MICROELECTRONIC CIRCUIT DESIGN

Fifth Edition

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Answers to Selected Problems – Updated 07/05/15

Chapter 1

1.5 1.52 years, 5.06 years

1.6 1.95 years, 6.52 years

1.9 402 MW, 1.83 MA

1.11 19.53 mV/bit, 10011101_2

1.13 2.441 mV, 5.00 V, 5.724 V

1.15 11 bits, 20 bits

1.17 0.0075 A, 0.003 cos (1000*t*) A

1.20 $v_{DS} = [5 + 2 \sin(2500t) + 4 \sin(1000t)]$ V

1.22 6.12 V, 1.88 V, 78.4 μA, 125 μA

1.23 100 μA, 100 μA, 8.2 V

1.25 39.8 Ω, v_i

1.28 (a) 75 kΩ, 89.6 v_i

1.30 2 MΩ, 1.00×10^8 i_i

1.31 (c) 4 kΩ

1.38 $50\angle{-12^\circ}$, $10\angle{-45^\circ}$

1.40 -82.4 sin 750πt mV, 11.0 sin 750πt μA

1.42 $1 + R_2/R_1$

1.44 -1.875 V, -2.500 V

1.46 Band-pass amplifier

1.48 50.0 sin (2000*πt*) + 30.0 cos (8000 *πt*) V

1.50 0 V

1.52 [4653 Ω, 4747 Ω], [4465 Ω, 4935 Ω], [4230 Ω, 5170 Ω]

1.57 6200 Ω, 4.96 Ω/$^\circ$C

1.64 3.29, 0.995, −6.16; 3.295, 0.9952, −6.155

Chapter 2

2.3 500 mA

2.4 144 Ω, 287 Ω

2.6 305.2 K

2.7 For Ge: $2.63 \times 10^{-4}/cm^3$, $2.27 \times 10^{13}/cm^3$, $8.04 \times 10^{15}/cm^3$,

2.10 $-1.75x10^6\ cm/s$, $+6.25x10^5\ cm/s$, $2.80x10^4\ A/cm^2$, $1.00x10^{-10}\ A/cm^2$

2.11 1.60 MA/cm^2, 160 pA/cm^2

2.12 4 MA/cm^2

2.16 316.6 K

2.21 Donor, acceptor

2.22 100 V/cm

2.23 1800 atoms

2.24 p-type, $7 \times 10^{18}/cm^3$, 14.3/cm^3, $5.28 \times 10^9/cm^3$, $7.54 \times 10^{-10}/cm^3$

2.27 $4 \times 10^{17}/cm^3$, 250/cm^3

2.29 $4 \times 10^{16}/cm^3$, $2.50x10^5/cm^3$

2.31 40/cm^3, $2.5x10^{18}/cm^3$, 187 cm^2/s, 58.7 cm^2/s, p-type, 42.5 mΩ-cm

2.33 $10^4/cm^3$, $10^{16}/cm^3$, 727 cm^2/s, 153 cm^2/s, p-type, 4.08 Ω-cm

2.35 $1.25 \times 10^{19}/cm^3$

2.38 5.66 MΩ-cm

2.39 $9.67 \times 10^{19}/cm^3$, $1.37 \times 10^{20}/cm^3$

2.42 1.89/Ω-cm, $3.30 \times 10^{17}/cm^3$

2.43 75K: 6.64 mV, 150K: 12.9 mV, 300K: 25.8 mV, 400K: 34.5 mV

2.44 -56.1 kA/cm^2

2.45 $1.20x10^5$ exp (-5000 x/cm) A/cm^2, 12.0 mA

2.49 1.108 μm

2.52 8 atoms, $1.60x10^{-22}$ cm^3, $5.00x10^{22}$ atoms/cm^3, $3.73x10^{-23}$ g, $1.66x10^{-24}$ g/proton

Chapter 3

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

3.4 10^{18}/cm^3, 10^{2}/cm^3, 10^{18}/cm^3, 10^{2}/cm^3, 0.921 V, 0.0488 μm

3.6 6.80 V, 1.22 μm

3.9 (b) 640 kA/cm^2

3.11 7.50 x 10^{20}/cm^4

3.15 (a) 290 K

3.17 339.2 K

3.19 1.34, 3.21 pA

3.20 0.776 V; 0.707 V; 0 A; 9.39 aA, -10.0 aA

3.23 1.34 V; 1.38 V

3.26 [0.535 V, 0.651 V]

3.27 327.97 K, 290.05 K

3.31 0.573 V; 0.528 V

3.32 −1.59 mV/K

3.35 0.691 V, 0.950 μm, 3.74 μm, 11.5 μm

3.37 1500 V

3.39 4 V, 0 Ω

3.42 10.5 nF/cm^2; 58.2 pF

3.43 1.00 pF, 25 fC; 12 pF, 0.3 pC

3.46 9.87 MHz; 15.5 MHz

3.47 0.495 V, 0.668 V

3.49 0.708 V, 0.718 V; 0.808 V

3.52 (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);

3.55 (a) (1.4 mA, 0.5 V), (e) (-2.1 mA, -4 V)

3.62 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)

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

3.70 (a-c) (270 μA, 0 V), (409 μA, 0 V); (b-c) (190 μA 0.7 V), (345 μA, 0.7 V)

3.71 (c) (0.861 mA, 0.650 V) (0 mA, -1.51 V) (0.951 mA, 0.650 V)

(d) (0 A, -0.450 V) (0 A, -0.950 V) (1.16 mA, 0.650 V)

3.73 (1.50 mA, 0 V) (0 A, -5 V) (1.00 mA, 0 V)

3.76 (b) (I_Z, V_Z) = (127 μA, 6.00 V)

3.78 (d) 12.6 mW

3.80 1.25 W, 3.50 W

3.85 17.1 V

3.89 -7.91 V, 1.05 F, 17.8 V, 3530 A, 840 A (ΔT = 0.628 ms)

3.91 (b) -7.91V, 904 μF, 17.8 V, 3540 A, 839 A

3.92 10.1 F, 8.6 V, 3.04 V, 1240 A, 16400 A

3.97 -11.7 V, 0.782 F, 25.5 V, 3750 A, 742 A

3.101 5.05 F, 8.6 V, 6.08 V, 1240 A, 6280 A

3.107 1330 μF, 2500 V, 1770 V, 126 A, 1250 A

3.114 5 mA, 4.4 mA, -3.6 mA, 6.39 ns

3.118 (0.969 A, 0.777 V); 0.753 W; 1 A, 0.864 V

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

Chapter 4

4.3 10.5 nF/cm^2

4.4 43.2 μA/V^2, 86.4 μA/V^2, 173 μA/V^2, 346 μA/V^2, ,

4.8 (a) 4.00 mA/V^2 (b) 8.00 mA/V^2, 15.00 mA/V^2

4.11 +840 μA; −880 μA

4.15 23.0 Ω; 50.0 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 (i) 1.56 mA, saturation region; 460 μA, triode region; 0 A, cutoff

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

4.27 6.50 mS, 13.0 mS

4.31 2.59 mA; 2.25 mA

4.34 9.03 mA, 18.1 mA, 11.3 mA

4.37 1.13 mA; 1.29 mA

4.39 Triode region

4.40 99.5 μA; 199 μA; 99.5 μA; 199 μA

4.44 0; 0

4.45 5.17 V

4.50 40.0 μA; 72.0 μA; 4.41 μA; 32.8 μA

4.53 581/1; 233/1

4.55 235 Ω; 235 Ω

4.56 0.629 A/V^2

4.57 400 μA

4.60 The transistor must be a depletion-mode device and the symbol is not correct.

4.64 (a) 6.91 x 10^{-8} F/cm^2; 1.73 fF

4.66 17.3 pF/cm

4.68 20.7 nF

4.70 (a) 1.35 fF, 0.20 fF, 0.20 fF

4.73 50U, 0.5U, 2.5U, 1V, 0

4.75 (a) 10U, 0.5U, 1.25U, -1V, 0

4.76 432 μA/V^2, 1.94 mA; 864 μA/V^2, 0.972 mA

4.79 6.37 GHz, 2.55 Ghz; 637 GHz, 255 GHz

4.81 Velocity saturation; cutoff; velocity saturation; triode; triode; velocity saturation

4.86 22λ x 12λ; 15.2%

4.89 12λ x 12λ; 13.9%

4.92 (572 μA, 7.94 V); (688 μA, 7.52 V)

4.94 (50.3 μA, 8.43 V) ; (54.1 μA, 8.16 V)

4.101 (a) (55.5 μA, 6.40 V)

4.104 One possiblity: 360 kΩ, 910 kΩ, 3 kΩ, 15 kΩ, 5/1

4.106 (350 μA, 1.7 V); triode region

4.109 (390 μA, 4.1 V); saturation region

4.110 (361 μA, 9.59 V)

4.112 430 kΩ, 1 MΩ, 1.5 kΩ, 3 kΩ

4.114 (109 μA, 1.08 V)**;** (33.5 μA, 0.933 V)

