The Decibel - dB or not dB?

If an Ohm is the place where a Volt lives, Watt is dB said for current? Does it live in a bun?

Joking aside, the subject of the meagre decibel is one of major confusion - maybe not amongst the really professional audio community, but out there in the end user market. Specification sheets are abound, quoting input and output specifications in **dBm**, **dBV**, **dBu** etc. but what do they actually mean?

What is a Decibel?

We all know about Volts, Amps, Ohms, Feet, Inches etc. but what is a Decibel?

It may interest you to know that, in fact, as an actual unit of measurement the Decibel doesn't exist !!!

So, what the hell is it?

The text books will tell you that a Bel is defined as "the common logarithm of a power ratio". Effectively it is an expression of the "ratio of two powers". Calculating these ratios in Bels generally gives numbers less than 1, so for power measurements, to make our numbers more meaningful we multiply the Logarithm by 10 to give us whole numbers that are easier to write and understand. For voltage measurements, due to the relationships between voltage,current and power, we have to multiply the Logarithms by 20.

To explain the idea of ratios, take a simple analogy :

X: <---more about this later….

You are standing at the bottom of a hill. You can measure that the gradient of the hill can be expressed by saying "if I move forward by 2 metres, the actual distance **up** with reference to ground level is 1 metre".

In basic terms, every 2 metres you move forward takes you another 1 metre higher. Using this example, it is easy to calculate that if you move forward by, say 6 metres, you actually raise yourself higher by 3 metres i.e. you can express the ratio of this expression as 2:1 .

With me so far ? If not, go back to **X:**

Expressions in Decibels use exactly the same analogy. Let's say we want to calculate the gain through a piece of equipment. You start with a reference point. Let's say **1 Volt**. We then put a 1 Volt signal into the device under test and measure what comes out of it. If, for example, the output is measured to be 2 volts then it's easy to see that we have a gain of 2. OK so far?

So how is this 2 Volt measurement expressed as a Decibel figure?

It's actually quite simple. Since the Decibel is a representation of a ratio, the Decibel figure represents the difference between the reference figure (in the case above, 1 Volt) and the measured value (in our case, 2 Volts). If you represent the difference in Volts you can easily see that the difference is just 1 Volt but a Decibel is not a linear expression. i.e. you cannot simply add or subtract the levels, they must be calculated because the relationship between the two levels is a Logarithmic one.

For voltage levels (that's what we're interested in here) the calculation is as follows :

Difference in dB = 20 * (LOG(measured voltage/reference voltage))

For the non-technical it's 20 times the LOG of the "measured voltage divided by the reference voltage".

For our example, substituting the figures : 20 * (LOG(2/1)) gives an answer of 6 dB (ignoring any figures to the right of the decimal point).

From this we can deduce that a "*doubling of voltage gives us a 6dB increase*".

So, Is This dBm, dBV, dBu, dBx?

Let's discount dBx - that's the trade mark of a very successful company specialising in noise reduction systems (- see where the link is?)

Let's also (for the moment) ignore dBm - more on this later.

Here's how it works. The figure after the "**dB**" tells you what the reference is.

For dBV, the reference is 1 Volt.

For dBu, the reference is 0.775 Volts.

Therefore if you see, say, an amplifier specification sheet stating "sensitivity = +6dBu) this simply means that to get the amplifier to full output you have to put in a signal 6dB above the 0.775V reference ('cos it has a little "u" after the dB). Calculating this up into real units (volts) gives us 1.55 volts.

If the sensitivity figure was 6 **dBV** , this would mean 6dB above the 1 Volt reference. Calculating this up gives us 2 volts.

These slight differences are only 2 dB, but 2dB of amplifier power is a LOT when you realise that doubling amplifier power only results in a 3dB increase in loudness! This means that our amplifier with the sensitivity rated in dBu would produce nearly TWICE as much output as the other one with the same input level.

NOW ARE YOU CONFUSED ? (Banged your head on the table yet?)

It doesn't take much to realise that the best way to represent amplifier sensitivity is to quote the sensitivity in real units i.e. Volts. That way there can be no confusion.

With amplifiers, the only figure you really need to know is what input voltage is required to produce maximum output. With other equipment, you're not really interested in the output of the device as such but you need to know its input parameters so that when you connect a load of these bits up together you don't have mismatch occurring. After all, you don't want to connect up say, three bits of kit only to find that when the signal comes out of the last device it has drastically reduced in level.

0dB Or Not 0dB .....

Most signal processing has input or output gain adjustment so this usually isn't a problem from the actual audible level point of view but it can make a drastic difference when reading the meters on each device.

Don't be fooled - a reading of 0 dB on each of the meters can easily be up to **4dB** out depending on what the reference for each piece of kit is. Aha! Are things starting to become clearer? They soon will.

If your mixer's "**0 dB**" indication is referenced to 0.775 Volts then at 0.775 Volts output, the meters will read "0". This makes sense.

