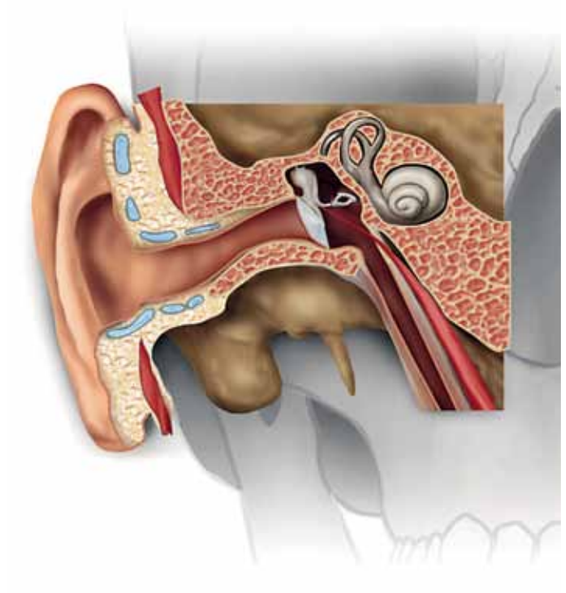
Headphone measurements

If you've had enough of booming basses from speakers installed near walls and corners, dislike ground reflections wich introduce a lack of warmth to human voices and are annoyed by the aggressive sound of modern concrete buildings: just pick up those headphones and immerse yourself in a world of untarnished music pleasure.

Headphone basics

A dream, which like all dreams evaporates in the face of reality. Unfortunately, the masking effects of headphones are not limited to room influences. Most obviously, they affect the function of the outer ear, which due to its asymmetrical shape largely influences the frequency response of the sound arriving at the ear differently from every direction. This is important. We can generally distinguish the direction from which a sound arrives on the basis of sound level and time differences between the two ears. But these differences would be for a sound source arriving from the left front nearly the same as for a source from the same angle on the left rear. The frequency response differences induced by the outer ear and head enable us to differentiate between front and back.

Another indication of the direction of sound incidence are slight rotational movements of the head while listening. If a natural sound source is situated at the rear left, a rotation of the head to the rear left will cause the left ear to approach the sound source while the distance to the right ear increases. The sound wave thus arrives at the left ear sooner and louder. When a sound source is situated at the left front, it is just the opposite. These useful motional influences are lost on what is heard on the headphone playback.



As we are generally aware that these important influences are missing, we are not even surprised that sound sources are localized inside the head when listening through headphones. An exception is dummy head recordings that shift the influence of head and outer ear shape from the listener to the recording. The more the dummy head replicates in every detail the ear and the shape of the listener's head, the better the effect. In scientific experiments on spatial hearing, the head movements are often also measured and the resulting interaural time and level variations are superimposed in real time during playback.

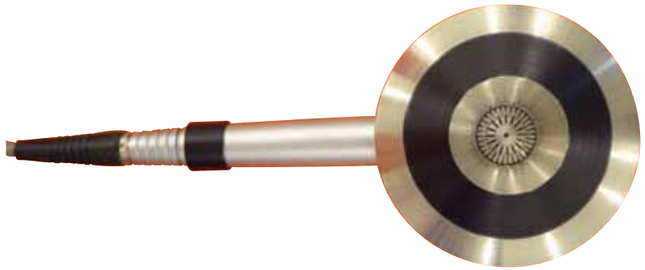
In-ear headphones must demonstrate their linearity on an HMS II dummy head of Herzogenrath-based Head Acoustics. The outer ear made of rubber (installed for the photo) is removed for the measurement.

Frequency response pitfalls

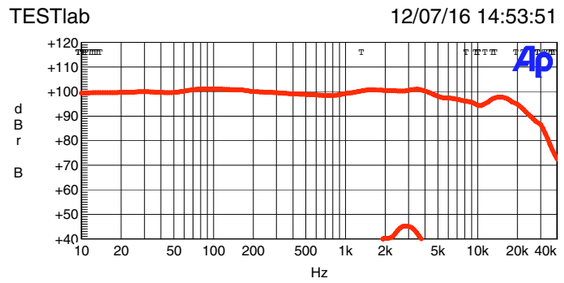
But this is still a futuristic vision for private music lovers, although progress in the computing power of digital signal processors (DSPs), the understanding of spatial hearing and the sensing of movements promise rapid progress in this field.

