MICROELECTRONIC CIRCUIT DESIGN

Third Edition

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Answers to Selected Problems – Updated 1/25/08

Chapter 1

1.3 1.52 years, 5.06 years

1.5 1.95 years, 6.46 years

1.8 113 MW, 511 kA

1.10 2.50 mV, 5.12 V, 5.885 V

1.12 19.53 mV/bit, 10001110_2

1.16 0.002 A, 0.002 cos (1000*t*) A

1.19 v_{DS} = [5 + 2 sin (2500*t*) + 4 sin (1000*t*)] V

1.21 15.7 V, 2.31 V, 70.0 μA, 210 μA

1.23 120 μA, 125 μA, 10.3 V

1.25 39.6 Ω, 0.0253 v_s

1.27 56 kΩ, 1.33 x 10^{-3} v_s

1.29 1.00 MΩ, 2.50 x 10^8 i_s

1.33 $5\underline{/-45°}$, $100\underline{/-12°}$

1.35 -90.1 sin 750πt mV, 11.0 sin 750πt μA

1.37 1 + R_2/R_1

1.39 -1.875 V, -2.500 V

1.41 Band-pass amplifier

1.43 50.0 sin (2000*πt*) + 30.0 cos (8000 *πt*) V

1.45 0 V

1.47 [2970Ω, 3030Ω], [2850Ω, 3150Ω], [2700Ω, 3300Ω]

1.52 6200Ω, 800 ppm/^{o}C

1.58 3.29, 0.995, −6.16; 3.295, 0.9952, −6.155

Chapter 2

2.4 For Ge: $35.9/cm^3$, $2.27 \times 10^{13}/cm^3$, $8.04 \times 10^{15}/cm^3$

2.7 $-1.75x10^6\ cm/s,\ +6.25x10^5\ cm/s,\ 2.80x10^4\ A/cm^2,\ 1.00x10^{-10}\ A/cm^2$

2.8 305.2 K

2.10 4 MA/cm^2

2.13 1.60 x 10^7 A/cm^2, 4.00 A

2.15 316.6 K

2.19 Donor, acceptor

2.20 200 V/cm

2.22 5 x 10^3 atoms

2.24 4 x $10^{16}/cm^3$, 2.50 x $10^5/cm^3$

2.28 6 x $10^{18}/cm^3$, $16.7/cm^3$, 5 x $10^9/cm^3$, 8.80 x $10^{-10}/cm^3$

2.30 3 x $10^{17}/cm^3$, $333/cm^3$

2.32 $100/cm^3$, $10^{18}/cm^3$, 375 cm^2/s, 100 cm^2/s, p-type, 62.4 mΩ-cm

2.34 $10^{16}/cm^3$, $10^4/cm^3$, 800 cm^2/s, 1230 cm^2/s, n-type, 0.781 Ω-cm

2.38 3.06 x $10^{18}/cm^3$

2.40 Yes—add equal amounts of donor and acceptor impurities. Then $n = n_i = p$, but the mobilities are reduced. See Prob. 2.37.

2.42 2.00/Ω-cm, 3.1 x $10^{19}/cm^3$,

2.44 75K: 6.64 mV, 150K: 12.9 mV, 300K: 25.8 mV, 400K: 34.5 mV

2.46 -1.20 x10^5 exp (-5000 x/cm) A/cm^2; 12.0 mA

2.48 The width in the figure should be 2 μm: For x = 0, -535 A/cm^2

2.50 1.108 μm

Chapter 3

3.1 0.0373 μm, 0.0339 μm, 3.39×10^{-3} μm, 0.979 V, 5.24×10^{5} V/cm

3.3 10^{18}/cm^3, 10^{2}/cm^3, 10^{18}/cm^3, 10^{2}/cm^3, 0.921 V, 0.0488 μm

3.6 2.55 V, 1.05 μm

3.10 6400 A/cm^2

3.13 1.00×10^{21}/cm^4

3.17 290 K

3.20 312K

3.21 1.39, 3.17 pA

3.22 0.837 V; 0.768 V; 0 A; 9.43×10^{-19} A, -1.00×10^{-18} A

3.25 1.34 V; 1.38 V

3.28 0.518 V; 0.633 V

3.31 0.757 V; 0.721 V

3.34 −1.96 mV/K

3.37 0.633 V, 0.949 μm, 3.89 μm, 12.0 μm

3.39 374 V

3.41 4 V, 0 Ω

3.43 9.80 nF/cm^2; 188 pF

3.45 400 fF, 10 fC; 100 pF, 0.5 pC

3.49 9.97 MHz; 15.7 MHz

3.51 0.495 V, 0.668 V

3.53 0.708 V, 0.718 V

3.56 (a) Load line: (450 μA, 0.500 V); SPICE: (443 μA, 0.575 V)
(b) Load line: (-667 μA, -4 V);
(c) Load line: (0 μA, -3 V);

3.59 (0.600 mA, -4 V) , (0.950 mA, 0.5 V) , (-2.00 mA, -4 V)

3.65 Load line: (50 μA, 0.5 V); Mathematical model: (49.9 μA, 0.501 V); Ideal diode model: (100 μA, 0 V); CVD model: (40.0μA, 0.6 V)

3.69 (a) 0.625 mA, 3 V; 0.625 mA, -5 V; 0 A, -5 V; 0 A, 7 V

3.71 (a) (409 μA, 0 V), (270 μA, 0 V); (c) (0 A -3.92 V), (230 μA, 0 V)

3.73 (a) (0.990 mA, 0 V) (0 mA, -1.73 V) (1.09 mA, 0)
(d) (0 A, -0.452 V) (0 A, -0.948 V) (1.16 mA, 0.600 V)

3.76 (1.50 mA, 0 V) (0 A, -5.00 V) (1.00 mA, 0)

3.78 (I_Z, V_Z) = (792 μA, 4.00 V)

3.81 10.8 mW

3.83 2.25 W, 4.50 W

3.88 17.6 V

3.91 −7.91 V; 1.05 F; 17.8 V; 3530 A; 841 A (ΔT = 0.628 ms)

3.94 -7.91V, 0.158 F, 17.8 V, 3540 A, 839 A

3.97 6.06 F; 8.6 V; 3.04 V; 1920 A; 9280 A

3.100 -20.2 V; 1.35 F; 42.4 V; 10800 A; 1650 A

3.103 3.03 F, 8.6 V, 3.04 V, 962 A, 4910 A

3.107 278 μF; 3000 V; 2120 V; 44.4 A; 314 A

3.115 5 mA, 4.4 mA, 3.6 mA, 5.59 ns

3.119 (0.969 A, 0.777 V); 0.753 W; 1 A, 0.864 V

3.121 1.11 μm, 0.875 μm; far infrared, near infrared

Chapter 4

4.3 10.5×10^{-9} F/cm^2

4.4 34.5 μA/V^2, 86.3 μA/V^2, 173 μA/V^2, 345 μA/V^2

4.9 (a) 4.00 mA/V^2 (b) 4.00 mA/V^2, 8.00 mA/V^2

4.11 840 μA; −880 μA

4.15 23.0 Ω; 35.7 Ω

4.18 125 μA/V^2; 1.5 V; enhancement mode; 1.25/1

4.20 0 A, 0 A, 1.88 mA, 7.50 mA, 3.75 mA/V^2

4.22 (a) 460 μA, triode region; 1.56 mA, saturation region; 0 A, cutoff

4.23 saturation; cutoff; saturation; triode; triode; saturation

4.27 6.50 mS, 13.0 mS

4.30 2.48 mA; 2.25 mA

4.33 9.03 mA, 18.1 mA, 10.8 mA

4.37 Triode region

4.38 1.13 mA; 1.29 mA

4.39 99.5 μA; 199 μA; 99.5 μA; 99.5 μA

4.43 202 μA; 184 μA

4.44 5.17 V

4.49 40.0 μA; 72.0 μA; 4.41 μA; 32.8 μA

4.50 5810/1; 2330/1

4.54 235 Ω; 235 Ω

4.55 0.629 A/V^2

4.57 400 μA

4.64 14λ x 18λ; 7.9%

4.71 3.45×10^{-8} F/cm^2; 17.3 fF

4.81 (350 μA, 1.7 V); triode region

4.84 (390 μA, 4.1 V); saturation region

4.86 (778 μA, 9.20 V)

