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 $t$

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

Resistance, measured in Ohms

Instantaneous power
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 (e.g., power or intensity) relative to a specified reference level.

• Since it expresses a ratio of two (same unit) quantities, it is dimensionless

\[ L_1 - L_{\text{reference}} = 10 \log_{10} \left( \frac{I_2}{I_{\text{reference}}} \right) \]

\[ = 20 \log_{10} \left( \frac{x_{\text{rms},2}}{x_{\text{rms},\text{reference}}} \right) \]
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

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.

- 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 (e.g., power or intensity) relative to a specified reference level.
- Since it expresses a ratio of two (same unit) quantities, it is dimensionless

\[
Level = 10 \log_{10} \left( \frac{P}{P_{\text{reference}}} \right) = 20 \log_{10} \left( \frac{x_{\text{RMS}}}{x_{\text{RMS\_REFERENCE}}} \right)
\]
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

EECS 352: Machine Perception of Music and Audio
Bryan Pardo 2008