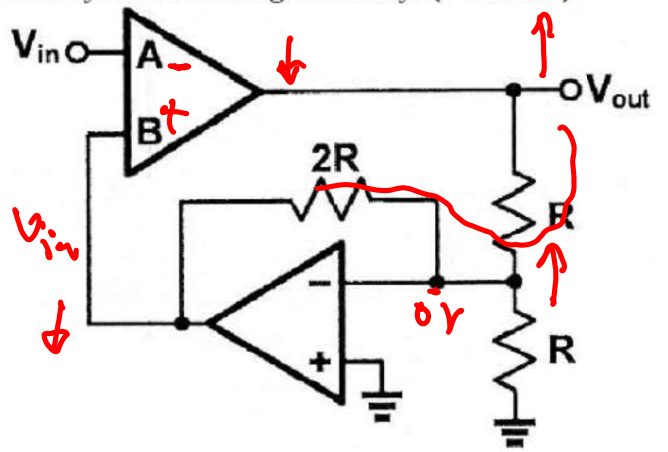
1) The circuit shown in the figure below operates in negative feedback configuration. Assume both opamps are ideal. Determine the signs of the opamp for proper negative feedback operation. State your reasoning carefully. **(5 Marks)**

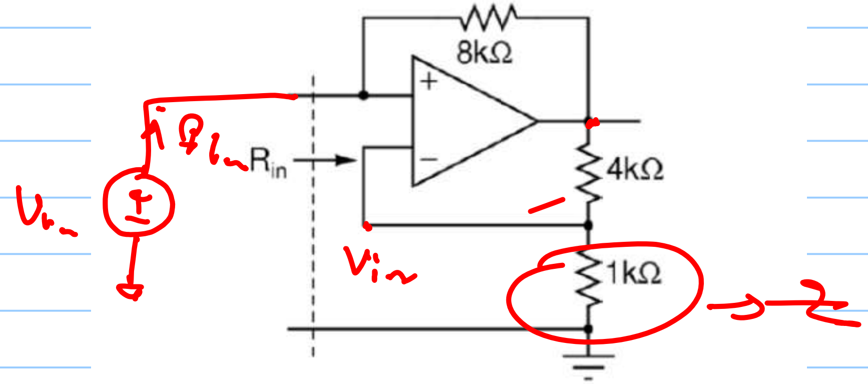


2) Determine the ac gain V_{out}/V_{in} of the circuit of problem 1 above. **(5 Marks)**

$\frac{V_o}{V_{in}} = ?$

$V_{in} = -\frac{2R}{R} \times V_{out} \Rightarrow \frac{V_o}{V_{in}} = -\frac{1}{2}$

3) Determine the input resistance of the circuit shown below. **(5 Marks)**



$$\frac{V_{in}}{i_{in}} = R_{in}$$

$$V_{out} = \frac{1}{\beta} V_{in}$$

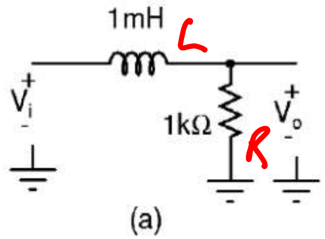
$$\beta = \frac{1k}{1k + 4k} = \frac{1}{5}$$

$$V_{out} = 5 V_{in}$$

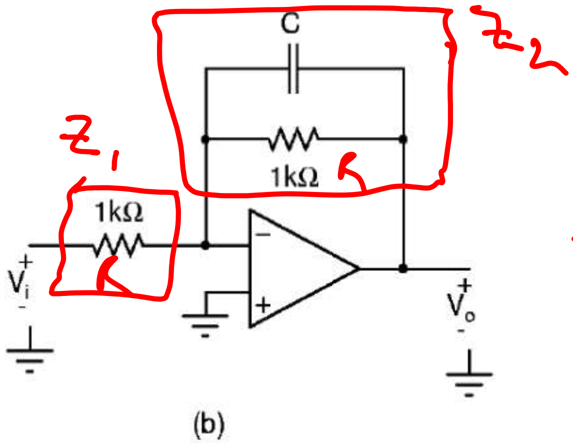
$$i_{in} = \frac{V_{in} - 5V_{in}}{8k} = \frac{-4V_{in}}{8k} = \frac{-1}{2k} V_{in}$$

$$\Rightarrow \boxed{\frac{V_{in}}{i_{in}} = -2k\,\Omega = R_{in}}$$

4) For the circuit shown below, determine C such that the circuits in (a) and (b) have identical transfer functions (magnitude). **(5 Marks)**



$$\Rightarrow \frac{V_o}{V_{in}} = \frac{R}{R + sL} = \frac{1}{1 + \frac{L}{R}s} \quad — (1)$$



$$\Rightarrow \frac{V_o}{V_i} = -\frac{Z_2}{Z_1} = \frac{Y_1}{Y_2} = \frac{1/R}{\frac{1}{R} + sC}$$

$$= \frac{1}{1 + RCs} \quad — (2)$$

comparing ① & ②

$$\frac{L}{R} = RC \Rightarrow C = \frac{L}{R^2} = \frac{1m}{(1k)^2} = \frac{10^{-3}}{10^6} = 1nF$$

2nd order system

Phase margin

$$H_{Lh}(s) = \frac{\beta A_0}{\left(1 + s/\omega_{p_1}\right)\left(1 + s/\omega_{p_2}\right)}$$

$$PM = 180^\circ - \tan^{-1}\left(\frac{\omega_{ugb}}{\omega_{p_1}}\right) - \tan^{-1}\frac{\omega_{ugb}}{\omega_{p_2}}$$

if $\omega_{p_1} = \frac{\omega_{ugb}}{10}$, $\omega_{p_2} = \omega_{ugb}$

$$PM = 180^\circ - 90 - 45 \approx 45^\circ$$ marginally stable

For a stable system, PM > 60°

$$60^\circ = 180 - 90 - \tan^{-1}\frac{\omega_{ugb}}{\omega_{p_2}}$$

$$\tan^{-1}\frac{\omega_{ugb}}{\omega_{p_2}} = 30^\circ \Rightarrow \frac{\omega_{ugb}}{\omega_{p_2}} = \tan 30^\circ = 0.57$$

$$\Rightarrow \omega_{p_2} = \frac{\omega_{ugb}}{0.57} \approx 2\,\omega_{ugb}$$

dc gain $= \beta A_0$

$$\omega_{ugb} < \omega_{p_1} \times \beta A_0$$