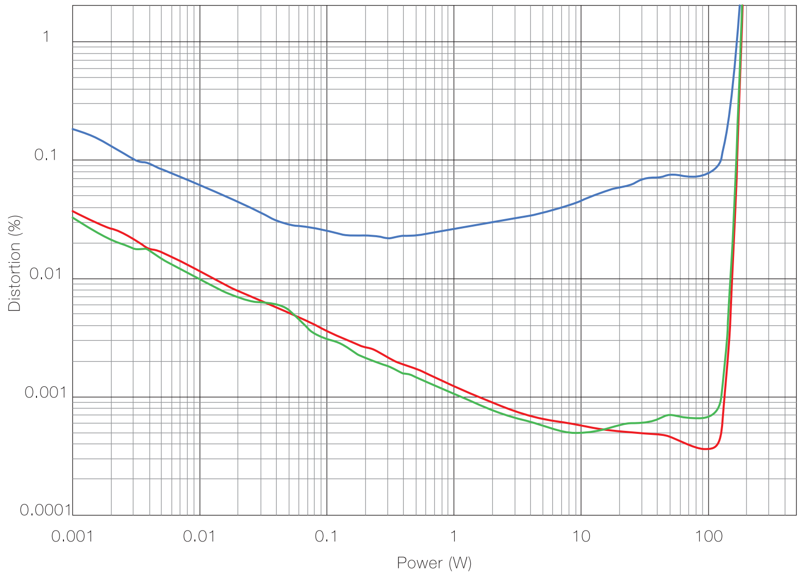
Crossover



Low distortion drive units and a very quiet cabinet can ruthlessly expose a poor crossover. This means that not only must the design of the crossover be exemplary but great care must be taken when choosing components. For instance, the laminated silicone steel core main inductor that had originally been specified introduced too much distortion and was obviously colouring the sound as can be seen from the blue trace in Figure 11 when compared to the amplifier output shown by the red trace. Instead, despite its physical size and associated mounting difficulties, a massive 10cm x 10cm Mundorf aircore inductor was chosen for the Concept 500. Securely mounted inside the base of the loudspeaker the inductor introduces virtually zero noise and distortion as evidenced by the green trace in Figure 11. For the same reason the crossover uses high grade polypropylene film capacitors including a Mundorf Supreme in series with the high frequency unit. The resistors are custom made bifilar wirewound types with astonishingly low inductance.

The overall topology of the crossover is 4th order acoustic Linkwitz-Riley which gives an excellent response on and off-axis, further strengthening the room-friendly character of the Concept 500.

The nominal impedance is a deliberately sensible 6Ω with an absolute minimum of 3.7Ω which makes the speakers relatively easy to drive.



