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HW 5

1) $V_p = V_n$ $\quad V_n = 0$ $\quad i_n = 0$ $\quad V = IR$ $\quad I = \frac{V}{R}$

$$i_1 = i_n + i_{10} = i_{10} = 0.5\,mA$$

$$i_{10} = \frac{(V_n - V_o)}{10k\Omega} = 0.5\,mA \cdot 10k\Omega = -V_o$$

$$V_o = -5\,V$$

$$i_o = \frac{V}{R} = \frac{-5}{5k\Omega} = -1\,mA$$

2) 1) $i_+ = i_- = 0\,A$

$$V_+ = V_-$$

$$V_+ = 0 \quad V_- = 0$$

$$I_2 = \frac{240 \cdot 10^{-3}}{8k\Omega} = 30\,mA$$

2) $i_4 = -\frac{V_a}{60k\Omega} = -(30\,mA)(60k\Omega) = -1.8\,V$

3) $-\frac{V_a}{40} + \frac{V_a - V_o}{30} - i_a = 0$

$$-\frac{1.8}{40k\Omega} + \frac{1.8 - V_o}{30k\Omega} = 30 \cdot 10^{-6}$$

$$V_o = -4.05\,V$$

4) $\frac{V_o - V_d}{30k\Omega} + \frac{V_o}{20k\Omega} + i_o = 0$

$i_o = \frac{4.05 - 6?}{30 \cdot 10^3} + \frac{4.05}{20 \cdot 10^3} = 2.775 \cdot 10^{-4} A$

3) $\frac{V_n - (-5)}{3000} + \frac{V_n - V_o}{6000} = 0$ $\quad V_p = V_n$

$\frac{V_p - (6)}{10000} + \frac{V_p}{5000} = 0$

$3V_p - 6 = 0 \quad V_p = 2V = V_n$

$V = IR$

$\frac{2+5}{3000} + \frac{2 - V_o}{6000} = 0$

$V_o = 16 V$

$I_L = \frac{16}{8000} = 0.002 A$

4) 1) $V_o = -\frac{220}{33} V_a - \frac{220}{22} V_b - \frac{220}{50} V_c$

inverting summing amplifier

2) $V_o = -\frac{220}{33}(1.2) - \frac{220}{22}(1.5) - \frac{220}{80}(4) =$

$-4 V$

3) $V_b = -(8 + 10V_b + 11)$ $\quad V_o = 6$

$6 = -8 - 10V_b - 11$

$V_b = -2.5V$

$V_o = -6$

$-6 = -8 - 10V_b - 11$

$V_b = -1.3\ V$

$-2.5\ V < V_b < -1.3\ V$

5) 1) $\frac{V_a - V_a}{40000} + \frac{V_a - V_b}{22000} + \frac{V_a - V_c}{100000} + \frac{V_a}{352000} + \frac{V_a - V_o}{220000} = 0$

$V_a\left(\frac{1}{40000} + \frac{1}{22000} + \frac{1}{100000} + \frac{1}{352000} + \frac{1}{220000}\right) - \frac{4}{40000} + \frac{9}{22000} - \frac{13}{100000} - \frac{V_o}{220000}$

$V_o = 14\ V$

2) $V_o = 15, -15$

$36 - 55V_a = 15 \quad V_a = -\frac{21}{55} = 3.818V$

$36 - 5.5V_a = -15 \quad V_a = 9.272\ V$

$3.818 < V_a < 9.272$

6) i) $\frac{V_p - V_g}{30000} + \frac{V_p}{48000} = 0$ $\frac{V_f - 3}{30000} + \frac{V_p}{45000} = 0$

$V_p\left(\frac{1}{30000} + \frac{1}{45000}\right) = \frac{3}{30000}$

$V_p = 1.8\,V = V_n$

$\frac{V_n}{15000} + \frac{V_n - V_o}{48000} = 0$ $\frac{1.8}{15000} + \frac{1.8 - V_o}{48000} = 0$

$V_g = 7.56\,V = 2.52 V_g$

b) $-10 < 2.52 V_g < 10$

$-3.968 < V_g < 3.968$

c) $\frac{V_f - 5}{30000} + \frac{V_p}{45000} = 0$ $V_p\left(\frac{1}{30000} + \frac{1}{45000}\right) = \frac{5}{30000}$

$V_f = 3$

$\frac{V_n}{15000} + \frac{V_n - V_o}{R} = 0$

$\frac{3}{15000} + \frac{3}{R} - \frac{V_o}{R} = 0$

$\frac{1}{R}(3 - V_o) = -\frac{3}{15000}$

$R = (3 - V_o)\left(-\frac{15000}{3}\right) = (-7)\left(-\frac{15000}{3}\right)$

$= 35000\,\Omega$

7) 1) $\frac{V_n}{20000} + \frac{V_n - V_o}{100000} = 0$

$$\frac{V_p - V_a}{R_a} + \frac{V_p - V_o}{15000} + \frac{V_p - V_c}{R_c} = 0$$

$$V_n = \frac{V_o}{6}$$

$$D = 2500R_a + \frac{R_a R_c}{6} + 2500R_c$$

$R_a = 30000\ \Omega$

$R_c = 10000\ \Omega$

2) $V_o = V_a + 2V_b + 3V_c$

$i_a = \frac{V_a - V_p}{R_a} = \frac{0.7 - 0.8}{30000} = -3.33\ \mu A$

$i_b = \frac{0.4 - 0.8}{15000} = -26.67\ \mu A$

$i_c = 30\ \mu A$

8) 1) Difference amplifier circuit

2) $\frac{V_n - V_1}{5000} + \frac{V_n - V_o}{20000} + i_n = 0$

$$\frac{1 - V_a}{5000} + \frac{1 - V_o}{20000} = 0$$

$$V_o = 5 - 4V_a$$

3) $\frac{1-2}{5000} = \frac{10-1}{R_f}$ $\quad R_f = -9 \cdot 5000$

$V_o = -10\,V$

$R_f = 11 \cdot 5000 = 55\,k\Omega$

9) $V_p = (-18)\left(\frac{1.5}{1.5+175}\right) = -3\,V$

$V_o = 0.009375 R_f - 3$

$9 = 0.009375 R_f - 3$

$R_f = \frac{12}{0.009375} = 1280\,\Omega$

$R_f = \frac{-6}{0.009375} = -640$

1280 Ω

10) $\frac{V_n}{2000} - i_a + \frac{V_n - V_o}{R_f} = 0$

$V_p = R_b i_b$

$\frac{R_b i_b}{2000} - i_a + \frac{R_b i_b - V_o}{R_f} = 0$ $\quad R_f = 8000\,\Omega$

$R_b = 1600\,\Omega$