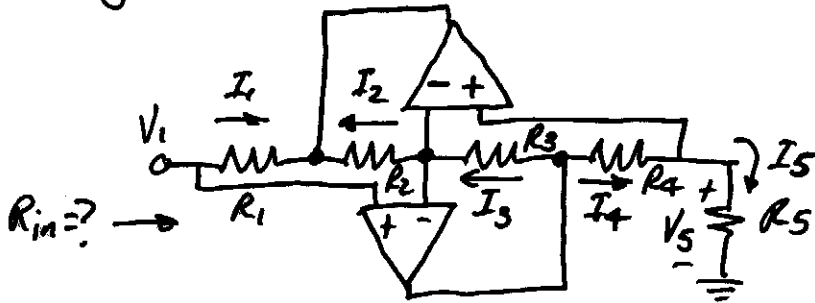


Challenge from last lecture -



Because  $N_{id} = 0$  and no current flows into the op amp inputs, we can write -

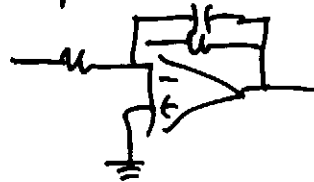
- (1)  $I_1 + I_2 = 0$
- (2)  $I_1 R_1 = I_2 R_2$
- (3)  $I_3 + I_4 = 0$
- (4)  $I_3 R_3 = I_4 R_4$
- (5)  $I_4 = I_5$
- (6)  $V_5 = I_5 R_5$
- (7)  $V_1 = V_5$
- (8)  $I_2 = I_3$

Now,  $V_1 = V_5 = I_5 R_5 = I_4 R_5 = \left(\frac{I_3 R_3}{R_4}\right) R_5 = I_2 \left(\frac{R_3 R_5}{R_4}\right)$

$$V_1 = \left(\frac{I_1 R_1}{R_2}\right) \left(\frac{R_3 R_5}{R_4}\right) = \frac{R_1 R_3 R_5}{R_2 R_4} I_1 \rightarrow \boxed{\frac{V_1}{I_1} = \frac{R_1 R_3 R_5}{R_2 R_4}}$$

Frequency Response of Op Amp -

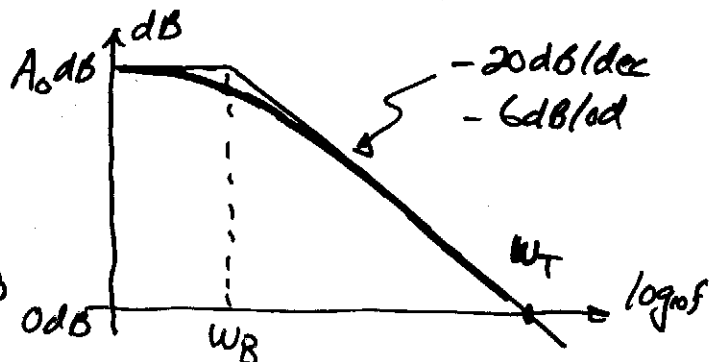
1.) Op amp ideal  $A \rightarrow \infty$   $GB (UGB) \rightarrow \infty$



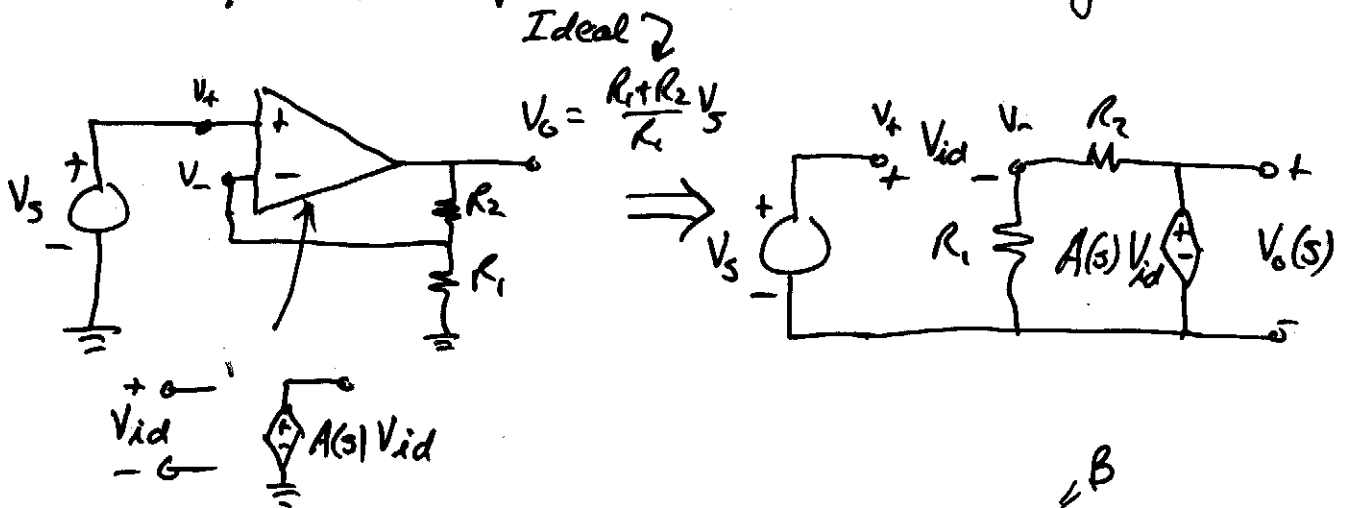
2.) Op amp has a finite  $GB (\neq \infty)$



