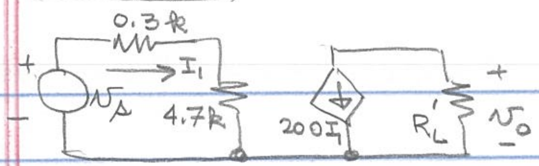
PROBLEM 1

A)



where $R_L' = 50k \| R_L$

$I_1 = \dfrac{v_s}{0.3k + 4.7k} = \dfrac{v_s}{5k}$ $\qquad v_o = -200 I_1 R_L' = -\dfrac{200 \times v_s}{5k} \times R_L'$

$|A_v| = 80 = \left|\dfrac{v_o}{v_s}\right| = \dfrac{200 R_L'}{5k}$ and $R_L' = \dfrac{80 \times 5k}{200} = 2 k\Omega$

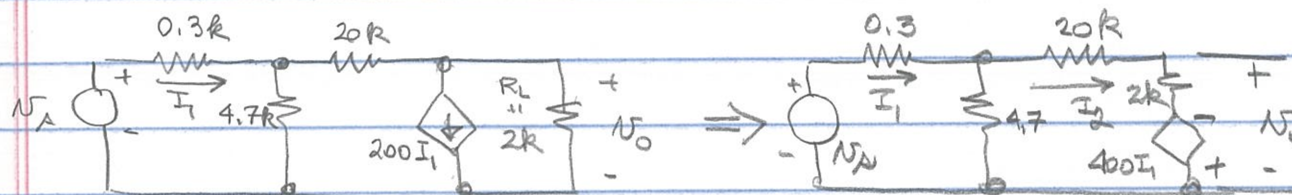
$R_L' = \dfrac{50 \times R_L}{50 + R_L} = 2$ (all Rs in kΩ)

Solving gives $48 R_L = 100$ and $R_L = 2.08 k\Omega$

B) For $A_i = 100$, I_1 remains the same but

$v_o = -100 I_1 \times R_L' = -100 \times \dfrac{v_s}{5k} \times 2k$ and $|A_v| = 40$

C) The circuit is



$-v_s + I_1(0.3k) + 4.7(I_1 - I_2) = 0$ or $5k I_1 - 4.7k I_2 = v_s$ ①

$4.7k(I_2 - I_1) + 20k I_2 + 2k I_2 + 400 I_1 = 0$ or $-404.7 I_1 + 26.7 I_2 = 0$ ②

Solving ① and ② simultaneously gives

$I_1 = -0.0151 v_s$, $I_2 = -0.2288 v_s$

$\dfrac{v_o}{v_s} = 2 I_2 - 400 I_1 = 2(-.2288) - 400(-0.0151) = 5.58$

With $A_i = 100$, the equations are:

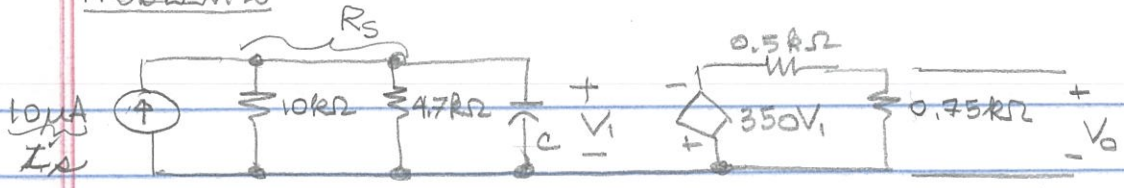
$5k I_1 - 4.7k I_2 = v_s$ ③ ; $-204.7 I_1 + 26.7 I_2 = 0$

Simultaneous solution gives $I_1 = -0.03222 v_s$; $I_2 = -0.247 v_s$

$v_o = -2(-0.247 v_s) - 200(-0.03222) v_s$ $\therefore \dfrac{v_o}{v_s} = 5.946$

Note that the feedback reduced the gain but also reduced the variation. Also, it is allowed to use MATLAB

PROBLEM 2



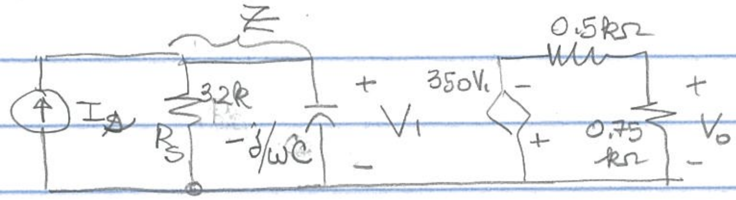
A) $C = 0$ (open-circuited); $10k\Omega \| 4.7k\Omega = R_S = \frac{10 \times 4.7}{10+4.7} = 3.2\,k\Omega$

$V_1 = 10\mu A \times 3.2\,k\Omega = 32\,mV$; $V_o = \frac{0.75}{0.75+0.5} \times (-350V_1) = 0.6(-350V_1) = -210V_1$

