

UTOPIA & ELIAR WHITE PAPER

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 **FOCAL**



Focal's DNA is, by essence, the combination of the absolute acoustic quest, total control of the manufacturing process and the "je ne sais quoi" brought by the company's designers into every single product. The extreme care paid to each detail, from the early stages of R&D, to utilizing the latest manufacturing techniques and thorough quality control sums up our philosophy.

Since the very beginning, Focal has brought major innovations that pushed the limits of loudspeakers and their performance, thanks to the flagship projects within the brand such as, Utopia III, Utopia Be car audio kits or SM9 studio monitors. During the development of these flagship products in each of their respective divisions, the amount of time and resources devoted to the research phase far outweighed the actual production. These products were "born" thanks to this approach in order to reach the ultimate acoustic truth.



> Grande Utopia EM



> SM9



> Ultima kit





> "W" composite sandwich cone

However, to keep on innovating and to reach such a target requires a different way of thinking. We needed to be able to capitalize on our core know-how and past experiences, but also to challenge traditional thinking of what is possible and what could be achieved.

This strategy resulted in the creation of numerous exclusive technology, such as "W" composite sandwich cones or IAL tweeters that brought major improvements in term of acoustic translation of the original audio signal.

Before starting on the Focal flagship headphone project, we already had the relevant background with our in-house knowledge, thanks to the well-received Spirit headphone line. However, it was also because we've spent years analysing and listening to the very best headphones available on the market.

But after all this research and testing, we simultaneously came to the same conclusion - while even those models that offer very good performance, they still made us feel that we were listening to music through a pair of headphones against listening through a high-end pair of speakers and wanted to change that.

So this challenge arose and we decided to follow only one guideline during this project - to forget about existing solutions, and transfer our reference pair of speakers, Grande Utopia EM, into the most unique pair of headphones we could imagine. So rather than think of them as headphones, we started referring to them as compact, ultra-nearfield speakers.



> IAL Beryllium Tweeter

# Analogies between speakers and headphones

As a starting point, it was important for us to notice that speakers and headphones are not miles away from each other in terms of construction or their interaction with their environment (room vs ears). With regards to these similarities, a room's acoustic properties depend on many factors outlined here:

## 1. ROOM ACOUSTIC VS HEADPHONES DESIGN

As a general rule, the bigger the room is the better the low frequencies should be as the overall volume will allow air displacement. In a large room, this occurs without room compression or non-linearity of the low frequencies due to the size of the room and its low frequency damping capabilities.

In order to deliver 100% of the "speaker's" (headphone) performance, Focal decided to utilize a fully open headphone design to reach the lowest possible acoustic impedance. This design choice plays a huge part in the vivid and extremely natural listening experience.



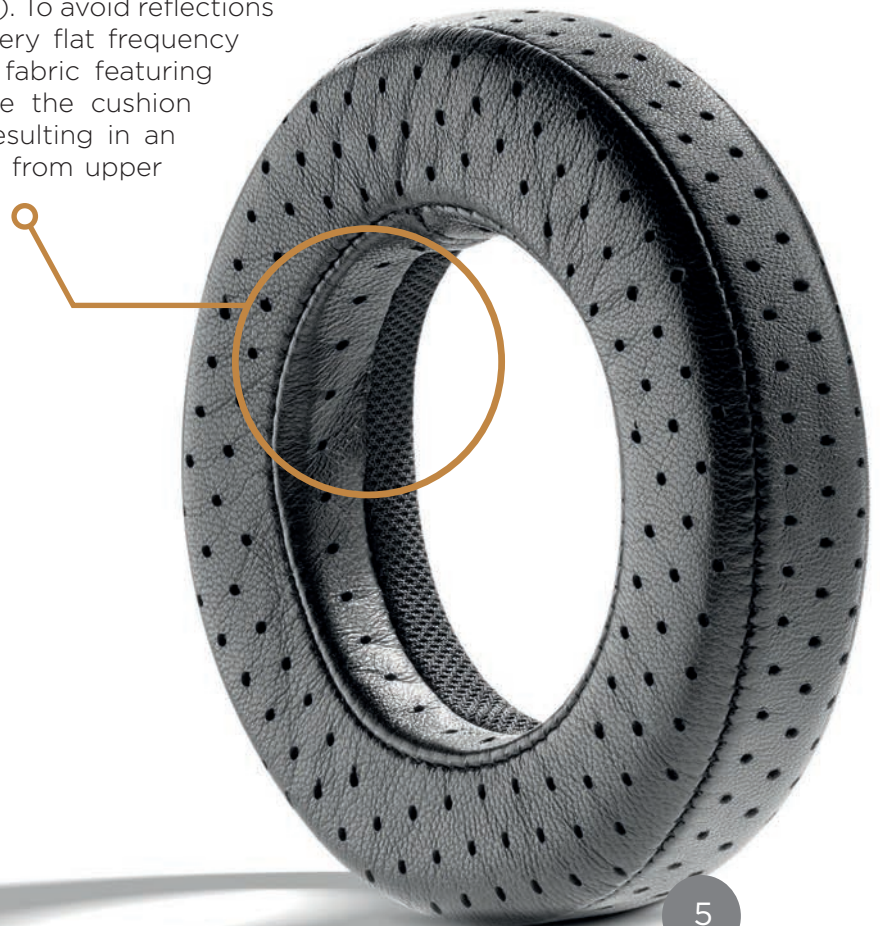
Similarly, core materials that are used in a room have a huge impact on the room's acoustic signature and interaction with the music, including reverberation and room linearity of the frequencies.

