Loudness Levels: The Decibel (dB)

The ear operates over an energy range of approximately 10^{13}:1 (10,000,000,000,000:1)—that's an extremely wide range. Because such a range is difficult for humans to deal with easily, a logarithmic scale has been adopted to compress the measurements into figures that are more workable. The system used for measuring sound-pressure level (SPL), signal level and relative changes in signal level is the *decibel (dB)*, a term that literally means 1/10th of a bell . . . a measurement unit that was named after Alexander Graham Bell, the inventor of the telephone.
In order to develop an understanding of the decibel, we first need to examine logarithms and the logarithmic scale (Figure 2.19). The *logarithm (log)* is a mathematical function that reduces large numeric values into smaller, more manageable numbers. Because log numbers increase exponentially in a way that's similar to how we perceive loudness (i.e., 1, 2, 4, 16, 128, 256, 65,536 . . .), it expresses our perceived sense of volume more precisely than a linear curve can.

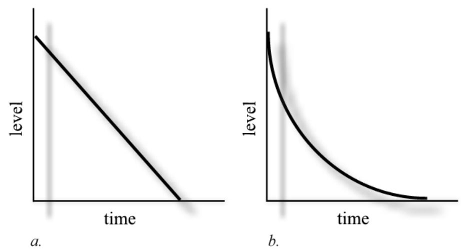

Figure 2.19. *Linear and logarithmic scales.*
a. *Linear.*
b. *Logarithmic.*

Before we delve into a deeper study of this important concept for understanding many of our perceptual senses, I'd like to take a moment out to stress the fact that much confusion has surrounded way in which the "log" scale relates to sound and hearing . . . especially when readers are confronted with tons of formulas that frankly don't seem to relate to their working lives.

In light of this, I'd like to do my best to present you with an understanding of the basic concepts and building block ideas behind the log scale and help you to understand just what examples like "+3 dB at 10,000 Hz" really mean. Be patient with yourself if you still don't get it . . .

over time the idea of the decibel will become as much a part of your working vocabulary as ounces, gallons and miles-per-hour.

Logarithmic Basics

In audio, we use logarithmic values to express the differences in intensities between two levels (often, but not always, comparing a measured level to a standard reference level). Because the differences between these two levels can be really, really big, we have to break these huge numbers down into values that are mathematical *exponents* of 10.

To begin with, finding the log of a number like 17,386 without a calculator isn't only difficult . . . in audio, it's unnecessary! All that's really important is that you memorize three simple guidelines:

- The log of the number 2 is 0.3.
- When a number is an integral power of 10 (i.e., 100, 1,000, 10,000 . . . etc.) the log can be found, simply by adding up the number of zeros.
- Numbers that are greater than 1 will have a positive log value, while those less than 1 will have a negative log value.

The first one is an easy fact: the log of 2 is 0.3 . . . this will make more sense shortly. The second one is even easier: the logs of numbers like 100, 1,000 or 10,000,000,000,000 can be arrived at by counting up the zeros. The last guideline relates to the fact that if the measured value is less than the reference value, the log will be negative.

For example:

$$\log 2 = 0.3$$

$$\log {}^{1}/_{2} = \log 0.5 = -0.3$$

and . . .

$$\log 10{,}000{,}000{,}000{,}000 = 13$$

$$\log 1000 = 3$$

$$\log 100 = 2$$

$$\log 10 = 1$$

$$\log 1 = 0$$

$$\log 0.1 = -1$$

$$\log 0.01 = -2$$

$$\log 0.001 = -3$$

All other numbers can be arrived at by using a calculator . . . however, it's unlikely that you'll ever need to know any log values, beyond understanding the "concepts" behind those that are listed above.

The dB

Now that we've gotten past this, I'd again like to break with tradition and attempt an explanation of the dB in a way that's less complex and relates more to our day-to-day needs in the sound biz.

First off, the dB is a logarithmic value that "expresses differences in intensities between two levels." From this, we can infer that these "levels" can be expressed in several units of measure . . . the most common level units are sound pressure level, voltage, and power (wattage). Now, let's look at the basic math for these three categories:

Sound-Pressure Level

Sound-pressure level (SPL) is the acoustic pressure that's built up within a defined atmospheric area (usually a square centimeter—cm^2). Quite simply, the higher the sound-pressure level, the louder the sound (Figure 2.20). In this instance, our measured reference (SPL_{ref}) is the threshold of hearing, which is defined as being the softest sound that an average person can hear. An average conversation usually has an SPL of about 70 dB, while average home stereo levels have a loudness of between 80 and 90 dB SPL. Sounds that are so loud as to be painful have SPLs of about 130 dB (10,000,000,000,000 times louder than the 0-dB reference).

We can arrive at an SPL rating by using the formula:

$$\text{dB SPL} = 20 \log SPL/SPL_{ref}$$

where SPL is the measured sound pressure in $dyne/cm^2$.

SPL_{ref} is a reference sound pressure (0.0002 $dyne/cm^2$—the threshold of hearing).

