1.

8. Consider the following specifications for an analog highpass filter:

$$\Omega_s = 10\ \tfrac{\text{rad}}{\text{sec}},\quad A_s = 40\text{ dB},\qquad \Omega_p = 15;\ \tfrac{\text{rad}}{\text{sec}},\quad A_p = 1\text{ dB}.$$

(a) Design an analog Butterworth highpass filter using the `buttord` and `butter` functions and plot its magnitude response.
(b) Using impulse-invariance transformation and $T_d = 1$ design a digital highpass filter and plots its magnitude response.
(c) Comment on the feasibility of using impulse-invariance for transforming an analog highpass filter to a digital highpass filter.

2.

9. Consider the specifications of a digital lowpass filter given below:

$$\omega_p = 0.25\pi \text{ radians},\quad A_p = 1\text{ dB},\qquad \omega_s = 0.4\pi \text{ radians},\quad A_s = 40\text{ dB}.$$

Design of IIR filters

(a) Design the digital filter using elliptic approximation and impulse-invariance transformation with $T_d = 1$. Plot the magnitude and log-magnitude responses and comment on the efficacy of the design.
(b) Repeat (a) using $A_s = 60$ dB. Is this design any better?

3.

10. Consider the design of a digital lowpass filter using impulse invariance transformation with specifications:

$$\omega_p = 0.25\pi \text{ radians},\quad A_s = 50\text{ dB},\qquad \omega_s = 0.4\pi \text{ radians},\quad A_p = 1\text{ dB}.$$

(a) Using a Butterworth prototype and $T_d = 1$ s, obtain the lowpass digital filter. Plot its magnitude and lag-magnitude responses. Also plot the impulse response of the digital filter superimposed on the impulse response of the analog prototype filter.
(b) Repeat (a) using $T_d = 0.1$ s.
(c) Repeat (a) using $T_d = 0.01$ s.
(d) Comment on the effect of T_d on frequency responses in the impulse-invariance design.

4.

11. A lowpass digital filter's specifications are given by:

$$\omega_p = 0.25\pi \text{ radians},\quad A_p = 1\text{ dB},\qquad \omega_s = 0.35\pi \text{ radians},\quad A_s = 50\text{ dB}.$$

(a) Obtain a system function $H(z)$ in the rational function form that satisfies the above specifications so that the response is equiripple in the passband and monotone in the stopband. Use an impulse invariance approach.
(b) Provide design plots in the form of log-magnitude, phase, group-delay, and impulse responses.

5.

12. A lowpass digital filter's specifications are given by:

$$\omega_p = 0.25\pi \text{ radians},\quad A_p = 1\text{ dB},\qquad \omega_s = 0.35\pi \text{ radians},\quad A_s = 50\text{ dB}.$$

(a) Using the bilinear transformation approach and the Butterworth approximation obtain a system function $H(z)$ in the rational function form that satisfies the above specifications.
(b) Provide design plots in the form of log-magnitude, phase, group-delay, and impulse responses.
(c) Determine the exact band-edge frequencies for the given attenuation.

6.

13. A lowpass digital filter's specifications are given by:

$$\omega_p = 0.2\pi \text{ radians},\quad A_p = 1\text{ dB},\qquad \omega_s = 0.3\pi \text{ radians},\quad A_s = 60\text{ dB}.$$

(a) Using bilinear transformation and the Chebyshev I approximation approach obtain a system function $H(z)$ in the cascade form that satisfies the above specifications.
(b) Provide design plots in the form of log-magnitude, phase, group-delay, and impulse responses.
(c) Determine the exact band-edge frequencies for the given attenuation.

7.

10. Design a highpass FIR filter to satisfy the specifications: $\omega_s = 0.3\pi$, $A_s = 50$ dB, $\omega_p = 0.0.5\pi$, and $A_p = 0.001$ dB.
(a) Use an appropriate fixed window to obtain a minimum length linear-phase filter. Provide a plot similar to Figure 10.12.
(b) Repeat (a) using the `fir1` function.

8.

12. Consider the lowpass filter specifications: $\omega_p = 0.2\pi$, $\omega_s = 0.3\pi$, $A_p = 0.2$ dB, and $A_s = 40$ dB.
(a) Design a length $L = 20$ linear-phase FIR filter using the basic frequency sampling technique. Graph the relevant filter response plots.
(b) You should note that the design in (a) cannot satisfy the given specifications. Hence choose $L = 40$ and using frequency sampling design with an optimum approach, design a linear-phase FIR filter. Use the transition coefficient tables given in Proakis and Manolakis (2007) Appendix B. Graph the relevant filter response plots and comment on the design.
(c) Repeat (b) using the `fir2` function.

