

Sound Power and Pressure Measurements

What is a decibel?

The decibel (**dB**) is a logarithmic unit used to describe a ratio. The ratio may be power, or voltage or intensity or several other things. To get a taste for logarithmic units, first let's look at some numbers:

For instance, suppose we have two loudspeakers, the first playing a sound with power P_1 , and another playing a louder version of the same sound with power P_2 , but everything else (how far away, frequency) kept the same.

The **difference in decibels** between the two is given by

$10 \log (P_2/P_1)$ dB where the log is to base 10.

If the second produces twice as much power than the first, the difference in dB is

$10 \log (P_2/P_1) = 10 \log 2 = 3$ dB.

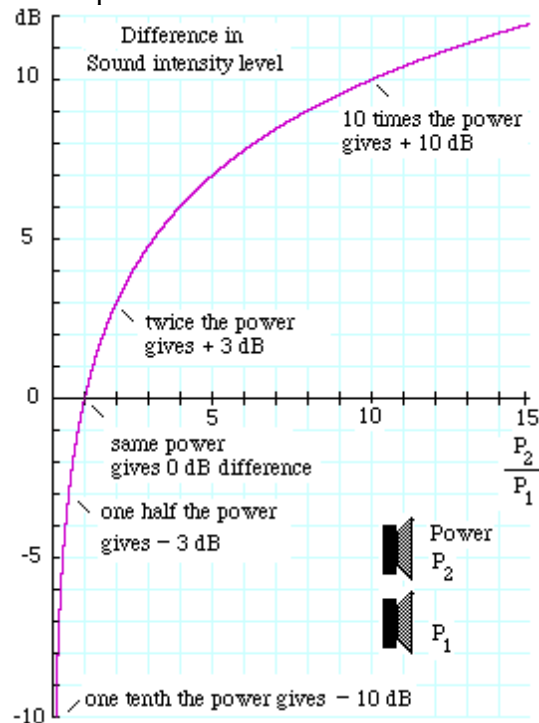
If the second had 10 times the power of the first, the difference in dB would be

$10 \log (P_2/P_1) = 10 \log 10 = 10$ dB.

If the second had a million times the power of the first, the difference in dB would be

$10 \log (P_2/P_1) = 10 \log 1000000 = 60$ dB.

This example shows one feature of decibel scales that is useful in discussing sound: they can describe very big ratios in power with numbers of modest size



Sound pressure, sound level and dB. Sound is usually measured with microphones and they respond (approximately) proportionally to the sound pressure, p . Now the power in a sound wave, all else equal, goes as the square of the pressure. The log of the square of x is just $2 \log x$, so this introduces a factor of 2 when we convert to decibels for pressures. The difference in sound pressure level between two sounds with p_1 and p_2 is defined as:

$20 \log (p_2/p_1)$ dB where the log is to base 10.

When the decibel is used to give the sound level for a single sound rather than a ratio, then a reference level must be chosen. For sound intensity, the reference level (for air) is usually chosen as 20 micropascals, or 0.02 mPa. (This is very low: it is 2 ten billionths of an atmosphere. Nevertheless, this is about the limit of sensitivity of the human ear, in its most sensitive range of frequency. Usually this sensitivity is only found in rather young people or in people who have not been exposed to loud music or other loud noises.

Personal music systems with in-ear speakers ('walkmans') are capable of very high sound levels in the ear, and are responsible for much of the [hearing loss in young adults](#) in developed countries.)

So if you read of a sound intensity level of 86 dB, it means that

$20 \log (p_2/p_1) = 86$ dB

where p_1 is the sound pressure of the reference level, and p_2 that of the sound in question.

Divide both sides by 20:

$\log (p_2/p_1) = 4.3$ dB

4 is the log of 10 thousand, 0.3 is the log of 2, so this sound has a sound pressure 20 thousand times greater than that of the reference level. 86 dB is a loud but not dangerous level of sound, if it is not maintained for very long.

What does 0 dB mean? This level occurs when the measured intensity is equal to the reference level. i.e., it is the sound level corresponding to 0.02 mPa. In this case we have sound level = $20 \log (p_{\text{measured}}/p_{\text{reference}}) = 20 \log 1 = 0$ dB

So 0 dB does not mean no sound, it means a sound level where the sound pressure is equal to that of the reference level. This is a small pressure, but not zero. It is also possible to have negative sound levels: - 20 dB would mean a sound with pressure 10 times smaller than the reference pressure, ie 2 micropascals.

Not all sound pressures are equally loud. This is because the human ear does not respond equally to all frequencies: we are much more sensitive to sounds in the frequency range about 1 kHz to 4 kHz than to very low or high frequency sounds. For this reason, sound meters are usually fitted with a filter whose response to frequency is a bit like that of the human ear. (More about these filters below.) If the "A weighting filter" is used, the sound pressure level is given in units of **dB(A)**. Sound pressure level on the dB(A) scale is easy to measure and is therefore widely used. It is still different from **loudness**, however, because the filter does not respond in quite the same way as the ear. To determine the loudness of a sound, one needs to consult some (idealised) curves representing the frequency response of the human ear. The unit of loudness is the **son**, which is defined so that it equals sound pressure level at a frequency of 1 kHz, and is assigned values at other frequencies by the response curves.

The ear is capable of hearing a very large range of sounds: the ratio of the sound pressure that causes permanent damage from short exposure to the limit that (undamaged) ears can hear is more than a million. To deal with such a range, logarithmic units are useful: the log of a million is 6, so this ratio represents a difference of 120 dB. Psychologists also say that our sense of hearing is roughly logarithmic. In other words, they think that you have to increase the sound intensity by the same factor to have the same increase in loudness. Whether you agree or not is up to you, because this is a rather subjective question.