

**2.59.** A system has the frequency-response function

$$H(f) = \frac{4\pi + j2\pi f}{8\pi + j2\pi f}$$

Determine and accurately plot the group delay and the phase delay.

**2.60.** The nonlinear system defined by

$$y(t) = x(t) + 0.1x^2(t)$$

has an input signal with the bandpass spectrum

$$X(f) = 4\Pi\left(\frac{f-20}{6}\right) + 4\Pi\left(\frac{f+20}{6}\right)$$

Sketch the spectrum of the output, labeling all important frequencies and amplitudes.

**2.61.**

**a.** Consider a nonlinear device with the transfer characteristic  $y(t) = x(t) + 0.1x^3(t)$ . The frequency of the input signal  $x(t) = \cos(2000\pi t)$  is to be tripled by passing the signal through the nonlinearity and then through a second-order BPF with a frequency response function approximated by

$$H(f) = \frac{1}{1 + j2Q(f - 3000)} + \frac{1}{1 + j2Q(f + 3000)}$$

Neglecting negative frequency contributions, compute, in terms of the parameter  $Q$ , the *total harmonic distortion* (THD) at the tripler output, defined as

$$\text{THD} = \frac{\text{total power in all output distortion terms}}{\text{power in desired output component}} \times 100\%$$

Note that the desired output component in this case is the third harmonic of the input frequency.

**b.** Find the minimum value of  $Q$  that will result in  $\text{THD} \leq 0.001\%$ .

**2.62.** A nonlinear device has  $y(t) = a_0 + a_1x(t) + a_2x^2(t) + a_3x^3(t)$ . If  $x(t) = \cos(\omega_1 t) + \cos(\omega_2 t)$ , list all the frequency components present in  $y(t)$ . Discuss the use of this device as a frequency multiplier.

**2.63.** Find the impulse response of an ideal highpass filter with the frequency response function

$$H_{\text{HP}}(f) = H_0 \left[ 1 - \Pi\left(\frac{f}{2W}\right) \right] e^{-j2\pi f t_0}$$

**2.64.** Verify the pulsewidth-bandwidth relationship of (2.250) for the following signals. Sketch each signal and its spectrum.

**a.**  $x(t) = A \exp(-t^2/2\tau^2)$  (Gaussian pulse)

**b.**  $x(t) = A \exp(-\alpha|t|)$ ,  $\alpha > 0$   
(double-sided exponential).

**2.65.**

**a.** Show that the frequency response function of a second-order Butterworth filter is

$$H(f) = \frac{f_3^2}{f_3^2 + j\sqrt{2}f_3f - f^2}$$

where  $f_3$  is the 3-dB frequency in hertz.

**b.** Find an expression for the group delay of this filter. Plot the group delay as a function of  $f/f_3$ .

**c.** Given that the step response for a second-order Butterworth filter is

$$y_s(t) = \left\{ 1 - \exp\left(-\frac{2\pi f_3 t}{\sqrt{2}}\right) \left[ \cos\left(\frac{2\pi f_3 t}{\sqrt{2}}\right) + \sin\left(\frac{2\pi f_3 t}{\sqrt{2}}\right) \right] \right\} u(t)$$

where  $u(t)$  is the unit step function, find the 10% to 90% risetime in terms of  $f_3$ .

## Section 2.8

**2.66.** A sinusoidal signal of frequency 1 Hz is to be sampled periodically.

**a.** Find the maximum allowable time interval between samples.

**b.** Samples are taken at  $\frac{1}{3}$ -s intervals (i.e., at a rate of  $f_s = 3$  sps). Construct a plot of the sampled signal spectrum that illustrates that this is an acceptable sampling rate to allow recovery of the original sinusoid.

**c.** The samples are spaced  $\frac{2}{3}$  s apart. Construct a plot of the sampled signal spectrum that shows what the recovered signal will be if the samples are passed through a lowpass filter such that only the lowest frequency spectral lines are passed.

**2.67.** A flat-top sampler can be represented as the block diagram of Figure 2.41.

**a.** Assuming  $T \ll T_s$ , sketch the output for a typical  $x(t)$ .

**b.** Find the spectrum of the output,  $Y(f)$ , in terms of the spectrum of the input,  $X(f)$ . Determine relationship between  $\tau$  and  $T_s$  required to minimize distortion in the recovered waveform?

**2.68.** Figure 2.42 illustrates so-called zero-order-hold reconstruction.

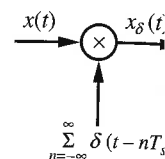


Figure 2.41

$$x_s(t) = \sum_{m=-\infty}^{\infty} x(mT_s) \delta(t - mT_s)$$

Figure 2.42

**a.** Sketch  $y(t)$  and  $y_s(t)$ . Discuss the relationship between  $y(t)$  and  $y_s(t)$ .

**b.** Find the frequency response  $Y(f)$  of  $y(t)$ . Discuss the relationship between  $Y(f)$  and  $X(f)$ .

**2.69.** Determine the frequency response  $Y(f)$  for the ideal lowpass filter.

$$x(t) = \cos(\omega_0 t)$$

which is sampled at  $f_s$  and  $X_s(f)$ . Find the frequency response  $Y(f)$ .

**2.70.** Given the frequency response  $X(f)$  in Figure 2.43, sketch the frequency response  $Y(f)$  for the ideal lowpass filter with cutoff frequencies  $f_c$  and indicate the values of  $f_c$  for (a)  $f_c = 2.5B$ , (b)  $f_c = 3B$ , (c)  $f_c = 4B$ , (d)  $f_c = 5B$ .

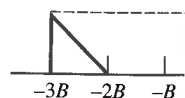


Figure 2.43

## Section 2.9

**2.71.** Using appropriate pairs, express the frequency response  $Y(f)$  in terms of the input spectrum  $X(f)$ .

**a.**  $y(t) = x(t) + x(t - T_s)$  in terms of the input spectrum  $X(f)$ . Sketch  $Y(f)$  for a lowpass with bandwidth  $B$ .

Sketch  $Y(f)$  for a lowpass with bandwidth  $B$ .