A PRACTICAL GUIDE TO dB CALCULATIONS

This is a practical guide to doing dB (decibel) calculations, covering most common audio situations. You see dB numbers all the time in audio. You may understand that 3 dB is considered a just noticeable change in volume level. But, you haven't a clue how to figure out how to figure out what 24 dB from your mixing console means to your amplifier rated for 1.4V input sensitivity. You may be aware that dB calculations involve "logs" (logarithms). Thanks to modern technology, you can do dB calculations without knowing a thing about the mathematics of logs, anti-logs, ratios, exponents, or even much about math. Unfortunately, there is no real substitute for doing these calculations, but there is a substitute for having to figure out how to do the calculations. This article figures most of that out for you. Along the way the math is explained to some extent so that you might understand what you are doing. Some of the whys about audio calculations are also explained.

This article is necessarily long in order to cover many situations where you might need to use dB. But, if you understand the calculations, you will find that most of them repeat the same things in different ways. If you begin to see this, it means you are beginning to understand how to calculate dB.

INTRODUCTION

First, if you don't have one, you need to buy yourself a cheap scientific calculator. This should cost around £10. It MUST have several specific functions on it. One is a "Log" function. There are two common Log functions. One is "Log base e" or "natural Log" which you DON'T want. The other is "Log base 10" which is what you need. You can check if it is "Log base 10" by simply entering 10 and hitting the "Log" key. The display should read 1. If it doesn't, don't buy it. Another function you need is a 10^x function (also called 10 to the x function or the anti-log function). You can check if this is the proper function by entering 2 then hitting the 10^x key. The display should read 100. You also need a +/- (change sign) key. It must also have plus, minus, divide, multiply, and equal (=) keys. You can basically ignore the other functions on it to do dB calculations.

Once armed with this tool, you can now learn to do dB calculations. Actually, you don't really have to learn much except to push the right buttons on the calculator. In each example, you will be told exactly what calculator key to hit and what your answer should be. Once you get the right answers as shown, you can substitute your own numbers in the various examples to figure out your own things. Remember, a calculator is a DUMB device. It will only do what you tell it to do. So you MUST use your brain a bit to see if your answers make sense. This means if you come up with a number like 23841 dB or 20,000,000 watts, it is wrong. Nothing in audio has 23841 dB of anything and 20,000,000 watts is out of the question, unless you are providing sound reinforcement for Space Shuttle launches.

All the answers given in this article only show the first two digits (numbers) to the right of the decimal point. Because fractions of a dB or a watt rarely have little practical significance in audio, these two digits are shown ONLY so you know you got the right answer. The answer on your calculator may be 15.84893192 but the answer given here is 15.84. As you will see in one of the examples, chopping off digits like this can lead to slight, but not significant, errors. Note again the last digit to the right in the examples is NOT a rounded off value in the examples, but chopped off. If it was rounded off, the answer would be shown as 15.85. Most calculators can be set to display only 2 digits after the decimal point. It rounds off numbers to do this so that 15.84893192 becomes 15.85. So, if you set the calculator to do this for figuring out the examples, your last digit to the right may be 1 larger or smaller than in the examples.

For actual audio work, you should only be concerned with dB numbers to the left of the decimal point. Thus an answer of either 15.84 or 15.85 dB should be rounded off to 16 dB when stating the result.

For each example calculation, the actual formula being used for the calculation is also shown in red. The actual calculation procedure is in blue.

The most common "Log" calculations you need are: dB to voltage, voltage to dB, voltage gain to dB, dB to voltage gain, calculating SPL for distances, and converting amplifier watts to SPL changes or SPL changes to amplifier watts. Therefore, these are the only examples given. With a little brainwork, you may be able to apply the example calculations to figure out other things.

DEFINITIONS

Some definitions you need to know:

Any dB value is a RATIO, meaning it represents one number divided by another. If you simply state something in dB then you are only stating the ratio in between one thing and another. So you might say the difference in two voltages is 6 dB but that only means one voltage is twice the other (6 dB = 2 times voltage). It doesn't tell you anything about the actual voltages.

If you want to state the actual value of something in dB, most common audio calculations have a 0 dB reference value that is indicated by suffix (a letter or letters following dB). The 0 dB reference value is always used as one of the numers for the ratio. You should always use a suffix when stating the dB of something as an actual value so that anyone else will know what 0 dB reference is. So when you say your mixer is putting out + 6 dB, you really need to say + 6 dBu or whatever the 0 dB reference is. Thus +6dB means you have twice as much voltage while +6 dBu means you have 0.775 volts or 1.55 volts.