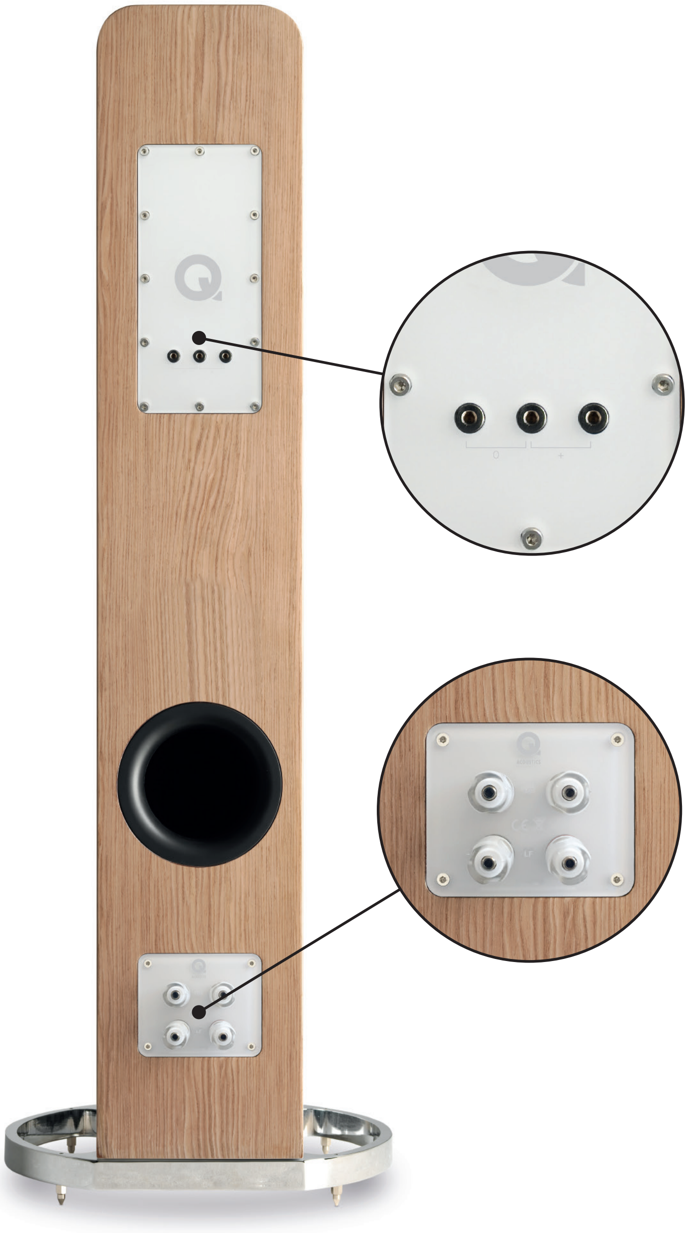
Steel Core (——), Air Core (——), Amplifier (——)

Figure 11 Distortion in a laminated steel inductor and a Mundorf Air Core Inductor compared to the amplifier output

The crossover is hard wired and mounted well away from the main inductor and driver radiated fields which can introduce distortion.

By configuring different jumpers on the rear access panel, the Concept 500 allows the HF level to be adjusted by +/- 0.5dB to suit the room or individual taste.

Terminal & Rear Access Panels



The terminal panel and rear access panel are designed in such a way that they are prevented from vibrating in sympathy with the music. It is surprising how often this can be a source of extraneous noise in many commercially available designs. The rear access panel in particular has been constructed by sandwiching layers of MDF, steel and bitumen to maintain the integrity of the Dual Gelcore™ cabinet.

The Concept 500 is equipped for bi-wiring or bi-amping with electrically isolated and oversized HF and LF terminals which can accept bare wires, spades or 4 mm banana plugs. If connected using a single run of cable the best performance will usually be obtained using bi-wire links made from the same cable as the speaker cable.

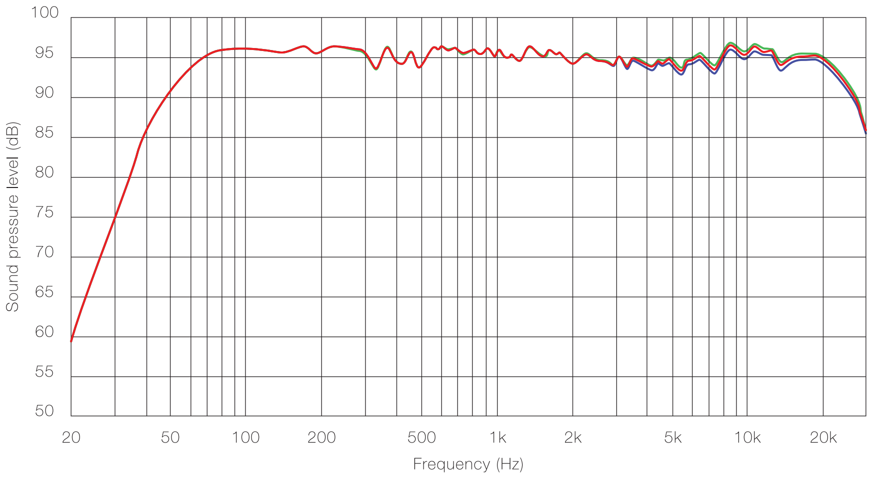
Industrial Design

Although this paper is principally concerned with the technology of the Concept 500, Q Acoustics believe that success has come through the integration of good engineering with good design and it would be inappropriate not to discuss the visual features of the product.