4.117 3.0040 x10^{-5} A; 2.8217 x 10^{-5} A

4.120 (73.1 μA, 9.37 V)

4.121 (69.7 μA, 9.49 V); (73.1 μA, 8.49 V)

4.124 (8.22 μA, 7.04 V), (6.78 μA, 7.56 V); (8.40 μA, 6.98 V), (6.92 μA, 7.51 V)

4.126 (93.1 μA, 8.65 V), (78.2 μA, 9.18 V); (98.9 μA, 8.44 V), (82.9 μA, 9.02 V)

4.127 2.25 mA; 16.0 mA; 1.61 mA

4.128 (322 μA, 0.340 V),

4.131 18.1 mA; 45.2 mA; 13.0 mA

4.133 1/3.84

4.134 (153 μA, -3.53 V) ; (195 μA, -0.347 V)

4.136 14.4 mA; 27.1 mA; 10.4 mA

4.137 4.04 V, 10.8 mA; 43.2 mA; 24.5 mA; 98.0 mA

4.139 (1.13 mA, 1.75 V)

4.140 (63.5 μA, -5.48 V) , R ≤ 130 kΩ

4.144 (125 μA, -1.54 V) , (115 μA, -2.49 V)

4.145 22.3 kΩ → (127 μA, -5.50 V)

4.148 (a) One possible design: 220 kΩ, 200 kΩ, 10 kΩ, 10 kΩ

4.149 (b) (260 μA, -12.4 V)

4.150 (32.1 μA, -1.41 V)

4.151 (36.1 μA, 80.6 mV); (32.4 μA, -1.32 V); (28.8 μA, -2.49 V)

4.153 (431 μA, 6.47 V)

4.154 2.5 kΩ, 10 kΩ

4.155 (b) I_D = 1.38 mA, I_G = 0.62 mA, V_S = -0.7 V

4.158 (76.4 μA, 7.69 V), (76.4 μA, 6.55 V), 5.18 V

4.160 (a) (69.5 μA, 3.52 V)

4.163 10.0 V; 10.0 mA, 501 mA; 13.8 V

4.165 15.0 V; 15.0 mA, 1.00 A; 12.2 V

Chapter 5

5.4 0.167, 0.667, 3.00, 0.909, 49.0, 0.995, 0.999, 5000

5.5 200 aA; 0.101 fA, −0.115 V

5.6 (d) $V_{BE} = V_{BC}$ (e) $I_E/I_C = -\beta_R/\beta_F$ (f) 0.374 μA, -149.6 μA, +150 μA, 0.626 V

5.9 4.04 fA

5.11 1.45 mA; −1.45 mA

5.14 -25 μA, -100 μA, +75 μA, 65.7, 1/3, 0, 0.611 V

5.17 1.77 μA, -33.2 μA, +35 μA, 0.663 V

5.20 (a) 868 μA

5.24 0.990, 0.333, 4.04 fA, 12.0 fA

5.26 83.3, 87.5, 100

5.31 39.6 mV/dec, 49.5 mV/dec, 59.4 mV/dec, 69.3 mV/dec

5.32 5 V, 40 V, 5 V

5.33 2.31 mA; 388 μA; 0

5.34 60.7 V

5.38 Cutoff

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

5.44 50.0 aA, 2.67 aA, 52.7 aA

5.45 I_C = 81.4 pA, I_E = 81.4 pA, I_B = 4.28 pA, forward-active region; although I_C, I_E, I_B are all very small, the Transport model still yields $I_C \cong \beta_F I_B$

5.46 79.0, 6.83 fA

5.47 83.3, 1.73 fA

5.48 55.3 μA, 0.683 μA, 54.6 μA

5.49 6.67 MHz; 500 MHz

5.51 1.5, 31.1 aA

5.53 -19.9 μA, 26.5 μA, -46.4 μA

5.56 17.3 mV, 0.251 mV

5.58 1.46 A, 9.57 A

5.60 0.771 V, 0.683 V, 27.5 mV

5.63 24.2 μA

5.64 4.0 fF; 0.4 pF; 40 pF

5.66 0.388 pF at 1 mA

5.68 750 MHz, 4.17 MHz

5.69 0.149 μm

5.71 61.7, 23.1 V

5.73 73.5, 37.5 V

5.74 Fig. 5.14(a) 100 μA, 4.52 μA, 95.5 μA, 0.647 V, 0.651 V

5.76 26.3 μA

5.77 (c) 33.1 mS

5.80 (b) 38% reduction

5.82 (86.2 μA, 2.92 V) ; (431 μA, 2.92 V); (17.3 μA, 2.92 V) ; (83.2 μA, 3.13 V);

5.87 (23.4 μA, 4.13 V)

5.90 36 kΩ, 75 kΩ, 3.9 kΩ, 3 kΩ; (0.975 mA, 5.24 V)

5.91 12 kΩ, 20 kΩ, 2.4 kΩ, 1.2 kΩ; (0.870 mA, 1.85 V)

5.94 (7.5 mA, 4.3 V)

5.97 30 kΩ, 620 kΩ; (24.2 μA, 0.770 V)

5.98 5.28 V

5.100 3.21 Ω

5.101 10 V, 100 mA, 98.5 mA, 10.7 V

5.102 10 V, 109 mA, 109 mA, 14.3 V

Chapter 6

6.1 10 μW/gate, 8 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} = 2.5 V, V_{REF} = 0.8 V; $Z = A$

6.7 3 V, 0 V, 2 V, 1 V, −3

6.9 2 V, 0 V, 2 V, 3.3 V, 1.3 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 0.250 μW/gate, 37.5 aJ

6.19 2.5 μW/gate, 1.39 μA/gate, 2.5 fJ

6.20 2.20 *RC*; 2.20 *RC*

6.22 −0.78 V, −1.36 V; 9.5 ns, 9.5 ns; 4 ns, 4 ns; 4 ns

6.25 Z = 0 0 0 1 0 0 1 1

6.27 Z = 0 1 0 1 0 1 0 1

6.30 2 ; 1

6.32 80 A

6.33 0.583 pF

6.36 57.6 kΩ, 1.26/1

6.37 (b) 2.5 V, 5.48 mV, 15.6 μW

6.41 (a) 0.450 V, 1.57 V

6.44 (a) 0.521 V, 1.81 V

6.47 NM_L: 0.242 V, 0.134 V, 0.351 V; NM_H: 0.941 V, 0.508 V, 1.25 V

6.49 34.1 kΩ; 1.82/1; 1.49 V, 0.266 V

6.51 81.8 kΩ, 1/1.15

6.52 250 Ω; 625 Ω; a resistive channel exists connecting the source and drain; 20/1

