

What defines the desired
(reference) Frequency Response
in high quality headphone drivers?

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Introduction

The target performance of a headphone driver should be to deliver an audio performance closest possible to the sound impression that the audience at a live concert experience. This paper specifically addresses the frequency range that the headphone needs to encompass in order to meet this challenge.

The **optimal** headphone driver can be considered as a two-port system, with the input being a voltage signal and the output being a sound pressure signal (fig. 1), with the two-port function acting as an infinite bandwidth transducer (fig. 2).

Fig. 1

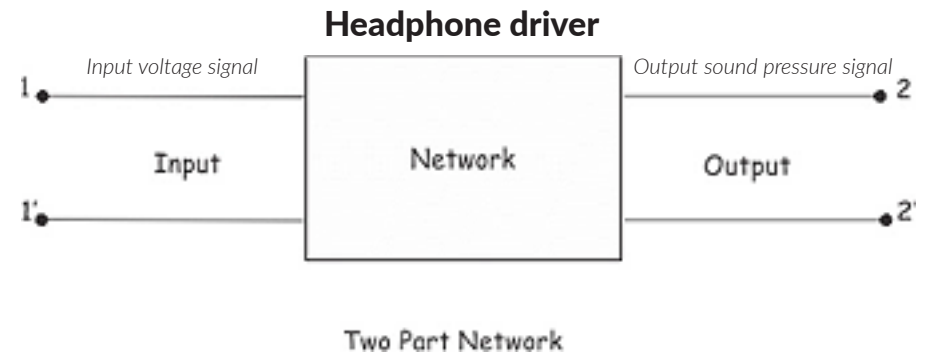


Fig. 1 - The two-port system in a headphone driver.

Fig. 2

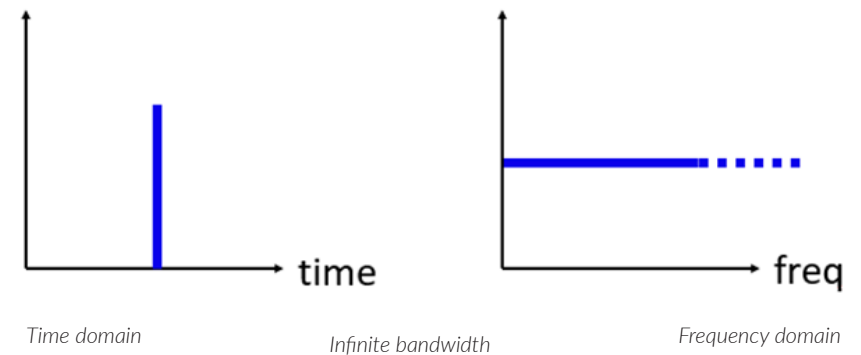


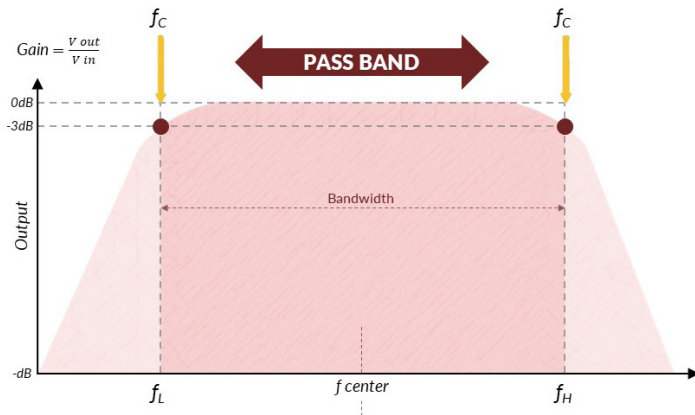
Fig. 2 - The two-port function acting as an infinite bandwidth transducer.

The headphone driver in practice

The headphone driver, like other driver technologies, is subject to certain limitations and can be considered to be a two-port system having a Pass Band filter inside. In this system, f_{low} is defined by the mechanical resonance of the moving system and f_{high} is defined by the moving mass (the weight of the voice coil & diaphragm) and the point at which the diaphragm undergoes breakup, transitioning into non-piston movements.

Typically, this bandwidth can be designed to range from 20Hz to 20kHz. Latest targets even range up to 40kHz, driven by certain HiFi enthusiasts asserting that human ears can perceive overtones (ultraharmonics) within this range (fig.3).

Fig. 3



Preferred Frequency Response of the headphone driver

To define the preferred Frequency Response of the driver, it's essential to examine the transfer function. This function can be measured in a far-field scenario, where the sound source is positioned in front of a listener, and it relates to the sound pressure detected at the entrance of the listener's outer ear. (fig.4, green dotted line, named "Obstacled effect" of Head & Torso).

This is caused by buildup of sound pressure at the listeners chest, characterized by a gain increase peaking at approximately 4.5kHz with an amplitude of around 8dB.

We aim to incorporate this curve into the passband curve to establish our reference curve.

On the contrary, the transfer function "Ear Entrance to Eardrum" (red curve) should not be implemented in the reference curve, as the headphone do not block the ear canal, allowing the ear canals Helmholtz resonator to remain intact. This differs from the situation when wearing earphones.

