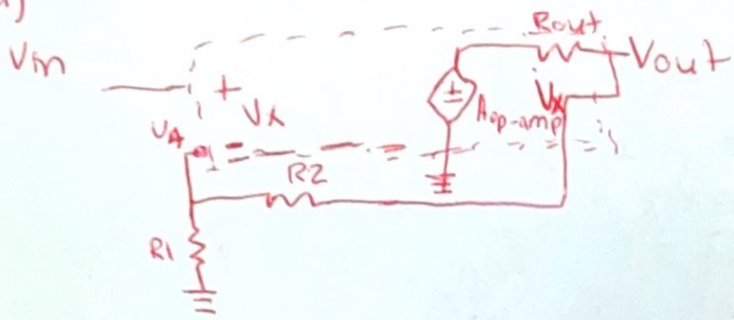
Maria Peregrina | Homework#5 | IECE-300

① Finite Gain

a)



$R_{in} \to \infty$

$R_{out} \to 0$

$A_{op\text{-}amp} \to$ finite

$$V_x = \frac{V_{out}}{A_{op\text{-}amp}}$$

b) KCL at A:

$$\frac{V_A}{R1} + \frac{V_A - V_{out}}{R2} = 0$$

$V_x = V_{in} - V_A$

$-V_A = V_x - V_{in}$

$V_A = -V_x + V_{in}$

$$\frac{-V_x + V_{in}}{R1} + \frac{-V_x + V_{in} - V_{out}}{R2} = 0$$

$$\frac{-\frac{V_{out}}{A_{op\text{-}amp}} + V_{in}}{R1} + \frac{-\frac{V_{out}}{A_{op\text{-}amp}} + V_{in} - V_{out}}{R2} = 0$$

$$R2\left(\frac{-V_{out}}{A_{op\text{-}amp}} + V_{in}\right) + R1\left(\frac{-V_{out}}{A_{op\text{-}amp}} + V_{in} - V_{out}\right) = 0$$

$$\cancel{-V_{out}}\ \frac{-R2\,V_{out}}{A_{op\text{-}amp}} + V_{in}R2 + \frac{R1(-V_{out})}{A_{op\text{-}amp}} + R1V_{in} - R1V_{out} = 0$$

$$V_{out}\left(\frac{-R2}{A_{op\text{-}amp}} - \frac{R1}{A_{op\text{-}amp}}\right) - R1V_{out} + V_{in}R2 + V_{in}R1 = 0$$

$$= -V_{in}R2 - V_{in}R1$$

$$-V_{out}\left(\frac{R2}{A_{op\text{-}amp}} + \frac{R1}{A_{op\text{-}amp}} + R1\right)$$

$$-V_{out}\left(\frac{R2 + R1 + R1A_{op\text{-}amp}}{A_{op\text{-}amp}}\right) = -V_{in}R2 - V_{in}R1$$

$$\left[-V_{out}\left(\frac{R2+R1+R1\,A_{op\text{-}amp}}{A_{op\text{-}amp}}\right) = -V_{in}R2 - V_{in}R1\right]\cancel{\left(\frac{1}{R2R1}\right)}$$

$$\cancel{-V_{out}\left(\frac{R2+R1+R1\,A_{op\text{-}amp}}{A_{op\text{-}amp}\,R2R1}\right)} = \cancel{\frac{-V_{in}}{R1}} - \cancel{\frac{V_{in}}{R2}}$$

$$-V_{out}\left(\frac{R2+R1+R1\,A_{op\text{-}amp}}{A_{op\text{-}amp}}\right) = -V_{in}\left(R2+R1\right)$$

$$\frac{V_{out}\left(\frac{R2+R1+R1\,A_{op\text{-}amp}}{A_{op\text{-}amp}}\right) = V_{in}\left(R2+R1\right)}{\left(\frac{R2+R1+R1\,A_{op\text{-}amp}}{A_{op\text{-}amp}}\right)}$$

$$V_{out} = \frac{V_{in}\left(R2+R1\right)}{\left(\frac{R2+R1+R1\,A_{op\text{-}amp}}{A_{op\text{-}amp}}\right)}$$

$$V_{out} = V_{in}\left(R2+R1\right)\left(\frac{A_{op\text{-}amp}}{R2+R1+R1\,A_{op\text{-}amp}}\right)$$

