Note Title 3/12/2019

Question-1 (10 marks)

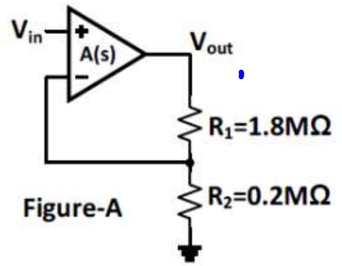


Figure-A

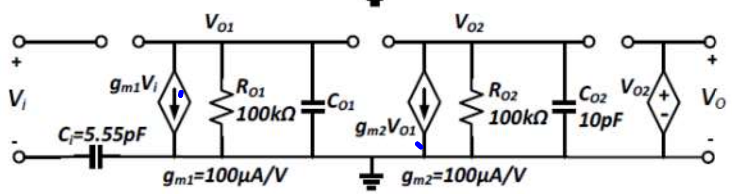


Figure-B

Closed loop amplifier shown in Figure-A needs to be designed for stable operation. Derive the loop gain transfer function and specify the poles and zeroes.

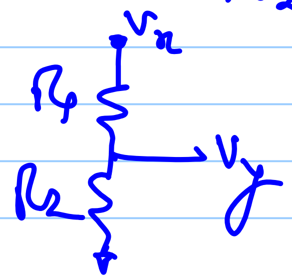
a) Find the loop gain transfer function *(2 marks)*

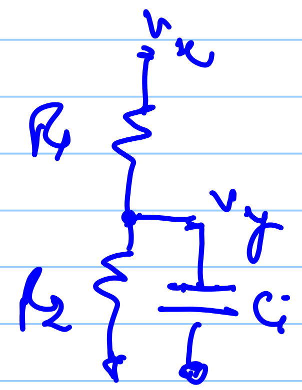
b) Calculate the value of capacitor C_{O1} to achieve the phase margin of 60 degrees *(4 marks)*

c) Draw the bode magnitude and phase plot of the loop gain transfer function. Clearly mention values of gain, phase, location of poles, zeroes and unity gain frequency. *(4 marks)*

$\omega_{p_1} = \frac{1}{R_{o1} C_{o1}}$, $\omega_{p_2} = \frac{1}{R_{o2} C_{o2}}$, $g_{m1}, R_{o1}, g_{m2} R_{o2}$

$\beta = \frac{R_2}{R_1 + R_2} \Rightarrow$





$$\frac{V_y(s)}{V_x(s)} = \beta = \frac{R_2}{R_1+R_2} \times \frac{1}{\left(1+s/\omega_{p_3}\right)} = \frac{R_2}{R_1+R_2} \frac{1}{1+\frac{R_1R_2}{R_1+R_2}C_i s}$$

$$\frac{V_y(s)}{V_x(s)} = \frac{R_2 \to Z_2}{R_1 + R_2 \to Z_2} = \frac{Z_2}{R_1 + Z_2} = \frac{1}{R_1 X_2 + 1}$$

$$= \frac{1}{R_1\left(\frac{1}{R_2} + X_i\right)+1} = \frac{R_2}{\underline{R_1} + R_1R_2C_i s + \underline{R_2}}$$

$$\frac{R_2/(R_1+R_2) \to \beta_0}{1+\frac{R_1R_2}{R_1+R_2}C_i s}$$

$$\beta A(s) = -\frac{R_2}{R_1+R_2} \times \frac{g_{m_1} R_{o_1}\, g_{m_2} R_{o_2}}{(1+R_{o_1}C_{o_1}s)(1+R_{o_2}C_{o_2}s)\left(1+\frac{R_1R_2}{R_1+R_2}C_i s\right)}$$

$$\omega_{p_1} = \frac{1}{R_{o_1}C_{o_1}} \quad \omega_{p_2} = \frac{1}{R_{o_2}C_{o_2}} = \frac{1}{100k \times 10\times10^{-12}}$$

