APPENDIX L

ANSWERS TO SELECTED PROBLEMS

Chapter 1

1.1 (a) 5 V, 25 mW; (b) 5 kΩ, 5 mW; (c) 10 mA, 1 kΩ; (d) 10 V, 100 kΩ; (e) 31.6 mA, 31.6 V

1.2 (a) 5 mA; (b) 5 kΩ; (c) 1 V; (d) 10 mA

1.5 990 kΩ, 190 kΩ, 90 kΩ, 10 kΩ; 9.9 kΩ, 9.09 kΩ, 5 kΩ

1.6 2 V, 1.2 kΩ; 1.88 V to 2.12 V; 1.26 kΩ to 1.14 kΩ

1.9 4.80 V, Shunt the 10-kΩ resistor with 157 kΩ; Add a series resistance of 200 Ω.

1.16 0.05 mA

1.17 $I_1 = 0.75$ mA; $I_2 = 0.5$ mA; $I_3 = 1.25$ mA; 2.5 V

1.19 2 V

1.22 (a) $(1 - j\,1.59)$ kΩ; (b) $(247.3 - j\,1553)$ Ω; (c) $(71.72 - j\,45.04)$ kΩ; (d) $(100 + j\,628)$ Ω

1.25 (a) $v_s = 1$ V, $i_s = 0.1$ mA, $R_s = 10$ kΩ;
(b) $v_s = 0.1$ V, $i_s = 1$ μA, $R_s = 100$ kΩ

1.27 (a) 2%; 9%; (b) 1%; 8%; (c) 9%; 0.4%; 0.5 mA; (d) 9%; 1%; 6.67 mA

1.28 55.2 Ω

1.29 5 kΩ

1.35 (a) 165 V; (b) 24 V; (c) 311 V; (d) 311 kV

1.37 2% lower

1.42 (b) b_N; b_1; (c) 0.996 mA; 3.91 μA

1.43 7.056×10^5 bits per second

1.44 66

1.45 (a) 100 V/V; 40 dB; 1000 A/A; 60 dB; 10^5 W/W; 50 dB; (b) 10^5 V/V; 100 dB; 1000 A/A; 60 dB; 10^8 W/W; 80 dB; (c) 5 V/V; 14 dB; 500 A/A; 54 dB; 2500 W/W; 34 dB

1.46 2.8 V_{rms}; 14 mV_{rms}; 6.4 V_{rms}; 32 mV_{rms}; 9.9 V_{rms}; 50 mV_{rms}

1.50 412.7 V/V

1.51 1.1 mA; 10 kΩ

1.52 4.95 A/A; 13.9 dB; 4.9 V/V; 13.8 dB; 24.3 W/W; 27.7 dB

1.53 38.1 V/V

1.54 38.4 dB; 71.4 dB; 85 mV; 0.1 W

1.55 0.69 V; −3.2 dB; 78.4 dB; 37.6 dB

1.62 0 V; 10 V

1.69 4 MHz; 0.8 V/V

1.76 0.53 kΩ; 10.5 Ω; 526 Ω

1.77 $0.51/CR$

1.81 90 kΩ; 6.61 kΩ; 27.9 mA/V

1.85 2.2×10^6 carriers/cm^3

1.88 1.5×10^{18} atmos/cm^3

1.94 9.26×10^{17}/cm^3

1.95 0.864 A/cm^2

1.96 $V_0 = 0.754$ V
$W = 0.328$ μm
$x_n = 0.298$ μm
$x_p = 0.03$ μm
$Q_J = 4.8 \times 10^{-14}$C

1.100 59.6 mV

1.104 7.85×10^{-17} A; 0.3 mA

1.109 10.42 mA; 41.7 mA

1.112 31.6 fF; 14.16 fF

Chapter 2

2.1 4004 V/V

2.4 8; 14

2.5 −1.000 V; 400 V/V

2.6 40,000 V/V

2.10 (a) −2 V/V; (b) −10 V/V; (c) −0.5 V/V; (d) −50 V/V; (e) −5 V/V

2.12 5 kΩ

2.14 $V_o = 5.1$ V to 4.9 V
$V_o = 4.85$ V to 5.15 V

2.17 (a) 10.2 kΩ

2.27 3 mA; $R_1 = 2$ kΩ; $R_2 = 20$ kΩ

2.28 ±2x%; −98 V/V to −102 V/V

2.30 ±2 mV

2.37 $-\frac{R_2}{R_1}\left(1 + \frac{R_4}{R_3} + \frac{R_4}{R_2}\right)$

2.40 $R_1 = 100$ kΩ, $R_2 = 100$ kΩ, $R_3 = 1.02$ kΩ; −2.48 V/V

2.46 $\frac{1 + R_2/R_1}{1 + R_3/R_4}$

2.50

Case	Gain (V/V)	R_{in}	R_1	R_2
a	–10	10 kΩ	10 kΩ	100 kΩ
b	–1	100 kΩ	100 kΩ	100 kΩ
c	–2	100 kΩ	100 kΩ	200 kΩ
d	+1	∞	∞	0
e	+2	∞	100 kΩ	100 kΩ
f	+11	∞	10 kΩ	100 kΩ
g	–0.5	20 kΩ	20 kΩ	10 kΩ

2.51 1980 V/V

2.53 $-10\text{ V} \le v_O \le +10\text{ V}$; $\Delta v_O = 1\text{ V}$

2.55 100 kΩ; no

2.58 2 sin $(2\pi \times 1000t)$

2.61 9.09 V/V; 81 kΩ in parallel with R_1; 9.52 V/V; 10.52 V/V

2.65 (a) 0 dB; (b) $20\log(1 + R_2/R_1)$

2.72 (a) 1 V/V; 0 V/V; (b) $-5\text{ V} \le v_{Icm}$; (c) 10 V/V; 0 V/V; $-3\text{ V} \le v_{Icm} \le +3\text{ V}$

2.73 1 MΩ; 756 Ω; 6.8 kΩ

2.81 (a) 1.59 kHz; (c) increase by 10×

2.84 $R = 10$ kΩ, $C = 159$ pF; $R_F = 1$ MΩ, 1 kHz; (a) v_O decreases linearly to −6.3 V, (b) v_O decreases exponentially, $v_O(t) = -100(1 - e^{-t/159})$, reaching −6.1 V at the end of the pulse.

