amplifier.

(e) $B = 0.184\Omega$; $T = 18.4$; output resistance is 19.4 times the output resistance of the amplifier.

(f) $B = 0.758\Omega$; $T = 75.8$; output resistance is 76.8 times the output resistance of the amplifier.

42 Use MATLAB

43 Use MATLAB

44 Use MATLAB

45 Use MATLAB

46 At maximum signal, the output is *reference* $\times$ 1000/1001. At smallest signal, the output is *reference* $\times$ 10/11. The change in the output signal amplitude is, therefore, approximately 10%.

47 The coordinates are logarithmic.

Chapter 2

1 (a) 1.2; (b) 1.05; (c) 0.9875; (d) 1.0083; (e) 1.37

2 (a) $C = 0.6$; $B = 0.833$; (b) $C = 2.1$; $B = 0.9524$; (c) $C = 7.9$; $B = 1.013$; (d) $C = 12.1$; $B = 0.992$; (e) $C = 0.373$; $B = 0.730$;

3 (a) $C = 0.5$; $FF = 0.1$; (b) $C = 2$; $FF = 0.1$;(c) $C = -8$; $FF = 0.1$; (d) $C = 12$; $FF = 0.1$; (e) $C = 0.272$; $FF = 0.1$;

4 For the system shown in Fig. P2.1, the input-output transfer function is the following:

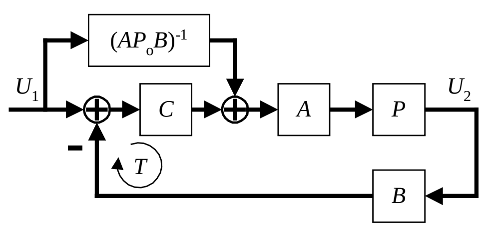

Fig. P2.1. Command feedforwarding

$$\frac{U_2}{U_1}=\left(\frac{1}{AP_oB}AP\right)F^{-1}+\frac{T}{BF}=\frac{1}{B}\left(\frac{P}{P_oF}+\frac{T}{F}\right)$$

or

$$\frac{U_2}{U_1}=\frac{1}{B}\frac{P+P_oT}{P_o+P_oT}=\frac{1}{B}\frac{1+T_o^{-1}}{1+T^{-1}}.$$

5 Without feedforward, input-output gain coefficient is within [0.952, 0.9756] interval (ratio of the limits is 1.025); with feedforward, within [0.984, 1.00813] interval, with the same ratio. As seen from the formula in Section 2.1, the ratio must be the same. Feedforward does not change the sensitivity.

6 At very low frequencies the feedback is large and performance is good even without the feedforward. At very high frequencies, feeforward is limited. Then, the advanrages of the feedforward show up mostly in the neighborhood of crossover.

7 Use MATLAB

8 Use MATLAB

9 The sensitivity is $W_1/(W_1 + W_2)$; (a) 0.98; (b) 0.5; (c) –9; (d) $s/(s + 10)$

10 $S_P = 1/[1 + (C_VA_V + C_MA_M)P$; $S_{AV} = S_PC_VA_V/(C_VA_V + C_MA_M)$;

$S_{AM} = S_PC_MA_M/(C_VA_V + C_MA_M)$

Numerical examples can be different.

11 $S_{AM} = A_M(1 - A_EB)/[(A_M + A_E - A_MA_EB)$; The sensitivity for nominal values of the links' transfer functions is 0; when A_E becomes 14.1, the sensitivity becomes 0.41.

12 (a) 0.05; (b) 0.052; (c) 0.073

13 The output signal of the error amplifier is $A_EA_{MS}(B - 1/A_M)$, then (a) 0; (b) 0.452; (c) 3.16; the large is the deviation of A_M from $1/B$, the larger must be the available output power of the error amplifier.

