MICROELECTRONIC CIRCUIT DESIGN

Fourth Edition

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Answers to Selected Problems – Updated 2/27/11

Chapter 1

1.4 1.52 years, 5.06 years

1.5 1.95 years, 6.46 years

1.8 402 MW, 1.83 MA

1.10 2.50 mV, 5.12 V, 5.885 V

1.12 19.53 mV/bit, 10011000_2

1.14 14 bits, 20 bits

1.16 0.003 A, 0.003 cos (1000*t*) A

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

1.20 15.7 V, 2.32 V, 75.4 μA, 206 μA

1.22 150 μA, 150 μA, 12.3 V

1.24 39.8 Ω, 0.0251 v_s

1.27 56 kΩ, 1.60×10^{-3} v_s

1.29 1.50 MΩ, 7.50×10^{8} i_i

1.36 $50\underline{/-12°}$, $10\underline{/-45°}$

1.38 -82.4 sin 750πt mV, 11.0 sin 750πt μA

1.40 1 + R_2/R_1

1.42 -1.875 V, -2.500 V

1.43 Band-pass amplifier

1.45 50.0 sin (2000*πt*) + 30.0 cos (8000 *πt*) V

1.48 0 V

1.47 [4653 Ω, 4747 Ω], [4465 Ω, 4935 Ω], [4230 Ω, 5170 Ω]

1.55 6200 Ω, 4.96 Ω/^{o}C

1.61 3.29, 0.995, −6.16; 3.295, 0.9952, −6.155

Chapter 2

2.3 500 mA

2.4 160 Ω, 319 Ω

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

2.9 305.2 K

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 $1.60 \text{ x } 10^6$ A/cm^2, $1.60 \text{ x } 10^{-10}$ A/cm^2

2.13 4 MA/cm^2

2.16 $1.60 \text{ x } 10^7$ A/cm^2, 4.00 A

2.17 316.6 K

2.22 Donor, acceptor

2.23 200 V/cm

2.25 $1.25 \text{ x } 10^4$ atoms

2.27 p-type, $6 \text{ x } 10^{18}$/cm^3, 16.7/cm^3, $5.28 \text{ x } 10^9$/cm^3, $8.80 \text{ x } 10^{-10}$/cm^3

2.29 $3 \text{ x } 10^{17}$/cm^3, 333/cm^3

2.30 $4 \text{ x } 10^{16}$/cm^3, $2.50 \text{ x } 10^5$/cm^3

2.34 40/cm^3, $2.5\text{x}10^{18}$/cm^3, 170 cm^2/s, 80 cm^2/s, p-type, 31.2 mΩ-cm

2.36 10^{16}/cm^3, 10^4/cm^3, 800 cm^2/s, 220 cm^2/s, n-type, 2.84 Ω-cm

2.38 $1.16 \text{ x } 10^{20}$/cm^3

2.40 $1.24 \text{ x } 10^{19}$/cm^3

2.41 Yes—add equal amounts of donor and acceptor impurities. Then $n = n_i = p$, but the mobilities are reduced. See Prob. 2.44.

2.43 $6.27 \text{ x } 10^{21}$/cm^3, $6.22 \text{ x } 10^{21}$/cm^3

2.46 2.00/Ω-cm, $2.50 \text{ x } 10^{19}$/cm^3

2.48 75K: 6.64 mV, 150K: 12.9 mV, 300K: 25.8 mV, 400K: 34.5 mV

2.49 -28.0 kA/cm^2

2.50 $1.20\text{x}10^5$ exp (-5000 x/cm) A/cm^2, 12.0 mA

2.54 1.108 μm

2.57 8 atoms, $1.60\text{x}10^{-22}$ cm^3, $5.00\text{x}10^{22}$ atoms/cm^3, $3.73\text{x}10^{-23}$ g, $1.66\text{x}10^{-24}$ g/proton

Chapter 3

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

3.4 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

3.10 640 kA/cm^2

3.13 1.00×10^{21}/cm^4

3.17 290 K

3.20 312 K

3.21 1.39, 3.17 pA

3.22 0.791 V; 0.721 V; 0 A; 9.39 aA, -10.0 aA

3.25 1.34 V; 1.38 V

3.28 0.518 V; 0.633 V

3.29 335.80 K, 296.35 K

3.33 0.757 V; 0.717 V

3.35 −1.96 mV/K

3.39 0.633 V, 0.949 μm, 3.89 μm, 12.0 μm

3.40 374 V

3.42 4 V, 0 Ω

3.44 10.5 nF/cm^2; 232 pF

3.46 800 fF, 20 fC; 20 pF, 0.5 pC

3.50 9.87 MHz; 15.5 MHz

3.51 0.495 V, 0.668 V

3.53 0.708 V, 0.718 V; 0.808 V

3.58 (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);

3.61 (0.600 mA, -4 V) , (0.950 mA, 0.5 V) , (-2.00 mA, -4 V)

3.68 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)

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

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

3.76 (b) (0.990 mA, 0 V) (0 mA, -1.73 V) (1.09 mA, 0)

(c) (0 A, -0.667 V) (0 A, -1.33 V) (1.21 mA, 0 V)

3.79 (1.50 mA, 0 V) (0 A, -5.00 V) (1.00 mA, 0)

3.82 (I_Z, V_Z) = (887 μA, 4.00 V)

3.84 12.6 mW

3.86 1.25 W, 3.50 W

3.91 17.6 V

3.95 -7.91 V, 1.05 F, 17.8 V, 3530 A, 840 A (ΔT = 0.628 ms)

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

3.99 6.06 F, 8.6 V, 3.04 V, 962 A, 9280 A

3.104 -24.5 V, 1.63 F, 50.1 V, 15600 A, 2200 A

3.107 3.03 F, 8.6 V, 3.04 V, 962 A, 3770 A

3.112 2380 μF, 2800 V, 1980 V, 126 A, 2510 A

3.119 5 mA, 4.4 mA, 3.6 mA, 5.59 ns

3.123 (0.969 A, 0.777 V); 0.753 W; 1 A, 0.864 V

3.125 1.11 μm, 0.875 μm; far infrared, near infrared

Chapter 4

4.3 10.5 x 10^{-9} F/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) 4.00 mA/V^2, 8.00 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 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

4.30 2.48 mA; 2.25 mA

4.34 9.03 mA, 18.1 mA, 10.8 mA

4.37 1.13 mA; 1.29 mA

4.39 Triode region

4.40 99.5 μA; 199 μA; 99.5 μA; 99.5 μA

4.44 202 μA; 184 μA

4.46 5.17 V

4.51 40.0 μA; 72.0 μA; 4.41 μA; 32.8 μA

4.53 5810/1; 2330/1

4.56 235 Ω; 235 Ω

4.57 0.629 A/V^2

4.58 400 μA

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

4.65 (a) 6.09 x 10^{-8} F/cm^2; 1.73 fF

4.67 17.3 pF/cm

4.69 20.7 nF

4.71 (a) 1.35 fF, 0.20 fF, 0.20 fF

4.74 50U, 0.5U, 2.5U, 1V, 0

4.77 10U, 0.5U, 25U, 1V, 0

4.79 432 μA/V^2, 1.94 mA; 864 μA/V^2, 0.972 mA

4.82 6.37 GHz, 2.55 Ghz; 637 GHz, 255 GHz

4.85 22λ x 12λ; 15.2%

4.88 12λ x 12λ; 15.2%

4.89 (350 μA, 1.7 V); triode region

4.92 (390 μA, 4.1 V); saturation region

4.95 (572 μA, 7.94 V); (688 μA, 7.52 V)

