DIGITAL SIGNAL PROCESSING: *Signals, Systems, and Filters*
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Errata Corrections for Printings #1 and #2
(Revision date: October 20, 2009)

NOTE:

I would greatly appreciate to be notified of any typographical errors in the textbook, the slides for the textbook, and the solutions of the end-of-chapter problems found at this website. Comments and suggestions for the next edition are especially welcome.

Author

Preface

- **Page xxiii** Replace line -7 (**a negative number indicates lines from the bottom of the page**) by the following:

  between pages 454 and 455 for more details. The software can be downloaded from the textbook's website:

Chapter 2

- **Page 58** The reference citation just after Theorem 2.5 should read as follows:

  (See pp. 9 and 29–30 of [5].)

- **Page 72** Table 2.1, column 2, replace a by α in the bottom two entries, as follows:

$$\frac{1}{\alpha + j\omega} \qquad \frac{\omega_0}{(\alpha + j\omega)^2 + \omega_0^2}$$

- **Page 75** Prob. 2.12, part (a), should read as follows:

  (a) $x(t) = \alpha t \quad \text{for} \quad -\tau_0/2 \le t \le \tau_0/2$

- **Page 75** Prob. 2.13, part (b), should read as follows:

  (b) $x(t) = \begin{cases} 0 & \text{for } -\tau_0/2 \le t < 0 \\ \sin\omega_0 t & \text{for } 0 \le t \le \tau_0/2 \end{cases}$

- **Page 75** Prob. 2.16, part (a), should read as follows:

  (a) $X(-j\omega) = X^*(j\omega)$

- **Page 75** Prob. 2.17, parts (b) and (c), should read as follows:

  (b) Assuming that $x(t)$ is purely imaginary and an even function of time, show that $\Re e\ X(j\omega) = 0$ and $\Im m\ X(j\omega)$ is an even function of frequency.

  (c) Assuming that $x(t)$ is purely imaginary and an odd function of time, show that $\Im m\ X(j\omega) = 0$ and $\Re e\ X(j\omega)$ is an odd function of frequency.

- **Page 76** Prob. 2.23, parts (a) and (b), should read as follows:

  (a) $X_2(j\omega) = X^*(-j\omega)$

  (b) $X_2(-j\omega) = X^*(j\omega)$

- **Page 76** Prob. 2.25, part (b), should read as follows:

  (b) Sketch the waveform of

$$x_2(t) = \sum_{n=-\infty}^{\infty} x_1(t - nT)$$

  assuming that $T > \tau$.

- **Page 77** Prob. 2.29, part (b), delete the parenthesis (See Prob. 2.25 for the definition of $u(t)$.)
- **Page 77** Prob. 2.31, part (a), should read as follows:
  (a) Find the Fourier transform of

  $$x(t) = \begin{cases} e^{-at} \sinh \omega_0 t & \text{for } -1 \le t \le 1 \\ 0 & \text{otherwise} \end{cases}$$

  where $\omega_0 = 2\pi/\tau_0$.
- **Page 77** Prob. 2.32, part (b), should read as follows:
  (b) $x(t) = \begin{cases} \sin \omega_0 t & \text{for } 0 \le t \le \tau_0/2 \\ 0 & \text{otherwise} \end{cases}$
  where $\omega_0 = 2\pi/\tau_0$.
- **Page 77** Prob. 2.34, part (b), should read as follows:
  (b) Using the result in part (a) find the Fourier transform of

  $$x(t) = \begin{cases} \alpha t & \text{for } -\tau_0/2 \le t \le \tau_0/2 \\ 0 & \text{otherwise} \end{cases}$$

- **Page 78** Prob. 2.35, part (b), should read as follows:
  (b) $x(t) = \begin{cases} 1+t & \text{for } -\tau_0/2 \le t < 0 \\ 1-t & \text{for } 0 \le t \le \tau_0/2 \\ 0 & \text{otherwise} \end{cases}$
- **Page 78** Prob. 2.36, should read as follows:
  Find the Fourier transforms of
  (a) $x(t) = \begin{cases} jt & \text{for } -\tau_0/2 \le t \le \tau_0/2 \\ 0 & \text{otherwise} \end{cases}$
  (b) $x(t) = \begin{cases} j\,|t| & \text{for } -\tau_0/2 \le t \le \tau_0/2 \\ 0 & \text{otherwise} \end{cases}$
- **Page 78** Prob. 2.37, part (a), should read as follows:
  (a) $x(t) = u(t)e^{-\alpha t} \cos^2 \omega_0 t$
  where $\alpha > 0$.

Chapter 3

- **Page 90** The equation in the last line should read as follows:

  $$\mathcal{Z}[x(nT+T) - x(nT)] = \lim_{n\to\infty} \sum_{k=-n}^{n} [x(kT+T) - x(kT)]z^{-k}$$

  Page 98 Line 3 should read as follows:
  where $\alpha > 0$.
  Page 98 Line 12 should read as follows:
  and with α assumed to be positive ...
- **Page 101** Line −3, change ‘one-sided signal” to “right-sided signal”.

- **Page 115** Line 3 should read as follows:

  polynomial and the poles of $X(z)$ are simple, then the inverse of $X(z)$ can very quickly be obtained through the use of partial fractions.

- **Page 123** The formula on line −4[1] should read as follows:

$$\arg a_1 = \begin{cases} 0 & \text{if } a_1 \geq 0 \\ -\pi & \text{otherwise} \end{cases}$$

- **Page 128** Prob. 3.15, part (b), should read as follows:

$$(b) \quad x(nT) = \begin{cases} 0 & \text{for } n < 0 \\ nT & \text{for } 0 \leq n < 5 \\ (n-5)T & \text{for } 5 \leq n < 10 \\ (n-10)T & \text{for } n \geq 10 \end{cases}$$

- **Page 128** Prob. 3.16, part (a), should read as follows:

$$(a) \quad x(nT) = \begin{cases} 0 & \text{for } n < 0 \\ 1 & \text{for } 0 \leq n \leq 9 \\ 2 & \text{for } 10 \leq n \leq 19 \\ -1 & \text{for } n \geq 20 \end{cases}$$

- **Page 128** Prob. 3.17, part (a), should read as follows:

$$(a) \quad x(nT) = \begin{cases} 0 & \text{for } n < 0 \\ 2 + nT & \text{for } n \geq 0 \end{cases}$$