Many studios are equipped with adjustable panels on the wall to adjust the damping ratio to make the room sound more "live" or more acoustically "dead." The adjustment of the room will be chosen by the sound engineer depending on the result/sound character he and the artists/band are looking for.

With both the Utopia and Elear models, a similar task needed to be addressed when it came to choosing the material for the ear cushions. The idea for both was to design the optimum "listening room experience" that would provide both comfort and a desired character for audio.

The Utopia cushion is made of two raw materials: real lambskin leather and a perforated fabric. The inner part of the cushion is composed of a perfect 50/50 ratio of lambskin leather (diffusion) and fabric (absorption). This gives a perfect "room character", ideally balanced between an ultra live room (with a lot of reverb) and a very damp room (with a lack of "vivid" sound).

During the development process, we also did a lot of benchmark testing and found out that all the headphones equipped with leather cushions only ensure a good performance from low to mid frequencies. However they always have problems in term of linearity in the upper part of the spectrum (from 1 to 10kHz). To avoid reflections from the cushion and to obtain a very flat frequency response curve from 1 to 10kHz, a fabric featuring micro punched holes is used inside the cushion to fine tune the absorption ratio, resulting in an impressively flat frequency response from upper mid to high frequencies.

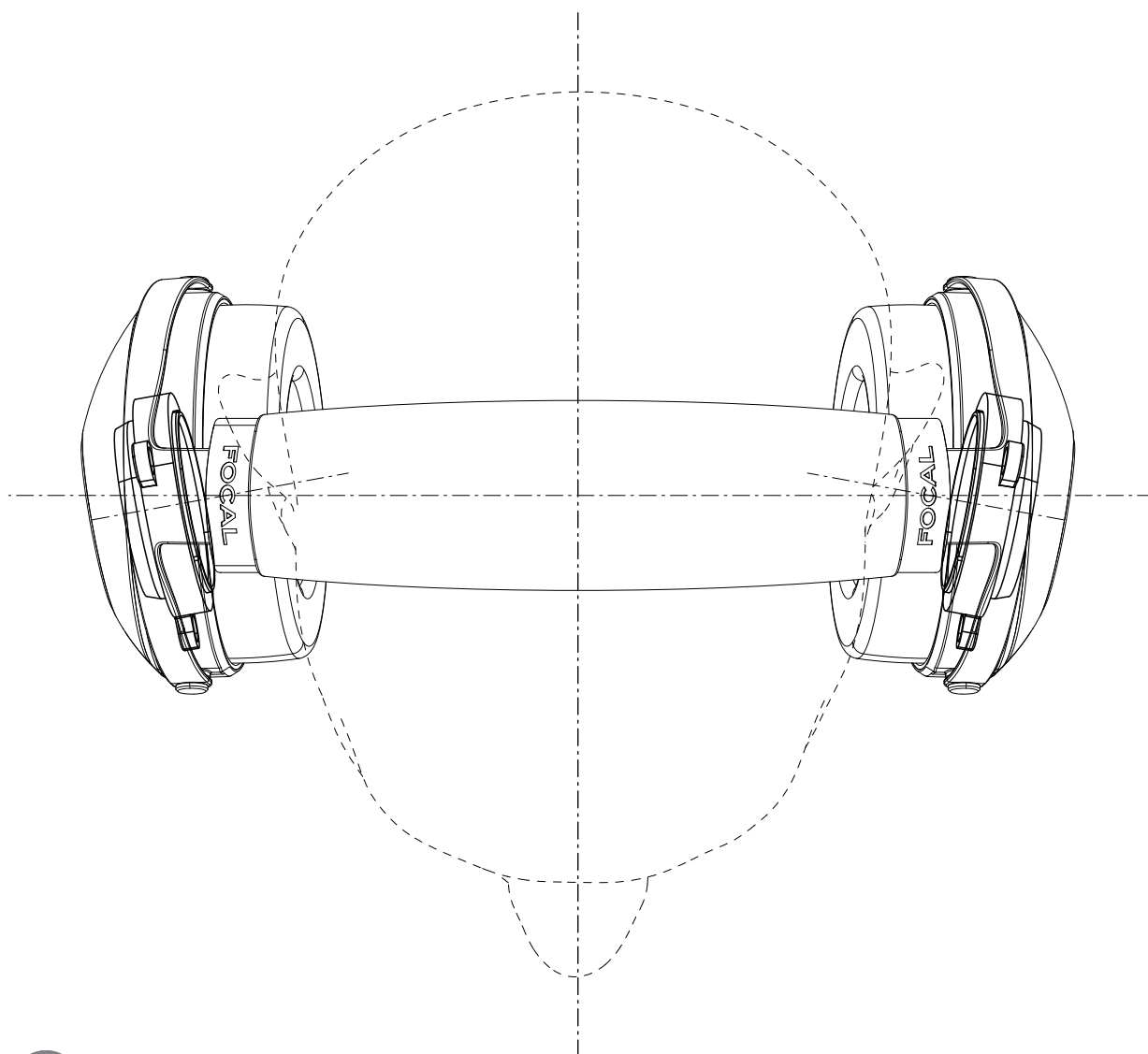




## 2. SPEAKER'S PLACEMENT AND HEADPHONES DRIVERS' PLATES DESIGN

The stereo image is one of the most critical points for headphones. To get a very good stereo image with a pair of speakers is quite easy as it mainly results in having the right space between both speakers and the listening position (usually the equilateral triangle principle is a good option to start with).