6.53 2.17 V

6.55 1.44 V

6.58 2.7 V, 0.20 V, 0.363 mW, 0.673 mW

6.59 **(a)** 2.5 V, 0.206 V, 0.434 mW

6.62 1.75/1, 8.33/1

6.64 (b) 14.3/1, 1.70

6.66 0.106 V

6.67 (b) 1.55 V, 0.20 V, 0.150 mW

6.69 -2.40 at v_O = 0.883 V; -2.44 at v_O = 1.08 V

6.71 3.79 V

6.73 3.3 V, 0.296 V, 1.25 mW

6.76 1.75/1, 1/8.79

6.78 2.5 V, 0.2 V, 0.12 mW

6.79 1.014

6.80 1.46/1, 1.72/1

6.83 -5.98 at v_O = 1.24 V

6.85 (a) 0.165 V, 80 μA (b) 0.860 V, 0.445 V

6.86 (a) 0.254 V, 100 μA (b) 0.600 V, 0.481 V

6.87 1.65/1, 1/2.32, 0.300 V, 0.426 V

6.89 2.22/1, 1/3.30, 1.43/1

6.91 (b) 14.3/1, 1/1.33

6.93 0.103 V, 84.8 μA

6.94 0.196 V

6.98 4.71/1, 1/1.68, 50 mV

6.99 6.66/1, 1.11/1, 0.203 V, 6.43/1, 6.74/1, 7.09/1

6.102 $Y = \overline{(A+B)(C+D)E}$, 6.66/1, 1.11/1

6.106 $Y = \overline{ACE + ACDF + BF + BDE}$, 3.33/1, 26.6/1, 17.8/1

6.110 1/1.80, 3.33/1

6.112 $Y = \overline{(C+E)[A(B+D)+G]+F}$; 5.43/1, 20.0/1, 6.66/1, 9.99/1

6.116 64.9 mV

6.117 1.81/1, 6.43/1, 7.09/1, 6.74/1

6.121 5.43/1, 9.99/1, 6.66./1, 20.0/1

6.122 (a) 7.24/1, 26.6/1, 13.3/1

6.126 $I_D^* = 2I_D \quad | \quad P_D^* = 2P_D$

6.127 1 ns

6.128 80 mW, 139 mW

6.131 60.2 ns, 16.6 MHz, a potentially stable state exists with no oscillation

6.133 31.7 ns, 4.39 ns, 5.86 ns

6.135 6.10 kΩ, 10.5/1

6.138 (a) 68.4 ns, 3.55 ns, 9.18 ns

6.140 47.1 ns, 6.14 ns, 5.39 ns

6.142 2.11/1, 16.7/1, 12.8 ns, 0.923 ns

6.143 2.28/1, 2.80/1, 924 μW

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

6.146 0.33 ns, 1.7 ns, 0.69 ns, 13.6 ns

6.149 −1.90 V, −0.156 V

6.150 1/3.30, 1.75/1

6.151 2.30 V, 1.07 V

6.153 $Y = \overline{A + B}$

Chapter 7

7.1 10 nm: 173 μA/V^2 ; 69.1 μA/V^2

7.3 250 pA; 450 pA; 450 pA

7.6 3.3 V, 0 V

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

7.11 1.25 V, 42.3 μA; 1.104 V, 25.3 μA

7.12 0.90 V, 20.3 μA; 0.80 V, 12.3 μA

7.13 1.104 V

7.14 (b) 2.5 V, 92.8 mV

7.16 0.799 V

7.17 1.16 V, 0.728 V

7.22 0.984 V, 2.77 mA

7.23 6.10/1, 1/5.37

7.24 (a) 1.90 ns, 1.90 ns, 0.947 ns

7.27 7.90 ns, 3.16 ns, 2.77 ns

7.31 2.11/1, 5.26/1

7.33 (a) 63.2/1, 158/1

7.36 5.52/1

7.37 5.76/1, 14.4/1

7.41 +0.25, +0.31

7.42 2.1 ns, 2.48 ns, 1.3 ns, 1.0 ns, $\langle C \rangle$ = 138 fF

7.44 0.75 V: 1.09 ns, 1.96 ns, 1.96 ns; (b) 2.20/1, 5.49/1; 3.07/1, 7.68/1

7.48 2.51/1, 6.27/1; 2.51/1, 12.5/1

7.50 11.3/1, 84.6/1

7.51 0.200 μW/gate; 55.6 A

7.52 0.5 μW/gate; 0.46 fF; 0.80 fF; 1.54 fF

7.54 5.00 W; 8.71 W

7.55 211,000/1; 0.0106 cm^2

7.56 2.00 μW, 25.0 ns

7.59 72.3 μA; 25.0 μA

7.61 545 fJ, 340 MHz, 926 μW

7.65 $\alpha\Delta T$, $\alpha^2 P$, $\alpha^3 PDP$

7.68 SPICE: 47.2 ns, 30.3 ns, 30.3 ns, 26.5 ns; Propagation delay formulas: 7.5 ns, 17.3 ns

7.69 1/3.75

7.70 2/1, 20/1; 4/1, 40/1

7.74 1.25/1

7.80 3.95 ns, 3.95 ns, 11.8 ns

7.81 4.67/1; 7.5/1

7.82 5 transistors; The CMOS design requires 47% less area.

7.84 $Y = \overline{(A+B)(C+D)E} = \overline{ACE + ADE + BDE + BCE}$; 12/1, 20/1, 10/1; 6/1; 30/1

7.86 $Y = (\overline{A}+\overline{B})(\overline{C}+\overline{D})(\overline{E}+\overline{F}) = \overline{AB + CD + EF}$; 4/1, 15/1; 6/1; 10/1

7.88 2/1, 4/1, 6/1, 15/1

7.91 (a) Path through NMOS A-D-E (c) Paths through PMOS A-C and B-E

7.93 24/1, 20/1, 40/1

7.94 6/1, 4/1, 10/1

7.101 5.37 ns, 1.26 ns

7.103 1.26 ns, 0.421 ns, 4.74 ns, 2.38 ns

7.105 4.74 ns, 2.37 ns

7.107 8; 2.90; 23.2 A_o

7.110 $A_o \dfrac{\beta^N - 1}{\beta - 1}$

7.111 263 Ω; 658 Ω

7.114 240/1, 96.2/1

7.115 1.41 V, 2.50 V

7.117 **1.16/1**

7.121 Latchup does not occur.

Chapter 8

8.1 1,048,576 bits, 4,294,967,296 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

8.11 "1" level is discharged by junction leakage current

8.13 1.47 V, 1.43 V

8.14 −16.6 mV; 2.48 V

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

8.18 3.30 V, 1.60 V; −1.58 V

8.22 135 μA, 346 mW

8.24 0.266 V

8.25 0.945 V (The sense amplifier provides a gain of 10.5.)

8.31 0 V, 1.43 V, 3.00 V

8.32 0.8 V, 1.2 V; 0.95 V, 0.95 V

8.34 53,296

8.38 $W_1 = 01000110_2$, $W_3 = 00101011_2$

Chapter 9

9.1 0 V, -1.50 V; 6 kΩ

9.2 0 V, -0.700 V

9.3 (a) -1.38 V, -1.12

9.6 0 V, −0.40 V; 3.39 kΩ; Saturation, cutoff; Cutoff, saturation

9.8 −0.70 V, −1.30 V, −1.00 V, 0.60 V

9.11 −0.70 V, −1.50 V, −1.10 V, 2.67 kΩ, 41 kΩ; 0.289 V; −0.10 V, +0.30 V

9.13 -1.70 V, -2.30 V, 0.60 V, Yes

9.15 Fig. P9.6: 1; In contrast, Fig. 9.6: 11

9.16 (a) 370 Ω, 400 kΩ, 2.34 kΩ, 8.40 kΩ

9.18 -1.10 V, -1.50 V, -1.30 V, 0.400 V, 0.107 V, 1.10 mW

9.19 0.383 V

9.21 -0.70 V, -1.50 V, -1.10 V, 11.3 kΩ, 2.67 kΩ, 2.38 kΩ; 0.289 V

9.22 0.413 V

9.25 50.0 μA, -2.30 V

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

9.29 +0.300 V, −0.535 V, 334 Ω

9.31 3.7 mA

9.33 (b) 0.135 mA

9.35 10.7 mA

9.37 400 Ω, 75.0 mA

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

9.42 $(b)\ Z = \overline{A} + \overline{B} = \overline{AB}$

9.44 −0.850 V; 3.59 pJ

9.46 359 ns

9.47 0 V, −0.600 V, 5.67 mW, 505 Ω, 600 Ω; $Y = A + B + C$, 5 vs. 6

9.50 5.00 kΩ, 5.40 kΩ, 31.6 kΩ, 113 kΩ

9.51 1 kΩ, 1 kΩ, 1.30 mW

9.53 2.23 kΩ, 4.84 kΩ, 60.1 kΩ

9.56 1.45 V for $V_{CB2} \geq 0$ V; 1.25 V for $V_{CB2} \geq -0.2$ V

9.57 +0.60, - 0.56, 314 Ω

9.60 1.446 mA, 1.476 mA, 29.66 μA; 1.446 mA, 1.476 mA, 29.52 μA

9.62 -0.9 V, -1.1 V, -1.8 V, -2.0 V, -2.7 V, -2.9 V, -4.2 V

9.63 $Y = AB + \overline{A}C$

9.68 0, -0.8. 0, -0.8, 3.8 V

9.70 2.98 pA, 70.5 fA

9.72 160; 0.976; 0.976; 0.773 V

9.73 0.691 V, 0.710 V

9.77 63.3 μA, 265 μA

9.79 40.2 mV, 0.617 mV

9.81 234 mA; 34.9 mA

9.85 (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

9.86 13.5 mW, 7.60 mW

9.88 1.85 V, 0.15 V; 62.5 μA, −650 μA; 13

9.89 2.5 V, 0.15 V, 0.66 V, 0.80 V, 0.51 V, 1.7 V

9.92 180

9.93 22

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, 4.50 mA, 0, 0; 0, 0, 0, 0, 1.23 mA, 0

9.102 $Y = A + B + C$; 0 V, −0.8 V; −0.40 V

9.103 1.05 mA, 26.9 μA

9.104 2 fJ; 10 fJ

9.106 1.67 ns; 0.5 mW

9.107 2.8 ns; 140 mW

Chapter 10

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

10.4 29.35

10.5 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

10.7 36.8 dB, 113 dB, 75.0 dB

10.9 22.0 dB, 90.0 dB, 56.0 dB; V_o = 12.7 V, recommend ±15-V supplies

10.11 3.01 x10^{-8} S, -6.62 x10^{-3}, 1.00, 66.2 Ω

10.13 0.167 mS, -0.333, -2000, 4.08 MΩ

10.15 1.000 mS, −1.000, 6001, 30.00 kΩ

10.16 53.7 dB, 150 dB, 102 dB; 11.7 mV; 31.3 mW

10.17 45.3 mV, 1.00 W

10.21 −5420

10.23 0, ∞, 80 mW, ∞

10.24 196

10.30 −10 (20 dB), 0.1 V; 0, 0 V

10.32 v_O = [8 – 4 sin (1000*t*)] volts; there are only two components; dc: 8 V, 159 Hz: −4 V

