Contact:

PRESS RELEASE
AKG Acoustics GmbH
International Press & Public Relations Office
Christina Burkhardt
Lemböckgasse 21-25, A-1230 Wien, Austria
☎ (++43)-1-866 54-1241, Fax. --ext. 1205
E-Mail: press@akg.com
htttp://www.akg.com

AKG Science
Author: Dr. Richard Barnert, AKG Acoustics GmbH, Wien

Contents: 2810 words, 7 pictures jpg hi-res
Publishing agreed for printed media

Old and New Dreams

AKG introduces professional Studio Series headphones

Choosing headphones becomes more and more difficult. The market is inundated every year with new brands, new models, new buzzwords, or new features, many of which are not quite as new as they seem to be. Manufacturers lavishly use such labels as "mega", "turbo", or "digital". With this flood of information it is therefore often difficult for users to decide what is relevant and what isn't.

To make things worse, one should be careful about what headphones to buy. After all, a pair of headphones is one of the few audio devices that we wear on the body. So headphones are rather like clothes in which we want to feel comfortable, that should be functional, and possibly look good on us. And, of course, they should sound good to boot.

But what does "sound good" mean?

Above all, professional users expect different sounds from their headphones, depending on whether they use them on stage, in the recording or broadcasting studio, for DJ performances, or at home, to give but a few examples. For this reason, there can be no "universal headphones". The new generation of AKG professional studio headphones therefore comprises four different models, the K 141 Studio, K 240 Studio, K 171 Studio, and K 271 Studio. All these models were derived from the proven classics K 141 Monitor, K 240 Monitor, and K 270 Studio. So every user can find the best model for their respective application. What, then, are the differences between the original and the new models? What criteria are relevant for selecting the optimum headphones?

The Design Defines The Sound

The new Studio Series headphones differ from one another mainly by their designs that provide four different sonic results. The K 141 Studio uses semi-open supraaural earphones. The K 240 Studio is a semi-open design, too, but uses circumaural earpads. The K 271 Studio, successor of the famous K 270 Studio, use closed-back circumaural earphones. The K 171 Studio is a supraaural, closed-back design.
At this point, it might be useful to take a look at the basic properties of each design.

Fig. 1: AKG Studio headphones

Circumaural headphones are usually comfortable to wear because the earpads surround the ears on all sides. This provides a highly accurate sound so this design is an ideal choice for analytical listening.

Supraaural headphones have smaller earpads so they take up less space in the van and are suited for mobile use as well. Since their enclosed air volume is smaller, their sound pressure levels are higher.

The actual sound also depends on the way you wear the headphones. This fact makes supraaural headphones particularly interesting, e.g., for studio musicians because they allow them to create their own mix of headphone and ambient signals. Vocalists love this technique because it gives them better control of their voice than the headphone signal alone does.

Besides earpad design, the acoustic design of the earcups is another important feature. **Semi-open designs** use defined openings in the earcup shells that allow sound to pass from the outside to the inside and vice versa. These so-called "leaks" are used to tune the frequency response, particularly in the bass range. Therefore, most semi-open headphones provide a well-balanced sound and are used primarily for hi-fi and analytical listening applications.

The distinguishing feature of the **closed-back design**, however, is its high attenuation of outside noise. This type of headphones is preferred by users who wish to isolate themselves from their acoustic surroundings or avoid disturbing others with noise from the headphones. Closed-back designs, however, have no leaks for acoustic tuning, so the bass range on many closed-back models is either too weak or too inaccurate for analytical listening.

The two closed-back models AKG K 171 Studio and AKG K 271 Studio are exceptions to the above rule. They use a particularly sophisticated design that combines the well-balanced sound of semi-open headphones with the high attenuation of closed-back designs. More about that later.

The Key Element Is The Transducer

The transducer (a.k.a. speaker) is that part of the headphones that converts the electrical source signal into sound waves. Besides the electrostatic transducers that are a rather insignificant market segment, it is mainly electrodynamic transducers that have taken the lion's share of the market. In a dynamic speaker, the diaphragm that produces the sound is permanently fixed to a coil of wire. The coil sits inside the field of a permanent magnet. Following the law of induction, the coil starts moving up and down as soon as a current flows through it. Simple though it sounds, designing a dynamic transducer is hard work and in fact it takes a lot of experience to get a dynamic transducer ready for production.