4.97 (50.3 μA, 8.43 V) ; (54.1 μA, 8.16 V)

4.102 (a) (116 μA, 4.15 V)

4.105 510 kΩ, 470 kΩ, 12 kΩ, 12 kΩ, 5/1

4.107 (124 μA, 2.36 V)

4.109 620 kΩ, 910 kΩ, 2.4 kΩ, 2.7 kΩ

4.111 (109 μA, 1.08 V)**;** (33.5 μA, 0.933 V)

4.113 (42.6 μA, 0.957 V); (42.6 μA, 0.935 V)

4.115 8.8043x10^{-5} A; 8.323310^{-5} A

4.118 (73.1 μA, 9.37 V)

4.119 (69.7 μA, 9.49 V); (73.1 μA, 8.49 V)

4.122 (8.17 μA, 7.06 V), (6.74 μA, 7.57 V); (8.36 μA, 6.99 V), (6.89 μA, 7.52 V)

4.124 (91.5 μA, 8.70 V), (70.7 μA, 9.23 V); (97.8 μA, 8.48 V), (81.9 μA, 9.05 V)

4.125 2.25 mA; 16.0 mA; 1.61 mA

4.127 (322 μA, 3.18 V),

4.129 18.1 mA; 45.2 mA; 13.0 mA

4.131 1/3.84

4.132 (153 μA, -3.53 V) ; (195 μA, -0.347 V)

4.134 4.04 V, 10.8 mA; 43.2 mA; 24.5 mA; 98.0 mA

4.135 14.4 mA; 27.1 mA; 10.4 mA

4.137 (1.13 mA, 1.75 V)

4.138 (63.5 μA, -5.48 V) , R ≤ 130 kΩ

4.140 (55.3 μA, -7.09 V) , R ≤ 164 kΩ

4.143 22.3 kΩ → (127 μA, -5.50 V)

4.146 35.2 μA , $R \leq 318$ kΩ

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

4.149 (281 μA, -12.2 V)

4.151 (32.1 μA, -1.41 V)

4.153 (36.1 μA, 80.6 mV); (32.4 μA, -1.32 V); (28.8 μA, -2.49 V)

4.155 (431 μA, 6.47 V)

4.156 2.5 kΩ, 10 kΩ

4.157 I_D = 1.38 mA, I_G = 0.62 mA, V_S = -0.7 V

4.159 (76.4 μA, 7.69 V), (76.4 μA, 6.55 V), 5.18 V

4.160 (a) (69.5 μA, 3.52 V)

4.162 (69.5 μA, 5.05 V); (456 μA, 6.20 V),

4.167 10.0 V; 10.0 mA, 501 mA; 13.8 V

4.169 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 0.2 fA; 0.101 fA, –0.115 V

5.6 0.374 μA, -149.6 μA, +150 μA, 0.626 V

5.9 0.404 fA

5.11 1.45 mA; –1.45 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 (a) 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 5 V, 60 V, 5 V

5.35 2.31 mA; 388 μA; 0

5.36 60.7 V

5.40 Cutoff

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

5.46 25.0 aA, 1.33 aA, 26.3 aA

5.47 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 $I_C \cong \beta_F I_B$

5.48 79.0, 6.83 fA

5.49 83.3, 1.73 fA

5.50 55.3 μA, 0.683 μA, 54.6 μA

5.51 6.67 MHz; 500 MHz

5.53 1.5, 31.1 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 0.768 V, 0.680 V, 27.5 mV

5.65 24.2 μA

5.66 4.0 fF; 0.4 pF; 40 pF

5.68 750 MHz, 3.75 MHz

5.71 0.149 μm

5.72 71.7, 43.1 V

5.74 74.1, 40.0 V

5.75 100 μA, 4.52 μA, 95.5 μA, 0.651 V, 0.724

5.77 26.3 μA

5.78 (c) 33.1 mS

5.79 0.388 pF at 1 mA

5.81 (b) 38% reduction

5.83 (80.9 μA, 3.80 V) ; (405 μA, 3.80 V); (16.2 μA, 3.80 V) ; (81.9 μA, 3.72 V);

5.88 (38.8 μA, 5.24 V)

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

5.93 12 kΩ, 20 kΩ, 2.4 kΩ, 1.2 kΩ; (0.870 mA, 1.85 V)

5.95 (7.5 mA, 4.3 V)

5.97 (5.0 mA, 1.3 V)

5.99 30 kΩ, 620 kΩ; 24.2 μA, 0.770 V

5.101 5.28 V

5.103 3.21 Ω

5.104 10 V, 100 mA, 98.5 mA, 10.7 V

5.105 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, 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 0.152 μW/gate, 22.7 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 1 0 1 0 1 0 1

6.27 Z = 0 0 0 1 0 0 1 1

6.30 2 ; 1

6.32 84.5 A

6.33 0.583 pF

6.37 3 μW/gate, 1.67 μA/gate

6.38 72 kΩ, 1/1.04

6.39 (b) 2.5 V, 5.48 mV, 15.6 μW

6.43 (a) 0.450 V, 1.57 V

6.46 (a) 0.521 V, 1.81 V

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

6.51 34.1 kΩ; 1.82/1; 1.49 V, 0.266 V

6.53 81.8 kΩ, 1/1.15

6.54 250 Ω; 625 Ω; a resistive channel exists connecting the source and drain; 20/1

