Painless Decibels (almost)

By Malcolm Chisholm

The decibel system as a mathematical concept is pretty arcane, and learning the math takes a lot more effort than most working engineers have been willing to put into it.

Until quite recently, an engineer who was not involved in equipment design or modification could get through a whole studio career without knowing exactly how Decibels worked, and any number of engineers did.

They treated decibels rather like horsepower, and while that led to an occasional absurdity, getting by without really understanding the system was pretty common. That was then, however, and this is now, and life is getting tougher as equipment grows both more complex and less forgiving. As an example, digital gear is far less flexible than analog in terms of peak levels.

This is especially true of CD's with their very rigid overload characteristics. The ability to translate decibels into the real world has always been useful, if hard won, and when it can be learned without spending a lot of time and energy, it's a cheap trick.

Knowing that +12Db is 3 odd times as much as +2Db rather than 6 times as much can avoid a lot of nasty surprises during playbacks, let alone while checking test pressings, film transfers, cassettes, and the like.

The purpose of this paper is to demonstrate that with a little explanation and the use of a simple mechanical aid which is always available to a working engineer, the decibel system can be mastered very quickly. The system, however, is only half the problem.

The other half has to do with the frameworks in which decibels are used. There are five ways in which the decibel system is utilized, and the framework or reference in use is rarely if ever defined in conversation or even in general articles about sound and recording.

The context supplies the framework and reference, which is fine for someone who's familiar with the system, but of no help to the engineers who don't have decibels wired up tight.

The frameworks and standards used are listed below. The first four are for voltage measurements.

1. Gain and loss. How much more out than in for amplifiers, how much less out than in for faders, inactive equalizers, losser networks, and the like. Expressed in simple decibels. No zero reference level
2. Line level zero, used for all in line equipment. Consoles, tape machines, limiters, and such. One milliwatt across 600 ohms, .775 volts. Zero Dbm. The m stands for milli-

watt. Plus 4 is 1.23 volts. There's also a one volt DbV zero, about 2 Db above zero Dbm, but it's not used for professional units. Microphones are rated at 150 ohms. On a transformerless input, the output is as stated. An input transformer multiples voltage by the square root of it's impedance ratio. For 150 to 600 ohms, twice the mike voltage or + 6

3. Tape level zero, expressed in nano webers. Generally 165 for cassette, 185 to 200 for standard professional machines. Higher references are sometimes used, but at the cost of peak signal headroom.
4. Vinyl record level, zero at 7 centimeters per second.
5. Sound pressure level, Db SPL, a power system. Reference zero at the threshold of hearing.

With the references at hand, it's time to take a look at the decibel itself. For openers, what's a decibel?

Easy. A decibel is 1/10th of a Bel. So what's a Bel?

Also easy, but a little obscure. The Bel, named after Alexander Graham Bell, who did a lot of work besides inventing the telephone, is the volume increase needed to make something sound twice as loud. In sound pressure levels, and therefore amplifier power, one Bel equals ten times as much.

This is not only obscure, it is unsettling, in that it states that twice as loud as 100 watts is 1000 watts. It is also a fact.

Since a Bel represents an increase or decrease of ten, it's pretty much a blunt instrument, and was divided by ten to make things more manageable: hence the Deci bel, 1/10 th Bel.

So 10 decibels equal one Bel. Twice as loud, ten times the power. This accounts for the odd sounding statement Ampex made on it's alignment tapes since the 40's that average recording level is minus ten. Odd sounding it may be, but as it makes sense to record solos and leads twice as loud as the background stuff, a -10 rhythm section is a reasonable idea.

Minus ten dB is one tenth the power of zero dB, but it's a little under one third the voltage.

That's because of the power laws. Specifically, power increases as the square of the voltage and decreases as the square root of the voltage. So to double the power, increase voltage by the square root of two, or 1.414. To increase power by ten, bump the voltage by 3.16, the square root of ten.

To decrease power by two, drop the voltage to 70.7%, and by ten, to 31.62% Which brings us to the mechanical aid mentioned in the opening of this paper. It's the VU meter, and anyone working with professional audio equipment has a voltage dB to voltage ratio converter at hand.

The standard audio VU has two scales, above and below a curved line. Decibel values are numbered at -20, -10, -7, -5, -3, -2, -1, 0, +1, +2, and +3, with short lines at the intermediate values.

