Errata for *Control System Design (1st Ed.)*

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1 Chapter 1

2 Chapter 2

- §2.6, p33: The paragraph following Equation (2.6.3) should read

  "...implements an approximate inverse of $f\langle\circ\rangle$, that is, $u = f^{-1}\langle r\rangle$, if..."

3 Chapter 3

- §3.6, p48: Equation (3.6.18) should read as follows

$$\frac{d}{dt}\begin{pmatrix} x_1(t) \\ x_2(t) \end{pmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -\frac{k_1 k_2}{JR} \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{k_1}{JR} \end{bmatrix} v_a(t)$$

- §3.10, p56: Equation (3.10.21) should read as follows

$$\ddot{\theta} = \frac{1}{\ell[\lambda_m + \sin^2\theta(t)]}\left[-\frac{f(t)}{m}\cos\theta(t) - \dot{\theta}^2(t)\ell\sin\theta(t)\cos\theta(t) + (1+\lambda_m)g\sin\theta(t)\right]$$

4 Chapter 4

- §4.4, p68: In Table 4.1, the Laplace-Transform of

$$e^{\alpha t}\sin(\omega_o t + \beta)$$

  should read

$$\frac{(\sin\beta)s + \omega_o\cos\beta - \alpha\sin\beta}{(s-\alpha)^2 + \omega_o^2}$$

- §4.10, p93: Insert the following paragraph after Equation (4.10.3)

  Actually, to be rigorous, we do need some extra conditions on $f(t)$. For example, $f(t)$ is often required in the literature to satisfy the Dirichlet conditions, which in their simplest form require that $f(t)$ and $f'(t)$ be piecewise continuous. Then the inverse transform gives $[f(t^-) + f(t^+)]/2$ at points of discontinuity. More simply we could require that $F(jw)$ be absolutely integrable but this would rule out some cases of interest to us.

- §4.10, p95: In Table 4.4, the Fourier-Transform of the product $f_1(t)f_2(t)$ should read

$$\frac{1}{2\pi}\int_{-\infty}^{\infty} F_1(j\zeta)F_2(j\omega - j\zeta)d\zeta$$

- §4.10, p96: Theorem 4.1 should read

  Let $F(j\omega)$ and $G(j\omega)$ denote the Fourier transform of $f(t)$ and $g(t)$ respectively, where $f(t)$ and $g(t)$ are assumed to be square integrable on the real axis. Then, ...

- §4.11, p98: In Table 4.5 the resonant system should read

$$\frac{\omega_n^2}{s^2 + 2\psi\omega_n s + \omega_n^2}$$

- §4.11, p99: At the top of this page the resonant system should read

$$\frac{\omega_n^2}{s^2 + 2\psi\omega_n s + \omega_n^2}$$

5 Chapter 5

- §5.6, p137: Equation (5.6.13) should read

$$1 + 4\frac{s+\alpha}{s(s^2+s-2)} = \frac{s(s^2+s-2)+4s+4\alpha}{s(s^2+s-2)} = 0 \Longrightarrow s(s^2+s+2)+4\alpha = 0$$

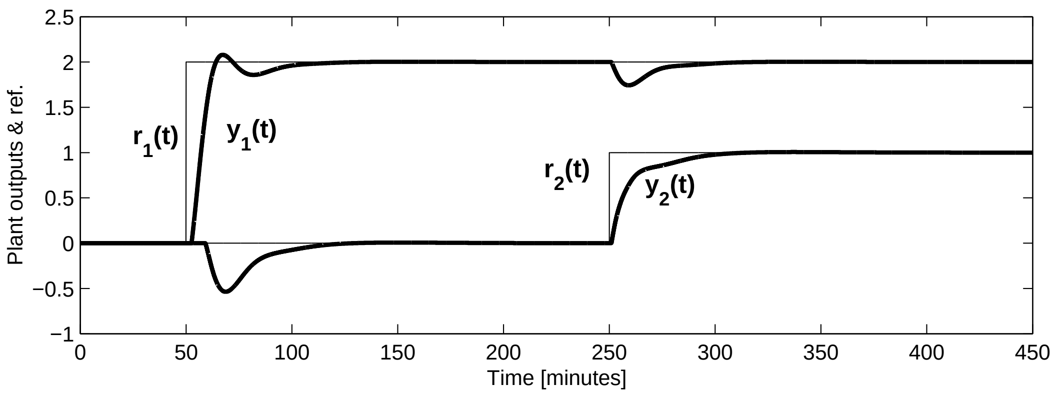
- §5.8, p144: In Figure 5.8, upper plot, the arrow for the gain margin should point upwards.