6.55 1.44 V

6.57 2.17 V

6.58 1.55 V, 0.20 V, 0.140 mW, 0.260 mW

6.62 2.5 V, 0.206 V, 0.434 mW

6.65 1.40/1, 6.67/1

6.67 (b) 2.43/1, 1/3.97

6.69 0.106 V

6.71 1.55 V, 0.20 V, 0.150 mW

6.74 -2.40 at v_O = 0.883 V

6.75 -2.44 at v_O = 1.08 V

6.77 3.79 V

6.79 3.3 V, 0.296 V, 1.25 mW

6.82 1.75/1, 1/8.79

6.84 1.014

6.85 1.46/1, 1.72/1

6.86 2.5 V, 0.2 V, 0.16 mW

6.89 -5.98 at v_O = 1.24 V

6.90 1.80/1, 0.610 V, 0.475 V

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

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

6.95 1.65/1, 1/2.32, 0.300 V, 0.426 V

6.97 0.103 V, 84.5 μA

6.98 0.196 V

6.102 2.22/1, 1.81/1

6.103 2.22/1, 1.11/1, 0.0643 V

6.104 6.66/1, 1.11/1, 0.203 V, 6.43/1, 6.74/1, 7.09/1

6.107 $Y = \overline{(A+B)(C+D)E}$, 6.66/1, 1.11/1

6.111 $Y = \overline{ACE + ACDF + BF + BDE}$, 3.33/1, 26.6/1, 17.8/1

6.115 1/1.80, 3.33/1

6.117 $Y = \overline{(C+E)[A(B+D)+G]+F}$; 3.62/1, 13.3/1, 4.44/1, 6.67/1

6.120 3.45/1, 6.43/1, 7.09/1, 6.74/1

6.122 1.11/1, 7.09/1, 6.43/1, 6.74/1

6.124 64.9 mV

6.126 (a) 5.43/1, 9.99/1, 6.66./1, 20.0/1

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

6.132 $I_D^* = 2I_D$ | $P_D^* = 2P_D$

6.133 80 mW, 139 mW

6.134 1 ns

6.137 60.2 ns, a potentially stable state exists with no oscillation

6.139 31.7 ns, 4.39 ns, 5.86 ns

6.141 5.50 kΩ, 11.6/1

6.144 68,4 ns, 3.55 ns, 9.18 ns

6.146 47.1 ns, 6.14 ns, 5.39 ns

6.148 2.11/1, 16.7/1, 12.8 ns, 0.923 ns

6.149 2.68/1, 3.29/1, 884 μW

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

6.152 −1.90 V, −0.156 V

6.153 1/3.30, 1.75/1

6.154 2.30 V, 1.07 V

6.156 $Y = \overline{A + B}$

Chapter 7

7.1 173 μA/V^2 ; 69.1 μA/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

7.12 0.90 V; 16.0 μA; 0.810 V; 96.2 μA

7.14 1.104 V

7.15 (b) 2.5 V, 92.8 mV

7.17 1.16 V, 0.728 V

7.18 0.810 V

7.22 0.9836 V, 2.77 mA

7.23 6.10/1, 1/5.37

7.24 (a) 1.89 ns, 1.89 ns, 0.630 ns

7.27 9.47 ns, 3.97 ns, 2.21 ns

7.31 2.11/1, 5.26/1

7.33 63.2/1, 158/1

7.35 6.00/1, 15.0/1

7.38 2.76/1

7.41 1.7 ns, 2.3 ns, 1.1 ns, 0.9 ns, $\langle C \rangle$ = 138 fF

7.43 0.200 μW/gate; 55.6 A

7.44 1.0 μW/gate; 18.4 fF; 32.0 fF; 61.7 fF

7.46 5.00 W; 8.71 W

7.49 90.3 μA; 25.0 μA

7.52 436 fJ; 425 MHz; 926 μW

7.55 $\alpha\Delta T$, $\alpha^2 P$, $\alpha^3 PDP$

7.58 SPICE: 22.3 ns, 24.2 ns, 16.3 ns, 18.3 ns; Propagation delay formulas: 7.6 ns, 6.9 ns

7.59 2/1, 20/1; 6/1, 60/1

7.61 1/3.75

7.63 1.25/1

7.70 3.95 ns, 3.95 ns, 11.8 ns

7.71 4.67/1; 7.5/1

7.72 5 transistors; The CMOS design requires 47% less area.

7.74 $Y = \overline{(A+B)(C+D)E} = \overline{ACE + ADE + BDE + BCE}$; 12/1, 20/1, 10/1; 2.4/1; 30/1

7.76 $Y = (\overline{A}+\overline{B})(\overline{C}+\overline{D})(\overline{E}+\overline{F}) = \overline{AB + CD + EF}$; 4/1, 15/1; 6/1; 10/1

7.78 2/1, 4/1, 6/1, 20/1

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

7.83 24/1, 20/1, 40/1

7.84 6/1, 4/1, 10/1

7.91 5.37 ns, 1.26 ns

7.93 1.26 ns, 0.737 ns, 4.74 ns, 4.16 ns

7.95 4.74 ns, 2.37 ns

7.103 $V_{DD} \rightarrow \frac{2}{3}V_{DD} \rightarrow \frac{1}{2}V_{DD}$; $R \geq \frac{2V_{IH}}{V_{DD} - V_{IH}} = \frac{2V_{IH}}{NM_H}$, $C_1 \geq 83.1C_2$

7.109 8; 2.90; 23.2 A_o

7.112 $A_o \frac{\beta^N - 1}{\beta - 1}$

7.113 263 Ω; 658 Ω

7.116 240/1, 96.2/1

7.117 1.41 V, 2.50 V

7.119 Latchup does not occur.

7.122 +0.25; +0.31

7.124 211,000/1; 0.0106 cm^2

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

8.11 "1" level is discharged by junction leakage current

8.13 1.47 V, 1.43 V

8.14 −19.8 mV; 2.48 V

8.16 0 V, 1.90; Junction leakage will destroy the "1" level

8.18 5.00 V, 1.60 V; −1.84 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

8.37 $V_{DD} \rightarrow \frac{2}{3}V_{DD} \rightarrow \frac{1}{2}V_{DD}$; $R \geq \frac{2V_{IH}}{V_{DD} - V_{IH}} = \frac{2V_{IH}}{NM_H}$; $C_1 \geq 2.88C_2$

8.41 $W_1 = 01000110_2$, $W_3 = 00101011_2$

8.45 1.16/1

Chapter 9

9.1 0 V, -0.700 V

9.2 (a) -1.38 V, -1.12

9.3 −1.50 V, 0 V

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; 0.289 V; −0.10 V, +0.30 V

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

9.15 11

9.16 11.1 kΩ, 12.0 kΩ, 70.2 kΩ, 252 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

9.23 0.413 V

9.25 50.0 μA, -2.30 V

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

9.30 +0.300 V, −0.535 V, 334 Ω

9.33 5.15 mA

9.36 0.135 mA

9.38 10.7 mA

9.40 400 Ω, 75.0 mA

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

9.45 $Y = A + \overline{B}$

9.47 −0.850 V; 3.59 pJ

9.49 359 ns

9.50 0 V, −0.600 V, 5.67 mW, 505 Ω, 600 Ω; $Y = A + B + C$, 5 vs. 6

9.53 5.00 kΩ, 5.40 kΩ, 31.6 kΩ, 113 kΩ

9.54 1 kΩ, 1 kΩ, 1.30 mW

9.56 2.23 kΩ, 4.84 kΩ, 60.1 kΩ

9.59 1.446 mA, 1.476 mA, 29.66 μA; 1.446 mA, 1.476 mA, 29.52 μA

9.61 -0.9 V, -1.1 V, -1.8 V, -2.0 V, -2.7 V, -2.9 V, -4.2 V

9.64 $Y = AB + \overline{A}\overline{C}$

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

9.69 2.98 pA, 70.5 fA

9.71 160; 0.976; 0.976; 0.773 V

9.72 0.691 V, 0.710 V

9.76 63.3 μA, 265 μA

9.78 40.2 mV, 0.617 mV

9.80 20.6 mW, 4.22 mW

9.82 68.2 mV

9.83 2.5 V, 0.15 V, 0.66 V, 0.80 V

9.85 44.8 kΩ, 22.4 kΩ

9.88 5 V, 0.15 V, 0, −1.06 mA; 31; −1.06 mA vs. −1.01 mA, 0 mA vs. 0.2 mA

9.95 8

9.97 $R_B \geq 5$ kΩ

9.99 7

9.100 234 mA, 34.9 mA

9.104 (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

9.107 180

9.108 22

9.111 1.85 V, 0.15 V; 62.5 μA, −650 μA; 13

9.113 $Y = \overline{ABC}$; 1.9 V; 0.15 V; 0, −408 μA

9.115 1.5 V, 0.25 V; 0, −1.00 mA; 16

9.116 0.7 V, 191 μA, 59 μA, 1.18 mA

9.117 -1.13 mA, 0, 4.50 mA, 0, 0, 1.80 mA; 0, 0, 0, 0, 1.23 mA, 0

9.119 $Y = A + B + C$; 0 V, −0.8 V; −0.40 V

9.121 1.05 mA, 26.9 μA

9.122 2 fJ; 10 fJ

9.124 1.67 ns; 0.5 mW

9.126 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 29.0 dB, 105 dB, 67.0 dB

