UNDERSTANDING DECIBELS

You don't have to be involved very long in electronics, hifi or professional audio before you come across the term *decibels*, or its contraction 'dB'. And because of the very general way in which these terms are used, it can often be hard working out what they mean, and why they're being used. Here's a quick explanation of what it's all about.

Early last century, when engineers were building the first telephone networks, they needed to be able to measure the performance of their cables, amplifiers, channel filters and so on. They soon discovered that because the human ear responded to both the frequency and loudness of sounds in a non-linear or *logarithmic* fashion, their measurements and comparisons between signals were a lot more meaningful if they were made in logarithmic terms too.

For comparing signal strengths they used at first a unit called the **Bel**, named in honour of Alexander Graham Bell, the inventor of the telephone. This was defined simply as the logarithm of the ratio of two signal power levels. So two signals were said to differ by one Bel if the logarithm of their *power* ratio was 1.0. In other words, if one signal had a power level 10 times that of the other, because log(10) = 1.

It was soon found, though, that the Bel was far too large a unit; the human ear could easily detect much smaller differences between signals. So engineers began to use a unit 10 times smaller, which not surprisingly they dubbed the **deciBel** or 'decibel' — or just 'dB' for short.

Mathematically the difference between two signals or signal levels is defined as:

$$N(dB) = 10 \times \log(P_1/P_2)$$

where P_1 and P_2 are the two signal power levels.

The decibel turned out to be a very practical way to compare two signals, because a signal difference of 1.0dB corresponds closely to the smallest change in sound level that the human ear can detect — what psychologists and audiologists call a 'just noticeable difference' (JND).

Now as you can see, the decibel is strictly speaking a way of comparing **power levels**, where the two levels may be measured in watts, milliwatts, microwatts or even kilowatts. However because signal voltages are proportional to power level, providing the impedance level is constant (or the same, in different circuits), you can also work out a ratio in decibels from the *voltage* ratio:

$$N(dB) = 20 \times \log(V_1/V_2)$$

where V_1 and V_2 are the two voltage levels, and the multiplier '20' comes in because the power level is proportional to the square of the voltage level (and squaring is equivalent to doubling the logarithm).

So knowing two signal voltage levels, we can work out their difference in decibels — providing they are associated with the same impedance level.

As you can see, though, the decibel strictly isn't a unit of absolute measurement like the metre, the kilogram, the ohm or the volt. It's basically just a unit of *relative* measurement; a way of comparing one signal level against another.

Nowadays decibels are used exactly like this in many different areas of electronics — measuring the frequency response of preamplifiers, amplifiers, filters, microphones and speakers, comparing the optical output levels of lasers or the microwave power output of transistors and ICs, and so on.

For example you may have noticed that the frequency response of things like amplifiers and filters is often measured between the points where the response is '3dB down'. Ever wondered why those points are chosen? Because a drop of 3dB corresponds to **halving** the power level, which is very clearly noticeable.

Other handy 'rules of thumb' to remember about decibels are that:

- a 20dB difference corresponds to a drop or gain of 10 times the voltage.
- a 10dB difference corresponds to a drop or gain of 10 times the power, or 3.162 times the voltage.
- a 6dB difference corresponds to a halving or doubling in voltage.
- a 3dB difference corresponds to a drop in voltage to 0.708 of the original level, or a rise in voltage to 1.413 times.
- a 1dB difference corresponds to a drop of 11% or a rise of 12% in voltage.
- a single-section RC filter has a rolloff slope of 6dB per octave, or 20dB per decade of frequency.
- a two-section RC filter has a rolloff slope of 12dB/octave, or 40dB/decade.

Quasi-absolute decibels

Although decibels are strictly speaking a unit of relative measurement, they are often also used in various fields as a unit of quasi-absolute measurement. This is done where it's more convenient to think of levels in terms of their magnitude relative to some arbitrary level, rather than their absolute value. The arbitrary level is then made the '0dB' reference level, and actual measurements can be quoted in decibels with respect to it.

In acoustics, for example, it's convenient to think of **a sound pressure level of 0.2 nanoBars** (the same as 0.2 millidynes/cm^2) as a reference level, because this is virtually the lowest sound level detectable by the human ear at 1kHz. This level is therefore called '0dB', and when measurements are made of actual sound levels they're quoted in dB relative to this level. So the voices in a typical conversation might have a level of '65dB', while an amplified rock band might produce levels of around '120dB'.

TABLE 1: Sound Pressure Levels in dB
(Relative to 0.2 nanoBar RMS at 1kHz)

140dB	Large industrial siren
130dB	Threshold of feeling or pain
120dB	Close vicinity of aircraft engine
110dB	Amplified rock band performance
100dB	Close to loud car or truck horn
90dB	Human hearing starts to become at risk (approximate).
80dB	Symphony orchestra playing fortissimo; inside older train
70dB	Inside typical factory (heavy industry)
65dB	Typical office conversation
45dB	Inside typical home residence
30dB	Soft or background music
20dB	Quiet whisper
0dB	Threshold of audibility (nominal)

Typical sound pressure levels measured according to this system are shown in the table. Just remember that they're really all relative to that reference level of 0.2 nanoBars at 1kHz, the nominal threshold of hearing.

Another example of quasi-absolute decibels is in the telephone, radio and recording industries, where audio signals are often handled in balanced circuits at a standardised impedance level of 600Ω. Because of this standardised environment it's often convenient to quote measurements of signal level not in terms of absolute power or voltage, but relative to an arbitrary reference signal level instead. In this case the reference signal level is **a power level of 1mW** (one milliwatt), which in a 600Ω circuit corresponds to a voltage level of 775mV. This level is called '0dBm', so when you see audio signal levels given as '+10dBm' or '-30dBm', that means they're being quoted relative to that reference level.

So '+10dBm' means 10dB above the 1mW level, for example (or 10mW), corresponding to a voltage of 2.448V across 600Ω. Similarly '-30dBm' means 30dB *below* the 1mW level, or 1uW (microwatt), corresponding to 24.5mV across 600Ω.

Yet another example of quasi-absolute decibels is in radio engineering, where signal and noise levels measured in 50Ω circuits are often quoted in 'dBuV' — or decibels relative to a reference signal level of **one microvolt**. So a signal level of +20dBuV is actually 10uV, while a noise level of -10dBuV is actually 0.316uV (or 316 nanovolts).

What are Nepers?

Finally, you may have heard signal or attenuation levels quoted in numbers that look like decibel figures, but with the term 'Nepers' instead of 'dB'. So what's a Neper (pronounced *nay-per*)?

Nepers are an alternative logarithmic unit of relative measurement, like the decibel but based on Naperian or 'natural' logarithms rather than common or 'base 10' logarithms. (Naperian logs use '*e*' or 2.71828 as their base, rather than 10.)

It's actually easy to convert relative measurements given in Nepers into decibels; just remember that one Neper = 8.686dB.