$C_{o_1} \to 2$

$$= 10^6 \text{ rad/sec}$$

$$R_1 \| R_2 = \frac{1.8 \times 0.2}{2} = 180k\Omega$$

$$\omega_{p_3} = \frac{1}{(R_1\|R_2)C_i} = \frac{1}{180k \times 5.5p} = 10^6 \text{ rad/sec}$$

$$\omega_{ugb} = \beta_0 A_0 \times \omega_{p_1} = \frac{\omega_{p_{2,3}}}{3.7}$$

$$\beta_0 = \frac{R_2}{R_1 + R_2} = \frac{0.2}{1.8 + 0.2} = \frac{1}{10}$$

$$A_0 = 100 \times 100 = 10^4$$

$$\beta_0 A_0 = \frac{10^4}{10} = 10^3$$

$$\frac{1}{\omega_{p_1}} = \frac{\beta_0 A_0 \times 3.7}{\omega_{p_{2,3}}} = \frac{\cancel{10^3} \times 3.7}{\cancel{10^6}} = 3.7 \times 10^{-3}$$

$$R_{o_1} C_{o_1} = 3.7 \times 10^{-3} \Rightarrow C_{o_1} = 3.7 \times 10^{-3} / 100k = 37\,nF$$

$$\omega_{p_2} = \omega_{p_3} = \omega_{p_{2,3}} = 1\ \text{M rad/sec}$$

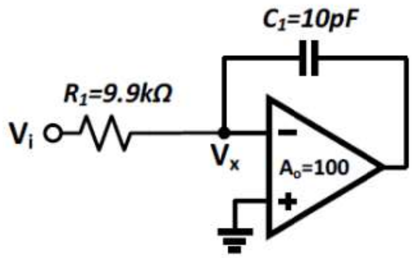
$$PM = 90 - \tan^{-1}\frac{\omega_{ugb}}{\omega_{p_2}} - \tan^{-1}\frac{\omega_{ugb}}{\omega_{p_3}}$$

$$60^\circ = 90 - 2\tan^{-1}\frac{\omega_{ugb}}{\omega_{p_{2,3}}}$$

$$\tan^{-1}\frac{\omega_{ugb}}{\omega_{p_{2,3}}} = 15^\circ$$

$$\frac{\omega_{ugb}}{\omega_{p_{2,3}}} = \tan 15^\circ \qquad \omega_{p_{2,3}} = 3.7\ \omega_{ugb}$$

Question-2 **(5 marks)**



For the circuit shown above:

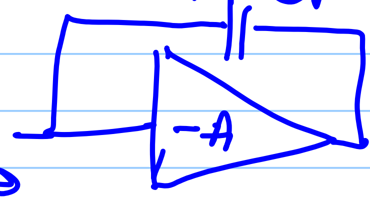
a) Find the the transfer function $Vx(s)/Vi(s)$ in terms of R1 and C1. *(2 marks)*

b) Find the expression for unit step response $Vx(t)$ and draw the waveform *(2 marks)*

