

Solutions

2.1

- $f_s/2M = 48/4 = 12$ kHz – everything above 12 kHz would fold.

2.2

- Images at multiples of 8 kHz around the original band: 8 kHz and 16 kHz (baseband copies centred there).

2.3

- $48/44.1 = 160/147$: $L = 160$, $M = 147$ (the classic ratio).

3.1

- Stages: low-pass below $f_s/2M = 4$ kHz, then keep every 4th sample ($M = 4$).
- Output rate $32/4 = 8$ kHz ✓.
- Everything above 4 kHz (the new Nyquist) folds onto the kept band – aliasing is permanent, so the fence goes up first.
- Filtering after the drop cannot undo the fold: the aliases are already inside the band – it only removes what was already destroyed.

3.2

- Naive: $200 \times 48\,000 = 9.6$ M multiplies/s.
- Polyphase: $200/6 \approx 33$ effective taps per subfilter input at 8 kHz – total $200 \times 8\,000 = 1.6$ M/s ✓ one sixth.
- Zero-stuffing loses a factor $L = 6$ of amplitude: the filter needs a passband gain of 6 (or scale by L after).
- Polyphase is bookkeeping, not approximation: the same multiplies against the same coefficients, regrouped by which input samples can ever reach which output samples.