$$\mathcal{L}^{-1}\left[\frac{1}{s} \times \frac{1/\beta}{1+s/\omega_p'}\right]$$

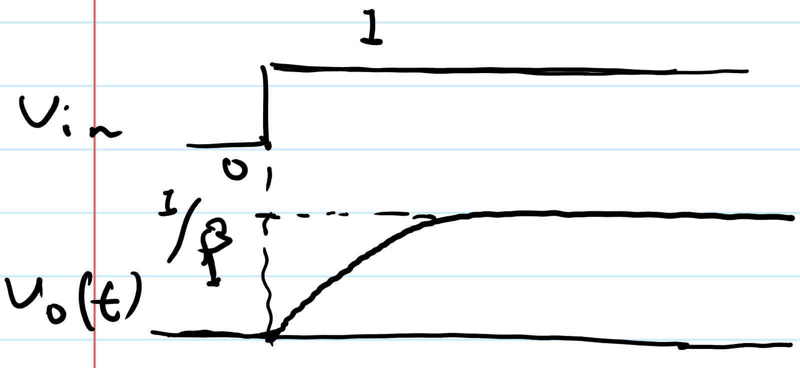
$$\mathcal{L}\left[\int_0^t f(t)\right] = \frac{1}{s}\mathcal{L}\, f(t)$$

$$\mathcal{L}^{-1}\left[\frac{1/\beta}{1+s/\omega_p'}\right] = \mathcal{L}^{-1}\left[\frac{\omega_p'/\beta}{s+\underset{\downarrow \atop A_0\beta\omega_p}{\omega_p'}}\right]$$

$$= \frac{\omega_p'}{\beta} e^{-\omega_p' t}$$

$$\int_0^t \frac{\omega_p'}{\beta} e^{-\omega_p' t}\, dt = \left[\frac{\cancel{\omega_p'}}{\beta}\left(-\frac{1}{\cancel{\omega_p'}}\right) e^{-\omega_p' t}\right]_0^t$$

$$v_o(t) = \frac{1}{\beta}\left[1 - e^{-\omega_p' t}\right]$$




time constant

$$\tau = \frac{1}{\omega_p'}$$

if $\beta < 0$ or -ve

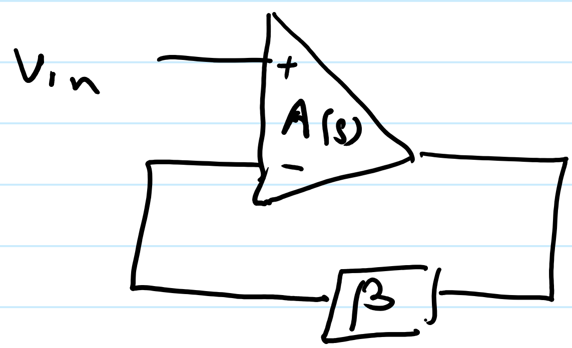
Pole $\omega_p'$ is shift to R.H.P and system becomes unstable

## Conclusion

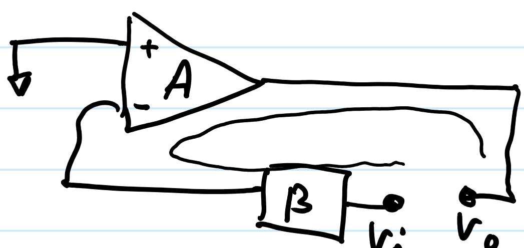
1. Stability of a negative feedback system can be analyzed using loop gain transfer function