If your next piece of processing is referenced to 1 Volt (for 0dB) then the meters on this one will <u>only</u> read 0 if you take the signal to 1 Volt - not 0.775 Volts.

Also, some units have a sensitivity button on the back that enables you to select 0 or +4 dB sensitivity.

If the +4 button is pressed , the meters on this one will only read 0 if the input reaches 1.23 Volts!

Using one each of these bits of kit and adjusting levels to give you 0 on each of the meters you'll start at 0.775 volts and get a hell of a lot more out at the other end!

This is why it is important to understand the relationship between the different specifications. What if, in the example above, you had the last piece of kit connected to an amplifier with a 0.775V sensitivity?
Although your meters read 0dB, if the last device is rated for "0" at +4dBu, you are actually putting out 1.23 Volts which will cause the amplifier to go into clip and probably burn out your loudspeakers! You'll call your amplifier manufacturer saying that you're only running at 0 and it's toasted your loudspeakers. How wrong you can be!

dBm

So, with trepidation, we move to dBm. A quick explanation is all that's necessary.

In the early days when transformers were extensively used in audio systems, the dBm was used to express power as an audio level.

The reference **power** for this unit is 1mW (one milliwatt). These days it is common to assume that 1 dBm represents 0.775 Volts into a 600 ohm load. Note that the dBm is "load dependent" because the reference unit is a power level, not merely a voltage.

In the days where input impedances were often 600 ohms, the dBm was a valid expression to use but these days transformer inputs are not so widely used so specification is rarely seen expressed in dBm. It can be useful, when looking at mixer output specifications. If the output level is expressed in dBm then you can be sure that the mixer output stage is indeed capable of high output drive capabilities as it can drive low impedance loads (at least down to 600 ohms) because the specification actually says so.

For most bits of kit, you can, if you think carefully about the application treat a dBm figure as a dBu figure as the voltage reference is the same, but bear in mind that the dBm figure is only absolutely true when measured into its specified load. Just as an aside to throw a spanner in the works, the voltage reference and the load can be <u>any value</u> just as long as together they represent 1mW (0.001 Watts)!

Those not technically minded - STOP here!

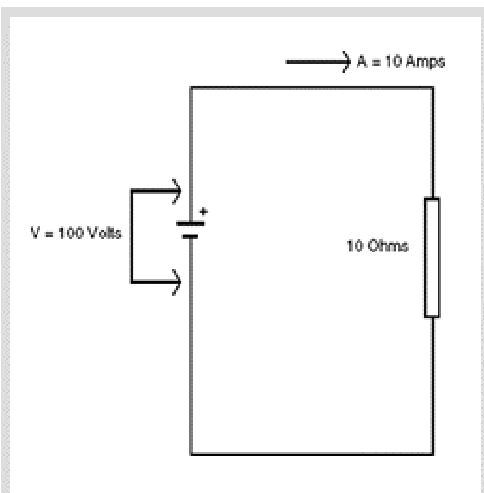
As I was writing this piece it occurred to me that some smart alec would eventually ask the question :

"Why, when measuring power does a doubling of power constitute a 3dB increase when doubling of voltage constitutes a 6 dB increase? Why when measuring power do we use 10 Log(P1/P2) and when measuring voltage do we use 20 Log (V1/V2)?"

Anyone want to know?..............

I just knew there would be someone!

I'll try to keep this simple (it seems to be bloody impossible)!



Refer to Figure on the left

Using Ohm's law the power in the load resistor can be calculated using several equations:

Where
P = Power in watts
I = Current in Amps (10A)
V = Voltage in Volts (100V)
R = Load resistance in ohms (10)

P = I x V = 10 x 100 = 1000 W
or
$P = V^2/R$ = (100 x 100) / 10 = 1000W or
$P = I^2 \times R$ = (10 x 10) x 10 = 1000 W
So using the values shown in Figure, the calculated power seems to be beyond doubt - 1000 Watts.

If the load impedance stays the same (i.e. 10 ohms) and we now double the voltage to 200 Volts what happens ?

Calculating the power in the load by V^2/R gives (200 x 200)/10 = 4000 Watts.

As you can see, doubling the voltage quadruples the power not doubles it. (If you do some further calculations you will see that the current doubles too). This new power value corresponds to a 6dB increase in power not a 3dB increase as you might expect.

So, to the maths. Calculating scenario 1 (voltage at 100V) versus scenario 2 (voltage at 200V) gives us the following formula :

Level change = $10 \times LOG((V2^2/R)/(V1^2/R))$

Quick Note: Putting V2 and V1 in these positions gives us a positive number. If we were to transpose these we'd get a negative number instead (i.e -dB instead of +dB).

As R does not change, this resolves to :

Level Change = $10 \times LOG (V2/V1)^2$

Which is the same as :

$20 \times LOG (V2/V1)$

Putting in our figures, the formula becomes :

$20 \times LOG(200/100)$ which is .... +6dB !

Questions on a postcard.....

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