24-2-12

Lec 21

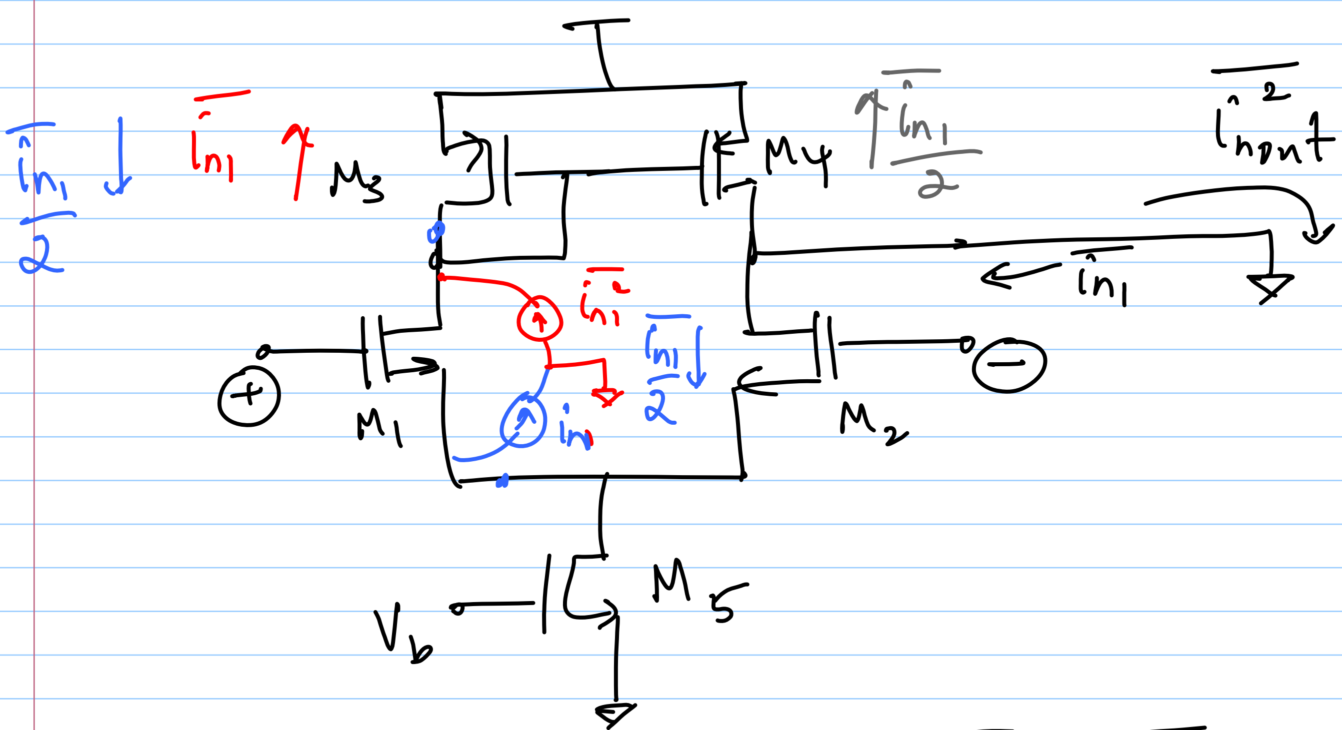
1-stage opamp w/ output cap C

DC gain : $\dfrac{g_{m_n}}{g_{ds_p}+g_{ds_n}}$

$$\omega_u = \frac{g_{m_n}}{C}$$

Stab : $\dfrac{g_{m_p}}{C_1} \gg \dfrac{g_{m_n}}{C}$

Noise



$$\overline{i^2_{n_{out}}} = \overline{i^2_{n_1}} + \overline{i^2_{n_2}} + \overline{i^2_{n_3}} + \overline{i^2_{n_4}}$$