- **Page 128** The first line of Prob. 3.21 should read as follows:

  Find $x(0)$ and $x(\infty)$ for the following z transforms:

- **Page 130** Prob. 3.39, part (a), should read as follows:

  (a) Show that the amplitude spectrum of the signal is given by

$$|X(e^{j\omega T})| = \frac{\sqrt{1 + a_0^2 + a_1^2 + 2a_1(1 + a_0)\cos\omega T + 2a_0 \cos 2\omega T}}{\sqrt{1 + b_0^2 + b_1^2 + 2b_1(1 + b_0)\cos\omega T + 2b_0 \cos 2\omega T}}$$

Chapter 4

- **Page 158** Line −2, delete extra right parenthesis, i.e., line should read as follows:

$$= u(nT)e^{j\omega nT}(1 + pe^{-j\omega T} + \cdots + p^n e^{-jn\omega T})$$

- **Page 167** Line 2, the equation should read as follows:

$$y(nT) = 1 + p^1 + p^2 + \cdots + p^n = 1 + \sum_{k=1}^{n} p^k$$

- **Page 171** Correct Fig. 4.16 as shown in the revised figure shown on p. 4.
- **Page 179** Line −1, add T in equation as follows:

$$y(nT) = q_1(nT) + q_2(nT) + 2q_3(nT)$$

- **Page 180** Line 3, add T in equation as follows:

$$y(nT) = \mathbf{c}^T \mathbf{q}(nT) + dx(nT)$$

[1] Fourth line from the bottom of the page.

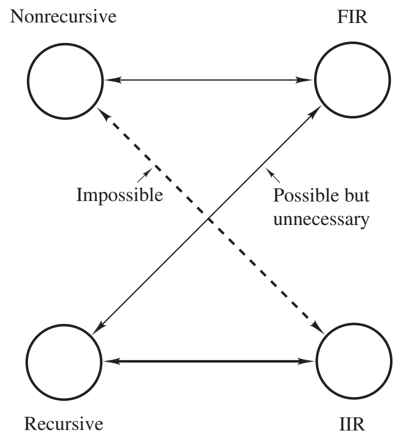

Figure 4.16

- **Page 186** Prob. 4.4, change "Prob. 1.1" to "Prob. 4.1".
- **Page 193** Prob. 4.21, part (c), should read as follows:
  (c) Sketch the response for $p = e^{\alpha}$ with $\alpha > 0, \alpha = 0$, and $\alpha < 0$.

Chapter 5

- **Page 203** Line −7, replace "p_N" by "p_P" as follows:
- **Page 208** The equation in line −4 should read as follows:

$$\sum_{n=0}^{\infty} |h(nT)| = |h(0)| + \sum_{n=1}^{\infty} \left| \sum_{i=1}^{N} r_i^{n-1} e^{j(n-1)\psi_i} \operatorname*{\mathfrak{Res}}_{z=p_i} H(z) \right|$$

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- **Page 208** The equation in line −4 should read as follows:

$$\sum_{n=0}^{\infty} |h(nT)| = |h(0)| + \sum_{n=1}^{\infty} \left| \sum_{i=1}^{N} r_i^{n-1} e^{j(n-1)\psi_i} \operatorname*{\mathfrak{Res}}_{z=p_i} H(z) \right|$$

- **Page 208** Eq. (5.17) should read as follows:

$$\sum_{n=0}^{\infty} |h(nT)| \le |h(0)| + \sum_{n=1}^{\infty} \sum_{i=1}^{N} r_i^{n-1} |\operatorname*{\mathfrak{Res}}_{z=p_i} H(z)| \tag{E}$$

- **Page 209** Line 10, the equation should read as follows:

$$\sum_{n=0}^{\infty} |h(nT)| \le |h(0)| + \frac{NR_{\max}}{r_{\max}} \sum_{n=1}^{\infty} r_{\max}^n$$

- **Page 209** Line 13, line should read as follows:
  the series converges and since $h(0)$ is finite we conclude that

- **Page 209** The equation should read as follows:

$$\sum_{n=0}^{\infty} |h(nT)| \le |R_0| + \frac{NR_{\max}}{r_{\max}} + \frac{NR_{\max}}{r_{\max}} \sum_{n=1}^{\infty} r_{\max}^n$$

- **Page 212** The equations in the middle of the page should read as follows:

and from Eq. (5.11a), we obtain

$$(z\mathbf{I} - \mathbf{A})^{-1} = \frac{1}{\det(z\mathbf{I} - \mathbf{A})} \begin{bmatrix} z^2 & z & 1 \\ -(\frac{1}{3}z + \frac{1}{4}) & (z + \frac{1}{2})z & z + \frac{1}{2} \\ -\frac{1}{4}z & -\frac{1}{4} & (z + \frac{1}{2})z + \frac{1}{3} \end{bmatrix}^T$$

Hence Eq. (5.9) yields

$$\begin{aligned} \frac{Y(z)}{X(z)} &= H(z) = \frac{N(z)}{D(z)} = \mathbf{c}^{\boldsymbol{T}}(z\mathbf{I} - \mathbf{A})^{-1}\mathbf{b} + d \\ &= \frac{1}{\det(z\mathbf{I} - \mathbf{A})} \begin{bmatrix} -\frac{1}{4} & \frac{1}{6} & \frac{1}{12} \end{bmatrix} \begin{bmatrix} z^2 & -(\frac{1}{3}z + \frac{1}{4}) & -\frac{1}{4}z \\ z & (z + \frac{1}{2})z & -\frac{1}{4} \\ 1 & z + \frac{1}{2} & (z + \frac{1}{2})z + \frac{1}{3} \end{bmatrix} \begin{bmatrix} 2 \\ 0 \\ 0 \end{bmatrix} + 2 \\ &= \frac{1}{\det(z\mathbf{I} - \mathbf{A})} \begin{bmatrix} -\frac{1}{4} & \frac{1}{6} & \frac{1}{12} \end{bmatrix} \begin{bmatrix} 2z^2 \\ 2z \\ 2 \end{bmatrix} + 2 \end{aligned}$$

