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/max7/tutorials/02_mspdigitalaudio>.

Terms & Concepts

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

Physical models
Simple harmonic motion
Pendulum
Tuning fork
Plucked string

Mathematical model
Sine function:

$$y = A \sin(2\pi f x + \phi)$$

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

Waveform (a vs. t)
Amplitude: a
Frequency: f
Phase: ϕ
Time: t
Periodic waveform

Simple vs. complex tone

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
Noise
- White noise

Randomness
- Pseudo-randomness

Band-limited noise

Range of Human Hearing
20 Hz to 20,000 Hz

Units
Hertz (Hz)
Decibels (dB)

Digital Representation of Sound
Continuous vs. discrete
Transducer
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 (sr/2)
- Aliasing, or foldover

Storage: 10 MB per min. for CD quality audio

Digital signal processing (DSP)

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

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

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

Reference

Cycling '74. 2015. *Max 7 Documentation*. Available online at: <https://docs.cycling74.com/max7/>.