Modulation percentages are written as 10% 20% 30% 40% 50% etc. thru 100, with dots marking the exact percentage position on the scale.

These two scales are in very precise alignment, and constitute a Rosetta stone for voltage decibels.

Under the -2dB line is a dot for 80% Therefore -2dB is a loss of 20% of voltage. Under -6 is 50% or one-half voltage, under -12, 25% and under -20, 10% The 10 dB 70% and 3dB 30% modulation dots look to be off a bit, as the exact percentages are 70.7 and 31.62, the square roots of two and ten.

For decibel figures of less than 6dB (50%) the meter conversions work only for minus values, because 50% of something is half, but 150% is not double. For 6dB and higher, decibels work both ways. -6dB = 1:.5 and +6dB = 1:2.

Minus six is half the previous or reference voltage, and plus six is double.

There are no percentages given for the plus figures on the meter, and the first few minus decibels are not well noted, so here are the exact ratios for the first minus and plus 6dB.

+1=1.122 +2=1.259 +3=1.413 +4=1.585 +5=1.778 +6=1.995 -1=0.891 -2=0.794 -3=0.708 -4=0.631 -5=0.562 -6=0.501

With the framework and some ratios in hand, it's time to look at how the decibel system is used to express gain, loss, and relative levels.

First keep in mind that the system is not exact. None of the decibel figures come out in even ratios except 20 dB (10:1 voltage, 100:1 power). Six (2:1 voltage, 4:1 power) is very close, but a little off, and the others are all over the place. No problem, as precision's not the point. Relativity is.

6dB (plus is assumed, minus stated) is twice the voltage. 6dB is always twice the voltage. 12dB is twice 6dB, 26dB twice 20dB, and 106dB twice 100dB.

And if it's - 6dB, it's always half.

So at any level, the percentage or ratio of change is instantly apparent. Example: Working in dBV, which puts zero at one volt, +6dBV =2v and +12dBV =4v. +20dBV would be 10 volts, and +26dBV, 20 volts. +100dBV comes up at 100,000 volts, and of course +106dBV is 200,000.

The change from zero to +6 is only 1 volt, and from +100 to +106 100,000 volts, but the relative change is identical at 1:2.

Another characteristic of the system is made obvious by the above. The ratios get very big very fast as the decibels increase.

Sticking with the dBV zero and adding 6dB increments, +6=2v, +12=4v, +18=8v, +24=16v, +30=32v, +36=64v, +42=128v, +48=256v, +54=512v, and +60=1024 volts. The ratios add up fast.

Actually, 1024 is a bit off, as 6dB is not exactly double. Running the series at 20dB, the only even ratio in the system, we get +20dBV= 10v, +40dBV= 100v, (10 X 10) and +60dBV= 1000 volts. (100 X 10) +20dB is 10 times and -20 1/10th of the reference or last voltage. Always. And square on the money.

Concerning power. The system is the same, but because of the way power works, increases are made by only half the voltage figures. This is again due to the power laws. Double voltage (+6dB) yields four times power. So double power is +3, 1.414 times zero. The same thing applies to other decibel figures, as in 20dB which is 10X voltage, but 100X power. It's pretty easy, really, as power decibels are simply half the voltage figure for any given ratio. You can look at + 20 as either 10X voltage or 100X power, but VU's read voltage, and it's logical to think in voltage dB when reading levels.

Finally, a look at how to decipher existing decibel figures.

For small figures, just use the meter.

Plus or minus 2dB, as an example, is roughly 20% each way, so the tolerance is about 40% For big numbers, go to or just over the figure in twenties and sixes, and come down with the smaller increments.

With a little thought, the conversions can be done mentally. Some examples of this are given.

Gain 46 dB. 20 plus 20 plus 6. X 10, X10, X 2: 10, 100, 200. 46dB is 200 : 1
Signal to noise 58 dB. 20 + 20 + 20: 10, 100, 1000: minus 2 (80%) 800 : 1
Headroom 15 dB. 20 minus 3 minus 2 or three 6's minus 3. Either way yields 5.6 : 1

To end, we return to the beginning. This method of learning decibels is not almost painless because there's no math, which is very big plus, but because once the references are understood, the learning process is automatic during the course of work, as we all spend hours a day staring at a VU meter, and the conversions from dB to ratio seem to osmose into the mind.

Try it. You'll see.