Thus polynomials $N(z)$ and $D(z)$ can be deduced as

$$N(z) = \begin{bmatrix} -\frac{1}{4} & \frac{1}{6} & \frac{1}{12} \end{bmatrix} \begin{bmatrix} 2z^2 \\ 2z \\ 2 \end{bmatrix} + 2\det(z\mathbf{I} - \mathbf{A}) \tag{5.19a}$$

and

- **Page 229** Lines 12 and 13, add square brackets in $\sin(\omega + k\omega_s nT)$ twice as follows:

  We conclude that discrete-time signals $\sin[(\omega + k\omega_s)nT]$ and $\sin \omega nT$ are numerically identical for any value of k as illustrated in Fig. 5.8. Consequently, if signal $\sin[(\omega + k\omega_s)t]$ is sampled at a sampling

- **Page 230** Replace the sentence in lines 7 to 9 of the third paragraph by "In this context, the sampling frequency, ω_s, is analogous to the number of wheel revolutions per second times the number of film frames per second whereas the number of revolutions per second is analogous the frequency of a signal component."

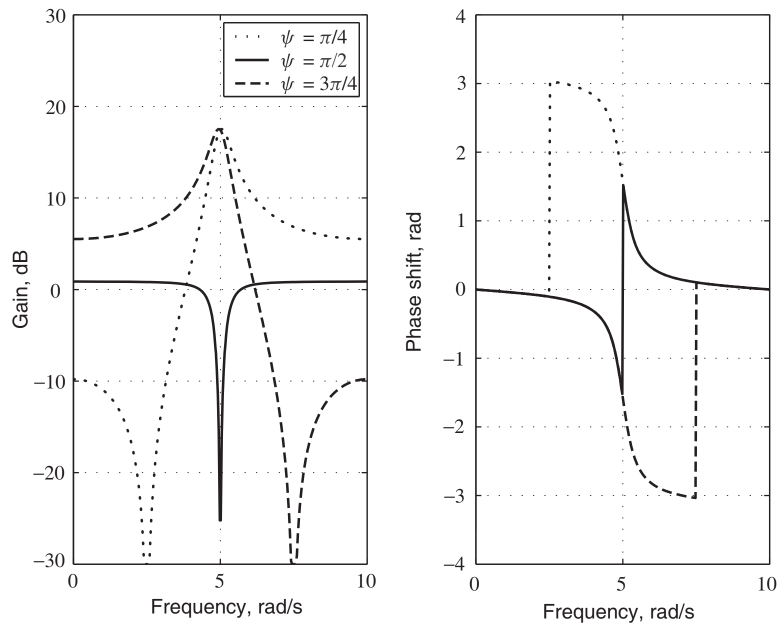
- **Page 244** Caption of Fig. 5.13c and d, replace "arg $|H(e^{j\omega T})|$" by "arg $H(e^{j\omega T})$", as follows:

  Figure 5.13 Cont'd Frequency response of bandpass filter (Example 5.11): (*c*) Plot of $20 \log |H(e^{j\omega T})|$ versus z, (*d*) corrected plot of arg $H(e^{j\omega T})$ versus z.

- **Page 250** Correct the legend in the left-hand graph of Fig. 5.17*b* as shown in the revised figure shown on p. 6.

- **Page 251** Eq. (5.41) should read as follows:

$$H_{AP}(z) = \frac{r^2 z^2 - 2r(\cos\phi)z + 1}{z^2 - 2r(\cos\phi)z + r^2} \tag{5.41}$$



(*b*)

Figure 5.17

- **Page 251** The equations in the middle of the page should read as follows:

$$
\begin{aligned}
M_{AP}(\omega) &= \left\{ \left[H_{AP}(z) \cdot H_{AP}(z^{-1}) \right]_{z=e^{j\omega T}} \right\}^{\frac{1}{2}} \\
&= \left\{ \left[\frac{r^2z^2 + 2r(\cos\phi)z + 1}{z^2 + 2r(\cos\phi)z + r^2} \cdot \frac{r^2z^{-2} + 2r(\cos\phi)z^{-1} + 1}{z^{-2} + 2r(\cos\phi)z^{-1} + r^2} \right]_{z=e^{j\omega T}} \right\}^{\frac{1}{2}} \\
&= \left\{ \left[\frac{r^2z^2 + 2r(\cos\phi)z + 1}{z^2 + 2r(\cos\phi)z + r^2} \cdot \frac{r^2 + 2r(\cos\phi)z + z^2}{1 + 2r(\cos\phi)z + z^2r^2} \right]_{z=e^{j\omega T}} \right\}^{\frac{1}{2}} = 1
\end{aligned}
$$

- **Page 252** Eqs. (5.42a) and (5.42b) should read as follows: 42

$$\tau_a(\omega) = -\frac{\theta(\omega)}{\omega} \tag{Ea}$$

$$\tau_g(\omega) = -\frac{d\theta(\omega)}{d\omega} \tag{Eb}$$

- **Page 252** Correct the labels in Fig. 5.18 as follows:

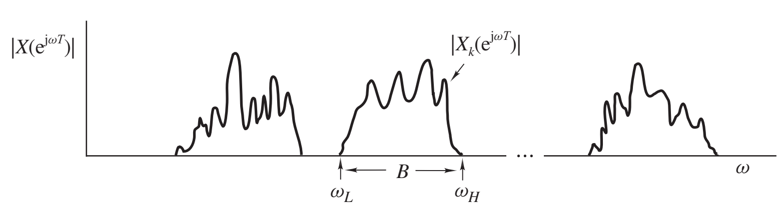


Figure 5.18

- **Page 258** Prob. 5.28 should read as follows:

5.28 (*a*) A system has a transfer function of the form

$$H(z) = \frac{N(z)}{(z-p)^k}$$

Assuming that the system is stable, i.e., $|p| < 1$, show that the steady-state sinusoidal response of the system is given by Eq. (5.30).

(b) Show that Eq. (5.30) applies equally well to systems with more than one higher-order pole in addition to several simple poles.