4.94 (134 μA, 4.64 V) ; (116 μA, 5.36 V)

4.97 510 kΩ, 470 kΩ, 12 kΩ, 12 kΩ, 5/1

4.100 (124 μA, 2.36 V)

4.103 (a) (33.3 μA, 1.01 V)

4.106 (23.5 μA, 0.967 V)

4.109 (73.1 μA, 9.37 V)

4.116 2.25 mA; 16.0 mA; 1.61 mA

4.119 18.1 mA; 45.2 mA; 13.0 mA

4.122 1/3.57

4.123 (153 μA, -3.53 V) ; (195 μA, -0.347 V)

4.125 4.04 V, 10.8 mA, 43.2 mA

4.126 14.4 mA; 27.1 mA; 10.4 mA

4.129 (59.8 μA, -5.47 V) , $\leq$ 130 kΩ

4.131 (55.3 μA, -7.09 V) , $\leq$ 164 kΩ

4.134 40.1 kΩ → (138 μA, -5 V)

4.138 One possible design: 220 kΩ, 200 kΩ, 5.1 kΩ, 4.7 kΩ

4.141 (260 μA, -12.4 V)

4.144 (36.1 μA, 80.6 mV); (32.4 μA, -1.32 V); (28.8 μA, -2.49 V)

4.146 34.5 fF, 17.3 fF

4.148 6.37 GHz, 2.55 GHz; 637 GHz, 255 GHz

4.149 690 μA, 86.3 μA

4.150 10^{-22} A, 10^{-15} A

Chapter 5

5.4 0.0167, 0.667, 3.00, 0.909, 49.0, 0.9950, 0.9990, 5000

5.5 2 fA; 1.01 fA, −0.115 V

5.6 0.374 μA, -149.6 μA, +150 μA, 0.591 V

5.9 2.02 fA

5.11 5.34 mA; −5.34 mA

5.14 25 μA, -100 μA, +75 μA, 65.7, 1/3, 0, 0.599 V

5.17 1.77 μA, -33.2 μA, +35 μA, 0.623 V

5.20 723 μA

5.24 0.990, 0.333, 2.02 fA, 6.00 fA

5.26 83.3, 87.5, 100

5.33 39.6 mV/dec, 49.5 mV/dec, 59.4 mV/dec, 69.3 mV/dec

5.34 6 V, 50 V, 6 V

5.35 2.31 mA; 388 μA; 0

5.36 65.7 V

5.40 Cutoff

5.42 saturation, forward-active region, reverse-active region, cutoff

5.46 13.3 aA, 0.263 fA, 0.25 fA

5.47 I_C = 16.3 pA, I_E = 17.1 pA, I_B = 0.857 pA, forward-active region; although I_C, I_E, I_B are all very small, the Transport model still yields $I_C \cong \beta_F I_B$

5.48 65.7, 6.81 fA

5.49 62.5, 1.73 fA

5.50 55.3 μA, 0.683 μA, 54.6 μA

5.51 6.67 MHz

5.53 0.875, 24.2 aA

5.55 -19.9 μA, 26.5 μA, -46.4 μA

5.58 17.3 mV, 0.251 mV

5.60 1.81 A, 10.1 A

5.62 0.803 V, 0.714 V, 27.5 mV

5.65 23.2 μA

5.66 4.0 fF; 0.4 pF; 40 pF

5.68 750 MHz, 3.75 MHz

5.71 0.147 μm

5.72 71.7, 43.1 V

5.74 72.9, 37.6 V

5.75 100 μA, 4.52 μA, 95.5 μA, 0.589 V, 0.593

5.77 (c) 38.7 mS

5.78 0.388 pF at 1 mA

5.82 (80.9 μA, 3.80 V) ; (405 μA, 3.80 V)

5.86 (42.2 μA, 4.39 V)

5.92 (7.5 mA, 4.3 V)

5.94 (5.0 mA, 1.3 V)

5.96 30 kΩ, 620 kΩ; 24.2 μA, 0.770 V

5.98 5.28 V

5.100 3.21 Ω

5.103 616 μA, 867 μA, 3.90 V, 5.83 V

5.107 4.4 percent; 70 percent

5.109 The minimum I_C case, (109 μA, 7.36 V). For the maximum I_C case, the transistor is saturated.

Chapter 6

6.1 10 μW/gate, 4 μA/gate

6.3 2.5 V, 0 V, 0 W, 62.5 μW; 3.3 V, 0 V, 0 V, 109 μW

6.5 V_{OL} = 0 V, V_{OH} = 3.3 V, V_{REF} = 1.1 V; $Z = A$

6.7 3 V, 0 V, 2 V, 1 V, −3

6.9 2 V, 0 V, 2 V, 5 V, 3 V, 2 V

6.11 3.3 V, 0 V, 3.0 V, 0.25 V, 1.8 V, 1.5 V, 1.2 V, 1.25 V

6.13 −0.80 V, −1.35 V

6.15 1 ns

6.17 1 μW/gate, 0.40 μA/gate, 1 fJ

6.19 2.20 RC; 2.20 RC

6.21 −0.78 V, −1.36 V, 1 ns, 1 ns, 9.5 ns, 9.5 ns, 4 ns, 4 ns, 4 ns

6.24 Z = 0 0 0 1 0 0 1 1

6.26 Z = 0 1 0 1 0 1 0 1

6.29 2 ; 1

6.31 84.5 A

6.32 0.583 pF

6.35 1 μW/gate, 0.556 μA/gate

6.37 155 kΩ, 1/1.08

6.39 (b) 2.5 V, 0.0329 V, 30.8 μW

6.40 (a) 0.412 V, 1.49 V

6.44 40.9 kΩ; 1.52/1; 1.49 V, 0.267 V

6.47 417 Ω; 1000 Ω; a resistive channel exists connecting the source and drain; 20/1

