The Decibel Unit of Measurement

©1999 by Ron Roscoe, MIT Department of Electrical Engineering & Computer Science

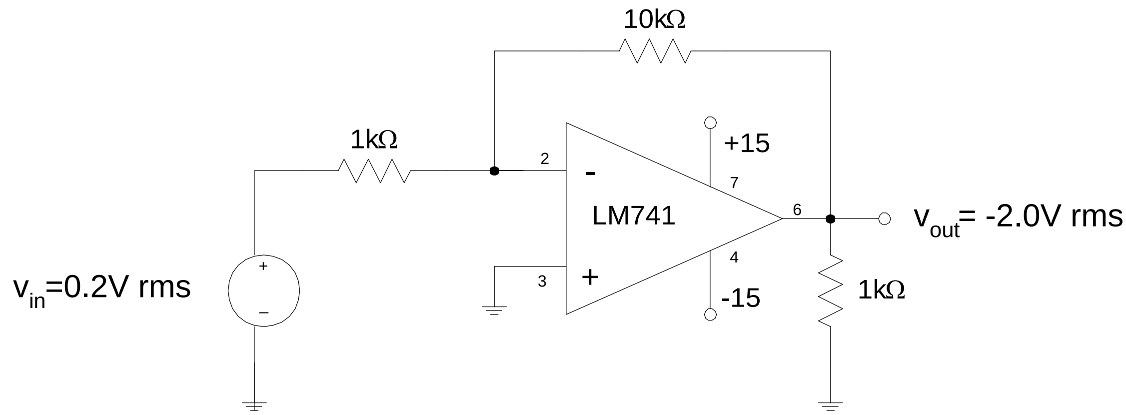
Course 6.101: Introductory Analog Electronics Laboratory

Voltage, power, [or current] gain can be expressed as a pure ratio or as a decibel value. The original unit was the Bel, named after Alexander Graham Bell, and was used in telephone work. One-tenth [deci-] of the original unit is more appropriate for modern use.

The original intent was to compare power gains or losses in communications circuits, at a time when power was a much more valuable commodity than it is today. Thus the power gain of a system is expressed as:

$$dB = 10\ \log_{10} \frac{P_{OUT}}{P_{IN}}$$

The power gain of the following system is calculated as follows [remember that pin 2 of the op-amp is at ac ground potential]:



$$dB = 10 \log_{10} \frac{P_{OUT}}{P_{IN}} = \frac{\frac{2.0^2}{1k}}{\frac{0.2^2}{1k}} = \frac{2.0^2}{0.2^2} = 20 \log_{10} \frac{2.0}{0.2} = 20 \log_{10} 10 = 20dB$$

Since the input and output load resistances are equal, they cancel, and the equation reduces to:

$$dB = 20 \log_{10} \frac{V_{OUT}}{V_{IN}}$$

If the input and output impedances were not equal, it would be appropriate to calculate the voltage gain using the equation directly above, but it would not give the correct power gain. It is perfectly acceptable to use the dB to express voltage [or current] ratios without consideration of power and resistance [impedance] levels, as long as it is understood that it will not be possible to calculate power gain from the voltage gain value.

Modern usage of the decibel concept has evolved to include several types of decibel "unit" that have built-in reference values. These values take the place of the V_{IN} or P_{IN} values in the denominators of the equations above. Some of the most often used referenced decibel units are:

dB UNIT	reference	application
dbV	1 Volt rms	routine voltage measurements [comparisons!]
dBm	1 mW into 50Ω [0.224V] or 600Ω [0.775V]	radio-frequency [50Ω] or audio [600Ω] power measurements [in England, the dBu is used to mean 0.775V reference without regard to impedance or power]
dB mV	1 millivolt rms	signal levels in cable systems
dbW	1 Watt	audio power amplifier output [usually into 8, 4, or 2Ω impedances]
dBf	1 femtowatt [10^{-15} watt]	communications and stereo receiver sensitivity [usually 50Ω, 75Ω unbalanced, or 300Ω balanced antenna input impedances]
dBSPL	0.0002μbar, = 20μPa [=Pascals] [1 bar = 10^6 dynes/cm^2 ~1AT]	Sound Pressure Level measurements: the reference is the "threshold of hearing".

To find the total gain of a string of amplifier stages, we MULTIPLY the raw gain ratios together to get the total gain, but we ADD the dB values together to get the total gain. [Adding logs equals multiplication.]

When a voltage is doubled in a circuit [impedance levels held constant], the gain changes by +6dB. When the voltage is halved, the gain changes by -6dB. When the power is doubled in a circuit [impedance levels held constant], the gain changes by +3dB. When the power is halved, the gain changes by -3dB. So, if I sell my 100-watt per channel power amplifier and buy one that puts out 200 watts per channel, each channel can only play 3 dB louder than the old amplifier could. [Actually, +6dB louder in the room, if the outputs from both speakers add directly, which isn't always the case. However, it would be true on average for music waveforms.] Average power on music waveforms is way below the peak capabilities of a power amplifier. One buys more power per channel to be able to increase the average power level in the room a little, while still having enough headroom in the amplifier to avoid clipping the amp on the loud peaks.] To increase the power level by 10 dB, your new power amplifier would need to put out 1000 watts per channel!!!

Power bandwidth in an audio amplifier is defined as the band of frequencies lying between the low frequency and the high frequency at which the power just drops to -3dB relative to the mid-frequency power output, usually referenced to 1kHz, and <u>*at a constant distortion*</u>. [3dB is the amount of power level change that the untrained ear can just perceive. Trained listeners can perceive level changes of about 1 dB.] If you are changing or observing just voltage, then the -3dB points occur at 0.707 of the reference or midband voltage, which again, for audio work, is usually 1 kHz.

Frequency response is usually plotted on a semi-log graph, with the horizontal axis being $\log_{10}$ frequency and the vertical axis being linear, usually in dB [which gives a log scale anyway!].