Chapter 6

- **Page 267** The formula at the bottom of the page should read as follows:

$$x(t) \simeq x(0) \qquad \text{for } |t| \le \epsilon/2$$

- **Page 268** Line 1, delete one "give".
- **Page 268** The formula after Eq. (6.10) should read, as follows:

$$i'(\omega) \simeq 1 \qquad \text{for } |\omega| \le \omega_\infty/2$$

- **Page 268** The footnote should read as follows:

[2] *See pp. 278–281 in Ref. [4] for a relevant discussion.*

- **Page 269** Insert equation numbers in Theorem 6.1A as follows:

12

(a) $$\int_{-\infty}^{\infty} \delta(t-\tau)x(t)\,dt = \int_{-\infty}^{\infty} \delta(-t+\tau)x(t)\,dt \simeq x(\tau) \qquad \text{(Fa)}$$

(b) $$\delta(t-\tau)x(t) = \delta(-t+\tau)x(t) \simeq \delta(t-\tau)x(\tau) \qquad \text{(Fb)}$$

(c) $$\delta(t)x(t) = \delta(-t)x(t) \simeq \delta(t)x(0) \qquad \text{(Fc)}$$

- **Page 275** Table 6.2, column 2, replace a by α in the bottom two entries, as follows:

$$\frac{1}{\alpha + j\omega} \qquad \frac{\omega_0}{(\alpha + j\omega)^2 + \omega_0^2}$$

- **Page 278** Change the index of the summations in Eq. (6.25) from k to n, as follows:

$$\begin{aligned}\mathcal{F}\tilde{x}(t) &= a_0\pi\delta(\omega) + \sum_{n=1}^{\infty} a_n\pi[\delta(\omega + n\omega_0) + \delta(\omega - n\omega_0)] \\ &\quad + \sum_{n=1}^{\infty} jb_n\pi[\delta(\omega + n\omega_0) - \delta(\omega - n\omega_0)] \quad \blacksquare \qquad (6.25)\end{aligned}$$

- **Page 284** Eq. (6.40) should read as follows:

$$\sum_{n=-\infty}^{\infty} x(t+nT) = \frac{1}{T}\sum_{n=-\infty}^{\infty} X(jn\omega_s)e^{jn\omega_s t} \qquad (6.40)$$

- **Page 289** Line 2, insert a minus as follows:

$$x(t) = \begin{cases} 0 & \text{for } t < -3.5 \text{ s} \\ 1 & \text{for } -3.5 \le t < -2.5 \\ 2 & \text{for } -2.5 \le t < 2.5 \\ 1 & \text{for } 2.5 \le t \le 3.5 \\ 0 & \text{for } t > 3.5 \end{cases}$$

- **Page 301** Change k to n twice in Eq. (6.59) as follows: 59

$$X_1(j\omega) = \mathcal{F}x_1(t) = a_0\pi\delta(\omega) + \sum_{n=1}^{\infty} a_n\pi[\delta(\omega + n\omega_0) + \delta(\omega - n\omega_0)]$$
$$+ \sum_{n=1}^{\infty} jb_n\pi[\delta(\omega + n\omega_0) - \delta(\omega - n\omega_0)] \quad \blacksquare \qquad \text{(F)}$$

- **Page 307** Line −11, change "converted" to "converter".
- **Page 311** The second equation in Prob. 6.1, part (a), should read as follows

$$\bar{p}_{\varpi}(\omega) = \begin{cases} 1/\varpi & \text{for } |\omega| \le \varpi/2 \\ 0 & \text{otherwise} \end{cases}$$

- **Page 311** Line −6, mark footnote 6 as follows:
  Obtain the Fourier transform of $\tilde{x}(t)$.[6]
- **Page 311** Insert the following footnote at the bottom of the page:
  [6] *In Probs. 6.2–6.7, assume that* $T > \tau$ *or* τ_0.
- **Page 315** The third line of Prob. 6.21, part (a), should read as follows:
  where $\tau = (N-1)T$ and N is odd. The sampling frequency is $\omega_s = 2\pi/T$.
- **Page 315** The equation in Prob. 6.22 should read as follows:

$$x(t) = \begin{cases} \alpha + (1-\alpha)\cos\dfrac{2\pi t}{\tau} & \text{for } |t| \le \tau/2 \\ 0 & \text{otherwise} \end{cases}$$

  where $\tau = (N-1)T$.
- **Page 317** Line 1, insert "transform" after Fourier as follows:
  Obtain the Fourier transform of
- **Page 317** Line 6, replace " $\omega_s \gg 16/\pi N$" by "$N \gg 4/\pi$" twice, as follows:
  if $N \gg 4/\pi$. (**Hint:** Note that $X(j\omega) \to 0$ if $N \gg 4/\pi$.)
- **Page 317** Replace Figure P6.29 by the following revised figure:

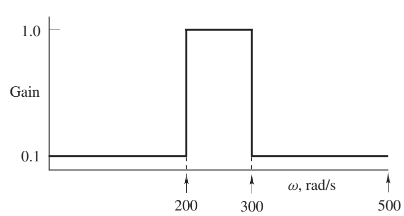


Figure P6.29

- **Page 318** Replace Figure P6.30 by the revised figure shown on p. 9.
- **Page 318** Delete part (c) in Prob. 6.31.

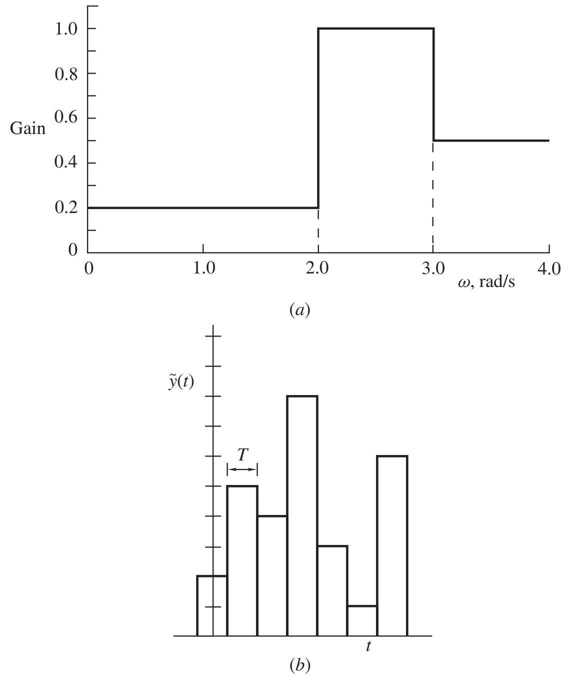


Figure P6.30

Chapter 7

- **Page 352** Insert the following new paragraph just before Sec. 7.8.3 as shown.

