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# F

## Answers to Selected Problems

### Chapter 1

- 1.1 (a) (i)  $1.9 \times 10^9 \text{ cm}^{-3}$ ,  
(ii)  $8.71 \times 10^{10} \text{ cm}^{-3}$   
(b) (i)  $1.34 \times 10^5 \text{ cm}^{-3}$ ,  
(ii)  $1.63 \times 10^7 \text{ cm}^{-3}$
- 1.3 (a) n-type:  $n_o = 5 \times 10^{15} \text{ cm}^{-3}$ ,  
 $p_o = 4.5 \times 10^4 \text{ cm}^{-3}$   
(b) n-type:  $n_o = 5 \times 10^{15} \text{ cm}^{-3}$ ,  
 $p_o = 6.48 \times 10^{-4} \text{ cm}^{-3}$
- 1.6 (a) Add donors,  $N_d = 7 \times 10^{15} \text{ cm}^{-3}$ ,  
(b)  $T = 324 \text{ K}$
- 1.10 (a)  $p_o = 10^{17} \text{ cm}^{-3}$ ,  $n_o = 3.24 \times 10^{-5} \text{ cm}^{-3}$ ,  
(b)  $n = n_o + \delta n \cong 10^{15} \text{ cm}^{-3}$ ;  $p =$   
 $p_o + \delta p = 1.01 \times 10^{17} \text{ cm}^{-3}$
- 1.13 For  $N_d = 10^{16} \text{ cm}^{-3}$  and  $N_a = 10^{15} \text{ cm}^{-3}$ ,  
 $V_{bi} = 0.637 \text{ V}$ ; For  $N_d = 10^{16} \text{ cm}^{-3}$  and  
 $N_a = 10^{18} \text{ cm}^{-3}$ ,  $V_{bi} = 0.817 \text{ V}$
- 1.17 (a)  $f_o = 8.38 \text{ MHz}$ ;  
(b)  $f_o = 13.2 \text{ MHz}$
- 1.20 (a)  $0.430 \text{ V}$ ; (b)  $0.549 \text{ V}$
- 1.23  $2.83 \times 10^3$
- 1.25 (a)  $I_D = 0.145 \mu\text{A}$ ,  $V_D = 0.046 \text{ V}$   
(b)  $I_D = -30 \text{ nA}$ ,  $V_D = -1.2 \text{ V}$
- 1.27  $V_I = 1.81 \text{ V}$
- 1.29 (a)  $I_D = 0.0267 \text{ mA}$ ,  $V_D = 0.7 \text{ V}$   
(b)  $V_D = 0.45 \text{ V}$ ,  $I_D = 0$
- 1.32  $I_{D1} = 0.65 \text{ mA}$ ,  $I_{D2} = 1.30 \text{ mA}$ ,  
 $R_I = 2.35 \text{ k}\Omega$

1.35 (a) and (b)  $v_d = 1.30 \text{ mV}$  (peak-to-peak)

1.37  $0.599 \text{ V}$ ;  $0.299 \text{ V}$

1.41 (a)  $V_O = 5.685 \text{ V}$ ,  
(b)  $\Delta V_O = 0.039 \text{ V}$ ,  
(c)  $V_O = 5.658 \text{ V}$

1.43 (a)  $6.921 \text{ V}$ ; (b)  $-0.13 \text{ V}$

### Chapter 2

2.4 (a)  $6.06$ , (b)  $1.58$ ; PIV =  $25.7 \text{ V}$  for  
(a), PIV =  $100.7 \text{ V}$  for (b)

2.8  $R = 1.19 \Omega$ ,  $32.25\%$ ,  $18 \text{ W}$

2.11  $3.04 \text{ V}$

2.13 (a)  $I_L = 26.3 \text{ mA}$ ,  $I_I = 45.0 \text{ mA}$ ,  
 $I_Z = 18.8 \text{ mA}$   
(b)  $R_L = 2 \text{ k}\Omega$   
(c)  $R_L = 585 \Omega$

2.15 (a)  $\Delta V_O = 0.815 \text{ V}$ , (b)  $4.08\%$

2.18  $R_I = 18.2 \Omega$ ,  $C = 9900 \mu\text{F}$

2.21 (a)  $v_O = v_I$  for  $0 \leq v_I \leq 5.7 \text{ V}$ ;  
 $v_O = \frac{v_I}{2.5} + 3.42$  for  $5.7 \leq v_I \leq 15 \text{ V}$   
(b)  $i_D = 0$  for  $0 \leq v_I \leq 5.7 \text{ V}$ ;  
 $i_D = \frac{0.6v_I - 3.42}{1 \text{ k}\Omega}$  for  
 $5.7 \leq v_I \leq 15 \text{ V}$

2.33 (a)  $I = I_{D1} = I_{D2} = 0$ ,  $V_O = 10 \text{ V}$

(b)  $I_{D1} = 0$ ,  $I = I_{D2} = 0.94 \text{ mA}$ ,  
 $V_O = 1.07 \text{ V}$

- (c)  $I_{D1} = 0, I = I_{D2} = 0.44 \text{ mA}, V_O = 5.82 \text{ V}$   
 (d)  $I = 0.964 \text{ mA}, I_{D1} = I_{D2} = 0.482 \text{ mA}, V_O = 0.842 \text{ V}$
- 2.35 (a)  $V_1 = 6.9 \text{ V}, V_2 = -0.6 \text{ V}, I_{D1} = 1.25 \text{ mA}, I_{D2} = 0, I_{D3} = 0.95 \text{ mA}$   
 (b)  $V_1 = 4.4 \text{ V}, V_2 = -0.3 \text{ V}, I_{D1} = 0.833 \text{ mA}, I_{D2} = 0.107 \text{ mA}, I_{D3} = 0$   
 (c)  $V_1 = 4.4 \text{ V}, V_2 = -0.6 \text{ V}, R_1 = 10 \text{ k}\Omega, R_2 = 5 \text{ k}\Omega, R_3 = 2.93 \text{ k}\Omega$
- 2.38 (a)  $I_{D1} = 0.86 \text{ mA}, V_O = 0;$   
 (b)  $I_D = 0, V_O = -3.57 \text{ V}$
- 2.40 (a)  $I_D = 0, V_D = -2.5 \text{ V};$   
 (b)  $I_D = 0.19 \text{ mA}, V_D = 0.6 \text{ V}$
- 2.43 (a)  $V_{O1} = V_{O2} = 5 \text{ V};$   
 (b)  $V_{O1} = 0.6 \text{ V}, V_{O2} = 1.2 \text{ V};$   
 (c)  $V_{O1} = 0.6 \text{ V}, V_{O2} = 1.2 \text{ V}$
- 2.47  $V_{PS} = 2.6 \text{ V}$

