Lehmann*audio*®

T e c h l e t t e r :

headphone amplifiers

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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 outperformed with the best headphones hooked up to a quality headphone amplifier.

In most cases headphones will be used to enjoy music either to acoustically disclose a noisy environment or 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 sufficient sonic results. Just connecting a headphone to any given headphone output without considering the headphone's electrical characteristics will most likely yield dissatisfactory performance.

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

Loudspeakers and headphones are both 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 effectively to acoustic anergy. When comparing the efficiency of 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 1mw (=1/1000W) The figure is given as dB/mw which means the resulting sound pressure level *at* 1mW (not *per* 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.

The formula to calculate the effective power is

p = u * i *(power = voltage * current)*

Because current = voltage / resitance above equation can be rewritten as

p = u ² / r *(power = voltage ² / resistance)*

As a result the power quadruples if the voltage is doubled.

From the given efficiency of a headphone the power and voltage level needed for a certain sound pressure level can be derived. In the real world the power for the same sound pressure level can differ up to a factor of 500 for the different headphone models that are currently on the market.

In the end what counts first when selecting a headphone or a headphone amplifier is if the desired volume can be reached without distortion.

Apart from reaching the desired output level 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 datat sheet of the headphone. From this power rating the maximum voltage can be derived. If the signal voltage at the headphone amplifier's out is higher then these voice coils of the headphones will be damaged or 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]

Taking a look at laws in the US and in Europe reveals substantial differences in what is thought to be suitable sound pressure levels for the listener:

Permissible noise exposures in Germany (dBA)[2]

SPL /dBA **Duration**	**85**	**88**	**91**	**94**	**97**	**100**	**103**	**106**	**109**	**112**	**115**	**118**	**121**
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 **Duration**	**90**	**92**	**95**	**97**	**100**	**102**	**105**	**110**	**115**
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 departemnt 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	0,016mV
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 efficiency of common headphones[4]

Type	Impedance /Ohms	Effektivity 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	350mV	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
HD 600, HD 650	300	97	775mV	2mW
Ultrasone				
HFI-15G	32	94	716mV	4mW
HFI-550	64	100	252mV	1mW
HFI-700	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 efficiency 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.