DIGITAL FILTERS
Analysis, Design, and Applications
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ERRATA

Printing #1

• Page vii, line −4†: Replace ‘Geophysicists’ by ‘Geoscientists’.
• Page 10, Table 1.1: The upper limit of the summation should be $K$.
• Page 10, Table 1.1: Adder input $x_k(nT)$ should read $x_K(nT)$.
• Page 18, line −2: Change l’Hospital’s to l’Hôpital’s.
• Page 21, line +12: Replace ‘$n \to 0$’ by ‘$n \to \infty$’.
• Page 61: Theorem 2.11 should read as follows:

Theorem 2.11 Parseval’s discrete-time formula A discrete-time signal and its $z$ transform evaluated on the unit circle $z = 1$ satisfy Parseval’s discrete-time formula given by

$$
\sum_{n=-\infty}^{\infty} |f(nT)|^2 = \frac{1}{\omega_s} \int_{0}^{\omega_s} |F(e^{j\omega T})|^2 \, d\omega
$$

and if $T = 1$ s, then

$$
\sum_{n=-\infty}^{\infty} |f(n)|^2 = \frac{1}{2\pi} \int_{0}^{2\pi} |F(e^{j\omega})|^2 \, d\omega
$$

• Page 61: The part of the proof after line +12 should read as follows:

$$
G(z) = \sum_{n=-\infty}^{\infty} f^*(nT)z^{-n} = \left[ \sum_{n=-\infty}^{\infty} f(nT)(z^{-1})^{-n} \right]^* = F^*(z^{-1})
$$

Hence $G(1/v) = F^*(v)$. From Theorem 2.10

$$
\mathcal{Z}[f(nT)g(nT)] = \sum_{n=-\infty}^{\infty} [f(nT)g(nT)]z^{-n} = \frac{1}{2\pi j} \oint_{\Gamma} F(v)G\left(\frac{z}{v}\right) v^{-1} \, dv
$$

If we let $z = 1$ and replace $g(nT)$ by $f^*(nT)$ and $G(1/v)$ by $F^*(v)$, we get

$$
\sum_{n=-\infty}^{\infty} f(nT)f^*(nT) = \frac{1}{2\pi j} \oint_{\Gamma} F(v)F^*(v)v^{-1} \, dv
$$

Now if we let $v = e^{j\omega T}$, we obtain Parseval’s formula.

†Count from the bottom of the page for negative lines.
function
\[ p_\epsilon(t) = \begin{cases} 
\frac{1}{2\epsilon} & \text{for } |t| \leq \epsilon \\
0 & \text{otherwise}
\end{cases} \]  \hspace{1cm} (6.3)

depicted in Fig. 6.4a, whose limit as \( \epsilon \to 0 \) has often been used to define the continuous-time impulse function. From Eq. (6.1), we can readily obtain the Fourier transform of \( p_\epsilon(t) \) as
\[ \mathcal{F}p_\epsilon(t) = \int_{-\infty}^{\infty} p_\epsilon(t)e^{-j\omega t}dt = \int_{-\epsilon}^{\epsilon} \frac{1}{2\epsilon}e^{-j\omega t}dt = \frac{\sin \omega \epsilon}{\omega \epsilon} \]
and so
\[ \lim_{\epsilon \to 0} \left[ \mathcal{F}p_\epsilon(t) \right] = 1 \]

- Page 183, Fig. 6.4a: Replace \( p_0(t) \) by \( p_\epsilon(t) \).
- Page 183, Fig. 6.4a: Replace \( \frac{1}{2\epsilon} \) by \( \frac{1}{2\epsilon} \).
- Page 183, Fig. 6.4b: Replace y-axis label \( S_b(n, t) \) by \( S_b(n, t) \).
- Page 184, line −3: Replace \( \tilde{F}(t) \) by \( \tilde{F}(j\omega) \).
- Page 191, line 11: Replace \( f_{-\infty}^{-\infty} \) by \( f_{-\infty}^{-\infty} \).
- Page 191, line 12: Replace \( f_{-\infty}^{-\infty} \) by \( f_{-\infty}^{-\infty} \).
- Page 193, line −6: Replace \( e^{j\omega t_0} \) by \( e^{j\omega t} \).
• Page 197: Eq. (6.19) should read:

\[ a_n = \frac{1}{T} \int_{-T/2}^{T/2} f(t)e^{-jn\omega_s t} dt \] (6.19)

• Page 206, Fig. 6.13:
  (i) Reverse each of the two arrows between the circles with labels \( X(s) \) and \( X(j\omega) \);
  (ii) Replace \( \hat{x}(j\omega) \) in the middle circle at the right-hand column by \( \hat{X}(j\omega) \);
  (iii) The formula \( j\omega \to \frac{1}{T} \ln z \) next to the arrow between the circles with labels \( \hat{x}(j\omega) \) and \( X_D(z) \) should read \( j\omega \to \frac{1}{T} \ln z \);
  (iv) The symbols \( T \) next to the arrows between the bottom two circles should be replaced by \( Z \).