However, this is much more complicated with a pair of headphones as the distance between the left driver and the left ear is far less than the distance between both ears. So, to favour the best possible stereo image, we designed a very unique speaker plate to allow positioning the drivers as far forward as possible. The limit of this principle is also to avoid having too much distance between the headphones' drivers and the ears to ensure the best dynamic and neutrality all across the audio spectrum.



### 3. SPEAKERS AND HEADPHONES CROSSOVER AND FILTERING PRINCIPLES

The first aim of a crossover in a speaker is to split the audio signal and then allocate each frequency band to the most appropriate loudspeaker. Another benefit of a crossover is that it allows an engineer to fine tune the speaker's sound.

Unlike electrodynamic headphones that only use one driver per channel, and therefore do not require a crossover, there is still a need to fine-tune the sound. Traditionally this is done using several components of the driver itself as well as parts of the earcup including the cushion material.

Currently, all of the electrodynamic drivers on the market are based on the same mechanical design principle in order to lower the frequency response of the driver. Holes are made on the edge or at the back of the driver to offer both a resonation and decompression solution.

This mono material principle (same raw material used for the dome and the surround) is interesting from a cost point of view, as it allows engineers to use an off-the-shelf driver (from a supplier) and easily integrate it in a specific pair of headphones but also allows an easy way to fine-tune the sound.

However, this always results in added distortion due to its mechanical principle as well as its resonances. So, our engineer rejected this technology as far as high-end headphones projects are concerned.

