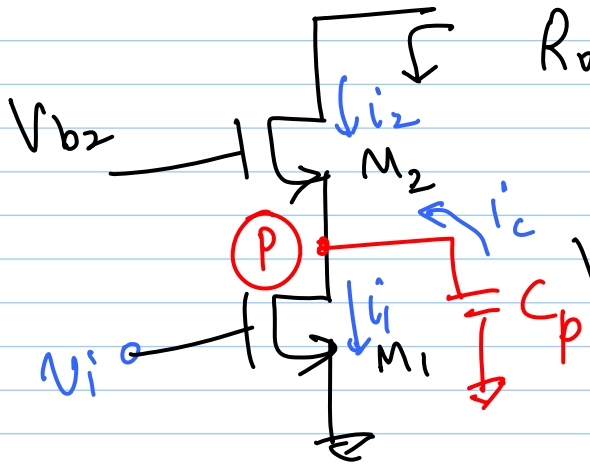
28-2-12

Lec-22

Cascode (Telescopic opamp)



$i_1 = i_2 + i_c$

$R_{out} = r_{ds_1} + r_{ds_2} + (g_{m_2} r_{ds_2}) r_{ds_1}$

$V_{b2} = V_{DSAT_1} + V_{GS_2}$

$= V_{T_2} + V_{DSAT_1} + V_{DSAT_2}$

↑ backgate effect

$C_p \simeq C_{gs_2} + C_{db_1}$ (ignore C_{gd})

Extra pole @ P: $\frac{g_{m_2}}{C_p}$

at every cascode node

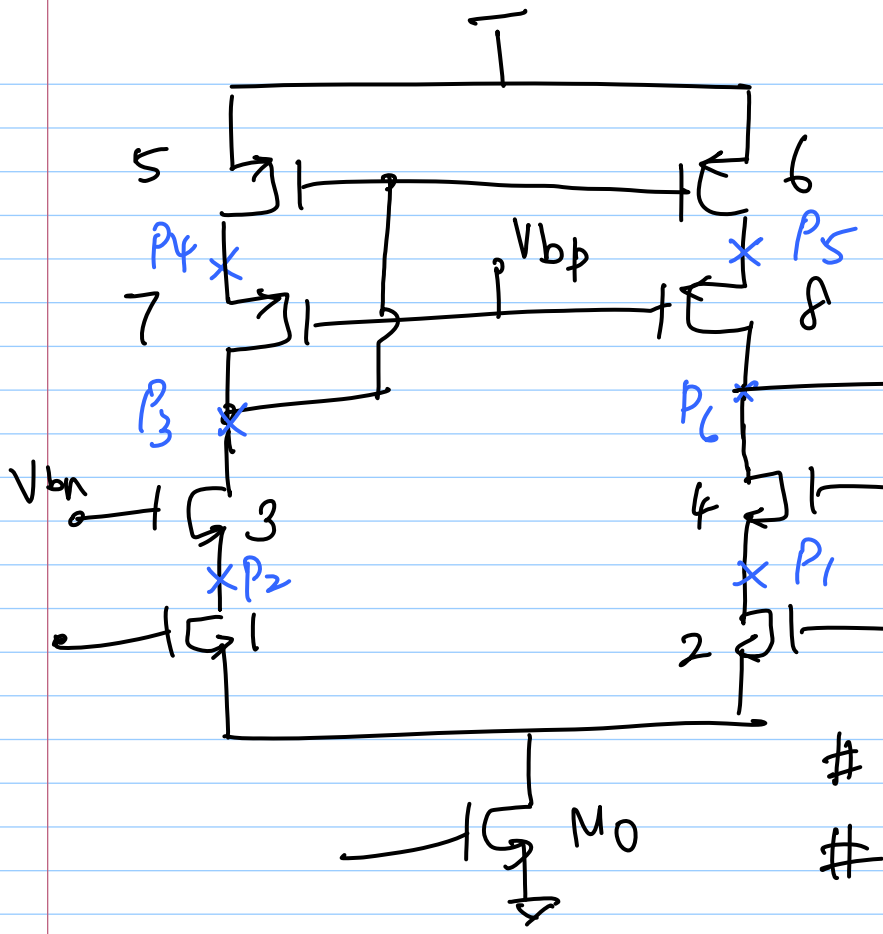
(but much better than ↑L

⇒ par. cap. ↑ a lot more)

