Q Series Technologies Explained

CONTENTS

INTRODUCTION

The multiple award-winning Q Series has always exemplified KEF's conviction that new materials and technologies can, when applied with intelligence and imagination, reproduce recordings so perfectly that they sound indistinguishable from the live event. This is more true now than ever before. As the latest expression of this design philosophy, the new range immerses you in three-dimensional imagery of a richness and clarity that until now has been the exclusive preserve of speakers costing many times more.

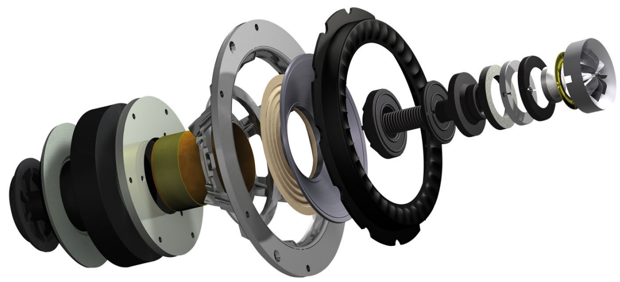
A class above

The all new Q Series from KEF represents a quantum leap in terms of listening pleasure.

At its heart is a brand new Uni-Q driver array. Derived from the Concept Blade project, with a new, larger, high performance vented tweeter mounted at the acoustic centre of a new metal cone LF/MF driver, it combines lavishly extended bandwidth with effortless dynamics, imperceptible distortion and outstanding acoustic clarity.

These are speakers with the power to strike a chord in your heart. Off-axis dispersion is unrivalled, so everyone in the room enjoys the same exceptionally realistic sonic imaging, wherever they sit. And with 30% larger capacity cabinets for even gutsier bass and minimalist crossovers assuring deliciously fluid transitions, new Q is both more eloquent and more emotive than its illustrious predecessor.

Movies or music, Mahler or Massive Attack, what you experience is the captivatingly sweet, accurate and natural live sound of the original performance.



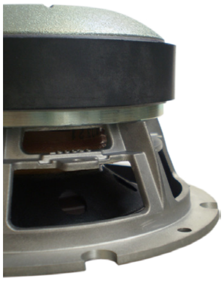
The brilliantly innovative engineering of the new Q Series surrounds you with a spacious sonic image of astonishing purity.

Technology with soul

A groundbreaking new Uni-Q array that conjures up a fluent, spacious and incredibly realistic 3D sound stage you can enjoy wherever you sit. A spectacular new high performance LF driver that delivers deeper, cleaner and more accurate bass.

And a 'total design' approach, with obsessive attention to detail and the pleasures of ownership. These are the qualities that set the new Q Series apart.

PART 1 - Q SERIES COMPONENTS



ALL NEW Uni-Q DRIVER ARRAY

The KEF Uni-Q Driver Array is a patented KEF technology first developed in 1988 and used in the C Series models 35, 55 and 75. For the new Q Series a brand new 11th generation Uni-Q has been developed. This driver array has been developed by the same team of KEF Engineers that worked on Concept Blade and consequently many of the new techniques developed for the Concept Blade design have been applied to this Uni-Q. In addition to the original patent, work by KEF Engineers has resulted in four other patented technologies which are all used on this one critical component.

- Tangerine Waveguide
- Optimal Dome Shape
- Stiffened Dome
- Z-Flex Surround

The KEF Uni-Q concept is, in effect, quite simple: rather than having two separately mounted drivers for mid and high frequencies, the tweeter and midrange driver are combined into one assembly. The two drivers are designed and positioned to form a single acoustic source coherent in position, directivity and time. There are several benefits of this approach, more information can be found in chapter 5.

The Q Series Uni-Q Array is the result of many man years of focused development. Numerous new features and innovations which have not been seen before elevate the driver performance to new levels.

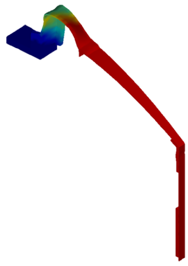
Midrange Driver

The midrange driver has a difficult job, it must bridge the gap between the low and high frequencies, and it covers the range over which our ears are most sensitive. Unlike tweeters it is very important that midrange drivers are well behaved above their working range otherwise they might conflict with the tweeter output.

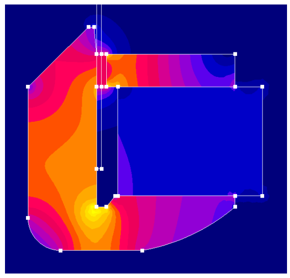
The shape of the midrange driver cone, surround and surrounding objects are very important. Additionally, the midrange driver cone experiences much higher bending forces than a bass driver cone because of the range over which it operates.

The midrange driver on the KEF Uni-Q Driver Array is a radical new design. The midrange cones are made from formed aluminium and have been carefully designed using KEF's advanced computer modelling techniques. This is particularly important as the cone of a Uni-Q Driver Array must perform two functions:

- Firstly it must function as the radiator for the midrange,
- Secondly it acts as a waveguide for the tweeter.



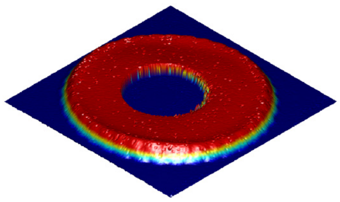
• Harmonic FEA model of the midrange driver assembly



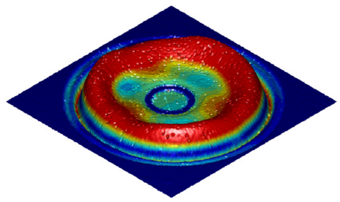
• FEA model of the midrange magnet system

The choice of aluminium as the cone material allows us greater freedom to optimise the shape of the cone so that it can more easily perform these two functions.

The mode of operation of the cone is also slightly different from the norm. The majority of loudspeakers use midrange drivers which have resonances in their working bandwidth. Resonances occur in both the cone and the surround and cause irregularities in the frequency and directional response of the loudspeaker. This is a problem that KEF wanted to avoid completely to ensure the best possible integration of the midrange with the tweeter. The combination of the aluminium cone and the Z-Flex Surround results in a midrange driver which has very little resonance in the working band. Additionally, the problem of the high frequency band resonance of the metal cone has also been overcome by the development of a new KEF technology called Cone Breakup Control.