10.33 24.1 dB, 2nd and 3rd, 22.4%

10.35 2.4588 0.0038 5.3105 0.0066 1.3341 0.0026 0.4427 0.0028 0.0883 0.0012 0.1863 0.0023

10.38 59.6 dB, 124 dB, 91.8 dB; 10.1 mV

10.41 R_{id} ≥ 4.95 MΩ

10.43 50.1 μV, 140 dB

10.45 (a) −46.8, 4.7 kΩ, 0, 33.4 dB

10.47 (d) (-2.20 + 1.50 sin 2500πt) V

10.48 $(a)\ v_O = (4.00 - 20V_i \sin 2000\pi t)\ V \quad (b)\ 0.4\ V$

10.53 15.0 kΩ, 374 kΩ, A_v = -24.9, R_{in} = 15.0 kΩ

10.56 -80.0, 15 kΩ, 0

10.59 2 MΩ

10.60 92.5, ∞, 0, 39.3 dB

10.63 (d) (5.74 – 3.13 sin 3250πt) V

10.67 1 kΩ, 200 kΩ, $A_v = 201$

10.69 -(1.88 sin 10000*t* +0.235 sin 3770*t*) V, 0 V

10.70 −0.750 sin 4000πt V; −1.375 sin 4000πt V; 0 to −1.875 V in -125-mV steps

10.71 455/1, 50/1

10.72 −10, 110 kΩ, 10 kΩ, , (-30 + 15cos 8300πt) V, (-30 + 30cos 8300πt) V

10.73 3.1 V, 3.2 V, 2.91 V, 2.91 V, 1.00 V, 0 V; 1.91 μA; 1.91 μA, 2.90 μA

10.76 60 dB, 10 kHz, 10 Hz, 9.99 kHz, band-pass amplifier

10.78 80 dB, ∞, 100 Hz, ∞, high-pass amplifier

10.81 60 dB, 100 kHz, 28.3 Hz, 100 kHz, band-pass amplifier

10.83 Using MATLAB: n = [1e4 0]; d = [1 200*pi]; bode(n,d)

10.84 (a) Using MATLAB: n = [-20 0 -2e13]; d = [1 1e4 1e12]; bode(n,d)

10.86 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

10.89 0.956 sin $(3.18x10^5\pi t + 101°)$ V, 5.00 sin $(10^5\pi t + 180°)$ V, 5.00 sin $(4x10^5\pi t - 179°)$ V

10.91 $A_v(s) = \dfrac{2x10^8\pi}{s+10^7\pi}$ | $A_v(s) = -\dfrac{2x10^8\pi}{s+10^7\pi}$

