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The dB Explained

The dB or decibel is a common term in audio systems but what is it and what does it all mean? The following is an attempt to explain the basics and give some useful reference points. This is a partially flawed document because I am making generalisations and trying to simplify the concept, however the general gist is true.

The human ear is not linear and has different sensitivity at different frequencies. it responds to changes in sound pressure levels in a logarithmic fashion and over a vast sensitivity range. The dB gives us a useful way of describing audible level changes in simple, meaningful and measurable terms.

Changes in audio levels are measured in Bel's. The basic premise is this, if something is creating x amount of sound pressure level and you turn it up until it is twice as loud as it was before then you have increased the volume by one Bel. Likewise it you turn something down until it is only half as loud as it was before then you have decreased the volume by one Bel. The unit of one Bel is rather large for convenient use and so we tend to work in increments of one tenth of one Bel otherwise known as the decibel and commonly abbreviated to the letters dB. Therefore a change of 10dB indicates a volume change of twice as loud or half as loud. This statement is technically flawed as I have simplified the concept but it is essentially true.

It is important to remember that the dB itself is simply a method of describing the difference between two audio levels or voltages, it does not mean anything by itself until it is qualified by a reference point or descriptive suffix.

dB-SPL

dB-SPL indicates that the measurement is based on sound pressure level. 0dB-SPL represents the lowest sound pressure level that the average human can hear and is based on a sound pressure level of 20µPa at 1KHz. This does not represent no sound, some people (not many) can hear sounds quieter than 0dB-SPL, as we age we usually lose the ability to hear down as low as 0dB-SPL. SPL measurements are normally plus (+dB) figures and are above 0dB-SPL.

dBu

dBu indicates that the audio signal is an electrical signal and that the reference point is based on an audio signal of 0.775 volts RMS into a 600 ohm load giving a dissipation of 1 milliwatt of power across the load. 0.775 volts RMS is the reference point and is therefore called 0dBu.

Any deviation from this point is given as a plus or minus figure. For example +4dBu is the external standard operating level of most professional audio equipment, it simply means that the operating level is 4dB above the 0dBu reference level (this equates to 1.23 volts RMS).

dBv

dBv indicates that the audio signal is an electrical signal and that the reference point is based on an audio signal level of 1 volt RMS unloaded (based on an original 600 ohm circuit that has been un-terminated). In this case 1 volt is the reference point and is called 0dBv, any deviation from this point is given as a plus or minus figure. For example -10dBv is the standard operating level for most Hi-Fi audio equipment (equates to 0.3 volts RMS) because this is 10dB below 0dBv. The dBv is not often used as a reference for professional audio equipment.

dBVU

dBVU indicates a VU meter (an average reading mechanical meter). In this case 0dBVU could be any level that the meter is aligned for, in the case of a dBu based system it could indicate 0VU (reference level) at 0.775 volts RMS or 1.23 volts RMS depending on what the meter is used for. In the case of a Hi-Fi system or some semi professional equipment it would probably indicate 0VU (reference level) for 0.3 volts RMS. In all cases the meter will indicate a minus figure for levels below the reference and a plus figure for levels above the reference point.

Peak reading meters can be calibrated in many ways and have many different scale types and they a bit hard to generalise on and so I wont go into them here. The are also some variations with VU meters but in general they conform to the norm.

dBFS

dBFS indicates a peak reading meter or operating system where the maximum level possible is 0dBFS (full scale). This is the most common meter type in digital audio systems as the level of digital audio can not exceed 0dBFS as there are no more bits available. All meter markings will be as minus figures from 0dBFS. A Sony PCM-7010 DAT machine shows its RMS reference point as -20dBFS, this means that there is 20dB of headroom to go before digital clipping if you feed this particular machine with a +4dBu input signal.

Power amplifier meters are often marked along the lines of dBFS with 0dB being an indication of the full output level just before clipping, this is often followed by a "clip" LED that shows that clipping has occurred and the amplifier is trying to exceed its full power capacity and is distorting. All other LED's will show the level up to full power and therefore below 0dBFS.

Following are useful reference points when using a dB scale to describe the difference between two points. Minus values are the same, just the inverse of what is shown below.

0dB = no change, also called "unity gain"

+3dB = 1.4 times the voltage, double the power dissipation (in watts), notably louder

+6dB = double the voltage, quadruple the power dissipation (in watts), much louder
+10dB = 3.16 times the voltage, approx 10 times the power (in watts), twice as loud
+20dB = 10 times the voltage
+40dB = 100 times the voltage
+60dB = 1000 times the voltage

So using the above :

0dB represents a total of no change. If a system has a net gain of 0dB then it is said that it has unity gain, in other words, what went in one end of the system came out the other end at the same level. The concept of unity gain is one of the most important things you can know if you work with audio systems.

3db points are useful as a 3dB change (plus or minus) represents a notable volume change and a doubling (or halving) of the power dissipation (measured in watts). Changes of less than 3db are audible but not as notable.

6dB points are very significant as they show a doubling (or halving) of voltage and a quadrupling (or quartering) of power dissipation levels.

10dB points are very significant as they show the doubling (or halving) of perceived volume.