10.9 19.0 dB, 87.0 dB, 53.0 dB; V_o = 8.94 V, recommend ±10-V or ±12-V supplies

10.11 3.61 x10^{-8} S, -7.93 x10^{-3}, 1.00, 79.3 Ω

10.13 0.333 mS, -0.333, -1600, 1.78 MΩ

10.15 1.00 mS, −1.00, 3001, 30.0 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 −5440

10.23 0, ∞, 80 mW, ∞

10.24 182

10.29 −10 (20 dB), 0.1 V; 0, 0 V

10.31 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

10.37 59.7 dB, 119 dB, 88.9 dB; 5.66 mV

10.41 R_{id} ≥ 4.95 MΩ

10.43 50 μV, 140 dB

10.44 (a) −46.8, 4.7 kΩ, 0, 33.4 dB

10.47 (d) (-1.10 + 0.75 sin 2500πt) V

10.49 $(a)\ v_O = \left(4.00 - 20V_i \sin 2000\pi t\right)\ V \quad (b)\ 0.3\ V$

10.53 30.1 kΩ, 604 kΩ A_v = -20.1, R_{in} = 30.1 kΩ

10.56 -70.0, 10 kΩ, 0

10.59 2 MΩ

10.60 83.9, ∞, 0, 38.5 dB

10.63 (d) (5.28 – 2.88 sin 3250πt) V

10.67 2 kΩ, 86.6 kΩ, $A_v = 44.3$

10.69 (-0.47 sin 3770*t* –0.94 sin 10000*t*) V, 0 V

10.70 –0.3750 sin 4000πt V; –0.6875 sin 4000πt V; 0 to –0.9375 V in - 62.5-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 3.2 V, 3.1 V, 2.82 V, 2.82 V, -1.00 V; 3.82 μA; 3.80 μA, 2.80 μA

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

10.77 80 dB, ∞, 100 Hz, ∞, high-pass amplifier

10.81 60 dB, 100 kHz, 28.3 Hz, 100 kHz

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

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

10.89 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

10.92 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

10.94 $A_v(s) = \frac{2x10^8\pi}{s+10^7\pi}$ | $A_v(s) = -\frac{2x10^8\pi}{s+10^7\pi}$