**Chapter 3**

- 3.1 (a)  $\beta_F = 85, \alpha_F = 0.9884, i_E = 516 \mu\text{A}$   
 (b)  $\beta_F = 53, \alpha_F = 0.9815, i_E = 2.70 \text{ mA}$
- 3.4  $i_C = 1.85 \text{ mA}, i_B = 0.0154 \text{ mA}, i_E = 1.865 \text{ mA}$
- 3.7  $I_{S1} = 1.69 \times 10^{-13} \text{ A}, I_{S2} = 6.94 \times 10^{-15} \text{ A}, I_{S1}/I_{S2} = 24.35$
- 3.10 60.6
- 3.14  $R_B = 120 \text{ k}\Omega, I_{CQ} = 1.05 \text{ mA}, R_C = 2.38 \text{ k}\Omega$
- 3.16 (a)  $I_E = 0, V_C = 6 \text{ V},$   
 (b)  $I_E = 0.3 \text{ mA}, V_C = 3 \text{ V},$   
 (c)  $I_E = 1.3 \text{ mA}, V_C = 1.5 \text{ V}$
- 3.19  $V_B = 1.19 \text{ V}, I_E = 0.49 \text{ mA}$
- 3.22  $V_E = -0.7 \text{ V}, V_C = 2.84 \text{ V}$
- 3.25  $I_{E1} = I_{E2} = 0.5 \text{ mA}, V_{C1} = V_{C2} = 3 \text{ V}$

- 3.28 3.97 V
- 3.31  $R_1 = 338 \text{ k}\Omega, R_2 = 58.7 \text{ k}\Omega, R_C = 6.49 \text{ k}\Omega$
- 3.34 (a)  $I_{BQ} = 0.0624 \text{ mA}, I_{CQ} = 4.68 \text{ mA}, V_{CEQ} = 5.22 \text{ V},$   
 (b)  $I_{BQ} = 0.0326 \text{ mA}, I_{CQ} = 4.89 \text{ mA}, V_{CEQ} = 4.41 \text{ V}$
- 3.37  $I_{CQ} = 4.41 \text{ mA}, V_{ECQ} = 6 \text{ V}, R_C = 1.26 \text{ k}\Omega$
- 3.40  $I_{CQ} = 2.73 \text{ mA}, V_{CEQ} = 6 \text{ V}, R_1 = 23.2 \text{ k}\Omega, R_2 = 2.83 \text{ k}\Omega$
- 3.43 (a)  $I_{BQ} = 0.0214 \text{ mA}, I_{CQ} = 1.60 \text{ mA}, V_{ECQ} = 15.2 \text{ V},$   
 (b)  $I_{BQ} = 0.0161 \text{ mA}, I_{CQ} = 1.61 \text{ mA}, V_{ECQ} = 15.1 \text{ V}$
- 3.46  $R_E = 4.90 \text{ k}\Omega, R_1 = 72.4 \text{ k}\Omega, R_2 = 50.9 \text{ k}\Omega, \text{ designed using } \beta = 60.$
- 3.49 (a)  $R_{TH} = 6.67 \text{ k}\Omega, V_{TH} = 1.67 \text{ V},$   
 (b)  $I_{BQ} = 0.593 \text{ mA}, I_{CQ} = 3.56 \text{ mA}, V_E = 2.76 \text{ V}, V_C = -2.17 \text{ V}$
- 3.52 (a)  $R_{TH} = 54.7 \text{ k}\Omega, V_{TH} = -3.03 \text{ V},$   
 (b)  $I_{CQ} = 0.227 \text{ mA}, V_{CEQ} = 7.51 \text{ V}$
- 3.55  $I_{E2} = 3.6 \text{ mA}, I_{B2} = 0.0444 \text{ mA}, I_{C2} = 3.56 \text{ mA}, I_{E1} = 0.259 \text{ mA}, I_{B1} = 0.0032 \text{ mA}, I_{C1} = 0.256 \text{ mA}$

**Chapter 4**

- 4.1 (a)  $g_m = 76.9 \text{ mA/V}, r_\pi = 2.34 \text{ k}\Omega, r_o = 75 \text{ k}\Omega,$   
 (b)  $g_m = 19.2 \text{ mA/V}, r_\pi = 9.36 \text{ k}\Omega, r_o = 300 \text{ k}\Omega$
- 4.4  $41.5 \leq g_m \leq 50.8 \text{ mA/V}, 1.58 \leq r_\pi \leq 2.89 \text{ k}\Omega$
- 4.7 (a)  $V_B = -0.0347 \text{ V}, V_E = -0.735 \text{ V},$   
 (b)  $R_C = 6.43 \text{ k}\Omega, (c) A_V = -83.7,$   
 (d)  $A_V = -74.9$
- 4.10 (a)  $I_{CQ} = 1.19 \text{ mA}, V_{ECQ} = 8.42 \text{ V},$   
 (b)  $A_V = -1.94,$   
 (c)  $1.76 \leq |A_V| \leq 2.14$
- 4.13 (a)  $R_E = 11.0 \text{ k}\Omega, (b) R_C = 3.71 \text{ k}\Omega,$   
 (c)  $A_V = -43.9, (d) R_i = 4.81 \text{ k}\Omega$
- 4.16 (a)  $39.0 \leq |A_V| \leq 43.2,$