10.93 12.8 kHz, -60 dB/decade

10.94 3.16 sin $(1000\pi t + 10°)$ + 1.05 sin $(3000\pi t + 30°)$+ 0.632 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)
```

10.96 -4.44 dB, 26.5 kHz

10.97 11 kΩ, 0.015 μF

10.100 60 dB, 100 Hz

10.101 -1.00 dB, 173 Hz

10.104 (b) -20.7, 29.5 kHz

10.105 20 kΩ, 200 kΩ, 8200 πF

10.107 0.265 cos(2000πt) V

10.109 $A_v(s) = \frac{V_o}{V_i} = +\frac{1+K}{sRC}$

10.110 T(s) = -sRC

10.113 −6.00, 20.0 kΩ, 0; +9.00, 91.0 kΩ, 0; 0, 160 kΩ, 0

10.114 0.5 A, 2.00 V, > 5 W (choose 7.5 W)

10.115 0.968 A; 0.748 V; 0.748 V; ≥ 14.5 W (choose 20 W), 14.5 W

Chapter 11

11.1 (c) 2.50, 8.00, 5.71, 28.6 %

11.3 124 dB

11.4 $1/(1+A\beta)$; 9.99×10^{-3} percent

11.5 (a) 13.49, 9.11×10^{-3}, 0.0675%

11.7 120 dB

11.9 (a) -19.98, 2.10×10^{-2}, 0.105%

11.13 106 dB

11.15 100 μA, 100 μA, -48.0 pA, +48.0 pA

11.17 (a) 13.5, 296 MΩ, 135 mΩ

11.20 (a) -19.6, 2.40 kΩ, 82.1 mΩ

11.22 If the gain specification is met with a non-inverting amplifier, the input and output specifications cannot be met.

11.24 $157V_s$, 1.95 Ω

11.26 ≤ 0.75 %

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

11.29 (a) Series-shunt (a) and and series-series (c) feedback

11.32 110 dB, 6.32 S

11.34 9.97, 10.3 MΩ, 2.43 Ω

11.35 9110, 3.00, 3.00, 368 MΩ, 0.400 Ω

11.37 (a) $+T/(1+T) \cong +1$ (c) $-T/(1+T) \cong -1$

11.39 -9.997 kΩ, 2.333 Ω, 0.2999 Ω

11.41 -23.99 kΩ, 5.957 Ω, 0.4398 Ω

11.44 $20000s/(s+4170)$, $20000/(4.80s+1)$

11.48 -3.33 mS, 26.8 MΩ, 8.74 MΩ

11.54 1.097, 28.12 Ω, 4.775 MΩ

11.56 10.98, 15.17 Ω, 33.11 MΩ

11.57 680.4, 0.334

11.59 6330, 0.0260

11.61 6.25 %, 16.7 %

11.62 0.00372 %, 0.0183 %

11.63 0 V, -26 mV, 90.9 kΩ

11.65 +7500, -0.667 mV

11.67 The nearest 5% values are 1 MΩ and 5.1 kΩ

11.69 +6.8 V, 0 V; -10 V, +0.462 V

11.71 -5.00 V, 0 V; -10.0 V, +0.182 V

11.73 12 V, 0 V; 15 V, 0.225 V

11.76 110 Ω and 22 kΩ represent the smallest acceptable resistor pair.

11.78 32.8 Ω

11.80 0 V, 3 V; 0.105 V; 0 V; 49.0 dB

11.82 (d) [0.357 sin(120πt) - 4.91 sin(5000πt)] V

11.84 **The middle resistor in Fig. P11.84 should be 20 kΩ, and part (b) should refer to the 20 kΩ resistor.** (b) 124 dB

11.85 66 dB

11.86 20.0 kΩ, 56.0 kΩ

11.87 (a) 20 Hz (c) 104 dB

11.89 50 Hz; 5 MHz; 2.5 MHz

11.91 200; 199

11.93 80 dB, 1 kHz, 1 MHz; 101 MHz, 9.90 Hz; 251 MHz, 3.98 Hz

11.95 100 dB, 1 kHz, 1 MHz; 8.4 Hz, 119 MHz; 5.3 Hz, 188 MHz

11.96 (a) $R_o\left(s+\omega_B\right)\Big/\left[s+\omega_B\left(1+A_o\beta\right)\right]$

11.99 (a) $R_{id}\left[s+\omega_B\left(1+A_o\beta\right)\right]\Big/\left(s+\omega_B\right)$

11.103 $A_v(s) = -\dfrac{3.285x10^{12}}{s^2+1.284x10^7 s+1.675x10^{11}}$; (2 poles: 2.08 kHz and 2.04 MHz)

11.105 $A_v(s) = -\dfrac{6.283x10^{10}}{s^2+3.142x10^7 s+6.283x10^{5}}$; (2 poles: 3.18 mHz and 5.00 MHz)

11.107 6.91, 7.53, 6.35; 145 kHz, 157 kHz, 133 kHz

11.109 3.14 V/μs; 3.14 V/ms

11.111 10 V/μs

11.115 10^{10} Ω, 7.96 pF, 4x10^6, R_o not specified

11.117 90.6 ^{o}; 90.2^o

11.118 8.1 ^{o}; 5.1^o

11.120 110 kHz; A ≤ 2048; larger

11.121 Yes, but almost no phase margin; 0.4°

11.123 88^o versus 90^o**;** 90^o versus 90^o

11.126 10 MHz, 90.0^o; 5 MHz, 90.0^o

11.128 $A_v(s) = -\dfrac{3.770x10^{10}}{s^2 + 1.885x10^7 s + 3.770x10^5}$; 90^o

11.130 Yes, but almost no phase margin; 1.83°

11.132 90.0^o

11.134 12^o**;** Yes, 796 pF → 50^o

11.139 Yes, 24.4^o, 50 %

11.141 1.8^o

11.142 38.4^o, 31 %

11.145 133 pF

11.147 90.1^o

11.150 (a) 72.2^o

11.151 (a) 44.4 MHz, 8.09^o, 80.0%

11.153 **(**a) 34.4, 23.4%

11.155 (a) 12.5 MHz

Chapter 12

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

12.3 -6500, 3 kΩ, 0

12.5 72, 556 MΩ, 4.50 mΩ

12.7 76.3 dB, 3.00 kΩ, 98.3 mΩ

12.8 (c) 2.00 mV, -37.3 mV, 3.73 μV, 0.696 V, 69.6 μV, 0 V, -12.0 V, 50.4 mV, 0V (ground node)

12.11 -2960, 3.9 kΩ, 0

12.12 **"2-kΩ" should be 3-kΩ;** 12.1 kΩ, 12.1 kΩ

12.16 3050, 3440, 2704, 1 MΩ, 1.02 MΩ, 980 kΩ, 0

12.17 -2970, 120 kΩ, 0; 4.00 mV, 4.00 mV, 54.0 mV, 0 V, -1.08 V, -1.08 V, -11.9 V, 0V (ground node)

12.19 (a) -15.0, 188 kHz; -4.70, 526 kHz; +70.4, 169 kHz

12.21 14.5, 345 kHz, 69.7 dB, 176 kHz

12.23 -2648, 662 MΩ, 75.5 mΩ, 26.0 kHz; 0 V, 10.0 mV, 49.2 mV, 215 μV, -4.30 V, -3.06 V, -15.0 V, +15.0 V, -15.0 V, 0 V

12.25 3

12.27 20 kΩ, 62 kΩ, 394 kHz

12.30 103 dB, 98.5 dB, 65 kHz, 38 kHz

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

12.36 -12, (-6.00 + 2.40 sin 4000πt) V

12.38 6.00 V, 5.02 V, 4.98 V, 4.00 V, 1.998 V, 1.998 V, 2.012 V, -600 μA, 0 μA, +400 μA, 0.002, -50.0, 88 dB

12.40 (b) 0.005 μF, 0.0025 μF, 900 Ω

12.44 $\frac{\mathbf{V_o}}{\mathbf{V_s}} = \frac{K}{s^2 R_1 R_2 C_1 C_2 + s\left[R_1 C_1 (1-K) + C_2 (R_1 + R_2)\right] + 1}$ | $S_K^Q = \frac{K}{3-K}$

12.46 -1

12.48 270 pF, 270 pF, 19.1 kΩ

12.49 (a) 51.2 kHz, 7.07, 7.24 kHz

12.52 (a) 1 rad/s, 4.65, 0.215 rad/s; $A_{BP}(s) = \left(\frac{-6s}{s^2 + \frac{s}{3} + 1} \right)^2$

12.54 5.48 kHz, 4.09, 1.34 kHz

12.56 $T = +K \frac{\frac{s}{R_2 C_2}}{s^2 + s\left[\frac{1}{R_2 C_2} + \frac{1}{(R_1 \| R_2) C_1}\right] + \frac{1}{R_1 R_2 C_1 C_2}}$

12.62 -5.5 V, -5.5, 10 %; -5.0 V, -5.0, 0

12.64 12.6 kHz, 1.58, 7.97 kHz

12.67 (a) -0.960 V (b) -1.440 V

12.68 10.6 mV, 5 %

12.71 379/1, 41.7/1

12.73 0.66 LSB, 0.33 LSB

12.74 1.43%, 2.5%, 5%, 10%

12.75 12 resistors, 4096:1

12.77 (a) 1.0742 kΩ, 0.188 LSB, 0.094 LSB

12.79 (a) $(2^{n+1}-1)C$

12.82 (b) 1.01 inches

12.83 3.49546875 V $\leq V_X \leq$ 3.49578125 V

12.84 1.90735 μV, 11010000101101000100_2, 01111111001111010110_2

12.87 0001011101_2, 93 μs

12.89 800 kHz, 125 ns

12.91 $v_O(t) = 2x10^5 \left(1 - \exp\frac{-t}{4x10^4 RC}\right)$ for $t \geq 0$ | $RC \geq 0.050$ s

12.92 19.1 ns

12.95 0.5774/RC, 1.83

12.96 1/RC, 2R

12.98 60 kHz, 6.8 V

12.100 17.5 kHz, 11.5 V

12.104 0.759 V

12.105 2.40 Hz

12.110 $V_O = -\dfrac{V_1 V_2}{10^4 I_S}$

12.111 3.11 V, 2.83 V, 0.28 V

12.113 0.445 V, -0.445 V, 0.89 V

12.115 9.86 kHz

12.116 $V_O = 0$ is a stable state, so the circuit does not oscillate. f = 0.

12.118 0, 0.298 V, 69.0 mV

12.120 42 kΩ, 2 kΩ, 51 kΩ, 120 pF