6.50 1.44 V

6.53 1.29 V, 0.06 V

6.56 1.40/1, 6.67/1

6.59 0.106 V

6.61 ratioed logic so V_H = 1.55 V, V_L = 0.20 V; P = 0.24 mW

6.65 3.79 V

6.69 1.014

6.71 1.16/1, 1.36/1

6.72 1.46/1, 1/2.48

6.74 1.80/1, 0.610 V, 0.475 V

6.77 (a) 88.8 μA, 0.224 V (b) 0.700 V, 0.449 V

6.80 1.65/1, 1/1.80, 0.821 V, 0.440 V

6.84 2.22/1, 1.81/1

6.87 6.66/1, 1.11/1, 0.203 V, 6.43/1, 6.74/1, 7.09/1

6.90 $Y = \overline{(A + B)(C + D)(E + F)}$, 6.66/1, 1.81/1

6.94 $Y = \overline{ACE + ACDF + BF + BDE}$, 3.33/1, 26.6/1, 17.8/1

6.97 1/1.80, 3.33/1

6.100 $Y = \overline{(C + E)[A(B + D) + G] + F}$; 3.62/1, 13.3/1, 4.44/1, 6.67/1

6.103 3.45/1, 6.43/1, 7.09/1, 6.74/1

6.105 7.09/1, 6.43/1, 6.74/1

6.108 7.24/1, 26.6/1, 8.88/1, 13.3/1

6.110 (a) 5.43/1, 9.99/1, 20.0/1

6.113 $I'_{DS} = 2I_{DS}$, $P'_D = 2P_D$

6.114 80 mW, 139 mW

6.116 1 ns

6.118 60.2 ns, a potentially stable state exists with no oscillation

6.119 31.7 ns, 4.39 ns, 5.86 ns

6.123 114 ns, 5.94 ns, 15.3 ns

6.126 78.7 ns, 10.2 ns, 9.00 ns

6.128 3.52/1, 27.8/1, 12.8 ns, 0.924 ns

6.130 (a) 1/1.68 (d) 1/5.89 (f) 1/1.60

6.132 −1.90 V, −0.156 V

6.133 1/3.30, 1.75/1

6.134 2.30 V, 1.07 V

6.136 $Y = \overline{A + B}$

Chapter 7

7.1 173 $\mu A/V^2$; 6.1 $\mu A/V^2$

7.3 250 pA; 450 pA; 450 pA

7.6 2.5 V, 0 V

7.8 cutoff, triode, triode, cutoff, saturation, saturation

7.11 1.25 V, 42.3 μA; 1.104 V, 25.4 μA

7.13 0.90 V, 16.0 μA; 0.810 V, 96.2 μA

7.15 (b) 2.5 V, 0.0928 V

7.17 0.9836 V, 2.77 mA

7.18 1.16 V, 0.728 V

7.22 2.36 ns, 2.36 ns, 0.788 ns

7.23 11.9 ns, 4.74 ns, 2.77 ns

7.26 2.11/1, 5.26/1

7.28 6.00/1, 15.0/1

7.30 1.7 ns, 2.3 ns, 1.1 ns, 0.9 ns, $\langle C \rangle = 138$ fF

7.33 2.5 μW/gate, 45.9 fF, 80.0 fF

7.35 1.00 W; 1.74 W

7.37 90.3 μA; 25.0 μA

7.41 0.290 pJ, 283 MHz, 616 μW

7.44 $\alpha\Delta T$, $\alpha^2 P$, $\alpha^3 PDP$

7.48 2/1, 20/1; 6/1, 60/1

7.53 1.25/1

7.59 3.95 ns, 3.95 ns, 11.8 ns

7.60 (a) 5 transistors (b) The CMOS design requires 47% less area.

7.62 $Y = \overline{(A+B)(C+D)E} = \overline{ACE + ADE + BDE + BCE}$, 18/1, 30/1, 15/1

7.64 $Y = \left(\overline{A} + \overline{B}\right)\left(\overline{C} + \overline{D}\right)\left(\overline{E} + \overline{F}\right) = \overline{AB + CD + EF}$, 4/1, 15/1

7.67 2/1, 4/1, 6/1, 20/1

7.69 (a) Path through NMOS A-D-E (d) Paths through PMOS A-C and B-E

7.71 4/1, 6/1, 10/1

7.72 20/1, 24/1, 40/1

7.78 5.37 ns, 2.21 ns

7.82 9.47 ns, 23.7 ns

7.84 5.8 ns, 3.7 ns

7.91 $V_{DD} \rightarrow \frac{2}{3}V_{DD} \rightarrow \frac{1}{2}V_{DD}$; $R \geq \frac{2V_{IH}}{V_{DD} - V_{IH}} = \frac{2V_{IH}}{NM_H}$, $C_1 \geq 83.1 C_2$

7.97 N = 8, A = 22.6 A_o

7.101 263 Ω, 658 Ω

7.103 240/1, 96.2/1

7.104 1.4 V, 2.5 V

7.106 Latchup does not occur.

Chapter 8

8.1 268,435,456 bits, 1,073,741,824 bits; 2048 blocks

8.2 3.73 pA/cell , 233 fA/cell

8.5 3 V, 0.667 μV

8.9 1.55 V, 0 V, 3.59 V

8.10 "1" level is discharged by junction leakage current

8.11 1.47 V, 1.43 V

8.12 −19.8 mV; 2.48 V

8.15 0 V, 1.90; Junction leakage will destroy the "1" level

8.16 5.00 V, 1.60 V; −1.83 V

8.18 33.6 mW

8.21 402 μA, 1.36 W

8.23 For C_{BL} = 500 fF, 0.266 V

8.24 0.945 V, (The sense amplifier provides a gain of 10.5.)

8.30 0 V, 1.43 V, 3.00 V

8.31 53,296

8.35 $V_{DD} \rightarrow \frac{2}{3}V_{DD} \rightarrow \frac{1}{2}V_{DD}$; $R \geq \frac{2V_{IH}}{V_{DD} - V_{IH}} = \frac{2V_{IH}}{NM_H}$; $C_1 \geq 2.88C_2$

8.37 $W_1 = 01000110_2$, $W_3 = 00101011_2$

8.41 1.16/1

Chapter 9

9.1 0 V, -1.70 V

9.2 -1.38 V, -1.12

9.3 −1.75 V, 0 V

9.6 0 V, −0.4 V; 3.39 kΩ; Saturation, cutoff; Cutoff, saturation

9.8 −0.700 V, −1.70 V, −1.20 V, 1.00 V

9.11 −0.700 V, −1.50 V, −1.10 V, 2.67 kΩ; 0.289 V, −0.100 V, +0.300 V

9.13 267 Ω, -1.90 V, -2.30 V, -2.10 V

9.15 14.8 kΩ, 16.0 kΩ, 93.6 kΩ, 336 kΩ

9.17 -1.10 V, -1.50 V, -1.30 V, 0.400 V, 0.107 V, 1.10 mW

9.18 0.383 V

9.21 0.430 V

9.23 50.0 μA, -2.30 V

9.24 Standard values: 11 kΩ, 150 kΩ, 136 kΩ

9.28 +0.300 V, −0.540 V, 336 Ω

9.31 5.15 mA

9.34 0.13 mA

9.38 500 Ω, 60.0 mA

9.40 (c) 0 V, -0.7 V, 3.93 mA (d) –3.7 V, 0.982 mA (e) 2920 Ω

9.43 $Y = A + \overline{B}$

9.45 359 ns

9.47 −0.850 V; 3.59 pJ

9.48 0 V, −0.600 V, 5.67 mW; $Y = A + B + C$, 5 vs. 6

9.51 5.00 kΩ, 5.40 kΩ, 31.6 kΩ, 113 kΩ

9.52 1 kΩ, 1 kΩ, 1.30 mW

9.54 2.23 kΩ, 4.84 kΩ, 60.1 kΩ

9.56 2.98 pA, 74.5 fA

9.58 160; 0.976; 5; 0.773 V

9.59 0.691 V, 0.710 V

9.64 40.2 mV, 0.617 mV

9.66 3 V, 0.15 V, 0.66 V, 0.80 V, 33

9.68 68.2 mV, 2.47 mA

9.72 44.8 kΩ, 22.4 kΩ

9.74 5 V, 0.15 V, 0, −1.06 mA, 31; −1.06 mA vs. −1.01 mA, 0 mA vs. 0.2 mA

9.82 8

9.84 234 mA, 34.9 mA

9.88 (I_B, I_C): (a) (135 μA, −169μA); (515μA, 0); (169 μA, 506 μA); (0, 0) (b) all 0 except $I_{B1} = I_{E1} =$ 203 μA

9.94 1.85 V, 0.15 V; 62.5 μA, −650 μA; 13

9.96 $Y = \overline{ABC}$; 1.9 V; 0.15 V; 0, −408 μA

9.98 1.5 V, 0.25 V; 0, −1.00 mA; 16

9.99 0.7 V, 191 μA, 59 μA, 1.18 mA

9.100 1.13 mA, 0, 4.28 mA, 0, 129 μA, 1.00 mA; 0, 0, 0, 0, 1.23 mA, 0

9.102 $Y = A + B + C$; 0 V, −1.0 V; −0.90 V

9.103 $Y = A + B + C$; 0 V, −0.80 V; −0.40 V

9.104 1.05 mA, 26.9 μA

9.105 2 fJ; 10 fJ

9.107 1.67 ns; 0.5 mW

Chapter 10

10.2 (a) 41.6 dB, 35.6 dB, 94.0 dB, 100 dB, -0.915 dB

10.3 Using MATLAB:

```
t = linspace(0,.004);
vs = sin(1000*pi*t)+0.333*sin(3000*pi*t)+0.200*sin(5000*pi*t);
vo= 2*sin(1000*pi*t+pi/6)+sin(3000*pi*t+pi/6)+sin(5000*pi*t+pi/6); plot(t,vs,t,vo)par
```

500 Hz: 1 0°, 1500 Hz: 0.333 0°, 2500 Hz: 0.200 0°; 2 30°, 1 30°, 1 30° 2 30°, 3 30°, 5 30° yes

10.5 35.0 dB, 111 dB, 73.2 dB

10.8 25.1 dB, 93.0 dB, 59.0 dB; Vo = 17.9 V, recommend ± 20-V supplies

10.13 −10 (20 dB), 0.1 V; 0, 0 V

10.14 $v_O = [8 - 4 \sin(1000t)]$ volts; there are only two components; dc: 8 V, 159 Hz: −4 V