• A Laser Vibrometer Scan showing how the new Q cone moves almost rigidly



• A Laser Vibrometer Scan showing how a conventional cone bends and resonates significantly

The motor systems of the new midrange drivers are substantially more powerful and of longer throw than those from previous generations of Q Series drivers. We have chosen to use Aluminium Voice Coils on the Midrange drivers as this allows us to use long throw coils whilst offsetting any increase in the coil mass. The voice coil diameter is substantially larger than that of most loudspeaker drivers on the market giving the new Q Series exceptional power handling and dynamic response. The motor systems are all designed on the computer by KEF's engineering team and we are able to try many iterations virtually, allowing us to identify potential problems and optimise the design much faster and more effectively than traditionally possible.

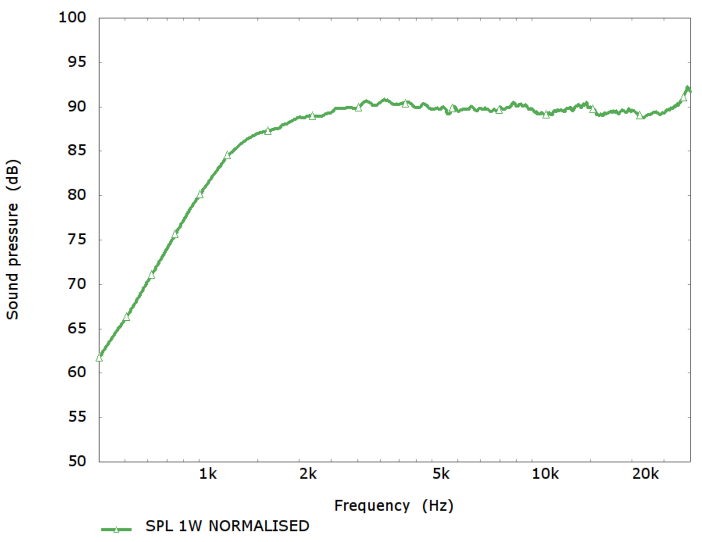
Tweeter

In recent years KEF has made great progress in tweeter technology and with this revision we have been able to dramatically improve the tweeter in the Q Series Uni-Q Driver Array by using the know-how developed for products such as KEF's Reference Series, Muon and the Concept Blade project. The tweeter shares more with these high end loudspeakers than it does with the previous generation of Q Series. As with all KEF drivers the starting point for the design is at the computer. Many hours of careful analysis and design have resulted in us being able to put technologies into this design which in previous years would only have been found in the very highest-end loudspeakers.

The dome of the new tweeter is made from aluminium and uses the KEF Stiffened Dome technology which was first seen in the Reference Series to extend the high frequency response comfortably beyond the audible range. The dome shape itself is critical to the performance of the Uni-Q Array and work by the KEF engineering team has greatly improved the performance of tweeters by ensuring that the dome is optimally shaped. [1]

A very noticeable new feature of the Q Series tweeter is the Tangerine Waveguide which not only protects the dome but also improves the efficiency and dispersion of the tweeter at the very highest frequencies.

The motor system of the new tweeter has been computer designed and optimised and incorporates KEF Vented Tweeter technology - again taken from the Reference Series.



• Frequency response of the Q Series Tweeter mounted in a test waveguide in the transient room 2pi baffle

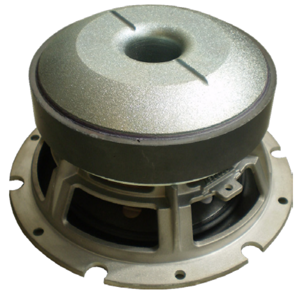
ADVANCED BASS TECHNOLOGIES

Bass Drivers

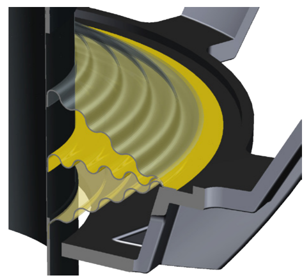
The Q Series bass drivers have been completely redesigned to complement the new technologies that we have introduced in the Uni-Q Driver Array. Like the new Uni-Q Midrange Drivers the bass drivers have very large Aluminium Voice Coils which means that they are able to handle extremely high power levels with much better linearity than most bass drivers. The cones are of a braced aluminium construction for maximum rigidity.

The computer designed motor system is significantly larger than that of a conventional low frequency driver, this powerful design is held rigidly in place by a cast aluminium chassis. An interesting feature of the new motor system is the large central venting hole which reduces the losses due to air flow around the back of the driver and maximises the acoustic output.

The linear and nonlinear parameters of the new bass drivers have been carefully optimized for the acoustic requirements of each cabinet and for each of the Q Series loudspeaker systems. As with all of the work we do, extensive computer modelling is used in the design of the driver parts.



• Rear view of the 5 inch Bass driver showing the large magnet system, the cast aluminium chassis and the vent hole.



• FEA simulation of suspension deformation.

ABR

The Q Series bass drivers are augmented by a new ABR (Auxiliary bass radiator). This provides the same low frequency extension as a port, but is free of turbulent noise and mid-band colouration. Our listening tests revealed a much cleaner sounding mid-range when using a well designed ABR than when using a port.

Non-linear Airflow

At high output levels air-flow in a port becomes turbulent. This results in distortion, acoustic compression and, most noticeably, broadband "chuffing" noises. One way to reduce these effects is to use a port with a larger cross sectional area. However, this requires the port to be longer (length is proportional to the square of port radius) which rapidly becomes impractical in a compact enclosure. Another way of dealing with the effects is to mount the ports on the rear panel of the speaker to reduce the perceived level at the listening position. This limits how close to a wall the speakers can be placed. Some manufacturers use specially textured surfaces on their ports to modify the air flow, however, the viability of this approach is questionable[2]. Using an ABR instead of a port completely eliminates these problems.