AKG has been one of the world's leading manufacturers of high quality transducers for years and one of the most innovative companies in the history of audio. More than 1400 patents granted in more than 50 years speak for themselves. The new generation of headphones required a new generation of transducers - giving birth to the XXL speaker! It should not be too surprising that the new speaker uses several proprietary innovations.

The diaphragm, for instance, is made using the well-known Varimotion technology. A special deep-drawing technique shapes the diaphragm in such a way that it remains thicker in the center than in its peripheral area. The hard dome projects the high frequencies while the softer peripheral zone produces the low frequencies. The diaphragm material is a special plastic mixture whose mechanical impedance has been optimized to prevent unwanted vibration modes including wobbling. If the coil on the diaphragm does not move like a piston within the magnetic field but in any other way, the coil may graze against the magnet and cause unwanted distortion. By optimizing the mechanical impedance, the designer can eliminate this problem even for extremely large diaphragm excursions. This results in lower harmonic distortion, extended bass response, and higher maximum loudness.

In developing the XXL speaker, AKG used the latest computer technology. The shapes of the magnetic field lines were calculated and optimized with software written by AKG engineers. The shape of the diaphragm is another essential element in designing the transducer's acoustic characteristics. Computer software normally used by vehicle manufacturers was used to study the vibration behavior of the diaphragm.

These so-called FEM/BEM simulations break the diaphragm down mathematically into minute fractions to calculate its dynamic performance more accurately. FEM/BEM stands for Finite Element Method/Boundary Element Method. Since computers can make errors or input data may not be sufficient for meaningful calculations, AKG uses another high-tech tool to verify the simulation results in practice. The non-contact laser vibrometer scans the transducer vibrations and processes the data for further analysis within the computer. Together with listening tests with human subjects, laser vibrometry is the most important verification tool in designing electrodynamic transducers. For a detailed description of these tools see [M. Opitz/R. Barnert – "Modern Development Tools for Dynamic Transducers", Proc. 111th AES Convention, 2001 Sept 21-24, New York, NY, USA].

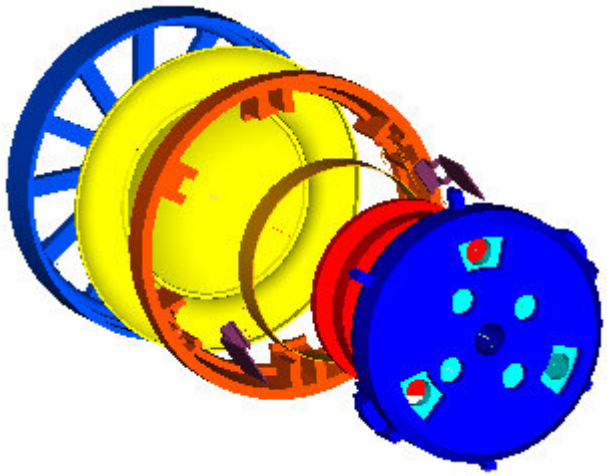

Fig. 2: XXL exploded view

Another essential design criterion for the XXL speaker was its ohmic impedance. Whereas the original AKG Monitor Series headphones had an impedance of 600 ohms, the impedance of the new-generation Studio models has been reduced to 55 ohms. The obvious result is a 12-dB increase in sensitivity. While high power headphone amplifiers hardly notice the difference, it does make a difference for mobile equipment. Portable mixers or minidisc players as well as the headphone outputs of standard hi-fi amplifiers can only drive low-impedance loads with maximum efficiency. The XXL speaker with its reduced impedance works perfectly with this kind of equipment.

Engineering Peculiarities Of Closed-back Headphones

As mentioned above, closed-back headphones have no acoustic leaks so their sound is more difficult to design than that of semi-open headphones. Therefore, AKG designer Thomas Stubics studied special sources of knowledge to design the K 171 and K 271 closed-back reference headphones.

Fig. 3: Thomas Stubics at the laser vibrometer

Let us take a look at the mechanical construction of a K 171 Studio earphone. The XXL speaker (1) sits in the middle of a support plate (2) that also holds acoustic resistors (3) that lead to the rear cavity (4). The rear of the transducer and the gimbal cavity (5) are mutually connected by a tube (6). As will be explained later, the design of the earpad (7) and the outer shell of the earcup (8) are also very important for the acoustic result. The latter does not only determine noise attenuation and therefore should be as tight as possible, its eigenmodes go a long way toward shaping the sound and must be taken into account in the design process. FEM computer simulations and laser vibrometric tests have turned out to be extremely useful to detect and effectively eliminate unwanted resonances.

