Amplitude and deciBels

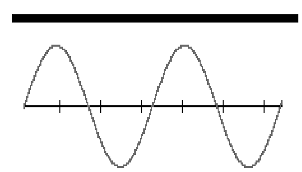
What is Amplitude?

- The amount of “displacement” of a waveform
- Amplitude in audio is also called “Loudness”
- Changes in loudness create “Dynamics”
- Change in amplitude in electronics is “Gain”

What are the levels associated with amplitude?

- Peak Level
- Nominal Level
- Noise Floor

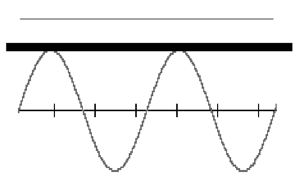
Peak Level



- The greatest possible level within the system.

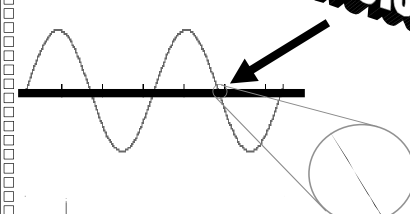
Note: Some measurements are from negative to positive: these are called “Peak-To-Peak Measurements.

Nominal Level



- The level of the measured signal within the system.

Noise Floor

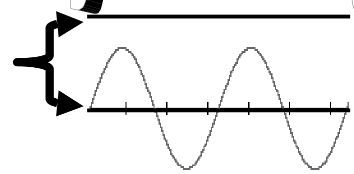


- The lowest measurable signal within the system.

Amplitude Relationships

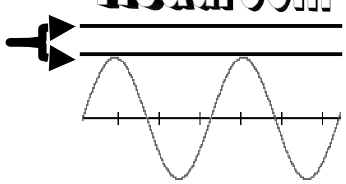
- Dynamic Range
- Headroom
- Signal-to-Noise (S/N) ratio

Dynamic Range



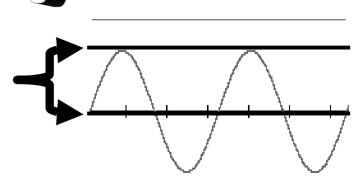
- Difference between the PEAK level and the NOISE FLOOR

Headroom



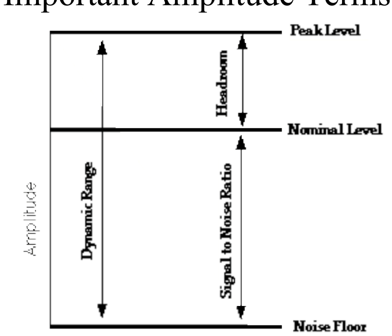
- Difference between the PEAK level and the NOMINAL LEVEL

Signal-to-Noise Ratio



- Difference between the Nominal Level and the Noise Floor

The Important Amplitude Terms



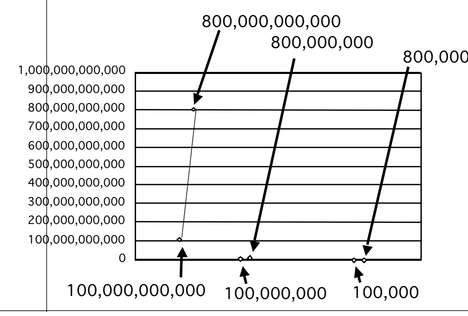
Measuring Amplitude

- Range of human hearing is huge:
- Largest Sound is a TRILLION times the displacement of the softest sound.
- Ear, However, hears various amplitudes in terms of the RATIO between the two sound levels.