On the basis of Eq. (7.34b), we note that for the special case where $X(e^{j(\omega-\varpi)T}) = 1$ for $0 \le \omega \le 2\pi/T$, we have

$$X_w(e^{j\omega T}) = \frac{T}{2\pi}\int_0^{2\pi/T} W(e^{j\varpi T})\,d\varpi$$

Therefore, $X_w(e^{j\omega T})$ would be equal to unity over the frequency range 0 to $2\pi/T$ only if

$$\int_0^{2\pi/T} W(e^{j\varpi T})\,d\varpi = \frac{2\pi}{T}$$

In other words, the level of the amplitude spectrum of the signal will be preserved only if the area under the window function is equal to $2\pi/T$. The rectangular and Kaiser windows have this property but some of the other windows described in Chap. 9, for example, the Dolph-Chebyshev window, do not and a scaling factor would be required to restore the correct level.

- **Page 352** Replace 'right-side' by 'right-sided' in the last line.
- **Page 353** The page should read as follows:

be readily obtained as

$$\vec{w}_K(nT) = \begin{cases} w_K(nT) & \text{for } 0 \le n \le (N_w-1)/2 \\ 0 & \text{for } [(N_w-1)/2+1] \le n \le [N-(N_w+1)/2] \\ w_K[(n-N)T] & \text{for } [N-(N_w-1)/2] \le n \le (N-1) \end{cases} \tag{7.35a}$$

and a corresponding periodic version can be constructed through periodic continuation as

$$\tilde{w}_K(nT) = \sum_{r=-\infty}^{\infty} \vec{w}_K(nT + rNT) \tag{7.35b}$$

as illustrated in the revised Fig. 7.19 shown on p. 10.

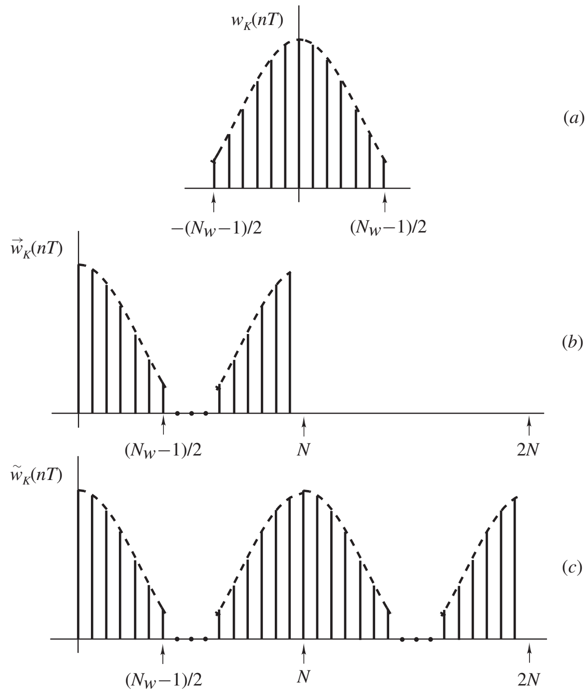


Figure 7.19 Generation of a periodic window function: (*a*) Nonperiodic two-sided window, (*b*) nonperiodic right-sided window of Eq. (7.35*a*), (*c*) periodic window of Eq. (7.35*b*).

- **Page 354** The first paragraph of the solution should read as follows:

The values of the periodic Kaiser window can be obtained as shown in column 2 of Table 7.1 by using Eq. (7.35a). The numerical values of the Kaiser window can be calculated using Eqs. (7.28), (7.29), and (7.26). ■

Page 354 Delete second column in Table 7.1 and change heading for new column 2 as shown in the revised table on p. 10.

Table 7.1 Values of periodic Kaiser window of length 13 (Example 7.4)

$\tilde{w}_K(nT)$	$\vec{w}_K(nT)$
$\tilde{w}_K(0)$	$w_K(0)$
$\tilde{w}_K(T)$	$w_K(T)$
$\tilde{w}_K(2T)$	$w_K(2T)$
$\tilde{w}_K(3T)$	$w_K(3T)$
$\tilde{w}_K(4T)$	$w_K(4T)$
$\tilde{w}_K(5T)$	$w_K(5T)$
$\tilde{w}_K(6T)$	$w_K(6T)$
$\tilde{w}_K(7T)$	0
$\tilde{w}_K(8T)$	0
$\tilde{w}_K(9T)$	0
$\tilde{w}_K(10T)$	$w_K(-6T)$
$\tilde{w}_K(11T)$	$w_K(-5T)$
$\tilde{w}_K(12T)$	$w_K(-4T)$
$\tilde{w}_K(13T)$	$w_K(-3T)$
$\tilde{w}_K(14T)$	$w_K(-2T)$
$\tilde{w}_K(15T)$	$w_K(-T)$

- **Page 356** The last paragraph should read as follows:

A problem of this type can be solved by obtaining the DFT of the signal for several increasing sampling frequencies until two consecutive DFTs differ from one another by an error that is considered acceptable for the application at hand. The last or last-but-one DFT can be deemed to be free of aliasing and the sampling frequency used in that evaluation can be taken to be the required one.

- **Page 357** Table 7.2 should read as follows:

Table 7.2 Values of N, T, and ω_s for Example 7.5

N	T	ω_s
16	1.6	3.9270
32	0.8	7.8540
64	0.4	15.7080
128	0.2	31.4159

- **Page 357** The last paragraph should read as follows:

Upon obtaining the DFT of $\tilde{x}_w(nT)$ for the sets of parameters shown in Table 7.2, the results plotted in Fig. 7.21 can be obtained. As can be seen, the difference between the amplitude spectrums for the last two cases is barely noticeable and we conclude, therefore, that the use of a sampling frequency of 15.7080 or 31.4159 rad/s would result in a negligible amount of aliasing. ■

- **Page 384** Add the following line after part (b) in Prob. 7.6:

The period is $10T$ in each case.

- **Page 384** Delete the following line just after part (a) in Prob. 7.7:

The period is 10 in each case.

- **Page 385** The line after part (b) in Prob. 7.7 should read as follows:

The period is $10T$ in each case.