$$S_{out} = \frac{16}{3} kT \left(g_{m1} + g_{m3} \right)$$

$$G_m = g_{m1}$$

$$S_{v_{in}} = \frac{S_{out}}{G_m^2}$$

$$= \frac{16}{3} \frac{kT}{g_{m1}} \left(1 + \frac{g_{m3}}{g_{m1}} \right)$$

Optimising noise : reduce g_{m3}

$\Rightarrow \downarrow (W/L)$

$\Rightarrow V_{DSAT_p} \uparrow \Rightarrow$ swing limits $\downarrow$

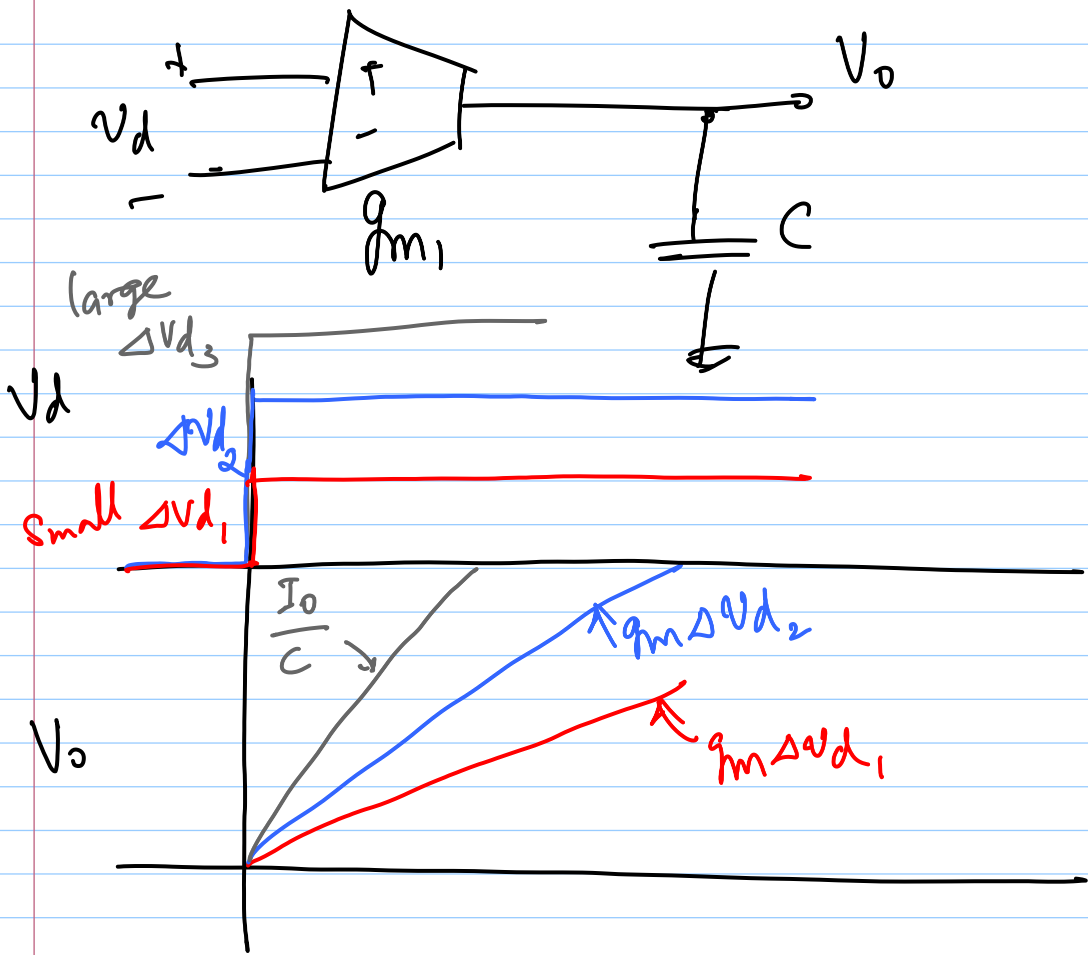
g_{m1} cannot change $\because \omega_u = \frac{g_{m1}}{C}$

<u>Offset</u>

$$\Delta i_{out} = g_{m1} \Delta V_{T_1} + g_{m3} \Delta V_{T_3}$$

$$\sigma_{V_{OS,in}}^2 = \frac{g_{m1}^2 \sigma_{V_{T_1}}^2 + g_{m3}^2 \sigma_{V_{T_3}}^2}{g_{m1}^2}$$

$$= \sigma_{V_{T_1}}^2 + \left(\frac{g_{m3}}{g_{m1}} \right)^2 \sigma_{V_{T_3}}^2 \quad \text{(compare w/ noise)}$$



$$C\frac{dv}{dt} = I$$

at some large v_d

$$\left.\begin{array}{l} I_1 = I_o \\ I_2 = 0 \end{array}\right) \quad v_d = \sqrt{2}\,(V_{GS_1} - V_{T_1})$$

