10.6 End of Chapter Problems

EOCP 10.1

We are trying to eliminate all frequencies that are higher than 1000 Hz from the incoming signal $x(t)$. Design a digital IIR filter to accomplish this task. Use all types of filters discussed in this chapter.

1. Start with the analogue IIR filter then get its equivalent digital IIR filter using the transformation methods discussed in this chapter.
2. Use MATLAB and directly design the IIR digital filter after obtaining the digital specifications.
3. Plot the magnitude responses in each case.

EOCP 10.2

Consider the input continuous signal

$$x(t) = \sin(1000t) + \cos(10t)$$

Design digital second- and fourth-order IIR lowpass Butterworth filters to attenuate the cos(1000t) term. Plot the input signal and the output of the filter.

EOCP 10.3

We are trying to eliminate all frequencies that are lower than 1000 Hz from the incoming signal $x(t)$. If the highest frequency in the incoming analogue signal is 1500 Hz, design a digital IIR filter to accomplish this task. Allow 5 dB for the maximum passband attenuation and 50 dB for the minimum stopband attenuation. Plot the magnitude response.

EOCP 10.4

Consider the input continuous signal

$$x(t) = \cos(100t) + \cos(150t) + \sin(400t)$$

1. Design a digital second- and third-order IIR elliptical filter to attenuate the cos(150t) term.
2. Design a digital second- and third-order IIR elliptical filter to attenuate the cos(100t) term.
3. Design a digital second- and third-order IIR elliptical filter to attenuate the cos(400t) term.
4. Plot the input signal and the output of the filter for each case above.

EOCP 10.5

We are trying to pass all frequencies that are higher than 10 Hz and below 50 Hz from the incoming signal $x(t)$. Design a digital IIR filter to accomplish this task. Use the Cheby1 and Cheby2 filters in the design. Use 5 dB for the maximum allowable ripple in the passband and 50 dB for the minimum allowable ripple in the stopband. Plot the magnitude responses of the digital filters.

EOCP 10.6

We are interested in passing the term sin(5000t) from the input signal

$$x(t) = \sin(10t) + \sin(1500t) + \sin(5000t)$$

Design an IIR Butterworth digital filter to accomplish this task. Plot the input signal along with the magnitude response of the filter and its output.

EOCP 10.7

We are trying to suppress all frequencies that are higher than 2000 Hz and below 4000 Hz from the incoming signal $x(t)$. Design a digital IIR filter to accomplish this task. Use the Cheby2 filter in the design. Use 60 dB for the minimum allowable ripple in the stopband. Plot the magnitude response of the digital filter.

EOCP 10.8

We are interested in suppressing the term sin(10t) from the input signal

$$x(t) = 1 + \sin(10t) + \sin(5000t)$$

Design an IIR Cheby2 digital filter to accomplish this task. Plot the input signal along with the magnitude response of the filter and its output.

EOCP 10.9

Consider the dc and the single frequency signal

$$x(t) = 1/2 + \sin(10t)$$

Assume the signal is corrupted by a noise (random noise). Assume that the noise signal is limited to 100π rad/sec.

1. Design a digital filter to smooth the noise and uncover the signal $x(t) = 1/2 + \sin(10t)$.
2. Design a digital filter to pass the sin(10t) term only.
3. Design a digital filter to pass the dc term only.
4. Plot the input and the output of the corresponding filter in each case.

EOCE 10.10

Consider the same corrupted input signal as in EOCP 10.9, but now we want to get rid of the dc component and the single frequency term. Design a Butterworth digital filter to accomplish this. Plot the input and the output of the designed filter.

EOCP 10.11

An elliptic bandstop digital IIR filter is to be designed. The corresponding analogue IIR filter should fulfill the following specifications:

$$1 >= |H(jw)|^2 >= 0.95 \qquad w <= 1200 \text{ and } w >= 1800$$
$$|H(jw)|^2 <= 0.02 \qquad 800 >= w >= 2200$$

1. Estimate the order and the cut-off frequencies of the analogue IIR filter.
2. Find the transfer function of the digital filter using the Bilinear and the Invariance methods.
3. Plot the magnitude response of the filter as well as the phase.

EOCP 10.12

Plot the magnitude and phase responses of Butterworth, Chebyshev Type I, Chebyshev Type II, and elliptic digital filters. Let the order be 5 and the cut-off frequency be 1 for the corresponding analogue counterparts. Also assume R_p = 3 dB and R_s = 60 dB for the analogue IIR filters.