9

28. Design a lowpass FIR filter to satisfy the specifications: $\omega_p = 0.3\pi$, $A_p = 0.5$ dB, $\omega_s = 0.5\pi$, and $A_s = 50$ dB.
(a) Use an appropriate fixed window to obtain a minimum length linear-phase filter. Provide a plot similar to Figure 10.12.
(b) Repeat (a) using the Kaiser window and compare the lengths of the resulting filters.

10.

29. Specifications of a bandstop filter are: $\omega_{p_1} = 0.2\pi$, $\delta_p = 0.056$, $\omega_{s_1} = 0.3\pi$, $\omega_{s_2} = 0.5\pi$, $\delta_s = 0.01$, $\omega_{p_2} = 0.65\pi$, and $\delta_p = 0.056$.
(a) Design a minimum length linear-phase FIR filter using the Hann window. Provide a plot similar to Figure 10.17.
(b) Verify your design using the `fir1` function.

11.

30. A bandpass filter is given by the specifications: $\omega_{s_1} = 0.2\pi$, $A_{s_1} = 45$ dB, $\omega_{p_1} = 0.3\pi$, $\omega_{p_2} = 0.5\pi$, $A_p = 0.75$ dB, $\omega_{s_2} = 0.65\pi$, and $A_{s_2} = 50$ dB.
(a) Design a minimum length linear-phase FIR filter using one of the fixed type windows. Provide a plot similar to Figure 10.17.
(b) Repeat (a) using the Kaiser window.
(c) Verify your designs using the `fir1` function.

12.

32. We want to use the frequency-sampling method to design a highpass filter with specifications: $\omega_s = 0.6\pi$, $\omega_p = 0.8\pi$, $A_s = 50$ dB, and $A_p = 1$ dB.
(a) Choose $M = 33$ so that there are two samples in the transition band. Using a linear transition obtain the filter impulse response. Provide a plot of the log-magnitude and impulse responses. Does this design satisfy the given specifications?
(b) Repeat (a) using the `fir2` function and the Hamming window. Does this design satisfy the given specifications?

13.

34. An ideal lowpass filter has a cutoff frequency of $\omega_c = 0.4\pi$. We want to obtain a length $L = 40$ linear-phase FIR filter using the frequency-sampling method.
(a) Let the sample at ω_c be equal to 0.5. Obtain the resulting impulse response $h[n]$. Plot the log-magnitude response in dB and determine the minimum stopband attenuation.
(b) Now vary the value of the sample at ω_c (up to four decimals) and find the largest minimum stopband attenuation. Obtain the resulting impulse response $h[n]$ and plot the log-magnitude response in dB in the plot window of (a).
(c) Compare your results with those obtained using the `fir2` function (choose an appropriate window).

14.

14. A lowpass digital filter's specifications are given by:

$$\omega_p = 0.5\pi \text{ radians},\quad A_p = 2\text{ dB},\qquad \omega_s = 0.6\pi \text{ radians},\quad A_s = 50\text{ dB}.$$

Problems

(a) Using bilinear transformation and the Chebyshev II approximation approach obtain a system function $H(z)$ in the parallel form that satisfies the above specifications.
(b) Provide design plots in the form of log-magnitude, phase, group-delay, and impulse responses.
(c) Determine the exact band-edge frequencies for the given attenuation.

15

38. A highpass digital filter's specifications are given by:

$$\omega_s = 0.6\pi \text{ radians},\quad A_s = 40\text{ dB},\qquad \omega_p = 0.8\pi \text{ radians},\quad A_p = 1\text{ dB}.$$

(a) Using the Butterworth approximation obtain a system function $H(z)$ in the cascade function form that satisfies the above specifications.
(b) Provide design plots in the form of log-magnitude, phase, group-delay, and impulse responses.
(c) Determine the exact band-edge frequencies for the given attenuation.

16.

46. Design an analog Butterworth lowpass filter with specifications: $F_p = 5$ kHz, $A_p = 1$ dB, $F_s = 7$ kHz, and $A_s = 50$ dB. Provide plots of the magnitude, log-magnitude, group-delay, and impulse responses. Also provide the zero-pole plot.

17.

48. Design an analog Chebyshev I lowpass filter with specifications: $\Omega_p = 4$ rad, $A_p = 1$ dB, $\Omega_s = 5$ rad, and $A_s = 40$ dB. Provide plots of the magnitude, log-magnitude, group-delay, and impulse responses. Determine the exact stopband edge. Also provide the zero-pole plot.