- **Page 385** Prob. 7.8 should read as follows:

7.8. Find the DFTs of the following periodic signals in closed form:

(a) $\tilde{x}(nT) = e^{-\beta n}$ for $0 \le n \le 31$ if $N = 32$.

(b) Repeat part (a) for $\tilde{x}(nT) = e^{-\gamma n}/2^{\epsilon}$ for $0 \le n \le 31$ if $N = 32$.

- **Page 385** Prob. 7.16 should read as follows:

7.16. Construct Table 7.1 for a Kaiser window of length 31 for a 32-point DFT.

- **Page 386** Part (a) for Prob. 7.19 should read as follows:

(a) Obtain an approximate expression for $W_{\text{TR}}(e^{j\omega T})$.

- **Page 386** Probs. 7.20–7.23 should read as follows:

7.20. An infinite duration discrete-time signal is described by

$$x(nT) = u(nT)\left[A_0 e^{p_0 nT} + 2M_1 e^{\sigma_1 nT}\cos(\omega_1 nT + \theta_1)\right]$$

where $A_0 = 4.532$, $M_1 = 2.350$, $\theta_1 = -2.873$ rad, $p_0 = -0.05$, $\sigma_1 = -0.5$, and $\omega_1 = 1.754$.

(a) Obtain an expression for the frequency spectrum of the signal.

(b) Plot the amplitude spectrum over the range $0 \le \omega \le \omega_s/2$ assuming a sampling frequency $\omega_s = 10$ rad/s.

(*c*) Repeat part (*b*) if the signal is truncated through the use of a rectangular window of length 31.

(*d*) Repeat part (*b*) if the signal is truncated through the use of a Kaiser window of length 31 and $\alpha = 1.0$.

(*e*) Compare the results obtained in parts (*c*) and (*d*).

7.21. An infinite-duration right-sided discrete-time signal $x(nT)$ is obtained by sampling the continuous-time signal

$$x(t) = u(t)\left[A_0 e^{p_0 t} + 2M_1 e^{\sigma_1 t}\cos(\omega_1 t + \theta_1)\right]$$

where $A_0 = 5.0$, $M_1 = 3.0$, $\theta_1 = -2.556$ rad, $p_0 = -2.0$, $\sigma_1 = -1.5$, and $\omega_1 = 2.5$. A finite duration signal can be obtained by applying the discrete-time Kaiser window with $\alpha = 2.0$. Following the approach in Example 7.5, find the lowest sampling frequency that would result in negligible aliasing error.

7.22. Repeat Prob. 7.21 if $A_0 = 5.0$, $M_1 = 3.0$, $\theta_1 = -2.556$ rad, $p_0 = -0.05$, $\sigma_1 = -0.5$, $\omega_1 = 2.5$, and $\alpha = 3.0$.

7.22. Prove Theorem 7.2*B*.

- **Page 386** The first line of Prob. 7.25 should read as follows:

  (*a*) Two periodic signals are given by

- **Page 387** Replace Prob. 7.26 by the following new problem:

7.26 Two periodic signals $x(n)$ and $h(n)$ can be represented by

$$x(n) = \sum_{r=-\infty}^{\infty} x_0(n + 10r) \qquad \text{and} \qquad h(n) = \sum_{r=-\infty}^{\infty} h_0(n + 10r)$$

where

$$x_0(n) = \begin{cases} -\alpha n & \text{for } -5 \le n \le 0 \\ \alpha n & \text{for } 0 \le n \le 5 \\ 0 & \text{otherwise} \end{cases}$$

and

$$h_0(n) = \begin{cases} 1 & \text{for } n = -2, -1, 1, 2 \\ 0 & \text{otherwise} \end{cases}$$

Find the periodic convolution of $x(n)$ and $h(n)$ at $n = 6$.

Chapter 8

- **Page 402** Eqs. (8.8c) and (8.8d) should read as follows:

$$N_{j-1}(z) = N_j(z) - \nu_j P_j(z) = \sum_{i=0}^{j-1} \alpha_{(j-1)i} z^{-i} \tag{8.8c}$$

$$D_{j-1}(z) = \frac{D_j(z) - \mu_j P_j(z)}{1 - \mu_j^2} = \sum_{i=0}^{j-1} \beta_{(j-1)i} z^{-i} \tag{8.8d}$$

- **Page 406** Line −3 Add missing z in equation as follows:

$$= 9 \times \frac{1}{1 + \frac{1}{2}z^{-1}} \times \frac{1 + \frac{4}{9}z^{-1} + \frac{1}{9}z^{-2}}{1 + \frac{7}{12}z^{-1} + \frac{1}{12}z^{-2}}$$

- **Page 408** Line 2, change a plus to a minus sign in the equation as follows:

$$H(z) = \frac{10z^4 - 3.7z^3 - 1.28z^2 + 0.99z}{(z^2 - z + 0.34)(z^2 + 0.9z + 0.2)}$$

- **Page 408** In Example 8.5, the transfer function of the filter should be

$$H(z) = \frac{10z^4 - 3.7z^3 - 1.28z^2 + 0.99z}{(z^2 - z + 0.34)(z^2 + 0.9z + 0.2)}$$

i.e., the coefficient of z in the first quadratic factor in the denominator should be -1.

- **Page 423** Replace Fig. P8.27 by the revised Fig. P8.27 shown below.

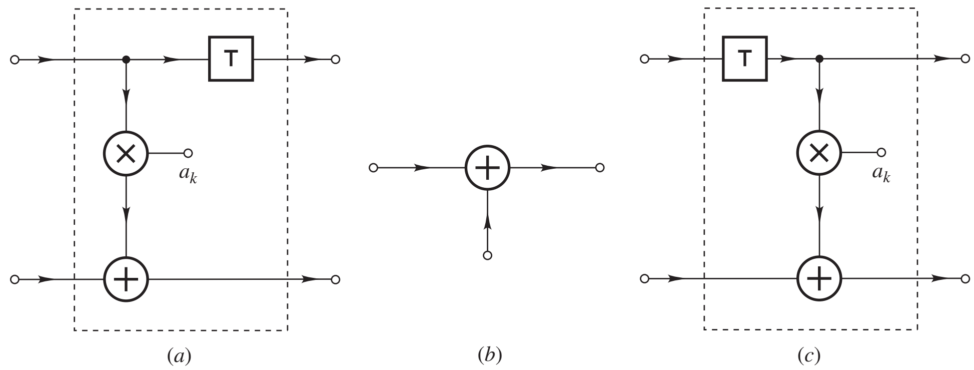


Figure P8.27

- **Page 423** The last line in Prob. 8.28 should read as follows:

using as many VLSI chips of the type shown in Fig. P8.27*c* as necessary and a 2-input adder of the type shown in Fig. P8.27*b*.