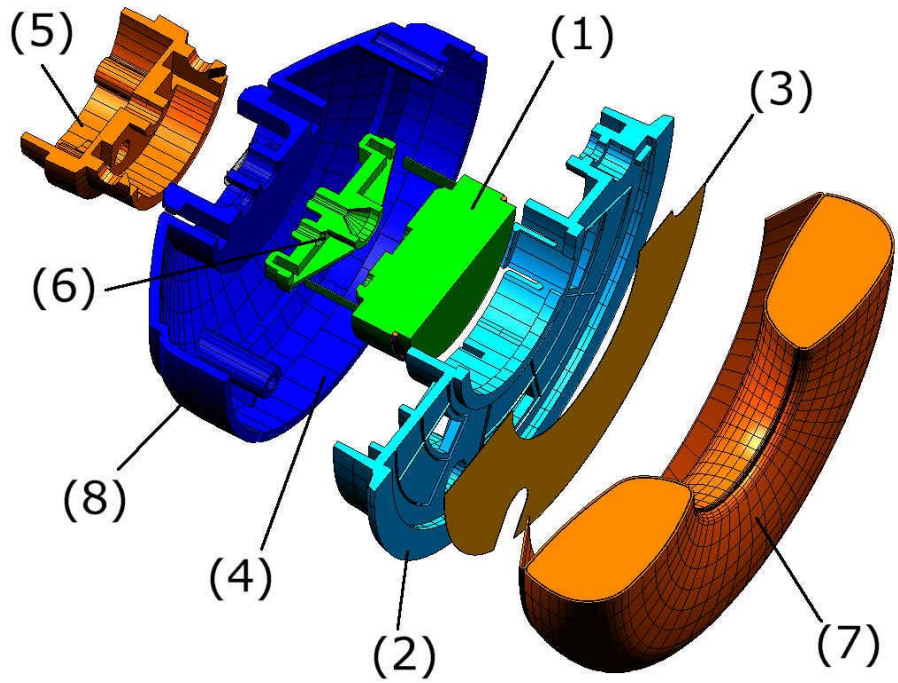

Fig. 4: AKG K 171 Studio (exploded view)

(1) XXL-speaker
(2) Support Plate
(3) Acoustic Resistors
(4) Rare Cavity
(5) Gimbal Cavity
(6) Tube
(7) Earpad
(8) Earcup

The art of the designer mainly consists in using acoustic resistors and lines to match the various cavities inside the earcup to one another in such a way as to achieve the best possible sound. But the magic does not end here. It is also necessary to find suitable materials.

The acoustic resistors in the support plate of all high quality Studio Series headphones, for instance, are made of a synthetic fabric with extremely close tolerances and strictly defined real and imaginary impedance components. Whereas the real component of such impedances is relatively easy to measure, the frequency dependent imaginary component can only be measured with costly, complex test equipment.

The tolerance range of the fabric being very narrow, it is very easy to control the critical influences of the imaginary component, to the obvious benefit of the speaker's acoustic performance. These resistors in the support plate are used to tune the mid-frequency range in which the human ear is most sensitive. In designing high quality headphones, no compromise must be made in this area for performance in this frequency range is the decisive criterion for analytical users requiring utmost accuracy.

The tube (6) is a very special feat. Acoustically speaking, it is a damped waveguide that connects the rear of the XXL speaker directly to the cavity of the gimbal case. In the electroacoustic equivalent circuit diagram, the tube would appear as a real resistor connected in series to an inductor. Simple as this

arrangement may seem, it provides a number of acoustic benefits. The most spectacular of these is certainly the fact that careful matching of all components made it possible to use the waveguide as the equivalent of the leaks in a semi-open design. The gimbal case volume in a way simulates the outside volume of air. This design elegantly works around the greatest disadvantage of closed-back headphones (difficult bass-range tuning) without affecting the good attenuation performance of the headphones.