6 Chapter 6

- §6.7, p173: Equation (6.7.7) should read

$$C_2(s) = 1 + \frac{0.15}{s}$$

- §6.7, p173: There is a problem with the simulation shown in Fig 6.12. The gain of G_{12} should be multiplied by 100 and the gain of G_{21} divided by 100. This (almost) gives the results in the text and the same qualitative conclusions apply. When these directions are followed and simulated this new Figure 6.12 results:



A Simulink schematic (fig6_12.mdl) which closely reproduces this figure has been added to the Matlab Support appendix of the web site.

7 Chapter 7

8 Chapter 8

9 Chapter 9

- §9.3, p246: Equation (9.3.3) should read

$$\int_{0^-}^{\infty} \frac{1}{\omega^2} ln|T_o(j\omega)|d\omega = \frac{\pi\tau}{2} - \frac{\pi}{2k_v}$$

- §9.3, p247: Equation (9.3.8) should read

$$\int_{0^-}^{\infty} \frac{1}{\omega^2} ln|T_o(j\omega)| d\omega = \int_0^{\infty} ln \left| T_o(\frac{1}{jv}) \right| dv = \frac{\pi\tau}{2}$$

- §9.3, p248: Equation (9.3.11) should read

$$\int_{0^-}^{\infty} \frac{1}{\omega^2} ln|T_o(j\omega)| d\omega = \frac{\pi\tau}{2} + \pi \sum_{i=1}^{M} \frac{1}{c_i} - \frac{\pi}{2k_v}$$

- §9.6, p257: Equation (9.6.2) should read

$$\ddot{\theta}(t) = \frac{1}{l(\lambda_m + \sin^2\theta(t))} \left(\frac{-f(t)}{m} \cos\theta(t) - (\dot{\theta}(t))^2 l \cos\theta(t) \sin\theta(t) + (1+\lambda_m) g \sin\theta(t) \right)$$

10 Chapter 10

- §10.5, p274: Equation (10.5.10) should read

$$U_d(s) = -S_{uo}(s) G_{o2}(s) D_g(s) + S_o(s) G_f(s) D_g(s)$$

11 Chapter 11

12 Chapter 12

- §12.7, p325: In Table (12.1) the entry in the second column for $f[k] = k^2$ should read

$$\frac{z(z+1)}{(z-1)^3}$$

- §12.7, p327: Equation (12.7.7) should read

$$G_q(z) = \frac{0.5z^2 - 1.2z + 0.9}{z^3}$$

- §12.7, p328: Equation (12.7.11) should read

$$G_q(z) = \frac{0.5}{z + 0.5}$$

- §12.13, p340: The top line of Equation (12.13.6) should read

$$H_{oq}(z) = \frac{(z-1)}{z} \mathcal{Z} \left\{ \frac{b_0}{a_0}(k\Delta) - \frac{b_0}{a_0^2} + \frac{b_0}{a_0^2} e^{-a_0 k\Delta} \right\}$$

- §12.14, p340: Equation (12.14.4) should read

$$x((k+1)\Delta) = e^{\mathbf{A}\Delta} x(k\Delta) + \int_0^{\Delta} e^{\mathbf{A}(\Delta-\tau)} \mathbf{B} u(\tau + k\Delta) d\tau$$

- §12.14, p341: Added **B** to the end of Equation (12.14.12)

$$\mathbf{B}_q \triangleq \int_0^{\Delta} e^{\mathbf{A}(\Delta-\tau)} \mathbf{B} d\tau = \mathbf{A}^{-1} \left[e^{\mathbf{A}\Delta} - I \right] \mathbf{B} \quad \text{if} \quad \mathbf{A} \quad \text{is nonsingular}$$

13 Chapter 13

14 Chapter 14

15 Chapter 15

- §15.7, p440: Equation (15.7.4) should read

$$C(s) = \frac{Q(s)}{1 - Q(s)G_o(s)} = \frac{\tilde{P}(s)A_o(s)}{\tilde{E}(s) - \tilde{P}(s)B_o(s)}$$

16 Chapter 16

- §16.2, p461: Remark 16.2 now reads:

  The factorization (16.2.11) is also known in the literature as an inner-outer factorization.

