**3.75** Consider the two LTI causal digital filters with impulse responses given by

$$h_A[n] = 0.3\delta[n] - \delta[n-1] + 0.3\delta[n-2],$$
$$h_B[n] = 0.3\delta[n] + \delta[n-1] + 0.3\delta[n-2].$$

(a) Sketch the magnitude responses of the two filters and compare their characteristics.

(b) Let $h_A[n]$ be the impulse response of a causal digital filter with a frequency response $H_A(e^{j\omega})$. Define another digital filter whose impulse response $h_C[n]$ is given by

$$h_C[n] = (-1)^n h_A[n], \qquad \text{for all } n.$$

What is the relation between the frequency response $H_C(e^{j\omega})$ of this new filter and the frequency response $H_A(e^{j\omega})$ of the parent filter?

**7.5** Let a causal LTI discrete-time system be characterized by a real impulse response $h[n]$ with a DTFT $H(e^{j\omega})$. Consider the system of Figure P7.1, where $x[n]$ is a finite-length sequence. Determine the frequency response of the overall system $G(e^{j\omega})$ in terms of $H(e^{j\omega})$, and show that it has a zero-phase response.

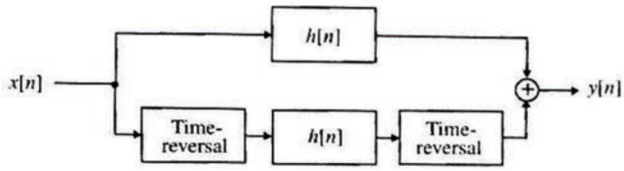


**Figure P7.1**

**7.16** (a) Design a length-5 FIR bandpass filter with an antisymmetric impulse response $h[n]$, i.e., $h[n] = -h[4-n]$, $0 \le n \le 4$, satisfying the following magnitude response values: $|H(e^{j0.3\pi})| = 0.3$ and $|H(e^{j0.6\pi})| = 0.8$.
(b) Determine the exact expression for the frequency response of the filter designed, and plot its magnitude and phase responses using MATLAB.

**7.28** Let $H_{LP}(z)$ denote the transfer function of an ideal real coefficient lowpass filter having a cutoff frequency of $\omega_p$, with $\omega_p < \pi/2$. Consider the complex coefficient transfer function $H_{LP}(e^{j\omega_o}z)$, where $\omega_p < \omega_o < \pi - \omega_p$. Sketch its magnitude response for $-\pi \le \omega \le \pi$. What type of filter does it represent? Now consider the transfer function $G(z) = H_{LP}(e^{j\omega_o}z) + H_{LP}(e^{-j\omega_o}z)$. Sketch its magnitude response for $-\pi \le \omega \le \pi$. Show that $G(z)$ is a real-coefficient bandpass filter with a passband centered at $\omega_o$. Determine the width of its passband in terms of $\omega_p$ and its impulse response $g[n]$ in terms of the impulse response $h_{LP}[n]$ of the parent lowpass filter.

**7.61** Let $H_1(z)$, $H_2(z)$, $H_3(z)$, and $H_4(z)$ be, respectively, Type 1, Type 2, Type 3, and Type 4 linear-phase FIR filters. Are the following filters (composed of a cascade of the above filters) linear phase? If they are, what are their types?

(a) $G_a(z) = H_1(z)H_1(z)$, (b) $G_b(z) = H_1(z)H_2(z)$, (c) $G_c(z) = H_1(z)H_3(z)$,
(d) $G_d(z) = H_1(z)H_4(z)$, (e) $G_e(z) = H_2(z)H_2(z)$, (f) $G_f(z) = H_3(z)H_3(z)$,
(g) $G_g(z) = H_4(z)H_4(z)$, (h) $G_h(z) = H_2(z)H_3(z)$, (i) $G_i(z) = H_3(z)H_4(z)$.

**M 7.12** Design a stable second-order IIR notch filter with a center frequency at $0.6\pi$ and a 3-dB bandwidth of $0.2\pi$. Plot its gain response.