2.89 $R_1 = 10$ kΩ; $R_2 = 100$ kΩ; $C_2 = 15.9$ pF; 2 MHz

2.92 $R_1 = 1$ kΩ, $R_2 = 100$ kΩ, $C = 79$ nF; 20 Hz

2.94 4 mV

2.96 (a) 0.2 V; (b) 0.3 V; (c) 10 kΩ; 20 mV; (d) 0.12 V

2.99 (a) 0.53 μA, into the input terminals; (b) −3 mV; (c) −60 nA

2.101 $R_1 = 1.01$ kΩ, $R_2 = R_3 = 100$ kΩ, $C_1 = 1.58$ μF, $C_2 = 0.16$ μF

2.103 6 V; 3 V; 9 mV

2.106 (a) 9.9 kΩ; (b) 0.222 V

2.107 80,000 V/V, 125 Hz, 10 MHz

2.111 (a) 50 Hz, 10 MHz; (b) 1 Hz, 2 MHz; (c) 10 kHz, 18 MHz; (d) 10 MHz, 1 GHz; (e) 24 kHz, 625 MHz

2.113 200 kHz; 21 kHz; 1.9 MHz

2.115 24 V/V

2.116 36.6 MHz

2.121 100 mV

2.124 40 V/μs

2.126 637 kHz

2.127 (a) 318.3 kHz; (b) 0.795 V; (c) 2 MHz; (d) 1 V

Chapter 3

3.1 (a) −3 V, 0.6 mA; (b) +3 V, 0 mA

3.3 (a) 0 V; 2 mA; (b) −1.5 V; 0 mA

3.4 4.2 kΩ; 169.7 V

3.5 $-7\text{ V} \leq v_I \leq 8\text{ V}$

3.6 1.95 A; 10 V

3.8 (a) $V = 2$ V, $I = 2.5$ mA; (b) $I = 1$ mA, $V = 1$ V

3.13 25 mA; 12.5 mA

3.16 $V = +3$ V ⇒ red ON, green OFF; $V = 0$ V ⇒ red OFF, green OFF; $V = -3$ V ⇒ red OFF, green ON

3.21 87.7 mV; 5.16 mA

3.24 0.230 V; $1.45 \times 10^{12} I_S$

3.28 Decrease by 17.3 mV

3.32 50° C; 6 W; 8.33°C/W

3.33 230 mV independent of current and temperature

3.35 0.664 V

3.39 (a) 1.3 mA; 0 V; (b) 0 mA; −1.675 V

3.40 4.23 kΩ; 169.7 V

3.42 (a) 0.767 mA; (b) 5.3×10^{-16} A; (c) 0.805 mA

3.47 14.71 V; 3.61 V

3.49 +22.1 % or −18.1 %; +2.38 mV or −2.63 mV

3.51 (a) 0 V/V; 0.167 V/V; 0.667 V/V; 0.952 V/V; 0.995 V/V; 0.9995 V/V; (b) $|\Delta v_D| <$ 2.5 mV; $I \geq 5\mu$ A; (c) 1 V; 1.005 V; $i_{D1} = i_{D4} = 0.45$ mA; $i_{D2} = i_{D3} = 0.55$ mA

3.54 0 V/V; 0.001 V/V; 0.01 V/V; 0.1 V/V; 0.5 V/V; 0.6 V/V; 0.9 V/V; 0.99 V/V

3.58 $R = 417$ Ω; 7.39 mA; 6.8 mV; −3.4 mV; −6.8 mV; −13.6 mV

3.64 (a) 9.825 V; (b) 207 Ω; (c) 33 mV/V; ±1.65%; (d) −6.77 V/A; −1.35%; (e) 70.9 mA; 732 mW

3.67 13.44 V; 48.4%; 8.3 V; 16.6 mA

3.69 (a) 10.1:1; (b) 1.072:1

3.72 (a) 12.77 V, 13.37 V; (b) 14.2%, 4.5%; (c) 102.5 mA, 310 mA; (d) 192 mA, 607 mA

3.76 0.441 V

3.79 (a) 9.7 V; (b) 542 µF; (c) 25.7 V (38.5 V with 1.5× safety factor); (d) 739 mA; (e) 1.42 A

3.86 −7.07 V

3.87 (a) 80 Ω; (b) 120 Ω

3.90 $0.70\text{ V} < V_R < 2.87\text{ V}$

Chapter 4

4.1 1. Active; 2. Saturation; 3. Active; 4. Saturation; 5. Active; 6. Cutoff

4.2 4.7×10^{-17} A, 1.87×10^{-16}A; $A_2/A_1 = 4$

4.4 80; 0.988

4.6 990 μA, 99, 0.99; 980 μA, 49, 0.98; 950 μA, 19, 0.95

4.9 $V_B = -0.616$ V; $V_C = -0.9$ V; $I_E = 0.51$ mA

4.12 0.31 V

4.14 0.45 mA; 0.587 V

4.18 $i_C = 7.2$ mA; $i_B = 144$ μA to 36 μA; $i_E = 7.344$ mA to 7.236 mA

4.21 437 kΩ; 8 kΩ

4.24 0.758 V; 0.815 V

4.31 $R_E = 1.62$ kΩ, $R_C = 3$ kΩ

4.33 125 kΩ; 125 V; 12.5 kΩ

4.35 (a) 2.3 V; (b) 2.64 V; (c) 10.5 V

4.40 (a) $I_E = 0.26$ mA, $I_B = 0.005$ mA, $I_C = 0.255$ mA, $V_E = -0.8$ V, $V_C = 0.81$ V; (b) $I_E = 0.35$ mA, $I_B = 0.007$ mA, $I_C = 0.343$ mA, $V_E = +0.8$ V, $V_C = -0.81$ V; (c) $I_E = 0.12$ mA, $I_B = 2.4$ μA, $I_C = 0.118$ mA, $V_E = +1.8$ V, $V_C = 0.236$ V; (d) $I_E = 0.15$ mA, $I_B = 3$ μA, $I_C = 0.147$ mA, $V_E = 0.7$ V, $V_C = 1.8$ V

4.43 (a) 632 mV; (b) 0.69 mA, 5.77 mA

4.46 0.1 mA, 0.11 mA; −8.16 V; +22 mV/°C; −7.06 V

4.49 100; 80; 1.18 mA

4.51 (a) 1.3 V, 3.7 V; (b) 1 V, 4 V; (c) 0 V, 5 V

4.52 0.3 V; 0.003 mA; 0.15 mA; 0.147 mA; −1.03 V; 49; 0.98

4.53 1.86 V, 1.16 V, 1.85 V; 2.14 V, 1.44 V, 1.64 V; 2.4 V, 1.7 V, 1.9 V

4.55 (a) −0.915 V, +1.218 V; (b) +1.258 V, 0.49 mA; (c) −0.9 V, −0.2 V, +1.4 V; (d) +1.7 V, −0.9 V; (e) +1 V, +1.7 V, −0.9 V

4.57 (a) 0 V, 0 V; (b) −1.8 V, −1.1 V; (c) +2.2 V, +1.5 V; (d) +3 V, 2.3 V

4.61 $R_1 = 35$ kΩ, $R_2 = 15$ kΩ; 0.078 mA; 4.22 V

4.63 +0.41 V, +1.11 V; −1.15 V; +1.2 V, +1.9 V, −1.9 V; 204

4.65 50 kΩ, 4 kΩ, 4 kΩ; 0.85 mA to 0.98 mA with 0.95 mA nominal; −1.6 V to −1.1 V with −1.2 V nominal.