c) Find the value of RC time constant *(1 mark)*

C looking at V_x

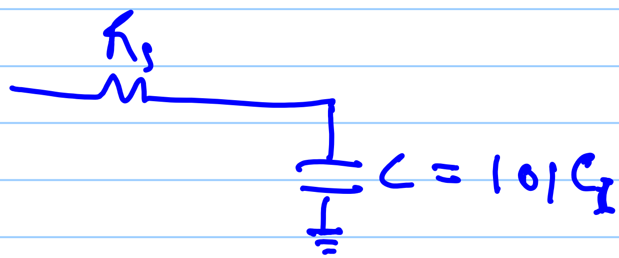
miller effect



$C_{in} = (1+A)C_1$

$A = 100$

$\Rightarrow$



time constant

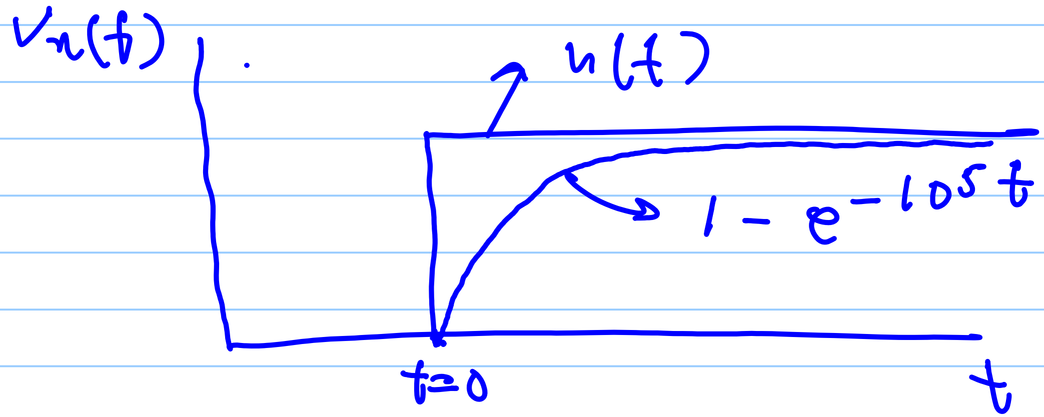
$= R_1 (101 C_1)$

$= 9.9k \times 101 \times 10pF = 10 \mu s$

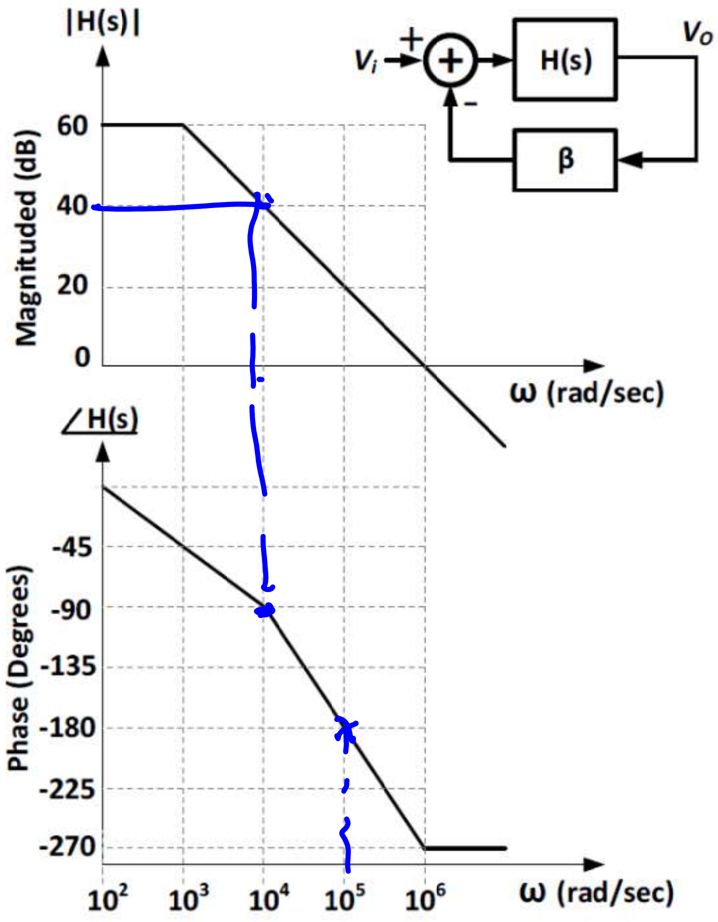
(a) $\dfrac{V_x(s)}{V_i(s)} = \dfrac{1}{1+101RC_1 s}$

(b) $V_x(t) = 1 - e^{-t/\tau} = 1 - e^{-t/101RC}$

$= 1 - e^{10^5 t}$



(c) 10 us



Question-3 **(5 marks)**

A system with transfer function, H(s) of the given bode magnitude and phase response below, is supposed to be operated in closed loop with feedback factor, β as shown in figure below.

a) Find the transfer function H(s) *(2 mark)*

b) Determine if the system is stable or unstable for β=1 *(1 mark)*

c) Find the value of β to achieve phase margin of 90 degrees *(2 marks)*

$\omega_{p_1} = 10^3$ rad/sec. (L.H.P)

$\omega_z = 10^5$ rad/sec (R.H.P)

$\omega_{p_2} = 10^5$ rad/sec (L.H.P)

(a) $H(s) = \dfrac{10^3 \left(1 - s/\omega_z\right)}{\left(1 + s/\omega_{p_1}\right)\left(1 + s/\omega_{p_2}\right)}$ $\qquad \dfrac{10^3 \left(1 - s/10^5\right)}{\left(1 + s/10^3\right)\left(1 + s/10^5\right)}$

(b) at Phase $= -180^\circ$ gain $> 0\,dB$ so system is unstable

(c) $\beta = \dfrac{1}{100}$