Fig. 4

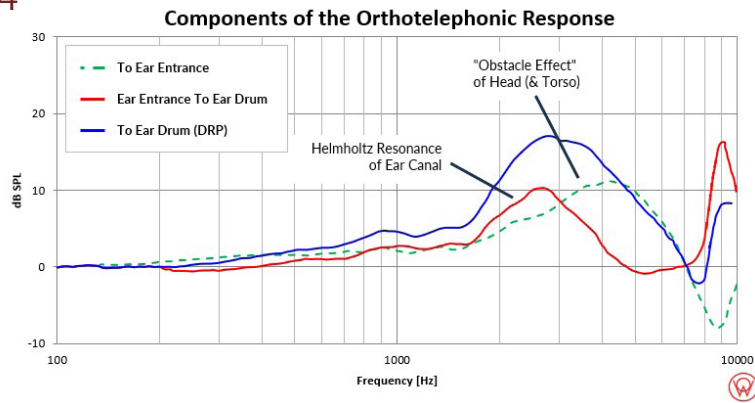
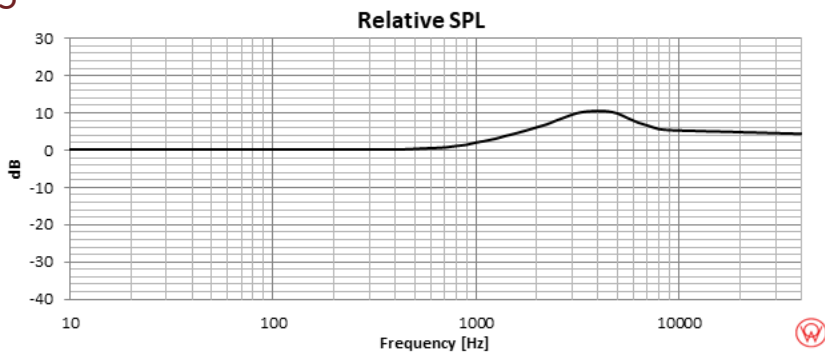


Fig. 4 - Illustrating various influencing factors contributing to the formation of a Head-Related Transfer Function (HRTF).

This lead us to the preferred frequency response curve for the headphone driver as shown in fig.5.

A slight gain increase, relative to the gain at 1kHz, is sought in levels from 10kHz and beyond, extending up to 40kHz as is a preference for some Hifi enthusiasts. This increase in gain at the highest frequencies is recommended due to the fact, that age-related hearing loss commonly occurs in this range. Therefore this HF compensation offers the best sound experience for the majority of people.

Fig. 5



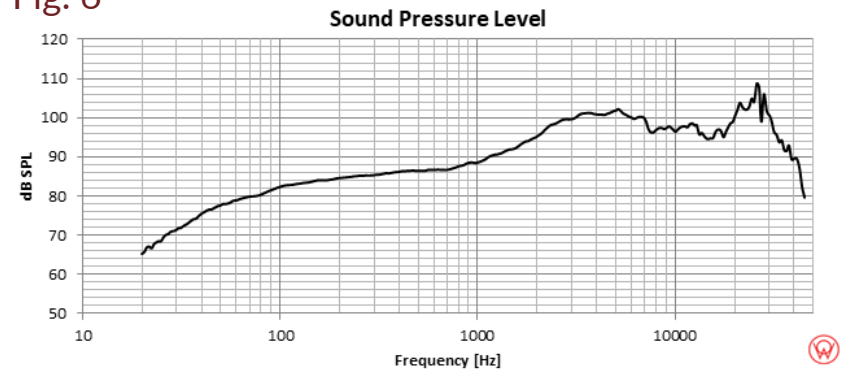
Ole Wolff headphone drivers match this reference FR curve

Ole Wolff have a huge lineup of headphone drivers in various sizes, catering to the diverse range of headphone designs being developed globally. (visit www.owolff.com for more information).

These drivers are uniformly tuned to align with the reference frequency response curve and depending on the technology employed for the diaphragm material, the HF response can extend as high as 40kHz.

As an example, the FR for the OWR Ø40mm Carbon diaphragm driver is illustrated in fig. 6 below:

Fig. 6



Optimal Stereo impression/ spatial effect

It is proven, that the high frequency range delivered by the two drivers in a headset has a huge impact on the perceived stereo impression. If the two drivers differ in gain and peaks/valleys (poles/zeros) within this range, the stereo perception can be greatly diminished.

A way to reduce the deviation at high frequencies from one driver to the other, is to use a very stiff yet lightweight material for the diaphragms piston area/cone.

New materials are being developed with these properties, such as carbon fiber foils, which has an extreme stiffness/mass ratio for minimizing breakup modes.

Ole Wolff is heavily engaged in integrating such advanced materials into our drivers, ensuring they closely resemble “clones” of each other, especially in the high-frequency range.

Conclusion

All Ole Wolff headset drivers are fine-tuned to match the highest requirements for delivering state-of-the-art lifelike sound reproduction.

This paper focuses solely on optimizing the frequency response of the drivers for headphone drivers to achieve the ideal curve for an authentic listening experience.

However, it's important to note that there are numerous other parameters to consider, such as low distortion/R&B, high dynamic range (particularly relevant for handling high SPL levels for ANC applications) etc., which are not addressed in this paper.

Please contact Ole Wolff in case of any questions related to this paper as well as questions regarding the other performance parameters for our high end headphone drivers.

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