4.66 1.74 kΩ; transistor saturates and $V_C = 2.8$ V

4.67 (a) 0 V, +0.7 V, −0.725 V, −1.425 V, +1.1 V; (b) +0.23 V, +0.93 V, −1 V, −1.7 V, +1.47 V

4.69 (a) +0.8 V, 2.3; (b) +2.07 V, 3.2; (c) $V_{C3} = 2.044$ V, $V_{C4} = 1.54$ V, $\beta_{\text{forced3}} = 0.8$, $\beta_{\text{forced4}} = 6.4$.

Chapter 5

5.2 $0.825 \text{ V} \le v_{GS} \le 1.8$ V

5.3 (a) 8.625×10^{-3} pF/μm^2, 388 μA/V^2; (b) 0.2 V, 0.7 V, 0.2 V; (c) 0.39 V, 0.89 V

5.5 (a) 4 mA; (b) 3 mA; (c) 1 mA; (d) 5.3 mA

5.7 0.16 fC

5.8 (a) 0.5; (b) 0.5; (c) 1.0; (d) 0.5

5.10 1.85 μm

5.12 0.5 V; 0.5 mA
5.14 96.2 Ω, 19.2 mV; 80
5.15 2.8 V; 500 Ω, 100 Ω
5.17 5 mA/V^2; 0.6 V
5.21 100 kΩ, 20 V, 0.05 V^{-1}
5.27 1.07 μm
5.29 2.5 kΩ to 125 Ω; (a) 5 kΩ to 250 Ω; (b) 1.5 kΩ to 62.5 Ω; 2.5 kΩ to 125 Ω
5.33 (a) 3%; (b) 5%
5.35 109 μA; 9%; double L to 2 μm
5.38 50 V; 0.5 μm
5.39 8 μA; 12 μA; 13.13 μA; 13.75 μA; 15 μA
5.45 2.25 μm, 0.56 μm, 4 kΩ
5.46 44.4, 1.25 kΩ
5.48 (a) 360 μA, 1 V; (b) 160 μA, 0.8 V; (c) 1 V, 360 μA
5.52 4 kΩ
5.54 $W_1 = 11.1$ μm; $W_2 = 25$ μm; $W_3 = 4$ μm
5.55 0.454 mA, +7.28 V; circuit is quiet tolerant to variations in device parameters.
5.57 (a) −0.6 V; (b) −0.816 V; (c) −1.5 V; (d) +0.6 V; (e) +1.5 V; (f) +0.6 V; (g) +1.5 V; (h) −0.6 V
5.62 1 V to 1.69 V; 3.74 V
5.65 488 million transistors
5.68 0.3 mA, 0.416 mA, 0.424 mA, 0.48 mA; each current value is doubled; for $v_{DS} = 2$ V, $i_D = 0.408$ mA, for $v_{DS} = 3$ V, $i_D = 0.412$ V, for $v_{DS} = 10$ V, $i_D = 0.44$ mA

Chapter 6

6.1 Point A: $v_{GS} = 0.5$ V, $v_{DS} = 5$ V; Point B: $V_{GS} = 0.72$ V, $V_{DS} = 0.22$ V
6.4 −160 V/V; 0.7 V; 4.4 mV
6.6 −40 V/V
6.7 (a) 108 V/V; (b) 1.5 V; (c) 3 kΩ; (d) 0.673 V; (e) 0.3 V; (f) 0.1 sin ωt, mA; (g) 0.005 mA, 0.001 sin ωt, mA; (h) 5 kΩ
6.9 0.214 V; 0.716 V
6.11 0.4 V; 8.33
6.15 1.08 V; 0.78 V; −156.7 V/V
6.20 $g_m = I_C/V_T = 20$ mA/V
6.23 (a) 0.1 mA, 0.5 V; (b) 1 mA/V; (c) −15 V/V; (d) −0.225 sin ωt, V, 0.275 V, 0.725 V; (e) 1.9%
6.26 −26.1 V/V; 1.25 V, −38.3 V/V
6.29 40 mA/V; 25 Ω; 2.5 kΩ; 1 V
6.32 1 V; 125 Ω; 80 V/V
6.38 (a) 0.1 mA, 0.8 V; (b) 1 mA/V; (c) −10 V/V; (d) 100 kΩ, −9.1 V/V

6.39 (a) 2 mA/V, 20 kΩ; (b) 2.9 mA/V, 10 kΩ
6.40 16 μm; 0.75 V
6.44 $\beta_{min} = 90$
6.45 1.04 kΩ to 4.7 kΩ
6.55 −1000 V/V; −5000 V/V
6.59 1000 V/V; 250 V/V
6.63 5 mA/V; 4 kΩ; 50 Ω
6.67 2.5 mA; 2.75 mA; 2.25 mA; 0.55 V
6.69 1 V/V; 105 Ω; 0.9 V/V
6.71 79.4 V/V; 4762 A/A
6.74 −10 V/V
6.75 1 mA/V; 125 μA; −7.5 V/V
6.79 0.5 kΩ
6.82 0.2 kΩ; 5.6 V/V; 0.64
6.83 0.5 mA; 25 V/V
6.84 8 V/V; 50 mV; 0.4 V
6.86 (a) 20.7 kΩ, 0.67 V/V, 0.65 V/V; (b) 0.615 V, 0.4 V; (c) 1 V/V, 104 Ω, 0.59 V/V
6.90 27.5 V/V, 41.2 V/V, 55.6 V/V, 57.1 V/V, 55.6 V/V; 0.325 mA
6.91 22 MΩ; 18 MΩ; 15 kΩ; 15 kΩ; 2.7 V above
6.96 6.2 kΩ; 6.2 kΩ; 100 kΩ; 82 kΩ; 0.5 mA; 0.49 mA; 3.8 V; 6 V
6.97 $R_E = 1.5$ kΩ; $R_C = 2.4$ kΩ; $R_B = 7.5$ MΩ; $\beta = \infty$: 0.52 mA, 0 V, 0.25 V; $\beta = 50$: 0.48 mA, −0.07 V, 0.35 V
6.101 5.07 V, 1.27 mA to 2.48 mA; 620 Ω; 0.91 mA to 1.5 mA
6.102 2 V; 2.4 V; 1.2 mA
6.106 (a) 1.25 V; (b) 1.85 V
6.113 $R_C = 3.3$ kΩ; $R_B = 120$ kΩ; 0.56 mA, 0.85 V
6.117 (a) 9.5 kΩ; (b) 12.5 kΩ; 10 MΩ; (b) 2 mA/V, 100 kΩ; (c) −9.6 V/V; (d) 0.946 V/V, 473 Ω; (e) 0.6 V
6.120 (a) 11.5 kΩ; (b) 12.5 kΩ; (c) −31.7 V/V
6.121 27.5 kΩ; −9.8 V/V; 20.5 mV; 0.2 V
6.123 (a) $\beta = 50$: 0.78 mA, 0.78 mA, 1.48 V; $\beta = 200$: 1.54 mA, 1.54 V, 2.24 V; (b) $\beta = 50$: 21.3 kΩ; $\beta = 200$: 50.9 kΩ; (c) $\beta = 50$: 0.64 V/V; $\beta = 200$: 0.81 V/V
6.130 −27.5 V/V; Comparing the results above to those of Problem 7.125, we see that raising the resistance values has indeed resulted in increasing the transmission from source to transistor base, from 0.371 V/V to 0.636 V/V. However, because IC has decreased and g_m has correspondingly decreased, the gain from base to collector has decreased by a larger factor (from 97.83 V/V to 43.2 V/V), with the result that the overall gain has in fact decreased (from 36.3 V/V to 27.5 V/V). Thus, this is not a successful strategy!
6.131 $R_B = 91$ kΩ; $R_C = 22$ kΩ; 0.2 mA; −176 V/V, −29.7 V/V
6.135 (a) 1.7 mA, 68.4 mA/V, 0.0145 kΩ, 1.46 kΩ; (b) 148.3 kΩ, 0.93 V/V; (c) 18.21 kΩ, 0.64 V/V
6.136 (a) 0.1 mA, 5 mA, 1.5 V, 0.8 V; (b) 0.995 V/V, 101.5 kΩ; (c) 456 kΩ, 0.9975 V/V; (d) 0.82 V/V; (e) 0.814 V/V

