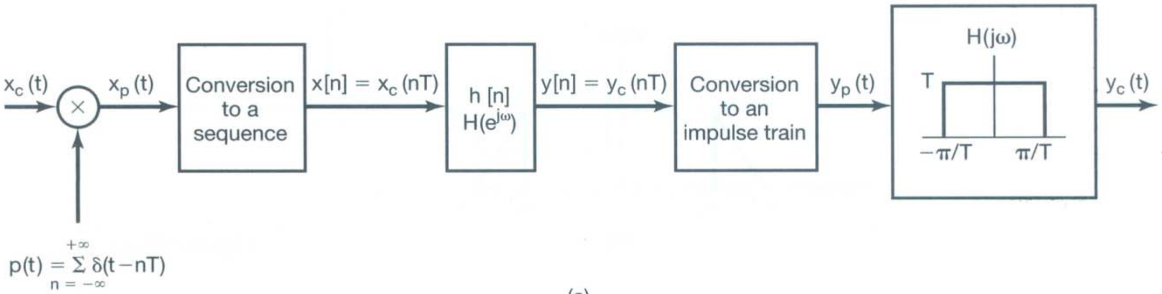
- Representation of of a CT Signal by Its Samples:
  - The Sampling Theorem
- Reconstruction of of a Signal from Its Samples
  - Using exact interpolation
  - Using zero-order hold
  - Using higher-order hold
- The Effect of Under-sampling
  - Overlapping in Frequency-Domain
  - Aliasing
- DT Processing of CT Signals
- Sampling of Discrete-Time Signals
  - Down-sampling
  - Up-sampling

7.29: Filtering CT Signal Using DT Filter

7.29. Figure P7.29(a) shows the overall system for filtering a continuous-time signal using a discrete-time filter. If $X_c(j\omega)$ and $H(e^{j\omega})$ are as shown in Figure P7.29(b), with $1/T = 20$ kHz, sketch $X_p(j\omega)$, $X(e^{j\omega})$, $Y(e^{j\omega})$, $Y_p(j\omega)$, and $Y_c(j\omega)$.



(a)

(b)

7.19: Zero-Insertion System, Decimation

7.19. Consider the system shown in Figure P7.19, with input $x[n]$ and the corresponding output $y[n]$. The zero-insertion system inserts two points with zero amplitude between each of the sequence values in $x[n]$. The decimation is defined by

$$y[n] = w[5n],$$

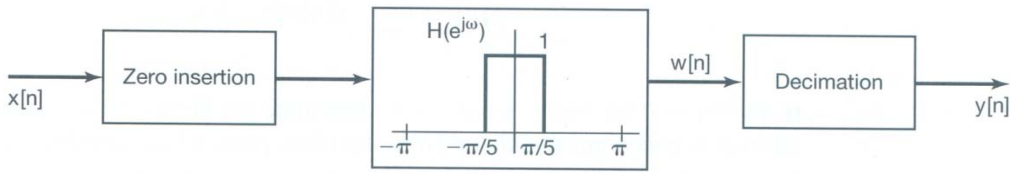
where $w[n]$ is the input sequence for the decimation system. If the input is of the form

$$x[n] = \frac{\sin \omega_1 n}{\pi n},$$

determine the output $y[n]$ for the following values of ω_1:

(a) $\omega_1 \le \frac{3\pi}{5}$

(b) $\omega_1 > \frac{3\pi}{5}$

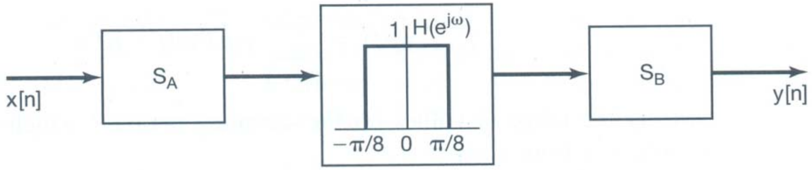


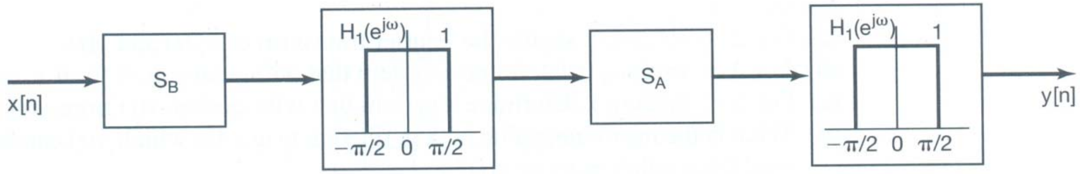
7.20: Zero-Insertion System, Lowpass Filter

7.20. Two discrete-time systems S_1 and S_2 are proposed for implementing an ideal lowpass filter with cutoff frequency $\pi/4$. System S_1 is depicted in Figure P7.20(a). System S_2 is depicted in Figure P7.20(b). In these figures, S_A corresponds to a zero-insertion system that inserts one zero after every input sample, while S_B corresponds to a decimation system that extracts every second sample of its input.

