APPENDIX L

ANSWERS TO SELECTED PROBLEMS

Chapter 1

1.1 (a) $I = 0.5$ mA; (b) $R = 2$ kΩ; (c) $V = 2$ V; (d) $I = 50$ mA

1.3 (a) $V = 2$ V, $P = 4$ mW; (b) $R = 50$ kΩ, $P = 20$ mW; (c) $I = 100$ mA, $R = 10$ kΩ; (d) $V = 20$ V, $R = 200$ kΩ

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

1.7 2 V; 667 kΩ; 1.93 V and 2.07 V; 700 kΩand 633 kΩ

1.9 0.96 V; shunt the 1-kΩresistor with 15.67 kΩ; add series 20 Ω

1.14 2 kΩ; 2.5 kΩ; $0.1 \sin \omega t$ mA

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 kΩ; (b) $-j265$ kΩ; $-j159$Ω; $-j0.016$Ω; (c) $-j265$ MΩ; $-j159$ kΩ; $-j15.9$Ω; (d) $j3.77$Ω; $j6.28$ kΩ; $j62.8$ MΩ; (e) $j0.377$ mΩ; $j0.628$Ω; $j6.28$ kΩ

1.23 (a) $(1 - j15.9)$ kΩ; (b) $(717 + j450)$Ω; (c) $(9.96 - j0.626)$ kΩ; (d) $(10^5 + j628)$Ω

1.25 3 V; 3 mA; 1 kΩ; (b) 0.5 V; 50 μA; 10 kΩ

1.27 55.2 Ω

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

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

1.35 0 V; −1 V; +1 V; 2 kHz

1.37 2% lower

1.39 0; 101; 1101; 10000; 111111

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

1.47 2.8 V_{rms}; 14 mV_{rms}; 6.4 V_{rms}; 32 mV_{rms}; 9.9 V_{rms}; 50 mV_{rms}

1.49 38.4 dB; 71.4 dB; 85 mV; 0.1 W

1.51 0.69 V; −3.2 dB; 78.4 dB; 37.6 dB

1.52 412.7 V/V

1.54 4; 16.37 V

1.56 (a) 400 V/V; (b) 40 kΩ; 2×10^4 A/A; 8×10^6 W/W; (c) 500 Ω; (d) 750 V/V; (e) (i) 100 kΩ; (ii) 100 Ω; (iii) 484 V/V

1.58 1.1 mA; 10 kΩ

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1.59 4.95 A/A; 13.9 dB; 4.9 V/V; 13.8 dB; 24.3 W/W; 27.7 dB
1.60 13.3 V/V
1.66 683.3 V/V; 56.7 dB; 3.333 A/A; 70.5 dB; 2.34×10^6 W/W; 127.4 dB
1.70 4 MHz; 0.8 V/V
1.72 57 nF
1.75 $0.51/CR$
1.77 0.8 kΩ; 3.98 kΩ; 8 nF at node B
1.81 90 kΩ; 6.61 kΩ; 27.9 mA/V
1.82 $R_2/(R_1 + R_2)$
1.83 15.9 ms; 15.9 μs; −0.04 dB; 10 Hz and 10 kHz

Chapter 2

2.1 8; 14
2.2 2502.5 V/V
2.3 −1 V; 1750 V/V
2.5 10^4 V/V
2.9 (a) −6 V/V; 15 kΩ; (b) −6 V/V; 15 kΩ; (c) −6 V/V; 15 kΩ; (d) −6 V/V; 15 kΩ
2.12 (a) −2 V/V; (b) −10 V/V; (c) −0.5 V/V; (d) −50 V/V; (e) −5 V/V
2.14 $R_1 = 1$ kΩ; $R_2 = 5$ kΩ
2.18 3 mA; $R_1 = 2$ kΩ; $R_2 = 20$ kΩ
2.19 $\pm 2x\%$; −98 V/V to −102 V/V
2.21 1.49 kΩ; 5.88 kΩ
2.23 ±2 mV
2.27 (b) $R_1 = 1$ kΩ; $R_2 = 30$ kΩ; 589 V/V
2.30 (a) 41.67 kΩ; (b) 111.1 kΩ; (c) 666.7 kΩ
2.32 $-\frac{R_2}{R_1}\left(1 + \frac{R_4}{R_3} + \frac{R_4}{R_2}\right)$
2.34 (a) 0.1 mA; 0.1 mA; 10 mA; 10.1 mA; −1 V; (b) 693 kΩ; (c) $I_L = 10.1$ mA; $-6.05 \text{ V} \le V_O \le -2.01$ V
2.37 $R_1 = 100$ kΩ, $R_2 = 100$ kΩ, $R_3 = 1.02$ kΩ; −2.48 V/V
2.40 $R_1 = 6$ kΩ; $R_2 = 1.5$ kΩ; $R_3 = 1$ kΩ; $R_f = 6$ kΩ
2.44 $R_f = 5.33$ kΩ
2.45 (a) $R_1 = 10$ kΩ, $R_2 = 40$ kΩ; (b) $R_1 = 10$ kΩ, $R_2 = 90$ kΩ; (c) $R_1 = 10$ kΩ, $R_2 = 200$ kΩ; (d) $R_1 = 10$ kΩ, $R_2 = 990$ kΩ
2.47 100 kΩ; no
2.50 $\frac{1 + R_2/R_1}{1 + R_3/R_4}$
2.55 $\frac{1}{1 + 1/A}$; 0.999, −0.1%; 0.990, −1%; 0.909, −9.1%
2.58 1980 V/V

