All about the Decibel (dB)

By Marc Basquin

Having read a good many letters and emails from various correspondents we concluded that although the decibel (dB) is one of the most frequently used units in audio, RF electronics and acoustics, it is unfortunately one of the least understood. High time, we thought, to clear up the misunderstandings and publish Mr. Basquin's article on the subject.

Basically, the dB is a relative unit, expressing the ratio of two values using the same unit:
– the value being measured
– a clearly defined and indicated reference value.

A logarithmic scale is used to make it easier to handle otherwise unwieldy numbers. For example, the ratio of 0.0000316 V to 1 V is expressed as: –90 dB.

Difference between dB for voltage and dB for power

dB (voltage) = $20 \log_{10} (U / U_0)$

In this formula, U_0 represents the reference voltage. Consequently, a value of +6 dB means a doubling of the voltage, since $20 \log_{10} (2) = 6$.

dB (power) = $10 \log_{10} (P / P_0)$
In this case, P_0 is the reference power level. Doubling the power equals a +3 dB increase.

Oddball dB's?

dBV expresses the ratio of two voltages using 1 V_{rms} as the reference level. Because the signal source is assumed not loaded, the unit has no relation to impedance (remember, the 'V' in 'dBV' stands for volts).

dBV = $20 \log_{10} (U / 1\ V_{rms})$
0 dBV = 1 V_{rms}
–10 dBV = 0.316 V_{rms}

This is the standard unit in hi-fi audio design and specification, as well as with some manufacturers like Tascam.

dBV = dBu + 2.2 dB

Table 1 shows the corresponding voltage values at different levels, expressed in dBV.

dBv = dBu
Because the unit dBv could easily be confused with dBV, it is often replaced by the less ambiguous 'dBu'.

The units dBv and dBV are not equivalent or equal.

dBv = $20 \log_{10} (U / 0.775\ V_{rms})$
0 dBv = 0.775 V_{rms}

dBu expresses the ratio of voltages, using 0.775 V_{rms} as the reference level. Because the signal source is assumed not loaded, the unit has no relation to impedance (u = unloaded or unterminated).

dBu = $20 \log_{10} (U / 0.775\ V_{rms})$
0 dBu = 0.775 V_{rms}
+4 dBu = 1.23 V

This is a frequently used level in professional audio equipment.

dBu = dBV – 2.2 dB

Table 2 shows the relation between dBu values and voltage.

dBj expresses the ratio of voltages using 1 mV_{rms} as the reference level. Because the signal source is assumed not loaded, the unit has no

Table 1.
dBV/voltage conversion

dBV	Voltage (V)	dBV	Voltage (V)
+1	1.112	–1	0.891
+2	1.259	–2	0.794
+3	1.413	–3	0.708
+4	1.585	–4	0.631
+5	1.778	–5	0.562
+6	1.995	–6	0.501
+7	2.239	–7	0.446
+8	2.512	–8	0.398
+9	2.818	–9	0.354
+10	3.162	–10	0.316
+20	10.00	–20	0.100
+30	31.62	–30	0.031
+40	100.0	–40	0.010
+50	316.2	–50	0.003
+60	1000	–60	0.001

relation to impedance.

dBj = 20 $\log_{10}$ (U / 1 mV_{rms})
0 dBj = 1 mV_{rms}

dBr allows the reference voltage to be specified ('r' for reference).

dBr = 20 $\log_{10}$ (U / U_0)
For example, 0 dBr = 'dBre +4' = 1.23 V_{rms} = +4 dBu

dBVU expresses the ratio of voltages with the reference level freely chosen and clearly specified. This unit helps to pinpoint a discrete level or a certain range on a measuring instrument. For example, a low-pass filter may be used with the measurement. Remember, VU = volume unit. The unit is typically used
- with radio, to indicate 100% modulation level;
- with analogue tape recorders, to indicate the ideal operating area depending on the magnetic tape being used. It then corresponds to a certain magnetic flux level expressed in Wb/m — This is not the highest permissible signal level;
- with digital tape recorders, to indicate the level above which distortion occurs.

dBVU = 20 $\log_{10}$ (U / U_0)

0 dBVU is a reference level at which the needle of a VU meter indicates 0. **Table 3** shows some reference values.

Table 2.
dBu/voltage conversion

dBu	Voltage (V)	dBu	Voltage (V)
+1	0.869	–1	0.690
+2	0.975	–2	0.615
+3	1.095	–3	0.548
+4	1.228	–4	0.489
+5	1.377	–5	0.435
+6	1.546	–6	0.388
+7	1.735	–7	0.346
+8	1.946	–8	0.308
+9	2.183	–9	0.274
+10	2.450	–10	0.245
+20	7.750	–20	0.0775
+30	24.50	–30	0.0245
+40	77.50	–40	0.0075
+50	245.0	–50	0.00245
+60	775.0	–60	0.000775

Table 3.
Subjective perception of sound pressure levels

Surroundings	dB SPL	Perception
Rocket launch	180	
30 m from a military jet plane at takeoff; rifle shot at 100 m	140	
Pain threshold, pneumatic press; large siren op 1 m distance	130	Unbearable
At 60 m from a plane taking off; machine room of an ocean liner	120	
Old subway, sewing shop	110	
Maximum level in a discotheque	105	Very loud
Book/magazine press, train on steel bridge; small fireworks	100	
Building site, average level of a hifi set	90	
Very busy road; alarm clock at 1 m	80	
Loud radio, busy street	70	Noisy
Conversation in a restaurant; large shop	60	
Office; normal conversation at 1 m	50	Quiet
Bedroom; buzz from conversation at 2 m	40	
Normal conversation at 3 m, buzz at 5 m	30	
Recording studio; rustling leaves	20	Very quiet
Desert	10	
Absolute hearing threshold	0	

dBm expresses a ratio of powers using 1 mW as the reference level ('m' is from 'mW').