(a) Does the proposed system S_1 correspond to the desired ideal lowpass filter?

(b) Does the proposed system S_2 correspond to the desired ideal lowpass filter?



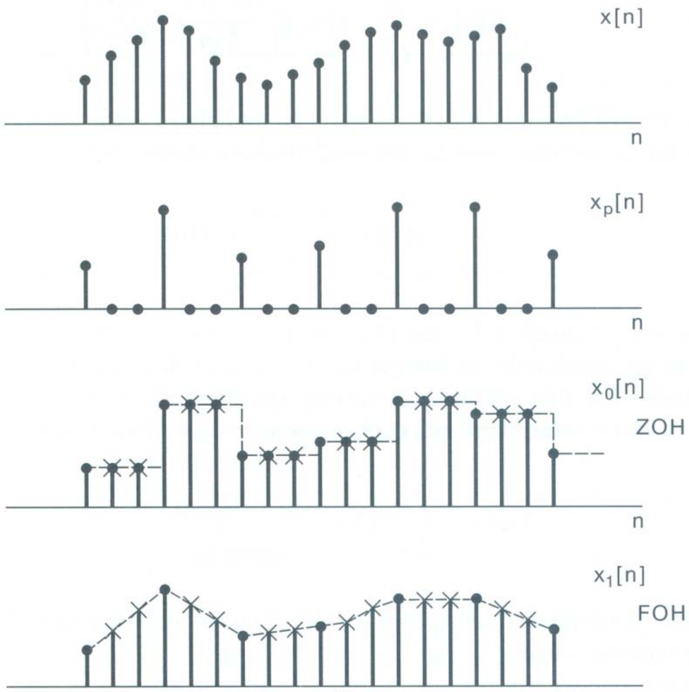


7.50: DT Zero-Order Hold First-Order Hold

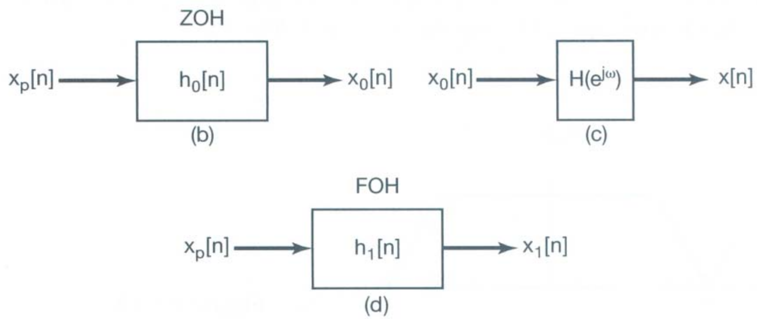
7.50. In this problem, we consider the discrete-time counterparts of the zero-order hold and first-order hold, which were discussed for continuous time in Sections 7.1.2 and 7.2.

Let $x[n]$ be a sequence to which discrete-time sampling, as illustrated in Figure 7.31, has been applied. Suppose the conditions of the discrete-time sampling theorem are satisfied; that is, $\omega_s > 2\omega_M$, where ω_s is the sampling frequency and $X(e^{j\omega}) = 0$, $\omega_M < |\omega| \leq \pi$. The original signal $x[n]$ is then exactly recoverable from $x_p[n]$ by ideal lowpass filtering, which, as discussed in Section 7.5, corresponds to band-limited interpolation.

The zero-order hold represents an approximate interpolation whereby every sample value is repeated (or held) $N - 1$ successive times, as illustrated in Figure P7.50(a) for the case of $N = 3$. The first-order hold represents a linear interpolation between samples, as illustrated in the same figure.



(a)



(b) (c) (d)

7.50: DT Zero-Order Hold First-Order Hold

(a) The zero-order hold can be represented as an interpolation in the form of eq. (7.47) or, equivalently, the system in Figure P7.50(b). Determine and sketch $h_0[n]$ for the general case of a sampling period N.

(b) $x[n]$ can be exactly recovered from the zero-order-hold sequence $x_0[n]$ using an appropriate LTI filter $H(e^{j\omega})$, as indicated in Figure P7.50(c). Determine and sketch $H(e^{j\omega})$.

(c) The first-order-hold (linear interpolation) can be represented as an interpolation in the form of eq. (7.47) or, equivalently, the system in Figure P7.50(d). Determine and sketch $h_1[n]$ for the general case of a sampling period N.

(d) $x[n]$ can be exactly recovered from the first-order-hold sequence $x_1[n]$ using an appropriate LTI filter with frequency response $H(e^{j\omega})$. Determine and sketch $H(e^{j\omega})$.