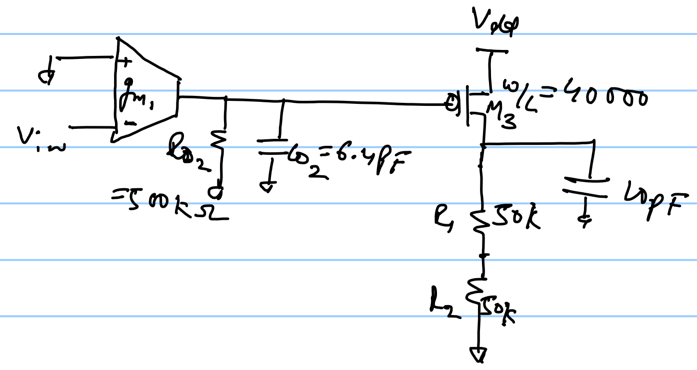
Let's assume, $C_{out} = 10pF$ and $I_{Load} = 0$ $(R_{Load} = \infty)$



$$\omega_{p_2} = 300k \text{ rad/sec}$$

$$\omega_{p_3} = \frac{1}{40k(10pF)} = 2.5 \text{ Mrad/sec}$$

$$I_d = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{gs} - V_{th})^2$$

$$15\mu A = \frac{1}{2}(50\mu)(40000)(V_{gs} - V_{th})^2$$

$$\frac{30}{50\mu\, 40000} = (V_{gs} - V_{th})^2 \Rightarrow V_{gs} - V_{th} = \sqrt{\frac{30}{50\mu\, 40000}} = 3.87 \text{ mV}$$

$g_m = 7.7\,mA/V$

$r_{o_3} = \dfrac{1}{\lambda I_d} = \dfrac{1}{15\mu} = 66.67k$

$R_{out} = 100k \,||\, 66.67k = 40k\,\Omega$

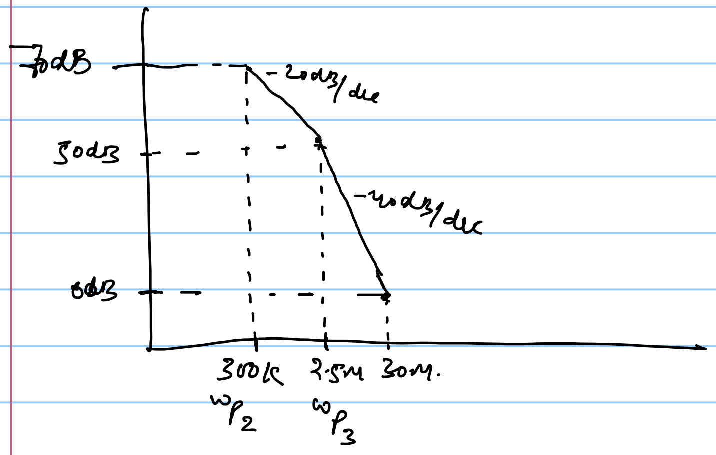
$A_3 = g_{m_3} \times R_{out} = 40 \times 7.7 = 308$

$A_2 = g_{m_1} \times R_{o_2} = 50\mu \times 500k$

$= 25$

$A_0 = 7700 = 77\,dB$

$\beta A_0 = \dfrac{7700}{2} \simeq 70\,dB$



Phase Margin $\simeq 0$ unstable.

compensate by adding C_c at ω_{p_2}

Phase Margin $= 60^\circ$

$$\omega_{ugb} = \frac{\omega_{p_3}}{1.7} = \frac{2.5M}{1.7} = 1.44 \text{ Mrad/sec.}$$

$$\omega_{p_2}(\text{compensated}) = \frac{1.44M}{\beta A_0} \approx 400\ \text{rad/sec}$$

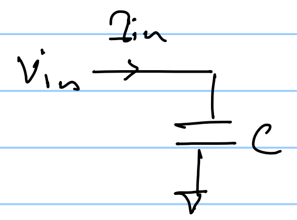
$$\omega_{p_2} = \frac{1}{R_{o2}(C_{o2}+C_c)} = 400\ \text{rad/sec.}$$

$$C_{o2}+C_c = \frac{1}{500k \times 400} = \frac{1}{2 \times 10^{8}} = \frac{10^{-8}}{2} = 5nF$$

$$C_c \approx 5nF$$

5nF is quite large to implement on-chip so we look for alternate way of reducing the capacitor size.

Miller compensation



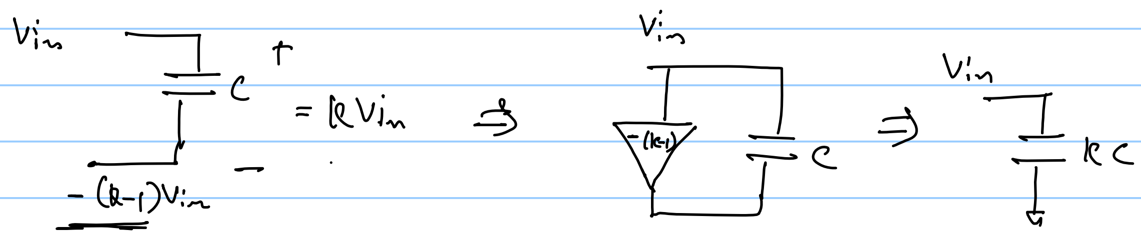
$I_{in} = V_{in} C s$

$I_{in} \rightarrow K \cdot I_{in}$

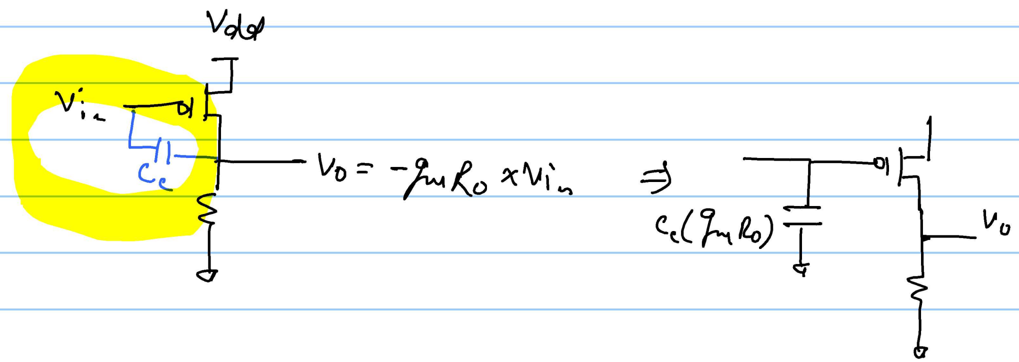
Two possibilities

1. Increase $C \rightarrow kC$

2. Increase $V_{in} \rightarrow k V_{in}$



Miller Effect



If $g_m R_o$ is large the C_c is quite small.

Assume previous case, C_c required was 5nF

$g_m R_o = 300$

$$C_c = \frac{5nF}{300} = 16.6 pF$$

$C_c = 16.67 pF$