• Page 210, line 11: Replace \( \hat{x}_6(nT) \) by \( \hat{x}_6(t) \)

• Page 210, line 16: Replace \( x_7(nT) \) by \( x_7(t) \)

• Page 214, Fig. 6.17: Replace \( x(kT) \) by \( y(kT) \).

• Page 227, Example 7.2: Change denominator coefficient \( b_{01j} \) in \( H_A(s) \) to \( b_{0j} \).

• Page 232, Fig. 7.6: The label of the \( y \) axis should read \( x(\tau) \); the label of the \( x \) axis should read \( \tau \).

• Page 279, eqn. (9.12): Add braces as follows:

\[
H(z) = \frac{1}{z^{(N-1)/2}} \left\{ \sum_{n=0}^{(N-3)/2} h(nT)(z^{(N-1)/2-n} \pm z^{-[(N-1)/2-n]}) \right. \\
\left. + \frac{1}{2} h \left[ \frac{(N-1)T}{2} \right] (z^0 \pm z^0) \right\} 
\] (9.12)

• Page 283, line +9: Change ‘Fig. 5a’ to ‘Fig. 9.5a’.

• Page 283, line +12: Insert the phrase ‘with \( \omega_s = 2\pi/T = 1 \).’ just before the word ‘According’.

• Page 292, line +8: The formula for the \( k \)th-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 309: Add caption ‘FIGURE P9.13’ to the top illustration.
• Page 319: The equation above Eq. (10.12) should read:

\[ \frac{1}{2} \cos (\omega_c t_1 - \omega_c t_2) + \frac{1}{2} E \{ \cos (\omega_c t_1 + \omega_c t_2 + 2\gamma) \} \]

• Page 320, line 8: The equation should read:

\[ P_{T_0} = \int_{-\infty}^{\infty} \frac{|X_{T_0}(j\omega)|^2}{2T_0} d\omega \]

• Page 321, Fig. 10.4: The symbol \( d\tau \) is the width of the elemental area shown along the \( t_2 \) axis.

• Page 323, line −3: Section heading should read:

**DISCRETE-TIME RANDOM PROCESSES**

• Page 342, line +6: Replace \( \sigma_{c_i}^2 \) by \( \sigma_{\Delta c_i}^2 \).

• Page 346: Eq. (11.24) should read:

\[ \frac{\beta_1}{\beta_1 - 2\bar{S}_{b_1}} \]

(11.24)

• Page 346: The equations after line +10 should read:

\[ |\bar{S}_{b_0}^{M}| \ll |\bar{S}_{b_0}^{M}| \quad \text{and} \quad |\bar{S}_{b_1}^{M}| \ll |\bar{S}_{b_1}^{M}| \]

• Page 347, Fig. 11.6: Replace labels \( E \) and \( m_2 \) by \( -E \) and \( -m_2 \), respectively.

• Page 357, line −4: Equation should read:

\[ \|X\|_1 = \frac{1}{2\pi} \int_{-\omega_0/2}^{\omega_0/2} \pi M [\delta(\omega - \omega_0) + \delta(\omega + \omega_0)] d\omega \]

\[ = M \]

• Page 360, Fig. 11.10: Add label ‘1’ next to outgoing branch from node \( x(n) \).

• Page 360, Fig. 11.10: Reverse the arrow in the lower branch with transmittance \( E^{-1} \).

• Page 362, line +5: The equation should read

\[ \|\tilde{G}_i\|^2 = \|\tilde{G}_j\|^2 \]

i.e., add tildes on the \( G \)’s.