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2.59 9.09 V/V; 81 kΩ in parallel with R_1; 9.52 V/V; 10.52 V/V
2.62 $0\text{ V} \le v_O \le +2\text{ V}$; 0.1 V
2.63 10 V/V; 10 kΩ; 0.0091 V/V; 66.8 dB
2.68 (a) 1 V/V; 0 V/V; (b) $-5\text{ V} \le v_{Icm}$; (c) 10 V/V; 0 V/V; $-3\text{ V} \le v_{Icm} \le +3\text{ V}$
2.69 1 MΩ; 756 Ω; 6.8 kΩ
2.73 $2v_{Id} + 0.01\dfrac{(3-6x)}{(1+x-x^2)}$; −60 mV; increase 100 Ω
2.75 (a) $-0.05\text{ V} \le v_{Icm} \le +0.05\text{ V}$; (b) $-5\text{ V} \le v_{Icm} \le +5\text{ V}$
2.76 (a) 0 dB; (b) $20\log(1 + R_2/R_1)$
2.79 (b) 4 V/V; (c) 4 $V_{P\text{-}P}$; 1.414 V_{rms}
2.81 (a) 1.59 kHz; (c) increase by 10×
2.83 1 MHz; 0.159 μs
2.84 10 kΩ; 10 nF; 10 kHz
2.88 $R_1 = 10$ kΩ; $R_2 = 100$ kΩ; $C_2 = 15.9$ pF; 2 MHz
2.92 $R_1 = 2$ kΩ; $R_2 = 200$ kΩ; $C = 79$ pF; 20 kHz
2.94 7.3 mV
2.96 27 mV; 30 mV
2.98 (a) 100 nA into the amplifier; (b) −5 mV; (c) 10 nA
2.100 1.01 kΩ; 100 kΩ; 100 kΩ; 15.8 nF; 1.6 nF
2.102 609 mV; 303 mV; 9 mV
2.104 (a) 0.2 V; (b) 0.3 V; (c) 10 kΩ; 20 mV; (d) 0.12 V
2.106 (a) 9.9 kΩ; (b) 0.222 V
2.108 200,000 V/V; 100 Hz; 20 MHz
2.110 (a) 50 Hz; 10 MHz; (b) 100 Hz; 20 MHz; (c) 10 kHz; 18 MHz; (d) 1 MHz; 1 GHz; (e) 2.5 kHz; 500 MHz
2.112 800 kHz; 84 kHz; 7.6 MHz
2.114 10 V/V
2.116 183 MHz
2.121 100 mV
2.124 4 V/μs
2.126 6.37 MHz
2.127 (a) 318.3 kHz; (b) 0.795 V; (c) 2 MHz; (d) 1 V

Chapter 3

3.2 $2.2 \times 10^6\text{ cm}^{-3}$
3.4 $2 \times 10^{18}\text{ cm}^{-3}$; 112.5 cm^{-3}
3.7 (a) 11.4×10^9 Ω; (b) 5 kΩ; (c) 50 Ω; (d) 15.63 kΩ; (e) 0.14 Ω
3.9 8 μm
3.11 0.864 A/cm^2
3.13 778 mV; 0.2 μm; 0.1 μm; 0.1 μm; 1.6×10^{-15} C

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3.15 0.8 pC
3.17 59.6 mV
3.20 0.626 μm; 9.1×10^{-15} C
3.23 1.57×10^{-17} A; 1.88 mA
3.24 4.46
3.26 10.42 mA; 41.7 mA
3.28 0.23 pF
3.30 0.25 pF; 64.8 ps

Chapter 4

4.1 (a) 0 A; −1.5 V; (b) 0.75 A; 0 V
4.3 (a) 2 V; 5.5 mA; (b) 1 V; 4 mA
4.7 (a) 0 V; 2 mA; (b) −1.5 V; 0 mA
4.9 4.2 kΩ; 169.7 V
4.11 25 mA; 12.5 mA
4.14 $V = +3$ V ⇒ red ON, green OFF; $V = 0$ V ⇒ red OFF, green OFF; $V = -3$ V ⇒ red OFF, green ON
4.15 $-7 \text{ V} \leq v_I \leq 8 \text{ V}$
4.17 1.95 A; 10 V
4.19 0.461 V; $1.45 \times 10^{12} I_S$
4.21 1.49 mA; 54.6 mA; 0.67 mA; 18.3 μA; 17.3 mV
4.23 (a) 6.91×10^{-15} A; 73.8 mA; (b) 6.91×10^{-16} A; 7.38 mA; (c) 1.27×10^{-13} A; 1.36 A; (d) 6.91×10^{-17} A; 0.738 mA; (e) 3.78×10^{-16} A; 4.04 mA
4.25 Decrease by 17.3 mV
4.27 87.7 mV; 5.16 mA
4.31 50° C; 6 W; 8.33°C/W
4.33 230 mV independent of current and temperature
4.35 0.664 V
4.38 (a) 0.767 mA; (b) 5.3×10^{-16} A; (c) 0.805 mA
4.41 (a) −4.3 V; 0.93 mA; (b) 5 V; 0 A; (c) 4.3 V; 0.93 mA; (d) −5 V; 0 A
4.43 (a) 1.3 mA; 0 V; (b) 0 mA; −1.675 V
4.45 4.23 kΩ; 169.7 V
4.47 14.71 V; 3.61 V
4.49 +22.1 % or −18.1 %; +2.38 mV or −2.63 mV
4.53 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
4.54 (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; $I \geq 5$ μA; (c) 1 V; 1.005 V; $i_{D1} = i_{D4} = 0.45$ mA; $i_{D2} = i_{D3} = 0.55$ mA
4.59 470 Ω; 7.39 mA; 11.09 mW; 1.5 mW; +6.8 mV; −3.4 mV; −6.8 mV; −13.6 mV
4.62 47.6 mV
4.64 (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

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4.67 0.441 V
4.69 13.44 V; 48.4%; 8.3 V; 16.6 mA
4.71 (a) 10.1:1; (b) 4.2:1; (c) 8.2
4.73 30.4 V (45 V with 1.5× safety factor)
4.75 (i) 333.3 μF; (ii) 3333 μF; (a) (i) 12.77 V; (ii) 13.37 V; (b) (i) 7.1%; (ii) 2.24%; (c) 384 mA; (ii) 1214 mA; (d) (i) 742 mA; (ii) 2.4 A
4.78 (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
4.81 10.74 V; 23.5 μs; 4.913 A
4.83 (a) 1 V; 2 V; 2.7 V; (b) 3 V; 6 V; 6.7 V; (c) 0 V; 0 V; −13 V; (d) 0 V; 0 V; −13 V
4.86 −7.07 V
4.89 0.70 V $< V_R <$ 2.87 V
4.91 (a) 80 Ω; (b) 120 Ω