- (b)  $1.64 \leq R_i \leq 2.13 \text{ k}\Omega$ ,  
 (c)  $3.70 \leq R_o \leq 3.85 \text{ k}\Omega$
- 4.19  $r_e = r_{\pi} \left\| \left( \frac{1}{g_m} \right) \right\| r_o$
- 4.25 3.24 V peak-to-peak
- 4.28 0.342 mA peak-to-peak
- 4.31  $\Delta i_C$  (peak-to-peak) = 1.29 mA,  
 $\Delta v_{CE}$  (peak-to-peak) = 2.58 V
- 4.33 (a)  $I_{CQ} = 2.09 \text{ mA}$ ,  $V_{CEQ} = 3.69 \text{ V}$ ,  
 (c)  $A_V = 0.988$ ,  
 (d)  $R_{ib} = 122 \text{ k}\Omega$ ,  $R_o = 12.2 \Omega$
- 4.37 (a)  $I_{CQ} = 0.650 \text{ mA}$ ,  $V_{ECQ} = 3.01 \text{ V}$ ,  
 (c)  $A_V = 0.977$ ,  $A_i = 4.61$ ,  
 (d)  $R_{ib} = 88.2 \text{ k}\Omega$ ,  $R_o = 38.7 \Omega$ ,  
 (e)  $4.21 \leq A_i \leq 5.05$
- 4.40 (a)  $V_B = 0.0617 \text{ V}$ ,  $V_E = 0.762 \text{ V}$ ;  
 (b)  $g_m = 19 \text{ mA/V}$ ,  $r_{\pi} = 4.21 \text{ k}\Omega$ ,  
 $r_o = 304 \text{ k}\Omega$ ;  
 (c)  $A_v = 0.906$ ,  
 $A_i = 14.8$ ; (d)  $A_v = 0.728$ ,  
 $A_i = 14.8$
- 4.44 (a)  $I_{CQ} = 1.46 \text{ mA}$ ,  $V_{CEQ} = 7.75 \text{ V}$ ;  
 (b)  $R_m = 1.93 \text{ k}\Omega$ ; (c)  $A_v = 26.0$
- 4.47 (a)  $V_E = 0.5 \text{ V}$ ,  $V_B = 1.20 \text{ V}$ ,  
 $V_C = 1.70 \text{ V}$ ,  
 (b)  $A_V = 9.36$ , (c)  $R_i = 49.5 \Omega$
- 4.50 (a)  $g_{m1} = 42.7 \text{ mA/V}$ ,  $r_{\pi 1} = 2.34 \text{ k}\Omega$ ,  
 $g_{m2} = 48.5 \text{ mA/V}$ ,  $r_{\pi 2} = 2.06 \text{ k}\Omega$ ,  
 $r_{o1} = r_{o2} = \infty$ ,  
 (b)  $A_{V1} = -85.4$ ,  $A_{V2} = -97$ ,  
 (c)  $A_V = 3890$
- 4.53 (a)  $I_{C1} = 12.8 \mu\text{A}$ ,  $V_{CE1} = 5.11 \text{ V}$ ,  
 $I_{C2} = 1.29 \text{ mA}$ ,  $V_{CE2} = 5.81 \text{ V}$ ,  
 (b)  $A_V = -55.2$ ,  
 (c)  $R_{is} = 74.4 \text{ k}\Omega$ ,  $R_o = 2.2 \text{ k}\Omega$
- 4.56 (a)  $P_{RE} = 1.66 \text{ mW}$ ,  $P_{RC} = 13.0 \text{ mW}$ ,  
 $P_Q = 7.0 \text{ mW}$ ,  
 (b)  $\bar{P}_{RL} = 1.44 \text{ mW}$
- 4.59 (a)  $P_{RC} = 7.02 \text{ mW}$ ,  $P_Q = 2.65 \text{ mW}$ ,

- (b)  $\bar{P}_{RL} = 0.290 \text{ mW}$ ,  
 $\bar{P}_{RC} = 0.0289 \text{ mW}$ ,  $\bar{P}_Q = 2.33 \text{ mW}$

## Chapter 5

- 5.1 (a) 3.06 mA, (b) 2.81 mA
- 5.4  $W/L = 9.375$
- 5.7 7.21  $\mu\text{m}$
- 5.10 (a)  $V_{SD}(\text{sat}) = 1 \text{ V}$ ,  $I_D = 0.12 \text{ mA}$   
 (b)  $V_{SD}(\text{sat}) = 2 \text{ V}$ ,  $I_D = 0.48 \text{ mA}$   
 (c)  $V_{SD}(\text{sat}) = 3 \text{ V}$ ,  $I_D = 1.08 \text{ mA}$
- 5.13 781 k $\Omega$ , 63.7 k $\Omega$ , 100 V
- 5.16 1.24 V<sup>1/2</sup>
- 5.19  $V_{GS} = 2.05 \text{ V}$ ,  $I_D = 0.775 \text{ mA}$ ,  
 $V_{DS} = 5.35 \text{ V}$
- 5.22  $V_S = 2.21 \text{ V}$ ,  $V_{SD} = 5.21 \text{ V}$
- 5.25 For example, let  $W/L = 10$ , then  
 $V_{SG} = 4 \text{ V}$ ,  $R_S = 5 \text{ k}\Omega$ ,  $R_D = 7.5 \text{ k}\Omega$ ,  
 $R_1 = 100 \text{ k}\Omega$ ,  $R_2 = 150 \text{ k}\Omega$
- 5.28  $R_D = 5 \text{ k}\Omega$ ,  $R_S = 2.36 \text{ k}\Omega$
- 5.31  $R_D = 4 \text{ k}\Omega$ . Let  $W/L = 10$ , then  
 $R_S = 3.94 \text{ k}\Omega$
- 5.34  $(W/L)_1 = 3.23$
- 5.37 20.3
- 5.40  $I_D = 0.49 \text{ mA}$ ,  $W/L = 0.731$
- 5.43  $V_{DS} > V_{DS}(\text{sat}) = -V_P$ ,  $I_D = I_{DSS}$
- 5.46  $V_{DD} \leq -2.5 \text{ V}$ ,  $V_S = -1.06 \text{ V}$
- 5.49  $V_{GSQ} = -1.17 \text{ V}$ ,  $I_{DQ} = 5.85 \text{ mA}$ ,  
 $V_{DSQ} = 7.13 \text{ V}$
- 5.52  $R_D = 0.9 \text{ k}\Omega$ ,  $R_1 = 8.6 \text{ k}\Omega$ ,  
 $R_2 = 91.4 \text{ k}\Omega$
- 5.55  $R_D = 1.75 \text{ k}\Omega$ ,  $I_D = I_{DSS} = 4 \text{ mA}$
- 5.58 128  $\mu\text{A/V}^2$