$$A(s) = \frac{A_0 \omega_B}{s + \omega_B} = \frac{\omega_T}{s + \omega_B}$$



2.) Frequency response of the noninverting amplifier.



$$V_o = A(s)V_{id} = A(s)[V_+ - V_-] = A(s)V_s - A(s)\frac{R_1}{R_1 + R_2}V_o$$

$$V_o = A(s)V_s - A(s)BV_o \quad \text{where } B = \frac{R_1}{R_1 + R_2}$$

$$V_o[1 + A(s)B] = A(s)V_s \rightarrow \frac{V_o}{V_s} = A_v(s) = \frac{A(s)}{1 + BA(s)}$$

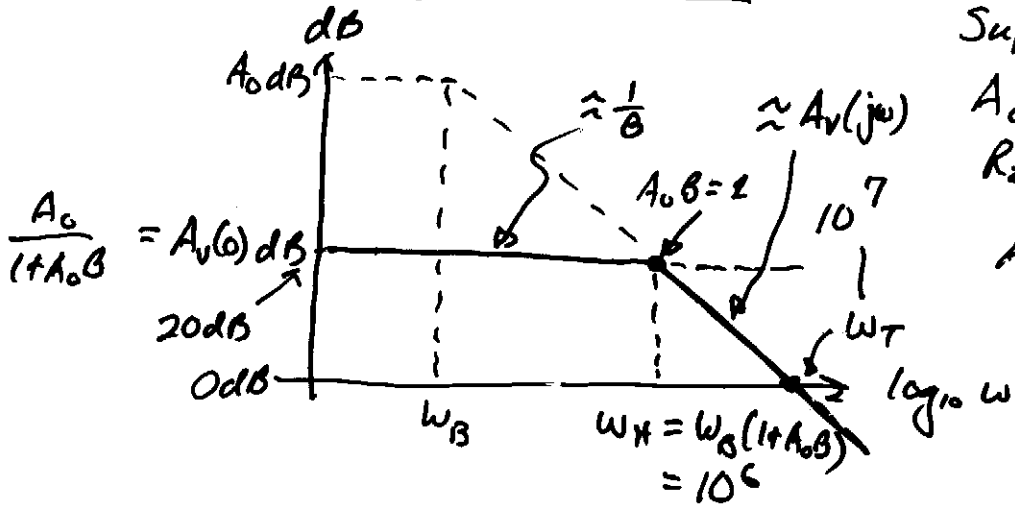
Note:  $\lim_{A(s) \rightarrow \infty} \frac{V_o}{V_s} = \frac{1}{B} = \frac{R_1 + R_2}{R_1}$

$$A_v(s) = \frac{1}{\frac{1}{A(s)} + B} = \frac{1}{\frac{s + \omega_B}{A_0 \omega_B} + B} = \frac{A_0 \omega_B}{s + \omega_B + BA_0 \omega_B}$$

$$= \frac{A_0 \omega_B}{s + \omega_B(1 + A_0 B)} = \frac{A_0 \omega_B}{\omega_B(1 + A_0 B)} \left( \frac{1}{\frac{s}{\omega_B(1 + A_0 B)} + 1} \right)$$

$$= \frac{A_v(0)}{\frac{s}{\omega_H} + 1} \quad \text{where } A_v(0) = \frac{A_0}{1 + A_0 B} \quad \omega_H = \omega_B(1 + A_0 B) \approx \omega_B A_0 B$$

Noninverting Conf. - Cont'd



Suppose:

$$A_0 = 10,000 \text{ \& } w_B = 10^3$$

$$R_2 = 9R_1 \Rightarrow \beta = \frac{1}{10}$$

$$A_v(0) = \frac{10^4}{1+10^3} \approx 10$$

$$w_H = 10^3(1+10^3)$$

$$w_H \approx 10^6$$

$$w_T = A_0 w_B$$

3.) Inverting Amplifier-