10.96 66 dB, 12.8 kHz, -60 dB/decade

10.97 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)
```

10.98 -4.44 dB, 26.5 kHz

10.100 10 kΩ, 0.015 μF

10.103 80 dB, 100 Hz

10.105 -1.05 dB, 181 Hz

10.107 (b) -20.7, 105 kHz

10.108 10.5 kΩ, 105 kΩ, 0.015 μF

10.113 T(s) = -sRC

10.116 −6.00, 20.0 kΩ, 0; +9.00, 91.0 kΩ, 0; 0, 160 kΩ, 0

10.117 1 A, 2.83 V, > 10 W (choose 15 W)

10.118 0.484 A; 0.730 V; 0.730 V; ≥ 7.03 W (choose 10 W), 7.27 W

Chapter 11

11.1 (c) 4, 5.00, 4.00, 20 %

11.3 120 dB

11.4 1/(1+Aβ); 9.99×10^{-3} percent

11.5 (a) 13.49, 9.11×10^{-3}, 0.0675%

11.7 120 dB

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

11.13 103 dB

11.16 100 μA, 100 μA, -48.0 pA, +48.0 pA

11.17 (a) 13.5, 296 MΩ, 135 mΩ

11.19 (a) -17.4, 2.70 kΩ, 36.8 mΩ

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

11.24 $145V_s$, 3.56 Ω

11.25 ≤ 0.75 %

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

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

11.32 122 dB, 31.5 S

11.33 9.96, 6.55 MΩ, 3.19 Ω

11.35 9130, 3.00, 3.00, 369 MΩ, 0.398 Ω

11.37 (c) -T/(1+T)

11.39 -9.998 kΩ, 1.200 Ω, 0.1500 Ω

11.41 -35.99 kΩ, 4.418 Ω, 0.2799 Ω

11.44 -99.91 μS, 50.04 MΩ, 17.79 MΩ

11.49 $10000s/(s+5000), \quad 10000/(2s+1)$

11.54 1.100, 1.899 Ω, 24.65 MΩ

11.56 10.96, 35.12 Ω, 3.461 MΩ

11.57 680.4, 0.334

11.59 330, 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

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

11.70 -6.2 V, 0 V; 10 V, -1.19 V

11.72 -5.00 V, 0 V; -10.0 V, 0.182 V

11.74 10 V, 0 V; 15 V, 0.125 V

11.77 110 Ω and 22 kΩ represent the smallest acceptable resistor pair.

11.79 39.2 Ω

11.81 0 V, 3 V; 0.105 V; 0 V; 49.0 dB

11.83 (d) [-0.313 sin 120πt - 4.91 sin 5000πt] V

11.85 (b) 124 dB

11.86 60 dB

11.87 20.0 kΩ, 56.0 kΩ

11.89 20 Hz

11.91 50 Hz; 5 MHz; 2.5 MHz

11.93 200; 199

11.95 80 dB, 1 kHz, 1 MHz; 101 MHz, 9.90 Hz; 251 MHz, 3.98 Hz

11.97 100 dB, 1 kHz, 1 MHz; 8.4 Hz, 119 MHz; 5.3 Hz, 188 MHz

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

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

11.105 $A_v\left(s\right)=-\dfrac{3.285x10^{12}}{s^2+1.284x10^7 s+1.675x10^{11}}$; (2 poles: 2.08 kHz and 2.04 MHz)

11.107 $A_v\left(s\right)=-\dfrac{6.283x10^{10}}{s^2+3.142x10^7 s+6.283x10^5}$; (2 poles: 3.18 mHz and 5.00 MHz)

11.109 6.91, 7.53, 6.35; 145 kHz, 157 kHz, 133 kHz

11.111 2.51 V/μs; 2.51 V/□s

11.113 10 V/μs

11.117 10^{10} Ω, 7.96 pF, $4x10^6$, R_o not specified

11.119 90.6°; 90.2°

11.120 8.1°; 5.1°

11.122 110 kHz; A ≤ 2048; larger

11.123 Yes, but almost no phase margin; 0.4°

11.125 75° versus 90°**;** 65° versus 90°

11.128 5 MHz, 90.0°; 2.5 MHz, 90.0°

11.130 $A_v(s) = -\dfrac{5.712x10^6 s}{s^2 + 5.741x10^5 s + 1.763x10^{10}}$; 143°

11.132 Yes, but almost no phase margin; 1.83°

11.134 90.0°

11.136 12°**;** Yes, 50°

11.141 Yes, 24.4°, 50 %

11.143 1.8°

11.144 38.4°, 31 %

11.147 133 pF

11.149 90.4°

11.152 (a) 72.2°

11.153 (a) 11.9 MHz, 5.73°, 85.4%

11.155 **(**a) 70.2, 23.4%

11.157 (a) 18.8 MHz

Chapter 12

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

12.3 -8000, 2 kΩ, 0

12.5 48.0, 968 MΩ, 46.5 mΩ

12.7 78.1 dB, 2.00 kΩ, 0.105 Ω

12.8 (c) 2.00 mV, -40.0 mV, 4.00 μV, 0.800 V, 80.0 μV, 0 V, -12.0 V, 0.190 V, 0V (ground node)

12.11 -1080, 3.9 kΩ, 0

12.12 8.62 kΩ, 8.62 kΩ

12.16 2744, 2434, 3094, 1 MΩ, 1.02 MΩ, 980 kΩ, 0

12.17 -1320, 75 kΩ, 0; 5.00 mV, 5.00 mV, 55.0 mV, 0 V, -1.10 V, -1.10 V, -6.60 V, 0V (ground node)

12.19 50.0, 298 kHz; 48.0, 349 kHz; -42.0, 368 kHz

12.21 14.0, 286 kHz, 68.8 dB, 146 kHz

12.23 -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

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 + 1.20 sin 4000πt) V

12.38 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, 0.002, -50.0, 88 dB

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

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, 23.2 kΩ

12.49 (a) 51.2 kHz, 7.07, 7.24 kHz

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

12.54 5.48 kHz, 4.09, 1.34 kHz

12.56 10 kΩ, 100 kΩ, 20 kΩ, 0.0133 μF

12.58 $T = +K \dfrac{\dfrac{s}{R_2 C_2}}{s^2 + s\left[\dfrac{1}{R_2 C_2} + \dfrac{1}{(R_1 \| R_2) C_1}\right] + \dfrac{1}{R_1 R_2 C_1 C_2}}$

12.64 -5.5 V, -5.5, 10 %; -5.0 V, -5.0, 0

12.66 12.6 kHz, 1.58, 7.97 kHz

12.69 (a) -1-125 V (b) -1.688 V

12.70 10.6 mV, 5 %

12.73 455/1, 50/1

12.74 0.31 LSB, 0.16 LSB

12.76 1.43%, 2.5%, 5%, 10%

12.77 11 resistors, 1024:1

12.79 **(a)** 1.0742 kΩ, 0.188 LSB, 0.094 LSB

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

12.84 (b) 2.02 inches

12.85 3.415469 V ≤ V_X ≤ 3.415781 V

12.86 1.90735 μV, 11010000101000111101_2, 01111111100111011101_2

12.89 0001011111_2, 95 μs

12.91 800 kHz, 125 ns

12.93 $v_O(t) = 2.5x10^5\left(1 - \exp\dfrac{-t}{5x10^4 RC}\right)$ for $t \geq 0$ | $RC \geq 0.0447\ s$

12.94 19.1 ns

12.97 1/RC, 2R

12.98 0.5774/RC, 1.83

12.100 60 kHz, 6.8 V

12.102 17.5 kHz, 11.5 V

12.106 0.759 V

12.107 2.4 Hz

12.112 $V_O = -V_1V_2/10^4I_S$

12.113 3.11 V, 2.83 V, 0.28 V

12.115 0.445 V, -0.445 V, 0.89 V

12.117 9.86 kHz

12.118 $V_O = 0$ is a stable state, so the circuit does not oscillate. f = 0.

12.120 0, 0.298 V, 69.0 mV