- §16.2, p463: The denominator in $W(s)$ of Equation (16.2.32) ends with 18 as follows:

$$W(s) = \frac{3s^2 + 13s + 102}{(s^2 + 5s + 16)(s^2 + 9s + 18)}$$

- §16.3, p468: Equation (16.3.19) now reads:

$$J = \int_{-\infty}^{\infty} \left| H(j\omega)\tilde{Q}(j\omega) + \frac{\tilde{\alpha}^2(\omega)|S_o(j\omega)|^2 Q_o(j\omega)}{H(-j\omega)} \right|^2 d\omega + \int_{-\infty}^{\infty} \tilde{\alpha}^2(\omega)|S_o(j\omega)|^2 |Q_o(j\omega)|^2 \left(1 - \frac{\tilde{\alpha}^2(\omega)|S_o(j\omega)|^2}{|H(j\omega)|^2}\right) d\omega.$$

- §16.3, p470: Equation (16.3.28) now reads:

$$J^{'} = \int_{-\infty}^{\infty} \left| H(j\omega)\tilde{Q}^{'}(j\omega) + \frac{\tilde{\alpha}^2(\omega)|S_o(j\omega)|^2 Q_o(j\omega)}{j\omega H(-j\omega)} \right|^2 d\omega + \int_{-\infty}^{\infty} \frac{\tilde{\alpha}^2(\omega)|S_o(j\omega)|^2 |Q_o(j\omega)|^2}{(j\omega)^2} \left(1 - \frac{\tilde{\alpha}^2(\omega)|S_o(j\omega)|^2}{|H(j\omega)|^2}\right) d\omega$$

- §16.3, p472: The bias error equation now reads:

$$\int_{-\infty}^{\infty} |G_o(j\omega)\tilde{Q}(j\omega)|^2 d\omega = 4.2$$

- §16.3, p472: The variance error equation now reads:

$$\int_{-\infty}^{\infty} |S_o(j\omega)Q_o(j\omega) + S_o(j\omega)\tilde{Q}(j\omega)|^2 \epsilon d\omega = 0.7$$

- §16.4, p479: At the bottom of the page should read:

  Noting that $B_o(s)P(s) = A^*(s)$ *at zero of* $A_o(s)$ ...

- §16.5, p480: Equation (16.5.1) now reads:

$$\frac{1}{\pi} \int_0^{\infty} \ln |S_o(j\omega)| d\omega + \frac{k_h}{2} = \sum_{i=1}^{N} p_i$$

- §16.5, p480: Equation (16.5.2) now reads:

$$\frac{1}{\pi}\int_0^\infty \frac{1}{\omega^2}\ln|T_o(j\omega)|d\omega + \frac{1}{2k_v} = \sum_{i=1}^{M}\frac{1}{c_i}$$

- §16.5, p482: Between (16.5.8) and (16.5.9) should read:

  ... values of $s, T_o(s)$ *...*

- §16.7, p484: The correct reference in the identification section should read as follows:

  Goodwin, G.C. and Payne, R.L. (1977). *Dynamic System Identification: Experiment Design and Data Analysis*, Academic Press, New York

17 Chapter 17

18 Chapter 18

- §18.3, p533: Equation (18.3.15) should read

$$\det(s\mathbf{I} - \overline{\mathbf{A}} + \mathbf{J_o}\overline{\mathbf{C}}) = s^n + (a_{n-1} + j_{n-1}^o)s^{n-1} + \ldots (a_0 + j_0^o) = 0$$

19 Chapter 19

- §19.10, p588: Example 19.6 should read

  "...reference is a square-wave of frequency 0.025[Hz]..."

- §19.10, p588: Example 19.6 should read

  "...the step in the reference at t=20[s]. The..."

- §19.10, p588: Theorem 19.2 item (i), should read

  "...the linear system $\dot{x} = \mathbf{A}x + \mathbf{B}\xi$*;* $y = \mathbf{C}x + \mathbf{D}u$ *is stable..."*

- §19.10, p588: Equation (19.10.10) should read

$$0 \leq y\varphi(t,y) \leq ky^2 \qquad \forall y \in \mathbb{R}, \forall t \geq 0$$

- §19.10, p589: Equation (19.10.15) should read

$$0 \leq \frac{\varphi(t,y)}{y} \leq k, \qquad \text{for all } y \neq 0$$

- §19.10, p590: Name mis-spelt, should read Yakubovich
- §19.14, p607: Equation (19.14.3) should read

$$y(t) = G_{olin}\langle f_D\langle u\rangle\rangle \qquad \text{with} \qquad G_{olin}(s) = \frac{1}{s(s+1)}$$

20 Chapter 20

- §20.3, p624: The second paragraph after equation (20.3.49) should read

  Also, the zero direction associated with zero $c > 0$ satisfies...

