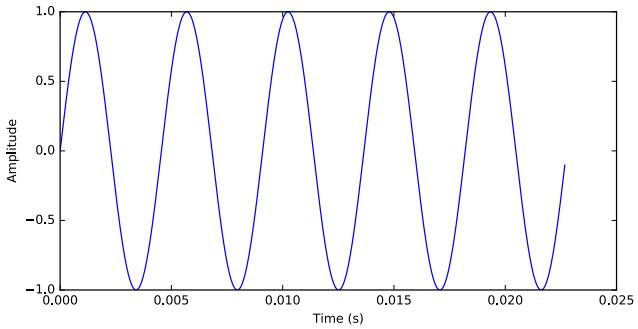
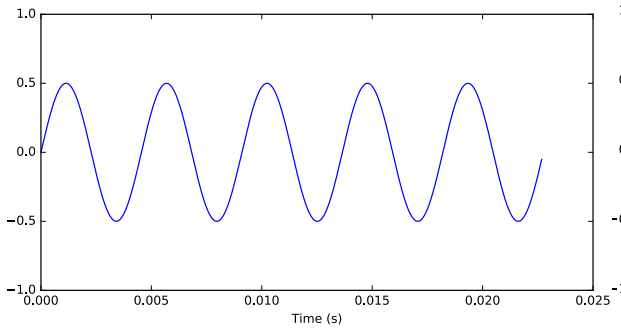
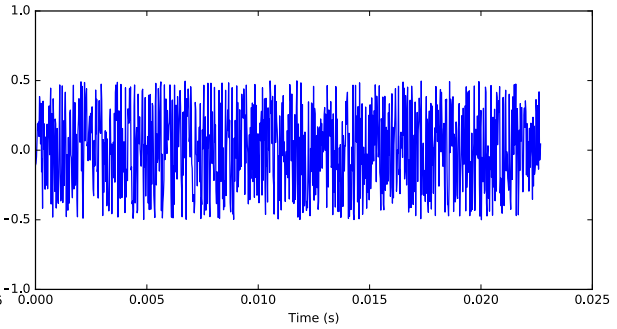
# Topic 2

## 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 0.000000000001 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

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

# 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. 0dBV = 1V.
- **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*.
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- **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

$$Level = 10\log_{10}(\bar{P} / \bar{P}_{reference})$$

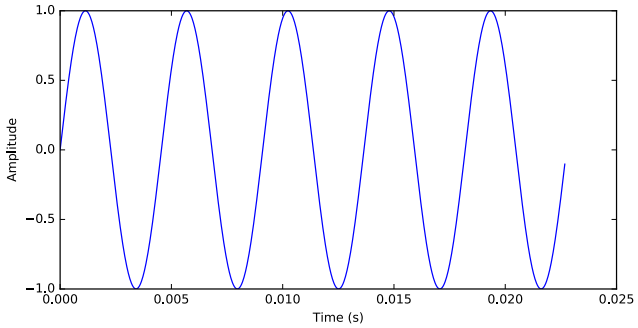
$$= 20\log_{10}(x_{RMS} / x_{RMS\_REFERENCE})$$

# Full-Scale deciBel

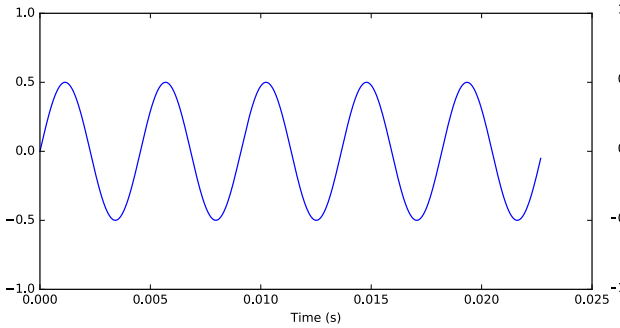
- ***dB FS  (dBVU)***
  - The VU (or Volume Unit) = 100% of the legal modulation for the particular radio station.
  - For tape recorders 0 dBVU means mean the recommended operating point for the tape in use.
  - For digital recordings 0 VU **is** the maximum allowable signal.
  - Values typically negative.

# Which is louder?

-3 dB FS




-9 dB FS




-11 dB FS