Moving away from that technology means we will have to develop and manufacture a new solution in-house and ask for criteria and behaviours that are usually fighting against each other, such as a very important X-Max of the mobile equipment, while reaching a very low mass to perfectly reproduce the entire audio spectrum, from the lowest to the highest frequencies, without any compression while reaching the lowest possible distortion. So we decided to develop a real full range loudspeaker instead of a conventional driver.



# A world first: a full range loudspeaker in a pair of headphones

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Based on our findings, we shifted key elements of our design in order to:

- Design a real fullrange loudspeaker, fully open on both the front and back. Additionally, we wanted it to be compact enough to fit in an ear cup of a fully open pair of headphones that can perform with the lowest possible distortion and ensure the most vivid listening experience.
- Develop loudspeakers offering a very flat frequency response curve, from the lowest to higher frequencies in order to avoid using any foam or other artefacts to ensure a total respect of the audio signal's dynamic.

Based on these requirements, the weight of each component within this micro-loudspeaker would present itself as a new challenge. Moreover, rigidity and geometry of the diaphragm are also key points to ensure a perfect piston functioning.

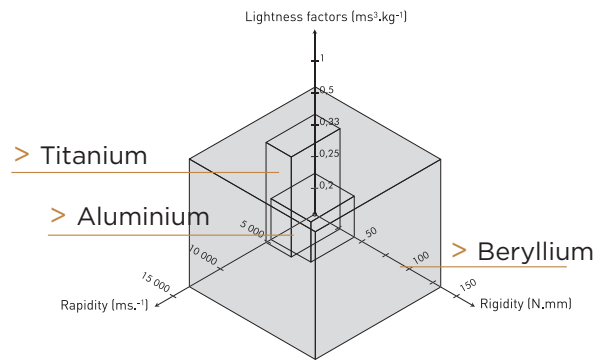




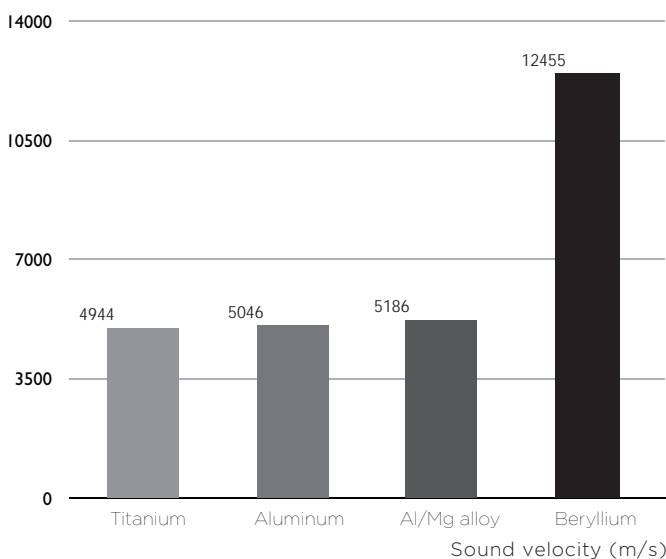
# Diaphragm requirements

As far as the mobile equipment components are concerned, the diaphragm's raw material is critical. It must combine 3 factors that usually fight against each other: the lowest possible mass to ensure a total respect of the signal's dynamic, the most important rigidity to avoid distortion, and a high damping to reproduce the slightest details without any coloration of the sound.

So, a pure Beryllium diaphragm came out as an obvious choice due to its impressive ratio between mass-rigidity and damping. Focal is using pure Beryllium diaphragm for the tweeters in the most high-end products from Home, Car to Professional audio divisions since 2002. Beryllium's density is 2.5 times lower than Titanium and 1.5 times lower than Aluminium while its rigidity is 3 times higher than Titanium and 5 times superior to Aluminium. Which means that for a dome of identical mass, a Beryllium version is 7 times more rigid than one made of Titanium.



## SOUND VELOCITY



Moreover, the velocity of sound in a Beryllium dome is 3 times faster than a Titanium version. This criteria shows how efficient is the damping of Beryllium compared to any other raw materials. However, the manufacturing of Beryllium remains very difficult and forming a sheet of Beryllium required 2 years of R&D at Focal to develop the machine able to properly transform a flat sheet made of pure Beryllium into a dome. As an highlight of Beryllium's rigidity, it is interesting to note that it is the only metal able to scratch glass - it is only used in strategic applications in the aeronautical and military industries and consequently, its unique characteristics make it extraordinarily expensive, much more than gold and nearly 100 times that of Titanium.