IDA principal, Kieron Dunk, led the design team that worked on Concept 500. He wanted an elegant design, compatible with a contemporary living space and not specific to any particular interior style. In keeping with the design DNA of Q Acoustics, the concept was pared-back to be as clean looking as possible. The designers were able to exploit the rear-mounted mid / bass driver feature to keep the baffle uncluttered and have also specified embedded magnets to secure the grille so no fixings are visible if it is removed.

The gloss black or white finishes have been combined with real-wood veneer (to be expected in a speaker of this calibre) but the veneer is used sparingly in a subtle strip to create a cabinet that is at once visually light and clean, whilst still retaining the high perceived value of a heavier full wood solution. The white gloss finish has been attractively paired with pale oak and the black gloss with deep rosewood. Additional coats of lacquer have been used to give a deep piano gloss finish, appropriate to a premium product like the Concept 500.

Conclusion

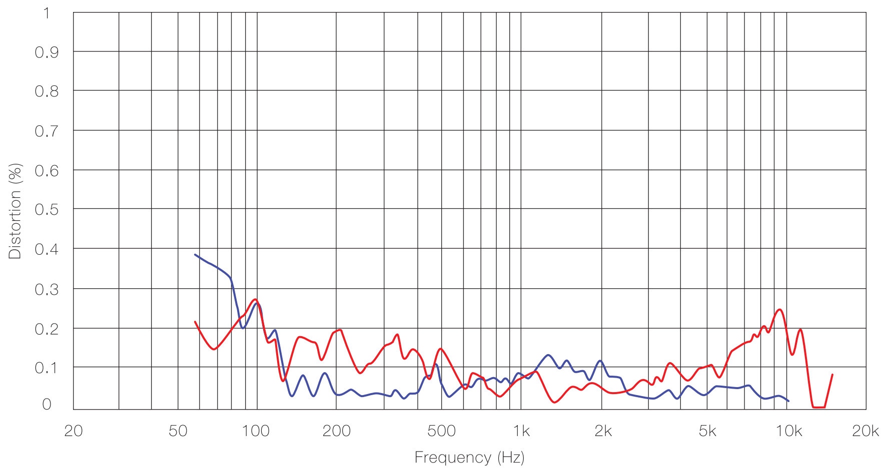


-0.5dB(——), Flat(——), +0.5dB(——)

Figure 12 Final frequency response curve

Concept 500 is a fine example of what can be achieved by a partnership of like-minded designers and engineers, with access to world-class facilities, such as that between Q Acoustics, Fink Audio-Consulting and IDA. It can also be seen that the design philosophy and engineering practices employed in the project have left no stone unturned in the quest to improve upon current thinking and solve the problems inherent in high-end loudspeaker systems. The success of this process is clearly demonstrated in Figures 12 & 13 where the excellent linearity and astonishingly low 2nd and 3rd harmonic distortion of the Q Acoustics Concept 500 can be seen.

We recognise that the choice of a loudspeaker is always a personal one, with system matching, room acoustics and personal taste all playing an important role, but we feel that the Concept 500 is easily good enough to be included in anyone's audition shortlist.



2nd Harmonic(——), 3rd Harmonic(——)

Figure 13 Harmonic distortion levels

Concept **500** Specifications

Performance	
Frequency Response (-6dB, +3dB)	41Hz – 30kHz
Nominal Impedance	6Ω
Minimum Impedance	3.7Ω
Sensitivity	90dB
Recommended Power	25 – 200watts
Distortion (120Hz – 20kHz)	0.2%
Crossover Frequency	2.5kHz
Driver dimensions	
Mid / Bass Driver	2 x 165mm
High Frequency Unit	28mm
Weight and dimensions	
Weight (per cabinet)	42kg
Cabinet (inc. plinth)	400 x 1150 x 350 mm
Cabinet (inc. spikes and terminals) (W x H x D)	400 x 1175 x 375 mm

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