Chapter 7

7.2 66 kΩ; 6 μm; 0.2 V; 40 kΩ; +5 μA

7.8 1.187 V; 0.113 V; 99.98 μA; 0.9998 mA, −0.02%; 0.3 V

7.9 700 Ω, 5 A/A, 10 kΩ.

7.11 0.2 V; 100 μA; 0.2 V; 27 kΩ; 81.5 μA; 100 μA; 118.5 μA; 137 μA

7.14 0.1 mA, 10%

7.17 1.013 mA; 2.28 kΩ; 2.7 V; +0.15 mA

7.18 (a) $I = 0.4$ mA; (b) $I = 0.04$ mA; (a) and (b): $V_1 = -0.7$ V, $V_2 = +2$ V, $V_3 = +0.7$ V, $V_4 = -0.7$ V, $V_5 = -1.7$ V

7.21 $\dfrac{I_O}{I_{REF}} \simeq \dfrac{1}{1+\dfrac{n+1}{\beta^2}}$; 44

7.23 20 μm; 80 μm; 0.8 μm; −0.6%

7.24 $v_o/v_i = g_{m1}R_L\,(W_3/W_2)$

7.29 0.5 μm; 12.5; 0.1 mA

7.34 (a) 0.2 mA; (b) 100 kΩ, 100 kΩ, 50 kΩ; (c) 6.25 kΩ, 8 mA/V; (d) 6.25 kΩ, −400 V/V, 50 kΩ

7.35 $I = 10\,\mu$A: 0.4 mA/V, 250 kΩ, 1 MΩ, 400 V/V; $I = 100\,\mu$A: 4 mA/V, 25 kΩ, 100 kΩ, 400 V/V; $I = 1$ mA: 40 mA/V, 2.5 kΩ, 10 kΩ, 400 V/V

7.36 40 V/V; 0.1 mA; 5 μm

7.38 0.5 mA; 4 mA/V

7.40 2 mA/V; 13.5 kΩ; 27 V/V; 14 μm

7.42 0.146 mA

7.46 0.75 V; 17.4; 69.4; −14.5 V/V

7.47 (a) 0.95 V, 0.475 μA, 2.4 V; (b) −86 V/V, 1.93 V, 22 mV; (c) 33.9 kΩ

7.48 50 μA; 4; 16, 16

7.49 (a) 0.125 mA, 0.125 mA; (b) −999 V/V; (c) −74.1 V/V, 13.3 kΩ; (d) −29.6 V/V; (e) −0.5 V to +0.5 V

7.50 21 kΩ; 0.976 A/A; 840 kΩ; 20.5 V/V

7.52 252 kΩ

7.54 1.4 kΩ; 0.98 A/A; 10.2 MΩ; 35.7 V/V

7.58 40 V/V; 0.6 μm

7.62 −1600 V/V

7.64 0.32 μm; 39.1; 0.7 V; 0.225 mA; 0.3 V

7.68 1 MΩ

7.70 5 V; 1 μm

7.74 0.2 V; 0.5 V to 0.8 V

7.78 -10^5 V/V

7.81 0.68 V; 1.1 MΩ

7.83 0.56 V; 1.12 V; 0.72 V

7.88 1.5 V

7.93 (a) 58.5 kΩ; (b) 79.9 MΩ,

Chapter 8

8.1 (a) 0.2 V, 0.6 V; (b) −0.6 V, 0.08 mA, 0.08 mA, +0.6 V, +0.6 V, 0 V; (c) −0.2 V, 0.08 mA, 0.08 mA, +0.6 V, +0.6 V, 0 V; (d) −0.7 V, 0.08 mA, 0.08 mA, +0.6 V, +0.6 V, 0 V; (e) 1.0 V; (f) −0.8 V, −0.2 V; (g) −0.2 V to 1.0 V

8.4 $I = 0.25$ mA; $\frac{W}{L} = 10$

8.5 0.25 V; 0.5 mA; 5 kΩ; 40

8.6 0.14 V; 0.25 mA; 4.4 kΩ; 25.5

8.11 (a) $0.1V_{OV}$; (b) 0 V, $0.338V_{OV}$, $0.05V_{OV}$, $0.005V_{OV}$; $1.072V_{OV}$

8.15 0.212 V; 554.5 μA

8.16 (a) $0.1V_{OV}$; (b) 0 V, $0.338V_{OV}$, $0.05V_{OV}$, $0.005V_{OV}$; $1.072V_{OV}$

8.19 (a) 0.426 mA/V; (b) 85 μA; (c) 2 V; (d) 0.1 V; (e) 2.11 V

8.21 2×

8.26 $V_{E1} = V_{E2} = -1.66\ V;\ V_{C1} = V_{C2} = +1.51\ V$

8.27 (a) −0.574 V, +0.4 V, +0.4 V; (b) −0.326 V to +0.674 V; (c) 5 mV

8.29 8 mA/V; 40 kΩ

8.32 Differential amplifier with a resistance R_e in each emitter; $I = 0.5$ mA; $R_e = 1.9$ kΩ; $R_C = 20$ kΩ

8.35 16 V/V

8.36 25 V/V; 101 kΩ

8.41 (a) $V_{CC} - (I/2)R_C$; (b) 2 V; (c) 0.4 mA, 5 kΩ

8.44 0.5 mA, 1.0 mA; 17.3 mV

8.47 (a) 0.2 mA, 15 kΩ, +1 V; (b) 50 kΩ; (c) ±0.3 V; (d) 1.1 V

8.50 400 V/V

8.55 12 V/V; 6×10^{-4} V/V; 86 dB

8.57 (a) 20 V/V; (b) 0.23 V/V; (c) 86.5; (d) $-0.023 \sin 2\pi \times 60t + 0.2 \sin 2\pi \times 1000t$, V