## Chapter 6

- 6.1 (a) 12.5, (b) 2.21 V
- 6.4 0.833 mA

- 6.6 (a)  $R_D = 8 \text{ k}\Omega$ ,  $W/L = 11.6$ ,  
 (b)  $g_m = 0.835 \text{ mA/V}$ ,  $r_o = 133 \text{ k}\Omega$ ,  
 (c)  $-6.3$
- 6.10  $2.1 \text{ mA/V}$
- 6.13 (b)  $-2.88$ , (c)  $2.76 \text{ V peak-to-peak}$
- 6.16 (a)  $R_S = 0.5 \text{ k}\Omega$ ,  $I_{DQ} = 1.0 \text{ mA}$ ,  
 (b)  $-1.33$
- 6.19  $K_n = 0.202 \text{ mA/V}^2$ ,  $V_{TN} = -2.65 \text{ V}$ ,  
 $R_D = 1.23 \text{ k}\Omega$ ,  $R_S = 0.10 \text{ k}\Omega$ ,  
 $R_1 = 529 \text{ k}\Omega$ ,  $R_2 = 123 \text{ k}\Omega$
- 6.23 (No load)  $A_V = 0.995$ ,  $R_o = 0.249 \text{ k}\Omega$ ;  
 (With load)  $A_V = 0.905$ ,  $R_o = 0.226 \text{ k}\Omega$
- 6.26 (a)  $47.0$ , (b)  $3.13 \text{ mA}$
- 6.30 (a)  $100 \Omega$ , (b)  $100 \Omega$
- 6.33 (a)  $I_{DQ} = 0.365 \text{ mA}$ ,  $V_{DSQ} = 4.53 \text{ V}$ ,  
 (b)  $g_m = 2.09 \text{ mA/V}$ ,  $r_o = \infty$ ,  
 (c)  $A_V = 4.64$
- 6.36 (a)  $R_S = 2.26 \text{ k}\Omega$ ,  $R_D = 1.07 \text{ k}\Omega$ ,  
 (b)  $A_V = 4.74$
- 6.39  $0.936 \text{ k}\Omega$
- 6.42 (a)  $0.731$ , (b)  $0.40 \text{ k}\Omega$
- 6.45 (a)  $R_1 = 545 \text{ k}\Omega$ ,  $R_2 = 1.50 \text{ M}\Omega$ ,  
 (b)  $I_{DQ1} = 0.269 \text{ mA}$ ,  $I_{DQ2} = 0.5 \text{ mA}$ ,  
 $V_{DSQ1} = 4.62 \text{ V}$ ,  
 (c)  $A_V = 0.714$ ,  $R_o = 1.25 \text{ k}\Omega$
- 6.48 (a)  $R_1 = 38.8 \text{ k}\Omega$ ,  $R_2 = 35 \text{ k}\Omega$ ,  
 $R_3 = 26.2 \text{ k}\Omega$ ,  $R_D = 0.6 \text{ k}\Omega$ ,  
 (b)  $A_V = -5.36$
- 6.53 (a)  $I_{DQ} = 1.42 \text{ mA}$ ,  $V_{SDQ} = 2.9 \text{ V}$ ,  
 (b)  $A_V = 0.844$ ,  $A_i = 4.18$ ,  
 (c)  $5.8 \text{ V peak-to-peak}$

**Chapter 7**

- 7.1 (c)  $v_o(t) = 1 - e^{-t/R_1 C_1}$
- 7.5 (a)  $\tau_S = (R_i + R_P)C_S = 0.40 \text{ s}$ ,  
 $\tau_P = (R_i || R_P)C_P = 0.375 \mu\text{s}$   
 (b)  $f_L = 0.398 \text{ Hz}$ ,  $f_H = 424 \text{ kHz}$ ,  
 $|T|_{\text{max}} = 7.5 \text{ k}\Omega$

- 7.8 (a)  $|A_V| = 159$ ;  
 (b)  $\tau_S$  (open circuit) =  $5.31 \text{ ms}$ ,  $\tau_P$   
 (short circuit) =  $0.332 \mu\text{s}$ ;  
 (c)  $C_C = 0.932 \mu\text{F}$ ,  $C_L = 55.3 \text{ pF}$
- 7.11 (a)  $959 \text{ Hz}$ , (b)  $|A_V| = 6.70$
- 7.13 (a)  $R_S = 2.59 \text{ k}\Omega$ ,  $R_D = 4.41 \text{ k}\Omega$ ,  
 (c)  $1.89 \mu\text{F}$
- 7.16 (a)  $I_{DQ} = 1.8 \text{ mA}$ ,  $V_{SDQ} = 5.68 \text{ V}$ ,  
 $g_m = 2.68 \text{ mA/V}$ ,  $r_o = \infty$   
 (b) For  $C_{C1}$ ,  $\tau_{S1} = 2.28 \text{ ms}$ ; For  $C_{C2}$ ,  
 $\tau_{S2} = 51.2 \text{ ms}$   
 (c)  $C_{C2}$  dominates;  $f_{3-\text{dB}} = 3.1 \text{ Hz}$
- 7.19  $C_C = 456 \mu\text{F}$
- 7.22 (a)  $C_E = 57.2 \mu\text{F}$ ,  
 (b)  $f_B \approx 199.7 \text{ Hz}$ ,  $f_A = 0.556 \text{ Hz}$
- 7.25  $C_L = 121 \text{ pF}$
- 7.31  $f_T = 511 \text{ MHz}$ ,  $f_\beta = 4.26 \text{ MHz}$
- 7.33 (a)  $f_\beta = 13.3 \text{ MHz}$ , (b)  $f = 199 \text{ MHz}$
- 7.37  $f_L = 540 \text{ Hz}$ ,  $f_H = 344 \text{ kHz}$
- 7.41 (a)  $r_S = 198 \Omega$ , (b)  $12\%$
- 7.44 (a)  $C_\pi = 2.21 \text{ pF}$ ,  $C_M = 27.7 \text{ pF}$ ,  
 (b)  $f_H = 3.06 \text{ MHz}$ ,  $A_V = -19.5$
- 7.47 (a)  $f_H = 10.4 \text{ MHz}$ , (b)  $C_M = 18.2 \text{ pF}$ ,  
 (c)  $A_V = -4.66$
- 7.50  $f_{P\mu} = 17.9 \text{ MHz}$ ,  $A_V = 0.863$

**Chapter 8**

- 8.2 (a)  $R_L = 7.2 \Omega$ ,  $R_B = 1.12 \text{ k}\Omega$ ,  
 (b)  $V_P = 26 \text{ mV}$
- 8.5 (b)  $9.38$ ,  $30$ ,  $39.4$ ,  $10.8$ ,  $7.16 \text{ W}$ ,  
 (c) Yes
- 8.9  $T_{\text{dev}} = 136^\circ\text{C}$ ,  $T_{\text{case}} = 101^\circ\text{C}$ ,  $T_{\text{snk}} = 85^\circ\text{C}$
- 8.11  $P_D = 10 \text{ W}$
- 8.13 (a)  $I_Q = 9.8 \text{ mA}$ ,  $R = 949 \Omega$ ,  
 $i_{E1}(\text{max}) = 19.6 \text{ mA}$ ,  
 $i_{E1}(\text{min}) = 0$ ,  $i_L(\text{max}) = 9.8 \text{ mA}$ ,  
 $i_L(\text{min}) = -9.8 \text{ mA}$ ,  
 (b)  $16.3\%$