Focal has manufactured pure Beryllium inverted dome since 2002. However, as far as headphones are concerned, it appears that neither an inverted dome nor a positive dome is suitable to achieve the best possible performances for headphone loudspeakers.

This is for two reasons: the listening distance which is more than ultra near field, as well as the fact that the loudspeaker is a full range one, able to cover 10 octaves!

On an ultra nearfield principle (listening distance lower than 10cm), an inverted dome does not offer a totally flat frequency response curve, especially in the high frequencies.

A positive dome is even less suitable as it has 2 main problems:

- a very poor mechanical coupling as the voice coil is attached to the edge of the dome. The center of the dome will react to it by an out of phase behaviour in the high frequencies.
- a lot of phase issue as well as a very low break up frequency that makes it useless in the high frequencies.

So, the idea of a new shape was born, the "M" shape. This shape principle is coming from our Car Audio range of tweeters with the brand new K2 Power line. The "M" shape tweeter made of kevlar (patent pending) shows two benefits highly interesting for both in-car and headphones user cases.



Thanks to this shape we can benefit from a bigger emissive area. A 25mm dome using M shape equals to a 45mm one. That allows even more SPL capabilities.

Also, the M shape offers a higher break up point compared to the one we will have from a regular dome. So it allows the extension of the frequency response even more in the upper part of the audio spectrum.

# Voice coil & surround: push the limits

Another major innovation is the combination of the lightest possible voice coil and speaker surround in order to reach a target never achieved in the headphones industry: 135mg for the mobile assembly to ensure the best transient response ever reached on an electrodynamic loudspeaker.

The unique shape of the Beryllium and Aluminium/Magnesium diaphragms, used on both Utopia and Elear headphones, allows an important Xmax for a total respect of the dynamic. This requires a 5mm high voice coil to ensure a total control of the mobile assembly (from 5Hz to 50kHz for Utopia and 5Hz-23kHz for Elear).

To do so, Focal once again had to innovate in this area as well by creating the first voice coil without any support in order to reach the lowest possible mass as well as create a voice coil twice as large as the competition. This was done in order to ensure the pistonic movement was functioning perfectly, and thus able to offer high SPL.

The efforts in research and design, once again resulted in some astonishing developments as engineers were able to create a 5mm tall voice coil with a 25mm diameter that was lighter than a 1.5mm x 15mm voice coil.

Reaching such a target was already an achievement, however the mass target must also take into account the surround. After trying several raw materials such as PE, Mylar, fabric, silicone and so on, the only one able to reach both compliance and mass targets was NBR.

This material combines softness, lightness and mechanical functioning linearity. At the end of the development process, Focal came out with a surround almost 3 times thinner than the competition (75 microns / 200 microns).

The result is that the Utopia loudspeaker mobile assembly's mass is 135 mg and the Elear is 150mg!



Achieving such a result had a huge impact in the manufacturing process, with dedicated machines and assembly line needed to create them while staying true to the goal to avoid increasing the mass during the manufacturing steps.