8.61 (a) 0.94 V; (b) 107 kΩ; (c) 0.93 V; (d) −2.26 V/V; (e) 0.12 V

8.65 (a) 40 V/V; (b) 5×10^{-3} V/V, 78 dB; (c) 1×10^{-4} V/V; 112 dB

8.68 1%

8.69 $\frac{2}{3}I$ in Q_1 and $\frac{1}{3}I$ in Q_3; 0.0125 V/V

8.72 2.5 mV

8.76 $I_{B\max} \simeq 2.5\ \mu A$; $I_{B\min} = 1\ \mu A$; $I_{OS\max} \simeq 1.5\ \mu A$

8.78 Worst-case $V_{os} = 14$ mV
If the three components are independent, $V_{OS} = 8.1$ mV

8.81 1.25 mV

8.84 1.6 kΩ; 0.8 kΩ; 2 kΩ

8.85 10 V/V

8.86 1.25 mA/V; 30 kΩ; 30 kΩ; 18.8 V/V

8.88 1 mA/V; 75 kΩ; 75 V/V; 75 kΩ

8.91 (a) 17.8, 17.8, 71.1, 71.1; (b) 0.6 μm; (c) −0.4 V to +0.65 V; (d) 77 dB

8.92 1 mA/V; 30 kΩ; 30 V/V; 30 kΩ; 0.984 kΩ; 0.9836 A/A; $5.56\times^{-4}$mA/V; 0.0167 V/V; 65.1 dB

8.93 20 kΩ; 40 V/V

8.98 (a) +4 V; (b) +2.5 V; (c) +1.4 V; (d) +1.1 V

8.103 81 kΩ

8.105 120 μA; 455 mV; 0.73 mV

8.107 25 V/V; 20 kΩ; 5000 A/A

8.109 (a) 0.52 mA, 1.04 mA, 2.1 mA, 0 V; (b) 4 kΩ, 65.5 Ω; (c) 8770 V/V

8.111 (a) $|V_{OV}|$ is reduced by a factor of 2 and g_m increases by a factor of 20; (b) Both increase by a factor of 20; (c) increases by a factor 2 (except for V_{OS} due to $\triangle V_t$).

8.115 R_5; 7.37 kΩ; reduced by a factor of 2; reduce R_4 to 1.085 kΩ.

Chapter 9

9.1 $g_m = 2.6$ mA/V; $g_{mb} = 0.6$ mA/V; $r_o = 50$ kΩ; $C_{gs} = 23.7$ fF; $C_{gd} = 3.1$ fF; $C_{sb} = 4.2$ fF; $C_{db} = 3.4$ fF; $f_T = 15.4$ GHz

9.2 7.1 GHz

9.3 $f_T = 353.7$ MHz; $f_\beta = 3.54$ MHz

9.5 $C_\pi = 0.54$ pF; $g_m = 40$ mA/V

9.9 265.3 MHz

9.14 −40 V/V; 34.6 MHz; 127.3 GHz

9.18 61 pF; 522 kHz

9.19 −29.3 V/V; 988 kHz

9.20 1 MΩ

9.22 3.18 MHz

9.27 −25 V/V; 49.7 MHz; 31.8 GHz

9.28 31.83 fF; 286.5 fF; 20 MHz

9.30 −81.4 V/V; 21.4 MHz; 11.2 GHz

9.39 $f_H = 52.2$ MHz; $f_Z = 63.7$ GHz

9.40 −80 V/V; 10.1 pF; 788 kHz; 652 kHz; the second estimate is more appropriate as it takes C_L into account.

9.42 −143 V/V; 3.2 MHz; 2.47 MHz; the second estimate as it takes C_L into account.

9.44 −41.7 V/V; 140 kHz

9.46 118 fF

9.49 −50 V/V; 479 kHz

9.52 −913 V/V; 5.76 MHz

9.53 0.2 V; 0.2 mA; 289.4 MHz; 57.9 MHz; −99 V/V; 2.9 MHz; 287.1 MHz

9.57 11.1 fF

9.64 0.9 V/V; 200 Ω; 398 MHz; 33.4 MHz, 90.7 MHz; 31.6 MHz

9.66 0.96 V/V; 2 GHz; 740 MHz, 4.6 GHz; 740 MHz

9.69 27 kΩ; 884 kHz; 0.33 mA/V

9.71 1.59 MHz
9.72 50 V/V; 15.9 MHz; 1.59 GHz; 3.18 GHz
9.74 $f_{P1} = 159$ kHz; $f_{P2} = 2$ MHz
9.79 (a) −100 V/V, 603 kHz, 60.3 MHz; (b) −50 V/V, 1.02 MHz, 51.2 MHz
9.82 $V_o/V_{sig} = 25$V/V; $f_{P1} = 637$ kHz, $f_{P2} = 6.37$ MHz; $f_H = 637$ kHz
9.86 (a) 2.5 MΩ, −4000 V/V; 107.6 MHz
9.88 50 V/V; 4.6 MHz
9.89 (a) 2500 V/V; (b) 9.1 MHz
9.93 −15.8 V/V; 1.9 Hz; 87.5 Hz; 8 Hz; 10.8 Hz; 87.5 Hz
9.95 $C_E = 5$ μF; $C_{C1} = 0.5$ μF; $C_{C2} = 0.5$ μF; 92.2 Hz; 6 μF
9.98 0.8 μF
9.99 10 μF; 88.4 Hz; 8.84 Hz
9.103 141.4

Chapter 10

10.1 4.9×10^{-3}; 169.5; −15.3%
10.2 0.01; 100; 10^4
10.5 0.1; 990; 9.9
10.6 500 V/V; 0.198 V/V
10.8 2500 V/V; 0.0196 V/V; 49; 50 V/V; 34 dB
10.10 99; 4
10.12 1000 V/V; 0.099 V/V
10.13 1135; 0.0395
10.15 100 kHz; 0.099 V/V
10.21 $A_{Mf} = \dfrac{A_M}{1 + A_M\beta}$

$\omega_{Lf} = \dfrac{\omega L}{1 + A_M\beta}$

Both the midband gain and the 3-dB frequency are lowered by the amount of feedback, $(1 + A_M\beta)$.
10.22 Three stages each with a closed-loop gain of 10 V/V and $\beta = 0.099$ V/V
10.25 (a) 0.9 kΩ; (b) 31.33, 9.7 V/V, −3%, make $R_F = 933\ \Omega$
10.27 90 kΩ; 100; 9.9 V/V; 91 kΩ
10.30 (a) $1 + \dfrac{R_2}{R_1} = 11$ V/V; (b) 0.1 mA, 0.3 mA, +7.7 V; (c) 23.2; (d) 10.55 V/V
10.32 9.9 V/V; 202 kΩ; 19.8 Ω
10.34 (a) $1 + \dfrac{R_2}{R_1} = 11$ V/V; (b) 0.1 mA, 0.3 mA, +7.7 V; (c) $A = \beta \dfrac{R_L \| (R_1 + R_2)}{R_s + r_{e1} + \dfrac{R_1 \| R_2}{\beta + 1}} =$ 255.3 V/V, $R_i = R_s + r_{e1} + \dfrac{R_1 \| R_2}{\beta + 1} = 0.359$ kΩ, $R_o = R_L \| (R_1 + R_2) = 0.917$ kΩ; (d)

