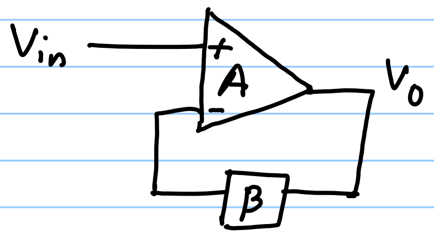
Stability



$$\frac{V_0}{V_{in}} = \frac{A}{1+A\beta}$$

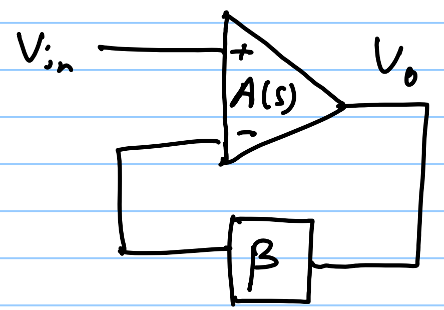
condition for instability

$|A\beta| = 1$ or $|A\beta| \geq 1$

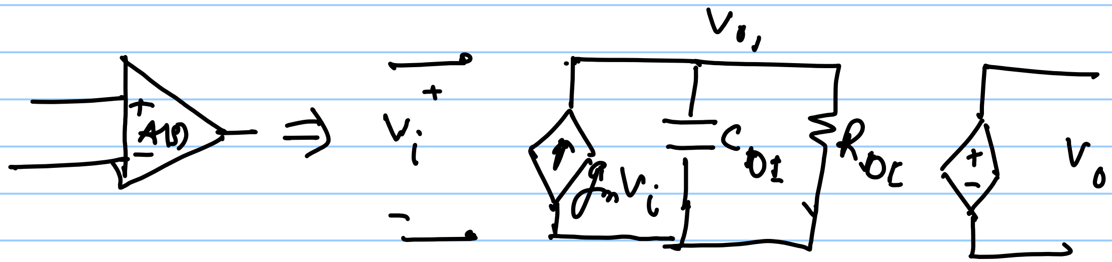
$\angle A\beta = 180°$

$A\beta \rightarrow$ Loop Gain

First order system



$$\frac{V_o(s)}{V_{in}(s)} = \frac{A(s)}{1+\beta A(s)} \quad \text{—} \ (1)$$



$$A(s) = \frac{\overbrace{g_m R_{o1}}^{A_0}}{1 + \underbrace{R_{o1} C_{o1}}_{1/\omega_p} s}$$

substitute in (1)

$A_0 = g_m R_{o1}$ & $\omega_p = \dfrac{1}{R_{o1} C_{o1}}$

$$\frac{\dfrac{A_0}{1+s/\omega_p}}{1+\dfrac{\beta A_0}{1+s/\omega_p}} = \frac{A_0}{1+s/\omega_p+\beta A_0} = \frac{A_0}{1+\beta A_0+s/\omega_p}$$

$$= \frac{A_0}{1+\beta A_0}\left[\frac{1}{1+\dfrac{s}{\omega_p(1+\beta A_0)}}\right]$$

$\omega_{p\_CL} \rightarrow$ Pole in Closed loop

$$\omega_{p\_CL} = \omega_p (1 + \beta A_0)$$

$$\beta A_0 >> 1$$

$$\omega_{p\_CL} \simeq \beta A_0 \omega_p$$

if β is negative $\rightarrow$ pole moves into right half plane & system becomes unstable.

