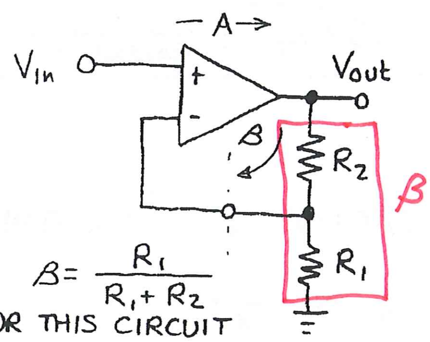
OP-AMP AS A CLASSICAL FEEDBACK SYSTEM

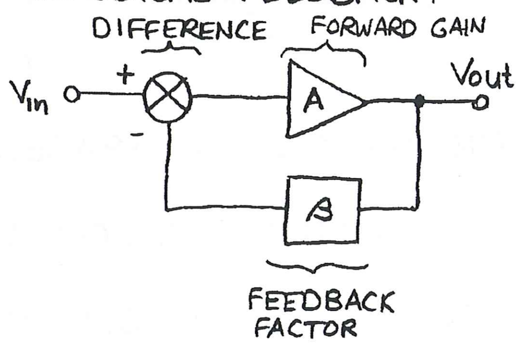
OP-AMP CIRCUIT:



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

FOR THIS CIRCUIT

CLASSICAL FEEDBACK:



β: "FEEDBACK FACTOR" FRACTION OF V_{out} FED BACK TO V_-

FIND CLOSED LOOP GAIN $G = \frac{V_{out}}{V_{in}}$

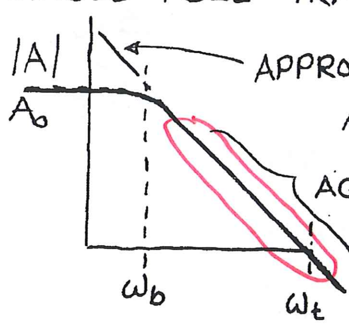
$$V_{out} = A(V_{in} - \beta V_{out}) \Rightarrow \boxed{\frac{V_{out}}{V_{in}} = \frac{A}{1 + A\beta} = G}$$

✓AS EXPECTED $G \to \frac{1}{\beta}$ AS $A \to \infty$

WHAT IS CLOSED LOOP GAIN G WHEN A IS FINITE?

REAL OP-AMP HAS SINGLE POLE TRANSFER FUNCTION

$$A = A(j\omega) = \frac{A_o}{1 + j\frac{\omega}{\omega_b}}$$



APPROXIMATE WITH $A(j\omega) \approx \frac{1}{j\omega\tau} = \frac{\omega_t}{j\omega}$

AGREES WELL FOR $\omega > \omega_b$, AROUND $\omega_t = \frac{1}{\tau}$

SUBSTITUTE IN G EXPRESSION

$$G = \frac{A}{1 + A\beta} = \frac{\frac{\omega_t}{j\omega}}{1 + \beta\frac{\omega_t}{j\omega}}$$

MULTIPLY NUM, DEN BY $\frac{j\omega}{\beta\omega_t}$

MASSAGE INTO GENERAL FIRST ORDER FORM

$$G = \frac{[\text{DC GAIN}]}{1 + j\frac{\omega}{\omega_{3dB}}}$$

$$G = \frac{\frac{\omega_t}{j\omega} \cdot \frac{j\omega}{\beta\omega_t}}{\left(1+\beta\frac{\omega_t}{j\omega}\right)\frac{j\omega}{\beta\omega_t}} \Rightarrow \frac{\boxed{\frac{1}{\beta}}}{1 + j\frac{\omega}{\boxed{\beta\omega_t}}}$$

$\frac{1}{\beta}$ } DC GAIN

$\beta\omega_t$ } CLOSED LOOP BANDWIDTH ω_{3dB}

GAIN-BANDWIDTH TRADEOFF!:

WHEN WE CHOOSE A FEEDBACK FACTOR β (FRACTION <1)

TO GET A CLOSED LOOP DC GAIN OF $\frac{1}{\beta}$

CLOSED LOOP BANDWIDTH ω_{3dB} IS $\beta\omega_t$

UNITY GAIN FREQUENCY ω_t REDUCED BY β FACTOR

INVERSE RELATIONSHIP: PRODUCT IS CONSTANT

[CLOSED LOOP GAIN] × [CLOSED LOOP BANDWITH] = [GAIN-BANDWIDTH PRODUCT]

NONINVERTING CONFIGURATION { $\frac{1}{\beta}$ $\qquad$ $\underbrace{\beta\omega_t}_{\omega_{3dB}}$ $\qquad$ $\underbrace{\omega_t}_{\text{UNITY GAIN FREQUENCY}}$

FOR LM741, $f_t = 1$ MHz

FOR LF356, $f_t = 4$ MHz

GRAPHICALLY