- 8.16 (a)  $v_o(\text{max}) = 8 \text{ V}$ ,  $i_L = 1.6 \text{ mA}$ ,  
 $v_I = 10 \text{ V}$ ,  
 (b) 62.7%
- 8.19 (a)  $V_{BB} = 5 \text{ V}$ ,  $P = 5 \text{ mW}$ ,  
 (b)  $v_o(\text{max}) = 8 \text{ V}$ ,  $i_L = i_{Dn} = 8 \text{ mA}$ ,  
 $i_{Dp} = 0$ ,  $v_I = 9.5 \text{ V}$ ,  $P_L = 64 \text{ mW}$ ,  
 $P_{Mn} = 16 \text{ mW}$ ,  $P_{Mp} = 0$
- 8.21 (a)  $200 \mu\text{A}/\text{V}^2$
- 8.24  $\bar{P}_L(\text{max}) = 112.5 \text{ mW}$ ,  $R_1 = 40.4 \text{ k}\Omega$ ,  
 $R_2 = 13.3 \text{ k}\Omega$
- 8.29 (a) Set  $V_e = 0.9V_{CC} = aV_P$ , then  
 $a = 2.86$ ;  
 (b)  $P_Q = 4.95 \text{ W}$
- 8.33  $R_i = 46.4 \text{ k}\Omega$

**Chapter 9**

- 9.2 (a)  $A_v = -10$ ,  $R_i = 10 \text{ k}\Omega$ ;  
 (b)  $A_v = -5$ ,  $R_i = 10 \text{ k}\Omega$ ;  
 (c)  $A_v = -20$ ,  $R_i = 5 \text{ k}\Omega$
- 9.5  $R_2 = 1 \text{ M}\Omega$ ,  $R_1 = 33.3 \text{ k}\Omega$
- 9.7 (a)  $v_o = -150 \sin \omega t (\text{mV})$ ;  
 (b)  $i_2 = 10 \sin \omega t (\mu\text{A})$ ,  
 $i_L = -37.5 \sin \omega t (\mu\text{A})$ ,  
 $i_o = -47.5 \sin \omega t (\mu\text{A})$
- 9.11 (a)  $450 \text{ k}\Omega$ , (b)  $4.95 \text{ M}\Omega$
- 9.15 (a)  $-1.996 \text{ V}$ , (b)  $+1.996 \text{ V}$
- 9.19 (a)  $v_o = -2.667 \text{ V}$ ,  
 (b)  $v_{I3} = 0.525 \text{ V}$
- 9.20  $R_1 = 20 \text{ k}\Omega$ ,  $R_2 = 160 \text{ k}\Omega$ ,  $R_F = 80 \text{ k}\Omega$
- 9.24 (a)  $R_F = 10 \text{ k}\Omega$ ,  
 (b)  $v_o = 0.3125 \text{ V}$ ,  $4.6875 \text{ V}$
- 9.27  $R_1 = 8 \text{ k}\Omega$ ,  $R_2 = 72 \text{ k}\Omega$
- 9.31  $A_v = 5$
- 9.34  $v_{O1} = -v_{O2} = \left(1 + \frac{R_2}{R_1}\right) \cdot v_I$
- 9.37 (b)  $R_S \geq 1.1 \text{ k}\Omega$
- 9.40  $R_2 = R_3 = 1 \text{ k}\Omega$ , Set  $R_1 = R_F = 1 \text{ k}\Omega$
- 9.43  $v_{12} = 2.5 \text{ V}$
- 9.47  $R_{if} = 1.52 \text{ k}\Omega$ , Potentiometer  $\approx 300 \text{ k}\Omega$
- 9.50 (a)  $f = 31.8 \text{ Hz}$ , Phase =  $-90^\circ$ ,  
 (b)  $f = 15.9 \text{ Hz}$ ,  $159 \text{ Hz}$
- 9.53 (a)  $A_v = -\frac{R_2}{R_1} \cdot \frac{j\omega R_1 C_1}{1 + j\omega R_1 C_1}$ ,  
 (b)  $A_v = -\frac{R_2}{R_1}$ , (c)  $f = \frac{1}{2\pi R_1 C_1}$

**Chapter 10**

- 10.2  $I_{C1} = I_{C2} = 962 \mu\text{A}$ ,  $I_{B1} = I_{B2} = 19.2 \mu\text{A}$
- 10.5  $I_{REF} = 0.54 \text{ mA}$ ,  $R_1 = 7.96 \text{ k}\Omega$
- 10.7 (a)  $R_1 = 9.3 \text{ k}\Omega$ , (b)  $I_O = 2 \text{ mA}$ ,  
 (c)  $R_{C2} = 4.65 \text{ k}\Omega$
- 10.11 (a)  $I_2 = 1.0 \text{ mA}$ ,  $I_3 = 1.5 \text{ mA}$ ;  
 (b)  $I_1 = 0.25 \text{ mA}$ ,  $I_3 = 0.75 \text{ mA}$ ;  
 (c)  $I_1 = 0.167 \text{ mA}$ ,  $I_2 = 0.333 \text{ mA}$
- 10.14  $I_{REF} = 0.500392 \text{ mA}$ ,  $R_1 = 17.19 \text{ k}\Omega$
- 10.17  $I_{REF} = 1.00053 \text{ mA}$ ,  $R_1 = 9.295 \text{ k}\Omega$
- 10.20 (a)  $0.466 \text{ mA}$ , (b)  $400 \Omega$
- 10.23  $R_O = 12.8 \text{ M}\Omega$ ,  $0.936\%$
- 10.25  $V_{BE1} = 0.681 \text{ V}$ ,  $I_{REF} = 0.482 \text{ mA}$ ,  
 $I_O = 8.7 \mu\text{A}$ ,  $V_{BE2} = 0.577 \text{ V}$
- 10.29  $R_{E2} = 10.17 \text{ k}\Omega$ ,  $R_{E3} = 2.44 \text{ k}\Omega$ ,  
 $R_1 = 18.6 \text{ k}\Omega$ ,  
 $V_{BE2} = 0.598 \text{ V}$ ,  $V_{BE3} = 0.6268 \text{ V}$
- 10.32 (a)  $I_{O1} = 4.64 \text{ mA}$ ,  $I_{O2} = 2.32 \text{ mA}$ ,  
 $I_{O3} = 6.96 \text{ mA}$ ,  
 (b)  $R_{C1} \approx 2 \text{ k}\Omega$ ,  $R_{C2} \approx 4 \text{ k}\Omega$ ,  $R_{C3} \approx 1.34 \text{ k}\Omega$
- 10.35 (a)  $0.475 \leq I_O \leq 0.525 \text{ mA}$ ,  
 (b)  $0.451 \leq I_O \leq 0.551 \text{ mA}$
- 10.38  $(W/L)_2 = 3.125$ ,  $(W/L)_1 = 1.25$ ,  
 $(W/L)_3 = 0.2$
- 10.41  $(W/L)_2 = 20$ ,  $(W/L)_1 = 60$ ,  
 $(W/L)_3 = 0.986$
- 10.44  $I_{REF} = I_O = 0.74 \text{ mA}$ ,  $V_{DS2}(\text{sat}) = 0.86 \text{ V}$
- 10.47 (a)  $I_{REF} = 80 \mu\text{A}$ ,  $I_O \approx 80 \mu\text{A}$ ;  
 (b) From a PSpice analysis,  
 $\Delta I_O = 0.052 \mu\text{A}$