$\beta = \frac{R_1}{R_1 + R_2} = 1/11$; (e) 10.55 V/V, 8.59 kΩ, 39.4 Ω, 4% less

10.36 (b) 0 V, 0 V; (c) $A = g_{m1,2}\,(r_{o2} \| r_{o4} \| R_{22}) = 47.62$ V/V; (d) 821 kΩ, 179 kΩ; (e) 5 kΩ; (f) 3.33 V/V; (g) 3.33 V/V

10.39 100 V/V; 1.001 MΩ

10.42 (b) 80 kΩ; (d) 928.5 V/V; (e) 0.2 V/V, 186.7; (f) 4.97 V/V; (g) 19.98 MΩ; (h) 2.66 Ω; (i) 18.67 kHz; (j) −0.47%

10.44 0.1 V/mA; 9.9 mA/V; 1.01 MΩ; 0.99 Ω

10.45 (a) $1/R_F$; (b) 100 Ω; (c) $\frac{\mu R_F}{\frac{1}{g_m} + R_F}$; (d) 166.7, 1667 mA/V; 9.94 mA/V

10.48 4.87 mA/V; 1.11 MΩ; 4.1 MΩ

10.49 100 Ω; 497 V/V; 9.94 mA/V

10.51 (a) 0 V, +0.6 V, +0.6 V; (b) $1/R_F$, 0.1 mA/V; (c) 0.099 mA/V; (d) 202 MΩ; (e) 0.99 V/V, 1.26 Ω

10.53 (a) $A_f\big|_{\text{ideal}} = \frac{1}{R_{S1}} + \frac{1}{R_{S2}} + \frac{R_F}{R_{S1}R_{S2}}$, 800 Ω; (b) 0.01 V/mA, 90 Ω, 90 Ω; (c) 5951 mA/V; (d) 60.51, 98.3 mA/V, 1.7% lower, increase R_F; (e) 29.1 kΩ, 1.76 MΩ

10.54 (a) 800 Ω; (b) 0.01 V/mA; (c) 90 Ω, 90 Ω; (d) 1.687μ mA/V; (e) 5868 V/V; (f) 99 mA/V; (g) 10 MΩ, 2.37 MΩ

10.60 0.94 V/mA; 28.3 Ω; 21.1 Ω

10.64 10 kΩ; −9.52 kΩ; 11.9 Ω; 244 Ω

10.69 (a) 100 μA, 60 kΩ, 30 kΩ, 12.5 12.5, (b) $-R_2/R_s$, $-1/R_2$; (c) 6 kΩ; (d) −404 kΩ, 4.62 kΩ, 875 Ω; (e) −4.65 V/V; (f) 337 Ω, 61 Ω

10.72 (a) +0.7 V; (b) −5 A/A, −0.2 A/A; (c) 2 mA/V, 50 kΩ; (d) 17.5 kΩ, −525.8 A/A, 332.8 kΩ; (e) 105.16, −4.95 A/A; (f) 164.8 Ω, 35.3 MΩ

10.79 (a) 0.865 mA, 0.77 mA; (c) 3.94 A/A, 3.47 A/A; (d) −0.254 A/A; (e) −216.3 A/A, 1.68 kΩ, 2.67 kΩ; (e) 54.9, 55.9, −3.87 A/A, 30.1 Ω, 149.2 kΩ; (g) 30.2 Ω, −3.41 A/A, 9.17 MΩ

10.80 10^4 rad/s; 0.02; 50

10.82 1.095×10^5 rad/s; 2.42×10^{-3}

10.86 0.099; 198 kHz; 140.7 kHz

10.88 2; 173.2 kHz

10.89 3.085×10^3 Hz; 18.15°; 10^{-3}; 60 dB

10.93 2.4×10^4 V/V or 87.6 dB; 9.09×10^3 V/V or 79.2 dB.

10.95 (a) 10 kHz; 100 Hz

10.97 100 Hz

Chapter 11

11.2 163 Ω; The incremental gain changes by 0.998 − 0.966 = 0.032, or about 3% over the range of v_o.

11.4 $\hat{V}$; $\hat{V}/R_L$; 25%
11.5 $-1.1\text{ V} < v_O < 1.91\text{ V}$; $-1.6\text{ V} < v_I < 3\text{ V}$;
11.8 $V_{CC}I$
11.10 5 V
11.12 10 V; 6.37 V; 6.85 Ω, 7.3 W; 9.62 Ω, 1.3 W
11.14 4.5 V; 6.4%; 625 Ω
11.15 33 V; 3.54 A; 74.4 W; 67.2%; 13.8 W
11.18 1.266 V; 12.5 Ω; 0.889 V/V; 0.998 V/V
11.21 2.15 mA
11.23 1 mA; −1.06 V; +4 V; −6 V
11.24 7.8
11.28 (a) 0.99 mA, 0 A, 0 V; (b) 1.15 MΩ, 0.89 V/V, 12.6 Ω
11.31 $-g_{m3}\beta R_L$
11.34 (a) 1.365 kΩ, 1.365 kΩ, 1.365 V; (b) 1.420; (c) 1.512 V; (d) 1.641 V
11.38 (a) 0.0164 mA, 1.64 mA; (b) 32.8 v_i, −66.2 V/V; (c) 27.2 kΩ
11.41 (a) 30.5 V; (b) $246.8/R_L$; $881.8/R_L$
11.43 6.5 Ω; 487.5 mV; 2.9 μA
11.45 35 mA; 5 mA
11.46 ±2.05 V
11.47 5Ω
11.50 (a) 533.3; 1333.3; (b) 10 V/V; (c) 5%; (d) ±1.85 V; (e) +0.3 V; −0.3 V; (f) $-1.77\text{ V} \le v_O \le +1.77\text{ V}$
11.52 +3 V; −3 V
11.54 2 W; +5 V; 3 W; +5 V; 600 mA; 30 V

Chapter 12

12.1 $-0.8\text{ V} \le V_{ICM} \le +0.2\text{ V}$; $-0.8\text{ V} \le v_O \le +0.8\text{ V}$
12.3 0.15 V
12.5 1.06 pF, 318.3 MHz, 360 MHz
12.8 5.67 MHz
12.9 180 Hz; 0.7 pF
12.11 (a) 2 pF; (b) 1.51 pF
12.15 3.2 pF; 30 MHz
12.18 11.4 MHz
12.19 636 kΩ
12.21 159.2 kHz; 10^8 rad/s or 15.9 MHz
12.23 (a) 0.16 V; (b) 2 pF; (c) 78.1
12.25 (b) 0.45 μm
12.27 +0.3 V; +0.45 V; −0.45 V; $-0.3\text{ V} \le V_{ICM} \le +1.25\text{ V}$; $-0.3\text{ V} \le v_O \le +0.7\text{ V}$

12.29 (a) $-0.25\ \text{V} \leq V_{ICM} + 1.3\ \text{V}$; (b) $-1.3\ \text{V} \leq V_{ICM} + 0.25\ \text{V}$; (c) $-0.25\ \text{V} \leq V_{ICM} + 0.25\ \text{V}$; (d) $-1.3\ \text{V} \leq V_{ICM} + 1.3\ \text{V}$