$$H(s) = \frac{A}{1+A\beta}$$

$\to$ Loop Gain $= A\beta$
or open loop gain

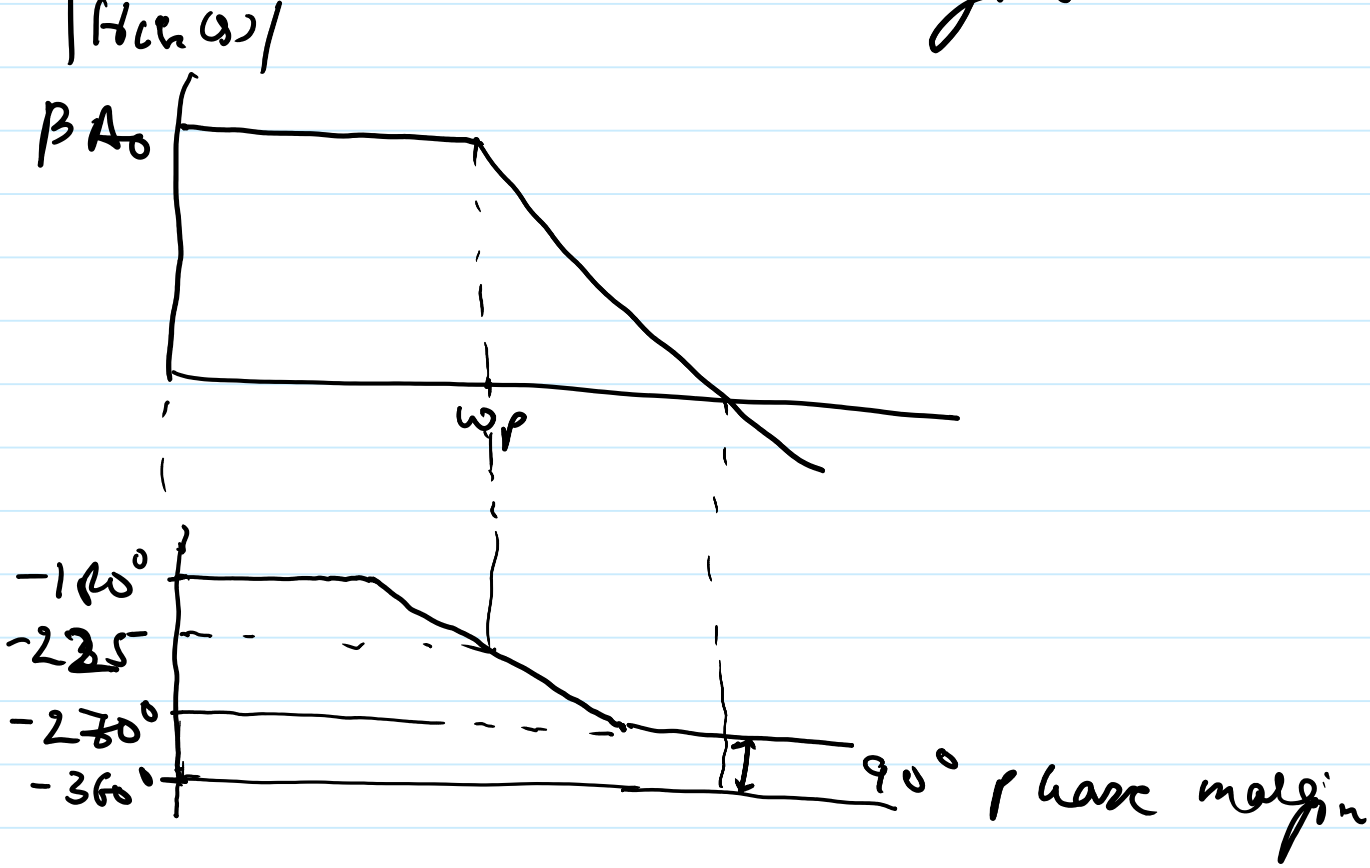



In order to find Loop gain T.F. we need to break the feedback and set $V_{in} = 0$




$$\frac{V_o(s)}{V_i(s)} = H_{LG}(s) = -\beta A(s)$$

Once we get the L.G T.F. we plot magnitude and phase response and find the phase margin