$$V_{out} = V_{in}\left[\frac{(R2+R1)\,A_{op\text{-}amp}}{R2+R1+R1\,A_{op\text{-}amp}}\right]$$

c) $A_{op\text{-}amp} = 10^6\ V/V \quad R1 = 1k\Omega$

$$\frac{V_{out}}{V_{in}} = \frac{(R2+1k)(10^6)}{R2+1k+1k(10^6)}$$

$$.90 = \frac{10^6 R2 + 10^9}{R2+1k+10^9}$$

$$.90R2 + 900 + 9\times10^8 = 10^6 R2 + 10^9$$

$$-10^6 R2 + .90R2 = 10^9 - 900 - 9\times10^8$$

$$R2 = -99.99 \approx 100$$

d) The internal gain of this op-amp is unlikely to affect the non-inverting amplifier gain under typical usage, because the non-inverting gain will be much larger than the internal gain of this op-amp that the result from part c won't affect it.

e) $$V_{out} = V_{in}\left[\frac{(R2+1k)(100)}{R2+1k+(1k\cdot 100)}\right] \Rightarrow \frac{V_{out}}{V_{in}} = \frac{(R2+1k)(100)}{R2+1k+(1k\cdot 100)}$$

$$.90 = \frac{100R2+10^5}{R2+1k+(10^5)}$$

$$R2 = -91.83 \approx 92$$

(2) $$A_{op\text{-}amp} = A_{internal}\frac{\omega_b}{s+\omega_b} = \frac{GBP}{s+\omega_b}$$

$$V_{out} = V_{in}\left[\frac{(R2+R1)\frac{GBP}{s+\omega_b}}{R2+R1+R1\left(\frac{GBP}{s+\omega_b}\right)}\right] \Rightarrow \frac{V_{out}}{V_{in}} = \frac{\frac{R2\,GBP}{s+\omega_b}+\frac{R1\,GBP}{s+\omega_b}}{R2+R1+\frac{R1\,GBP}{s+\omega_b}}$$

$$A_{circuit} = \frac{R2GBP}{s+\omega_b}+\frac{R1\,GBP}{s+\omega_b}\cdot\frac{1}{R2+R1+\frac{R1GBP}{s+\omega_b}}$$

$$= \frac{R2GBP+R1GBP}{s+\omega_b}\left(\frac{1}{R2+R1+\frac{R1GBP}{s+\omega_b}}\right)$$

$$= \frac{GBP(R2+R1)}{s+\omega_b\left(R2+R1+\frac{R1GBP}{s+\omega_b}\right)}$$

$$= \frac{GBP(R2+R1)}{s+\omega_b(R2+R1)+R1\,GBP}$$

$$A_{circuit}\left[(s+\omega_b)(R2+R1)\right]+R1\,GBP = GBP(R2+R1)$$

$$\cancel{\frac{A_{circuit}\left[(S+\omega_b)(R2+R1)\right]+R1\,GBP = GBP(R2+R1)}{R2+R1}}$$

$$\cancel{\frac{A_{circuit}\left[(S+\omega_b)(R2+R1)\right]+R1\,GBP}{R2+R1}} = GBP$$

$$A_{circuit}\left[(S+\omega_b)(R2+R1)\right]+R1\,GBP = GBP\,(R2+R1)$$
$$-R1\,GBP \qquad -R1\,GBP$$

$$\frac{A_{circuit}\left[(S+\omega_b)(R2+R1)\right] = R2\,GBP}{R2}$$

$$\boxed{GBP = \frac{A_{circuit}\,(s+\omega_b)(R2+R1)}{R2}}$$

$$GBP\,R2 = A_{circuit}\,(s+\omega_b)(R2+R1)$$

$$R2\,GBP = A_{circuit}\,(sR2+sR1+R2\omega_b+R1\omega_b)$$

$$R2\,GBP = A_{circuit}\left[s(R2+R1)+\omega_b(R2+R1)\right]$$

$$\frac{R2\,GBP}{A_{circuit}} = s(R2+R1)+\omega_b(R2+R1)$$
$$\cancel{-s(R2+R1)}$$

$$\frac{\frac{R2\,GBP}{A_{circuit}} - s(R2+R1) = \omega_b(R2+R1)}{R2+R1}$$

$$\boxed{\frac{R2\,GBP}{A_{circuit}}\cdot\frac{1}{R2+R1} - S = \omega_b}$$