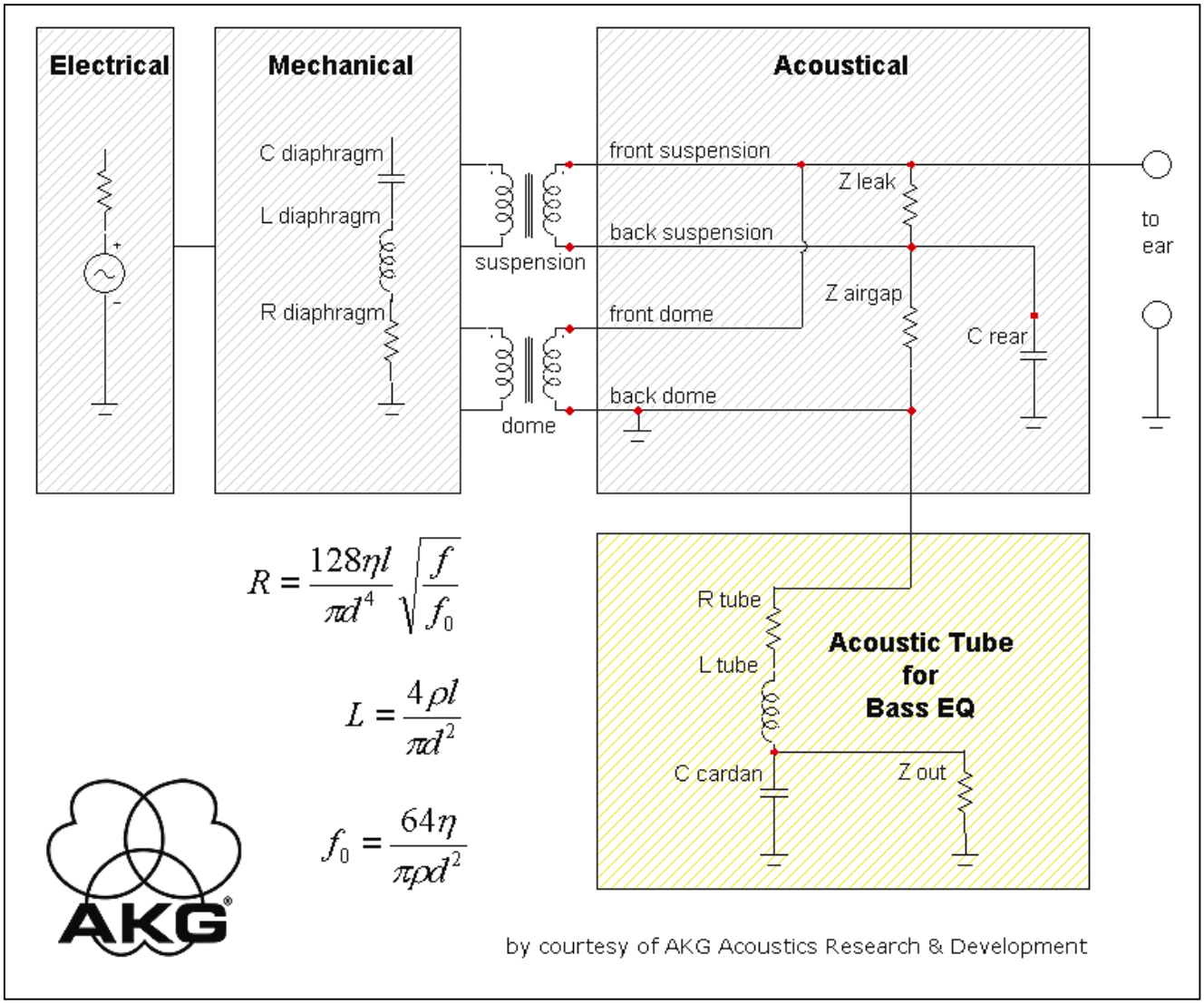

Fig. 5: Simplified equivalent circuit diagram

The story does not end here, though. As a "side effect", some other features were dramatically improved, too. One was the normally inevitable occlusion effect of closed-back headphones. This is the aural sensation you get when your ears are tightly sealed so pressure differences cannot be compensated for. Cover your ears and gnash your teeth. With your ears covered, you will perceive frequencies up to 2 kHz conducted by your bones as much louder. This effect

does not only occur when you cover your ears but also when you wear closed-back headphones that also form an airtight seal around your ears. On the K 171 Studio and K 271 Studio, this unwanted effect is much weaker because the tube makes sure that low-frequency pressure variations are compensated for in the same way as they would be by a semi-open design.