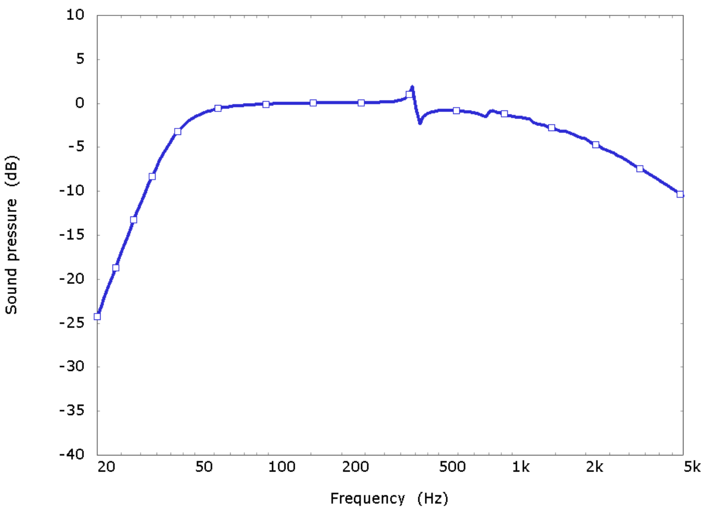
References

1. M. Dodd, "Optimum Diaphragm and Waveguide Geometry for Coincident source Drive Units," presented at The 121st Convention of the AES, preprint 6886, Oct 2006.

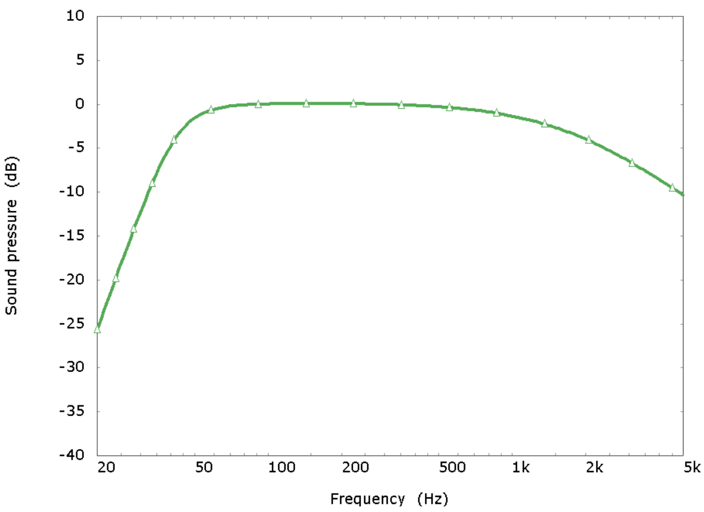
2. Salvatti, Alex; Devantier, Allan; Button, Douglas J., "Maximizing Performance from Loudspeaker Ports" The Journal of the Audio Engineering Society, Volume 50 Issue 1/2 pp. 19-45; February 2002

Port Resonances

Internal resonances of a braced, sealed enclosure are well controlled by a sound absorbing material. In a ported system however, these internal resonances can be radiated from the port opening. Also, standing waves from within the port itself are radiated. Since a port is like an open pipe with little damping, these resonances can be quite severe. The graphs below show how port resonances affect the upper bass/ midrange response. To the listener, this amounts to a loss of clarity in the midrange. With an ABR, there is no pipe resonance, and the diaphragm helps to prevent the radiation of internal cabinet resonances.

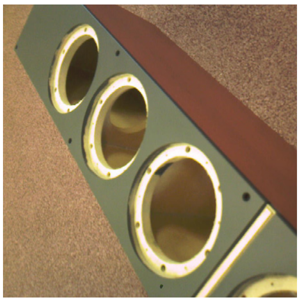


• Simulated low frequency response of a ported loudspeaker, notice the port resonance in the midband.



• Simulated low frequency response of a loudspeaker with ABR.

• Spikes on floor-stands are easily adjustable from above so the cabinets do not need to be turned upside down for adjustment.



• The cabinets house the minimalist crossover and terminal panel, which has provision for problem-free single or bi-wired connections.

Stunning Cabinets

The braced cabinets use newly-sourced wood-pulp derived surfacing materials, which enable superb moisture and scratch-resistant exotic wood-effect finishes without cutting down any rainforest timber or using kilometres of PVC film.

Acoustically Inert

• Structural resonances of the cabinet walls are controlled by carefully positioned internal bracing

Cabinet mechanics is an important part of the system design and special care has been taken to ensure these new cabinets are acoustically inert. This is critical for maintaining the well controlled bass and clean midrange produced by the new drive units. Structural resonances of the cabinet walls are controlled by carefully positioned internal bracing. Standing wave modes are eliminated by the careful use of acoustic damping materials - the quantity, positioning and choice of material being all important. Too little damping in critical places allows resonances to be excited. Too much damping reduces bass output and causes the sound to become 'slow'. To reduce the transmission of internal acoustic energy into the listening room we have opted, wherever possible, to use a new ABR instead of a port.

TOTAL SYSTEM DESIGN

Cabinet

The new Q Series cabinets are easy to install and have been carefully designed to look good as well as remain rigid. All models are taller than their equivalents in the previous range and, because of the rectilinear shape, have around 30% more internal volume than the previous curved cabinets. This is an advantage because, when combined with optimised bass drivers, internal volume determines the bass performance possible for a given system at a given target sensitivity.

Crossover

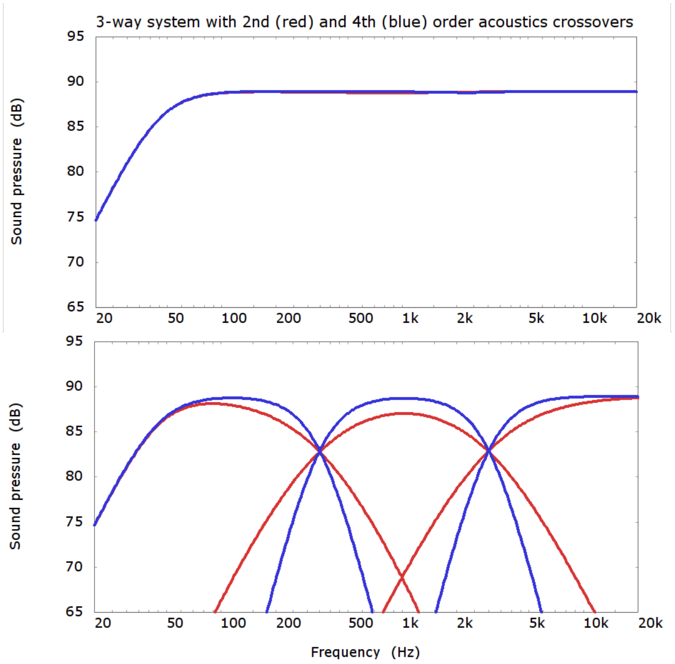
It is extremely difficult to design a single drive unit that will cover the entire audio frequency range with the tonal accuracy, low distortion, dynamic capability and controlled directivity expected from a high quality loudspeaker system. The simplest hi-fi speakers are therefore of a two-way design with dedicated bass/midrange and treble units integrated by the internal crossover network to sound like a single high performance driver. The simplest format for a 'full range' speaker is the three-way with dedicated bass, midrange and treble drivers - integrated with a correspondingly more complex crossover network.