10.17 24.1 dB, 11.2%

10.20 4.12×10^{-8} S, -9.90×10^{-3}, 1.00, 99.0 Ω

10.22 0.286 mS, -0.286, -1710, 1.78 MΩ

10.23 1.00 mS, −1.00, 2001, 20.0 kΩ

10.25 53.7 dB, 150 dB, 102 dB; 11.7 mV; 31.3 mW

10.26 45.3 mV, 1.00 W

10.30 −7800

10.33 0, ∞, 125 mW, ∞

10.37 -4.44 dB, 26.5 kHz

10.39 10 kΩ, 0.015 μF

10.41 -1.05 dB, 181 Hz

10.43 60 dB, 10 kHz, 10 Hz, 9.99 kHz, band-pass amplifier

10.44 80 dB, ∞, 100 Hz, ∞, high-pass amplifier

10.48 60 dB, 100 kHz, 28.3 Hz, 100 kHz

10.56 $0.030 \sin(2\pi t + 89.4°)$ V, $1.34 \sin(100\pi t + 63.4°)$ V, $3.00 \sin(10^4\pi t + 1.15°)$ V

10.59 $0.956 \sin(3.18\times10^5\pi t + 101°)$ V, $5.00 \sin(10^5\pi t + 180°)$ V, $5.00 \sin(4\times10^5\pi t - 179°)$V

10.61 $\dfrac{2x10^8\pi}{s+10^7\pi} \quad | \quad -\dfrac{2x10^8\pi}{s+10^7\pi}$

10.63 60 dB, 16.1 kHz, -40 dB/decade

10.64 66 dB, 12.8 kHz, -60 dB/decade

10.65 $10 \sin(1000\pi t + 10°) + 3.33 \sin(3000\pi t + 30°) + 3.00 \sin(5000\pi t + 50°)$ V; Using MATLAB:

```
t = linspace(0,.004);
A=10^(10/20);
vs = sin(1000*pi*t)+0.333*sin(3000*pi*t)+0.200*sin(5000*pi*t);
vo = A*sin(1000*pi*t+pi/18)+3.33*sin(3000*pi*t+3*pi/18)+2.00*sin(5000*pi*t+5*pi/18);
plot(t, A*vs, t, vo)
```

Chapter 11

11.1 59.9 dB, 120 dB, 89.9 dB; 5.05 mV

11.3 $R_{id} \geq 4.95$ MΩ

11.5 0.100 mV, 140 dB

11.7 (a) −46.8, 4.7 kΩ, 0, 33.4 dB

11.10 (d) (-1.10 + 0.75 sin 2500πt) V

11.13 30.1 kΩ, 1.00 MΩ + 576 kΩ, , A_v = -20.1, R_{in} = 30.1 kΩ

11.15 92.5, ∞, 0, 83.9 dB

11.18 (d) (1.98 – 1.08 sin 3250πt) V

11.21 20.0 kΩ, 1.05 kΩ, A_v = 20.0

11.24 (0.510 sin 3770*t* −1.02 sin 10000*t*) V, 0

11.25 −0.3750 sin 4000πt V; −0.6875 sin 4000πt V; 0 to −0.9375 V in - 62.5-mV steps

11.26 455/1, 50/1

11.27 −10, 110 kΩ, 10 kΩ, , (-30 + 15cos 8300πt) V, (-30 + 30cos 8300πt) V

11.28 3.2 V, 3.1 V, 2.82 V, 2.82 V, -1.00 V; 3.80 μA; 3.80 μA, 2.80 μA

11.30 -12, (-6.00 + 1.20 sin 4000πt) V

11.34 (a) 10 kΩ, 100 kΩ, 79.6 pF (b) 10 kΩ, 100 kΩ, 82 pF, 19.4 kHz

11.35 T(s) = -sRC

11.38 −6.00, 20.0 kΩ, 0; +9.00, 75.0 kΩ, 0; 0, 160 kΩ, 0

11.39 -70.0, 10 kΩ, 0

11.40 1 A, 2.83 V, > 10 W (choose 15 W)

11.41 0.484 A; 0.730 V; 0.730 V; ≥ 7.03 W (choose 10 W), 7.27 W

11.44 $\frac{v_1 - v_2}{R}$, ∞ ; If the voltage gain were finite with value A, $R_{out} = R(1 + A)$

11.46 3.99 V, 3.99 V, 1.99 V, 1.99 V, 3.99 V, 200 μA; −5 MΩ !

11.48 4.96 kΩ, ∞

11.50 -1.00 kΩ

11.51 11 resistors, 1024:1

11.53 -0.3125 V, -0.6250 V, -1.250 V, -2.500 V

11.54 $3.415469 \text{ V} \leq V_X \leq 3.415781 \text{ V}$

11.55 1.90735 μV, 11010000101000111101_2 , 01111111100111011101_2

11.56 19.1 ns

11.58 *A* and *B* taken together, *B* and *C* taken together

11.61 48.0, ∞, 0

11.64 -1080, 3.9 kΩ, 0

11.65 8.62 kΩ, 8.62 kΩ

11.66 -1500, 47 kΩ, 0, 0.010 V, 0V, -0.100 V, 0 V, +1.00 V, 0 V, -15.0 V, 0V (ground node)

11.70 2744, 2434, 3094, 1 MΩ, 1.02 MΩ, 980 kΩ

11.73 (b) 0.005 μF, 0.0025 μF, 1.13 kΩ

11.77 $\frac{\mathbf{V_O}}{\mathbf{V_S}} = \frac{K}{s^2 R_1 R_2 C_1 C_2 + s\left[R_1 C_1 (1-K) + C_2 (R_1 + R_2)\right] + 1}$ | $S_K^Q = \frac{K}{3-K}$

11.79 -1

11.81 270 pF, 270 pF, 23.2 kΩ

11.82 (a) 51.2 kHz, 7.07, 7.23 kHz

11.85 (a) 1 rad/s, 4.65, 0.215 rad/s

11.87 5.48 kHz, 4.09, 1.34 kHz

11.89 10 kΩ, 100 kΩ, 20 kΩ, 0.0133 μF

11.92 0.759 V

11.93 2.4 Hz

11.98 $V_O = -V_1V_2/10^4 I_S$

11.99 2.62 V, 2.38 V, 0.24 V

11.101 0.487 V, -0.487 V, 0.974 V

11.103 9.86 kHz

11.104 f = 0. V_O = 0 is a stable state. The circuit does not oscillate.

11.106 0, 0.298 V, 69.0 mV

11.107 13 kΩ, 30 kΩ, 51 kΩ, 150 pF

Chapter 12

12.1 (a) 13.49, 9.11×10^{-3}, 0.0675%

12.3 (a) -9.997, 2.76×10^{-3}, 0.0276%

12.5 106 dB

12.10 100 μA, 100 μA, -48.0 pA

12.11 (a) 13.5, 371 MΩ, 169 mΩ

12.13 (a) -8.39, 5.60 kΩ, 37.5 mΩ

12.15 785 MΩ, 785 MΩ, 3.75 mΩ

12.17 If the gain specification is met, the input and output specifications cannot be met.

12.21 ≤ 0.374%

12.23 0.869 V, 1.00 V, 13.1%

12.26 114 dB

12.27 60 dB

12.29 4.500 V, 4.99 V, 5.01 V, 5.500 V, 2.7473 V, 2.7473 V, 0.991 V, -75.4 μA, -375 μA, +175 μA

12.31 -0.026 V, -26 mV, 90.9 kΩ

12.33 +7500, 0.667 mV

12.36 The nearest 5% values are 1 MΩ and 10 kΩ

12.40 -5.00 V, 0 V; -12.0 V, 0.182 V

12.42 10 V, 0 V; 15 V, 0.125 V

12.45 220 Ω and 22 kΩ represent the smallest acceptable resistor pair.