From this, I feel that the only concept that needs to be understood is the idea that SPL levels change with the square of the distance (hence the 20 log part of the equation). This means that whenever a source/pickup distance is doubled, the SPL level will reduce by 6 dB ($20 \log 2/1 = 20 \times .3 = 6$ dB SPL); as the distance is halved, it will increase by 6 dB ($20 \log 1/2 = 20 \times 0.3 = 6$dB SPL), as shown in Figure 2.21.

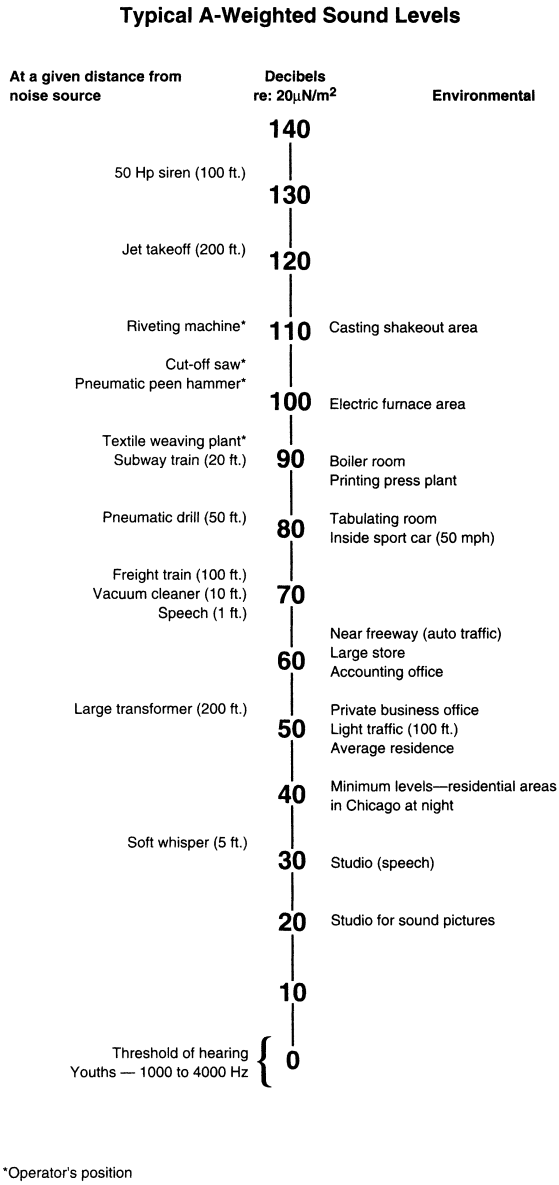

Figure 2.20. *Chart of sound-pressure levels. (Courtesy of General Radio Company)*

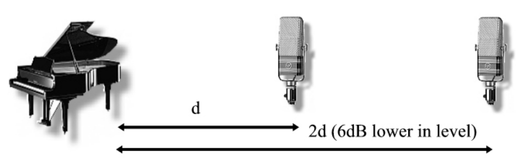

Figure 2.21. *Doubling the distance of a pickup will lower the direct signal level by 6 dB SPL.*

Voltage

As with acoustic energy, comparing one voltage level to another level (or reference level) can be expressed as dBv using the equation:

$$dBv = 20 \log V/V_{ref}$$

where:

V is the measured voltage

V_{ref} is a reference voltage (0.775 volt)

Power

Power is usually a measure of wattage or current . . . both of which are generally associated with signals that are carried throughout audio signal paths. Unlike SPL and voltage, the equation for signal level (which is often expressed in dBm) is:

$$dBm = 10 \log P/P_{ref}$$

where:

P is the measured voltage

P_{ref} is referenced to 1 milliwatt (0.001 watt = 1mW) across a 600? line

The Simple Heart of the Matter

I'm going to stick my neck out and state that, when dealing with dBs, it's far more common for working professionals to deal with the concept of power when it comes to understanding the dB. The dBm equation expresses the "spirit" of the term dB when dealing with the markings on a device or numeric values in a computer dialog box. This is due to the fact that power is the unit of measure that's most often expressed when dealing with audio equipment controls. Therefore, it's my personal opinion that the average working stiff only needs to grasp the following basic concepts, when relating the dB to audio equipment and their markings:

- A 1-dB change will be barely noticeable to most ears.
- Turning something up by 3 dB will double the signal's level (believe it or not, doubling the signal level won't increase the perceived loudness as much as you might think).
- Turning something down by 3 dB will halve the signal's level (likewise, halving the signal level won't decrease the perceived loudness as much as you might think).
- The log of an exponent of ten can be easily figured by simply counting the zeros (i.e., the log of 1000 is 3). Given that this figure is multiplied by 10 ($10 \log P/P_{ref}$) . . . turning something up by 10 dB will increase the signal's level tenfold, 20 will yield a hundredfold increase, 30 dB will yield a thousandfold increase, etc.

Most pros know that turning a level fader up by 3 dB will effectively double its energy output (and vice versa). Beyond this, it's unlikely that anyone will ever ask "Would you please turn that up a thousand times?" . . . It just won't happen. However, when a pro asks his/her assistant to turn up the gain by 20 dB, that assistant will often instinctively know what 20 dB is . . . and what it sounds like. I guess I'm saying that the math really isn't *nearly* as important as getting an instinctive "feel" for the dB and how it relates to relative levels within audio production.