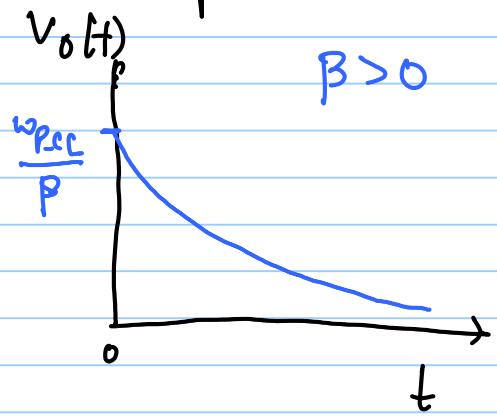
$$\beta A_0 >> 1 \rightarrow 1 + A_0 \beta \simeq A_0 \beta$$

$$\frac{V_0(s)}{V_{in}(s)} = \frac{1}{\beta} \frac{1}{1 + s/\omega_{p\_CL}}$$

for impulse response $V_{in}(s) = 1$

take inverse laplace

$$V_o(t) = \frac{1}{\beta} \quad \omega_{p\_CL} \; e^{-\omega_{p\_CL} t}$$

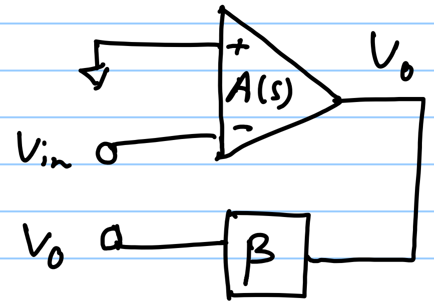


Stability Analysis

For closed loop $\longrightarrow$ impulse or step response (in time domain)

or location of poles & zeros (in frequency domain)

Any closed loop system can be analyzed using loop gain analysis which is done in open loop

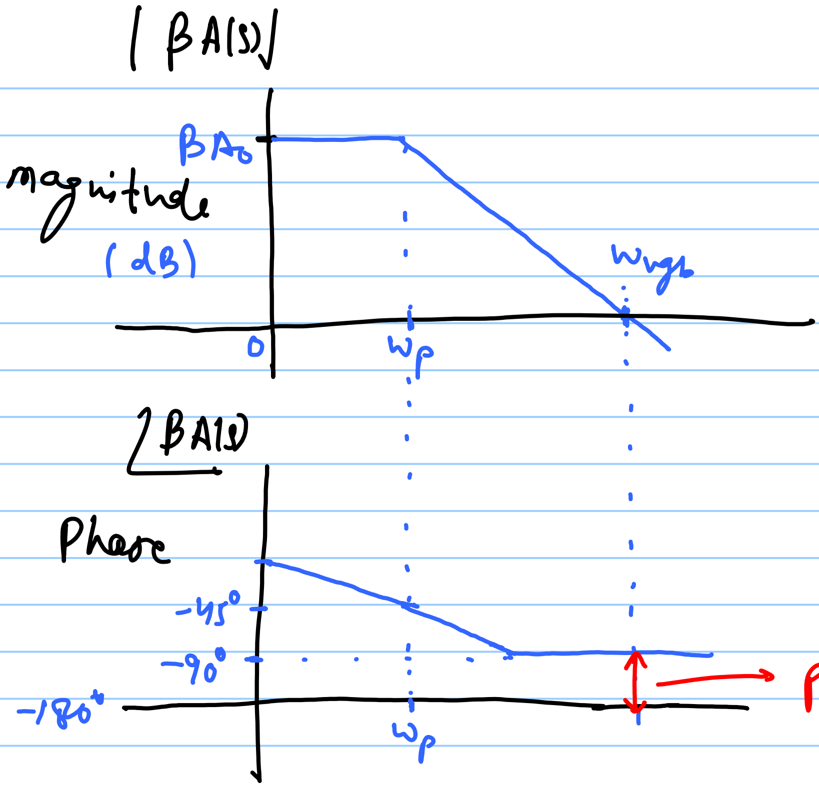


$$\frac{V_o}{V_{in}} = -\beta A(s)$$

$\beta A(s) \rightarrow$ loop gain

For loop gain analysis, we need to break the loop

we do bode analysis to find the magnitude and phase of $\beta A(s)$ or LG



Phase margin → phase needed to get 180° phase shift