Chapter 5

5.2 0.16 fC
5.4 (a) 0.5; (b) 0.5; (c) 1.0; (d) 0.5
5.5 1.3 V to 0.62 V; 1.3 μm
5.7 1.85 μm
5.10 (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
5.13 96.2 Ω, 19.2 mV; 80
5.16 1.5 V; 500 Ω to 100 Ω
5.18 2 mA/V^2, 0.4 V
5.19 1.07 μm
5.20 0.4 V; 5; 0.25 mA; 0.6 V, 0.45 mA
5.22 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
5.28 (a) 2%; (b) 4%
5.29 100 kΩ, 20 V, 0.05 V^{-1}
5.32 109 μA; 9%; double L to 2 μm
5.35 15 V; 1.5 μm
5.37 8 μA; 12 μA; 13.13 μA; 13.75 μA; 15 μA
5.40 1.6 V, saturation region; 0.4 V, triode region
5.44 0.045 mA, 20 kΩ, 10 kΩ; 31.1 kΩ
5.47 8 kΩ
5.49 2.25 μm, 0.56 μm, 4 kΩ
5.51 0.454 mA, +7.28 V; circuit is quiet tolerant to variations in device parameters.
5.53 44.4, 1.25 kΩ
5.55 (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
5.58 (a) 360 μA, 1 V; (b) 160 μA, 0.8 V; (c) 1 V, 360 μA

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5.60 (a) 0.5 V, 0.5 V, −0.723 V; (b) 0.4 V, 0.6 V, −0.745 V

5.62 488 million transistors

5.63 1 V to 1.69 V; 3.74 V

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

6.2 3.7×10^{-17} A; 1.87×10^{-16} A; 5:1

6.4 0.276 V

6.7 0.18 mA; 0.605 V

6.12 0.5 mA → 2mA; 0.51 mA → 2.01 mA; 20 mW

6.14 990 μA, 99, 0.99; 980 μA, 49, 0.98; 950 μA, 19, 0.95

6.18 437 kΩ; 8 kΩ

6.22 −1 V; 0.41 mA; −0.668 V

6.25 238 mA; 6×10^{-14} A; 87 times

6.28 (a) 1 mA, −0.7 V; (b) −2 V; (c) 1 V, 1 mA; (d) 0.77 mA, −2 V

6.30 2.3 kΩ; 20; 100; 200

6.34 $R_E = 1.62$ kΩ, $R_C = 3$ kΩ

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

6.42 0.1 mA, 0.11 mA; −8.16 V; +22 mV/°C; −7.06 V

6.43 200 kΩ; 100 V; 20 kΩ

6.47 100; 80; 1.18 mA

6.48 (a) 1.3 V; (b) 1.64 V; (c) 5.5 V

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

6.53 −1.7 V, +1.7 V; −0.7 V, +0.7 V; +0.3 V, −0.3 V; −1.17 V; −1,5 V; −2 V, +2 V; 0.55 V; −0.15 V, +0.15 V; 1.08 V

6.55 $R_1 = 35$ kΩ, $R_2 = 15$ kΩ; 0.078 mA; 4.22 V

6.56 0.3 V; 0.003 mA; 0.15 mA; 0.147 mA; −1.03 V; 49; 0.98

6.58 +0.41 V, +1.11 V; −1.15 V; +1.2 V, +1.9 V, −1.9 V; 204

6.60 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

6.62 (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

6.63 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.

6.64 1.74 kΩ; transistor saturates and $V_C = 2.8$ V

6.66 (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

6.68 (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

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

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Chapter 7

7.1 A: (0.5 V, 3 V); B: (0.69 V, 0.19 V)
7.2 12 kΩ; 6 kΩ
7.4 0.214 V; 0.716 V
7.6 0.5 V; 8
7.10 −80 V/V; 0.7 V; 8.8 mV
7.12 0.75 V; 0.45 V; −90 V/V
7.15 −40 V/V
7.19 (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
7.24 (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%
7.25 (a) 0.2 mA, 0.44 V; (b) 2 mA/V; (c) −13.6 V/V; (d) 25 kΩ, −10.7 V/V
7.27 (a) 2 mA/V, 20 kΩ; (b) 2.9 mA/V, 10 kΩ
7.29 12 kΩ; 10 μm; 0.75 V
7.31 −26.1 V/V; 1.25 V, −38.3 V/V
7.32 NMOS: 0.91 mA/V, 25 kΩ, 0.22 V; PMOS: 0.447 mA/V, 30 kΩ, 0.447 V
7.36 16 mA/V, 6.25 kΩ, 61.9 Ω; 1.6 mA/V, 62.5 kΩ, 618.8 Ω
7.37 20 mA/V; 50 Ω; 5 kΩ; 0.5 V
7.38 0.5 mA; 80
7.48 0.5 V; 100 Ω; 100 V/V
7.49 0.005 V, 0.001 mA
7.54 1 V; 5 kΩ; 3.33 kΩ; −30.8 V/V, 9.7 mV; 7.5 mV
7.55 $V_A = 20$ V: −800 V/V; $V_A = 120$ V: −4800 V/V
7.57 17.2 kΩ; 18 kΩ; 90 V/V
7.59 82.6 V/V; 9086 A/A
7.60 190 kΩ; 111 V/V; 55.6 Ω
7.61 1000 V/V; 250 V/V
7.64 −20 V/V
7.66 1.5 mA/V; 0.15 mA; −7.5 V/V
7.68 10 kΩ; 10 kΩ; −160 V/V; −80 V/V; −40 V/V; 10 mV; 0.4 V
7.71 200 Ω
7.73 5 mA/V; 4 kΩ; 50 Ω
7.75 600 Ω; 0.375 mA; −7.4 V/V; 0.74 V
7.77 0.2 kΩ; 5.6 V/V; 0.64
7.79 0.5 mA; 25 V/V
7.81 8 V/V; 50 mV; 0.4 V
7.83 2.5 mA; 2.75 mA; 2.25 mA; 0.55 V
7.85 (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
7.87 1 V/V; 105 Ω; 0.9 V/V
7.91 27.5 V/V, 41.2 V/V, 55.6 V/V, 57.1 V/V, 55.6 V/V; 0.325 mA