12.32 I/C_L

12.37 0.75 V, 2 V_{OV}, 14.8 MΩ

12.38 $0.176C_L$

12.41 $A_7 = 3A_3$; $A_8 = 10A_3$; $R_3 = R_4 = 6.67$ kΩ; $R_7 = 2.22$ kΩ; $R_8 = 667$Ω

12.44 12.5 kΩ; 0.8 V to 3.35 V; 100 kΩ; 10 µA, 50 kΩ

12.46 2

12.47 50 µA

12.52 1.8 kΩ

12.54 (a) $0.1\ \text{V} \leq V_{ICM} \leq 2.2\ \text{V}$; (b) $0.8\ \text{V} \leq V_{ICM} \leq 2.9\ \text{V}$

12.55 125 kΩ; 95.4 V/V

12.57 (b) 367.3; (c) 6.75 mV

12.61 $152 \leq \beta_N \leq 165$

12.63 105.3 dB

12.64 $R = 18.2$ kΩ; 15.55 MΩ

12.67 (a) $0.1\ \text{V} \leq v_O \leq 2.9\ \text{V}$; (b) 20 kΩ; (c) 0.2 Ω; (d) 12.3 mA; 0.3 mA; 1.6 kΩ; (e) 12.3 mA; 0.3 mA; 2.4 kΩ

12.68 10.6 µA; minimum current is 0.3 mA

Chapter 13

13.2 1 V/V; 0.977 V/V; 0.001 V/V

13.3 0.42 dB, 66 dB, 1.25

13.6 (a) 0.995 V, −5.7°; (b) 0.707, −45°, (c) 0.1 V, −84.3°; (d) 0.01 V, −89.4°

13.8 0.765 rad/s, 3.85 rad/s, 5

13.10 3; low-pass; $\dfrac{0.3125(s^2+4)}{(s+1)(s^2+s+1.25)}$

13.12 4; $\dfrac{4.512 \times 10^5 s^2}{(s^2 + s\,10^3 + 10^6)(s^2 + s\,10^2 + 1.44 \times 10^6)}$

13.15 $10^9/(s^2 + s\,1.414 \times 10^4 + 10^8)$

13.18 $\dfrac{0.64(s^2 + 1.5625 \times 10^8)}{s^2 + 5 \times 10^3\, s + 10^8}$;0.64

13.20 $T(s) = 0.2656\,(s^2+4)/(s^2+0.5s+1.0625)$; 0.2656

13.22 $1/(s^3 + 2\,s^2 + 3\,s + 2)$; All zeros at $s = \infty$; Poles: $s = -1$, $s = -0.5 \pm j1.323$

13.25 $\dfrac{10^8}{s^2 + 5000\,s + 10^8}$; 9354 rad/s; 2,066

13.26 (a) 1 rad/s, $1/\sqrt{2}$, 12.3 dB; (b) 0.8427 rad/s, 1.3, 17 dB

13.28 $\dfrac{s^2}{s^2+s+1}$; 1 rad/s; 1

13.32 35.7 dB

13.33 $1.234 \times 10^3(0.309 \pm j0.951)$, $1.234 \times 10^3(-0.809 \pm j0.588)$, -1.234×10^3

13.34 $N = 4$; $2\pi \times 10^4(-0.383 \pm j0.924)$, $2\pi \times 10^4 \ (-0.924 \pm j0.383)$; $\omega_0^4/(s^2 + 0.765\,\omega_0 s + \omega_0^2) \times (s^2 + 1.848\,\omega_0 s + \omega_0^2)$ where $\omega_0 = 2\pi \times 10^4$ rad/s; 38.2 dB

13.37 45.3 dB

13.38 (a) 10, 4 dB;

(b) $p_{1,10} = \omega_p(-0.0224 \pm j0.9978)$,

$p_{2,9} = \omega_p(-0.0651 \pm j0.9001)$,

$p_{3,8} = \omega_p(-0.1013 \pm j0.7143)$,

$p_{4,7} = \omega_p(-0.1277 \pm j0.4586)$,

$p_{5,6} = \omega_p(-0.1415 \pm j0.1580)$;

$$\frac{7.60 \times 10^{40}}{(s^2 + s\,0.0448\,\omega_p + 0.9961\,\omega_p^2)(s^2 + s\,0.1302\,\omega_p + 0.8144\,\omega_p^2)} \times$$
$$\frac{1}{(s^2 + s\,0.2026\,\omega_p + 0.5205\,\omega_p^2)(s^2 + s\,0.2554\,\omega_p + 0.2266\,\omega_p^2)}$$
$$\frac{1}{(s^2 + s\,0.2830\,\omega_p + 0.0450\,\omega_p^2)}$$

13.39 7; 23.15 dB, 0.25 dB

13.41 Peaks: $0.95\,\omega_p$, $0.59\,\omega_p$, 0; Valleys: ω_p, $0.81\,\omega_p$, $0.31\,\omega_p$

13.48 (a) -0.5%; (b) -0.5%; (c) no change

13.49 (a) $C_1/(C_1 + C_2)$, $C_1/(C_1 + C_2)$, no zeros; (b) 0, $C_1/(C_1 + C_2)$, zero at $s = 0$; (c) $L_2/(L_1 + L_2)$, $L_2/(L_1 + L_2)$, no zeros; (d) 0, $L_2/(L_1 + L_2)$, zero at $s = 0$

13.51 $$V_o = \frac{s^2 V_y + s\left(\frac{\omega_0}{Q}\right)V_z + \omega_0^2 V_x}{s^2 + s\left(\frac{\omega_0}{Q}\right) + \omega_0^2}$$

13.56 $R = 2\ \text{k}\Omega$, $C = 796$ pF, $R_6 = 200\ \text{k}\Omega$

13.59 $$\frac{V_o}{V_i} = \frac{K R_2/C_4 C_6 R_1 R_3 R_5}{s^2 + s\frac{1}{C_6 R_6} + \frac{R_2}{C_4 C_6 R_1 R_3 R_5}}$$

13.60 (a) $$T(s) = \frac{0.4508 \times 10^5(s^2 + 1.6996 \times 10^{10})}{(s + 0.7294 \times 10^5)(s^2 + s\,0.2786 \times 10^5 + 1.0504 \times 10^{10})}$$

(b) First-order section: $R_1 = R_2 = 13.71\ \text{k}\Omega$, $C = 1$ nF, Second-order section: $R_1 = R_2 = R_3 = R_5 = 9.76\ \text{k}\Omega$, $C_{61} = 618$ pF, $C_{62} = 382$ pF, $R_6 = 35.9\ \text{k}\Omega$, $K = 1$

13.63 $R = 1/\omega_0 C$; $R_1 = \infty$, $C_1 = GC$, $R_2 = \left(\frac{R}{G}\right)\left(\frac{\omega_0}{\omega_n}\right)^2$, $R_3 = \infty$