The function of the crossover network is twofold:

1. To take the signal from the input terminals of the speaker and filter it to provide the appropriate separate signals for the bass, midrange and treble drivers and

2. To provide overall equalization to ensure a smooth response and good tonal accuracy.

The outputs of the drivers will then sum acoustically at the listening position to provide full-range, high quality sound. The precise way in which the crossover achieves integration of the units will depend on the target function set by the designer. The main criteria to set is the 'order' of the acoustical crossover, or equivalently, the 'roll-off' slopes of the two units. A 'first order' acoustical crossover has the units rolling off at 6dB per octave (an octave is a doubling, or halving, of frequency) This provides a very gradual transition from one unit to the other but requires the units to have a smooth response over a wide frequency range. In a second order filter the acoustical roll-off slopes are 12dB per octave and the filter is correspondingly more complex with more components and tracks being required. A fourth order filter has 24dB per octave acoustical slopes and provides a swift transition between the units with minimal overlap - however, the filter becomes more complicated still and careful design is critical. The fourth order characteristic is about the practical limit with a passive crossover network, however active loudspeakers, with digital filters, often used very steep slopes such as 6th order, 36dB per octave, to provide a very swift transition between the units.



Passive crossover networks are made up from resistors, inductors and capacitors which must be of high quality to minimize loss of sound quality. In complex crossovers, such as fourth order with subsequently more components in the signal path, this becomes even more critical. In some instances even more components are added to compensate for irregularities in a driver's response or cabinet diffraction. However, the improvement in the tonal accuracy must be weighed against the extra losses and possible distortions created by the inclusion of extra components in the network. Extra components and signal tracks also need to be packaged carefully on the printed circuit board to avoid interactions which can further reduce sound quality.

All things being equal, low order acoustic crossovers using simple electrical filter topologies tend to produce a sound that is free flowing with natural, unconstrained, dynamic swings and a big, open, stereo image with believable overall geometry. These subjective attributes are related to a number of technical elements already discussed as well as other factors such as the reduced phase shift through the crossover regions that also comes with low order crossovers. The drawback of low order acoustic crossovers is typically a 'roughness' or 'lack of refinement' in the sound caused by the drivers not having a smooth enough response over a wide enough bandwidth and the fact that, with the lower roll-off rate, more than one unit is operating over more of the frequency range, which can cause a confusion if the integration is not good enough. High order crossovers, on the other hand tend to produce a sound that has good tonal resolution and refinement, and good fine detail in the stereo image.

There are a numbers of reasons, therefore, that provided the acoustic performance is maintained, the use of high performance, low order, acoustic crossovers is desirable - especially where cost effectiveness is important.

The key to achieving good acoustic performance with simple crossover networks is careful design of the drive units and enclosures such that the natural acoustic responses of the drivers require only minimal extra filtering to achieve the desired acoustical crossover target. The new Q Series drivers have been designed from the ground up to allow second order acoustic crossovers with minimal response equalization. This is then achievable with simple, low order, electrical filters with only a small number of carefully chosen, high specification, components. The challenge has been to develop drivers that are genuinely good enough to allow the full potential of low order acoustic crossovers to be realised - this includes wideband and consistent accuracy of the tonal balance and stereo image - which is often compromised in so-called 'minimalist' designs. The new Q Series drivers, which demonstrate wideband pistonic motion, are the key to achieving this ideal.

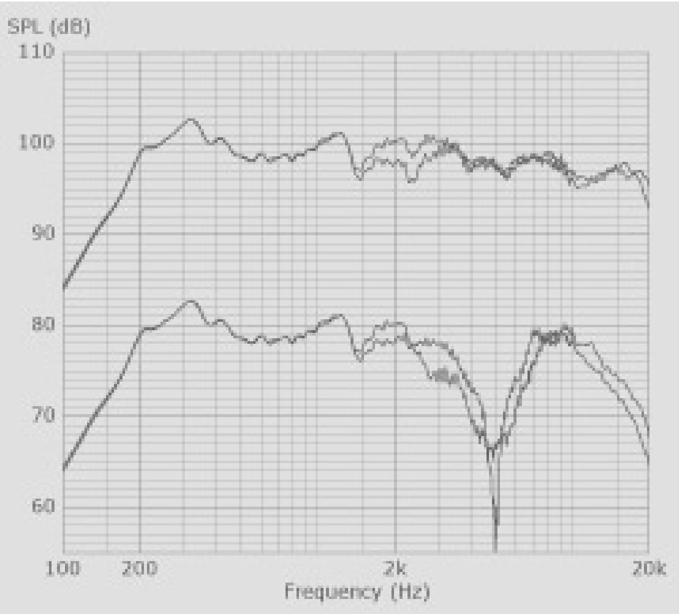
References

Crossover Filters - An integral part of overall system engineering. KEFTOPICS Vol.4 No.2. Available for download from the KEF website.

PART 11 - Q SERIES TECHNOLOGIES

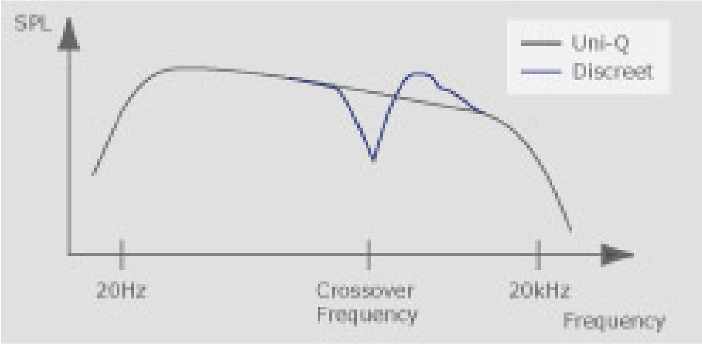
KEF Uni-Q

Of the many landmark innovations KEF has pioneered, arguably the greatest of all is the Uni-Q point source driver array with its outstanding acoustic clarity and off-axis dispersion. With over 20 years of continuous innovation and development the Uni-Q driver array achieves a level of sound quality over a broad area simply not achieved from conventional speakers.