# Translation of these innovations into the manufacturing process

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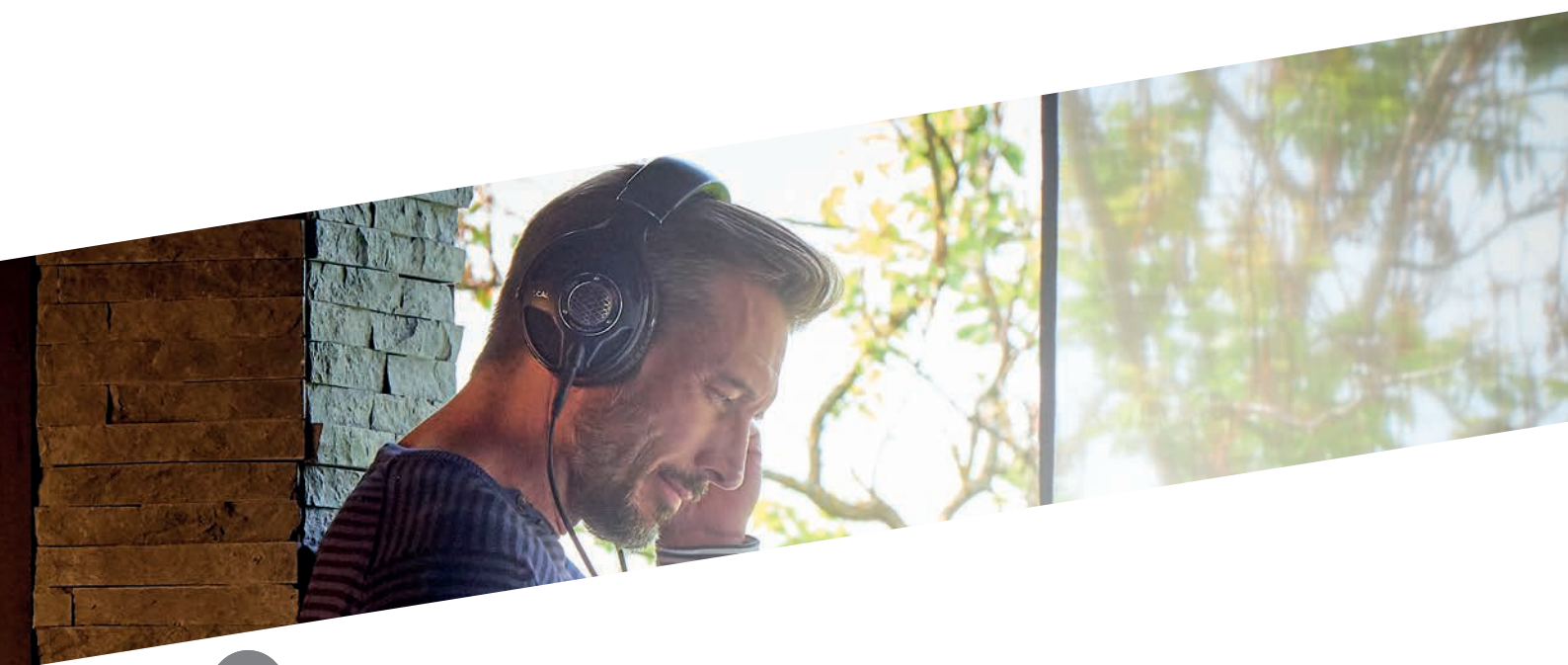
All these innovations resulted in two amazing loudspeakers (pure Beryllium dome for Utopia and Aluminium/Magnesium dome for Elear) offering an impressive ratio of high damping, high rigidity and the lowest possible mass.

Once again, this had a strong impact on the manufacturing process with one key area – allowing us to keep very precise control of the gluing process in order to ensure the lowest possible manufacturing tolerances for a perfect left and right loudspeaker pairing.

The 5 steps of the manufacturing process are:

- Assembly of basket-surround-dome-voice coil
- Centering of the magnet with the voice coil
- Measurement of the loudspeakers and pairing of loudspeakers
- Assembly of loudspeakers into the headphones
- Headphones and cable measurement and final QC

At the end of this process, all loudspeakers fit in a  $\pm 0,5\text{dB}$  window. This manufacturing tolerance is very small, however we wanted to manufacture the best possible loudspeakers so we added a pairing process ensured through Klippel®.