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7.92 22 MΩ; 18 MΩ; 15 kΩ; 15 kΩ; 2.7 V above
7.94 5.07 V; 1.27 mA to 2.48 mA; 620 Ω; 0.91 mA to 1.5 mA
7.96 2 V; 2.4 V; 1.2 mA
7.97 $R_S = 5$ kΩ; $R_D = 7.5$ kΩ
7.101 (a) 1.25 V; (b) 1.85 V
7.102 9.5 kΩ
7.103 1.3 kΩ; 1.7 MΩ; 13 MΩ
7.106 6.2 kΩ; 6.2 kΩ; 100 kΩ; 75 kΩ; 3.6 V; 2.9 V; 6.1 V; 0.46 mA
7.107 6.2 kΩ; 6.2 kΩ; 100 kΩ; 82 kΩ; 0.5 mA; 0.49 mA; 3.8 V; 6 V
7.109 $R_E = 1.5$ 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
7.111 $R_C = 3.3$ kΩ; $R_B = 120$ kΩ; 0.56 mA, 0.85 V
7.113 0.505 mA; 160 kΩ
7.116 4.6 kΩ; +0.4 V
7.117 −26.7 V/V
7.119 (a) 3 kΩ; (b) 3 kΩ; (c) 0.135 V, 1.62 V; (d) 4.6 kΩ, −18.4 V/V
7.121 (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
7.125 0.47 mA; 4.7 kΩ; −30.4 V/V
7.128 $R_B = 91$ kΩ; $R_C = 22$ kΩ; 0.2 mA; −176 V/V, −29.7 V/V
7.129 (a) 11.5 kΩ; (b) 12.5 kΩ; (c) −31.7 V/V
7.131 27.5 kΩ; −9.8 V/V; 20.5 mV; 0.2 V
7.135 163.4 kΩ; 0.6 V/V; 52.9 A/A; 789 Ω
7.136 (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
7.137 (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 8

8.2 66 kΩ; 6 μm; 0.2 V; 40 kΩ; +5 μA
8.5 0.2 V; 100 μA; 0.2 V; 27 kΩ; 81.5 μA; 100 μA; 118.5 μA; 137 μA
8.7 5 μm; 20 μm; 12.5 μm; 3.125 μm; 6.25 μm; 15 kΩ; 37.5 kΩ; 30 kΩ
8.10 0.01 mA; 5%
8.14 1.013 mA; 2.28 kΩ; 2.7 V; +0.15 mA
8.16 (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,
8.19 1.187 V; 0.113 V; 99.98 μA; 0.9998 mA, −0.02%; 0.3 V
8.23 20 μm; 80 μm; 0.8 μm; −0.6%
8.24 $v_o/v_i = g_{m1}R_L\,(W_3/W_2)$
8.26 (a) 800 Ω; (b)125 Ω

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8.28 10 kΩ; −1200 V/V; 60 kΩ; 0.1 mA; −1200 V/V; 300 kΩ; −400 V/V
8.29 40 V/V; 0.1 mA; 5 μm
8.31 0.5 μm; 12.5; 0.1 mA
8.33 0.25 mA; 2 mA/V
8.35 2 mA/V; 13.5 kΩ; 27 V/V; 14 μm
8.37 0.146 mA
8.40 40 V/V; 5.6 μm; 0.67 mA/V; 60 kΩ
8.41 0.75 V; 17.4; 69.4; −14.5 V/V
8.44 (a) 0.95 V, 0.475 μA, 2.4 V; (b) −86 V/V, 1.93 V, 22 mV; (c) 33.9 kΩ
8.46 50 μA; 4; 16, 16
8.48 (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
8.49 (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
8.50 21 kΩ; 0.976 A/A; 840 kΩ; 20.5 V/V
8.52 40 V/V; 0.6 μm
8.54 252 kΩ
8.56 1.4 kΩ; 0.98 A/A; 10.2 MΩ; 35.7 V/V
8.59 0.1 mA; 12.2 MΩ; 0.16 μA
8.62 2 V; 0.5 μm
8.63 −1600 V/V
8.66 0.32 μm; 39.1; 0.7 V; 0.225 mA; 0.3 V
8.68 1.6 mA/V; 640 kΩ; 640 kΩ; 320 kΩ; −512 V/V
8.71 0.2 V; 0.5 V to 0.8 V
8.75 1.24 MΩ
8.78 -3.2×10^4 V/V
8.80 360 μA; 2.4 mA/V; 0.48 mA/V; 15 kΩ; 0.8 V/V; 0.33 kΩ; 0.72 V/V
8.81 0.68 V; 1.1 MΩ
8.84 5 MΩ; +0.2 μA; +0.1%
8.88 0.56 V; 1.12 V; 0.72 V
8.93 (a) 58.5 kΩ; (b) 100 MΩ

Chapter 9

9.1 (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
9.4 −0.283 V to +0.283 V; At $v_{id} = -0.283$ V: $v_S = 0.4$ V, $v_{D1} = -0.1$ V, $v_{D2} = -0.9$ V, $v_O = -0.8$ V; At $v_{id} = +0.283$ V: $v_S = +0.683$ V, $v_{D1} = -0.9$ V; $v_{D2} = -0.1$ V, $v_O = +0.8$ V
9.7 0.365; 15; 1.1 mA/V

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9.9 0.177 V; 400 μA

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

9.13 0.25 V; 0.5 mA; 5 kΩ; 40

9.15 0.14 V; 0.25 mA; 4.4 kΩ; 25.5

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

9.18 2×

9.23 4 kΩ; 50, 50, 100, 12.5, 12.5, 100, 25; 0.1 mA, 0.1 mA, 0.2 mA, 0.1 mA, 0.1 mA, 0.2 mA, 0.2 mA; 0.6 V, 0.6 V, 0.6 V, 0.6 V, 0.6 V, 0.6 V, 0.6 V

9.26 −1.14 V; +1 V; +1 V

9.28 −0.56 V to +1.41 V

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

9.32 (a) $V_{CC} - \frac{I}{2}R_C$; (b) 1.5 V; (c) 0.2 mA, 7.5 kΩ;

9.36 0.2 mA, 0.4 mA; 17.3 mV

9.38 4 mA/V; 80 kΩ

9.39 0.2 mA; 20 kΩ

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

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

9.49 20 V/V

9.51 20 V/V

9.52 20 V/V; 101 kΩ

9.53 20 V/V; 101 kΩ

9.55 12 V/V; 6×10^{-4} V/V; 86 dB

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

9.58 4%

9.59 1 μm; 102 dB

9.61 (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

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

9.68 1%

9.69 $\frac{2}{3}I$ in Q_1 and $\frac{1}{3}I$ in Q_3; 0.0125 V/V

9.72 8 mV; $\triangle V_t$; 8%

9.73 1.6 mV, 1.6 mV, 4 mV; 7.2 mV; 4.6 mV

9.75 2 mV

9.79 1.25 mV

9.81 (a) 0.25; (b) 0.28

9.84 1.6 kΩ; 0.8 kΩ; 2 kΩ

9.86 15 V/V

9.87 1.25 mA/V; 30 kΩ; 30 kΩ; 18.8 V/V

9.89 2.6 V

9.92 1 mA/V; 44.4 kΩ; 44.4 V/V; 44.4 kΩ;

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9.94 25 kΩ; 25 kΩ; 8 mA/V; 200 V/V; 100 V/V

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

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

9.101 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

9.103 81 kΩ

9.106 (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 $\triangle V_t$).