10.50  $I_{REF} = 89.5 \mu\text{A}$ ,  $I_1 = 17.9 \mu\text{A}$ ,  
 $I_2 = 112 \mu\text{A}$ ,  $I_3 = 71.6 \mu\text{A}$ ,  $I_4 = 358 \mu\text{A}$

10.52 (a)  $i_D = 2.5 \text{ mA}$ , (b)  $i_D = 3 \text{ mA}$ ,  
 (c)  $i_D = 3.5 \text{ mA}$

10.56 (a)  $V_{BE} = 0.5208 \text{ V}$ ,  
 (b)  $R_1 = 8.96 \text{ k}\Omega$ ,  
 (c)  $V_I = 4.462 \text{ V}$ ,  
 (d)  $A_v = -1846$

10.60  $A_v = -4447$

### Chapter 11

11.1 (a)  $R_E = 2 \text{ k}\Omega$ ,  $R_C = 4 \text{ k}\Omega$ ;  
 (c)  $v_{CM}(\text{max}) = 4 \text{ V}$ ,  $v_{CM}(\text{min}) = -8 \text{ V}$

11.5 (a) (i)  $0 \text{ V}$ , (ii)  $-0.1 \text{ V}$   
 (b) (i)  $0.768 \text{ V}$ , (ii)  $0.758 \text{ V}$

11.8 (a)  $R_E = 62 \text{ k}\Omega$ ,  
 (b)  $A_d = 71.0$ ,  $A_{cm} = -0.398$ ,  
 $\text{CMMR}_{\text{dB}} = 45 \text{ dB}$   
 (c)  $R_{id} = 70.4 \text{ k}\Omega$ ,  $R_{icm} = 6.28 \text{ M}\Omega$

11.18 (a)  $R_{id} = 46.8 \text{ k}\Omega$ ,  
 (b)  $R_{icm} = 43.1 \text{ M}\Omega$

11.22 (a)  $R_D = 47.5 \text{ k}\Omega$ ,  $R_1 = 73.75 \text{ k}\Omega$ ,  
 $I_Q = I_1 = 240 \mu\text{A}$   
 (b)  $\Delta I_Q \cong 13 \mu\text{A}$

11.25 (a)  $v_d = 1 \text{ V}$ , (b)  $v_{d,\text{max}} = 1.58 \text{ V}$

11.30  $v_{cm}(\text{max}) = 6 \text{ V}$

11.36 (a)  $I_Q = 1 \text{ mA}$ ,  $R_D = 6 \text{ k}\Omega$ ,  
 (b)  $g_f(\text{max}) = 0.25 \text{ mA/V}$ ,  
 (c)  $A_d = 1.5$

11.41 (a)  $A_d \cong 2307$ , (b)  $R_L = 150 \text{ k}\Omega$

11.44 (a)  $I_Q = 2 \mu\text{A}$ , (b)  $A_d = 1923$ ,  
 (c)  $A_d = 641$

11.48 (a)  $V_{DS3} = V_{DS4} = 2 \text{ V}$ ,  
 $V_{DS1} = V_{DS2} = 10 \text{ V}$ ,  
 (b)  $A_d = 80$ , (c)  $R_o = 400 \text{ k}\Omega$

11.56 (a)  $A_d = 88.9$

11.62  $R_i \cong 1.05 \text{ M}\Omega$ ,  $R_o = 0.472 \text{ k}\Omega$ ,  
 $A_v = -438$

11.66 (a)  $R_{C1} = 80 \text{ k}\Omega$ ,  $R_{C2} = 20 \text{ k}\Omega$ ;  
 (b)  $A_{d1} = -69.6$ ,  $A_d = -5352$

### Chapter 12

12.1 (a)  $1.249 \times 10^{-2}$ ,  
 (b)  $-0.016\%$ ,  $79.987$ ,  
 (c)  $\beta = 1.15 \times 10^{-2}$ ,  $-1.6\%$ ,  $78.72$

12.4  $A = 4999$

12.6 (a)  $f_H = 8 \text{ kHz}$ , (b)  $f_H = 40 \text{ kHz}$

12.8 1000

12.11 (a)  $R_i(\text{max}) = 10^5 \text{ k}\Omega$ ,  $R_i(\text{min}) = 1 \Omega$   
 (b)  $R_o(\text{max}) = 10^4 \text{ k}\Omega$ ,  
 $R_o(\text{min}) = 0.1 \Omega$

12.14  $R_{if} \cong 500 \text{ M}\Omega$ ,  $R_{of} = 0.0219 \Omega$

12.18  $R_{if} = 10^6 \text{ k}\Omega$ ,  $R_{of} = 5.04 \text{ M}\Omega$

12.22 (a)  $I_{C1} = I_{C2} = 0.5 \text{ mA}$ ,  
 $I_{C3} = 2 \text{ mA}$ ,  $v_O = 0$ ;  
 (b)  $A_{vf} = 5.68$

12.26  $A_{vf} = 45.4$

12.30 (a)  $r_{\pi 1} = 15.8 \text{ k}\Omega$ ,  $g_{m1} = 7.62 \text{ mA/V}$ ,  
 $r_{\pi 2} = 2.28 \text{ k}\Omega$ ,  $g_{m2} = 52.7 \text{ mA/V}$   
 (b)  $A_{vf} = 8.63$ ; (c)  $R_{if} = 45.1 \Omega$

12.34  $A_{vf} = 5.33$

12.38  $A_{gf} = 98.06 \text{ mA/V}$

12.41 (a)  $A_v = -3.41$ ,  
 (b)  $A_{vf} = -85.0 \text{ V/mA}$ ,  
 (c)  $R_{if} = 14.9 \text{ k}\Omega$ ,  
 (d)  $R_{of} = 4.88 \text{ k}\Omega$

12.45  $R_F = 27.2 \text{ k}\Omega$

12.49  $T = 84.45$

12.51 (a)  $f_{180} \cong 1.05 \times 10^4 \text{ Hz}$ ,  
 (b)  $\beta = 4.42 \times 10^{-4}$

12.55 (c) For  $\beta = 0.005$ , system is stable.  
 Phase margin =  $14^\circ$ ;  
 For  $\beta = 0.05$ , system is unstable.