12.122 13 kΩ, 30 kΩ, 51 kΩ, 150 pF

Chapter 13

13.1 (0.700 + 0.005 sin $2000\pi t$) V, -1.03 sin $2000\pi t$ V, (5.00 −1.03 sin $2000\pi t$) 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.

13.13 (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 (1.46 mA, 5.36 V)

13.18 (19.2 μA, 6.37 V)

13.20 (62.2 μA, 43.65 V)

13.24 (91.3 μA, 6.05 V)

13.28 (245 μA, 3.73 V)

13.32 (423 μA, -6.76 V)

13.34 (1.25 mA, 8.63 V)

13.46 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

13.51 118 Ω, 3.13 TΩ, ≤ -28.5 mV

13.52 **(c)** 8.65 Ω

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

13.54 (c) 1.25 μA

13.55 (213 μA, ≥ 0.7 V), 8.52 mS, 469 kΩ

13.60 (b) +16.7%, -13.6%

13.61 90, 120; 95, 75

13.66 [−76.7, −75.8]

13.68 -40.0

13.72 −90

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

13.76 3

13.77 20 mA; 24.7 V

13.78 0.500 V

13.79 No, there will be significant distortion

13.80 −263

13.85 32/1, 0.500 V

13.86 0.800 A

13.87 10%, 20%

13.90 (78 μA, 9 V)

13.91 Virtually any desired Q-point

13.92 $400 = 133{,}000 i_P + v_{PK}$; (1.4 mA, 215 V); 1.6 mS, 55.6 kΩ, 89.0; -62.7

13.93 FET

13.94 BJT

13.95 37.5 μA, 2400

13.96 2000, 200, 8.00 mS, 0.800 mS

13.99 23.5 dB

13.101 (142 μA, 7.5 V)

13.102 0.300 V

13.103 1.0 V, 56 V

13.105 3

13.107 −11.0

13.110 −7.28

13.115 29.4 kΩ, 93.4 kΩ

13.118 833 kΩ, 1.46 MΩ

13.120 243 kΩ, 40.1 kΩ

13.122 6.8 MΩ, 45.8 kΩ, independent of K_n

13.124 1 MΩ, 3.53 kΩ

13.125 $-281v_i$, 3.74 kΩ

13.127 $-23.6v_i$, 508 kΩ

13.129 38.9 dB, 6.29 kΩ, 9.57 Ω

13.131 36.4 dB, 62.9 kΩ, 95.7 kΩ

13.135 138 μW, 182 μW, 1.28 mW, 0.780 mW, 0.820 mW, 3.19 mW

13.139 0.552 mW, 0.684 mW, 0.225 mW, 18.7 μW, 50.4 μW, 1.53 mW

13.142 $V_{CC}/15$

13.143 3.38 V, 13.6 V

13.144 $(V_{CC})^2/8R_L$, $(V_{CC})^2/2R_L$, 25%

13.145 0.992 V

13.147 2.24 V

13.148 1.65 V

13.149 2.93 V

13.153 833 μA

13.154 -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

14.14 −32.6, 9.58 kΩ, 596 kΩ, -27.1; −17.2, 11.6 kΩ, 1060 kΩ, -17.1

14.15 −3.77, 2 MΩ, 26.5 kΩ, -3770; −8.03, 2 MΩ, 10.0 kΩ, -10000

14.16 (a) −6.91 (e) −240

14.17 3.3 kΩ, 33 kΩ

14.20 −178, -□58, 21.4 kΩ, 39 kΩ, 5.13 mV

14.21 121, -□62, 2.84 kΩ, 7.58 kΩ, 6.76 mV, -120

14.22 −12.3, −9.62, 368 kΩ, 82 kΩ, 141 mV, -7.50

14.24 -2.74, -762, 10 MΩ, 1.80 kΩ, 0.800 V

14.25 -3790, -5.44, 1.30 kΩ, 68.5 kΩ, 5.96 mV

14.27 0.747, 29.8 kΩ, 104 Ω, 29.7

14.28 0.896, 2 MΩ, 125 Ω, 16,000

14.29 0.987, 44.8 kΩ, 15.2 Ω, 1.54 V

14.30 0.960, 1 MΩ, 507 Ω, 6.19 V

14.31 0.992, 12.6 MΩ, 1.32 kΩ, 0.601 V

14.32 □□□, 7.94 MΩ, 247 Ω, ∞

14.33 $v_i \le \left(0.005 + 0.2V_{R_E}\right)$ V

14.35 0.9992, 30.1 V

14.37 190, 980 Ω, 2.52 MΩ, 0.990; 62.1, 980 Ω, 7.57 MΩ, 0.969

14.38 39.4, 1.20 kΩ, ∞, 0.600; 7.94, 1.43 kΩ, ∞, 0.714

14.41 40.7, 185 Ω, 39.0 kΩ, 18.5 mV

14.42 4.11, 1.32 kΩ, 20 kΩ, 354 mV

14.43 5.01, 3.02 kΩ, 24 kΩ, 352 mV

14.46 32.1 Ω, 260 Ω

14.47 633 Ω, 353 Ω

14.49 $\left(\beta_o + 1\right)r_o = 244\ M\Omega$

14.51 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.

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

14.55 Common-drain amplifier.

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

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

14.59 1.66 Ω

14.62

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%

14.64 (b) $479v_i$, 384 kΩ

14.65 v_i, 297 Ω

14.68 g_m, 0; 400 μS, 0

14.70 $-g_m\left(1+\frac{1}{\mu_f}\right) \quad | \quad -g_o \quad | \quad \mu_f + 1 \;;\; -502\ \mu S,\ -2.00\ \mu S$

14.71 $-\frac{g_m}{1+g_m R_E} \quad | \quad -\frac{g_o}{\left(1+g_m R_E\right)}\left(\frac{R_E}{R_E + r_\pi}\right) \quad | \quad \frac{G_m}{G_r} = \mu_f\left(1+\frac{r_\pi}{R_E}\right) >> 1$

14.74 -0.984, 0.993, 0.766 V

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

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

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

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

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

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

14.87 (430 μA, 1.97 V), (430 μA, 3.03 V), -2.89, 257 kΩ, 3.22 kΩ, (Note A_{tr} = 743 kΩ)

14.88 (4.50 mA, 2.50 V), (4.50 mA, 2.50 V), -83.5, 6.63 kΩ, 10.3 kΩ,

14.89 0.485, 182 kΩ, 435 Ω

14.92 1.80 μF, 0.068 μF, 120 μF; 2.7 μF

14.94 0.20 μF, 270 □F; 100 μF, 0.15 μF

14.96 1.5 μF, 0.027 μF

14.98 8200 pF, 820 pF

14.102 33.3 mA

14.103 R_1 = 120 kΩ, R_2 = 110 kΩ

14.106 45.1 ≤ A_v ≤ 55.3 - Only slightly beyond the limits in the Monte Carlo results.

14.108 The second MOSFET

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

14.113 4.08, 1.00 MΩ, 64.3 Ω

14.116 2.17, 1.00 MΩ, 64.3 Ω

14.121 468, 73.6 kΩ, 18.8 kΩ

14.122 0.670, 107 kΩ, 20.0 kΩ

14.124 7920, 10.0 kΩ, 18.8 kΩ

14.125 140, 94.7 Ω, 113 Ω

14.127 19.2 Hz; 18.0 Hz

14.129 1.56 Hz; 1.22 Hz

14.131 6.40 Hz; 5.72 Hz

14.133 0.497 Hz, 0.427 Hz

14.134 1.70 kHz; 1.68 kHz

Chapter 15

15.1 (26.2 μA, 7.08 V); −346, 191 kΩ, 660 kΩ; −0.604, 49.2 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 (85.6 μA, 10.1 V); −342, -0.494, 50.8 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, 13.5 kΩ

15.9 2.478 V, 6.258 V, -2.78 V, 4.64 V