- **Page 423** The transfer function in Prob. 8.29 should read as follows:

$$H(z) = H_0 \frac{z+1}{z+b_{11}} \cdot \frac{z^2 + a_{22}}{z^2 + b_{12}z + b_{22}}$$

- **Page 437** Line 12 should read as follows:

and on using the complex-scale-change theorem of the z transform (Theorem 3.5), we have

Chapter 9

- **Page 441** The formula for the kth-order Chebyshev polynomial should read as follows:

$$T_k(x) = \begin{cases} \cos(k \cos^{-1} x) & \text{for } |x| \leq 1 \\ \cosh(k \cosh^{-1} x) & \text{for } |x| > 1 \end{cases}$$

- **Page 443** Eq. (9.24) and the line before it should read as follows:

and hence we get

$$h(nT) = \begin{cases} 1 - \dfrac{2\omega_c}{\omega_s} & \text{for } n = 0 \\ -\dfrac{1}{n\pi} \sin \omega_c nT & \text{otherwise} \end{cases} \qquad (9.24)$$

- **Page 448** The specifications for Example 9.4 should read as follows:
  - Maximum passband ripple in frequency range 0 to 3.0 rad/s: 0.1 dB
  - Minimum stopband attenuation in frequency range 5.0 to 10.0 rad/s: 40 dB
  - Sampling frequency: 20 rad/s

- **Page 452** The equations for $h(nT)$ and the line that follows should read as follows:

$$\begin{aligned} h(nT) &= \frac{1}{\omega_s}\left[\int_{-\omega_{c2}}^{-\omega_{c1}} e^{j\omega nT}\,d\omega + \int_{\omega_{c1}}^{\omega_{c2}} e^{j\omega nT}\,d\omega\right] \\ &= \frac{1}{\omega_s}\left[\frac{e^{-j\omega_{c1}nT}}{jnT} - \frac{e^{-j\omega_{c2}nT}}{jnT} + \frac{e^{j\omega_{c2}nT}}{jnT} - \frac{e^{j\omega_{c1}nT}}{jnT}\right] \\ &= \frac{1}{n\pi}\left[\frac{e^{j\omega_{c2}nT} - e^{-j\omega_{c2}nT}}{2j} - \frac{e^{j\omega_{c1}nT} - e^{-j\omega_{c2}nT}}{2j}\right] \\ &= \frac{1}{n\pi}(\sin\omega_{c2}nT - \sin\omega_{c1}nT) \end{aligned}$$

where $h(0) = 2(\omega_{c2} - \omega_{c1})/\omega_s$. Now according to step 2,

- **Page 459** In Prob. 9.3, change the second "(a)" to "(b)".
- **Page 460** In Prob. 9.4, change the second "(a)" to "(b)".
- **Page 461** Prob. 9.12, part (b), should read as follows:

(b) Assuming that the passband extends from 3.8 to 6.2 rad/s modify the design in part (a) so as to achieve an amplitude response that oscillates about unity.

- **Page 461** Prob. 9.13 should read as follows:

(a) Repeat Prob. 9.12 assuming a ripple ratio of −25 dB, a passband that extends from 3.91 to 6.09 rad/s, and stopbands that extend from 0 to 2.0 and 8.0 to 10 rad/s.

(b) Compare the design of this problem with that of Prob. 9.12.

- **Page 462** Delete part (c) in Prob. 9.20.
- **Page 489** Replace $D(s)$ by $D_0(s)$ in Eqs. (10.37a) and (10.37b).

Chapter 10

- **Page 497** The line after Eq. (10.58) should read as follows:

are the *selectivity constant* and *discrimination constant*, respectively. The loss is given by

- **Page 513** Replace line 4 by the following line

only objective in the approximations described is to achieve a specific loss characteristic, there

- **Page 513** Replace $B(s)$ by $B(\cdot)$ in line 11.
- **Page 516** The equation should read as follows:

$$H_{LP}(\bar{s}) = H_N(s)\Big|_{s=\lambda\bar{s}}$$

- **Page 520** The first line of Prob. 10.4 should read as follows:

10.4 Filter specifications are often described pictorially as in Fig. P10.4, where ω_p and ω_a are the desired passband

- **Page 522** The first line of Prob. 10.13 should read as follows:

A fourth-order normalized lowpass inverse-Chebyshev filter with a minimum stopband loss of 40 dB is required.

- **Page 523** Prob. 10.17 should read as follows:

In a particular application an elliptic lowpass filter is required. The specifications are

- Selectivity k: 0.6
- Maximum passband loss A_p: 0.5 dB
- Minimum stopband loss A_a: 40.0 dB

(a) Determine the order of the transfer function.
(b) Determine the minimum stopband loss.
(c) Obtain the transfer function.

- **Page 523** Prob. 10.18 should read as follows:
  An elliptic lowpass filter satisfying the specifications

  - Selectivity k: 0.95
  - Maximum passband loss A_p: 0.3 dB
  - Minimum stopband loss A_a: 60.0 dB

  is required.

  (a) Determine the order of the transfer function.
  (b) Determine the minimum stopband loss.
  (c) Obtain the transfer function.

- **Page 525** Prob. 10.27, part (a), replace B_0 by B .
- **Page 525** Prob. 10.28, part (a), replace B_0 by B .
- **Page 526** Prob. 10.38, replace the second “Lower stopband edge” by “Upper stopband edge”.
- **Page 527** Prob. 10.43, replace the second “Lower stopband edge” by “Upper stopband edge”.
- **Page 527** Prob. 10.43, replace the second “Lower stopband edge” by “Upper stopband edge”.