• Page 363:
(i) Eq. (11.63) should read

\[
T = \begin{bmatrix}
\|\hat{F}_1\|_2^{-1} & 0 \\
0 & \|\hat{F}_2\|_2^{-1}
\end{bmatrix}
\] (11.63)

(ii) Eq. (11.64) should read

\[
T = \begin{bmatrix}
\|\hat{F}_1\|_{\infty}^{-1} & 0 \\
0 & \|\hat{F}_2\|_{\infty}^{-1}
\end{bmatrix}
\] (11.64)

(iii) Eq. (11.66c) should read

\[
\hat{a}_{21} = (K_1 \mp K_2)/(1 + \gamma_0)
\] (11.66c)

(iv) The equation

\[
T = \begin{bmatrix}
\|F_{1i}\|_p^{-1} & 0 \\
0 & \|\hat{F}_{2i}\|_p
\end{bmatrix}
\]

should read

\[
T = \begin{bmatrix}
\|F_{1i}\|_p^{-1} & 0 \\
0 & \|F_{2i}\|_p^{-1}
\end{bmatrix}
\]

• Page 364: Eq. (11.67) should read:

\[
\lambda = \frac{1}{\|H\|_2}
\] (11.67)

• Page 371, caption of Fig. 11.13a: Replace the comma after ‘Eq. (11.77)’ by a period.

• Page 371, bottom of the page: Correct the right-hand inequality signs in the three equations as follows:

\[
0.5 \leq |b_0| < 0.75 \\
0.75 \leq |b_0| < 0.833 \\
\frac{2k-1}{2k} \leq |b_0| < \frac{2k+1}{2(k+1)}
\]

• Page 377, Fig. 11.16: The constants of the left-hand multipliers should be $-\alpha_1$ and $-\alpha_2$ and those of the next two multipliers to the right should be $\beta_1$ and $\beta_2$, i.e., the $\alpha$’s and the $\beta$’s should be interchanged.

• Page 380, lines +2 to +4 after Fig. 11.18: Replace $Q_k$ by $Q_k[x]$ three times.

• Page 387: Prob. 11.26, should read as follows:

11.26. (a) Apply error-spectrum shaping to the scaled cascade canonic realization obtained in Prob. 11.13.
(b) The modified realization is to be implemented in terms of fixed-point arithmetic and product quantization is to be by rounding. Compute and plot the relative, output-noise PSD versus frequency assuming the $L_2$ scaling obtained in Prob. 11.18.

(c) Compare the results with those obtained without error-spectrum shaping in Prob. 11.18.

- Page 412, line +3: ‘Eq. (16.22)’ should read ‘Eq. (12.22)’.
- Page 442: Prob. 12.24 should read as follows:

12.24. Obtain a digital realization for a general 2-port represented by Eqs. (12.14a) and (12.14b).

- Page 452, Fig. 13.5: Replace $nT$ in the top, right-hand graph by $\omega_s$.
- Page 455, Fig. 13.7: Replace ‘Eq. (6.22), ‘Eq. (6.14)’, and ‘Eq. (6.20)’ by ‘Eq. (6.44)’, ‘Eq. (6.36)’, and ‘Eq. (6.42)’, respectively.
- Page 481, line –7: The line should read ‘then for $kL - (k - 1)(N - 1) \leq n \leq (k + 1)L - k(N - 1) - 1$’.
- Page 490, line –13: Add ‘with $N$ even after ‘recursive filter’.
- Page 496, line +8: Replace $x_0$ by $x_0^T$.
- Page 507, line +17: Replace ‘$\alpha_k(\sigma - 1)g_k^T d_k$’ by ‘$\alpha_k(\sigma - 1)g_k^T d_k$’.
- Page 519: Delete ‘14.06ab’ and ‘14.07ab’ just before Example 14.4.
- Page 535, Fig. 14.11: Replace $\omega$-axis labels 3.0, 3.5, 4.0, 4.5, and 5.0 by 0.30, 0.35, 0.40, 0.45, and 0.50, respectively.
- Page 538: Prob. 14.1 should read as follows:

14.1. The step response $y(t)$ of a digital filter is required to approximate the ideal step response

$$y_0(t) = \begin{cases} 
  t & \text{for } 0 \leq t < 2 \\
  2 & \text{for } 2 \leq t < 3 \\
  -t + 5 & \text{for } 3 \leq t < 4 \\
  1 & \text{for } 4 \leq t \leq 5 
\end{cases}$$

where $t = nT$. Formulate a least-squares objective function for the solution of the problem.