13.64 $$\frac{V_o}{V_i} = \frac{s^2\left(\frac{C_1}{C}\right) + s\frac{1}{C}\left(\frac{1}{R_1} - \frac{r}{RR_3}\right) + \frac{1}{C^2 RR_2}}{s^2 + s\frac{1}{QCR} + \frac{1}{C^2R^2}}$$

13.72 Second-order section: $R_1 = R_2 = 10\ \text{k}\Omega$, $C_3 = 492$ pF, $C_4 = 5.15$ nF; Second order section: $R_1 = R_2 = 10\ \text{k}\Omega$, $C_3 = 1.29$ nF, $C_4 = 1.97$ nF; First-order section: $R_1 = R_2 = 10\ \text{k}\Omega$, $C = 1.59$ nF

13.73 100 MΩ; 20 MΩ; 10 MΩ; 2 MΩ; 1 MΩ

13.78 (a) 100 pF; (b) 50 kΩ; (c) 0.001

13.80 0.125%; 0.042%

13.82 ω_0; 1/A

13.85 0.6 mA/V; 15.92 MHz

13.87 $s^2 + s\frac{1}{CR}\left(2 - \frac{r_2}{r_1}\right) + \frac{1}{C^2R^2}$; 2; $1/CR$

13.89 2.55 V

13.93 3.36 nF, 560 kΩ

13.94 $C = 1.59$ nF; R_f slightly smaller than 20 kΩ; $R_3 = 2.74$ kΩ; $R_4 = 10$ kΩ

13.96 $\omega_0 = \frac{0.925}{CR}$

13.99 7.88 V

13.100 $C = 1.59$ nF; 8.6 kHz; change the shunt resistor to 7.5 kΩ and R_2/R_1 to 2.35.

13.107 $j\omega[-\omega^2 LC_1C_2 + (C_1 + C_2)] + \left(g_m + \frac{1}{R_L} - \omega^2\frac{LC_2}{R_L}\right) = 0$;

$\omega_0 = 1/\sqrt{L\left(\frac{C_1C_2}{C_1 + C_2}\right)}$; $g_mR_L = \frac{C_2}{C_1}$

13.108 $L_1 = 2.41$ μH; $L_2 = 0.12$ μH

13.109 2.0165 MHz to 2.0173 MHz, an 800 Hz range.

13.116 (a) Output will be either +12 V or −12 V; (b) The output is a symmetric square wave (±12 V) of frequency f and it lags the sine wave by an angle of 65.4°; 0.1 V.

13.117 1989 Hz

13.119 (a) $V_{TH} = \left(\frac{L_+}{R_2} + \frac{V}{R_3}\right)(R_1 \| R_2 \| R_3)$; $V_{TL} = \left(\frac{L_-}{R_2} + \frac{V}{R_3}\right)(R_1 \| R_2 \| R_3)$;
(b) $R_2 = 656.7$ kΩ, $R_3 = 19.7$ kΩ

Chapter 14

14.1 (a) 2.18 kΩ; (b) 5.40 kΩ; (c) 3.71

14.6 (a) 6.0 (b) 1.67 kΩ

14.18 $V_M = V_{IL} = V_{IH} = 0.9$ V; $V_{OL} = 0$ V; $V_{OH} = 1.8$ V; $NM_L = NM_H = 0.9$ V; gain = ∞

14.19 $V_{DD} = 1.0$ V; $R_D = 31.6$ kΩ; $W/L = 1.7$; P_D (high output) = 30 μW; P_D (low output) = 0

14.22 $NM_H = 0.5$ V; $NM_L = 0.4$ V

14.23 $NM_H = 0.2V_{DD}$; $NM_L = 0.3V_{DD}$; transition region width = 0.2 V_{DD}; $V_{DD} = 1.25$ V

14.26 $V_{DD} = 1.2$ V; $R_D = 27.6$ kΩ; $W/L = 2.1$; $V_{IL} = 0.435$ V; $V_M = 0.6$ V; $V_{IH} = 0.7$ V; $NM_L = 0.385$ V; $NM_H = 0.5$ V

14.32 3.5 mV; 15.4 mV

14.33 135

14.34 (a) 84 nm (b) $V_{OH} = 0.9$ V; $V_{OL} = 0$ V; $V_{IH} = 0.49$ V; $V_{IL} = NM_H = NM_L = 0.41$ V (c) $r_{DSP} = r_{DSN} = 1.11$ kΩ (d) $r = 0.816$; $V_M = 0.43$ V

Chapter 15

15.4 (a) $V_{OL} = 0$ V; $V_{OH} = 1.2$ V; $NM_L = NM_H = 0.6$ V (b) $t_{PHL} = 138$ ps; $t_{THL} = 440$ ps (c) $t_{PLH} = 138$ ps; $t_{TLH} = 440$ ps

15.6 293.3 ps

15.7 $t_{PLH} = 27.6$ ps; $t_{PHL} = 13.8$ ps; $t_P = 20.7$ ps

15.9 (a) 475 ps (b) 400 ps; $t_P = 175$ ps

15.10 $(W/L)_n \geq 1.95$; $(W/L)_p \geq 7.8$

15.13 $t_{PHL} = 34.4$ ps; $t_{PLH} = 42.6$ ps; $t_P = 38.5$ ps; $f_{max} = 13$ GHz

15.15 $t_{PHL} = t_{PLH} = t_P = 7.7$ ps; 3.16 fF

15.17 $S = 3$. This is the factor by which $(W/L)_n$ and $(W/L)_p$ must be scaled. The inverter area will be increased by the same ratio, that is, 3.

15.23 (a) 0.54 V (b) 0.47 V

15.25 (a) $x = 6.32$; $t_P = 25.3$ CR (b) $n = 7$; $x = 2.87$; $t_P = 20.1$ CR

15.28 0.36 pF

15.31 0.188 pJ

15.35 (a) 0.184 to 0.216 mA (b) 46.3 to 54.3 ps

Chapter 16

16.2 (a) V_{DD} (b) $|V_{tn}|$ (c) 178 ps

16.4 0.834 V

16.6 25.8 ps

16.8 $V_{OH} = 0.59$ V; $V_{OL} = 0$ V; $i_{DP}(V_{OH}) = 1.08$ μA; $t_{PLH} = 51.6$ ps; $t_{PHL} = 27.0$ ps

16.11 64.3 ps

16.19 $V_M = 0.46$ V; $(W/L)_{5-8} = 1.42$

16.23 (a) (1.64,0.385) (b) (3,0.5) (c) (3.69,0.538)

16.26 1024 cells; 10 address rows; 12 bits

16.27 4.5

16.28 $(W/L)_5/(W/L)_1 \leq 0.397$; $W_5 = 65$ nm; $W_1 = 164$ nm

16.31 (a) 3 (b) 4.93 ns (c) 3.33 ns

16.33 $(W/L)_p \leq 3(W/L)_a$

16.37 222 ps; 200 MHz

16.41 10 address bits; 1024 output lines; 20 input lines; 11,264 transistors

16.43 10 address bits; 10 levels of pass gates; 2046 transistors