

The Nyquist rule, the frame-rate math, and which rate to use per product.

The one rule (Nyquist)

Sample more than twice the highest frequency you want to keep.

$2 \times 20,000 \text{ Hz} = 40,000 \text{ Hz} = 40 \text{ kHz}$ minimum for human hearing.

Why 44.1 vs 48 kHz

44.1 kHz A 1970s video-tape storage accident; the CD enshrined it. Music still uses it.

48 kHz Divides cleanly into video frame rates, so audio stays locked to picture.

Samples per video frame (24 fps)

$48,000 / 24 = 2,000$ whole number -> clean sync

$44,100 / 24 = 1,837.5$ fractional -> drift over time

96 / 192 kHz — when they help

- Help during recording/editing: filter headroom + room for distortion harmonics.
- Do NOT improve playback: blind tests show no audible gain above 48 kHz.
- Cost is real: 96 kHz = 2x data & CPU; 192 kHz = 4x. Deliver at 48 kHz.

Which rate by product

Your situation	Use	Why
Real-time calls (WebRTC, telemedicine)	48 kHz	Native to Opus + OS audio stack
Video streaming / OTT / e-learning	48 kHz	Matches frame rates & YouTube default
Pure-music app (44.1 kHz catalogue)	44.1 kHz	Avoids one lossy resample
Studio capture with heavy effects	96 kHz	Headroom; deliver downsampled to 48
Archival master	96 kHz/24-bit	High-resolution preservation grade
Voice-only narrowband (legacy)	8 / 16 kHz	Set by the codec (G.711, Opus NB)