Hearing Power Ratio

- Threshold of hearing 1/trillionth of a watt
- Threshold of pain 1 watt
- Huge ratio, unwieldy numbers

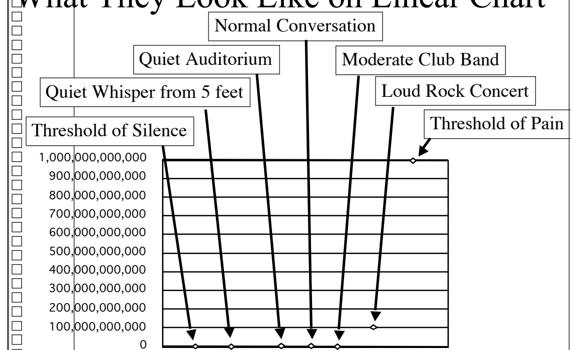
Clumsy Number Values



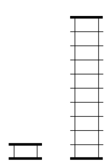
Some sound levels using normal numbers

One	Threshold of Silence
One Thousand	Quiet Whisper from 5 feet
Ten Thousand	Quiet Auditorium
One Million	Normal Conversation
One Billion	Moderate Club Band
One Hundred Billion	Loud Rock Concert
One Trillion	Threshold of Pain

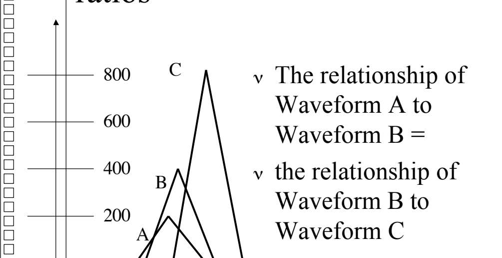
What They Look Like on Linear Chart



The ear hears a ten times power increase as only a doubling of loudness



So, the ear hears relationships as ratios



- The relationship of Waveform A to Waveform B =
- the relationship of Waveform B to Waveform C

Ratios

- Audio is therefore interested in ratios.
- How much louder/softer is this than that?

$$\frac{this}{that}$$

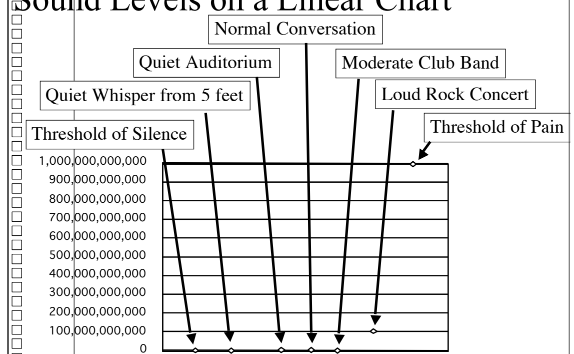
What we want in an audio amplitude measurement system

- Not have to work with cumbersome numbers
- Handle value ranges in the trillions.
- Logarithms are the solution

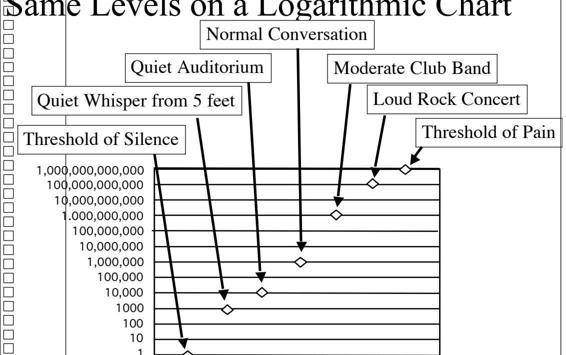
Why logarithms?

- Big range of numbers can be represented by more reasonable numbers
- Logs model the way the ear responds to loudness

Sound Levels on a Linear Chart



Same Levels on a Logarithmic Chart



First, a review of scientific notation

$$x \bullet 10^{n}$$

Some Scientific Notation Conversions

500 = $5.0 * 10^{2}$

6,000,000 = $6.0 * 10^{6}$

200,000,000 = $6.0 * 10^{8}$

40,000,000,000 = $4.0 * 10^{10}$

The Important Value for logs is the Exponent

$$x \bullet 10^{n}$$

What is a logarithm?