Some real world applications of the dB in signal levels

You will note that most audio mixing console faders are marked with 0dB as being at 70% of the fader travel. 100% of fader travel is marked as +10dB and approx 50% of fader travel is marked as -10dB. The faders are specially trimmed logarithmic devices to accommodate the way we hear. The 0dB mark is where the console designer wants you to normally operate the fader, you do this by pushing the fader to the 0dB mark and trimming the gain pot for the correct volume or signal level. The fader will then give you a wide 20dB operating range over 50% of its total travel, +10dB of boost (twice as loud) from normal and -10dB of cut (half as loud) from normal, most audio mixing operations can be accommodated over this fader range.

Equalisation cut/boost potentiometers also have a 0dB mark, usually at 50% of their travel. The 0dB mark means no cut and no boost and therefore the equaliser pot is doing nothing at the 0dB point and is said to be flat at that frequency (this refers to how a frequency response graph would look if you made one for this frequency band). If the knob is turned towards +15dB (or whatever it is) then you are boosting the equalisation at that point and if the knob is turned towards -15dB (or whatever it is) then you are cutting the equalisation at that point.

Differences in level measured in dB are simply added together to arrive at the total amount of system gain. Most audio mixing consoles provide significant gain control only at the input stage, this would typically be from +10dB to +60dB of gain, with a -20dB pad providing for the times when you need a gain loss (negative gain). If the gain pot is set to +10dB and you press the -20dB pad switch, you then have an overall net gain of -10dB, in other words a loss of 10dB (+10dB plus -20dB = -10dB).

Electronically balanced output drivers carry half the signal on the "hot" wire and the other half of the signal on the "cold" wire. The signal on the "hot" wire is said to be "in phase", the signal on the "cold" wire is the same signal but is 180 degrees "out of phase" relative to the "hot" wire. These two halves make a whole. If you are running an actively balanced audio system and the signal level in one channel drops by 6dB, this indicates that one of the balanced signal wires has broken. This is also referred to as going "one legged". One legged balanced systems will often be noisy electronically and sound engineers will sometimes describe something as sounding "one legged". Transformer coupled devices (such as dynamic microphones) will drop by more than 6dB if they become "one legged". I will cover why this is so in another document that will explore balanced audio systems and how they work.

3dB (half power) points are often used when measuring the frequency response of equipment. Any frequency response specification needs to indicate what the roll off points are if it is to be at all meaningful. A specification that quotes a response of +/-3dB is really indicating that the deviation could be a total of 6dB, this does not sound as good on paper as +/-3dB. Many manufacturers of quality signal processing equipment will therefore quote +0/-3dB if they are defining the frequency response rolloff points, this indicates a tighter specification than +/-3dB.

Mathematics (the 20 log law)

Now for the maths part. Using the dB to describe something is **always a comparison of two things**, a change of 0dB indicates that the "other" is the same as the "original", a plus or minus number of dB indicates that the "other" is greater than or smaller than the "original". If we want to describe the difference between two voltages we use the following formula and need a scientific calculator.

20 log X/Y or X divided by Y, "log" and then multiplied by 20

For example if I measure 0.775 volts RMS at the mixing console output and only 0.388 volts RMS at the graphic equaliser output then I would divide 0.775 volts by 0.388 volts = a difference of 2, then press the "log" button and multiply the answer by 20 = 6dB. Therefore the difference in level between these two points is 6dB. You will notice if you try this with a calculator that I round figures as I go as no ones needs to know about lots of decimal points.

I can reverse the formula. I could have a 6dB difference in level and want to know what this is as a voltage difference. I take the 6dB and divide by 20 = 0.3, then hit the "arc" (inverse) button followed by the log button and get a result of 2, this means that a level difference of 6dB is the same as a voltage difference of 2 times.

Confused ? Don't worry, its only one formula and you learn it if you use it, just like Ohm's law.

While it is handy to know, only some audio folk need to learn the 20 log law, most people only really need to know the following :

0dB = no change from the reference point

3dB = half or double power

6dB = half or double voltage

10dB = half or double volume

Notes :

The rule of 10dB being twice as loud only really applies to midband frequencies such as the human voice and is a convenient generalisation. The human ear responds differently at low frequencies and high frequencies and differently at different loudness levels, not to mention obvious variations between individuals. When Alexander Graham Bell was researching all this stuff he came up with the generalisation of twice as loud and half as loud and tried to match this with the average citizen with an average hearing ability.

0dBu is based on 0.775 volts of signal across a 600 ohm load developing a power dissipation across the load of 1 milliwatt. This system was created with the telephone system in mind where telephone lines travel vast distances and need to be terminated to work properly. Until 20 years ago (or so) most broadcast radio studios and many recording studios were wired with 600 ohm termination resistors fitted to every device and all equipment was optimised to work in this way. These days terminated lines are only used in a few applications. We have retained the operating level of 0.775 volts RMS as our 0dBu reference point and no longer terminate the destination end unless there is a specific reason to do so. We still assume the output driver may have to feed a destination load of 600 ohms and all professional audio devices are designed to do this. The input impedance of most professional audio equipment is greater than 10,000 ohms and so we can daisy chain large systems together if we wished to do so.

I have referred to RMS several times in this document. An audio signal is an AC signal and is comprised of a peak to peak voltage if viewed on an oscilloscope. The RMS (root mean squared) voltage is how we express an AC voltage as an equivalent of a DC voltage. We need to do this to work out how much power an AC voltage will cause to be dissipated into any given load. The RMS voltage is the peak to peak voltage divided by 2 and then divided again by the square root of 2. Therefore a voltage swing of 30 volts peak to peak has an RMS voltage of 10.6 volts (equates to +22.7dBu), this does not sound as impressive but it is more useful when working stuff out.

Last updated : 30/07/04