12.60  $\beta = 0.01428$

12.65  $f_{PD} = 555 \text{ Hz}$



## Chapter 13

- 13.5 56.4 V
- 13.9  $I_{C2} = 10.28 \mu\text{A}$ ,  $I_{C9} = 17.13 \mu\text{A}$ ,  
 $I_{B9} = 1.713 \mu\text{A}$ ,  $I_{B4} = 0.9345 \mu\text{A}$ ,  
 $I_{C4} = 9.345 \mu\text{A}$
- 13.12  $I_{C14} = 21.8 \text{ mA}$ ,  $I_{C15} = 0.071 \text{ mA}$
- 13.14  $R_1 = 30.32 \text{ k}\Omega$ ,  $R_2 = 33.96 \text{ k}\Omega$
- 13.18  $R_{id} = 2.095 \text{ M}\Omega$
- 13.22 (a)  $I_{REF} = I_Q = I_{D7} = 89.2 \mu\text{A}$ ,  
 (b)  $A_d = 141$ ,  $A_{v2} = 141$ ,  $A_v = 19,881$
- 13.26  $R_o = 1.26 \text{ M}\Omega$
- 13.38  $-15 \leq v_{CM} \leq 11.6 \text{ V}$
- 13.41  $A_d = 10.38$ ,  $|A_{v2}| = 1917$ ,  $|A| = 19,895$
- 13.43  $I_{DSS} = 0.8 \text{ mA}$

## Chapter 14

- 14.1 (a)  $A_{CL} = -4.52$ ,  $R_{if} = 90.8 \Omega$   
 (b)  $A_{CL} = -4.92$ ,  $R_{if} = 98.9 \Omega$   
 (c)  $A_{CL} = -4.965$ ,  $R_{if} = 99.8 \Omega$
- 14.5 (a)  $A_v \approx 1$ , (b)  $R_{of} = 0.02 \Omega$
- 14.8 (a)  $R_{if} = 99.1 \Omega$ , (b)  $R_{of} = 18.4 \Omega$ ,  
 (c)  $A_{CL} = 0.65$ , (d) 0.65
- 14.11  $f_{3\text{-dB}} = 40 \text{ Hz}$ ,  $f_T = 2 \text{ MHz}$
- 14.14  $f_{\text{max}} = 159 \text{ kHz}$
- 14.18 6.37 V
- 14.22  $10^3 \text{ s}$
- 14.26  $i_{C1}/i_{C2} = 1.0155$
- 14.31 (a)  $v_{O1} = v_{O2} = 0.5 \text{ V}$ ,  $v_{O3} = -0.3 \text{ V}$ ,  
 (b)  $R_A = 8.33 \text{ k}\Omega$ ,  $R_B = 10 \text{ k}\Omega$ ,  
 (c)  $v_{O1} = v_{O2} = 0.1 \text{ V}$ ,  $v_{O3} = -0.14 \text{ V}$
- 14.34 (a)  $R_2 = 22.48 \text{ M}\Omega$ , (b)  $R_1 = 6 \text{ k}\Omega$
- 14.37 For (a)  $v_O = 9 \text{ mV}$ ,  
 for (b)  $v_O = -1.0815 \text{ V}$
- 14.40 (a) Circuit a:  $v_O = 0$ , Circuit b:  
 $v_O = -0.975 \text{ V}$

- (b) Circuit a:  $v_O = -0.010 \text{ V}$ , Circuit  
 b:  $v_O = -1.18 \text{ V}$
- (c) Circuit a:  $I_B \rightarrow v_O = 0$ ,  
 $I_{OS} \rightarrow v_O = 0.0125 \text{ V}$   
 Circuit b:  $I_B \rightarrow v_O = -1.365 \text{ V}$ ,  
 $I_{OS} \rightarrow v_O = -1.62 \text{ V}$

14.42  $\text{CMRR}_{\text{dB}} = 37.5 \text{ dB}$

## Chapter 15

- 15.6  $N = 5$
- 15.10 (b)  $|A_v|_{\text{max}} = 28.3$ ,  $f_o = 5.305 \text{ kHz}$ ,  
 $f_1 = 5.315 \text{ kHz}$ ,  $f_2 = 5.296 \text{ kHz}$
- 15.13 (b)  $R_2 = 524 \text{ k}\Omega$ ,  $C_1 = 0.0732 \mu\text{F}$ ,  
 $C_2 = 66.3 \text{ pF}$
- 15.15 (a)  $10 \text{ M}\Omega$ , (b)  $1 \text{ M}\Omega$ , (c)  $333 \text{ k}\Omega$
- 15.18 (a)  $\tau = 60 \mu\text{s}$ , (b)  $\Delta v_O = 0.167 \text{ V}$ ,  
 (c)  $N = 78$
- 15.21  $R = 8.12 \text{ k}\Omega$ ,  $R_2 = 236 \text{ k}\Omega$
- 15.25 (a)  $f_o = \frac{1}{2\pi\sqrt{R_A R_B C_A C_B}}$ ,  
 (b)  $\frac{R_2}{R_1} = \frac{R_A}{R_B} + \frac{C_B}{C_A}$
- 15.29  $f_o = \frac{1}{2\pi\sqrt{\frac{C_1 + C_2}{C_1 C_2 L}}}$ ,  $\frac{C_1}{C_2} = g_m R_L$
- 15.34  $V_{REF} = -5 \text{ V}$ ,  $R_F = 10 \text{ k}\Omega$ ,  
 $R_{VAR} = 40 \text{ k}\Omega$
- 15.36 (a)  $V_{TH} = 2 \text{ V}$ ,  $V_{TL} = -2 \text{ V}$
- 15.40 (b)  $R_2 = 190 \text{ k}\Omega$ ,  $V_{REF} = 1.579 \text{ V}$
- 15.42 (a)  $R_2 = 12.6 \text{ k}\Omega$ , (b)  $R = 3.02 \text{ k}\Omega$
- 15.47 (b) Duty cycle = 50%,  $f_o = 257 \text{ Hz}$
- 15.52  $T = 3.80 \text{ ms}$ , recovery time  $\approx 2 \text{ ms}$
- 15.56  $627 \text{ Hz} \leq f \leq 4.81 \text{ kHz}$ ,  
 $52.2 \leq \text{d.c.} \leq 66.7\%$
- 15.60  $\frac{R_2}{R_1} = 14$ ,  $\frac{R_4}{R_3} = 15$ , Bias voltage =  
 $\pm 12 \text{ V}$ ,  $I_P = 2 \text{ A}$ ,  
 Peak output voltage =  $\pm 10 \text{ V}$

