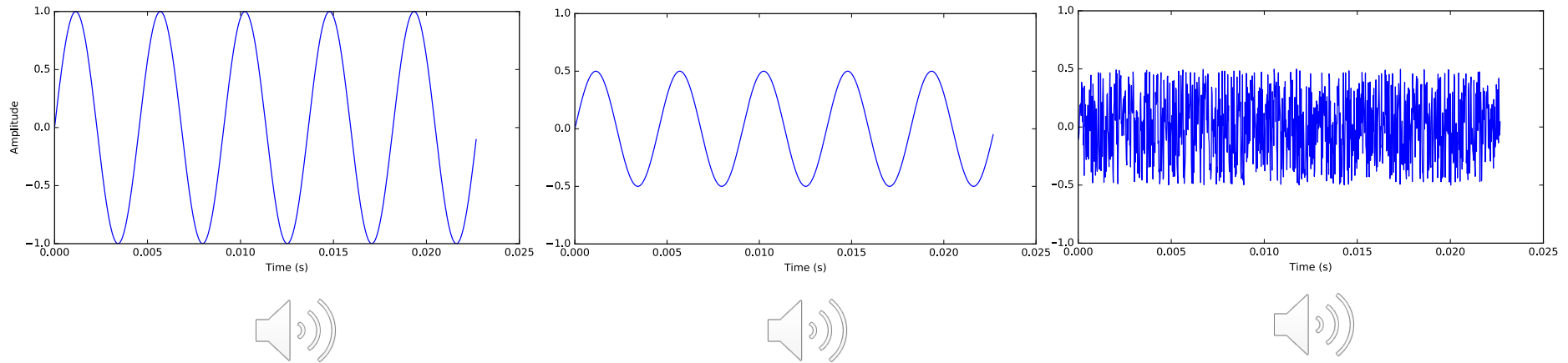


Topic 2

Amplitude

Which is louder?



How do we tell how “loud” it is?

- Instantaneous value?
- Average value?
- Something else?
- What is our basis of comparison?

Voltage and Power

Let $x(t)$ = voltage at time t

$$P(t) = \frac{x^2(t)}{R}$$

↑
Instantaneous
power

← Resistance, measured in Ohms

Average Power

- A measure of the average value of the signal

$$\bar{P} = \frac{1}{T_D} \int_0^{T_D} dt P(t)$$

$$\bar{P} = \frac{1}{T_D} \int_0^{T_D} dt x^2(t) / R$$

Root Mean Squared Amplitude

$$\frac{x_{RMS}^2}{R} = \bar{P} = \frac{1}{T_D} \int_0^{T_D} dt x^2(t) / R$$

- For convenience, we assume a resistance R of 1 Ohm.

$$x_{RMS}^2 = \bar{P} = \frac{1}{T_D} \int_0^{T_D} dt x^2(t)$$

$$x_{RMS} = \sqrt{\frac{1}{T_D} \int_0^{T_D} dt x^2(t)}$$

Root Mean Squared Amplitude

In the digital world, our integral becomes a sum...

$$x_{RMS} = \sqrt{\frac{1}{T_D} \sum_0^{T_D} x^2(t)}$$

Sound Pressure Level (SPL)

- Softest audible sound intensity
 $0.00000000000001 \text{ watt/m}^2$ (intensity measure)
- Threshold of pain is around 1 watt/m^2
- 12 orders of magnitude difference
- A log scale helps with this
- The Bel scale is a log scale, with respect to a reference value

The deciBel

- A logarithmic measurement that expresses the magnitude of a physical quantity (eg power or intensity) relative to a specified *reference level*.
- Since it expresses a ratio of two (same unit) quantities, it is dimensionless

$$\begin{aligned} L_1 - L_{reference} &= 10 \log_{10} (I_2 / I_{reference}) \\ &= 20 \log_{10} (x_{rms,2} / x_{rms,reference}) \end{aligned}$$

Typical Values

- Jet engine at 3m 140 db-SPL
- Pain threshold 130 db-SPL
- Loud motorcycle, 5m 110 db-SPL
- Vacuum cleaner 80 db-SPL
- Quiet restaurant 50 db-SPL
- Rustling leaves 20 db-SPL
- Human breathing, 3m 10 db-SPL
- Hearing threshold 0 db-SPL

Information from S. S. Stevens, F. Warshofsky, and the Editors of Time-Life Books, *Sound and [Hearing](#)*, Life Science [Library](#), Time-Life Books, Alexandria, VA, 1965, p. 173.

Lots of references!

- **dBV** is the level compared to 1 Volt RMS. $0\text{dBV} = 1\text{V}$.
- **dBu** is the level compared to 0.775 Volts RMS with an unloaded, open circuit.
- **dBm** is the power level compared to 1 mWatt. This is a level compared to 0.775 Volts RMS across a 600 Ohm load impedance. Note that this is a measurement of *power*, **not** a measurement of *voltage*.
-
- **dbFS** - relative to digital full-scale.
- **dB SPL** - A measure of sound pressure level. Not related to voltage at all.

The deciBel

- A logarithmic measurement that expresses the magnitude of a physical quantity (eg power or intensity) relative to a specified *reference level*.
- Since it expresses a ratio of two (same unit) quantities, it is dimensionless

$$\begin{aligned} \textit{Level} &= 10 \log_{10} \left(\bar{P} / \bar{P}_{\textit{reference}} \right) \\ &= 20 \log_{10} \left(x_{\textit{RMS}} / x_{\textit{RMS_REFERENCE}} \right) \end{aligned}$$

Full-Scale deciBel

- ***dB FS (dBVU)***

- The VU (or Volume Unit) = 100% of the legal modulation for the particular radio station.
- For tape recorders 0 dBVU means mean the recommended operating point for the tape in use.
- For digital recordings 0 VU is the maximum allowable signal.
- Values typically negative.

Which is louder?

