Topic 1

Recording & Sampling
The Edison Cylinder Recorder
Recording sound

Mechanical Vibration
Pressure Waves
Motion->Voltage Transducer
Voltage over time
Microphones

Cross-Section of Dynamic Microphone

- Sound Waves
- Diaphragm
- Audio Signal
- Wires carrying electrical audio signal
- Magnet
- Coil
- Diaphragm
Magnetic tape

**Recording**

Audio signal is sent through the coil of wire to create a **magnetic field** in the core.

At the gap, magnetic flux forms a **fringe pattern** that magnetizes the oxide on the tape.

**Playback**

The motion of the tape pulls a varying magnetic field across the gap.

This creates a varying magnetic field in the core and therefore a signal in the coil.

This signal is amplified to drive the speakers.
Digital Sampling

Digital sampling involves converting a continuous signal (amplitude over time) into a discrete representation. The diagram illustrates the process with a graph showing the relationship between amplitude and time, indicating how samples are taken at regular intervals and then quantized to a finite number of levels. The reconstructed signal is depicted as a red line, showing how the sampled data points are connected to represent the original signal. The quantization increment refers to the range of values that each sample point can represent, impacting the fidelity of the reconstructed signal.
More quantization levels mean more dynamic range
Bit depth and dynamics

- More bits = more quantization levels
- More quant. levels = more dynamic range
- More dynamic range = better sound

- Compact disc = 16 bits = 65,536 levels
- POTS = 8 bits = 256 levels
Faster sample rates = better reconstruction

![Graph showing amplitude over time with sample interval marked.](image-url)
Aliasing and Nyquist
Aliasing and Nyquist
Sample rates

• You can’t reproduce things if your sample rate isn’t fast enough to catch them

• Nyquist frequency (def 1)
  Over twice the frequency of the highest frequency you want to represent

• Nyquist frequency (def 2)
  \( \frac{1}{2} \) the sample frequency…
Common Encodings

• Compact Disc
  – 16 bits
  – 44,100 Hz

• POTS (Plain old telephone service)
  – 8 bits
  – 8,000 Hz

• MP3
  – It’s complicated. Tell you later.
Pure Tone = Sine Wave

\[ x(t) = A \sin(2\pi f t + \phi) \]

- time
- amplitude
- frequency
- phase
Reminders

- Frequency, $f = \frac{1}{T}$ is measured in cycles per second, AKA Hertz (Hz).

- One cycle contains $2\pi$ radians.

- Angular frequency, $\omega$, is measured in radians per second and is related to frequency by $\omega = 2\pi f$.

- So we can rewrite the sine wave as $x(t) = A \sin(\omega t + \phi)$.
Alternate Representation

![Graph showing a sine wave on the AMPLITUDE vs. TIME axes.](image)

- **AMPLITUDE**
  - Y-axis labels: -1, -0.8, -0.6, -0.4, -0.2, 0, 0.2, 0.4, 0.6, 0.8, 1
  - Values range from -1 to 1

- **TIME**
  - X-axis labels: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
  - Values range from 0 to 100

- **Frequency**
  - Single point on graph

- **Phase**
  - Circular representation

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EECS 352: Machine Perception of Music and Audio
Bryan Pardo 2008
Complex Tone = Sine Waves

220 Hz

660 Hz

1100 Hz

Bryan Pardo 2008
Alternately

![Amplitude vs Time Graph]

![Amplitude vs Frequency Graph]
Harmonic Sound

- 1 or more sine waves
- Strong *components* at INTEGER MULTIPLES of a *FUNDAMENTAL FREQUENCY* in the range of human hearing (20 Hz to 20,000 Hz)

**Examples**

- $220 + 660 + 1100$ is HARMONIC
- $100 + 220 + 263$ is NOT HARMONIC
Noise

- Lots of sines at random freqs. = NOISE
- Example: 100 sines with random frequencies, such that $100 < f < 10000$
A Fun Example (Thanks to Robert Remez)