For electronic calculations (voltage and wattage) the 0 dB references are:
0 dBu (or dBv) = 0.775 volts
0 dBV = 1 volt
0 dBm = 1 milliwatt (0.001 watts). The standard reference value for 0dBm is 0.775 volts into a load of 600 Ohms. For most audio calculations, simply assume you are NOT using a 600 Ohm load and thus dBm can equal dBu. For example, a +24 dBm output specification on a mixing console can be used as +24 dBu to calculate voltages. The reason for this is that modern audio equipment will put out the same voltage whether there is a "load" on it or not. Thus knowing the power in a line level audio circuit is of little value and simply complicates what you need to know.

Example: 6 dBu is the *ratio* of some voltage divided by 0.775 volts. That voltage is 1.55 volts.

For SPL (Sound Pressure Level) calculations the 0 dB reference is:
0 dB SPL = 0.0002 pascals (a pascal is a measure of pressure, in this case air pressure, just like a meter is for distance).

Example: 100 dB SPL is the *ratio* of some sound pressure to 0.0002 Pascals. That pressure is 20 Pascals

These are the symbols used in the formulas:
"x" means multiply
"/" means divide
"^" This symbol indicates what follows is an exponent of the number preceding it. An exponent means "raised to the power of", as in 10^2 is 10 raised to the power of 2 or more simply stated as "10 squared". With dB calculations you get "funny" powers like 10^(34/20). Spelled out this is "ten to the power of thirty four divided by twenty". Don't be afraid of this. The instructions and your trusty calculator will get you through it without having to fully

understand it.
"( )" in the formulas means that everything inside the parenthesis is calculated first to come up with a single number. In the first example below, (24/20) is calculated first to come up with 1.2. Then 10 is raised to the power of 1.2.

dBu TO VOLTAGE

How many volts does a mixing console put out with a maximum rating of +24 dBm? Although rated in dBm you can "change" this, as stated above, to dBu for this calculation. Using you new calculator you need to find out how many volts +24 dBu is above 0 dBu.

Formula: Volts = 10^(dB/20) x volts @ 0 dBu or 10^(24/20) x 0.775

Enter 24 (dBu)
Hit the divide key
Enter 20
Hit the = key
Your answer should be 1.2
Hit the 10^x key.
Your answer should be 15.84
Multiply this by 0.775
Your final answer should be 12.28 volts

The reason you multiply by 0.775 is that any dB number is always a RATIO (one number divided by another). So 15.84 is the numerical ratio of +24 dBu to 0 dBu. Put another way the voltage at +24 dBu is 15.84 times bigger than 0.775 volts so you must multiply 0.775 by 15.84. The 15.84 is used as a multiplier and will be called this from now on. However, to be mathematically correct, this multiplier is actually a ratio representing one number divided by another.

dBv TO VOLTAGE

Suppose the output was rated as +24 dBv? What would its voltage be?

Formula: Volts = 10^(dB/20) x volts @ 0 dBv or 10^(24/20) x 1

Enter 24 (dBv)
Hit the divide key
Enter 20
Hit the = key
Your answer should be 1.2
Hit the 10^x key.
Your answer should be 15.84
Multiply this by 1
Your final answer is, of course, still 15.84 volts

In this case +24 dBv is 15.84 times larger than 1 volt.

GAIN

Your amplifier puts out 70V with a 1.4V input. How much gain does it have?

Formula: dB = 20 x Log (volts1/volts2) or 20 x Log (70/1.4)

Enter 70 (volts1)
Hit the divide key
Enter 1.4 (volts2)

Hit the = key
Your answer should be 50.00
Hit the Log key
Your answer should be 1.69
Hit the multiply key
Enter 20
Hit the = key
Your answer should be 33.97 dB gain

Suppose you only knew your amplifier had 33.97 dB voltage gain (we'll round this up to 34 dB). What would its maximum output voltage be?

Formula: Multiplier = 10^(dB/20) or 10^(34/20)

Enter 34 (dB)
Hit the divide key
Enter 20
Hit the = key
Your answer should be 1.7
Hit the 10^x key
Your answer should be 50.11

The voltage at the output will be 50.11 times bigger than the voltage at the input. (Note: this number appeared during the first calculation for this amplifier as 50.00 but we rounded up the gain from 33.97 dB to 34 dB.)

Take the next step. The input sensitivity on the amplifier is 1.4 volts.