Sounds come at you so naturally that it seems as if the musicians or actors are actually there in front of you. Whether you are in the centre of the room or off to one side recordings sound real and convincing. Uni-Q achieves this because, unlike conventional speakers, the sound that is critical to the experience comes from the same point in space and is produced in a controlled and continuous way over the whole audio range.

It is not easy to produce a convincing and realistic illusion of a live performance because the sound from a high quality loudspeaker does not come from a single source or drive unit. Two or more units are required to faithfully reproduce the entire audio spectrum from the low bass produced by a concert organ or a cinema explosion to the delicate nuances of the human voice in the midrange right up to the shimmering treble of cymbals. Most loudspeakers have the midrange and treble drive units mounted one above the other so the sound is coming from two different places causing audio 'confusion' and losing the chance of achieving a truly natural sound. With Uni-Q the midrange and treble units are mounted at precisely the same point in space allowing them to integrate perfectly and create the ideal sound field for the listener to experience a convincingly natural sound.



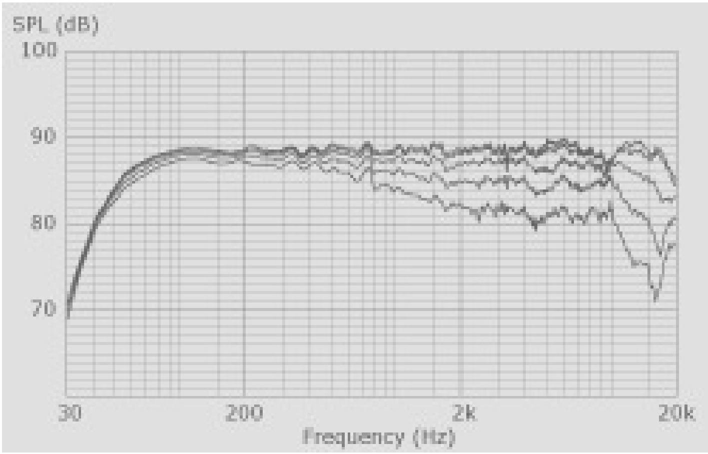
Acoustic Point Source

It has been well known for many years in the audio industry that one of the ideal forms for a loudspeaker is the 'point source'- where all the sound is radiated from the same point in space. To do this, the drive units (for example, the bass and treble units in a two-way system) need to be mounted so that their acoustic centres are at the same place. The problem in achieving this was the sheer physical size of the treble unit, which prevented it from fitting in the centre of the bass unit. Various forms of co-axial units emerged where the tweeter was mounted either in front of or behind the acoustic centre of the bass unit but these have significant drawbacks. The key to the invention of Uni-Q was the arrival on the market of a new magnetic material called Neodymium-Iron-Boron, which has ten times the magnetic strength of a conventional ferrite magnet. This material allowed a high sensitivity treble unit to be made small enough to fit within the voice coil diameter of a typical bass unit and so be placed at the precise point where the acoustic sources are 'coincident'.

With the acoustic centres at the same point in space the acoustic outputs of the bass and treble units are 'time-aligned' in all directions. This allows the designer to achieve perfect integration between the units, not just on one axis as is the situation with vertically separated units, but in all directions. The first advantage of Uni-Q, therefore, is the lack of the vertical interference pattern of separated bass and treble units which restricts the region of high quality sound output to only +/- 10 degrees above and below the principle axis. This same effect not only limits the vertical listening area but also produces a dip in the total energy output in the bass/treble crossover region, causing a distortion of the reverberant energy in the listening room. In Uni-Q systems this effect is completely eliminated.

Matched Directivity

The second advantage of Uni-Q is what we call 'matched directivity'. With the treble unit mounted at the centre of the bass driver's cone, its directivity (the spread of sound away from the main axis) is governed by the angle of the cone which also largely determines the directivity of the bass driver. So with the coincident mounting of the two units the directivity of the treble unit is adjusted to be virtually the same as that of the bass driver. As a listener moves away from the main axis, the output of the treble unit falls off at approximately the same rate as that of the bass unit, thus improving the uniformity of tonal balance across the listening area and improving the off-axis stereo imaging. The listener is not, therefore, as limited to a central 'sweet-spot' as with conventional speakers. And, of course, the same is also happening in the vertical plane so the reverberant energy in the listening room maintains an even balance adding realistic ambience to the sound without introducing tonal colorations. The directivity is often referred to in engineering terms as the 'Q', and the 'Unifying' of the 'Q' gives rise to the name 'Uni-Q'.



From a listener's perspective, the combination of the matched directivity and precise time alignment in all directions gives significantly improved stereo imaging over a wide listening area, the realism of which is enhanced by the even balance of the reverberant energy within the listening room.

VENTED TWEETER

The Q Series Uni-Q has a Vented Tweeter. This increases the amount of air enclosed behind the dome to reduce distortion of the sound.

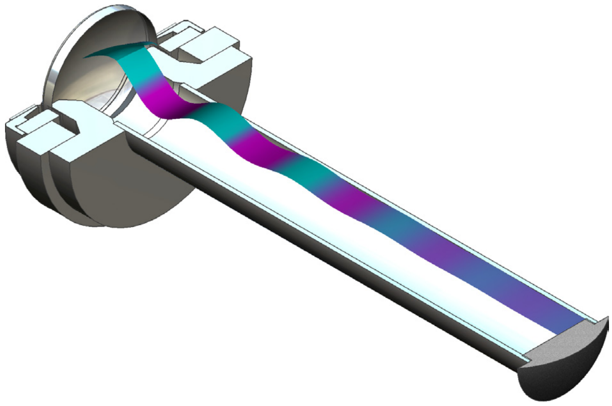
An Analogy

Imagine two mattresses made from the same type of foam, one thick and one thin. Most people would find the thick mattress more comfortable. This is because their weight on the thin mattress compresses it to the point they can feel the hard bed slats beneath. The extra material of the thick mattress means it is not compressed fully and thus still feels soft and springy.

Air Behind the Tweeter Dome

The dome of a tweeter vibrates the air around it. In front of the dome this vibration is propagated away as sound. To the rear is an enclosed pocket of air.

The dome pushing on the enclosed air experiences something similar to the person on the mattress. If the enclosure is too small the air undergoes large compressions and expansions. It will behave in a non-linear manner and cause distortion. This can be compared to the discomfort of laying on the thin mattress. In a larger enclosure the compressions and expansions are relatively small. The air in this case will act as a spring and the sound we hear will have much lower distortion.