- The power to which a number must be raised to equal another number

$$number = base^{\exp onent}$$

$$100 = 10^{2}$$

$$anti\log = base^{\log}$$

Logarithm Example

- The power to which a number must be raised to equal another number

$$\log_{base} number = \exp onent$$

$$\log_{10} 100 = ?$$

$$\log_{10} 100 = 2$$

Another view of logs for math brains: What we have is a way to express MULTIPLICATION using ADDITION

Note that multiplying the number by 10 is the same as adding 1 to the exponent

$$3 \bullet 10^{2} = 300$$

$$3 \bullet 10^{3} = 3000$$

Multiplying the number by 1000 is the same as adding 3 to the exponen

$$3 \bullet 10^{2} = 300$$

$$3 \bullet 10^{5} = 300,000$$

Audio relationships

- Thus, we will always say "Waveform A is x greater than Waveform B"
- We will express these as a ratio

$$n = \frac{\text{Waveform A}}{\text{Waveform B}}$$

The Bel

- The Value of n, expressed as a log, is a measurement of relative acoustic amplitude called a Bel

$$n = \frac{\text{Waveform A}}{\text{Waveform B}}$$

$$Bel = \log(n)$$

Bels

- Power ratios of large audio quantities.
- Named after Alexander Graham Bell

$$\text{relative power} = \log_{10}\left(\frac{P1}{P0}\right)$$

Why use dB's?

- Bels too coarse
- dB's correspond to the way ears work
- Sound Levels are always measured as a RATIO to each other
- There is no such thing as an absolute amplitude
- Even Acoustic Pressure is Measured against the threshold of Silence

deciBels—Power

$$Bels = \log_{10}\left(\frac{P1}{P0}\right)$$

DeciBel is 1/10th of a Bel, so there are 10 times as many bels, so the equation is:

$$deciBels = 10\log_{10}\left(\frac{P1}{P0}\right)$$

Sample deciBel calculation: Hearing Range

$$deciBels = 10\log_{10}\left(\frac{P1}{P0}\right)$$

$$10\log_{10}\left(\frac{1W}{.000000000001W}\right) = ?dB$$

$$10\log_{10}(1{,}000{,}000{,}000{,}000) = ?\,dB$$

$$10 * 12 = ?\,dB$$

$$10 * 12 = 120dB$$

If Waveform A is 10x the Power of Waveform B

$$?\,dB = 10 \bullet \log(\tfrac{A}{B}) \quad A = 10B$$

$$= 10 \bullet \log(\tfrac{10B}{B})$$

$$= 10 \bullet \log(10)$$

$$= 10 \bullet 1$$

$$= +10dB$$

If Waveform A is 2x the Pressure of Waveform B

$$?\,dB = 10 \bullet \log(\tfrac{A}{B}) \quad A = 2B$$

$$= 10 \bullet \log(\tfrac{2B}{B})$$

$$= 10 \bullet \log(2)$$

$$= 10 \bullet .3$$

$$= +3dB$$

The decibel formula for pressure

$$dB = 20 \bullet \log(\frac{V_a}{V_b})$$

Sound Pressure Level (SPL)

- 0 dB SPL = Threshold of hearing Pressure of 0.0002 dynes/cm^2

dB SPL Examples

- Quiet recording studio = 20 dB SPL
- Suburban Home at night = 50 dB SPL
- Street traffic = 90dB SPL
- Loud classical music 100dB SPL
- Rock concert 90-120dB SPL

Other dB References (you don't need to remember this!)

- 0 dBm = 1mW (at 600 Ohms)
  - Relative power.
  - Slightly archaic.
- 0 dBu = .775 Volts
  - Same as dBm at 600 Ohm
- 0 dBV = 1 Volt
- 0 dBv = .775 Volts

Common dB Interface levels

- -10dBV is consumer line level
- +4dBm is professional line level (usually balanced)
- You do need to remember this.

dB ear rules of thumb

- 0dB is no change
- 3dB is just barely louder, and represents a doubling of power
- 10dB is twice as loud, and represents 10 times as much power
- Remember these!