15.11 V_O = 5.99 V, v_o = 0; V_O = 5.99 V; v_o = 1.80 V; 33.3 mV

15.15 (37.4 μA, 5.22 V); Differential output: −300, 0, ∞; single-ended output: −150, −0.661, 47.2 dB; 200 kΩ, 22.7 MΩ

15.16 -5.850 V, -3.450 V, -2.40 V

15.18 (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, -.004429, 94.9 dB

15.24 (107 μA, 10.1 V); differential output: −18.2, 0, ∞; single-ended output: −9.10, −0.487, 25.4 dB; ∞, ∞

15.27 2.4 kΩ, 5.6 kΩ

15.31 (150 μA, 5.62 V); differential output: −26.0, 0, ∞; single-ended output: −13.0, −0.232, 35.0 dB; ∞, ∞

15.34 (20.0 μA, 9.05 V); differential output: −38.0, 0, ∞; single-ended output: −19.0, −0.120, 44.0 dB; ∞, ∞

15.35 312 μA, 27 kΩ

15.38 -20.26, -0.7812, 22.3 dB , ∞, ∞

15.40 −3.80 V, −2.64 V, 48.3 mV

15.44 -79.9, -0.494, 751 kΩ

15.45 (99.0 μA, 8.80 V), −30.4, −0.167, 550 kΩ

15.47 (49.5 μA, 3.29 V), (49.5 μA, 8.70 V); −149, -0.0625, 101 kΩ

15.48 (100 μA, 1.20 V), (100 μA, 3.18 V); −13.4, 0, ∞

15.51 (24.8 μA, 15.0 V), (625 μA, 15.0 V); 896, 202 kΩ; 20.0 kΩ; 153 MΩ; v_2

15.52 [-13.6 V, 14.3 V]

15.57 (24.8 μA, 14.3 V), (4.95 μA, 14.3 V), (495 μA, 15.0 V); 5010, 202 kΩ; 19.4 kΩ; 150 MΩ; v_2

15.58 (98.8 μA, 17.1 V), (360 μA, 17.1 V); 620, 40.5 kΩ; 48.8 kΩ; 37.5 MΩ; v_2

15.59 [-16.6 V, 16.4 V]

15.63 (98.8 μA, 15.3 V), (300 μA, 15.3 V); 27700, 40.5 kΩ; 2.59 MΩ

15.67 (250 μA, 18.6 V), (500 μA, 18.0 V); 4490, ∞; 170 kΩ

15.69 5770

15.71 (250 μA, 7.42 V), (6.10 μA, 4.30 V), (494 μA, 5.00 V); 4230, ∞; 97.5 kΩ

15.75 (49.5 μA, 18.0 V), (360 μA, 17.3 V), (990 μA, 18.0 V); 12700, 101 kΩ; 1.88 kΩ; 69.2 MΩ; v_2

15.77 (300 μA, 5.10 V), (500 μA, 2.89 V), (2.00 mA, 5.00 V); 528, ∞, 341 Ω

15.79 (300 μA, 5.55 V), (500 μA, 2.89 V), (2.00 mA, 5.00 V), 2930, ∞, 341 Ω

15.81 (250 μA, 10.9 V), (2.00 mA, 9.84 V), (5.00 mA, 12.0 V); 868, ∞; 127 Ω

15.82 (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

15.84 (49.5 μA, 11.0 V), (98.0 μA, 10.3 V), (735 μA, 16.0 V); 2680, 101 kΩ, 3.05 kΩ; □□□□□□□□□□d for an ideal current source, 10.3 V]; 1.44 mV

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

15.88 (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, 22.0 Ω

15.90 250 $\mu A/V^2$; 280; 868

15.92 196; 896

15.94 0.9996, 239 MΩ, 21.2 Ω

15.96 9.992, 67.6 MΩ, 1.48 Ω

15.98 36.8 μA

15.101 391 μA

15.104 22.8 μA

15.106 5 mA, 0 mA, 10 mA, 12.5 percent

15.107 66.7 percent

15.110 46.7 mA, 13.5 V

15.112 23.5 μA

15.113 6.98 mA, 0 mA

15.114 25.0 mΩ

15.116 (a) 18.7 μA, 61.5 MΩ

15.118 (a) 134 μA, 8.19 MΩ

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

15.122 59.4 μA, 15.7 MΩ

15.123 0, ∞

15.125 88.6 μA, 18.6 MΩ

15.127 17.0 μA, 131 MΩ

15.130 390 kΩ, 210 kΩ, 33 kΩ

15.132 157.4 μA, 16.61 MΩ, 31.89 μA, 112.2 MΩ

15.133 44.1 μA, 22.1 MΩ, 10.1 μA, 209 MΩ

15.136 400 μA, 2.89 x 10^{11} Ω

15.137 (4.64 μA, 7.13 V), (9.38 μA, 9.02 V); 40.9 dB, 96.5 dB

15.140 $\beta_{o1}\mu_{f1}/2$, For typical numbers: 20(100)(70) = 140,000 or 103 dB

15.141 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

Chapter 16

16.1 [4.28 kΩ, 4.50 kΩ]

16.2 2.50 mV; 5.02 mV; 1%

16.4 7.7%, 0.813 μA, 0.855 μA, (I_{OS} = -42.0 nA)

16.7 25.0 mV; 1.2%; 0.4%

16.8 (a) 94.8 μA, 186 μA, 386 μA, 1.16 MΩ, 580 kΩ, 290 kΩ

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

16.12 316 μA, 332 kΩ, 662 μA, 166 kΩ

16.16 (a) 693 μA, 93.8 kΩ, 1.11 mA, 56.8 kΩ

16.18 422 kΩ, 112 μA; 498 kΩ, 112 μA

16.21 202 μA, 327 μA

16.22 472 μA, 759 μA; 479 μA, 759 μA; 430 μA, 692 μA

16.24 63.8 kΩ, 11.8 μA, 123 μA

16.26 10

16.28 15 kΩ, 2/3

16.30 138 μA, 514 MΩ

16.32 4.90 kΩ

16.34 172 kΩ, 15.0 kΩ, 0.445

16.36 21.8 μA, 18.4 MΩ; 43.7 μA, 9.17 MΩ

16.38 29.8 μA, 92.9 MΩ; 87.9 μA, 31.5 MΩ; 2770; 1.40 V

16.42 17.0 μA, 80/1; 89.9 MΩ

16.44 $2/g_{m2}$

16.46 5.49/1

16.49 11.7 MΩ, 0, 6.687, 90.4 MΩ

16.51 1.33 MΩ, 1, 126, 84.4 MΩ

16.52 20.0 μA, 953 MΩ; 19.1 kV; 2.21 V

16.54 21.0 μA, 4.40 nA

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

16.60 16.9 μA, 163 MΩ, 2750 V; $2V_{BE}$ = 1.40 V

16.62 2.86 kΩ

16.64 (a) 102 GΩ

16.66 (a) 51.0 GΩ

16.68 (a) 64.0 μA, 3.10 MΩ

16.70 5.71 kΩ

16.72 317 μA; 295 μA; 66.5 μA

16.74 $\cong \beta_o r_{o4}/2$

16.76 14.5 kΩ, 226 kΩ

16.78 11.5 kΩ, 313 kΩ

16.80 $I_{C1} = 137\ \mu A, \quad I_{C1} = 44.8\ \mu A, \quad S_{V_{CC}}^{I_{C1}} = 4.40x10^{-2}, \quad S_{V_{CC}}^{I_{C2}} = 1.54x10^{-2}$

16.82 n > 1/3

16.84 6.24 mA

16.86 (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.

16.88 14.4 μA, 36.0 μA, 6.56 μA, 72.0 μA, 9.48 μA

16.90 I_{C2} = 16.9 μA I_{C1} = 31.5 μA - Similar to hand calculations.

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

16.92 (a) 388 μA, 259 μA

16.94 110 μA

16.96 4.90 V, 327.4 K

16.98 1.20 V, 304.9 K

16.100 5.07 V, +44.0 μV/K

16.102 -472 μV/K, -199 μV/K

16.104 2.248 kΩ, 10.28 kΩ, 80 kΩ, 23.9 kΩ, 126 kΩ

16.105 79.1, 6.28 x10^{-5}, 122 dB

16.107 47.2, 6.97 x10^{-5}, 117 dB

16.109 1200, 4 x10^{-3}, 110 dB, ±2.9 V

16.113 (100 μA, 8.70 V), (100 μA, 7.45 V), (100 μA, -2.50 V), (100 μA, -1.25 V), 324, 152

16.115 (125 μA, 1.54 V), (125 μA, -2.79 V), (125 μA, 2.50 V), (125 μA, 1.25 V); 19600

16.118 171 μA

16.119 (b) 100 μA

16.120 (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

16.122 12,600