Q Series Uni-Q Design

The Q Series Tweeter has been designed to avoid the small enclosure problem. It is a Vented Tweeter, that is, it has a sealed narrow duct to the rear to increase the amount of enclosed air. To eliminate resonances the duct is filled with a high damping material.

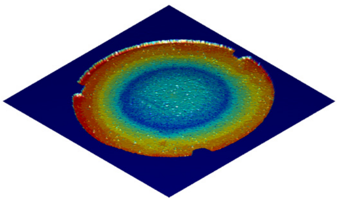
The image above shows the behaviour of the tweeter vent. Rear radiation from the dome travels down the duct and is gently absorbed in the acoustic damping material.

STIFFENED DOME

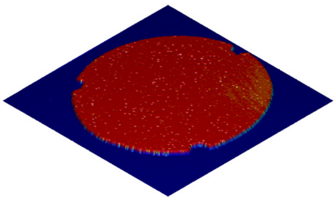
The Q Series Tweeter is part of the Uni-Q Driver Array. We have specified the shape of the dome for optimum acoustic performance in the Uni-Q, you can read more about this at the section on Optimal Dome Shape. However, the acoustics is only half of the story; to achieve the highest possible level of performance the Q Series uses another patented KEF technology to control the mechanical behaviour of the tweeter dome.

The Tweeter dome is constructed from extremely thin aluminium. Aluminium is chosen as it has a remarkably high stiffness combined with very low density. This is important for the tweeter dome because for best performance the dome must move rigidly without deforming even at and above the highest frequencies that we can hear. The highest frequency that a human can hear is approximately 20,000Hz, this means that we can hear sounds which repeat themselves as fast as twenty thousand times a second. In order to move this quickly the tweeter undergoes some seriously high levels of acceleration. At normal listening levels the tweeter hits peak acceleration levels of around 10,000m/s^2. If your car could accelerate this fast it would do 0mph to 60mph in 0.003 seconds - unfortunately it would be very hard to drive at the time as you would be pinned back in your seat from the 1000G of acceleration.

At such high levels of acceleration it is extremely difficult for the tweeter dome to remain rigid. The inertia due to the mass of the dome material itself can easily generate enough stress to deform the dome during normal use. The acceleration of the dome increases with frequency - ultimately there is a maximum frequency above which the dome is unable to remain rigid. The dome motion, including these deformations, is too small to see with the naked eye but it is possible to see them using a laser to record and amplify the motion as shown below.



• Laser Vibrometer Scan of Tweeter Dome Bending at High Frequencies



• Laser Vibrometer Scan of Well Behaved Rigid Tweeter Dome

Optimum Geometry

Research work was carried out at KEF in the 1990s to determine the dome shape that gave maximum resistance to the acceleration force and hence maximised the operational bandwidth. The study concluded that the optimum shape for the dome was an ellipse.

In-fact, the optimum dome shape to resist the acceleration forces and remain rigid is quite close to the shape of the rounded end of a chicken egg.

Using this shape it is possible to improve the bandwidth that a dome can be used over by around 75% compared to a conventional dome shape.

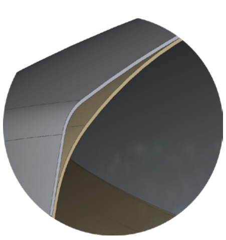
Unfortunately, recent research work tells us that the optimum shape that we require for the acoustics of the dome is a spherical cap.[4] There is some information on this work on the page Optimal Dome Shape.

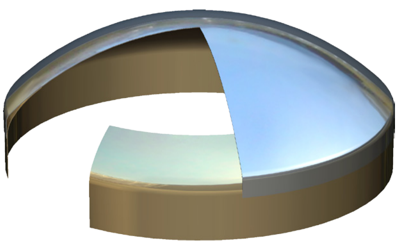
The Solution

KEF research has resulted in two optimum shapes of dome for different uses:

- The elliptical shape, optimum for the mechanics
- The spherical cap, optimum for the acoustics

The Stiffened Dome is a concept that enables us to use both of these optimum shapes at the same time - resulting in the best possible mechanical and acoustical performance of dome. The Q-Series Tweeter dome is made from two parts: one elliptical, one a spherical cap. These two shapes are superimposed, one placed on top of the other, forming the patented KEF Stiffened Dome.





At the edge of the dome the two shapes form a triangle.

The triangle is a fundamentally strong shape and the edge of the dome is normally the weakest part. Triangles are widely used in many engineering structures because of their inherent strength.

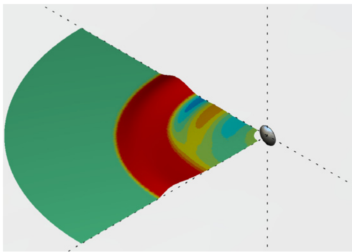
The Stiffened Dome gives a far higher performance than either the elliptical dome or the spherical cap shape alone.

OPTIMAL DOME SHAPE

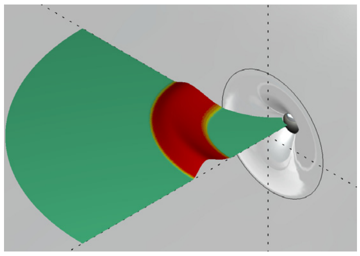
It is a common misconception in audio that the perfect environment for a tweeter is a plain flat baffle and that any waveguide or discontinuity will always degrade the performance even if carefully designed[5]. Recent work by KEF engineers has shown this not to be the case[6].

In fact, if exactly the right shape of dome and waveguide are used together their combined performance can beat the conventional ideal of tweeter in flat baffle. This is a KEF patented technology.

The images below demonstrate this. The soundfield in front of two tweeters has been modelled using Finite Element Analysis. A short pulse is sent to the tweeters and the corresponding sound wave can be seen radiating through the air. On the left is a model of a simple dome tweeter in a baffle; on the right a model of a dome tweeter and waveguide in the same configuration found on the Q-Series Uni-Q. The dome and waveguide model on the right uses the patented KEF Optimum Dome and Waveguide geometry.



• Finite Element Analysis of a Conventional Tweeter



• Finite Element Analysis of a Uni-Q Tweeter with Optimal Dome and Waveguide Shape

The soundfield of the tweeter on the right is more distinct with virtually no ringing following the soundfield. With the conventional tweeter layout there is a significant amount of ringing which occurs after impulse has passed particularly around the side of the dome.

