BAIN MUSC 336
Introduction to Computer Music

HOW DIGITAL AUDIO WORKS

> "Any sound in digital form…is just a series of numbers. Any arithmetic operation performed with those numbers becomes a form of audio processing."
>
> – Cycling '74, *How Digital Audio Works*

Reading
Cycling '74, MSP: How Digital Audio Works," Available online at: <https://docs.cycling74.com/max8/tutorials/02_mspdigitalaudio>.

Terms & Concepts

Sound
Vibrating objects
Oscillation
Atmospheric pressure
Compression/rarefaction
Momentum and inertia

Simple Harmonic Motion
Tuning fork
Pendulum

Mathematical model
Sine function:
$y = A \sin(2\pi ft + \phi)$

Waveform (A vs. t)
Amplitude: A
Frequency: f
Phase: ϕ
Time: t

Periodic waveform
Simple tone
Complex tone

Plucked string physical model
Multiple resonant modes of vibration
Fixed endpoints
Nodes
Length (L), density, and tension
Integer divisions of L

Spectrum (A vs. f)
Harmonic
Nearly harmonic
Inharmonic
Closely-spaced

Timbre
Individual amplitude levels and trajectories
Instrumental tone color
Timbral perception

Harmonic series
As a chord/scale of nature
Fundamental frequency
Integer multiples
Partials, harmonics & overtones
Harmonic partials
Fusion
Octave
Fourier theory

Amplitude Envelope
Stages: Attack (A), Decay (D), Sustain (S) and Release (R)
Unipolar vs. bipolar signal

Inharmonic tones and noise
Non-integer multiples
Inharmonic partials
White noise
Randomness
Band-limited noise

Units
Hertz (Hz)
Decibels (dB)

Range of Human Hearing
ca. 20 Hz to 20,000 Hz

Digital Representation of Sound
Continuous vs. discrete
ADC and DAC
Sample and hold
Sampling rate (44.1k, 48k, etc.)
Clipping
Low-pass filter
Instantaneous amplitude values
Resolution
Bit depth
- 16-bit amplitude values
- $2^{16} = 65{,}536$

Quantization
- Staircasing
- Quantization error
- Quantization noise

Signal-to-quantization noise ratio (SQNR)
Nyquist theorem
- Nyquist rate ($R/2$)
- Aliasing, or foldover

Digital signal processing (DSP)
$y = A \sin(2\pi fn/R + \phi)$

where n is the sample number (0, 1, 2, 3, …), and R is the sampling rate.

$$dB = 20 \log_{10}(A / A_{ref})$$

If $A = 0.5$ & $A_{ref} = 1$;

$$20 \log_{10}(0.5 / 1) = -6\ dB$$

Reference
Cycling '74. 2021. *Max 8 Documentation*. Available online at: <https://docs.cycling74.com/max8/>.