

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

<p>Sound Vibrating objects Oscillation Atmospheric pressure Compression/rarefaction Momentum and inertia</p> <p>Physical models Simple harmonic motion Pendulum Tuning fork Plucked string</p> <p>Mathematical model Sine function: $y = A \sin(2\pi fx + \phi)$</p> <p>Plucked string physical model Multiple resonant modes of vibration Fixed endpoints Nodes Length (L), density and tension Integer divisions of L</p> <p>Waveform (a vs. t) Amplitude: a Frequency: f Phase: ϕ Time: t Periodic waveform</p> <p>Simple vs. complex tone</p>	<p>Spectrum (a vs. f) Harmonic Nearly harmonic Inharmonic Closely-spaced</p> <p>Timbre Individual amplitude levels and trajectories Instrumental tone color Timbral perception</p> <p>Harmonic series As a chord/scale of nature Fundamental frequency Integer multiples Partial, harmonics & overtones Harmonic partials Fusion Octave Fourier theory</p> <p>Amplitude Envelope Stages: Attack (A), Decay (D), Sustain (S) and Release (R) Unipolar vs. Bipolar signal</p> <p>Inharmonic tones and noise Non-integer multiples Inharmonic partials Noise - White noise Randomness - Pseudo-randomness Band-limited noise</p>	<p>Range of Human Hearing 20 Hz to 20,000 Hz</p> <p>Units Hertz (Hz) Decibels (dB)</p> <p>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</p> <p>Storage: 10 MB per min. for CD quality audio</p> <p>Digital signal processing (DSP)</p>
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$$dB = 20 \log_{10}(A / A_{ref})$$

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

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

Reference

Cycling '74. 2019. *Max 8 Documentation*. Available online at: <<https://docs.cycling74.com/max8/>>.