## Chapter 16

- 16.1 (a)  $V_{SB} = 1\text{ V} \Rightarrow \Delta V_{TN} = 0.315\text{ V}$ ,  
 $V_{SB} = 2\text{ V} \Rightarrow \Delta V_{TN} = 0.544\text{ V}$   
 (b)  $I_D = 0.578, 0.384, 0.267\text{ mA}$
- 16.5  $v_{i1} = 4.67\text{ V}$ ,  $v_{O1} = 2.67\text{ V}$ ,  $v_O = 1.09\text{ V}$
- 16.8 5.79
- 16.11  $V_{TNL} = -2.88\text{ V}$
- 16.14 (a) (i) 0, (ii) 1.16 mW;  
 (b) (i) 0, (ii) 825  $\mu\text{W}$ ;  
 (c) (i) 0, (ii) 200  $\mu\text{W}$
- 16.17 (a) (i) 4.2 V, (ii) 3.4 V
- 16.20 (a) 1.82;  
 (b)  $(W/L)_L = 0.444$ ,  
 $(W/L)_D = 0.808$ ;  
 (c) 0.0369 V
- 16.24  $\overline{(B \cdot C)} + A$
- 16.28 (a)  $V_{i1} = 2.5\text{ V}$ ,  $V_{ON1} = 1.7\text{ V}$ ,  
 $V_{OP1} = 3.3\text{ V}$ ;  
 (c) 4.64 V, 0.356 V
- 16.33 (a) 144.5  $\mu\text{A}$ , (b) 99.4  $\mu\text{A}$
- 16.37  $V_{iL} = 4.125\text{ V}$ ,  $V_{OHU} = 9.125\text{ V}$ ,  
 $V_{iH} = 5.875\text{ V}$ ,  $V_{OLU} = 0.875\text{ V}$   
 $NM_L = 3.25\text{ V}$ ,  $NM_H = 3.25\text{ V}$
- 16.39 (a) 2.5 V, (b)  $\left(\frac{W}{L}\right)_n = 4.5\left(\frac{W}{L}\right)_p$ ,  
 (c) 1.65 V
- 16.43  $\overline{(A \text{ OR } B) \text{ AND } C}$
- 16.46 (b)  $v_{O2} = (v_A \text{ OR } v_B) \text{ AND } v_C$
- 16.50 6.25 ms
- 16.55 Exclusive-OR function
- 16.67 (a)  $(W/L) = 0.329$ ;  
 (b) 32.8 mA, 65.6 mW
- Chapter 17**
- 17.1 (a)  $i_E = 0.56\text{ mA}$ ,  $v_{O1} = 3.5\text{ V}$ ,  
 $v_{O2} = 2.38\text{ V}$   
 (b)  $i_E = 0.76\text{ mA}$ ,  $v_{O2} = 3.5\text{ V}$   
 (e) For  $v_{O1} = 2.38\text{ V}$ ,  $R_{C1} = 1.47\text{ k}\Omega$
- 17.4  $R_5 = 2.8\text{ k}\Omega$ ,  $R_E = 2.1\text{ k}\Omega$ ,  $R_2 = 2.1\text{ k}\Omega$ ,  
 $R_1 = 0.5\text{ k}\Omega$ ,  $R_3 = 1.1\text{ k}\Omega$ ,  
 $R_4 = 0.767\text{ k}\Omega$ ,  
 $R_{C2} = 1\text{ k}\Omega$ ,  $R_{C1} = 0.808\text{ k}\Omega$
- 17.8 (a) AND logic function;  
 (b) Logic 0 = 0 V, Logic 1 = 1.8 V;  
 (c)  $i_{E1} = 1.65\text{ mA}$ ,  $i_{C3} = 0$ ,  
 $i_{C2} = i_{E3} = 3\text{ mA}$ ,  $V_2 = 0$   
 (f)  $i_{E1} = 0.962\text{ mA}$ ,  $i_{C2} = 0$ ,  
 $i_{C3} = i_{E2} = 2.25\text{ mA}$ ,  $V_2 = 1.8\text{ V}$
- 17.10 (a) Logic 1 = +0.2 V, Logic 0 = -0.2 V,  
 (b)  $R_E = 3\text{ k}\Omega$ , (c)  $R_1 = 1\text{ k}\Omega$ ,  
 (d)  $i_{R2} = 0.4\text{ mA}$ ,  $i_{D2} = 0.467\text{ mA}$ ,  
 (e) 10.98 mW
- 17.13 (a) Logic 1 = 0 V, Logic 0 = -0.4 V,  
 (b)  $v_{O1} : A + B$ ,  $v_{O2} : C + D$ ,  
 $v_{O3} : (A + B) \cdot (C + D)$
- 17.15 (a) (i)  $v^1 = 0.8\text{ V}$ ,  $i_1 = 0.525\text{ mA}$ ,  
 $i_3 = i_4 = 0$ ,  $v_O = 5\text{ V}$   
 (ii)  $v^1 = 2.2\text{ V}$ ,  $i_1 = 0.35\text{ mA}$ ,  
 $i_3 = 2.04\text{ mA}$ ,  $i_4 = 0.297\text{ mA}$   
 (b) 7, (c) 5
- 17.18 (a) (i)  $i_1 = 0.683\text{ mA}$ ,  
 $i_{B2} = i_2 = i_4 = i_{B3} = i_3 = 0$ ,  
 (ii)  $i_1 = i_{B2} = 0.45\text{ mA}$ ,  
 $i_2 = 2.05\text{ mA}$ ,  $i_4 = 0.533\text{ mA}$ ,  
 $i_{B3} = 1.97\text{ mA}$ ,  $i_3 = 2.23\text{ mA}$
- 17.22 (a)  $i_{B1} = 1.05\text{ mA}$ , other currents = 0,  
 (b)  $i_{B1} = 0.926\text{ mA}$ ,  $i_{B2} = 1.59\text{ mA}$ ,  
 $i_{C2} = 2.05\text{ mA}$ ,  
 $i_{B3} = 2.64\text{ mA}$ ,  $i_{C3} = 7.29\text{ mA}$
- 17.26 (a)  $v_{B1} = 1.1\text{ V}$ ,  $i_{B1} = 1.39\text{ mA}$ ,  
 $v_{B2} = 0.8\text{ V}$ ,  $i_{B4} = 0.0394\text{ mA}$ ,  
 $i_{C4} = 1.18\text{ mA}$ ,  $v_{B4} = 4.97\text{ V}$ ,  
 all other currents = 0  
 (b)  $v_{B1} = 1.7\text{ V}$ ,  $v_{B2} = 1.4\text{ V}$ ,  
 $v_{BO} = 0.7\text{ V}$ ,  $v_{C2} = 1.1\text{ V}$   
 $i_{B1} = 1.18\text{ mA}$ ,  $i_{B2} = 1.42\text{ mA}$ ,  
 $i_{B4} = 0.00369\text{ mA}$ ,  
 $i_{C2} = 5.13\text{ mA}$ ,  $i_{BO} = 6.55\text{ mA}$
- 17.29 (a)  $i_{E1} = 0.0975\text{ mA}$ ,  $P = 0.4875\text{ mW}$ ;  
 (b)  $P = 1.98\text{ mW}$ ;  
 (c)  $i_{Sc} \cong 78\text{ mA}$

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