Until then, the ability of the headphone to convert amplifier signals into sound waves can at least be analysed by measurement. A measure of the reproduction quality is the (amplitude) response, which describes how a linear headphone reproduces the spectrum, from the lowest tones of a pipe organ to the highest notes of a chime.

Those who believe that a straight frequency response is virtually inevitable through the simple structure of headphone membrane/short inner ear canal/eardrums will be disappointed, given the large frequency response deviations of many headphones. After all, the auditory canal itself boosts frequencies at around 3kHz, which is the why we hear particularly well in the presence range. What's more, flexible tissue behind the eardrum also affects the frequency response of the ear. Since the measurement is intended to reflect listening practice, the in-house measurement laboratory Testlab commissioned by *stereoplay* works with the artificial ear type 4153 from the specialist Brüel & Kjær. These replicate the resonance behaviour of a real ear through a system of chambers, holes and slots. On-ear and over-ear headphones have to deal with this resonance system. This works very well when the design is highly proficient, as impressively demonstrated by the frequency response of Audeze Sine, top right.



An artificial ear from the acoustic specialists Brüel & Kjær based in Copenhagen ensure exact measurements in on-ear and over-ear headphones.

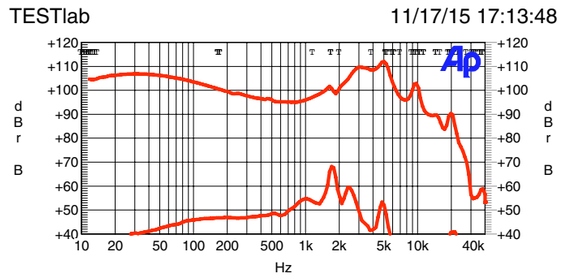


The Audeze Sine – which also impresses with extremely low distortion – has an extremely smooth frequency response with a slight, probably intended drop in treble.

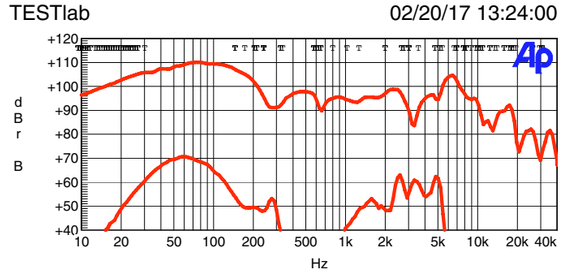
But before headphones are subjected to the frequency response measurement, it is first necessary to determine their efficiency. To do this, Testlab measures the mean sound pressure in the range of 100 hertz to 4 kilohertz with a generator voltage of 358 millivolts and 32 ohm source output impedance. This combination delivers exactly one milliwatt to a 32-ohm headphones. Handset with lower or higher impedance receive less power from under these conditions – this is also a protection against overload. In the age of MP3 players and smartphones, 32-ohm headphones are emerging as the standard, as this impedance is very easy to operate by a 3.7-volt lithium-ion battery-powered booster.

Once the efficiency is determined, the output voltage of the Audio Precision System Two Cascade used for the measurement is increased so that the headphones put out 100 dB on average in the range 100 Hz to 4 kHz. Then the headphones pass the measurement of the frequency response and the THD in one go. The THD (Total Harmonic Distortion) is A-weighted based on the human hearing sensitivity, to take account of the fact that distortions in the presence area are particularly irritating.

Testlab generally measures in-ear headphones according to the same routine. The only difference is that the left ear of an HMS II artificial head from the Herzogenrath-based specialists Head Acoustics – also deployed for smartphone acoustic measurements – is used here as an acoustic sensor.



This headphones feature a downward slope from the fundamentals to the lower mids. It shows level increases and distortions where it really hurts.



Especially in the upper bass response, the headphones show increased output level and distortions. Its distortion factors are also high in the area of the greatest ear sensitivity.

Precision is a matter of honour

Critical for both measuring options, alongside the adjustment of the headphones at exactly the right angle, is the tightness between the measuring microphone and the membrane of the sound source. An incorrectly built up pressure chamber will manifest itself as a pronounced drop in the low bass. This will immediately alert the responsible laboratory engineer, who will seal any leaks, as far as this is allowed by the headphone design. If the leaks are construction-related, the technicians will have to live with them (image bottom right). But leaving that aside, many headphones have such large frequency response errors and distortions that a look at the measured values is worthwhile anyway.

Bernd Theiss,
Head of Testlab ■