Formula: Volts Out = Multiplier x Volts In or 50.11 x 1.4

With the 50.11 (multiplier) still displayed, hit the multiply key
Enter 1.4 (volts in)
Hit the = key
Your answer should be 70.16 volts

Thus, your amplifier will put out 70.16 volts with a 1.4 volt input with the input control at maximum. If you wanted to put 8 volts in your amplifier it will clip unless you turn the input control down. But, your control is marked in dB, so how far do you turn it down? Not a problem to figure out. Read on.

VOLTAGE TO dB

The question is what is the difference in dB between 1.4 volts and 8 volts?

Formula: dB = 20 x Log (volts1/volts2) or 20 Log (1.4/8)

Enter 1.4 (volts1)
Hit the divide key
Enter 8 (volts2)
Hit the = key
Your answer should be 0.17
Hit the Log key
Your answer should be -0.75
Hit the multiply key
Enter 20
Your answer should be -15.13 dB

So guess what? Turn your input control down to the -15 dB point and now when you put 8 volts in, the amplifier will put out its full 70.16 volts. Why? Back to the calculator.

You amplifier has 34 dB gain. You turn your input control down 15 dB so now it effectively has 34 dB - 15 dB = 19 dB gain between the input jack and the output.

Formula: Multiplier = 10^(dB/20) or 10 ^ (19/20)

Enter 19 (dB)
Hit the divide key
Enter 20
Hit the = key
Your answer should be 0.95
Hit the 10^x key
Your answer should be 8.91

Your output will now be 8.91 times bigger than the input. Your input is 8 volts so multiplying 8 times 8.91 gives you 71.30. Well, that's not exactly the 70.16 volts we got before. Why? Because the numbers were chopped off in these calculations. If you used the numbers with all the digits, the answer would have come out as 70.16621271 volts which is the precise answer arrived at previously. Is this difference significant? No. You can find out why it isn't by using the next example calculation to find the dB difference between 71.30V and 70.16V.

Suppose you have one device that has a maximum 15.5 volt output and the device you wish to drive with it accepts a maximum input of only 7.75 volts. What is the dB difference?

Formula: dB = 20 x Log (volts1/volts2) or 20 x Log (15.5/7.75)

Enter 15.5 (volts1)
Hit the divide key
Enter 7.75 (volts2)
Hit the = key
Your answer should be 2
Hit the Log key
Your answer should be 0.30
Hit the multiply key
Enter 20
Hit the = key
Your answer should be 6.02 dB

The output of the first device is 6 dB more than what the second device can accept.

You'll notice that in the first voltage to dB calculation you ended up with a minus dB number and in this one a plus or positive dB number.

+dB AND -dB

In the last example, if you used the formula 20 x Log (7.75/15.5), your answer would be -6.02 dB. It simply depends whether a larger number is divided by a smaller one (answer is always +dB) or a smaller one is divided by a larger one (answer is always -dB). The basic number will be the same no matter which way you divide. Try reversing the 7.75 and 15.5 in the last example. You should get -6.02 as the answer. Also, if you calculated the dB difference between the 71.30V and the 70.16V for the amplifier outputs, you would have gotten 0.139 dB or -0.139 dB, depending on which number you divided by which. This is why the difference was not significant: you can not hear a 0.139 dB difference.

The main reason for dividing a smaller by a larger number when calculating dB is to figure out the LOSS in dB. You will see this in the SPL and amplifier calculations below.

VOLTS TO dBu or dBv

You have a device that puts out 8.8 volts. What is that in dBu?

Formula: dBu = 20 x Log (volts1/volts2) or 20 x Log (8.8/0.775)

Enter 8.8 (volts1)
Hit the divide key
Enter 0.775 (volts2)
Hit the = key
Your answer should be 11.35
Hit the Log key
Your answer should be 1.05
Hit the multiply key
Enter 20
Hit the = key
Your answer should be 21.10 dBu

To find dBv simply substitute "1" for "0.775" in the calculation. Your answer should be 18.88 dBv.

SPL CALCULATIONS

You do SPL calculations using exactly the same formulas as for voltages. Both SPL and voltages are "pressures" and the factor "20" is used for both.

Your loudspeaker puts out a maximum of 120 dB SPL at 3.3 feet = 1 meter. What is the SPL at 60 feet?
First, you must understand that SPL drops 6 dB for each doubling of distance. Why is this? Calculate the multiplier for a pressure change of 6 dB.

Formula: Multiplier = 10^(SPL/20) or 10^(6/20)

Enter 6 (dB SPL)
Hit the divide key
Enter 20
Hit the = key
Your answer should be 0.3
Hit the 10^x key
Your answer should be 1.99 = about 2

So the multiplier for a 6 dB SPL change is 2. This means if you move twice as close to the loudspeaker, it will be 6 dB louder.

