

# 12.4 FIR filter design

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 25 marks

KEY WORDS FIR

- Hamming window

## Objective

Size FIR filters from window tables, verify measured responses against promises, and account for linear-phase delay.

## 1 Key knowledge and worked examples

### ■ The window table

Approximate first sidelobes of the windows: rectangular  $-13$  dB, Hann  $-31$  dB, Hamming  $-43$  dB, Blackman  $-58$  dB. These describe the windows, not a guaranteed stopband level for every resulting filter. Use transition  $\approx 3.3 \cdot f_s/N$  as a Hamming design estimate. Symmetric taps: exactly linear phase, delay  $(N - 1)/2$  samples.

### ■ Worked example: size and verify

50 Hz transition at  $f_s = 1$  kHz:  $N = 3.3 \times 1000/50 = 66 \rightarrow$  take 67 (odd, Type-I), delay 33 samples. This estimates the length; without specified taps and a measured frequency response, it does not verify the stopband attenuation.

### ■ The verification step

Generate  $|H(f)|$  from the taps and check passband ripple and stopband depth against the stated filter specification. If a  $-43$  dB stopband target is met only to  $-37$  dB, the design fails that target. Check the cutoff, tap count and window; that result alone does not identify the cause.

## 2 Practice

2.1 Hamming FIR,  $f_s = 8$  kHz, transition 100 Hz: estimate  $N$  and the linear-phase delay for the odd choice. [3]

**2.2** Which of Hann, Hamming and Blackman has a tabulated first window sidelobe below  $-50$  dB? Explain why this comparison does not verify a designed filter's stopband. [3]

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**2.3** Why must a Type-I design use an odd  $N$ ? [3]

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### 3 Exam-style questions

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**3.1** Design a Hamming low-pass at  $f_s = 1$  kHz: passband to 200 Hz, transition 50 Hz. The design targets are stopband level at or below  $-43$  dB and passband ripple within  $\pm 0.05$  dB.

Size  $N$  (odd). State the delay in samples and milliseconds. Compute what transition  $N = 31$  would deliver, and state which way the design misses. Give the two measurements that verify the design, with their expected values. [8]

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**3.2** An anti-alias FIR before a  $\downarrow 4$  decimator at  $f_s = 48$  kHz must pass 0–5 kHz and attenuate above 6 kHz.

Compute the transition band available and the required  $N$  (Hamming). The group delay of this filter in ms; the decimator drops 3 of 4 samples – explain why the filter must run BEFORE the drop. Compare the multiply rate of filtering at 48 kHz versus a polyphase scheme. [8]

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