12.47 39.2 Ω

12.49 +50.0, 24.0 kΩ, 6.00 mΩ

12.51 -42.0, 3.57 GΩ, 14.0 mΩ

12.53 3

12.54 $A_v(s) = \frac{\mathbf{V_O}}{\mathbf{V_S}} = \left(1 + \frac{R_2}{R_1}\right)\frac{SC\left(R_1 \| R_2\right) + 1}{SCR_2 + 1}$

12.55 -33.0, -40.3, -27.0; 4.83 kHz, 3.65 kHz, 10.7 kHz

12.56 3 stages, 270 pF, 15.0 kΩ, 1.5 kΩ

12.57

$$Z_{out} = \frac{R_o}{\left(1 + A_o\beta\right)} \frac{1 + \frac{s}{\omega_B}}{1 + \frac{s}{\omega_B\left(1 + A_o\beta\right)}} \cong \frac{R_o}{\left(1 + A_o\beta\right)} \frac{1 + \frac{s}{\omega_B}}{1 + \frac{s}{\beta\omega_T}}$$

12.59

$$Z_{in} = R_1 + \left(R_{id} \left\| \frac{R_2}{\left(1 + A_o\right)} \right. \right) \frac{\left(1 + \dfrac{s}{\omega_B}\right)}{1 + \dfrac{s}{\omega_B\left(1 + A_o\right)} \dfrac{R_{id} + R_2}{R_{id} + \dfrac{R_2}{\left(1 + A_o\right)}}}$$

12.62

$$(a)\ A_v(s) = \frac{V_O(s)}{V_S(s)} = -\frac{1}{sRC}$$

$$(b)\ A_v(s) = -\frac{\dfrac{\omega_T}{RC}}{s^2 + s\left(\omega_B + \omega_T + \dfrac{1}{RC}\right) + \dfrac{\omega_B}{RC}} \cong -\frac{\dfrac{\omega_T}{RC}}{\left(s + \omega_T\right)\left(s + \dfrac{1}{A_o RC}\right)}$$

12.64 -20, 143 kHz; -8000, 72.9 kHz

12.67 Two stages

12.69 (a) In a simulation of 5000 cases, 33.5% of the amplifiers failed to meet one of the specifications.
(b) 1.5% tolerance.

12.71 6.91, 7.53, 6.35; 145 kHz, 157 kHz, 133 kHz

12.73 1.89 V/μs

12.75 10.0 V/μs

12.82 10^{10} Ω, 7.96 pF, $4\text{x}10^6$, R_o not specified

12.84 -1500, 47.0 kΩ, 40.0 mΩ, 79.9 kHz; 50.0 mV, 5.00 μV, -500 mV, -50.0 μV, +5.00 V, +3.56 V, -18.0 V, +18.0 V, -18.0 V, 0 V

12.88 2740, 3070, 2460; 1 MΩ, 1.02 MΩ, 980 kΩ; 21.0 mΩ, 21.8 mΩ, 20.2 kΩ; 357 kHz, 371 kHz, 344 kHz

12.89 -2380, 613 MΩ, 98.0 mΩ, 29.6 kHz; 0 V, 10.0 mV, 49.0 mV, 389 μV, -3.89 V, -3.06 V, -15.0 V, +15.0 V, -15.0 V, 0 V

Chapter 13

13.1 0.700 + 0.005 sin 2000πt V; -1.03 sin 2000πt V; 5.00 −1.03 sin 2000πt V; 2.82 mA

13.3 (a) C_1 is a coupling capacitor that couples the ac component of v_I into the amplifier. C_2 is a coupling capacitor that couples the ac component of the signal at the collector to the output v_O. C_3 is a bypass capacitor. (b) The signal voltage at the top of resistor R_4 will be zero.

13.5 (a) C_1 is a coupling capacitor that couples the ac component of v_I into the amplifier. C_2 is a bypass capacitor. C_3 is a coupling capacitor that couples the ac component of the signal at the collector to output v_O. (b) The signal voltage at the emitter will be $v_e = 0$.

13.7 (a) C_1 is a coupling capacitor that couples the ac component of v_I into the amplifier. C_2 is a coupling capacitor that couples the ac component of the signal at the drain to output v_O.

13.11 (a) C_1 is a coupling capacitor that couples the ac component of v_I into the amplifier. C_2 is a bypass capacitor. C_3 is a coupling capacitor that couples the ac component of the signal at the drain to the output v_O. (b) The signal voltage at the top of R_4 will be zero.

13.15 (22.5 μA, 6.71 V)

13.17 (1.78 mA, 6.08 V)

13.19 (98.4 μA, 4.96 V)

13.23 (82.2 μA, 6.04 V)

13.27 (307 μA, 3.88 V)

13.31 (338 μA, 5.41 V)

13.33 (1.25 mA, 10.6 V)

13.45 Thévenin equivalent source resistance, gate-bias voltage divider, gate-bias voltage divider, source-bias resistor—sets source current, drain-bias resistor—sets drain-source voltage, load resistor

13.46 94.4 Ω, 2.5 TΩ, ≤ -0.150 V

13.47 17.3 Ω for T = 200K

13.48 Errors: +10.7%, -9.37%; +23.0%, - 17.5%

13.49 (c) 1.25 μA

13.51 (188 μA, $V_{CE} \geq 0.7$ V), 7.50 mS, 533 kΩ

13.55 (b) +16.7%, -13.6%

13.56 90, 120; 95, 75

13.61 [−95.0, −94.1]

13.63 -40.0

13.65 3

13.67 −120

13.69 Yes, using $I_C R_C = (V_{CC} + V_{CE})/2$

13.71 2.5 mA; 30.7 V

13.72 0.500 V

13.73 No, there will be significant distortion

13.74 (b) −314

13.76 50/1, 0.160 V

13.77 1.25 A

13.79 10%, 20%

13.82 (156 μA, 9 V)

13.83 Virtually any desired Q-point

13.84 $400 = 133{,}000 i_P + v_{PK}$; (1.4 mA, 215 V); 1.6 mS, 55.6 kΩ, 89.0; -62.7

13.85 BJT

13.86 FET

13.87 111 μA, 1400

13.88 2000, 200, 8.00 mS, 0.800 mS

13.91 21.6 dB

13.93 0.300 V

13.94 (125 μA, 7.5 V)

13.95 0.5 V, 28 V

13.97 3

13.99 −10.9

13.102 −7.34

13.107 33.3 kΩ, 94.4 kΩ

13.109 833 kΩ, 1.46 MΩ

13.111 243 kΩ, 40.1 kΩ

13.113 6.8 MΩ, 45.8 kΩ, independent of K_n

13.115 1 MΩ, 3.53 kΩ

13.117 $-336v_i$, 3.62 kΩ

13.119 $-23.6v_i$, 508 kΩ

13.116 (b) 1 MΩ, 0, −7.45 MΩ, 3.53 MΩ

13.121 -31.8, 1.42 kΩ, 982 Ω

13.123 -27.0, 142 kΩ, 98.2 kΩ

13.127 1.38 μW, 0.581 mW, 0.960 mW, 0.887 mW, 2.43 mW

13.131 0.497 mW, 0.554 mW, 0.182 mW, 16.4 μW, 44.3 μW, 1.29 mW

13.134 $V_{CC}/15$

13.135 3.38 V, 13.6 V

13.136 $(V_{CC})^2/8R_L$, $(V_{CC})^2/2R_L$, 25%

13.137 0.854 V

13.139 2.80 V

13.141 2.80 V

13.139 1.76 V

13.153 2.5 V, 8.5 V

Chapter 14

14.1 (a) C-C or emitter-follower (b) not useful, signal is being injected into the drain (c) C-E (h) C-B (k) C-G (o) C-D or source-follower