16.124 (250 μA, 7.50 V), (250 μA, 7.50 V), (250 μA, -1.75 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), 3160

16.126 (b) 42.9/1 (c) 23000

16.130 7.78, 574 Ω, 3.03 x 10^5, 60.0 kΩ

16.132 ±1.4 V, ±2.4 V

16.133 (a) 9.72 μA, 138 μA, 46.0 μA

16.134 271 kΩ, 255 Ω

16.136 $V_{EE} \geq 2.8$ V, $V_{CC} \geq 1.4$ V; 3.8 V, 2.4 V

16.138 2.84 MΩ, 356 kΩ. 6.11 x 10^5

16.141 100 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), (2.00 μA, 29.3 V), (100 μA, 0.700 V), (100 μA, 13.6 V); 1.00 mS, 752 kΩ

16.142 (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

16.143 **(**50 μA, 2.50 V), (25 μA, 3.20 V)

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

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

Chapter 17

17.1 $A_{mid} = 50,\ F_L(s) = \frac{s^2}{(s+4)(s+30)}$, yes, $A_v(s) \approx 50\frac{s}{(s+30)},\ 4.77\ Hz,\ 4.82\ Hz$

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

17.7 200, $\frac{s^2}{(s+1)(s+2)}, \frac{1}{\left(1+\frac{s}{500}\right)\left(1+\frac{s}{1000}\right)}$, 0.356 Hz, 142 Hz; 0.380 Hz, 133 Hz

17.9 (b) -14.3 (23.1 dB), 11.3 Hz

17.10 (b) -15.6, 8.15 Hz

17.11 1.52 μF; 1.50 μF, 49.4 Hz

17.13 0.213 μF; 0.22 μF; 1940 Hz

17.14

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

35.5 dB, 13.2 Hz; -5.0 V, 7.9 V

17.16 123 Hz; 91 Hz; (145 μA, 3.57 V)

17.18 -131, 49.9 Hz, 12.0 V

17.19 45.5 Hz

17.21 7.23 dB, 19.8 Hz

17.23 0.739, 11.9 Hz, 10.0 V

17.24 0.15 μF

17.25 1.8 μF

17.27 Cannot reach 2 Hz; f_L = 13.1 Hz for $C_1 = \infty$, limited by C_3

17.29 0.15 μF

17.30 308 ps

17.33 (a) 22.5 GHz

17.34 –96.7; –110

17.35 0.978; 0.979

17.37 (a) −5100, −98.0, −5000, −100, 2% error (b) −350, −42.9, −300, −50, 18% error

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

17.41 (3.31 mA, 2.71 V); -89.6, 1.45 MHz; 130 MHz

17.43 -14.3, 540 kHz

17.45 (0.834 mA, 2.41 V); -8.27, 3.29 MHz; 27.2 MHz

17.49 61.0 pF, 303 MHz

17.52 $1/10^5\ RC$; $1/10^6\ RC$; $-1/sRC$

17.54 39.2 dB, 5.51 MHz

17.56 -114, 1.11 MHz; 127 MHz, 531 MHz

17.59 680 Ω, -18.0, 92.7 MHz

17.60 -29.3, 7.41 MHz, 227 MHz

17.62 300 Ω, 1 kΩ

17.63 −1300; −92.3; −100, −1200

17.64 9.55, 64.4 MHz

17.66 59.7, 1.72 MHz

17.69 2.30, 14.1 MHz

17.70 3.17, 14.1 MHz, 15.4 Hz

17.71 0.960, 114 MHz

17.74 -1.56 dB, 73.3 MHz

17.75 $C_{GD} + C_{GS}/(1 + g_m R_L)$ for $\omega << \omega_T$

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

17.81 672 mA - not a realistic design. A different FET is needed.

17.83 393 kHz; 640 kHz

17.87 294 kHz

17.89 48.2 kHz

17.90 52.9 kHz

17.92 (a) 568 kHz

17.94 (a) 2.01 MHz

17.96 53.4 dB, 833 Hz, 526 kHz

17.97 1.52 MHz; 323 μH, 3.65 MHz

17.99 -45^o; -118^o; -105^o

17.101 22.5 MHz, -41.1, 2.91

17.102 20.1 pF; 12.6; *n* = 2.81; 21.8 pF

17.103 15.2 MHz; 27.5 MHz

17.104 13.4 MHz, 7.98, $112\underline{/-90}°$; 4.74 MHz, 5.21, $46.1\underline{/-90}°$

17.105 10.1 MHz, 3.96, −35.3; 10.94 MHz, 16.8, −75.1

17.108 65 pF; 240, -4.41×10^4, 25.1 kHz

17.110 62.3 pF; 152 kHz, 40

17.112 (b) 497 Ω, 108 pF

17.113 100 Ω, 104 fF; 52.2 Ω, 144 fF

17.117 (a) 100 MHz, 1900 MHz

17.119 58.9 dB

17.121 -19.5 dB; -23.9 dB

17.123 0.6 A

17.125 -13.5 dB; -17.9 dB

17.127 0.2 A

17.129 1, 0.5, 0.5

17.131 0.567 V

17.133 $0.2I_1R_C$

Chapter 18

18.1 (b) 200, 4.975, 0.498%

18.3 1/40, 790.6, -38.95

18.5 104 dB

18.7 1/(1+T); 0.0498 %

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

18.13 857 Ω, 33.3, 57.1, 506 Ω

18.15 245 Ω, 0, 0.952, 126 Ω

18.17 $8.33x10^5$, 16.7 S

18.19 12.9, 8.88 MΩ, 1.52 Ω

18.21 31.1 Ω, 2.01, 17.9, 195 Ω

18.23 10.1, 252 kΩ, 358 Ω

18.25 2.66 Ω; (32.2 Ω, 0, 11.1)

18.27 141 Ω; (13.0 kΩ, 0, 91.2)

18.29 0.9987, 110.4 MΩ, 2.845 Ω vs. 0.999, 108 MΩ, 2.70 Ω

18.31 −39.0 kΩ, 8.31 Ω, 0.295 Ω

18.33 33.2 Ω, 45.6 Ω, −38.9 kΩ

18.35 29.7 kΩ, 1.48 kΩ, -672 kΩ

18.37 0.133 mS, 60.4 MΩ, 26.8 MΩ

18.39

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

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

18.41 0.467 mS, 95.0 MΩ

18.42 8.48, 15.1 Ω, 3.51 MΩ

18.43 400 Ω, 12.5 MΩ, 0.992

18.45 29.8 MΩ, 799 MΩ, 1.08 GΩ

18.47 2.97, 14.5 Ω, 24.3 MΩ; 2.99, 14.6 Ω, 18.1 MΩ

18.49 30.39 GΩ; 33.3 GΩ

18.51 47.32 MΩ; 37.5 MΩ

18.53 $T_v = 105,\ T_i = 18.1,\ T = 15.2,\ R_2/R_1 = 5.55$

18.55 $T_v = 988,\ T_i = 109,\ T = 98.0,\ R_2 / R_1 = 8.99$

18.57 110 kHz, 2048, ≤ 2048

18.59 219 pF

18.61 76.6°

18.63 107°

18.67 9.38 MHz, 41.7 V/μS

18.69 (b) 95.5 MHz, 30 V/μS

18.71 ±8.57 V/μS

18.73 71.5 MHz, 11.4 kHz, 236 MHz, 326 MHz, 300 MHz; 84.4 dB; < 0; 16.8 pF

18.75 12 kΩ; 9.05 MHz, 101 MHz, 74.8 MHz, 320 MHz; 2.60 MHz, 44.6 pF

18.77 (a) 81.9°

18.79 6.32 pF; 315 MHz, 91.5 MHz; 89.4°

18.81 17.5 MHz; [20.1 MHz, 36.3 MHz]; 0.211 mS, 5.28 μA

18.82 5.17 MHz, 4.53 MHz

18.84 9.00 MHz, 1.20

18.86 7.96 MHz, 8.11 MHz, 1.05

18.88 7.5 MHz, 80 $V_{p\text{-}p}$

18.89 7.96 MHz

18.90 11.1 MHz, 18.1 MHz, 1.00

18.91 $L_{EQ} = L_1 + L_2 \quad | \quad R_{EQ} = -\omega^2 g_m L_1 L_2$

18.92 $\omega_o^2 = \dfrac{1}{L\left(C + C_{GS} + 4C_{GD}\right)} \quad | \quad \mu_f \geq 1 + \dfrac{r_o}{R_P}$

18.94 5.13 pF; 1 GHz can't be achieved.

18.95 6.33 pF; 2.81 mA; 3.08 mA; 1.32 V

18.97 15.915 mH, 15.915 fF; 10.008 MHz, 10.003 MHz

18.99 9.28 MHz; 9.19 MHz