$\Rightarrow$ $I_3 = I_o$; $I_4 = I_o$ flows through output cap C

$\Rightarrow$ slope $= \dfrac{I_o}{C}$ (SLEW RATE)

max. current pulled in from $C = I_o$

$(I_1 = 0,\ I_2 = I_o)$ (−ve slew rate)

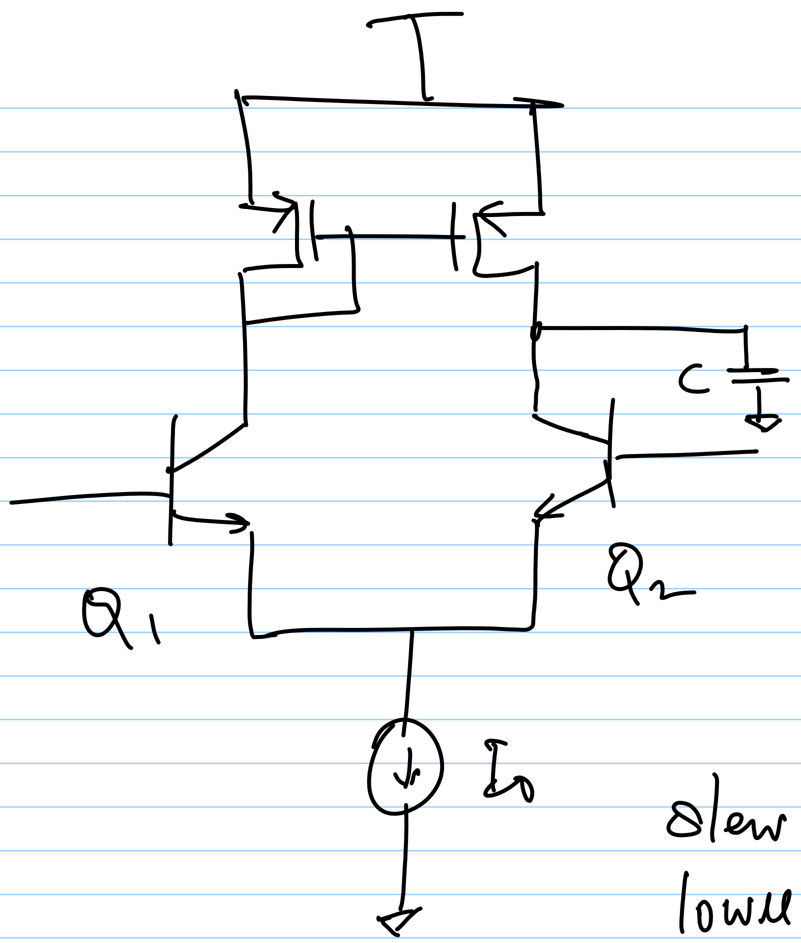
How to ↑ slew rate (given ω_u)