14.8 −3.64, 2 MΩ, 26.5 kΩ, -3770; −8.03, 2 MΩ, 10.0 kΩ, -10000

14.9 −32.2, 9.58 kΩ, 596 kΩ, -27.1; −17.0, 11.6 kΩ, 1060 kΩ, -17.1

14.10 (a) −6.91 (e) −240

14.11 3.3 kΩ, 33 kΩ

14.14 −182, -7.10, 19.0 kΩ, 39 kΩ, 5.13 mV

14.15 -75.9, -4.23, 3.86 kΩ, 8.20 kΩ, 6.30 mV, -90

14.16 −12.9, −10.1, 368 kΩ, 75 kΩ, 160 mV, -18.8

14.18 -3.43, -952, 10 MΩ, 1,80 kΩ, 1.00 V

14.19 -3560, -6.41, 1.55 kΩ, 95.1 kΩ, 5.81 mV

14.20 0.747, 29.8 kΩ, 104 Ω, 9.7

14.21 0.907, 2 MΩ, 100 Ω, 20,000

14.22 0.874, 7.94 MΩ, 247 Ω, ∞

14.23 0.984, 45.2 kΩ, 27.8 Ω, 0.784 V

14.24 0.960, 1 MΩ, 507 Ω, 6.19 V

14.25 0.992, 12.6 MΩ, 1.34 kΩ, 0.601 V

14.26 $v_i \leq (0.005 + 0.2\ V_{RE})$ V

14.28 0.999, 25.0 V

14.30 48.7, 1.94 kΩ, 4.92 MΩ, 0.990; 23.6, 1.94 kΩ, 10.1 MΩ, 0.969

14.31 28.8, 1.20 kΩ, ∞, 0.600; 5.81, 1.43 kΩ, ∞, 0.714

14.33 40.7, 185 Ω, 39.0 kΩ, 18.5 mV

14.35 4.12, 1.32 kΩ, 20 kΩ, 354 mV

14.37 5.01, 3.02 kΩ, 24 kΩ, 352 mV

14.39 44.5 Ω

14.40 633 Ω

14.42 $(\beta_o + 1) r_o = 154\ M\Omega$

14.43 Low R_{in}, high gain: Either a common-base amplifier operating at a current of 71.4 μA or a common-emitter amplifier operating at a current of approximately 7.14 mA can meet the specifications with $V_{CC} \approx 14$ V.

14.45 Large R_{in}, moderate gain: Common-source amplifier.

14.47 Low R_{in}, high gain: Common-emitter amplifier with 5-Ω input "swamping" resistor.

14.49 Common-drain amplifier.

14.51 Cannot be achieved with what we know at this stage in the text.

14.53 1.66 Ω

14.55

v_i	1 kHz	2 kHz	3 kHz	THD
5 mV	5.8 mV	0.335 mV (5.7%)	0.043 mV (0.74%	5.9%
10 mV	12.4 mV	1.54 mV (12.5%)	0.258 mV (2.1%)	12.8%
15 mV	20.6 mV	4.32 mV (21%)	1.18 mV (5.4%)	22%

14.57 479v_i, 384 kΩ

14.59 v_i, 297 Ω

14.61 0.947, 0

14.63 41.7, -0.167

14.65 -9.75, 0

14.67 -0.984, 0.993, 0.703 V

14.69 SPICE: (116 μA, 7.53 V), −150, 19.6 kΩ, 37.0 kΩ

14.71 SPICE: (115 μA, 6.30 V), -20.5, 368 kΩ, 65.1 kΩ

14.73 SPICE: (12.7 μA, 5.68 V), 0.986, 10.7 MΩ, 2.00 kΩ

14.75 SPICE: (66.7 μA, 4.47 V), −16.8, 1.10 MΩ, 81.0 kΩ

14.77 SPICE: (5.59 mA, -5.93 V), -3.27, 10.0 MΩ, 1.52 kΩ

14.79 SPICE: (6.20 mA, 12.0 V), 0.953, 2.00 MΩ, 388 Ω

14.81 0.01 μF, 270 μF, 0.15 μF; 2.7 μF

14.83 0.20 μF, 270 μF; 100 μF, 0.15 μF

14.85 1.80 μF, 0.033 μF

14.87 8200 pF, 820 pF; 0.042 μF, 1800 pf, 0.015 μF

14.89 33.3 mA

14.91 R_1 = 120 kΩ, R_2 = 110 kΩ

14.93 The second MOSFET

14.95 $45.1 \leq A_v \leq 55.3$ - Only slightly beyond the limits in the Monte Carlo results.

14.99 Voltage is not sufficient - transistor will be saturated.

14.101 4.08, 1.00 MΩ, 64.3 Ω

14.104 2.17, 1.00 MΩ, 64.3 Ω

14.109 468, 73.6 kΩ, 18.8 kΩ

14.110 0.670, 107 kΩ, 20.0 kΩ

14.112 7920, 10.0 kΩ, 18.8 kΩ

14.113 140, 94.7 Ω, 113 Ω

14.115 Use C_3 = 2.2 μF, 19.2 Hz, 18.0 Hz

14.117 1.56 Hz, 1.22 Hz

14.119 6.40 Hz, 5.72 Hz

14.121 0.497 Hz, 0.427 Hz

14.122 Use 1 μF for all capacitors; 1.42 kHz, 1.68 kHz

Chapter 15

15.1 (20.7 μA, 5.87 V); −273, 243 kΩ, 660 kΩ; −0.604, 47.1 dB, 27.3 MΩ

15.2 (5.25 μA, 1.68 V); −21.0, -0.636, 24.4 dB, 572 kΩ, 4.72 MΩ, 200 kΩ, 50.0 kΩ

15.4 (182 μA, 0.92 V); −728, -1.05, 50.8 dB, 27.4 kΩ, 4.75 MΩ, 200 kΩ, 50.0 kΩ

15.7 R_{EE} = 1.1 MΩ, R_C = 1.0 MΩ

15.8 (a) (198 μA, 4.98 V); differential output: −309, 0, ∞ (b) single-ended output: −155, −0.0965, 64.1 dB; 25.2 kΩ, 20.2 MΩ, 78.0 kΩ, 19.5 kΩ

15.9 2.593 V, 5.663 V, -3.078 V, 3.94 V

15.11 V_O = 0.991 V, v_o = 0; V_O = 0.991 V; v_O = 1.36 V, V_O = 0.991 V, v_o = 0.360 V; 5.48 mV

15.14 (47.4 μA, 6.22 V); Differential output: −380, 0, ∞; single-ended output: −190, −0.661, 49.2 dB; 158 kΩ, 22.7 MΩ

15.15 -5.850 V, -3.450 V, -2.40 V

15.17 (4.94 μA, 1.77 V); differential output: −77.2, 0, ∞; single-ended output: −38.6, −0.661, 25.4 dB; 808 kΩ, 405 MΩ, 1.60 V

15.19 -283, -.00494, 95.2 dB

15.19 -300, -.00499, 95.6 dB

15.23 (107 μA, 10.1 V); differential output: −18.2, 0, ∞; single-ended output: −9.1, −0.487, 25.4 dB; ∞, ∞

15.25 2.4 kΩ, 5.6 kΩ

15.29 (20 μA, 4.32 V); differential output: −38.0, 0, ∞; single-ended output: −19.0, −0.120, 44.0 dB; ∞, ∞

15.31 (20 μA, 5.71 V); differential output: −38.1, 0, ∞; single-ended output: −19.0, −0.120, 44.0 dB; ∞, ∞

15.33 312 μA, 27 kΩ

15.35 -21.6, -0.783, 13.8 , ∞, ∞

15.37 −3.80 V, −2.64 V, 48.3 mV

15.39 -79.9, -0.494, 751 kΩ

15.40 (99.0 μA, 10.8 V); −30.1, −0.165, 554 kΩ

15.42 (49.5 μA, 3.29 V), (49.5 μA, 8.70 V); −149, -0.0619, 101 kΩ

15.43 (100 μA, 1.63 V), (100 μA, 3.16 V); −13.4, 0, ∞

15.45 (24.8 μA, 12.0 V), (500 μA, 12.0 V), 893, 202 kΩ, 20.6 kΩ, 147 MΩ, v_2

15.46 [-10.6 V, 11.3 V]

15.49 (24.8 μA, 11.3 V), (4.95 μA, 11.3 V), (495 μA, 12.0 V), 9180, 202 kΩ, 19.2 kΩ, 145 MΩ, v_2

15.50 (98.8 μA, 14.3 V), (300 μA, 14.3 V); 551, 40.5 kΩ; 34.6 MΩ; v_2

15.51 [-13.6 V, 13.6 V]

15.55 (98.8 μA, 14.3 V), (300 μA, 14.3 V); 27800, 40.5 kΩ; 2.51 MΩ

15.59 (250 μA, 15.6 V), (500 μA, 15.0 V); 4300, ∞; 165 kΩ

15.61 5770

15.63 (250 μA, 4.92 V), (6.10 μA, 4.30 V), (494 μA, 5.00 V); 4230, ∞; 97.5 kΩ

15.67 (49.5 μA, 15.0 V), (360 μA, 14.3 V), (990 μA, 15.0 V); 12100, 101 kΩ; 1.80 kΩ; 66.3 MΩ; v_2