9.107 120 μA; 455 mV; 0.73 mV

9.110 0.2 mA, 0.2 mA, 0.2 mA, 0.2 mA, 0.25 mA, 0.5 mA; 1.61×10^5 V/V

9.111 12.5 V/V; 40 kΩ; 3300 A/A

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

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

Chapter 10

10.1 $g_m = 2.6$ 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

10.2 12.7 GHz

10.6 578.9 MHz; 5.79 MHz

10.10 0.22 pF; 20 mA/V; 6 kΩ; 100 MHz

10.14 3.18 MHz

10.15 −40 V/V; 34.6 MHz; 127.3 GHz

10.18 100.1 pF; $-\dfrac{1000}{1+s\,C_{\text{in}}\,R_{\text{sig}}}$;159 kHz; 159 MHz

10.21 259 kHz; −27.8 V/V; changing R_L: $R_L = 6.17$ kΩ, $|A_M| = 12.4$ V/V; changing R_{in}: $R'_{\text{sig}} = 25$ kΩ, $R_{\text{in}} = 33.3$ kΩ, $|A_M| = 13.9$ V/V

10.22 −25 V/V; 49.7 MHz; 31.8 GHz

10.24 31.83 fF; 286.5 fF; 20 MHz

10.26 −25 V/V; 254.6 MHz; 31.8 GHz

10.27 61 pF; 522 kHz

10.30 −29.3 V/V; 988 kHz

10.33 1 MΩ

10.37 (a) 0.54 mA; (b) 21.6 mA/V, 4.63 kΩ; (c) −10.8 V/V; (d) 4 kΩ, 2.14 kΩ; (e) −7.4 V/V; (f) 14.37 pF; (g) 16.3 MHz

10.40 39.8 MHz; 159 GHz

10.41 −41.7 V/V; 140 kHz

10.43 −80 V/V; 10.1 pF; 788 kHz; 652 kHz; the second estimate is more appropriate as it takes C_L into account.

10.45 118 fF

10.48 −143 V/V; 3.2 MHz; 2.47 MHz; the second estimate as it takes C_L into account.

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10.49 −50 V/V; 479 kHz
10.50 8 V/V; 159 MHz; 5 MHz; 5 MHz
10.53 14.4 fF
10.54 31.8 MHz
10.56 −913 V/V; 5.76 MHz
10.58 0.2 V; 0.2 mA; 289.4 MHz; 57.9 MHz; −99 V/V; 2.9 MHz; 287.1 MHz
10.61 −50 V/V; 4 MHz
10.64 0.9 V/V; 200 Ω; 398 MHz; 33.4 MHz, 90.7 MHz; 31.6 MHz
10.68 27 kΩ; 884 kHz; 0.33 mA/V
10.69 0.96 V/V; 2 GHz; 740 MHz, 4.6 GHz; 740 MHz
10.70 (a) 0.2 V, 1 mA/V; (b) 25 V/V; (c) 212 MHz; (d) 42.3 MHz
10.73 15.9 MHz; 40 MHz
10.76 25 V/V; 63.7 MHz; 3.18 GHz; 6.37 GHz
10.79 (a) −80 V/V, 8.9 MHz, 712 MHz; (b) −40 V/V, 16.6 MHz, 664 MHz
10.85 (a) 2.5 MΩ, −4000 V/V; 107.6 MHz
10.86 20 V/V; 1.33 MHz, 19.9 MHz; 1.33 MHz
10.88 50 V/V; 4.6 MHz
10.89 (a) 2500 V/V; (b) 9.1 MHz
10.93 20 nF
10.95 8 μF; 89.5 Hz; 10 Hz
10.96 −15.8 V/V; 1.9 Hz; 87.5 Hz; 8 Hz; 10.8 Hz; 87.5 Hz
10.98 −31.6 V/V; $C_S = 7$ μF; $C_{C1} = 90$ nF; $C_{C2} = 0.4$ μF; 90.9 Hz
10.99 $C_E = 5$ μF; $C_{C1} = 0.5$ μF; $C_{C2} = 0.5$ μF; 92.2 Hz; 6 μF
10.101 $C_{C1} = 0.8$ μF; $C_{C2} = 0.8$ μF; $C_E = 9$ μF
10.102 141.4

Chapter 11

11.1 100; 99; 9.9×10^{-3}; 99.89; 0.11%; 91.7; 8.3%
11.2 0.01; 100; 10^4
11.5 0.1; 990; 9.9
11.8 1500 V/V; 30 V/V; 50; 49; 0.0327
11.10 99; 9
11.12 2000 V/V; 0.0495 V/V
11.16 1000 V/V; 0.099 V/V, 1961 V/V
11.19 100 kHz; 0.099 V/V
11.21 Three stages each with a closed-loop gain of 10 V/V and $\beta = 0.099$ V/V
11.22 0.089 V/V; for $|v_s| \leq 0.45$ V, $v_o/v_s = 11.1$ V/V, for $0.45 \text{ V} \leq |v_s| \leq 0.95$ V, $\triangle v_o/\triangle v_s = 10.1$ V/V, and for $|v_s| \geq 0.95$ V, $v_o = \pm 10$ V
11.24 90 kΩ; 100; 9.9 V/V; 91 kΩ
11.26 (a) 4 kΩ; (b) 37.1, 4.87 V/V

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11.28 (a) 0.9 kΩ; (b) 31.33, 9.7 V/V, −3%, make $R_F = 933\ \Omega$