Now recalculate this using another function on your calculator called the change sign key. This changes a number in the display from a plus to a minus number.

Formula: Multiplier = 10^(-SPL/20) or 10^(-6/20)

Enter 6 (dB SPL)
Hit the "+/-"
Your display should change to -6 (dB SPL)
Hit the divide key
Enter 20
Hit the = key
Your answer should be 0.3

Hit the 10^x key
Your answer should be 0.50 = 1/2

So the multiplier for a -6 dB SPL change is 1/2. This means if you move so you are only 1/2 as close (meaning twice as far) to the loudspeaker, the SPL is 6 dB less.

Back to the problem. Your are 60 feet away and you know what the SPL is at 3.3 feet = 1 meter. You already know this should be a -dB number so you are going to divide the small number by the big one. Distances are equivalent to voltages so you simply divide the two distances. You can do this for any two distances and substitute the SPL at one of the distances for the Max SPL in this example. If this SPL is for the further distance, you must divide the further by the nearer distance. Always divide the distance you are finding the SPL for into the distance for which you know the SPL. Otherwise, you will find your answer will not make sense, such as having more SPL at a further distance. Sound just doesn't seem to work this way.

Formula: dB SPL = Max SPL + (20 x Log (distance1/distance2)) or 120 + (20 x Log (3.3/60)

Enter 3.3 (distance1)
Hit the divide key
Enter 60 (distance2)
Hit the = key
Your answer should be 0.055
Hit the Log key
Hit the multiply key
Enter 20
Hit the = key
Your answer should be -25.19
Hit the + key
Enter 120
Hit the = key
Your answer should be 94.80 dB SPL

Note: the SPL formula is only valid outdoors and for the direct sound from the loudspeaker indoors. Indoors the reverberation of the room will take over at some distance from the loudspeaker and the sound level will remain more or less constant the further you move away. This is a subject beyond the scope of this article, but it will at least give you a rough idea of what to expect indoors.

AMPLIFIERS

There are really only two dB calculations you generally need for amplifier outputs. One is how many dB SPL is there between two wattage levels. The other is what is the difference in watts you need to achieve a given change in dB SPL. Because amplifier watts are power, that number 20 you've been using thus far in the calculations changes to 10 for doing the "log" calculations. Otherwise, the formulas are the same. Through a quirk in mathematics, you can use the dB answers you get when calculating differences in wattages as representing the change in SPL from the loudspeaker. While this is not mathematically correct, it is a perfectly practical thing to do. Substitue some other numbers in the following example, such as 2 watt and 4 watts. Then use 2000 watts and 4000 watts. You will find the answer is exactly the same (but the price tags are definately not!!).

WATTS TO dB (or Watts to SPL)

You have a 100W amplifier and want to change to a 350W amplifier. How many more dB will you get out of your loudspeaker?

Formula: dB = 10 x Log (watts1/watts2) or 10 x Log (350/100).
Note the larger number is divided by smaller will give you +dB. You DO expect higher SPL, don't you?

Enter 350 (watts1)
Hit the divide key
Enter 100 (watts2)
Hit the = key
Your answer should be 3
Hit the Log key
Your answer should be 0.54
Hit the multiply key
Enter 10
Hit the = key
Your answer should be 5.4 dB

This is the power difference in dB between these amplifiers. If you were going from a 350W to a 100W, the answer would be -5.4 dB as the smaller number would be divided by the larger. Try it.

You could go through correct mathematical conversions, but because we are being practical, the SPL from your loudspeaker will be 5.4 dB greater with the 350W amplifier than the 100W amplifier. Or, it will be -5.4 dB less using a 100W amplifier instead of a 350W amplifier.

dB TO WATTS (or SPL to Watts)

Suppose you want to increase your SPL by 8 dB and you have 100 watts to start with. How many more watts would this take?

Formula: Multiplier = 10^(dB/10) or 10^(8/10)

Enter 8 (dB)
Hit the divide key
Enter 10
Hit the = key
Your answer should be 0.8
Hit the 10^x key
Your answer should be 6.30

So you need 6.30 times as many watts to get an 8 dB SPL increase. How many watts is that?

Formula: New Watts = Multiplier x watts or 6.3 x 100

Enter 6.3 (multiplier)
Hit the multiply key
Enter 100 (watts)
Hit the = key
Your answer should be 630W

Thus, if you start with 100W, you need 630W to increase your SPL by 8 dB.

SUMMARY

The above examples should give you valuable tools you need to calculate dB in the most of the ways you need for audio signals. Use them wisely.