15.69 (250 μA, 10.9 V), (2.00 mA, 9.84 V), (5.00 mA, 12.0 V); 868, ∞; 127 Ω

15.71 (300 μA, 5.10 V), (500 μA, 2.89 V), (2.00 mA, 5.00 V), 528, ∞, 341 Ω

15.73 (300 μA, 5.55 V), (500 μA, 2.89 V), (2.00 mA, 5.00 V), 2810, ∞, 341 Ω

15.75 (99.0 μA, 4.96 V), (500 μA, 3.41V), (2.00 mA, 5.00 V), 11400, 50.5 kΩ, 224 Ω

15.77 (49.5 μA, 13.0 V), (98.0 μA, 13.7 V), (735 μA, 18.0 V); 2700, 101 kΩ, 3.37 kΩ; [undefined, 12.3 V]; 0.689 mV

15.79 No, R_{id} must be reduce or R_{out} must be increased.

15.81 (24.8 μA, 17.3 V), (24.8 μA, 17.3 V), (9.62 μA, 15.9 V), (490 μA, 16.6 V), (49.0 μA, 17.3 V), (4.95 mA, 18.0 V), 88.5 dB, 202 kΩ, 18.1 Ω

15.83 36.8 μA

15.85 196 μA

15.89 22.8 μA

15.91 5 mA, 0 mA, 10 mA, 12.5 percent

15.93 66.7 percent

15.95 70.0 mA, 19.6 V

15.97 23.5 μA

15.98 6.98 mA, 0 mA

15.99 25.0 mΩ

15.101 (a) 22.8 μA, 43.9 MΩ

15.103 (a) 144 μA, 7.83 MΩ

15.105 Two of many: 75 kΩ, 62 kΩ, 150 Ω; 68 kΩ, 12 kΩ, 1 kΩ

15.107 0, ∞

15.109 88.6 μA, 18.6 MΩ

15.111 94.6 μA, 13.1 MΩ

15.113 17.0 μA, 131 MΩ

15.115 430 kΩ, 200 kΩ, 33 kΩ

15.117 97.2 μA, 27.4 MΩ, 201 μA, 11.0 MΩ, 391 μA, 4.30 MΩ

15.119 44.1 μA, 22.1 MΩ, 10.1 μA, 209 MΩ

15.122 100 μA, 6.57×10^{11} Ω

15.123 (4.62 μA, .62 V), (9.34μA, 9.03 V); 40.9 dB, 96.5 dB

15.125 $\beta_{o1}\mu_{f1}/2$, For typical numbers: 20(100)(70) =140,000 or 103 dB

15.127 3σ limits: I_O = 199 μA ± 32.5 μA, R_{OUT} = 11.8 MΩ ± 2.6 MΩ
3σ limits: I_O = 201 μA ± 34.7 μA, R_{OUT} = 21.7 MΩ ± 3.6 MΩ

15.129 2.50 mV; 5.02 mV; 2%

15.131 7.7%, 0.813 μA, 0.855 μA, (I_{OS} = -42.0 nA)

15.133 25.0 mV, 1.2%, 0.4%

15.135 84.3 μA, 164 μA, 346 μA, 909 kΩ, 455 kΩ, 227 kΩ

15.137 75.0 μA, 150 μA, 300 μA, 0.124 Lsb 0.187 LSB,).613 LSB

15.139 274 μA, 383 kΩ, 574 μA, 192 kΩ

15.143 (a) 631 μA, 103 kΩ, 1.02 mA, 61.8 kΩ

15.145 507 kΩ, 93.1 μA; 599 kΩ, 93.2 μA

15.147 185 μA, 299 μA

15.149 472 μA, 759 μA; 479 μA, 759 μA; 430 μA, 692 μA

15.151 63.8 kΩ, 11.8 μA, 123 μA

15.153 10

15.155 63.8 kΩ, 0.667

15.157 15.7 μA, 5.10 MΩ

15.159 5.35 kΩ

15.161 115 kΩ, 17.0 kΩ, 0.297

15.163 22.7 μA, 18.3 MΩ; 45.5 μA, 9.17 MΩ

15.165 49.6 μA, 55.8 MΩ; 146 μA, 19.0 MΩ; 2770; 1.40 V

15.169 21.8 μA, 80/1

15.171 $2/g_{m3}$

15.173 3.80/1

15.175 17.5 μA, 1.16 GΩ; 20.3 kV; 2.11 V

15.177 18.4 μA, 3.89 nA

15.179 (b) 50 μA, 240 MΩ; 12.0 kV; 3.07 V

15.181 16.9 μA, 163 MΩ, 2750 V; $2V_{BE}$ = 1.40 V

15.183 2.86 kΩ

15.185 (a) 64.0 μA, 3.59 MΩ

15.187 8.22 kΩ

15.189 318 μA, 295 μA, 66.5 μA

15.193 14.5 kΩ, 225 kΩ

15.195 11.4 kΩ, 210 kΩ

15.197 I_{C1} = 140 μA, I_{C2} = 47.8 μA
$S_{V_{CC}}^{I_{C1}} = 2.92x10^{-2}$ $S_{V_{CC}}^{I_{C2}} = 9.92x10^{-3}$

15.199 n > 1/3

15.201 26.4 μA

15.203 (b) I_{D1} = 8.19 μA I_{D2} = 7.24 μA $S_{V_{DD}}^{I_{D1}} = 7.75x10^{-2}$ $S_{V_{DD}}^{I_{D2}} = 6.31x10^{-2}$
The currents differ considerably from the hand calculations. The currents are quite sensitive to the value of λ. The hand calculations used λ = 0. If the simulations are run with λ = 0, then the results are identical to the hand calculations.

15.205 5.23 μA, 6.00 μA, 3.45 μA

15.207 I_{C2} = 15.2 μA I_{C1} = 28.5 μA - Similar to hand calculations.

$$S_{V_{CC}}^{I_{C1}} = 1.81x10^{-3} \quad S_{V_{CC}}^{I_{C2}} = 7.07x10^{-4}$$

15.209 462 μA, 308 μA

15.211 107 μA

15.212 79.1, 6.28 $x10^{-5}$, 122 dB

15.214 47.2, 6.97 $x10^{-5}$, 117 dB

15.216 1200, 4 $x10^{-3}$, 110 dB, ±2.9 V

15.220 (100 μA, 8.70 V), (100 μA, 7.45 V), (100 μA, -2.50 V), (100 μA, -1.25 V), 323, 152

15.222 (125 μA, 1.54 V), (125 μA, -2.79 V), (125 μA, 2.50 V), (125 μA, 1.25 V); 19600

15.225 171 μA

15.226 (b) 100 μA

15.227 (250 μA, 5.00 V), (250 μA, 5.00 V), (250 μA, -1.75 V), (250 μA, -1.75 V), (500 μA, -3.21 V), (135 μA, 5.00 V), (135 μA, -5.00 V), (250 μA, 2.16 V), (500 μA, 3.25 V), (500 μA, 3.21 V), (500 μA, 3.58 V); 4130; 2065

15.229 12,600

15.231 (250 μA, 7.50 V), (250 μA, 7.50 V), (250 μA, -1.75 V), (1000 μA, -5.13 V), (330 μA, 7.50 V), (330 μA, -7.50 V), (1000 μA, 4.75 V), (250 μA, 2.16 V), (500 μA, 5.75 V), (1000 μA, 5.13 V), 3180

15.233 (b) 42.9/1 (c) 14800

15.237 7.78, 574 Ω, 3.03 x 10^5, 60.0 kΩ

15.239 ±1.4 V, ±2.4 V

15.240 (a) 9.72 μA, 138 μA, 46.0 μA

15.241 271 kΩ, 255 Ω

15.243 $V_{EE} \geq 2.8$ V, $V_{CC} \geq 1.4$ V; 3.8 V, 2.4 V

15.245 2.84 MΩ, 356 kΩ. 6.11 x 10^5

15.248 (100 μA, 15.7 V), (100 μA, 15.7 V), (50 μA, -12.9 V), (50 μA, -0.700 V), (50 μA, -0.700 V), (50 μA, -12.9 V), (50 μA, 1.40 V), (50 μA, 1.40 V), (1.00 μA, 29.3 V), (100 μA, 0.700 V), (100 μA, 13.6 V); 1.00 mS, 752 kΩ