References

4. M. Dodd, "Optimum Diaphragm and Waveguide Geometry for Coincident source Drive Units," presented at The 121st Convention of the AES, preprint 6886, Oct 2006.

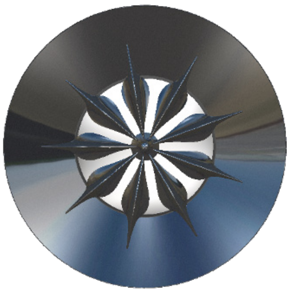
5. P. J. Anthony, J. R. Wright, "Finite-Element Analysis in the Design of High-Quality Loudspeakers" presented at The 108th Convention of the AES, preprint 5162, Feb 2000.

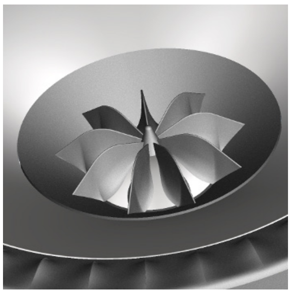
6. M. Dodd, "Optimum Diaphragm and Waveguide Geometry for Coincident source Drive Units," presented at The 121st Convention of the AES, preprint 6886, Oct 2006.

TANGERINE WAVEGUIDE

The Tangerine Waveguide is a patented KEF Technology which is now used in a number of products throughout the range. This technology was developed from research work into compression drivers which are used in high power systems for concerts.[7]

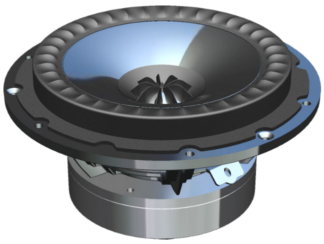
Compression drivers are very susceptible to acoustic resonances which occur in front of the tweeter dome. Whilst looking into the behaviour of compression drivers in detail, it was realised that the source of these acoustic resonances is also present in a normal direct radiating tweeter. The Tangerine Waveguide is designed to compensate for these problems improving the coupling between the tweeter dome and the air. [8]





The Tangerine Waveguide on the Q-Series is a totally new design. On previous products the Tangerine Waveguide has been designed to be relatively gentle and only have a small effect on the tweeter. With the Q-Series Tangerine Waveguide we have tried to really push the concept for maximum benefit.

Z-FLEX SURROUND



• New Uni-Q driver showing the Z-Flex surround

One of the most distinctive features of the new Q-Series Uni-Q Driver Array is the new Z-Flex Surround. The surround is a critical component of any bass/midrange driver. The designer must carefully choose the material and shape so as to avoid irregularities in the midband response due to resonance in the surround whilst at the same time allowing sufficient excursion of the cone in order to reproduce bass frequencies. Most modern drivers use a half roll design typically moulded from butyl rubber. The half-roll design can often perform well if carefully designed, however, KEF's computer modelling techniques allow us to investigate some more adventurous possibilities. The Z-Flex surround is the result.

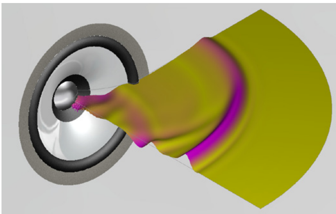
Improved High-frequency Performance

The Z-Flex Surround has a big impact on the high frequency performance of the Q-Series Uni-Q Driver Array.

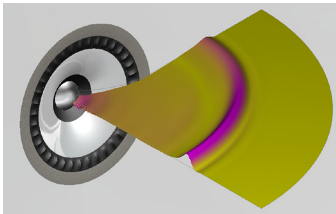
Ideally, the Uni-Q tweeter would be in the throat of a perfectly smooth waveguide. Under these circumstances, provided the dome is correctly shaped, the driver will give smooth hemispherical "point-source" radiation and higher sensitivity than a tweeter in a flat baffle. With loudspeakers such as those from of KEF Reference Series, where the Uni-Q is used only at midrange frequencies and the cone excursion is low, it is possible to use a completely smooth surround and come very close to this ideal.

Unfortunately, with a Uni-Q designed to reproduce midrange and bass signals it is not possible to use a completely flat surround design. Previous full-range Uni-Q designs have used conventional half roll surrounds but with this arrangement the ideal situation is compromised. The waveguide created by the cone and surround is not perfectly smooth - it has an abrupt discontinuity at the surround. This discontinuity causes diffraction and secondary radiation which smears the sound from the tweeter.

When the Z-Flex surround is mounted in the cabinet and correctly trimmed it does not form a discontinuity as a conventional surround does. In-fact, it creates a close approximation to the ideal smooth waveguide. The performance of the waveguide is extremely good and very little diffraction is generated. This is the first time that this compromise has been eliminated on a full-range Uni-Q driver array.



• FEA model showing the diffraction effect of a conventional surround in a Uni-Q driver.



• FEA model showing the diffraction effect of a Z-Flex surround in a Uni-Q driver

Improved Midrange Performance

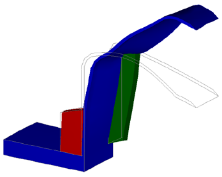
The images below show how the Z-Flex surround deforms when the cone moves back and forth. This is quite unlike the motion that is normally seen with a conventional half roll design. One of the benefits of the Z-Flex approach is that, for a given cone excursion, less of the surround is moved and hence the surround contributes a much lower effective mass to the cone edge. This is particularly helpful for maximizing the breakup frequency of the cone. Unlike a conventional surround, the Z-Flex surround allows very fine control over the surround behavior. There are three main features which are critical to the performance;

References

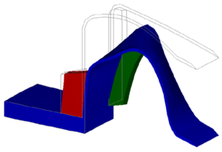
7. M. Dodd and J. Oclee-Brown, "A New Methodology for the Acoustic Design of Compression Driver Phase Plugs with Concentric Annular Channels," presented at The 123rd Convention of the AES, preprint 7258, Oct 2007.

8. M. Dodd and J. Oclee-Brown, "A New Methodology for the Acoustic Design of Compression Driver Phase Plugs with Radial Channels," presented at The 125th Convention of the AES, preprint 7532, Oct 2008.

- The membrane sections which form the air seal.
- The supporting blocks attached to the membrane.
- The undulations on the front surface of the membrane.