$\therefore V_o = -210 \times 32\,mV = 6.72\,V$

$\frac{V_o}{I_s} = \frac{6.72}{10^{-5}} = 6.72 \times 10^{5} = 672 \times 10^{3} = 672\,k\Omega$ ($\frac{V}{I}$ = ohms)

B) With C connected



NOTE: The right-hand loop is independent of frequency. Thus, the only cause of attenuation in V_o/I_s is due to C in the left hand loop. Therefore we must find out what value of C causes $|V_1(j\underbrace{2\pi \times 10^4}_{\text{given } \omega})| = \frac{1}{\sqrt{2}} \times V_1$ (part A)

$$\underline{V}_1(j\omega) = I_s \times Z \; ; \; Z = R_S \| -j/\omega C = \frac{-jR_S/\omega C}{R_S - j/\omega C} \times \frac{j/\omega C}{j/\omega C}$$

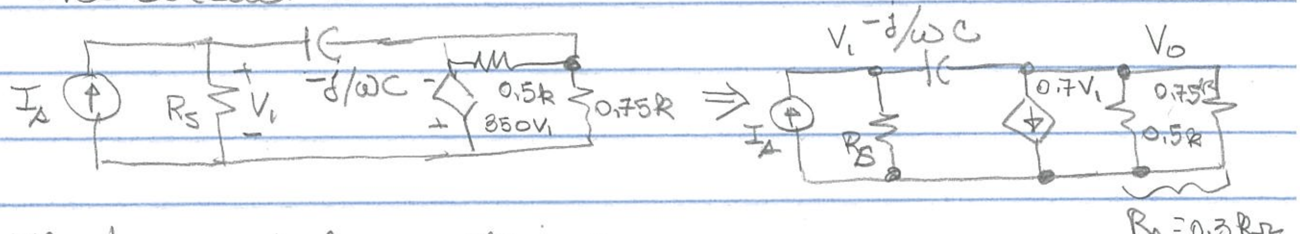
$$I_s Z = \frac{R_S I_s}{1 + j\omega R_S C} = \frac{3.2 \times 10^{3} \times 10^{-5}}{1 + j\,2\pi \times 10^4 \times 3.2 \times 10^3 C} = V_1 = \frac{3.2 \times 10^{-2}}{1 + j\,20.1\,C \times 10^7}$$

$$|V_1| = \frac{3.2 \times 10^{-2}}{\sqrt{1 + (20.1\,C \times 10^7)^2}} = \frac{3.2 \times 10^{-3}}{\sqrt{2}}$$

or $1 + (20.1 \times 10^7 C)^2 = 2$ and $(20.1 \times 10^7 C)^2 = 1$

and $20.1 \times 10^7 C = 1$ or $C = 4.975 \times 10^{-9} \approx 4.98\,nF$

c) The circuit is



The two nodal equations are

$$-I_s + \frac{V_1}{R_S} + \frac{V_1 - V_o}{-j/\omega C} = 0 \quad \text{or} \quad V_1\left(\frac{1}{R_S} + j\omega C\right) - j\omega C V_o = I_s$$

$$\frac{+(V_o - V_1)}{-j/\omega C} + \frac{V_o}{R_A} + 0.7V_1 = 0 \quad \text{or} \quad V_1(0.7 - j\omega C) + V_o\left(\frac{1}{R_A} + j\omega C\right) = 0$$

Solving for V_o gives

$$V_o = \frac{\begin{vmatrix} \frac{1}{R_S} + j\omega C & I_s \\ 0.7 - j\omega C & 0 \end{vmatrix}}{\begin{vmatrix} \frac{1}{R_S} + j\omega C & -j\omega C \\ 0.7 - j\omega C & \frac{1}{R_A} + j\omega C \end{vmatrix}} = \frac{-I_s(0.7 - j\omega C)}{\frac{1}{R_S R_A} - \omega^2 C^2 + \omega^2 C^2 + j\omega C\left[\frac{1}{R_A} + \frac{1}{R_S} + 0.7\right]}$$

$$\frac{V_o}{I_s} = \frac{0.7 - j\omega C}{\frac{1}{3.2\times10^3 \times 0.3\times10^3} + j\omega C\left[\frac{1}{3.2\times10^3} + \frac{1}{0.3\times10^3} + 0.7\right]}$$

Evaluating gives $\frac{V_o}{I_s} = \frac{672\times10^3 (1 - j2\pi\times10^4 \times 1.43)}{1 + j\omega C\left[0.3\times10^3 + 3.2\times10^3 + 0.7\times0.96\times10^6\right]}$

The numerator term occurs well after the denominator term

so $\omega C\left[3.5\times10^3 + 672\times10^3\right] = 1$ or $C = \frac{1}{2\pi\times10^4 \times 672\times10^3}$

and $C = 23.7$ pF

NOTE: this value of C is 21 times smaller than in B.