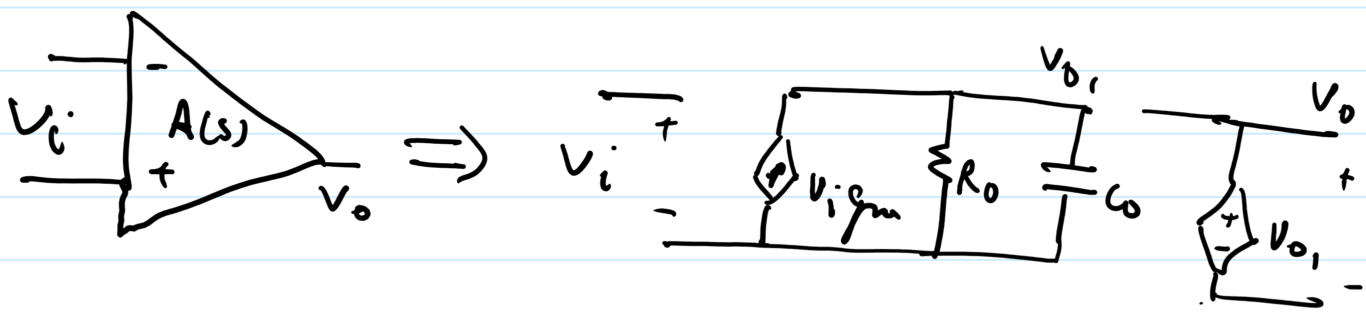



Phase margin is the distance to 180° additional phase shift or distance to 360° total phase shift.

Wednesday, February 13, 2019 10:00 AM

we also use gain margin for stability
Gain at 180° phase shift.

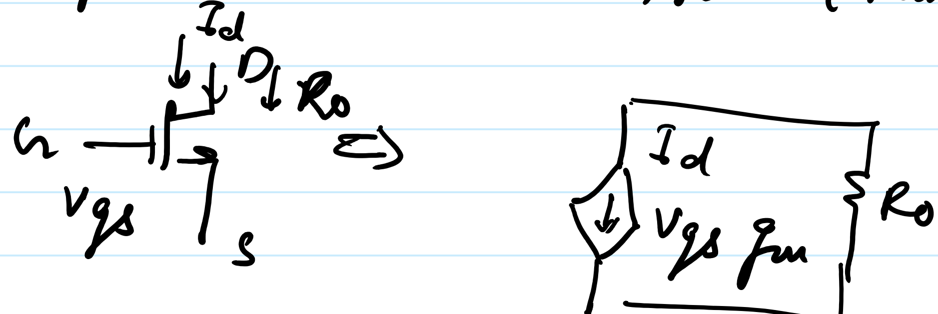
- First order system with negative feedback is inherently stable as long as $\beta > 0$




first order or single stage model of op-amp.

$A_o = g_m R_o$

$g_m$ & $R_o$ comes from transistor.

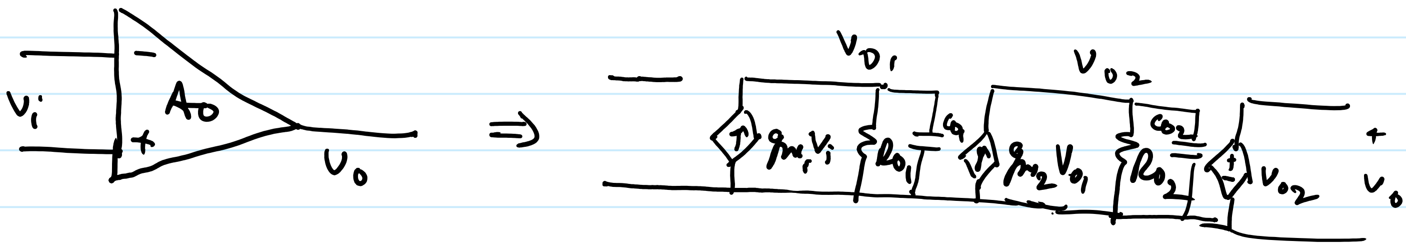



Transistor have some limitations on $g_m R_o$ and usually single stage can't achieve >100

~ 400ks

most of the applications require gain of > 60 dB or 1000 which can't be achieved with single stage.

we need two stage amplifier




$$A_0 = g_{m1} R_{o1} \cdot g_{m2} R_{o2}$$

$$g_{m1} R_{o1} = g_{m2} R_{o2} = 100$$

$$A_0 = 10^4 = 80\,dB$$

capacitors $C_{o1}$ & $C_{o2}$ introduce two poles in op-amp

$$\omega_{p_1} = \frac{1}{R_{o1} C_{o1}}, \quad \omega_{p_2} = \frac{1}{R_{o2} C_{o2}}$$

$$A(s) = \frac{g_{m1} R_{o1} \, g_{m2} R_{o2}}{(1 + s/\omega_{p_1})(1 + s/\omega_{p_2})}$$