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 drain to output v_O. (b) The signal voltage at the source of M_1 will be $v_s = 0$.

13.7 (a) C_1 is a coupling capacitor that couples the ac component of v_I into the amplifier. C_2 is a 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 terminal will be $v_e = 0$.

13.9 (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.

13.12 (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.

13.16 (1.91 mA, 2.78 V)

13.18 (a) (18.3 μA, 6.50 V)

13.20 (56.4 μA, 3.67 V)

13.24 (99.7 μA, 9.74 V)

13.28 (184 μA, 15.5 V)

13.32 (943 μA, -7.89 V)

13.34 (1.01 mA, 9.20 V)

13.43 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

13.45 118 Ω, 3.13 TΩ, ≤ -28.5 mV

13.46 (c) 8.65 Ω

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

13.48 (c) 1.00 μA

13.49 (188 μA, ≥ 0.7 V), 7.50 mS, 533 kΩ

13.54 (b) +16.7%, -13.6%

13.55 90, 120; 95, 75

13.60 [−59.0, −58.3]

13.62 -48.1

13.66 −90

13.68 Yes, using $I_C R_C = \frac{V_{CC} + V_{EE}}{2}$

13.70 3

13.71 25 mA; 30.7 V

13.72 1.00 V

13.73 No, there will be significant distortion

13.74 −345

13.79 40/1, 0.500 V

13.80 0.960 A

13.81 10%, 20%

13.84 (66 μA, 7.5 V)

13.85 Virtually any desired Q-point (set by the choice of R_G)

13.86 $400 = 133{,}000 i_P + v_{PK}$; (1.4 mA, 215 V); 1.6 mS, 55.6 kΩ, 89.0; -62.7

13.87 FET

13.88 BJT

13.89 35.3 μA, 2800

13.90 2000, 200, 8.00 mS, 0.800 mS

13.93 23.5 dB

13.95 (180 μA, 9.0 V)

13.96 0.360 V

13.97 1.0 V, 45 V

13.99 3

13.101 −10.3

13.104 −6.66

13.109 25.0 kΩ, 91.9 kΩ

13.112 455 kΩ, 1.42 MΩ

13.114 243 kΩ, 40.1 kΩ

13.116 6.8 MΩ, 45.8 kΩ, independent of K_n

13.118 1 MΩ, 3.53 kΩ

13.119 $-150v_i$, 95.5 kΩ

13.121 $-23.6v_i$, 508 kΩ

13.123 (a) 38.9 dB, 6.29 kΩ, 9.57 kΩ

13.125 36.4 dB, 62.9 kΩ, 95.7 kΩ

13.129 92.6 μW, 221 μW, 1.26 mW, 0.761 mW, 0.865 mW, 3.19 mW

13.133 528 μW, 765 μW, 252 μW, 51.6 μW, 132 μW, 1.73 mW

13.136 $V_{CC}/15$

13.137 2.35 V, 9.72 V

13.138 $V_{CC}/2$, $(V_{CC})^2/8R_L$, $(V_{CC})^2/2R_L$, 25%

13.139 0.955 V

13.141 2.35 V

13.142 1.86 V

13.143 3.19 V

13.147 694 μA

13.148 -4.60, 1 MΩ, 6.82 kΩ

Chapter 14

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

14.16 (a) −38.5, 8.99 kΩ, 552 kΩ, -30.1, 34.7 mV

14.17 Assume (V_{GS}-V_{TN}) = 0.5 V (a) −5.82, 2 MΩ, 29.8 kΩ, -4030

14.18 (a) −6.52 (e) −240

14.19 3.29 kΩ, 50.0 kΩ

14.22 −215, -9.85, 22.4 kΩ, 56 kΩ, 5.11 mV

14.23 -145, -5.54, 3.49 kΩ, 10.0 kΩ, 6.76 mV, -120

14.24 −12.9, −10.1, 368 kΩ, 82 kΩ, 149 mV

14.26 -2.40, -667, 10 MΩ, 1.80 kΩ, 0.700 V

14.27 -3330, -3.65, 848 Ω, 50.1 kΩ, 6.41 mV

14.29 0.779, 35.6 kΩ, 105 Ω, 29.6, 6.40 mV

14.30 Assume (V_{GS}-V_{TN}) = 0.5 V: 0.914, 2 MΩ, 125 Ω, 16,000, 2.50 V

14.31 0.986, 44.6 kΩ, 13.7 Ω, 1.62 V

14.32 0.961, 1 MΩ, 542 Ω, 7.02 V

14.33 0.992, 12.6 MΩ, 1.18 kΩ, 0.664 V

14.34 0.874, 7.94 MΩ, 247 Ω, ∞

14.35 $v_i \leq \left(0.005 + 0.2V_{R_E}\right)$ V

14.35 0.9992, 30.1 V

14.39 (b) 77.7, 702 Ω, 6.88 MΩ, 0.969, 20.7 mV

14.40 49.8, 1.25 kΩ, ∞, 0.750, 1.13 V (Assume (V_{GS}-V_{TN}) = 1 V)

14.42 43.6, 146 Ω, 39.0 kΩ, 22.1 mV

14.44 4.11, 1.32 kΩ, 20.0 kΩ, 354 mV

14.46 4.75, 3.19 kΩ, 24.0 kΩ, 326 mV

14.48 44.4 Ω; 260 Ω

14.49 633 Ω; 408 Ω

14.51 $\left(\beta_o + 1\right)r_o = 198\ M\Omega$

14.52 Low R_{in}, high gain: Either a common-base amplifier operating at a current of 50.0 μA or a common-emitter amplifier operating at a current of approximately 5.00 mA can meet the specifications with $V_{CC} \approx 14$ V.

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

14.57 Common-drain amplifier.

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

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

14.61 Part (b) should be $I_C = 1$ mA: (a) 4.13 Ω

14.64

v_i	1 kHz	2 kHz	3 kHz	THD
5 mV	621 mV	26.4 mV (4.2%)	0.71 mV (0.11%)	4.2%
10 mV	1.23 V	0.104 V (8.5%)	5.5 mV (0.45%)	8.5%
15 mV	1.81 V	0.228 V (12.6%)	18.2 mV (1.0%)	12.7%

14.66 (b) $1230v_i$, 583 kΩ

14.67 v_i, 297 Ω

14.70 g_m, 0; -500 μS, 0

14.71 (a) $-g_m\left(1+\dfrac{1}{\mu_f}\right) \;|\; -g_o \;|\; \mu_f + 1$

14.74 (a) $-\dfrac{g_m}{1+g_mR_E} \;|\; -\dfrac{g_o}{\left(1+g_mR_E\right)}\left(\dfrac{R_E}{R_E+r_\pi}\right) \;|\; \dfrac{G_m}{G_r} = \mu_f\left(1+\dfrac{r_\pi}{R_E}\right) >> 1$

14.76 -0.984, 0.993, 0.703 V

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

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

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

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

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

14.88 SPICE: (175 μA, 4.29 V), -4.49, 500 kΩ, 17.0 kΩ

14.89 (430 μA, 1.93 V), (430 μA, 3.07 V), -2.89, 193 kΩ, 3.22 kΩ, (Note A_{tr} = 743 kΩ)

14.90 (4.50 mA, 2.50 V), (4.50 mA, 2.50 V), -83.9, 8.94 kΩ, 10.5 kΩ

14.91 0.486, 182 kΩ, 348 Ω

14.95 1.00 μF, 0.039 μF, 68 μF; 2.7 μF

14.96 2000 pF, 33 pF; 10 μF, 150 pF

14.99 0.68 μF, 0.015 μF

14.101 8200 pF, 1500 pF

14.105 33.3 mA

14.106 R_1 = 120 kΩ, R_2 = 110 kΩ

14.109 45.1 ≤ A_v ≤ 55.3 - Only slightly beyond the limits in the Monte Carlo results.

14.111 The second MOSFET

14.114 The supply voltage is not sufficient - transistor will be saturated.

14.116 4.08, 1.00 MΩ, 64.3 Ω

14.119 2.17, 1.00 MΩ, 64.3 Ω

14.124 468, 73.6 kΩ, 18.8 kΩ

14.125 0.670, 107 kΩ, 20.0 kΩ

14.127 7920, 10.0 kΩ, 18.8 kΩ

14.128 140, 94.7 Ω, 113 Ω

14.132 1.56 Hz; 1.22 Hz

14.133 19.2 Hz; 18.0 Hz

14.134 6.40 Hz; 5.72 Hz

14.136 0.497 Hz, 0.427 Hz

14.137 1.70 kHz; 1.68 kHz

Chapter 15

15.1 (20.7 μA, 5.86 V); −273, 242 kΩ, 484 kΩ; −0.604, 47.0 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 (70.8 μA, 8.62 V); −283, -0.494, 47.1 dB, 58.4 kΩ, 10.1 MΩ, 200 kΩ, 50.0 kΩ

15.7 R_{EE} = 1.1 MΩ, R_C = 1.0 MΩ

15.8 (a) (198 μA, 3.39 V); differential output: −372, 0, ∞ (b) single-ended output: −186, −0.0862, 66.7 dB; 25.2 kΩ, 27.3 MΩ, 94.0 kΩ, 23.5 kΩ

15.10 3.478 V, 6.258 V, -2.78 V, 4.64 V

15.12 V_O = 5.72 V, v_o = 0; V_O = 5.79 V; $v_i \le$ 27 mV, the small-signal limit.

15.15 (27.5 μA, 4.20 V); Differential output: −220, 0, ∞; single-ended output: −110, −0.661, 44.4 dB; 272 kΩ, 22.7 MΩ