- Page 541, line –7: Add ‘sixth-order’ before ‘lowpass’.
- Page 551, line +7: Replace ‘$\omega_{N_{j+1}}$’ by ‘$\omega_{(N_{j+1})j}$’.
• Page 563, line −13: Replace ‘ρ − r’ by ‘ρ − (r + 1)’.

• Page 575, Eqs. (15.55c) to (15.55e) should read:

\[ a_k = \frac{1}{2}(\tilde{c}_{k-1} - \tilde{c}_{k+1}) \text{ for } k = 2, 3, \ldots, c - 2 \] (15.55c)
\[ a_{c-1} = \frac{1}{2}\tilde{c}_{c-2} \] (15.55d)
\[ a_c = \frac{1}{2}\tilde{c}_{c-1} \] (15.55e)

• Page 577: Eqs. (15.58c) and (15.58d) should read:

\[ b_k = \frac{1}{2}(\tilde{b}_{k-1} + \tilde{b}_k) \text{ for } k = 2, 3, \ldots, d - 1 \] (15.58c)
\[ b_d = \frac{1}{2}\tilde{b}_{d-1} \] (15.58d)

• Page 577: Eqs. (15.59c) and (15.59d) should read:

\[ b_k = \frac{1}{2}(\tilde{d}_{k-1} - \tilde{d}_k) \text{ for } k = 2, 3, \ldots, d - 1 \] (15.59c)
\[ b_d = \frac{1}{2}\tilde{d}_{d-1} \] (15.59d)

• Page 589, Prob. 15.16: Delete ‘Lower’ in ‘Lower passband edge’ and ‘Lower stopband edge’.

• Page 599, caption of Fig. 16.6: Add ‘and interpolator’ after ‘upsampler’.

• Page 610: The last two lines before Example 16.2 should read ‘by Gazsi (see Sec. 12.5 and [10] of Chap. 12) or by a method proposed by Vaidyanathan, Mitra, and Neuvo (see Additional References of Chap. 12, p. 438).’

• Page 613: Correct Eq. (16.27) as follows:

\[ ||H(e^{j\omega T}) - 1|| = |H(e^{j(\omega_s/2 - \omega)T})| \leq \delta \] (16.27)

• Page 613: Modify Eq. (16.28) as follows:

\[ |H_0(e^{j\omega T})|^2 + |H_0(e^{j(\omega - \pi)T})|^2 = G = 1 + 2\delta \] (16.28)

• Page 613, Eq. (16.29): Add a minus sign just after the equal sign.

• Page 619, line −4 above Table 16.2a: Replace the sentence ‘Using this ... impulse response as’ by ‘By letting nT = t in Eq. (16.40) and then sampling the function h(t) at t = (n - 0.5)T for −(N/2 − 1) ≤ n ≤ N/2, we have’

• Page 623, line +7: Correct \[ e^{j[\omega_c nT + \phi(nT)]} \] to read \[ e^{j[\omega_c nT + \phi(nT)]}. \]

• Page 629, Fig. 16.26: Connect node \( a_0 \) to the adjacent multiplier.

• Page 629, line +5 after Fig. 16.26: Replace \( a_n \) by \( a_n. \)
• Page 646, line −1: Replace ‘for $1 \leq |\omega| \leq 3$ ’ by ‘for $1 \leq |\omega| \leq 10$ ’.

• Page 647, line +2: Replace ‘for $1 \leq |\omega| \leq 3$ ’ by ‘for $1 \leq |\omega| \leq 10$ ’.

• Page 648, line −17: Replace ‘of the two filters in cascade’ by ‘of the QMF bank’.

• Page 648, line −11: Correct the equation

$$\frac{1}{2}[d_A(s)d_B(-s) - d_A(-s)d_B(s)] = N(s)$$

to read

$$\frac{1}{2}[d_A(s)d_B(-s) + d_A(-s)d_B(s)] = N(s)$$

• Page 648, line −9: Replace ‘Butterworth’ by ‘fifth-order Butterworth’.

• Page 648, line −5: Replace ‘Chebyshev’ by ‘fifth-order Chebyshev’.

• Page 650, Fig. P16.10: Replace the three $L$’s next to the down arrows by $M$’s.

• Page 650, line −11: Replace $R_n$ by $R_n$.

• Page 651, line −6: Replace ‘Equalize’ by ‘Identify’.

• Page 677, line 10: Replace ‘Maison’s’ by ‘Mason’s’.