15.248 (50 μA, 15.7 V), (50 μA, 15.7 V), (50 μA, 12.9 V), (50 μA, 12.9 V), (50 μA, 1.40 V), (50 μA, 1.40 V), (1.00 μA, 29.3 V), (100 μA, 1.40 V), (1 μA, 0.700 V), (1 μA, 13.6 V); 1.00 mS, 864 kΩ

Chapter 16

16.1 $A_{mid} = 50,\ F_L(s) = \dfrac{s^2}{(s+2)(s+30)}$, yes, $A_v(s) \approx 50\dfrac{s}{(s+30)},\ 4.77\ Hz,\ 4.80\ Hz$

16.4 300, $\dfrac{1}{\left(1+\dfrac{s}{10^4}\right)\left(1+\dfrac{s}{10^5}\right)}$, yes, 1.58 kHz, 1.58 kHz

16.7 300, $\dfrac{s^2}{(s+1)(s+2)}$, $\dfrac{1}{\left(1+\dfrac{s}{500}\right)\left(1+\dfrac{s}{1000}\right)}$, 0.356 Hz, 142 Hz; 0.380 Hz, 133 Hz

16.9 (b) -16.5, 7.58 Hz

16.10 (b) −14.1 (23.0 dB), 11.5 Hz

16.11 1.52 μF; 1.50 μF, 49.3 Hz

16.13 (b) 0.33 μF; 1770 Hz

16.14

$$A_v(s) = A_{mid}\frac{s^2}{(s+\omega_1)(s+\omega_2)} \quad | \quad \omega_1 = \frac{1}{C_1\left(R_S + R_E \left\| \dfrac{1}{g_m}\right.\right)} \quad | \quad \omega_2 = \frac{1}{C_2(R_C + R_3)} \quad | \quad 2\ zeros\ at\ \omega = 0$$

19.4 dB, 151 Hz; -5.0 V, 7.9 V

16.16 123 Hz; 91 Hz

16.18 -131, 50.0 Hz, 12.0 V

16.19 45.5 Hz

16.21 7.24 dB, 19.2 Hz

16.23 0.739, 15.5 Hz, 12.0 V

16.24 0.15 μF

16.25 0.56 μF

16.27 Cannot reach 1 Hz; f_L = 13.1 Hz for $C_1 = \infty$, limited by C_3

16.29 0.39 μF

16.31 308 ps

16.33 (a) 22.5 GHz

16.34 −117; −113

16.35 0.977; 0.978

16.37 −5100, −98.0, −5000, −100, 2% error; −350, −42.9, −300, −50, 18% error

16.39 Real roots: -100, -20, -15, -5

16.41 -90.0, 1.96 MHz, 176 MHz

16.43 -15.7, 849 kHz

16.45 -12.0, 2.75 MHz, 33 MHz

16.49 61.0 pF, 303 MHz

16.51 $1/10^5 RC$; $1/10^6 RC$; $1/sRC$

16.53 39.2 dB, 5.53 MHz

16.55 -114, 1.12 MHz, 128 MHz, 531 MHz

16.57 865 Ω, -31.9, 160 MHz

16.59 -29.3, 7.41 MHz

16.61 300 Ω, 1 kΩ

16.62 −1300; −92.3; −100, −1200

16.63 13.1, 64.4 MHz

16.65 9.14, 40.9 MHz

16.68 2.30, 10.9 MHz

16.69 3.19, 11.3 MHz, 20.6Hz

16.71 0.964, 114 MHz

16.73 -1.46 dB, 75.4 MHz

16.75 $C_{GD} + C_{GS}/(1 + g_m R_L)$ for $\omega << \omega_T$

16.77 Using a factor of 2 margin: 8 GHz, 19.9 ps

16.79 672 mA - not a realistic design. A different FET is needed.

16.81 8.33 MHz

16.82 393 kHz, 640 kHz

16.85 294 kHz

16.87 48.2 kHz

16.89 66.2 KHz

16.91 568 kHz

16.93 2.01 MHz

16.95 54.3 dB, 833 Hz, 526 kHz

16.96 22.5 MHz, -41.1, 2.90

16.97 20.1 pF, 12.6, n = 2.81, 21.9 pF

16.98 15.2 MHz; 27.5 MHz

16.99 13.4 MHz, 7.98, $112\underline{/-90°}$; 4.74 MHz, 5.21, $46.1\underline{/-90°}$

16.100 10.1 MHz, 3.96, −35.4; 10.9 MHz, 16.4, −75.1

16.103 65 pF; 240, $-4.41\text{x}10^4$, 25.1 kHz

16.105 67.3 pF; 40

Chapter 17

17.1 (b) 2000, 5.00, 0.05%

17.3 1/101, 99.0, -99.0

17.5 80 dB

17.7 100 dB

17.8 $1/(1+A\beta)$; 9.99×10^{-3} percent

17.9 (b) shunt-series feedback (d) series-shunt feedback

17.13 8.00×10^{5}, 20 S

17.15 9.96, 6.58 MΩ, 3.18 Ω

17.17 8.27, 1.51 MΩ, 3.60 Ω

17.18 0.999, 43.9 MΩ, 2.49 Ω, 98.9 μS

17.21 −36.0 kΩ; 11.1 Ω; 0.790 Ω

17.23 82.2 Ω; 46.2 Ω; −32.4 kΩ; −32.4

17.25 −446 kΩ, 50.2 kΩ, 2.45 kΩ

17.27 0.973, 973 Ω

17.28 1.00, 36.0 Ω

17.31 1/10.5 kΩ, 2.82 kΩ, -1/11, 4000; -11.0, 35.2 Ω, 3.57 MΩ

17.33 -1.00, 36.5 MΩ, 14.9 MΩ

17.37 $\beta_o/(\beta_o+1)$, $2/g_m$, $(\beta_o+1)r_o$

17.39 $\mu_{f4}(1+\mu_{f3})r_{o2}$, 21.9 GΩ

17.41 58.9 dB

17.43 8.95

17.45 $(s/R_2C_2)/[s^2 + s(1/R_2C_2 + 1/(R_1\|R_2)C_1) + 1/R_1R_2C_1C_2]$

17.47 816

17.49 18.5

17.53 41.2 Ω, 21.3 Ω

17.55 38.0 MΩ, 2.48 Ω

17.57 $\mu_{f4}r_{o2}(1+\mu_{f3})$, $1/g_{m3}$

17.59 80 dB, 1 kHz, 1 MHz; 101 MHz, 9.90 Hz; 251 MHz, 3.98 Hz

17.61 100 dB, 1 kHz, 1 MHz; (-0.637 ± j9.98) Hz, (-6.37 ± j100) MHz; (-2.20 ± j19.9) Hz, (-6.37 ± j49.8) MHz

17.63 19.0 Hz, 3.04 MHz

17.65 +1, 9.99%

17.67 8.1°; 5.1°

17.69 110 kHz; A ≤ 2048; larger

17.71 yes, but almost no phase margin; 0.4°

17.74 90.0°

17.75 yes, but almost no phase margin; 1.83°

17.76 12°, yes, 50°

17.81 26°

17.83 phase margin is undefined; $|T(j\omega)| < 1$ for all ω

17.85 1.8°

17.86 38.4°

17.87 10.6 MHz, 33.3 V/μs

17.89 8.1 MHz, -100°; 8.0 MHz, -92°

17.91 159 MHz, 50 V/μs

17.93 12.5 V/μs

17.94 21.2 MHz

17.96 1/RC, 2R

17.97 0.5774/RC, 1.83

17.98 63.7 kHz, 6.85 V

17.100 18.4 kHz, 10.7 V

17.102 17.5 MHz, 20.1 MHz, 36.3 MHz, 0.211 mS, 5.28 μA

17.103 5.17 MHz, 4.53 MHz

17.105 9.00 MHz, 1.20

17.107 7.96 MHz, 8.11 MHz, 1.05

17.109 7.5 MHz, 80 $V_{p\text{-}p}$

17.110 7.96 MHz

17.111 11.1 MHz, 18.1 MHz, 1.00

17.112 15.9155 mH, 15.9155 fF; 10.008 MHz, 10.003 MHz

17.113 9.190 MHz; 9.190 MHz

17.114 9.28 MHz; 9.19 MHz