11.29 (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

11.30 (a) 0.95 kΩ; (b) 22.22, 19.1 V/V

11.32 9.95 V/V; 402 kΩ; 10 Ω

11.35 10 V/V; 1.001 MΩ

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

11.40 (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

11.42 (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%

11.44 0.1 V/mA; 9.9 mA/V; 1.01 MΩ; 0.99 Ω

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

11.48 4.87 mA/V; 1.11 MΩ; 4.1 MΩ

11.49 100 Ω; 497 V/V; 9.94 mA/V

11.52 (a) $A_f\big|_{\text{ideal}} = \dfrac{1}{R_{S1}} + \dfrac{1}{R_{S2}} + \dfrac{R_F}{R_{S1} R_{S2}}$, 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

11.53 (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

11.58 (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

11.60 0.94 V/mA; 28.3 Ω; 21.1 Ω

11.62 (a) $-R_F/R_s$, 100 kΩ; (b) −9.89 V/V, 100.9 Ω, 11 Ω; (c) 180.2 kHz

11.65 (a) +0.5 V, +1.0 V, +0.5 V; (b) 4 mA/V, 20 kΩ; (c) $A = -g_{m1} r_{o1} R_F \dfrac{R_F \| r_{o2}}{(R_F \| r_{o2}) + 1/g_{m2}}$; (d) $-1/R_F$; $g_{m1} r_{o1} \dfrac{R_F \| r_{o2}}{(R_F \| r_{o2}) + 1/g_{m2}}$; (e) $-\dfrac{g_{m1} r_{o1} R_F (R_F \| r_{o2})}{(R_F \| r_{o2}) + 1/g_{m2} + (g_{m1} r_{o1})(R_F \| r_{o2})}$; (f) R_F, $R_F \Big/ \left[1 + g_{m1} r_{o1} \dfrac{R_F \| r_{o2}}{(R_F \| r_{o2}) + 1/g_{m2}}\right]$, $\left(R_F \| r_{o2} \| \dfrac{1}{g_{m2}}\right)$, $\left(R_F \| r_{o2} \| \dfrac{1}{g_{m2}}\right) \Big/ \left[1 + g_{m1} r_{o1} \dfrac{R_F \| r_{o2}}{(R_F \| r_{o2}) + 1/g_{m2}}\right]$; (g) −1561 kΩ, −0.05 mA/V, 78 −19.8 kΩ, 20 kΩ, 244 Ω, 253 Ω, 3.1 Ω

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11.67 (a) +0.75 V; (b) −456 kΩ, 3.33 kΩ, 119 Ω; (c) −0.1 mA/V, 45.6, 46.6; (d) −9.79 kΩ, 71.5 Ω, 2.6 Ω

11.68 20 kΩ; −19 kΩ; 24; Ω; 488 Ω

11.70 (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

11.72 10 kΩ; 990 kΩ; −1020 V/V; 1.02 GΩ

11.74 (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

11.80 (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

11.81 10^4 rad/s; 0.02; 50

11.83 1.095×10^5 rad/s; 2.42×10^{-3}

11.84 10^4 V/V; 1 MHz; 10 MHz; $(1 + A_0\beta)$

11.87 0.049; 980 kHz; 700 kHz

11.89 2; 173.2 kHz

11.91 3.085×10^3 Hz; 18.15°; 10^{-3}; 60 dB

11.93 87.6 dB; 81.8 dB

11.96 200 Hz

11.98 (a) 10 kHz; 100 Hz

Chapter 12

12.2 $-1.1\text{ V} < v_O < 1.91\text{ V}$; $-1.6\text{ V} < v_I < 3\text{ V}$;

12.4 $R = 152\Omega$; $A_v = 0.998, 0.996, 0.978$ V/V; 2%

12.7 $V_{CC}I$

12.9 $\hat{V}$; $\hat{V}/R_L$; 25%

12.10 2.5 V

12.12 4.5 V; 6.4%; 625 Ω

12.14 10 V; 6.37 V; 2.74 Ω, 18.25 W; 3.86 Ω, 3.24 W

12.18 1.382 V; 12.5 Ω; 0.889 V/V; 0.998 V/V

12.20 4.9 mA

12.23 1.35 mA; −1.05 V; +4 V; −6 V

12.25 1.96 mA; $-10\text{ V} < v_O < 5.1$ V; 99; 3.92 mA; 3.84 mA

12.27 $-g_{m3}\beta R_L$

12.30 1.34 kΩ; 1.04 kΩ

12.32 60.2 Ω

12.36 (a) 9.1 mA; 0 mA; 0 V; (b) 220 Ω; 0.93 V/V; 1.51 Ω

12.38 (a) 0.0144 mA; 1.44 mA; (b) −43.6 V/V; (c) 137.1 kΩ

12.41 (a) 30.5 V; (b) $246.8/R_L$; $881.8/R_L$

12.43 4.3 Ω; 325 mV; 4.4 nA

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12.45 35 mA; 5 mA
12.47 10 Ω
12.50 (a) 533.3; 1333.3; (b) 10 V/V; (c) 5%; (d) ±1.85 V; (e) +0.3 V; −0.3 V; (f) $-1.77\text{ V} \le v_O \le +1.77\text{ V}$
12.52 +4 V; −4 V
12.54 2 W; +5 V; 3 W; +5 V; 600 mA; 30 V

