



Audio Engineering

An Online Continuing Education Course for Engineers

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Audio Engineering

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1. Introduction

Since sound is such a part of our daily experience, it seems to me that we ought to know a little more about it. We all hear things, but how does that happen? It all seems so natural and easy until sound is no longer perceived by an individual who loses their hearing. That doesn't mean that the sound is not there. We'd like to know what happened to someone who can no longer hear. Then, there is also the issue of where does the sound go? We will explore some ideas of what happens to sound. And, we have our own opinions of what sounds good and what doesn't sound good. There is actually a frequency response that sounds good on our amplified equipment. When the product of the low frequency cutoff times the high frequency cutoff is 450,000 it sounds good. There seems to be no reason for this, but it makes sense that our typical amplifier has a frequency response of from 20 to 20,000 cycles per second. And then, what are the levels of sound, and how are they measured? These are some of the questions that will be answered as we study the phenomena of sound.

2. First, What Is Sound?

An interesting experiment that I have done is to take the cover of a low frequency dynamic speaker (often called a woofer) and watch it move. At about 15 cycles per second (people now use the term "Hertz", but I prefer to use cycles per second because it gives more information) you can watch the speaker cone move in and out. Look at Figure 2.1.

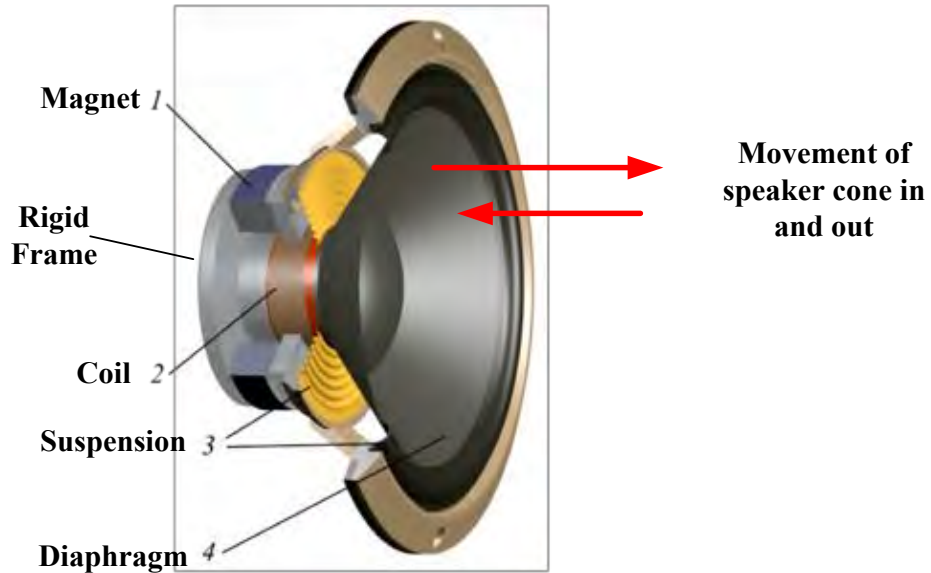


Figure 2.1 Picture of an Audio Speaker Showing Movement of Speaker Cone

The speaker cone is entirely suspended by flexible membranes at the top and bottom of the cone. The coil is attached to the cone and floats in a magnetic field created by the permanent magnet. When current flows through the coil, it causes a force to be exerted and the cone moves forward or backward, depending on the direction of current flow. It looks simple enough. There is a pressure change and also a movement of air. The movement of the cone actually causes an air pressure increase or decrease. Let's look at how much pressure change and air movement is involved and how these items are measured and how distance affects sound level measurements. Maybe it's not all that simple. Wait until we get to how the hearing mechanism actually works in the human body.

A standard symbol of a speaker is shown in Figure 2.2.

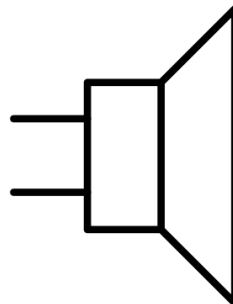


Figure 2.2 Standard Symbol for a Speaker

3. Bels, Decibels, and Logarithms

Since sound level measurements are usually given in decibels (dB) let's first look at the basic definition of logarithms. The shortened form "log" is often used in the place of the word "logarithm".

$$\log_{10}X = Y \text{ means that } 10^Y = X$$

Since audio measurements are usually given in logarithms using the base 10, that is what we are using throughout this paper. Logarithms have the property of compressing data. As an example, let's let X take on values from 1 to 10,000. That's a pretty wide range. But the log of 1 is 0, and the log of 10,000 is 4. So the former range of 1 to 10,000 is now only a range of 0 to 4. We have compressed the data range of 1 to 10,000 (X in our example) to a range of 0 to 4 (Y in our example). As a matter of interest, the log of 0 is undefined. This can be seen by trying to find an exponent (Y) in the above equation that will make X have the value 0. The following chart shows the logarithms of some numbers from 1000 to 0.001. Notice that X does not take on the value of 0. This will be used later to show gains of various audio components in terms Bels and decibels. This is very important when doing frequency response where the log of the frequency is often used on the X axis and gain in either voltage gain or dB is used on the Y axis.

X, the number that we are taking the logarithm of, can get smaller and smaller, but never goes to 0 or becomes negative or goes below 0. **This particular property is useful in determining power gains and pressure ratios, neither of which cannot be thought of in terms of being 0 or negative.** We can have a power gain of less than one, but not zero. The same is true of pressure ratios, which will be useful when we talk about what sound really is.