15.16 -6.815 V, -3.905 V, -2.91 V

15.20 (4.94 μA, 1.77 V); differential output: −77.2, 0, ∞; single-ended output: −38.6, −0.0385, 60.0 dB; 810 kΩ, 405 MΩ, [-1.07 V, 1.60 V]

15.21 -283, -.00494, 95.2 dB

15.22 -273.6, -.004942, 94.9 dB

15.24 (330 μA, 6.83 V); differential output: −11.3, 0, ∞; single-ended output: −5.65, −0.689, 18.3 dB; ∞, ∞

15.26 (329 μA, 6.87 V); differential output: −8.8, 0, ∞; single-ended output: −4.40, −0.677, 16.3 dB; ∞, ∞

15.29 5.1 kΩ, 27 kΩ

15.30 (70.2 μA, 10.9 V); differential output: −14.7, 0, ∞; single-ended output: −7.35, −0.484, 23.6 dB; ∞, ∞; (83.5 μA, 8.47 V)

15.33 (750 μA, 3.50 V); differential output: −11.3, 0, ∞; single-ended output: −5.65, −0.223, 28.1 dB; ∞, ∞

15.34 (750 μA, 4.25 V); differential output: −5.63, 0, ∞; single-ended output: −2.81, −0.218, 22.2 dB; ∞, ∞

15.35 (20.0 μA, 10.3 V); differential output: −38.1, 0, ∞; single-ended output: −19.0, −0.120, 44.0 dB; ∞, ∞

15.38 312 μA, 27 kΩ

15.41 -20.26, -0.7812, 22.3 dB , ∞, ∞

15.44 −3.80 V, −2.64 V, 40 mV

15.47 -79.85, -0.4936, 751.4 kΩ

15.48 (99.0 μA, 6.80 V), −30.4, −0.167, 550 kΩ

15.50 (49.5 μA, 3.29 V), (49.5 μA, 11.7 V); −149, -0.0625, 101 kΩ

15.51 (100 μA, 1.38 V), (100 μA, 4.68 V); −13.4, 0, ∞

15.54 (24.8 μA, 18.0 V), (750 μA, 18.0 V); 8980, 202 kΩ; 19.5 kΩ; 160 MΩ; v_2

15.56 6.33 mV, 106 dB, $PSRR_+$ = 105 dB, $PSRR_-$ = 60.3 dB

15.58 [-16.6 V, 17.3 V]

15.63 4550, 21.98 nA, 0.879 μA, 99.1 μA, 72.8 MΩ, 653 kΩ

15.66 (24.8 μA, 17.3 V), (7.35 μA, 17.3 V), (743 μA, 18.0 V);
6760, 202 kΩ; 17.9 kΩ; 158 MΩ; v_2

15.67 (98.8 μA, 20.9 V), (440 μA, 20.9 V); 699, 40.5 kΩ; 48.6 kΩ

15.68 (98.8 μA, 18.0 V), (8.8 μA, 18.0 V), (360 μA, 18.0 V);
3740, 40.4 kΩ; 36.1 MΩ

15.70 390 Ω, 1.1 k Ω, 3.74 mA

15.75 (250 μA, 15.6 V), (500 μA, 15.0 V); 3300, ∞; 165 kΩ

15.78 5770

15.79 [-5.32 V, 2.93 V]

15.80 (250 μA, 7.42 V), (6.10 μA, 4.30 V), (494 μA, 5.00 V); 4230, ∞; 97.5 kΩ

15.84 (49.5 μA, 22.0 V), (360 μA, 21.3 V), (990 μA, 22.0 V); 13500, 101 kΩ; 1.98 kΩ;
73.5 MΩ; v_2

15.86 (300 μA, 6.10 V), (500 μA, 3.89 V), (2.00 mA, 6.00 V); 541, ∞, 339 Ω

15.88 (300 μA, 6.55 V), (500 μA, 3.89 V), (2.00 mA, 6.00 V), 3000, ∞, 336 Ω

15.90 Error in Problem Statement: K_n = 5 mS
(375 μA, 11.0 V), (2.00 mA, 9.84 V), (5.00 mA, 12.0 V); 708, ∞; 127 Ω

15.91 Error in Problem Statement: K_n = 5 mS
(375 μA, 11.7 V), (2.00 mA, 9.75 V), (5.00 mA, 12.0 V); 1270, ∞; 159 Ω

15.92 15.32 mV, 77.5 dB, $PSRR_+$ = 77.5 dB, $PSRR_-$ is limted by numerical noise

15.93 (99.0 μA, 4.96 V), (99.0 μA, 5.00 V), (500 μA, 3.41V), (2.00 mA, 5.00 V);
11400, 50.5 kΩ, 224 Ω

15.95 (49.5 μA, 10.0 V), (98.0 μA, 9.30 V), (735 μA, 15.0 V); 2680, 101 kΩ, 3.05 kΩ; [undefined for an ideal current source, +9.3 V]; 1.81 mV

15.97 No, R_{id} must be reduced or R_{out} must be increased.

15.108 30.6 μA

15.111 438 μA

15.114 32.2 μA

15.116 4 mA, 0 mA, 8 mA, 10.0 percent

15.117 66.7 percent

15.120 46.7 mA, 13.5 V

15.122 23.5 μA

15.123 6.98 mA, 0 mA

15.124 25.0 mΩ

15.126 (a) 18.7 μA, 61.5 MΩ

15.129 (a) 134 μA, 8.19 MΩ

15.130 Two of many: 75 kΩ, 6.2 kΩ, 150 Ω; 68 kΩ, 12 kΩ, 1 kΩ

15.131 570 μA, 655 kΩ

15.132 543 μA, 674 kΩ

15.135 0, ∞

15.136 68.0 μA, 22.4 MΩ

15.139 19.6 μA, 123 MΩ

15.142 390 kΩ, 210 kΩ, 33 kΩ

15.144 157.4 μA, 16.61 MΩ, 31.89 μA, 112.2 MΩ

15.145 139 μA, 3.15 MΩ, 486 μA, 432 kΩ

15.149 100 μA, 6.57×10^{11} Ω

15.150 (4.64 μA, 7.13 V), (9.38 μA, 9.02 V); 40.9 dB, 96.5 dB

15.153 $\beta_{o1}\mu_{f1}/2$, For typical numbers: (100)(40)(70)/2 = 140,000 or 103 dB

15.141 3σ limits: I_O = 200 μA ± 31.9 μA, R_{OUT} = 11.7 MΩ ± 2.1 MΩ
3σ limits: I_O = 197 μA ± 33.8 μA, R_{OUT} = 11.5 MΩ ± 1.7 MΩ

Chapter 16

16.1 [4.39 kΩ, 4.62 kΩ]

16.2 2.00 mV; 3.76 mV; 2%

16.4 7.7%, 0.678 μA, 0.712 μA, (I_{OS} = -34.7 nA)

16.7 25.0 mV; 1.2%; 0.4%

16.8 (a) 122 μA, 239 μA, 496 μA, 904 kΩ, 452 kΩ, 226 kΩ

16.11 87.5 μA, 175 μA, 350 μA; 0.0834 LSB, 0.126 LSB, 0.411 LSB

16.12 273 μA, 385 kΩ, 574 μA, 192 kΩ

16.16 (a) 687 μA, 94.6 kΩ, 1.11 mA, 56.8 kΩ

16.18 469 kΩ, 109 μA; 515 kΩ, 109 μA

16.21 202 μA, 327 μA

16.22 Use β_{FO} = 80 and V_A = 60 V.
514 μA, 827 μA; 522 μA, 827 μA; 423 μA, 681 μA

16.24 **Use transistor parameters from Prob. 16.23**
581 kΩ, 13.6 μA, 142 μA

16.26 10

16.28 15 kΩ, 2/3

16.30 142 μA, 592 MΩ

16.32 4.90 kΩ; 4.90 kΩ

16.34 215 kΩ, 13.9 kΩ, 0.556

16.36 (a) 21.8 μA, 18.4 MΩ

16.38 (a) 24.8 μA, 143 MΩ (c) 1410 V

16.42 (a) 14.0 μA, 80/1; 122 MΩ

16.44 (a) $2/g_{m2}$

16.46 9.49/1

16.49 23.1 MΩ, 0, 6.04, 163 MΩ

16.51 n = 4: 643 kΩ, 0.25, 27.8, 14.8 MΩ

16.52 40.0 μA, 335 MΩ; 13.4 kV; 2.81 V

16.54 2 μA or 5%, 12.5 nA

16.57 (b) 50 μA, 240 MΩ; 12.0 kV; 3.05 V

16.60 193 μA, 171 MΩ, 3300 V; $2V_{BE}$ = 1.40 V

16.63 2.50 kΩ

16.65 $\cong \beta_o r_{o4}/2$

16.66 (a) 102 GΩ

16.67 (a) 51.0 GΩ

16.73 (a) 66.5 μA, 3.07 MΩ

16.75 5.86 kΩ

16.77 317 μA; 295 μA; 43.7 μA

16.80 13.2 kΩ, 332 kΩ

16.82 8.48 kΩ, 449 kΩ

16.84 $I_{C1} = 111\ \mu A, \quad I_{C2} = 37.9\ \mu A, \quad S_{V_{CC}}^{I_{C1}} = 0.147, \quad S_{V_{CC}}^{I_{C2}} = 0.0496$

16.86 n > 1/3

16.88 38.9 μA

16.90 (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.

16.92 4.57 μA, 11.4 μA, 3.16 μA, 22.9 μA, 2.91 μA

16.94 I_{C2} = 18.3 μA I_{C1} = 34.1 μA - Similar to hand calculations.

$S_{V_{CC}}^{I_{C1}} = 9.36x10^{-3}$ $S_{V_{CC}}^{I_{C2}} = 2.64x10^{-3}$

16.96 (a) 331 μA, 220 μA

16.98 (a) 199 μA, 166 μA

16.101 1.20 V, 304.9 K

16.103 4.90 V, 327.4 K

16.104 5.07 V, +44.0 μV/K

16.106 -472 μV/K, -199 μV/K

16.109 60.9, 9.02 x10^{-5}, 117 dB, ±8.2 V

16.111 90.9, 7.29 x10^{-5}, 122 dB

16.113 1200, 4 x10^{-3}, 110 dB, ±2.9 V

16.117 R_{SS} = 25 MΩ
(100 μA, 8.70 V), (100 μA, 8.70 V), (100 μA, -2.50 V), (100 μA, -1.25 V),
(100 μA, -1.25 V); 323; 152; 4.18 mV

16.119 (125 μA, 1.54 V), (125 μA, -2.79 V), (125 μA, 2.50 V), (125 μA, 1.25 V); 19600

16.123 171 μA

16.124 (b) 100 μA

16.125 (250 μA, 5.00 V), (250 μA, 5.00 V), (250 μA, -1.46 V), (250 μA, -1.46 V), (500 μA, -3.63 V), (97.7 μA, 5.00 V), (97.7 μA, -5.00 V), (250 μA, 1.75V), (500 μA, 3.54 V), (500 μA, 3.63 V), (500 μA, 3.54 V); 8340; 4170

