# Techletter Headphone amplifier

*- Understanding the specs -*

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## Why headphones?

Using 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 hifi setup with high quality loudspeakers. Detail resolution and dynamics of even the best loudspeakers can easily be reached and even outperformed 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 like family and neighbours.

## 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.

Loudspeakers and headphones are manufactured in a dazzling variety. However, 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!

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 a the SPL versus voltage figure. Today still SPL versus power is most widely used but 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 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 can handle, the headphone will be destroyed.

## Hearing stress

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 in this context 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<br><br>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<br><br>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 |

No matter where you live you should take these times seriously to avoid damage for your hearing and having a look at the differing figures rather be on the cautious side. Better always start with a very soft level and turn up the volume later to avoid unforeseen stress for your ears.

Data of any given headphones can be combined with a voltage level to calculate the resulting sound pressure level online at . **www.headphone-amplifier.com.** You then can easily look up the maximum time per day you should expose your hearing to the resulting sound pressure level.

[1] Quotation from US department of labor noise regulations
[2] Roughly harmonized throughout Europe
[3] Figures taken from US departement 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 (odB = 775mV) | -12,7 | -10 | -7 | -3 | 0 |
| dBV (odB = 1V) | -14,9 | -12,2 | -9,2 | -5,2 | -2,2 |

## Table of efficiency of common headphones[4]

| Type | Impedance /Ohms | Efficiency dB/1mW | Voltage level for 100dB | Power needed for 100dB |
|---|---|---|---|---|
| *AKG* | | | | |
| K141Studio | 55 | 101 | 209mV | 0,8mW |
| K240DF | 600 | 88 | 3,1V | 16mW |
| K501 | 120 | 94 | 691mV | 8mW |
| K601 | 120 | 92 | 870mV | 6,3mW |
| K701 | 62 | 93 | 558mV | 5mW |
| K1000 | 120 | 74 | 6,93V | 400mW |
| *Beyerdynamic* | | | | |
| DT660 | 32 | 97 | 253mV | 2mW |
| DT770, DT880, DT990 | 250 | 96 | 800mV | 2,6mW |
| T1 | 600 | 102 | 620mV | 0,64mW |
| T5p | 32 | 102 | 142mV | 0,63mW |
| *Grado* | | | | |
| Alle | 32 | 98 | 225mV | 1,6mW |
| *Koss* | | | | |
| Portapro | 60 | 101 | 218mV | 0,8mW |
| *Sennheiser* | | | | |
| HD 500 | 32 | 97 | 253mV | 2mW |
| HD 555 | 120 | 94 | 691mV | 4mW |
| HD 600/650/800 | 300 | 97 | 775mV | 2mW |
| HD 700 | 150 | 97 | 550mV | 2mW |
| *Ultrasone* | | | | |
| HFI-15G | 32 | 94 | 716mV | 4mW |
| HFI-550 | 64 | 100 | 252mV | 1mW |
| HFI-700 | 75 | 94 | 548mV | 4mW |
| Edition 10 | 32 | 99 | 201mV | 1,26mW |
| Signature Pro | 32 | 98 | 225mV | 1,58mW |

All models listed in the table above are full size on ear headphones. So called in ear models made especially for low power battery devices have very often a much higher efficiency.

## Conclusion

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 and without any applicable warranty claims against Lehmann audio.