In audio engineering, 0 dBm equals 1 mW into an impedance of 600 Ω.

dBm = 10 $\log_{10}$ (P / 0.001 W)

The corresponding voltages are easily extracted using

$U_0 = \sqrt{(P_0 Z_0)}$

Normally, 0 dBm = 1 mW into 600 Ω = 0.775 V_{rms}, this is proved by

$U_0 = \sqrt{(0.001 \text{ W} \times 600\ \Omega)} = \sqrt{0.06} =$ 0.775 V

In RF engineering, 50 Ω is the more commonly used impedance (because of the typical impedance of coax cables and connectors), so 0 dBm = 1 mW into 50 Ω.

dBW expresses a power ratio using 1 watt as the reference level. This allows easy comparison of output levels produced by power amplifiers ('w' from 'watt').

dBW = 10 $\log_{10}$ (P / 1 W)
0 dBW = 1 W

Therefore, a 100-watt amplifier can be said to deliver +20 dBW, since 10 $\log_{10}$ (100/1) = 20. Similarly, a 1-kW amplifier delivers +30 dBW to the loudspeakers, and a combination of a transmitter and an antenna system may produce +40 dBW = 10 kW effective radiated power (ERP).

dBk is a power ratio using 1 kW (1,000 watts) as the reference level. This unit, too, is used to compare amplifier performance ('k' from 'kilowatt')

dBk = 10 $\log_{10}$ (P / 1 kW)
0 dBk = 1 kW

dBi in RF engineering expresses gain over an isotropic (hypothetical, sphere-shaped) reference antenna.

dBd in RF engineering expresses gain over a dipole antenna.
0 dBd ≈ +2,15 dBi

dBPWL indicates the ratio of acoustic powers, allowing for the reverberation time in a closed space ('PWL' from 'PoWer Level').
dBPWL = 10 $\log_{10}$ (P / P_0)

where P = effective power level (in watts) and $P_0 = 10^{-12}$ W = 1 pW.

However, you'll find that the unit dBSWL is more commonly used.

dBSWL = dBPWL
('SWL' from 'Sound PoWer Level')

dBSPL indicates a ratio of an acoustic sound

Table 4.
A- (acoustic-) weighted filter coefficients

f in Hz	dBA	f in Hz	dBA	f in kHz	dBA	f in kHz	dBA
10	–70.4	100	–19.1	1	0	10	–2.5
12.5	–63.4	125	–16.1	1.25	+0.6	12.5	–4.3
16	–56.7	160	–13.4	1.6	+1	16	–6.6
20	–50.5	200	–10.9	2	+1.2	20	–9.3
25	–44.7	250	–8.6	2.5	+1.3		
31.5	–39.4	315	–6.6	3.15	+1.2		
40	–34.6	400	–4.8	4	+1		
50	–30.2	500	–3.2	5	+0.5		
63	–26.2	630	–1.9	6.3	–0.1		
80	–22.5	800	–0.8	8	–1.1		

pressure level and a reference pressure (‘SPL’ from ‘Sound Pressure Level’)

$0 \text{ dBSPL} = 0.0002 \text{ dynes/cm}^2$
$= 0.00002 \text{ N/m}^2$
$= 0.0002\ \mu\text{bar} = 20\ \mu\text{Pa}$

$\text{dBSPL} = 20 \log_{10} (\text{SPL} / \text{SPL}_0)$

where SPL = the effective pressure in Pa and $\text{SPL}_0 = 20\ \mu\text{Pa}$ (in air).

From this we could be lead to believe that a 6-dB increase in sound pressure means ‘twice as loud’. This is not the case, however, because psychoacoustics has shown human hearing response to be frequency as well as pressure dependent (physiological curve, *loudness*). For reference purposes, **Table 3** lists the sound levels of a few typical sound-related phenomena.

dBA expresses the ratio of acoustic pressure and a reference level (SPL = Sound Pressure Level) using an A-weighted filter.

In **Table 4** you find the frequency-dependent attenuation of an A-weighted network relative to the 1-kHz reference frequency.

dBFS represents the maximum permissible voltage level before clipping (or limiting) occurs (‘FS’ from ‘full scale’).

The full-scale value depends on the A/D and D/A converters applied. It is established by applying a 997-Hz digital signal and measuring the resultant analogue voltage, observing that (THD+N) < –40 dB (THD+N = Total Harmonic Distortion plus Noise).

Some typical dynamic ranges:

16-bit converter: –96 dBFS
20-bit converter: –120 dBFS
24-bit converter: –144 dBFS

0 dBFS is the maximum level with digital audio equipment — all applied signals need to stay well below this level.

(020192-1)