16.127 (250 μA, 7.50 V), (250 μA, 7.50 V), (250 μA, -1.46 V), (250 μA, -1.46 V), (500 μA, -6.12 V), (99.2 μA, 7.50 V), (99.2 μA, -7.50 V), (500 μA, 2.75 V), (250 μA, 1.75 V), (500 μA, 5.75 V), (500 μA, 6.12 V), 3160. 278 μV

16.128 25300

16.131 (b) 31.2/1 (c) 39500

16.136 7.81, 703 Ω, 3.02×10^5, 75.0 kΩ

16.138 ±1.4 V, ±2.4 V

16.139 (a) 9.72 μA, 138 μA, 46.0 μA

16.140 271 kΩ, 255 Ω

16.142 $V_{EE} \geq 2.8$ V, $V_{CC} \geq 1.4$ V; 3.8 V, 2.4 V

16.144 2.84 MΩ, 356 kΩ. 6.11×10^5

16.147 (80 μA, 15.7 V), (80 μA, 15.7 V), (40 μA, -12.9 V), (40 μA, -0.700 V), (40 μA, -0.700 V), (40 μA, -12.9 V), (40 μA, 1.40 V), (40 μA, 1.40 V), (1.60 μA, 29.3 V), (80 μA, 0.700 V), (80 μA, 13.6 V); 0.800 mS, 940 kΩ

16.148 (37.5 μA, 15.7 V), (37.5 μA, 15.7 V), (37.5 μA, 12.9 V), (37.5 μA, 12.9 V), (37.5 μA, 1.40 V), (37.5 μA, 1.40 V), (0.75 μA, 29.3 V), (75 μA, 1.40 V), (0.75 μA, 0.700 V), (0.75 μA, 13.6 V); 0.750 mS, 1.15 MΩ

16.150 **(**50 μA, 2.50 V), (25 μA, 3.20 V)

16.151 (a) 125 μA, 75 μA, 62.5 μA, 37.5 μA,

16.146 $\left(500 - 195\sin 5000\pi t\right)\mu A,\ \left(500 + 195\sin 5000\pi t\right)\mu A;\ 0.488\ mS$

Chapter 17

17.1 $A_{mid} = 50, F_L(s) = \frac{s^2}{(s+3)(s+40)}$, yes, $A_v(s) \approx 50\frac{s}{(s+40)}$, 6.37 *Hz*, 6.40 *Hz*

17.4 200, $\frac{1}{\left(\frac{s}{10^4}+1\right)\left(\frac{s}{10^5}+1\right)}$, yes, 1.59 kHz, 1.58 kHz

17.7 400, $\frac{s^2}{(s+1)(s+2)}$, $\frac{1}{\left(1+\frac{s}{500}\right)\left(1+\frac{s}{1000}\right)}$, 0.356 Hz, 71.2 Hz; 0.380 Hz, 66.7 Hz

17.9 (b) -20.4 (26.2 dB), 13.3 Hz

17.10 (b) -22.3, 10.7 Hz (c) 16.2 V

17.11 2.06 μF; 2.20 μF, 47.1 Hz

17.13 0.194 μF; 0.20 μF; 1940 Hz

17.14

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

27.2 dB, 369 Hz; -7.15 V, 7.60 V

17.16 123 Hz; 91 Hz; (144 μA, 3.67 V)

17.18 -131, 49.9 Hz, 12.0 V

17.19 53.4 Hz

17.21 7.23 dB, 12.7 Hz

17.23 +0.739, 11.9 Hz, 7.5 V

17.24 0.15 μF

17.25 3.9 μF

17.27 0.82 μF

17.29 0.33 μF

17.30 308 ps

17.33 (a) 22.5 GHz

17.35 750 Ω

17.36 −96.7; −110

17.37 0.976; 0.977

17.39 $8.00\angle -90^o$; $272\Omega\angle -23.0^o$

17.41 (a) −5000, −100.0, −4989, −122, 2% error (b) −250, −60.0, −150, −100, 60% error

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

17.45 (0.924 mA, 2.16 V); -89.6, 1.45 MHz; 130 MHz

17.47 -20.4, 429 kHz; $4900\Omega\angle -90^o$, $2.80\angle -90^o$

17.49 (0.834 mA, 2.41 V); -8.70, 3.22 MHz; 28.0 MHz

17.53 61.0 pF, 303 MHz

17.56 $1/(4x10^4 RC)$; $1/(4x10^5 RC)$; $-1/sRC$

17.58 39.2 dB, 6.85 MHz

17.64 -120, 1.40 MHz; 168 MHz, 979 MHz

17.63 1.90 kΩ, -51.2, 204 MHz

17.64 -29.3, 7.41 MHz, 227 MHz

17.66 220 Ω, 1.1 kΩ, -15.9, 201 MHz

17.67 −1300; −92.3; −100, −1200

17.68 +8.44, 64.4 MHz

17.70 88.0, 1.72 MHz

17.73 2.96, 14.0 MHz

17.74 0.957, 13.6 MHz, 7.64 Hz

17.77 0.964, 114 MHz

17.80 -1.43 dB, 76.0 MHz

17.81 $C_{GD} + C_{GS}/(1 + g_m R_L)$ for $\omega << \omega_T$

17.83 Using a factor of 5 margin: 20 GHz, 7.96 ps

17.87 672 mA - not a realistic design. A different FET is needed.

17.89 (a) 393 kHz (b) 640 kHz

17.93 434 kHz

17.95 36.2 kHz

17.96 42.2 kHz

17.98 (a) 543 kHz

17.100 (a) 2.12 MHz

17.102 53.4 dB, 833 Hz, 526 kHz

17.103 1.63 MHz; 300 μH, 2.80 MHz

17.105 -45°; -118°; -105°

17.107 22.5 MHz, -41.1, 2.91

17.108 20.4 pF; 12.6; n = 2.81; 21.9 pF

17.109 15.9 MHz; 28.9 MHz

17.110 13.0 MHz, 7.18, $116\underline{/-90}°$; 4.36 MHz, 5.59, $51.3\underline{/-90}°$

17.111 10.1 MHz, 3.52, −33.3; 10.94 MHz, 6.86, -70.8

17.114 65 pF; 240, $-4.41\text{x}10^4$, 25.1 kHz

17.116 67.3 pF; 152 kHz, 40

17.118 (b) 497 Ω, 108 pF

17.119 100 Ω, 104 fF; 52.2 Ω, 144 fF

17.125 (a) 100 MHz, 1900 MHz

17.126 61.1 dB

17.129 -19.5 dB; -23.9 dB

17.131 0.6 A

17.133 -13.5 dB; -17.9 dB

17.135 0.1 A

17.137 1, 0.5, 0.5

17.139 0.567 V

17.142 $0.2I_1R_C$

Chapter 18

18.1 (b) 250, 3.984, 0.398%

18.3 1/40, 396.2, -38.90

18.5 97.5 dB

18.7 1/(1+T); 0.0995 %

18.9 (a) Series-series feedback (b) Shunt-shunt feedback

18.13 (a) 857 Ω, 33.3, 57.1, 506 Ω

18.15 25.9 Ω, 0, 0.952, 13.3 Ω

18.17 $2.13x10^6$, 24.8 S

18.19 2.53 mV

18.21 13.0, 8.76 MΩ, 1.54 Ω

18.23 31.1 Ω, 2.01, 17.9, 195 Ω

18.25 10.1, 252 kΩ, 358 Ω

18.27 2.66 Ω; (32.2 Ω, 0, 11.1)

18.29 132 Ω; (13.0 kΩ, 0, 97.6)

18.31 0.9989, 106.4 MΩ, 3.301 Ω vs. 0.999, 131 MΩ, 4.53 Ω

18.33 −36.0 kΩ, 7.60 Ω, 0.262 Ω

18.35 37.0 Ω, 50.4 Ω, −43.1 kΩ

18.37 34.1 kΩ, 1.72 kΩ, -625 kΩ

18.39 0.133 mS, 60.4 MΩ, 26.8 MΩ

18.41

SPICE Results: $A_{tc} = 9.92x10^{-5}\ S \quad R_{in} = 144.1\ M\Omega \quad R_{out} = 11.91\ M\Omega$

Hand Calculations: $A_{tc} = 9.92x10^{-5}\ S \quad R_{in} = 148\ M\Omega \quad R_{out} = 11.1\ M\Omega$

18.43 0.468 mS, 95.1 MΩ

18.44 10.1, 17.9 Ω, 3.34 MΩ

18.46 50.0 Ω, 5.63 MΩ, 0.993

18.47 14.92 MΩ, 399.8 MΩ, 540.1 MΩ

18.49 2.97, 14.5 Ω, 24.3 MΩ; 2.99, 14.6 Ω, 18.1 MΩ

18.51 30.39 GΩ; 33.3 GΩ

18.53 47.32 MΩ; 37.5 MΩ

18.55 $T_v = 106.3,\ T_i = 15.93,\ T = 13.62,\ R_2/R_1 = 6.34$

18.57 $T_v = 1472,\ T_i = 168,\ T = 150.6,\ R_2/R_1 = 8.716$

18.59 110 kHz, 2048, ≤ 2048

18.61 285 pF

18.63 76.6^o

18.65 107^o

18.69 6.63 MHz, 20.8 V/μS

18.72 (b) 95 MHz, 30 V/μS

18.74 ±8.57 V/μS, SPICE +8.1 V/μS, -8.8 V/μS

18.76 71.5 MHz, 11.3 kHz, 236 MHz, 326 MHz, 300 MHz; 84.4 dB; < 0; 16.8 pF

18.78 11.9 kΩ; 9.04 MHz, 101 MHz, 66.8 MHz, 286 MHz; 10.0 MHz, 11.3 pF

18.79 (a) 37^o

18.82 6.32 pF; 315 MHz, 91.4 MHz; 89.4^o

18.85 15.9 MHz; [18.4 MHz, 33.1 MHz]; 0.211 mS, 5.28 μA

18.86 5.45 MHz, 4.78 MHz

18.88 10.3 MHz, 1.18

18.90 7.96 MHz, 8.11 MHz, 1.05

18.92 7.5 MHz, 80 $V_{p\text{-}p}$

18.93 7.96 MHz

18.94 11.1 MHz, 18.1 MHz, 1.00

18.95 $L_{EQ} = L_1 + L_2 \quad | \quad R_{EQ} = -\omega^2 g_m L_1 L_2$

18.97 $\omega_o = \dfrac{1}{\sqrt{(L_1 + L_2 + 2M)C}}$

18.99 $\omega_o^2 = \dfrac{1}{L(C + C_{GS} + 4C_{GD})} \quad | \quad \mu_f \geq 1 + \dfrac{r_o}{R_P}$

18.101 5.13 pF; 1 GHz can't be achieved.

18.102 4.33 pF; 2.81 mA; 3.08 mA; 1.32 V

18.104 15.915 mH, 15.915 fF; 10.008 MHz, 10.003 MHz

18.106 9.281 MHz, 9.192 MHz

18.111 16.3 MHz