- §20.5, p627: Lemma 20.2 should read

  Consider the nominal control loop in Figure 20.3.
  Then the nominal loop is internally stable if and only if
  the three independent sensitivity functions defined in
  (20.4.11) to (20.4.14) plus $S_{uo}(s)G_o(s)$ are stable.

- §20.5, p627: In Lemma 20.2 the last sentence of the proof should be deleted.
- §20.11, p648: In Equation (20.11.2) the **C** matrix should read

$$\mathbf{C} = \begin{bmatrix} 0 & 1 \\ 1 & 1 \end{bmatrix}$$

- §20.11, p649: In Equation (20.11.3) the element (1,1) in the $\mathbf{T_o}(s)$ matrix should read

$$\frac{4}{s^2 + 3s + 4}$$

- §20.11, p650: In Equation (20.11.6) the $\mathbf{G_q}(z)$ matrix should read

$$\mathbf{G_q}(z) = \frac{0.01}{z^3(z-0.4)^2(z-0.8)^2} \begin{bmatrix} 3z & 20(z-0.4)^2(z-0.8) \\ 60z^2(z-0.4)(z-0.8)^2 & 12(z-0.4)(z-0.8) \end{bmatrix}$$

21 Chapter 21

- §21.10, p672: In Equation (21.10.1) the element $(1, 1)$ in the $\mathbf{G_o}(s)$ matrix should read

$$\frac{2e^{-0.5s}}{s^2 + 3s + 2}$$

22 Chapter 22

- §22.5, p689: In Lemma 22.1 it should read

  "..closed loop system, $\mathbf{A} - \mathbf{B}\mathbf{\Phi}^{-1}\mathbf{B}^T\mathbf{P}_\infty^\mathbf{s}$, has all its ..."

- §22.5, p689: In Lemma 22.2 should read

  "... imaginary axis, and that $P(t_f) = \mathbf{\Psi}_f > \mathbf{P}_\infty^\mathbf{s}$ and that
  ... detectable then $P(t_f) = \mathbf{\Psi}_f \geq 0$ suffices.)"

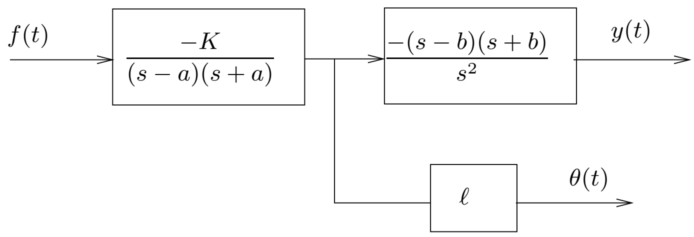
- §22.10, p700: Equation (22.10.61) should read

$$y[k] = \mathbf{C}x[k] + v[k]$$

23 Chapter 23

24 Chapter 24

- §24.11, p799: In Figure 24.8 there should be an extra ℓ scaling factor



25 Chapter 25

26 Chapter 26

- §26.4, p867: The expression for $\mathbf{B}_\lambda$ (near the bottom of the page) should read

$$\mathbf{B}_{\boldsymbol{\lambda}} = \mathbf{B}'_{\mathbf{e}}[\mathbf{D}'_{\mathbf{e}}]^{-1}$$

- §26.7, p880: In Equation (26.7.6) the integral starts at minus infinity:

$$\frac{1}{\pi}\int_{-\infty}^{\infty} \ln|5[\mathbf{S_o}(j\omega)]_{11} - 6[\mathbf{S_o}(j\omega)]_{21}| \frac{1}{1+\omega^2} d\omega \geq \ln(5)$$

- §26.7, p880: In Equation (26.7.7) the integral starts at minus infinity:

$$\frac{1}{\pi}\int_{-\infty}^{\infty} \ln|5[\mathbf{S_o}(j\omega)]_{12} - 6[\mathbf{S_o}(j\omega)]_{22}| \frac{1}{1+\omega^2} d\omega \geq \ln(6)$$

- §26.7, p880: In Equation (26.7.10) the integral starts at minus infinity:

$$\frac{1}{\pi}\int_{-\infty}^{\infty} \ln|[\mathbf{S_o}(j\omega)]_{11}| \frac{1}{1+\omega^2} d\omega \geq 0$$

- §26.7, p880: In Equation (26.7.11) the integral starts at minus infinity:

$$\frac{1}{\pi}\int_{-\infty}^{\infty} \ln|[\mathbf{S_o}(j\omega)]_{22}| \frac{1}{1+\omega^2} d\omega \geq 0$$

27 Subject Index

The following index items refer to pages in the appendicies that are present on the website.

- Analytic function
- Hamiltonian matrix
- Riccati Equation - dynamic - solution