



Frequency, Sampling, Nyquist, and Spectra

<https://musicreason.com/resources/frequency-sampling-nyquist-and-spectra/> · Last updated 2026-09-06

A sample rate, an FFT spectrum, and a harmonic series are all useful evidence about a digital signal, but each carries its own resolution limit and assumptions that have to stay visible for the evidence to mean what you think it means.

The Nyquist limit, at your own sample rate

At 44,100 Hz, the Nyquist limit is 22,050 Hz, and 1024 samples last about 23.2 ms.

A digital system needs at least two samples per cycle to represent a waveform unambiguously, so the highest representable frequency is always exactly half the sample rate. [Sample Rate and Nyquist Explorer](#) and [Samples to Milliseconds Calculator](#) both build directly on this fixed relationship.

Frequency resolution and time resolution trade off

A longer FFT analysis window gives finer frequency resolution but blurs together events that happen close together in time; a shorter window does the reverse. [Spectrum Viewer](#) and [Spectral Peak Finder](#) cannot escape this tradeoff, they can only choose a specific point on it and state that choice.

Bit depth sets an ideal dynamic-range ceiling

[Bit Depth Dynamic Range Explorer](#) reports the theoretical dynamic-range ceiling a given bit depth allows (about 6.02 dB per bit); real-world noise floor and converter quality can keep an actual recording well under that ideal ceiling.

A spectrum shows frequency content, not source identity

[Harmonic Spectrum Explorer](#) shows which frequencies are present in an idealized waveform and how strong each is; identifying a specific instrument or sound source from a spectrum shape is a separate, much less certain inference this site does not claim to make.

Frequently asked questions

Why is the highest representable frequency always half the sample rate?

This is the Nyquist limit: a digital system needs at least two samples per cycle to reconstruct a waveform unambiguously, so at a 44.1 kHz sample rate the highest representable frequency is 22.05 kHz, exactly half.

Does a higher-resolution FFT spectrum show more detail for free?

No, there is a real tradeoff: a longer analysis window gives finer frequency resolution but coarser time resolution (it blurs together events that happen close in time), and vice versa for a shorter window. Spectrum Viewer and Spectral Peak Finder cannot escape this tradeoff, only choose a point on it.

Can a spectrum alone identify what instrument or sound source produced it?

No. A spectrum shows which frequencies are present and how strong they are; identifying a specific instrument or source from that shape is a separate, much less certain inference this site does not claim to make.

Where this shows up

PRODUCTION AND AUDIO MATH

Sample Rate and Nyquist Explorer

PRODUCTION AND AUDIO MATH

Samples to Milliseconds Calculator

PRODUCTION AND AUDIO MATH

Bit Depth Dynamic Range Explorer

AUDIO ANALYSIS

Spectrum Viewer

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Spectral Peak Finder

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Harmonic Spectrum Explorer