• FEA model showing the Z-Flex surround deformation as the cone moves forward



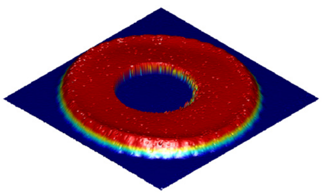
• FEA model showing the Z-Flex surround deformation as the cone moves backward

The membrane section is present to form an air seal, the size of the front and side walls are chosen to allow the driver to move to its full extent. The supporting blocks and the front surface undulations are present to control the behaviour of the surround in the mid band. The positions, shapes and sizes of these two features fine tune both the mechanical impedance which the surround presents to the cone edge and also the dynamic behavior of the surround itself. Conventional problems, for example the surround termination dip, can then be completely avoided by fine tuning the design.

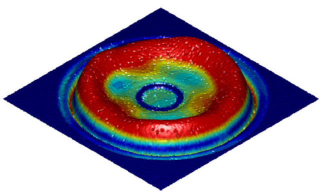
In essence the Z-Flex will readily allow simple deformations, such as those occurring at low frequencies when the cone is moving some distance back and forward, but greatly resist complex deformations, such as those which can cause problems in the mid-band.

Metal Cone

The new Q-Series Midrange and Bass drivers both use aluminium cones. Aluminium is very stiff and light; and compared to other materials an aluminium cone remains rigid to a higher frequency before cone breakup occurs. This means that in the new Q-Series the cones are not operating in the breakup zone. This is unusual as most other bass/midrange drivers have cone resonances in their working range. This gives the new Q-Series drivers an exceptionally smooth response with no trace of resonance in the working band.



• Laser Vibrometer Scan showing how the new Q Series cone moves almost rigidly



• Laser Vibrometer Scan showing how a conventional cone bends and resonates significantly

Cone Breakup Control

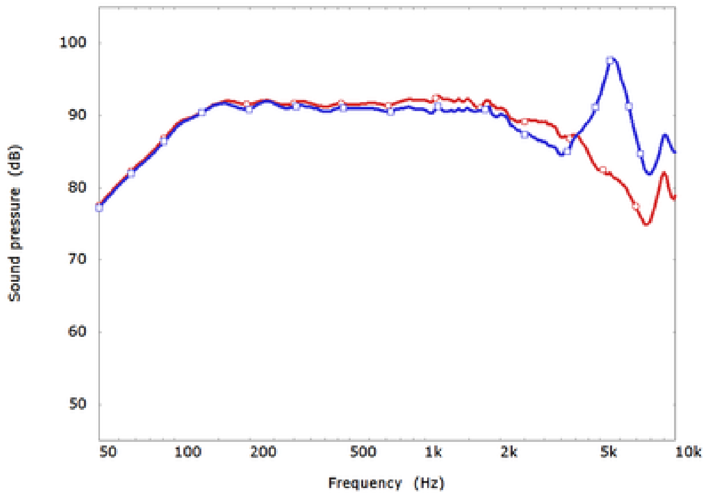
Aluminium has been used for the cone because it is very stiff and light, meaning it can be free of breakup throughout its working frequency range. However, it has lower damping than conventional materials meaning the breakup is more severe. Although this occurs outside the operating bandwidth, it can cause problems in the integration of the mid-range and the tweeter.

Cone Breakup Control

To overcome this a new KEF technology has been developed called Cone Breakup Control. A decoupling moulding is mounted between the cone and the rest of the motor system, very effectively controlling the mid-range resonance. The latest computer simulation methods have been used to optimise the behaviour of the Cone Breakup Control device.

At lower frequencies, the Cone Breakup Control device is rigid so it does not compromise the driver's performance and its main operating bandwidth. Above the working bandwidth the device absorbs high frequency motion preventing excitation of the cone resonance. The midrange and tweeter integration is therefore greatly improved. Physically, the effect is very similar to the way that a car's suspension absorbs the small undulations in the road.

The graph below shows the effect of the Cone Breakup Control device. Without the device fitted the cone breakup is very severe. With the device in place the response is much better at the top end. This allows us to use a very simple crossover, not something which is normally possible with a metal coned driver.



• Comparison of Q-Series 5 inch midrange driver with cone breakup control (red) and without (blue)

Aluminium Voice Coil

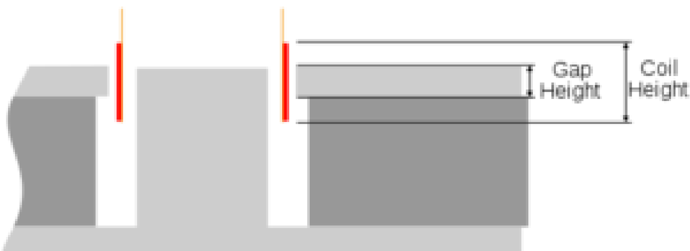
The new Q Series Midrange and Bass drivers use aluminium wire voice coils, the majority of loudspeaker voice coils use copper wire. Aluminium is slightly less conductive than copper but much lighter. Overall, this means that a lightweight aluminium coil can deliver the same performance as a much heavier copper coil. As a result we have been able to make the new Q Series voice coils very large without being overly heavy. This improves the Q Series performance in two critical areas:

- Distortion
- Power Handling

	Density	Conductivity	Conductivity/Density
Copper	8900	59,000,000	6630
Aluminium	2700	37,000,000	13704

Reduced Distortion

The new Q Series Midrange and Bass drivers use an overhung voice coil arrangement.



Even when the voice coil moves a long distance there is still the same amount of wire in the high magnetic flux area of the motor system. This arrangement allows the drivers to play louder and with less distortion. The use of aluminium wire means that a long voice coil, subsequently with more wire, can be used without incurring any mass penalty because of the lower density of aluminium.

Power Handling

Mechanical and electronic components heat up when in use which can affect their behaviour. This is true of the voice coil in a driver. A hot voice coil has higher resistance. This leads to power compression; for increasing electrical power input there are ever diminishing returns of sound power output. This limits the driver's dynamic range. Also, if a voice coil becomes excessively hot it may 'burn out' and break. This is a limiting factor on the power handling of the driver.

The voice coils of the new Midrange and Bass drivers have unusually large diameters. This gives them a large surface area which dissipates heat quickly. Compared with standard voice coils these are less susceptible to power compression and have a superb dynamic range. They can also handle greater input power without 'burning out'. Once again, the choice of aluminium as the voice coil wire is essential to ensure that the large voice coils are not overly heavy.

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