* $C_{in} \simeq C_{gs_1} + C_{gd_1}$

gain from G_1 to $D_1 = \frac{g_{m_1}}{g_{m_2}} \simeq 1$

for normal opamp, C_{in} is much larger

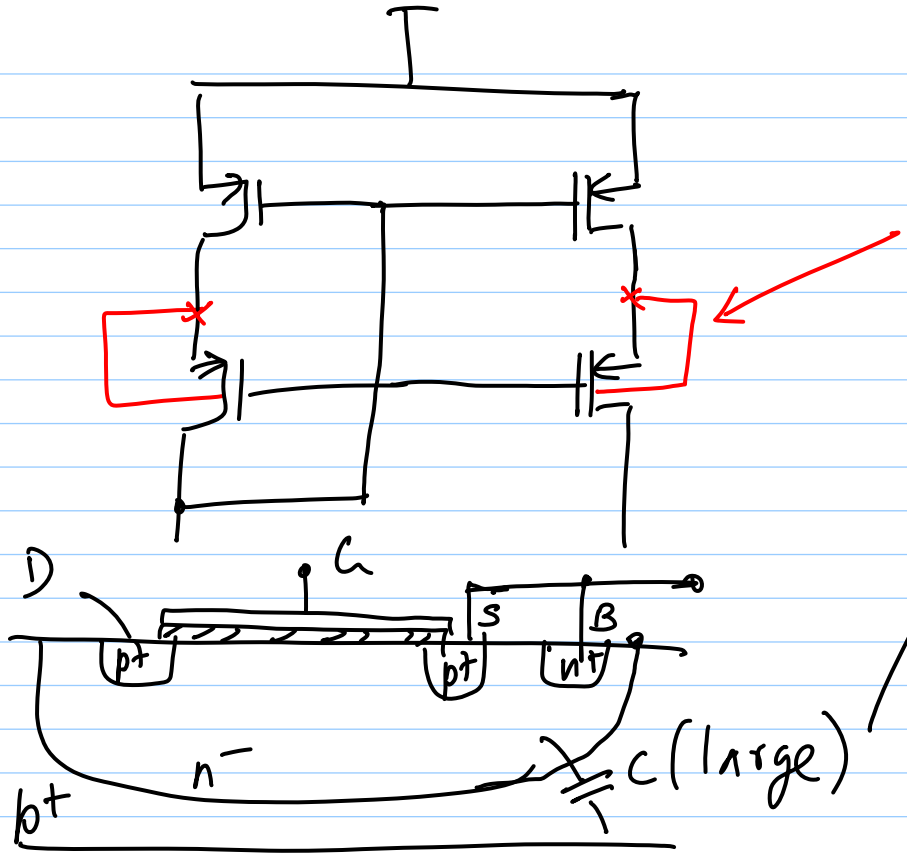


$$\omega_{p_1} \approx \frac{g_{m_4} + g_{mbs_4}}{C_{p_1}}$$

$$C_{p_1} = C_{gs_4} + C_{sb_4} + C_{db_2}$$

N.D. poles = 5

zeros = 4



* body effect is lesser
* N.D. pole will move in a lot

1) DC gain = $g_{m_1}(g_{m_3} r_{ds_3} r_{ds_1} \| g_{m_7} r_{ds_7} r_{ds_5})$

2) UGF = $\frac{g_{m_1}}{C_L}$

3) non-dominant poles
zeros

4) $\overline{V_{OS,in}^2}$ ← ITN (similar to noise)

5) Noise PSD ← same as before
@ low freq.

6) SR ← I_D / C_L

7) Output swing limit
— lower (more trans stacked up)