Chapter 13

13.1 $-0.8\text{ V} \le V_{ICM} \le +0.2\text{ V}$; $-0.8\text{ V} \le v_O \le +0.8\text{ V}$
13.3 0.15 V
13.6 0.8 pF; 477.5 MHz; 477 MHz
13.8 3.18 pF; 0.1 mA; 0.3 mA
13.10 3.2 pF; 30 MHz
13.12 62.8 V/μs; 1.6 pF
13.14 11.4 MHz
13.16 636 kΩ
13.18 318.3 kHz; 8.0 MHz
13.20 (a) 1 pF; (b) 0.41 pF
13.23 (a) 0.16 V; (b) 2 pF; (c) 78.1
13.25 (b) 0.45 μm
13.27 +0.3 V; +0.45 V; −0.45 V; $-0.3\text{ V} \le V_{ICM} \le +1.25\text{ V}$; $-0.3\text{ V} \le v_O \le +0.7\text{ V}$
13.29 1 mA/V; 833 kΩ; 833 V/V; 9.88 V/V; 10 kΩ
13.31 I/C_L
13.36 (a) $-0.25\text{ V} \le V_{ICM} + 1.3\text{ V}$; (b) $-1.3\text{ V} \le V_{ICM} + 0.25\text{ V}$; (c) $-0.25\text{ V} \le V_{ICM} + 0.25\text{ V}$; (d) $-1.3\text{ V} \le V_{ICM} + 1.3\text{ V}$
13.38 $0.176C_L$
13.40 6.93 kΩ; 40 kΩ; 40 kΩ
13.43 1.8 kΩ
13.45 $A_7 = 3A_3$; $A_8 = 10A_3$; $R_3 = R_4 = 6.67\text{ k}\Omega$; $R_7 = 2.22\text{ k}\Omega$; $R_8 = 667\Omega$
13.47 (a) $0.1\text{ V} \le V_{ICM} \le 2.2\text{ V}$; (b) $0.8\text{ V} \le V_{ICM} \le 2.9\text{ V}$
13.50 125 kΩ; 95.4 V/V
13.52 (b) 367.3; (c) 6.75 mV
13.56 2
13.58 $190 \le \beta_N \le 211$
13.60 105.3 dB
13.63 50 μA
13.65 $R_1 = 5.76k\Omega$; $R_2 = 6.22k\Omega$; 521 Ω
13.67 (a) $0.1\text{ V} \le v_O \le 2.9\text{ V}$; (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
13.70 10.6 μA; minimum current is 0.3 mA

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Chapter 14

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

14.4 1 V/V; 0.944 V/V; 0.0001 V/V

14.5 0.59 dB; 60 dB; 1.2

14.7 0.509 rad/s; 3 rad/s; 5.89

14.10 3; low-pass; $\dfrac{0.3125(s^2+4)}{(s+1)(s^2+s+1.25)}$

14.12 4; $\dfrac{4.512\times10^5 s^2}{(s^2+s\,10^3+10^6)(s^2+s\,10^2+1.44\times10^6)}$

14.13 $\dfrac{0.17(s^2+6.25)}{s^2+0.5\,s+1.0625}$; 0.17

14.15 $1/(s^3+2\,s^2+3\,s+2)$; All zeros at $s=\infty$; Poles: $s=-1$, $s=-0.5\pm j1.323$

14.18 $10^9/(s^2+s\,1.414\times10^4+10^8)$

14.21 $\dfrac{0.64(s^2+1.5625\times10^8)}{s^2+5\times10^3\,s+10^8}$; 0.64

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

14.28 $\dfrac{s^2}{s^2+s+1}$; 1 rad/s; 1

14.32 42.1 dB

14.34 7; 23.15 dB, 0.25 dB

14.36 7; Poles: $\omega_0=2\pi\times10^4$ rad/s, $Q_1=2.247$, $Q_2=0.802$, $Q_3=0.555$, real pole at $s=-2\pi\times10^4$; $\dfrac{\omega_0^7}{(s^2+s\,\dfrac{\omega_0}{2.247}+\omega_0^2)(s^2+s\,\dfrac{\omega_0}{0.802}+\omega_0^2)(s^2+s\,\dfrac{\omega_0}{0.555}+\omega_0^2)(s+\omega_0)}$; 66.8 dB

14.39 45.3 dB

14.40 Peaks: 0.95 ω_p, 0.59 ω_p, 0; Valleys: ω_p, 0.81 ω_p, 0.31 ω_p

14.42 (a) 10, 4 dB;
(b) $p_{1,10}=\omega_p(-0.0224\pm j0.9978)$,
$p_{2,9}=\omega_p(-0.0651\pm j0.9001)$,
$p_{3,8}=\omega_p(-0.1013\pm j0.7143)$,
$p_{4,7}=\omega_p(-0.1277\pm j0.4586)$,
$p_{5,6}=\omega_p(-0.1415\pm j0.1580)$;

$$\frac{7.60\times10^{40}}{(s^2+s\,0.0448\,\omega_p+0.9961\,\omega_p^2)(s^2+s\,0.1302\,\omega_p+0.8144\,\omega_p^2)}\times$$
$$\frac{1}{(s^2+s\,0.2026\,\omega_p+0.5205\,\omega_p^2)(s^2+s\,0.2554\,\omega_p+0.2266\,\omega_p^2)}$$
$$\frac{1}{(s^2+s\,0.2830\,\omega_p+0.0450\,\omega_p^2)}$$

14.44 2 nF, 12.5 mH

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14.46 (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 $s=0$

14.51 $$V_o = \frac{s^2V_y + s\left(\frac{\omega_0}{Q}\right)V_z + \omega_0^2 V_x}{s^2 + s\left(\frac{\omega_0}{Q}\right) + \omega_0^2}$$

14.52 $R_1 = R_2 = R_3 = R_5 = 10\,\text{k}\Omega$; (a) $C_4 = 0.1\,\mu\text{F}$; (b) $C_4 = 10\,\text{nF}$; (c) $C_4 = 1\,\text{nF}$

14.56 First-order section: $T_1(s) = \dfrac{2\times10^4}{s+10^4}$, $R_1 = 50\,\text{k}\Omega$, $R_2 = 100\,\text{k}\Omega$, $C = 1\,\text{nF}$; Second-order section: $T_2(s) = \dfrac{2\times10^8}{s^2 + s\dfrac{10^4}{1.618} + 10^8}$, $C = 1\,\text{nF}$, $R = 100\,\text{k}\Omega$, $R_6 = 1.61.8\,\text{k}\Omega$, $K = 2$; Second-order section: $T_3(s) = \dfrac{2.5\times10^8}{s^2 + s\dfrac{10^4}{0.618} + 10^8}$, $C = 1\,\text{nF}$, $R = 100\,\text{k}\Omega$, $R_6 = 61.8\,\text{k}\Omega$, $K = 2.5$

14.59 $R = 2\,\text{k}\Omega$, $C = 796\,\text{pF}$, $R_6 = 200\,\text{k}\Omega$

14.60 (a) $$T(s) = \frac{0.4508\times10^5(s^2 + 1.6996\times10^{10})}{(s+0.7294\times10^5)(s^2 + s\,0.2786\times10^5 + 1.0504\times10^{10})}$$