EOCP 10.13

Design a digital bandstop IIR filter where the analogue counterpart should have a bandwidth β of 1000 rad/sec. The analogue IIR filter should reject the component sin(1414t) from the following signal:

$$x(t) = \sin(500t) + \sin(1414t) + \cos(2500t)$$

The analogue filter should ensure attenuation of at least 45 dB of the rejected component. Plot the input and the output of the digital filter.

EOCP 10.14

Given the following signal

$$x(t) = 1 + \sin(t) + \sin(6t)$$

design a digital filter that eliminates the component sin(t). Plot the filter magnitude response. Assume 40 dB allowable ripple in the stopband. Plot the input and the output of the digital filter.

EOCP 10.15

Consider the circuit in Figure 10.19. Use 1 Henry (H) for L, 1 Ω for R_1 and 1 Ω for R_f. Design a digital filter to approximate the input–output characteristics of the circuit. Plot the input and the output of the filter by choosing appropriate input. Use the Bilinear transformation with T_s = 0.1. Repeat for different values for T_s. What do you conclude?

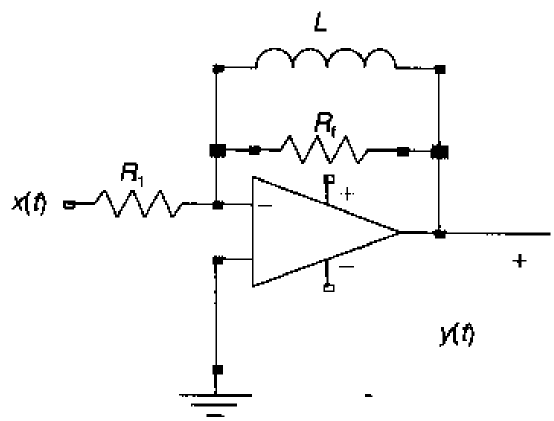

FIGURE 10.19 Circuit for EOCP 10.15.

EOCP 10.16

Consider the same circuit in Figure 10.19. Replace the inductor by a 1-F capacitor. Use 1 Ω for R_1 and 1 Ω for R_f. Design a digital filter to approximate the input–output characteristics of the circuit. Plot the input and the output of the filter by choosing appropriate input. Use Bilinear transformation with $T_s = 0.1$. Repeat for different values for T_s. What do you conclude?

EOCP 10.17

Consider the same circuit as in Figure 10.19. Add a capacitor of 1 F in series with the 1-H inductor. Use 1 Ω for R_1 and 1 Ω for R_f. Design a digital filter to approximate the input–output characteristics of the circuit. Plot the input and the output of the filter by choosing appropriate input. Use Bilinear transformation with $T_s = 0.1$. Repeat for different values for T_s. What do you conclude?

EOCP 10.18

Consider the following differential equation:

$$y''(t) + y'(t) + y(t) = x(t)$$

Design a digital filter to approximate the input–output characteristics of the system. Plot the input and the output of the filter by choosing appropriate input. Use the Bilinear transformation with $T_s = 0.1$. Repeat for different values for T_s. What do you conclude?

EOCP 10.19

Consider the following differential equation:

$$y''(t) + y(t) = x(t)$$

Design a digital filter to approximate the input–output characteristics of the system. Plot the input and the output of the filter by choosing appropriate input. Use the Bilinear transformation with $T_s = 0.1$. Repeat for different values for T_s. What do you conclude?

EOCP 10.20

Consider the following differential equation:

$$y''(t) + y'(t) + y(t) = x(t) + x'(t)$$

Design a digital filter to approximate the input–output characteristics of the system. Plot the input and the output of the filter by choosing appropriate input. Use the Bilinear transformation with $T_s = 0.1$. Repeat for different values for T_s. What do you conclude?

EOCP 10.21

The transfer functions of an integrator and a differentiator are

$$H_1(s) = \frac{1}{s} \text{ and } H_2(s) = s$$

1. Use the Bilinear transformation to approximate the two transfer functions with T_s as the sampling interval. Find $H_1(z)$ and $H_2(z)$.
2. Use the Impulse Invariance transformation to approximate the two transfer functions with T_s as the sampling interval. Find $H_1(z)$ and $H_2(z)$.
3. Plot the magnitude responses for $H_1(s)$ and $H_2(s)$.
4. For different values of T_s, plot the magnitude responses for $H_1(z)$ and $H_2(z)$.
5. Give comments on the results.