14 $S_E = A_E(1 - A_MB)/[(A_M + A_E - A_MA_EB)F_E$

15 (a) 1; (b) 3; (c) 2; (d) 2

16 (a) 8%; (b) 2.8 dB; (c) 2.23 dB; (d) 2.5 dB

17 To drive a dissipative load 10 times faster, the motor power needs to be increased 10 times. This makes the motor much bigger. On the other hand, a 10 times faster vernier actuator with the maximum motion amplitude of only 0.05 of the main actuator consumes 0.5 of the main actuator power. Therefore, addition of the vernier actuator will only increase the total power consumption 1.5 times, and the total size, weight, and cost of the system will be much smaller than when using one powerful and fast motor.

18 The transfer function can be instantly found using Mason's rule: $abc/(1 + abd + bce)$

19 $(C_V A_V + C_M A_M)P/(1 + C_V A_V P + C_M A_M P)$

20 $CDAP/(1 + DB_D + CAB_A + CDAPB_P)$

21 (a) $abcde/[(1 + g)(1 - h)] + af/(1 + g)$;

(b) $abcde/[(1 + g)(1 + h)] + afde/(1 + h)$;

(c) $abcde/[(1 + g)(1 - h)] + f$;

(d) $abcde/[(1 - g)(1 - h)(1 - m)] + abf/(1 - g)$;

(e) $abcde/[(1 + g)(1 + h + cdem)] + af/(1 - g)$;

22 (a) $x \approx 0.5x' - 0.05y' - 0.075z'$

$y \approx -0.024x' + 0.476y' - 0.024z'$

$z \approx -0.010x' - 0.026y' + 0.526z'$

(which is close to the solution obtained by inverting the matrix of coefficients:

$x = 0.5038x' + 0.0443y' + 0.0772z'$

$y = -0.0235x' + 0.4796y' - 0.0215z'$

$z = -0.0094x' - 0.0243y' + 0.5291z'$)

The accuracy of the approximate expressions (even of the first approximation) is sufficient if the decoupling matrix is placed in the forward path. (Often the coupling terms are not that accurate anyway.) The flow-chart is shown in Fig. P2. 2.

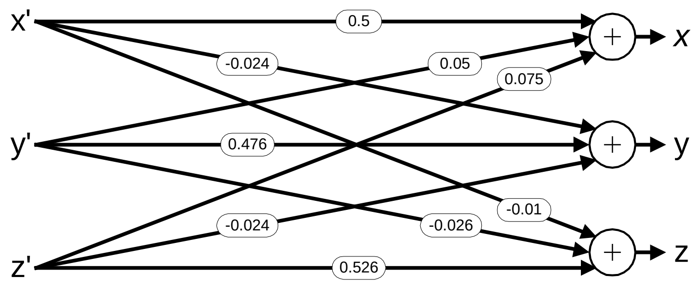

Fig. P2.2 Decoupling matrix flowchart

The commands are in terms of *x*, *y*, *z* if the decoupling matrix is placed in the feedback path, and in terms of *x*', *y*', *z*' if the matrix is in the forward path.

(b), (c), (d), (e) Use MATLAB to invert the matrices.

23 The range due to temperature variations is 10^{-5} Hz, and due to voltage variations, 0.5×10^{-5} Hz, so the total range is 1.5×10^{-5} Hz.

24 Since $W = (aw + b)/(cw + d)$, the sensitivity of W to w is $S = (w/W)(dW/dw) = w(ad - cb)/(aw + b)$, and if $S = 0$, then $ad = cb$, and $W = b/d$, i.e. W does not depend on w.

Chapter 3

1 $1 - \exp(-at_r) = 0.9$; $\exp(-at_r) = 0.1$; $\exp at_r = 10$; $at_r = \ln 10$; $t_r = 2.3/2\mathrm{p}f_p = 1/(3f_p)$.

2 (a) 0.0667 (b) 6,67 msec (c) 167 (d) 0.333 nsec (e) 0.333 psec.

3 *

4 (a) 0; (b) –6 dB/oct, –20 dB/dec; (c) –12 dB/oct, –40 dB/dec

5 (a)–6 dB/oct, –20 dB/dec; (b) –12 dB/oct, –40 dB/dec

6 Use MATLAB

7 Use, for example, programs for *RC* filter design available free of charge from Burr-Brown Corp.

8 (a) 7.3 dB; (b) 4.4 dB; (c) 2.3 dB; (d) 0.7 dB.