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

14.61 $C = 10\,\text{nF}$, $R = 5.31\,\text{k}\Omega$, $R_1 = 10\,\text{k}\Omega$, $R_f = 10\,\text{k}\Omega$, $R_2 = 1\,\text{k}\Omega$, $R_3 = 119\,\text{k}\Omega$, $K = 1.983$, gain = 119 V/V

14.64 $R = 1/\omega_0 C$; $R_1 = \infty$, $C_1 = GC$, $R_2 = \left(\dfrac{R}{G}\right)\left(\dfrac{\omega_0}{\omega_n}\right)^2$, $R_3 = \infty$

14.68 $C_1 = C_2 = 10\,\text{nF}$, $R_3 = 12.73\,\text{k}\Omega$, $R_4 = 200\,\Omega$, gain $= -32$ V/V

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

14.73 100 MΩ; 20 MΩ; 10 MΩ; 2 MΩ; 1 MΩ

14.77 0.1 pF; 0.1 pF; 0.1414 pF; 0.1 pF

Chapter 15

15.1 ω_0; 1/A

15.3 (a) 100 pF; (b) 50 kΩ; (c) 0.001

15.5 0.6 mA/V; 15.92 MHz

15.8 $s^2 + s\dfrac{1}{CR}\left(2 - \dfrac{r_2}{r_1}\right) + \dfrac{1}{C^2R^2}$; 2; $1/CR$

15.10 2.55 V

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15.11 0.125%; 0.042%

15.14 $0.878/CR$

15.16 6.6 kΩ, 6.6 kΩ; $\hat{V}_0 = 1.05$ V

15.19 7.88 V

15.20 $C = 1.59$ nF; 8.6 kHz; change the shunt resistor to 7.5 kΩ and R_2/R_1 to 2.35.

15.26 $C = 1.59$ nF; R_f slightly smaller than 20 kΩ; $R_3 = 2.74$ kΩ; $R_4 = 10$ kΩ

15.28 4.97 kΩ; 3.6 V; add a diode in series with each of the diodes in the limiter.

15.29 (a) 0; (b) 4.17×10^{-3}; (c) 1.39×10^{-3}; (d) 4.5×10^{-3} or 0.45%

15.30 $j\omega\left[-\omega^2 LC_1C_2 + (C_1 + C_2)\right] + \left(g_m + \dfrac{1}{R_L} - \omega^2 \dfrac{LC_2}{R_L}\right) = 0;$

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

15.33 $L_1 = 2.41$ μH; $L_2 = 0.12$ μH

15.35 $C = 1.25$ pF; $g_m = 2.7$ mA/V

15.36 2.0165 MHz to 2.0173 MHz, an 800 Hz range.

15.37 30 kΩ

15.43 (a) either +5 V or −5 V; (b) symmetric square wave of frequency f, lagging the sine wave by 65.4°, having ±5 V swing; 0.1 V

15.44 9.518 kHz

Chapter 16

16.1 (a) 1.90 kΩ (b) 10.26 kΩ (c) 8.1

16.2 (a) 6.0 (b) 1.67 kΩ

16.16 $NM_H = 0.5$ V; $NM_L = 0.4$ V

16.18 $NM_H = 0.2V_{DD}$; $NM_L = 0.3V_{DD}$; transition region width = 0.2 V_{DD}; $V_{DD} = 1.25$ V

16.20 $V_M = V_{IL} = V_{IH} = 0.9$ V; $V_{OL} = 0$ V; $V_{OH} = 1.8$ V; $NM_L = NM_H = 0.9$ V; gain = ∞

16.23 $V_{DD} = 1.0$ V; $R_D = 31.6$ kΩ; $W/L = 1.7$; P_D (high output) = 30 μW; P_D (low output) = 0

16.24 $V_{DD} = 1.2$ 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

16.28 (a) $W_p = 527$ nm; area = 40,560 nm^2 (b) $V_{OH} = 1$ V; $V_{OL} = 0$ V; $V_{IH} = 0.5375$ V; $V_{IL} = 0.4625$ V; $NM_H = NM_L = 0.4625$ V (c) $r_{DSP} = r_{DSN} = 1.9$ kΩ

16.31 3.5 mV; 15.4 mV

16.32 135

16.35 (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

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Chapter 17

17.4 t_{PLH} = 27.6 ps; t_{PHL} = 13.8 ps; t_P = 20.7 ps
17.5 (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
17.7 (a) 475 ps (b) 400 ps; t_P = 175 ps
17.9 $(W/L)_n \geq 1.95$; $(W/L)_p \geq 7.8$
17.11 293.3 ps
17.14 t_{PHL} = 34.4 ps; t_{PLH} = 42.6 ps; t_P = 38.5 ps; f_{max} = 13 GHz
17.16 $t_{PHL} = t_{PLH} = t_P$ = 7.7 ps; 3.16 fF
17.17 S = 3; area increases by a factor of 3
17.23 (a) 0.54 V (b) 0.47 V
17.24 (a) x = 6.32; t_P = 25.3 CR (b) n = 7; x = 2.87; t_P = 20.1 CR
17.26 4.32 fJ; 54 W; 45 A
17.28 0.175 pF
17.30 0.188 pJ
17.35 (a) 0.184 to 0.216 mA (b) 46.3 to 54.3 ps

Chapter 18

18.2 0.834 V
18.4 25.8 ps
18.6 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
18.7 (a) V_{DD} (b) $|V_{tn}|$ (c) 178 ps
18.11 64.3 ps
18.18 V_M = 0.46 V; $(W/L)_{5-8}$ = 1.42
18.23 4.5
18.24 (a) (1.64,0.385) (b) (3,0.5) (c) (3.69,0.538)
18.26 $(W/L)_5/(W/L)_1 \leq 0.397$; W_5 = 65 nm; W_1 = 164 nm
18.29 (a) 3 (b) 4.93 ns (c) 3.33 ns
18.31 $(W/L)_p \leq 3(W/L)_a$
18.34 1024 cells; 10 address rows; 12 bits
18.38 222 ps; 200 MHz
18.43 10 address bits; 1024 output lines; 20 input lines; 11,264 transistors
18.45 10 address bits; 10 levels of pass gates; 2046 transistors

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