$V_{out,max}$: $V_{DD} - V_{DSAT_6} - V_{DSAT_8}$

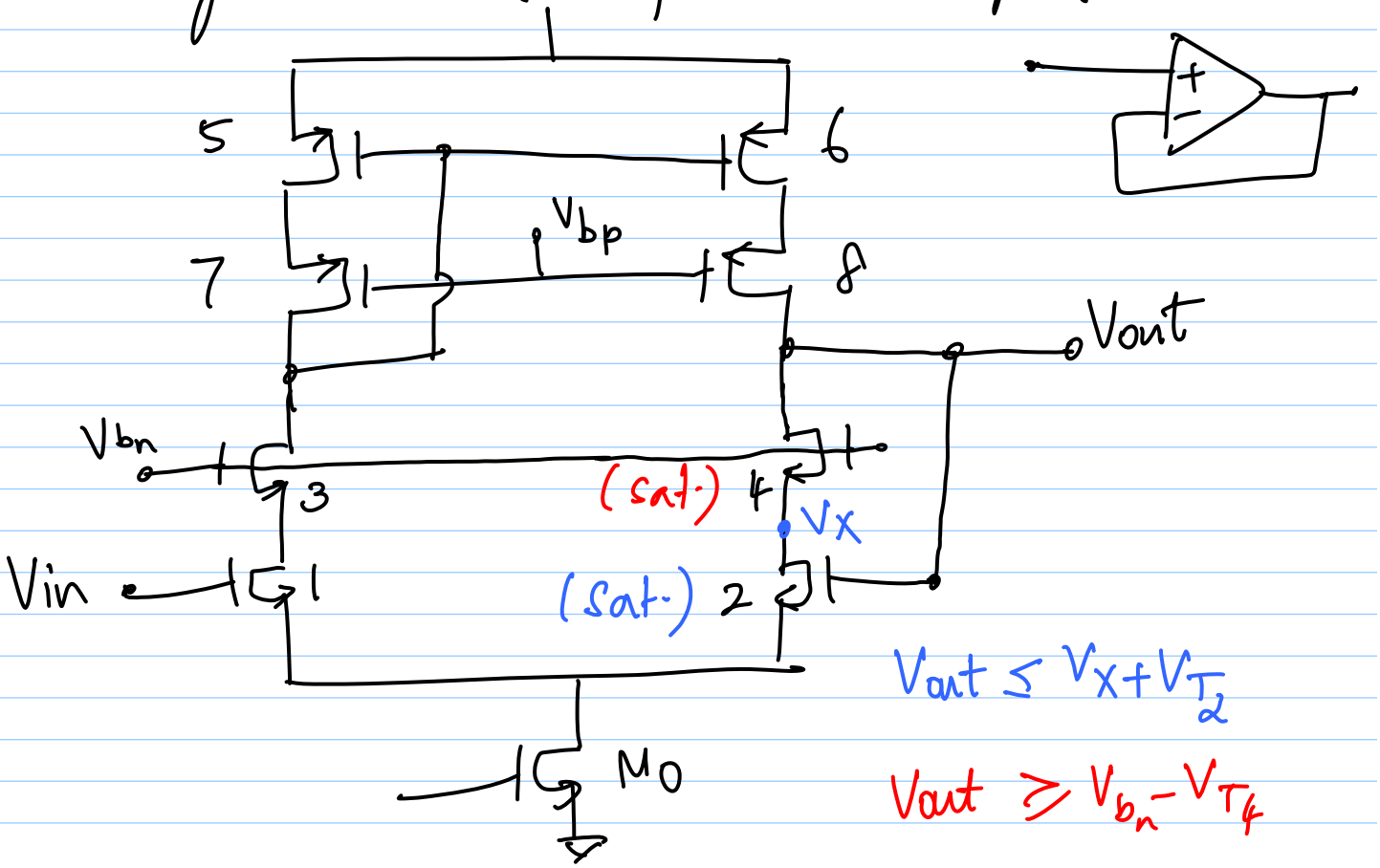
$V_{out,min}$: $V_{bn} - V_{T_4}$

8) Input swing limit — lower

$V_{CM,in}(min.) = V_{GS_1} + V_{DSAT,D}$

$V_{CM,in}(max.) = V_{DD} - V_{GS_5} - V_{DSAT_3} + V_{T_1}$

Can you short input to output?



$$V_X = V_{b_n} - V_{GS_4}$$

$$\Rightarrow \underbrace{V_{b_n} - V_{T_4}}_{V_{min.}} \leq V_{out} \leq \underbrace{V_{b_n} - V_{GS_4} + V_{T_2}}_{V_{max.}}$$

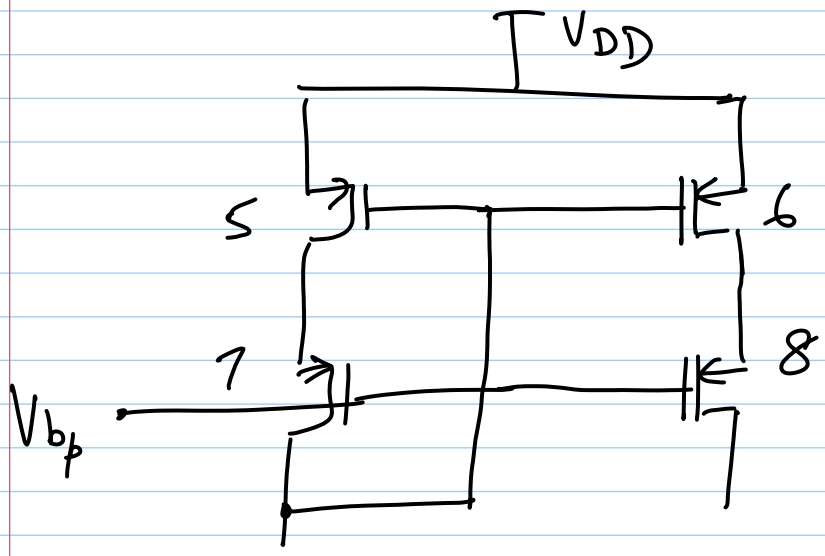
$$V_{max} - V_{min.} = V_{T_4} + V_{T_2} - V_{GS_4}$$