D) The transfer function is

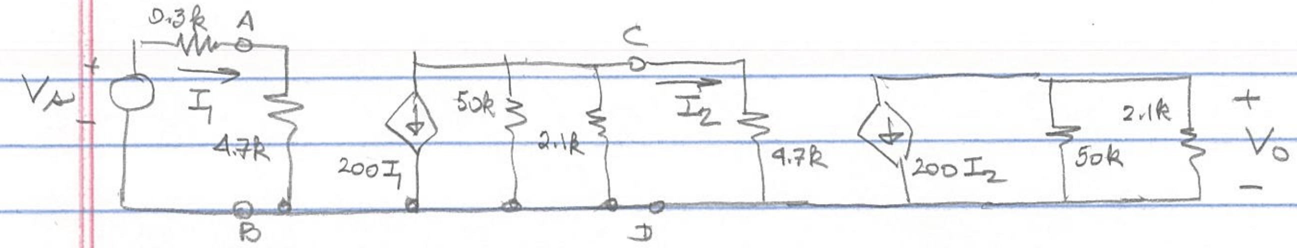
$$\frac{V_o}{I_s} = \frac{672\times10^3}{1 + j\omega/2\pi\times10^4} \quad \text{or} \quad \frac{672\times10^3}{1 + jf/10^4}$$

E) For $f = 10^6$, $\frac{V_o}{I_s} = \frac{672\times10^3}{1 + j10^6/10^4} = 6.72\times10^3$ (magnitude)

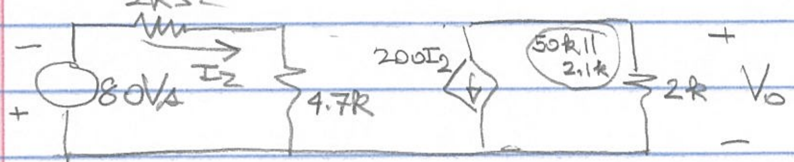
For $\omega = 10^6$ $\frac{V_o}{I_s} = \frac{672\times10^3}{1 + j10^6/2\pi\times10^4} = \frac{672\times10^3}{1 + j15.9}$ and $\left|\frac{V_o}{I_s}\right| = 42.1\times10^3$

159×10^3

PROBLEM 3



A) To the left of terminals C-D we have the circuit you analyzed in Problem 1. The Thévenin voltage $V_{TH} = -80V_s$ and the Thévenin resistance $R_{TH} = 50k \| 2.1k = 2k\Omega$. Then, the circuit becomes

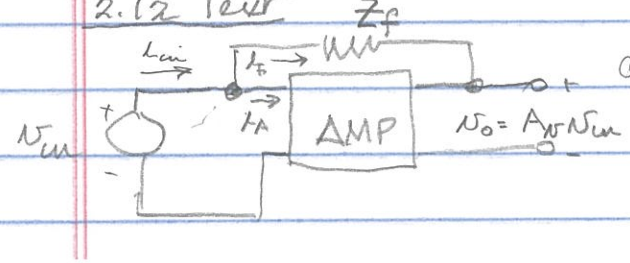


$$I_2 = \frac{-80V_s}{\underbrace{2k+4.7k}_{6.7k}} \qquad V_o = -200 \times \left(\frac{-80\ V_s}{6.7\,k\Omega}\right) \times 2k = 4{,}776\,V_s$$

$$\text{Gain} = \frac{V_o}{V_s} = 4{,}776$$

B) No, it is lower. Even though the circuits look alike they differ in one significant way. Stage 1 has a source resistance of $0.3k\Omega$ while Stage 2 is driven by $R_{TH} = 2k\Omega$. Thus, in the left hand loop $R_{TOTAL} = 5k\Omega$ for Stage 1 and $6.7k\Omega$ for Stage 2. Their ratio is 1.34 just the amount that the overall gain deviates from 6,400.

2.12 Text



a) $Z_{in} = v_{in} / i_{in}$; $i_{in} = i_f$

$i_f = \dfrac{v_{in} - A_v v_{in}}{Z_f}$ or $Z_f\, i_{in} = v_{in}(1-A)$

$\therefore Z_{in} = Z_f/(1-A)$

b) $Z_{in} = \frac{10\,k\Omega}{1-(-10^5)} = 0.1\,\Omega$

c) $Z_{in} = \frac{10\,k\Omega}{1-2} = -10\,k\Omega$

Circuit uses positive feedback and will oscillate prior to measurement. The circuit is unstable and once the amplifier's frequency response is included, it will oscillate.

d) $Z_{in} = \frac{-j/\omega C}{1-(-100)} = \frac{-j}{\omega C(101)}, \frac{-j}{\omega \times 101 \times 10^{-12}}$

Input looks like a 101 pF capacitor. This is used extensively in IC design to limit the area required to fabricate a "large" capacitor. In the 741 Op-Amp a C = 30pF is used to obtain a -3dB frequency of 5Hz. The effective resistance is 1MΩ

$5 = \frac{1}{2\pi 10^6 C}$ or $C \approx 31.5\,nF$. With a gain (A_v) of just over 1,000 this C becomes the needed 31.5nF