$\Rightarrow$ ↑ I_0, ↓ V_{ov}

otherwise g_m ↑, ω_u ↑

$\Rightarrow$ stability gets affect

larger slew rate $\Rightarrow$ larger power & larger V_{ov}



$$g_{m_1} = \frac{I_0}{2V_t}$$

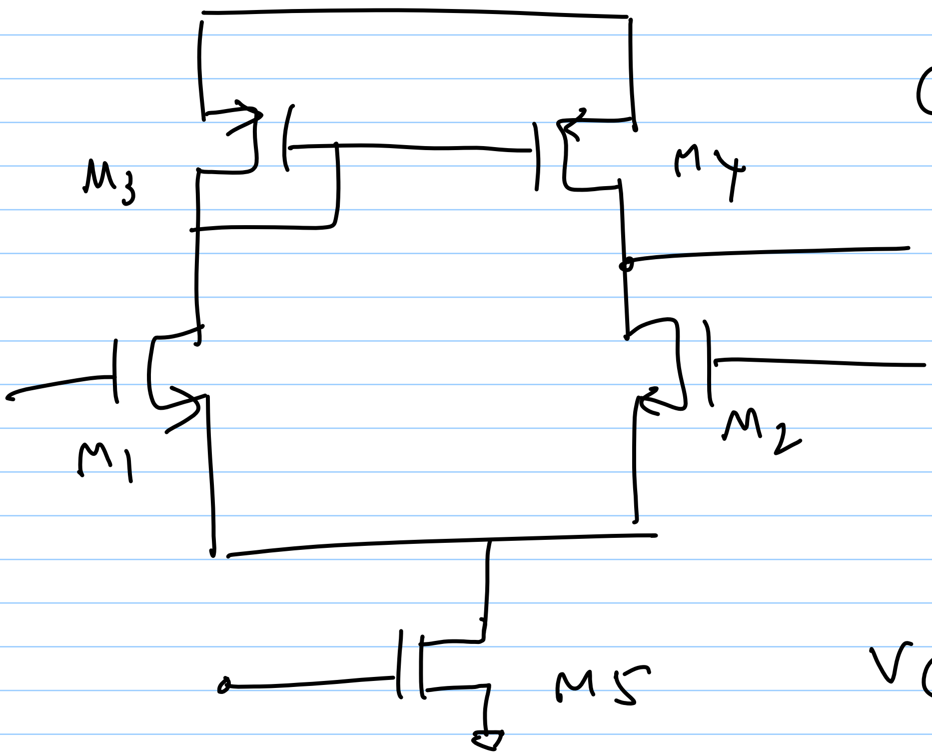
$$V_t = \frac{kT}{q}$$

slew rate $= \frac{I_0}{C}$

slew rate <u>may be</u> lower for BJT designs

$\because$ I_0 is lower for same g_m

CM range



CM range @ input :

$V_{CM,max} = V_{DD} - V_{GS_3} + V_{T_1}$ (M_1 - triode)

$V_{CM,min.} = V_{DSAT_5} + V_{GS_1}$

$$V_{DD} - V_{DSAT_4} > V_o > V_{CM,in} - V_{T_1}$$

Data Sheet

1) DC gain $= \dfrac{g_{m_1}}{g_{ds_1} + g_{ds_3}}$

2) UGF $\omega_u = \dfrac{g_{m_1}}{C_L}$

3) Non-dominant poles & zeroes $p_2 = -\dfrac{g_{m_3}}{C_1}$; $z_1 = -2\dfrac{g_{m_3}}{C_1}$

4) Input referred offset

$$\sigma_{os,in}^2 = \sigma_{V_{T_1}}^2 + \left(\frac{g_{m_3}}{g_{m_1}}\right)^2 \sigma_{V_{T_3}}^2$$

5) Input-ref. Noise PSD

$$= \frac{16kT}{g_{m1}}\left[1 + \frac{g_{m3}}{g_{m1}}\right]$$

6) +ve SR, -ve SR $\rightarrow \frac{I_o}{C_L}$

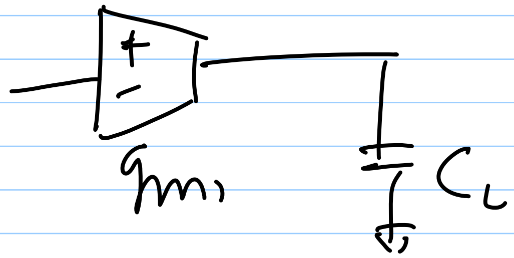
7) Output swing limit

$$V_{DD} - V_{DSAT3} > V_O > V_{CM,in} - V_{T1}$$

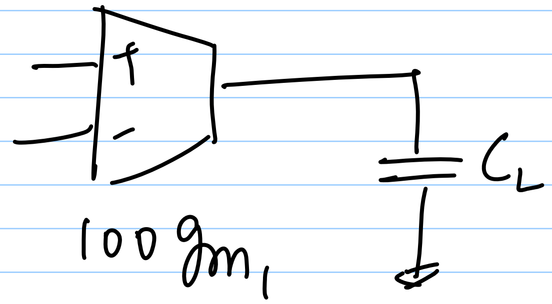
8) Input CM swing limit

$$V_{DD} - V_{GS3} + V_{T1} > V_{CM_{in}} > V_{GS1} + V_{DSAT5}$$

<u>Ckt scaling</u> $\left(\frac{W}{L}\right)_i \rightarrow 100X \left(\frac{W}{L}\right)_i$



$\rightarrow$



$g_{mi} \rightarrow 100X$
$C_i \rightarrow 100X$

p_2 & z_2 also scale 100 times

$W_u \sim 100 \frac{g_{m1}}{C_L}$, but <u>parasitics exist</u>

actual $C_c = C + C_{par}$ & $C_{par} \rightarrow 100 C_{par}$

⇒ ultimate limit to scaling in a given technology (parasitic limited)