$$= V_{T_2} - V_{DSAT_4}$$

$$< V_{T_2}$$

$\therefore$ Unity gain buffers are difficult!

Conditions on Vbp

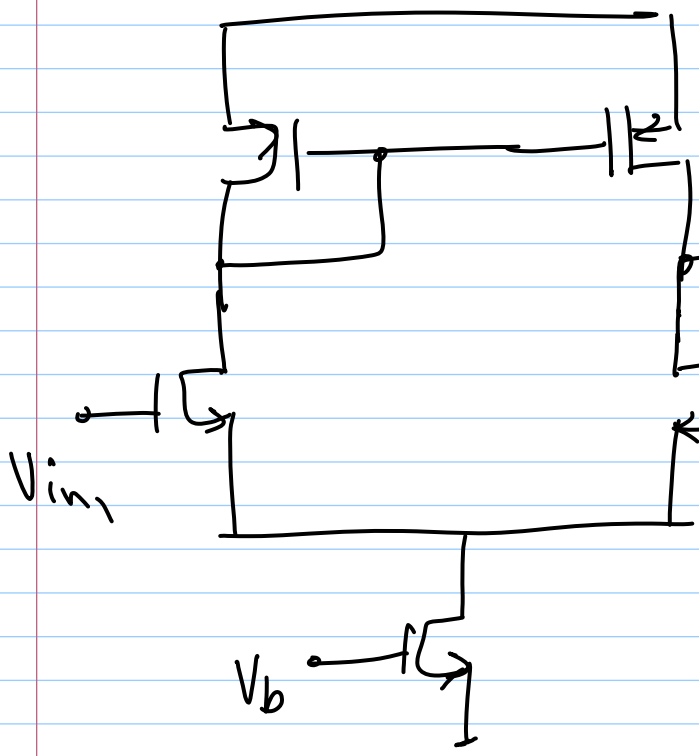


$V_{bp} < V_{DD} - V_{DSAT_5} - V_{SG_7}$

$V_{bp} > V_{DD} - V_{SG_5} - V_{T_7}$

Design example : see Razavi' example 9.5 (fully diff. calc.)

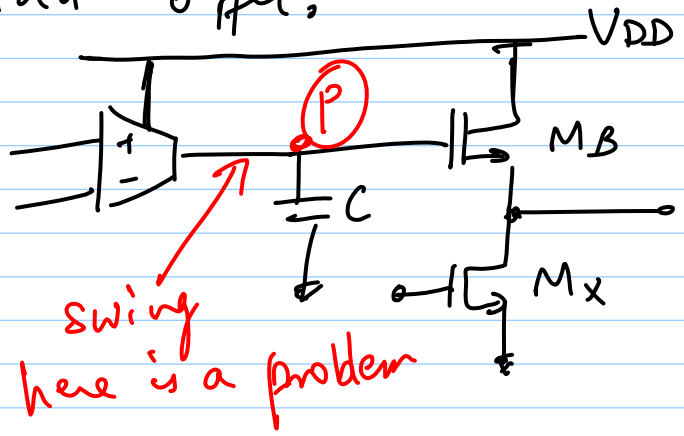
Output CM



* $V_{out,cm}$ is not set well ⇒ requires CM feedback.

* same for telescopic opamp

Add buffer?



$V_{DSAT_X} < V_o < V_{DD} - V_{DSAT_B}$

$V_{DSAT} \sim 200mV$

$V_{DD} \sim 1.2V$

$\Rightarrow$ V_o range $= 0.8V$

For $V_o = V_{DD} - V_{DSATB}$,

$V_p = V_{DD} + V_T \rightarrow$ not possible

e.g. $V_T = 0.4V$, $V_{DSAT} = 0.2V$, $V_{DD} = 1.2V$

$V_{pmax.} = V_{DD} - V_{DSAT} = 1V$

$V_{omax.} = V_{pmax.} - V_{GSB}$

$= V_{pmax.} - (V_T + V_{DSAT})$

$= 1 - (0.4 + 0.2) = 0.4V!$