

Lehmann*audio*[®]

Techletter Headphone amplifier

Understanding the specs

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Why headphones?

When you use headphones you can reach a very high level of sound reproduction at a fraction of the price you would have to spend for a regular hfi setup with high quality loudspeakers. Detail resolution and dynamics of even the best loudspeakers can easily be reached with the best headphones. In most cases headphones will be used to enjoy music either to acoustically disclose a noisy environment to just to be able to listen to louder levels without disturbing other people.

What makes headphones different?

There is a number of parallels between (dynamic) headphones and loudspeakers. Technically they are complex loads for the amplifiers driving them and should therefore be used with stable outputs. There are headphones with higher impedance that need a higher signal voltage and low impedance types which need more current for optimal sonic results. Just connecting a headphone to any given headphone output without considering the headphone's electrical characteristics will most likely yield dissatisfactory results.

Impedances of common dynamic headphones can vary from 30 Ohms to 600 Ohms. Transferred to loudspeakers this would result in impedances from 4 Ohms to 80 Ohms. This means that the same signal amplitude results in a power consumption difference of factor 20!

Loudspeakers and headphones are manufactured in a dazzling variety. Irrespective of their impedance headphones and loudspeakers can have very different efficiencies which means that the electrical signal is converted more or less efficient into acoustic energy. When comparing different loudspeakers the dimension used is the sound pressure level (SPL) reached at a given power of 1W (at 1m distance). There is a similar parameter for the efficiency of headphones except for the fact that the standard power is usually 1mW (=1/1000W) The figure is given as dB/mW which means the resulting sound pressure level *at* 1mW (not *per* 1mW).

If the headphone amplifier's output is very stable (= ideal situation), then the power consumption becomes practically irrelevant and the calculation gets much easier by having only a look at the SPL versus voltage figure. Today still SPL versus power is most widely used. Some headphone manufacturers just give an SPL figure without stating if this relates to 1V or to 1mW.

If the power is doubled then the resulting sound pressure level is 3dB higher. If this is calculated the other way round it means that only half of the power is needed when using a headphone with 3dB more efficiency to reach the same sound pressure level. The 3dB formula is valid for headphones and for loudspeakers as well.

From the given efficiency the power needed for a certain sound pressure level can be derived. The power for the same sound pressure level can differ up to a factor of 500 for the different headphones on the market. In the end what counts when selecting a headphone or a headphone amplifier is if the desired volume can be reached without distortion. At least equally important is to avoid damage for the headphone and – most important – to avoid damage for your hearing. The maximum power rating is a figure that can be found in the data sheet of the headphone. From this power rating the maximum voltage can be derived. If the voltage applied to the headphones will be higher then the voice coils of the headphones will be destroyed.

Today most headphones allow hearing levels well above a secure level for the listener. This means that a standard pair of cans might survive extremely high levels without any degradation of long term performance but the hearing of the listener might be seriously damaged. Especially interesting are the standards of different regions concerning long term noise exposures. *„When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each.“*¹

Permissible noise exposures in Germany (dBA)²

SPL /dBA	85	88	91	94	97	100	103	106	109	112	115	118	121
Duration													
hours per day	8	4	2	1									
minutes per day					30	15	7,5						
seconds per day								225	112	56	28	14	7

Permissible noise exposures in the USA (dBA)³

SPL /dBA	90	92	95	97	100	102	105	110	115
Duration									
hours per day	8	6	4	3	2	1,5	1		
minutes per day								30	15

¹ Quotation from US department of labor noise regulations
² Roughly harmonized throughout Europe
³ Figures taken from US department of labour noise regulations

Overview of power consumption of different headphones at different signal levels:

level (v_{eff})	Headphone impedances				
	32 Ohms	60 Ohms	120 Ohms	300 Ohms	600 Ohms
0,1V	0,31mW	0,16mW	0,08mW	0,033mW	0,016mW
0,5V	7,8mW	4,2mW	2,1mW	0,83mW	0,42mW
1V	31,3mW	16,7mW	8,3mW	3,3mW	1,7mW
2V	125mW	66,7mW	33,3mW	13,3mW	6,7mW
3V	281mW	150mW	75mW	30mW	15mW
4V	500mW	267mW	133mW	53mW	27mW
5V	781mW	420mW	210mW	83mW	42mW
6V	1,13W	600mW	300mW	120mW	60mW
7V	1,53W	817mW	408mW	163mW	82mW
8V	2W	1,06W	533mW	213mW	107mW
9V	2,53W	1,35W	680mW	270mW	135mW

Voltage needed for 1mW power

units	Headphone impedances				
	32 Ohms	60 Ohms	120 Ohms	300 Ohms	600 Ohms
Volts	179mV	245mV	347mV	550mV	775mV
dBu (0dB = 775mV)	-12,7	-10	-7	-3	0
dBV (0dB = 1V)	-14,9	-12,2	-9,2	-5,2	-2,2

Table of effectivity of common headphones⁴

Type	Impedance /Ohms	Efficiency dB/1mW	Voltage for 100dB SPL	Power for 100dB SPL
AKG				
K141Studio	55	101	209mV	0,8mW
K240DF	600	88	3,1V	16mW
K501	120	94	694mV	4mW
K1000	120	74	6,93V	400mW
Beyerdynamic				
DT660	32	97	253mV	2mW
DT770, DT880, DT990	250	96	800mV	2,6mW
Grado				
All	32	98	225mV	1,6mW
Koss				
Portapro	60	101	218mV	0,8mW
Sennheiser				
HD500	32	97	253mV	2mW
HD555	120	94	694mV	4mW
HD650	300	97	775mV	2mW
HD800	300	97	775mV	2mW
Ultrasone				
HFI-500 DJ1	64	103	178mV	0,5mW
HFI-700 DVD	75	94	548mV	4mW

It can easily be seen that even among the products of one manufacturer there can be huge differences as far as impedance and/or effectivity are concerned. This makes it very important that you either choose headphone and headphone amplifier as a matching combination or go for a headphone amplifier with switchable gain that can be used with a wide variety of headphones.

⁴ All figures were taken from freely available data sheets of different manufacturers and have been partly recalculated from other dimensions. Voltage and power are referring to effective values and not to peak values. All figures are given without any guarantee and without any applicable warranty claims against Lehmann audio.

Notes

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