Chapter 11

- **Page 545** The first line in Sec. 11.6.3 should read as follows:
  Let ω and Ω be the frequency variables in the analog filter and the derived digital filter,
- **Page 556** The value of parameter R_1 in Prob. 11.4 should be as follows:

$$R_1 = -2.26 - j0.624$$

- **Page 558** Prob. 11.12, part (a), should read as follows:

  (a) Redesign the filter of Prob. 11.5 by employing the invariant sinusoid-response method (see Prob. 11.11). The value of ω_0 may be assumed to be 1 rad/s.

Chapter 12

- **Page 572** Line 3, replace “$\tan \Omega T/2$” by “$\tan(\Omega T/2)$”.
- **Page 572** Line 11, replace

$$\frac{\omega_p}{\omega_p} \geq K_2$$

by

$$\frac{\omega_p}{\omega_a} \geq K_2$$

- **Page 572** Line −10, replace “$\Omega_{a1} \geq \Omega_{a1}$” by “$\Omega_{a1} \geq \tilde{\Omega}_{a1}$”.

Chapter 14

- **Page 622** Line 8 should read as follows:

  system (i.e., $-8/8$ in Table 14.1) but not in the other two.

- **Page 645** The paragraph after Eq. (14.48) should read as follows:

  In the case of parallel or cascade realizations, efficient scaling can be accomplished by using one scaling multiplier at the input of each section and, if necessary, one at the output of the realization to maximize the output level.

- **Page 646** The equations for λ_0, λ_1, ..., should read as follows:

$$\lambda_0 = \frac{1}{\max\left(\|F_1'\|_\infty,\ \|F_1\|_\infty\right)} \qquad \lambda_1 = \frac{1}{\lambda_0 \max\left(\|F_1 F_2'\|_\infty,\ \|F_1 F_2\|_\infty\right)}$$

$$\lambda_2 = \frac{1}{\lambda_0\lambda_1 \max\left(\|F_1 F_2 F_3'\|_\infty,\ \|F_1 F_2 F_3\|_\infty\right)} \qquad \lambda_3 = \frac{1}{\lambda_0\lambda_1\lambda_2 \|F_1 F_2 F_3\|_\infty} \qquad \blacksquare$$

- **Page 646** Replace Fig. 14.9 by the revised figure shown below.

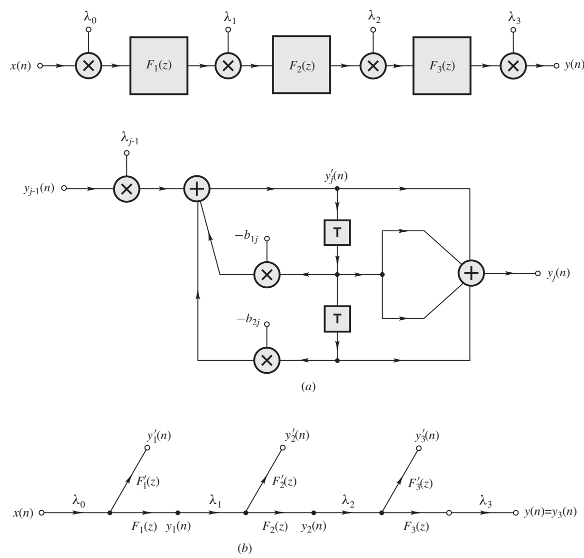


Figure 14.9

- **Page 656** Line −7, the formula should read as follows:

$$\theta = \cos^{-1} \frac{b_1}{2\sqrt{b_0}}$$

- **Page 672** In Prob. 14.26, replace references to Prob. 11.13 and Prob. 11.18 by Prob. 14.13 and Prob. 14.18, respectively.

Chapter 15

- **Page 698** Caption of Fig. 15.5, change "gain" to "error".
- **Page 699** Caption of Fig. 15.6, change "gain" to "error".
- **Page 703** Caption of Fig. 15.7, change "gain" to "error".
- **Page 704** Eq. (15.54) should read as follows:

$$P_c'(\omega) = (\sin\omega) P_{c-1}(\omega) \qquad (15.54)$$

- **Page 714** Caption of Fig. 15.10, change “gain” to “error”.

Chapter 16

- **Page 725** Line 4 should read as follows:

  tolerance on the change in the objective function, e.g., $|f_{k+1} - f_k| < \varepsilon$, may be preferable and sometimes

- **Page 732** Delete “(more positive)” in the first line after Eq. (16.25).

- **Page 746** Line 9, put square brackets in equation as follows:

$$\nabla |e_i(\mathbf{x})| = [\text{sgn } e_i(\mathbf{x})] \, \nabla e_i(\mathbf{x})$$

- **Page 747** Lines 10 and 11 should read as follows:

  large minimum stopband attenuation. If the required specifications call for a maximum passband error that is different from the maximum stopband error, then by using a sufficiently large filter order one would be

- **Page 747** Lines −15 and −14 should read as follows:

  satisfy the inequality

$$-\frac{\delta}{w_m} \le [M(\breve{\mathbf{x}}, \omega_i) - M_0(\omega_i)] \le \frac{\delta}{w_m}$$

- **Page 756** The inequality on line 11 should read as follows:

$$\omega_1 \le \omega_i \le \omega_K$$

Appendix A

- **Page 912** Replace Theorem A.3 by Theorems A.3a and A.3b as follows:

  Theorem A.3a Ratio Test ***If $w_n \neq 0$ for $n = 0,\ 1,\ 2, \ldots$ and in addition***

$$\left| \frac{w_{n+1}}{w_n} \right| \le q \qquad \text{for all } n > N$$

  where q is a fixed number less than 1, then the series in Eq. (A.39) converges. On the other hand, if

$$\left| \frac{w_{n+1}}{w_n} \right| \ge 1 \qquad \text{for all } n > N$$

  then the series diverges. ▲

  Theorem A.3b Root Test ***If***

$$\sqrt[n]{|w_n|} \le q \qquad \text{for all } n > N$$

  where q is a fixed number less than 1, then the series in Eq. (A.39) converges. On the other hand, if

$$\sqrt[n]{|w_n|} \ge 1 \qquad \text{for all } n > N$$

  then the series diverges. ▲

- **Page 920** Line 9, replace “can obtained” by “can be obtained”.

- **Page 920** Line 13, replace “can obtained” by “can be obtained”.

- **Page 922** Line −3, replace “5. Inversion and scaling” by “6. Inversion and scaling”.