

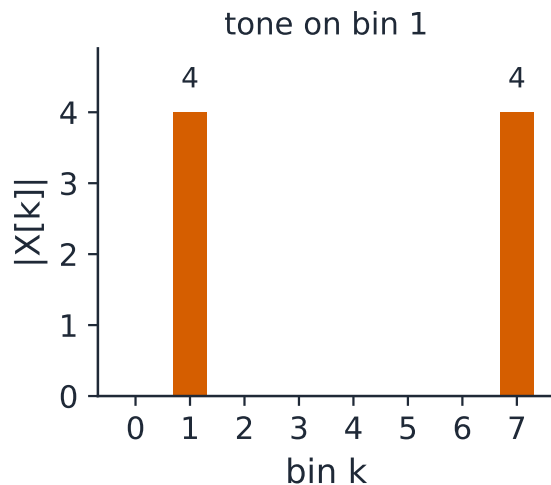
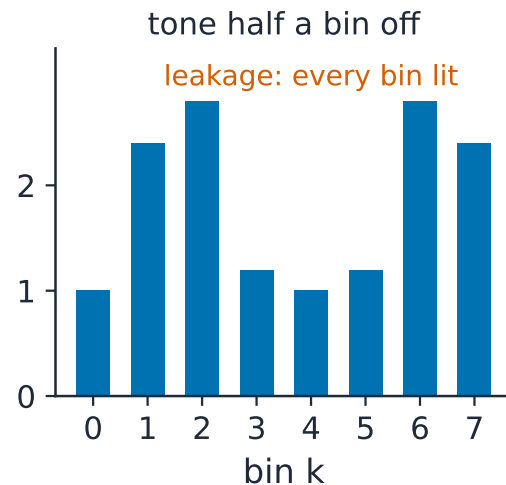
Exercise walk-through

12.7

Signal-processing project

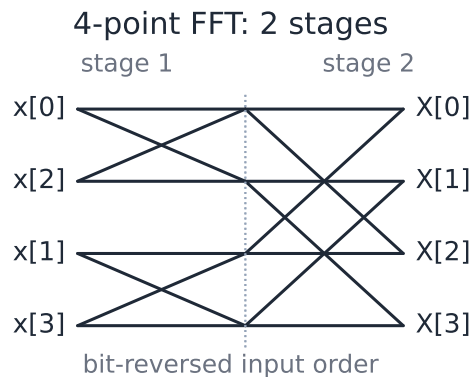
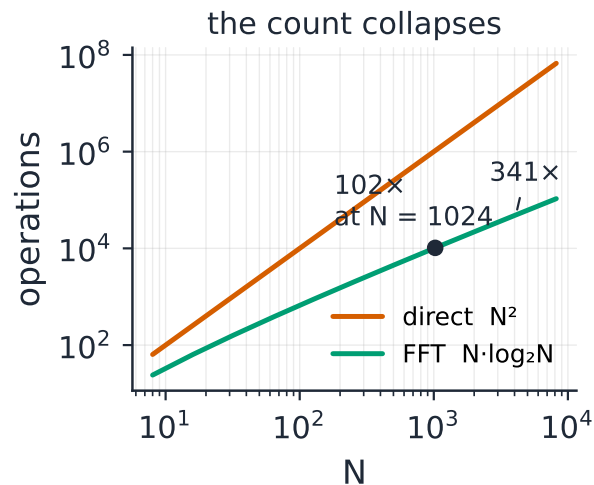
University Electrical Engineering

Two spikes become every bin



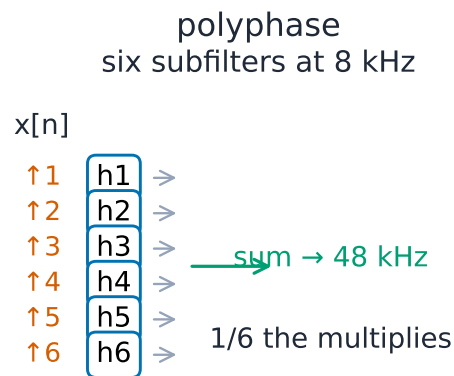
On bin 1: two clean spikes of 4. Half a bin off: every bin lit - **leakage** is the rectangular window speaking.

The butterfly ladder



Two stages of butterflies build a 4-point **FFT**; at $N = 1024$ the count collapses 102x and keeps falling.

Images every 8 kHz



Stuffing 5 zeros paints images every 8 kHz; one low-pass at 4 kHz erases them; **polyphase** pays 1/6 the multiplies.

Exercises 2.1-2.3

2.1 Compute the bin processing gain at $N = 256$. [3]

2.2 A spec demands 0.5 Hz bins at $f_s = 2$ kHz. Minimum record length? [3]

2.3 Why is “tuning the detector until the lab tone is found” a defect rather than a method? [3]

Exercises 2.1-2.3

2.1 Compute the bin processing gain at $N = 256$. [3]

2.1

- $10 \log_{10}(128) = 21.1 \text{ dB}$.

2.2 A spec demands 0.5 Hz bins at $f_s = 2 \text{ kHz}$. Minimum record length? [3]

2.2

- $\Delta f = f_s/N \leq 0.5 \text{ Hz} \rightarrow N \geq 4000 \rightarrow 2.0 \text{ s of data}$.

2.3 Why is “tuning the detector until the lab tone is found” a defect rather than a method? [3]

2.3

- It tunes to the test signal (overfitting): the detector passes the lab tone and fails the world – measurement, not memorisation, is the method.

Exercise 3.1

3.1 A tone detector must find a 440 Hz tone within ± 2 Hz at $f_s = 4$ kHz, reporting within 0.5 s, at -6 dB SNR.

Size N (power of two) and check the latency line. Compute the bin number of 440 Hz and the quantisation error in Hz. State the processing gain and the decision-bin SNR. State one spec line this design misses (or exactly meets) and its margin. [9]

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3.1

- $\Delta f \leq 2$ Hz $\rightarrow N \geq 2000 \rightarrow N = 2048$ (power of two): $\Delta f = 1.953$ Hz ✓.
- Latency: 2048 samples / 4000 Hz = 0.512 s – misses the 0.5 s line by 12 ms $\times$ (the trade the margin table must show).
- Bin: $440/1.953 = 225.28 \rightarrow$ bin 225, exact frequency 439.45 Hz, quantisation error 0.55 Hz ✓ inside ± 2 .
- Processing gain $10 \log_{10}(1024) = 30.1$ dB $\rightarrow$ decision-bin SNR $-6 + 30.1 = 24.1$ dB ✓.

Exercise 3.2

3.2 The project report of a rival team claims “meets all specs” with a 6-line table where two rows read “PASS” but show no measured value.

Give the three defects of this table against the honest method. Compute what the missing numbers would need to show for a 1 Hz-bin spec with $N = 900$ at $f_s = 1$ kHz. State the single change that turns the table honest. [7]

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3.2

- Defects: no measured values (PASS is a claim, not a number); no margins (nothing to audit); silent goals (lines measured in code but not reported).
- $N = 900$ at 1 kHz: $\Delta f = 1.111$ Hz – the 1 Hz line FAILS with a -0.111 Hz margin, which the table must show.
- Change: every row lists spec, measured value, and signed margin – no unnumbered PASS.