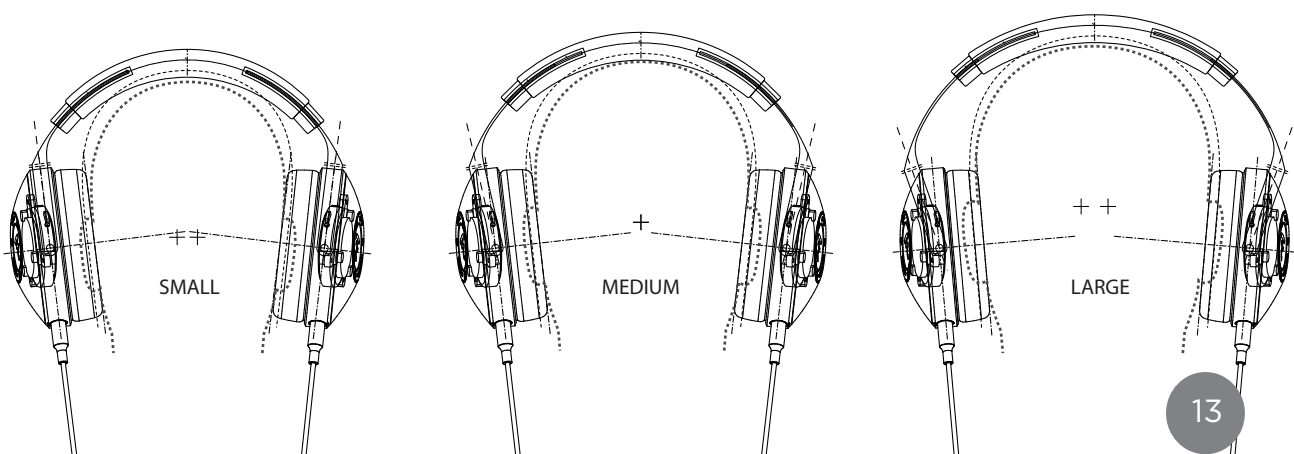
# Mechanical design and ergonomics

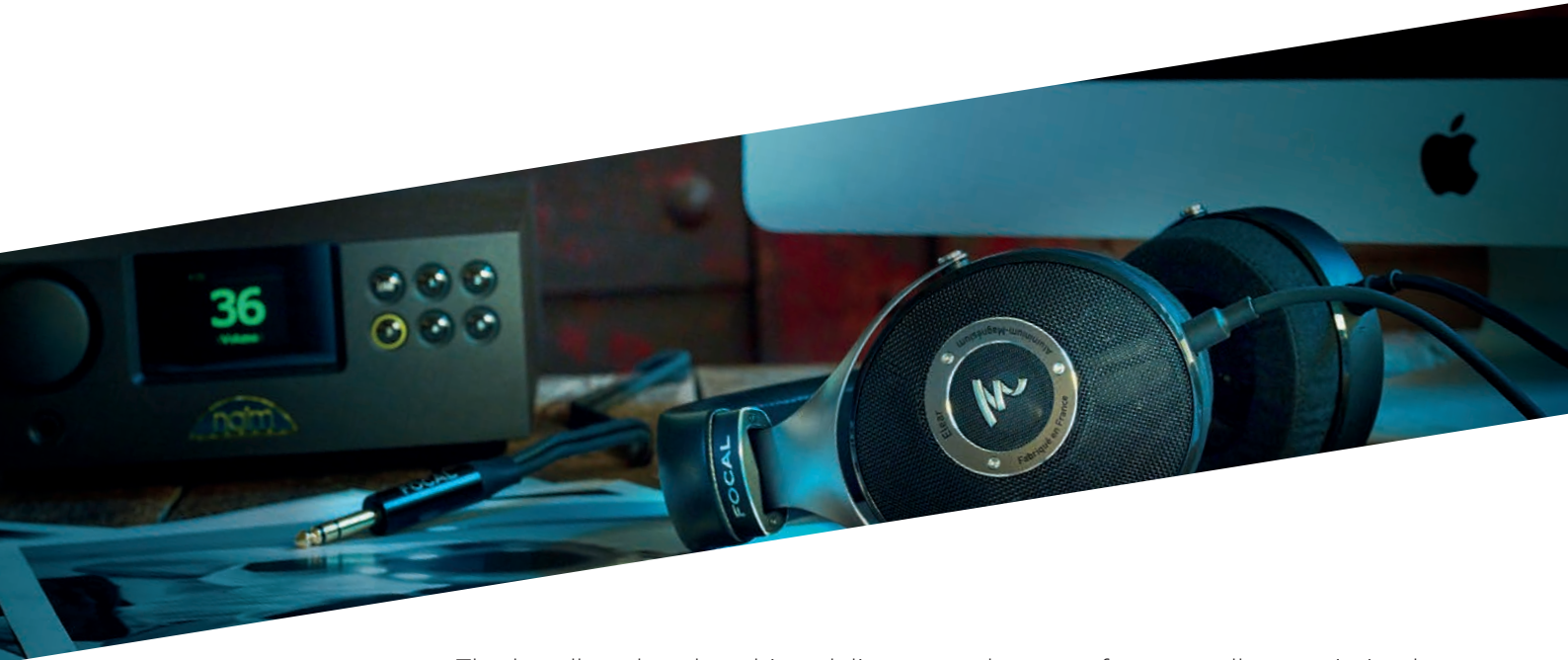
Headphones provide a completely unique set of technical, ergonomic, design and engineering challenges. Like speakers, they need to be 'present' yet at the same time they need to 'disappear'. The listener must be provided with a direct pathway to the performance without any unwanted barriers so clearly comfort was a design priority.