Figure 3.1 shows graphically why the use of logarithms can be useful. The chart shows the logarithms of gains of 0.001 to 1000. This range of a million to one is not unusual in the audio world. It can also happen in the electronic world where voltage and power gains of a million are common. The data for the two graphs is the same, except that the straight line the log of the gain is used. It is much easier to get information from the straight line log graph than it is to get information from the linear graph. At gains of less than 1 it is almost impossible to see any difference between gains of 0.001 and 1, or even 10.

$\log_{10} X = Y$	
X (Gain)	Y {log(Gain)}
1000	3
100	2
10	1
1	0
0.1	-1
0.01	-2
0.001	-3

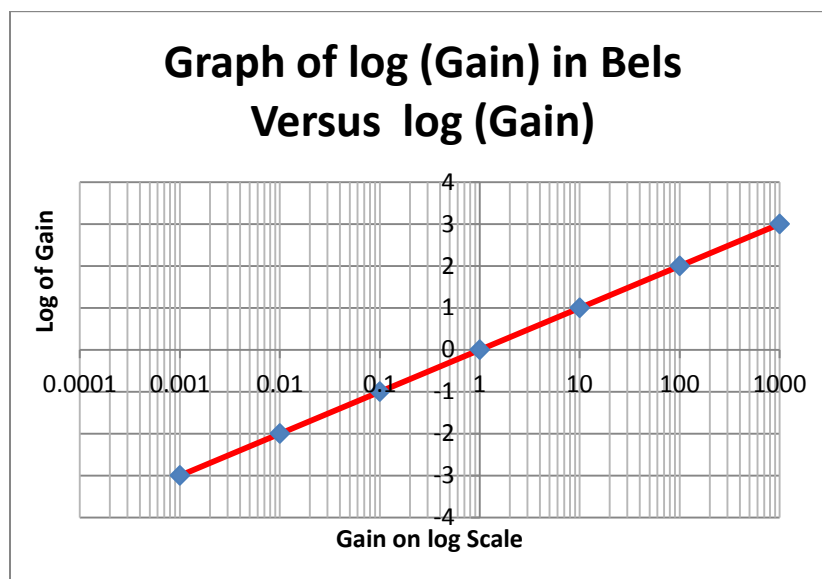
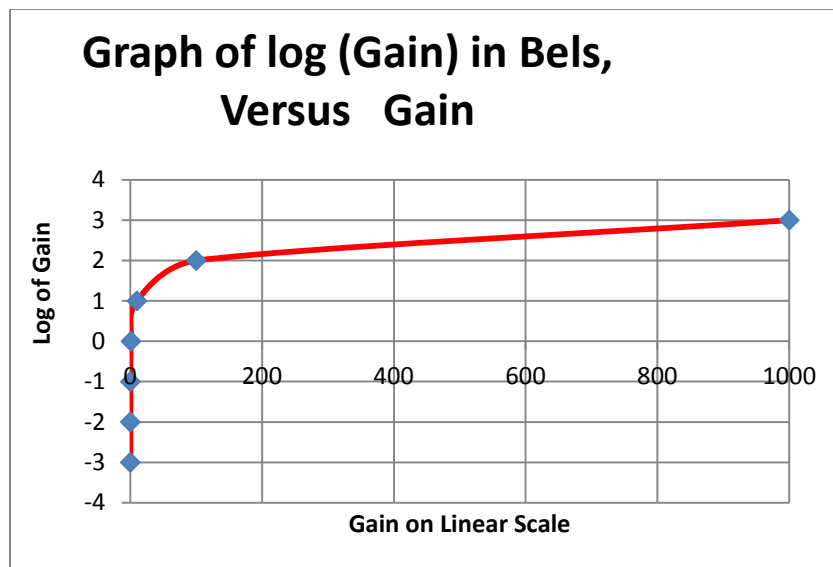


Figure 3.1 Chart Showing Logarithms of Numbers from 0.001 to 1000 and 2 Graphs Showing 2 Ways to Look at the Same Data

This leads to the definition of a power ratio, the Bel. A Bel is defined as the logarithm of a power ratio.

$$\text{Bel} = \log_{10} (P_{\text{out}}/P_{\text{in}})$$

P_{out} and P_{in} are the output and input powers of a device. The speaker that we talked about in Section 2 can have an input electrical power and an output audio power. This will come later, but for now we note that the basic unit of measurement is the logarithm of a power ratio. As

such, it is dimensionless. If the output power is 0, talking about gain is meaningless, and the Bel is undefined. And if we get an output power with 0 input power, the ratio is undefined, and the unit of measurement, the Bel is again meaningless. For the Bel to have a real meaning, the power ratio must be non zero and positive.

And now, for the definition of the commonly used expression, the Decibel, often abbreviated as dB.

This may be confusing. If we have a power gain of 100 (100 = 2). But a Bel gain of 100 is a dB gain of 20. There are 10 dB in a Bel. So if you call me and we'll work on this.

Audio power measurement is in terms of pressure. And, in both sound level measurements and pressure phenomenon.

4. Sound Level Measurement

Since this is about audio, the concept, "The Threshold of Hearing" is defined at a certain frequency, 1000 cycles per second. This makes sense because the typical human hears the frequency range of 1000 to 5000 cps better than higher and lower frequencies. Then to make this even more artificially generated, the Threshold of Hearing is said to be the sound level of a mosquito buzzing at a distance of 3 meters from the ear perceiving the mosquito. This is used as the reference value. It is often given the symbol "p". Here are three ways of looking at p.

$$\rho = 20 * 10^{-6} \text{ Pa}$$

$$\rho = 0.0002 \text{ dynes / cm}^2$$

$$\rho = 3 * 10^{-9} \text{ pounds / inch}^2$$

$$\rho = 0 \text{ dB}$$