There was yet another important parameter for designing the closed-back Studio Series headphones. The designers further improved the maximum sound pressure level of the headphones by optimizing the acoustic tuning for minimum distortion. The sudden increase of the distortion factor at great excursions at low frequencies is a limiting factor in the design of transducers and headphones.

Special tuning improved the situation dramatically. Low frequencies essentially pass through tube (6) rather than into the rear cavity (4). This minimizes the acoustic coupling between the transducer front and rear that would otherwise partially cancel low frequencies. The transducer requires much smaller excursions than conventional designs to produce the same sound pressure level and therefore provides a lower distortion factor, too. Finally, it is easy to demonstrate with the laser vibrometer that the tube reduces the mechanical vibrations of the shell parts, thus making the frequency response even smoother.

Another acoustically important component is the earpad. Ideally, good closed-back headphones should seal the ears completely - if they do not, they could not really be called closed-back. This means that the earpad, too must contribute to isolation by providing the highest possible acoustic attenuation. A leatherette covered foam filling provides the required attenuation but what happens inside the enclosed cavity?

Inside an enclosed cavity, reflections may occur and give rise to standing waves. The latter develop at frequencies whose half-wavelength is equivalent to a multiple of the earpad inside diameter and cause periodical irregularities in the frequency response of the headphones. To prevent this effect, the inside surfaces of the K 171 Studio's earpads are made of transparent fabric. The foam thus acts as a so-called wave sink where incoming sound waves damp themselves rather than being reflected. This arrangement effectively prevents reflections and standing waves while maintaining consistent, high isolation.

More Useful Features

Besides all these engineering innovations, many of the proven features of the previous line were retained or improved in various details. One often underrated feature, for instance, is the self-adjusting headband that automatically adjusts the headphones for optimum fit with no need for manual adjustment by the user. The already legendary flexibility of the headband was retained and the headband made even more rugged. This allows the user to rotate the earphones against each other effortlessly to put them on in almost any desired position. Single-ear listening is no problem, either, an important feature for users who must keep a free ear at all times.

Another almost legendary feature of high quality AKG headphones that has not been changed is the gimbal suspension. It automatically ensures the optimum position of the earpad against the auricle. On the K 141 Studio and K 240 Studio, the suspension is inside the earcup while on the K 171 Studio and K 271 Studio, the gimbal case is mounted externally, on top of the speaker shell.

The material of the earpads has often been praised, too, and not without reason, for professional users in particular have appreciated the qualities of the leatherette used by AKG ever since its introduction. Besides their acoustic benefits and good comfort, the earpads meet the highest hygienic standards as they are very easy to clean. Whenever the need arises, the user can replace the earpads in a few seconds.

A replaceable cable is an important feature, too. Different applications require different cables in different lengths, extra-rugged materials, or coiled versions. Responding to the demands of professional users, AKG fitted the new Studio Series headphones with plug-in cables. The cables are terminated in a high quality miniaturized XLR connector that has been a studio standard for many years. This makes replacing cables child's play. AKG offers a choice of original cables in various configurations and lengths as optional accessories.

Fig. 6: The new XLR connector.

Old and New Dreams

The new professional Studio Series headphones from AKG combine innovative technologies with the proven features of previous models. When I was asked to head the new generation headphone project, this combination was an important goal for me. After all, an AKG K 141 Monitor was the first pair of headphones I owned. It accompanied me throughout many years of my life and became dear to my heart. Within my team of designers, I had the privilege of relying on the experience of collaborators who had been involved in the development of the classic K 240 Monitor more than twenty years ago. Having the honor of contributing to the development of the next generation in a leading position almost fulfills a secret desire - as if old and new dreams had come true.

Dr. Richard Barnert
http://www.richardbarnert.com

The Author:

Fig. 7: Richard Barnert

Dipl.-Ing. Mag.art. Dr.techn. Richard Barnert studied double bass and audio engineering. He received a Ph.D. with distinction in digital audio technology in 1998. He worked as a freelance musician, sound engineer, and scientist. He currently works for AKG Acoustics GmbH as a project manager.