As we had addressed with previous models, a user must be able to listen over long periods of time without any fatigue or signs of discomfort. These requirements place a great deal of emphasis on designing weight efficient structures, components and mechanisms. For the same priority of low weight, the use of cutting edge low mass materials was also a key design priority. Elear and especially Utopia drive units are large, extremely precise and complex sub-assemblies and they require substantial radial magnet assemblies to deliver class-leading standards of music reproduction. Clearly these critical parts could not be reduced in weight without reducing performance.

So the design challenge was to deliver an ultra-light weight headphone construction that support and optimise the drive unit performance without any compromise in strength, comfort or adjustability. This led naturally to the incorporation of lightweight aluminium, specialist engineering polymers and carbon fibre sheet materials for large elements of the headphones construction. As we find in the performance automotive industry, the design needed to lose weight in order to maximize performance. The aluminium and carbon fiber yokes are particularly innovative as they deliver linear as well as rotational adjustment in a controlled and precise way through thin walled structures whilst adding absolutely minimal weight to the Elear and Utopia designs.

Another key design challenge was to deliver consistent levels of comfort across the widest range of head sizes possible. During the design concept phase and during engineering development there was a great deal of detailed ergonomic evaluation and computer modelling done to establish exact geometry parameters for fit and adjustment. The final results deliver high degrees of comfort and complete adjustability for virtually all head shapes and sizes. This geometry optimization also ensures extremely consistent levels of clamping force over all head sizes. This ensures the higher sound performances consistency, whatever the user's head size and geometry, as well as comfort and fit.





The headband and cushion deliver complete comfort as well as optimised acoustic performance. The headband shapes to the head perfectly and offers soft compliant surfaces in all contact points of the head of the listener. The premium materials (leather / acoustic grade fabrics) allow the users skin to breath for maximum comfort. The cushions are shaped to provide a perfect contact relationship to the areas surrounding the user's ears.

The cup shape, size and design offered many design challenges, as ergonomics, fit, comfort and performance could not be compromised. The elliptical design of the cup follows a smooth and 'organic' approach to integrate with the natural form of the human head and to offer the most comfortable 'footprint' for a circum-aural cushion design with the benefits of excellent air sealing ability as well as very equal clamping pressure equalisation.

The design process respected these relationships and developed an elliptical domed form to capture and locate the drive units precisely. This natural arrangement delivers the distinctive non-concentric drive unit expression shown on the outer cup faces. A fine steel inner mesh is surrounded by a CNC radial clamping ring, held in place with precision machine screws. A heavier gauge outer woven mesh provides air flow for an open backed design whilst also protecting the delicate internal mechanisms. The combination of the form, the various mesh materials, the clamping ring and the partially hidden drive units combine to create the perfect marriage of performance, engineering function and a premium appearance and user experience.

Across the whole headphone (both Elear and Utopia) all edges are well controlled with no sharp corners. Care was also given to ensure that the adjustment mechanisms would not interfere with the user by trapping hair unintentionally or 'fighting' the use of reading glasses.

The final results confirm that both designs deliver completely on the original product brief: Focal has created two ultra-premium, precise and musical headphones for the most discerning of music lovers. Elear and Utopia are a delight for all the senses. In appearance, touch, fit, materials and of course in musicality and performance we believe these products fully represent the successful marriage of cutting edge technical ability and design and engineering artistry in the true Focal tradition.







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