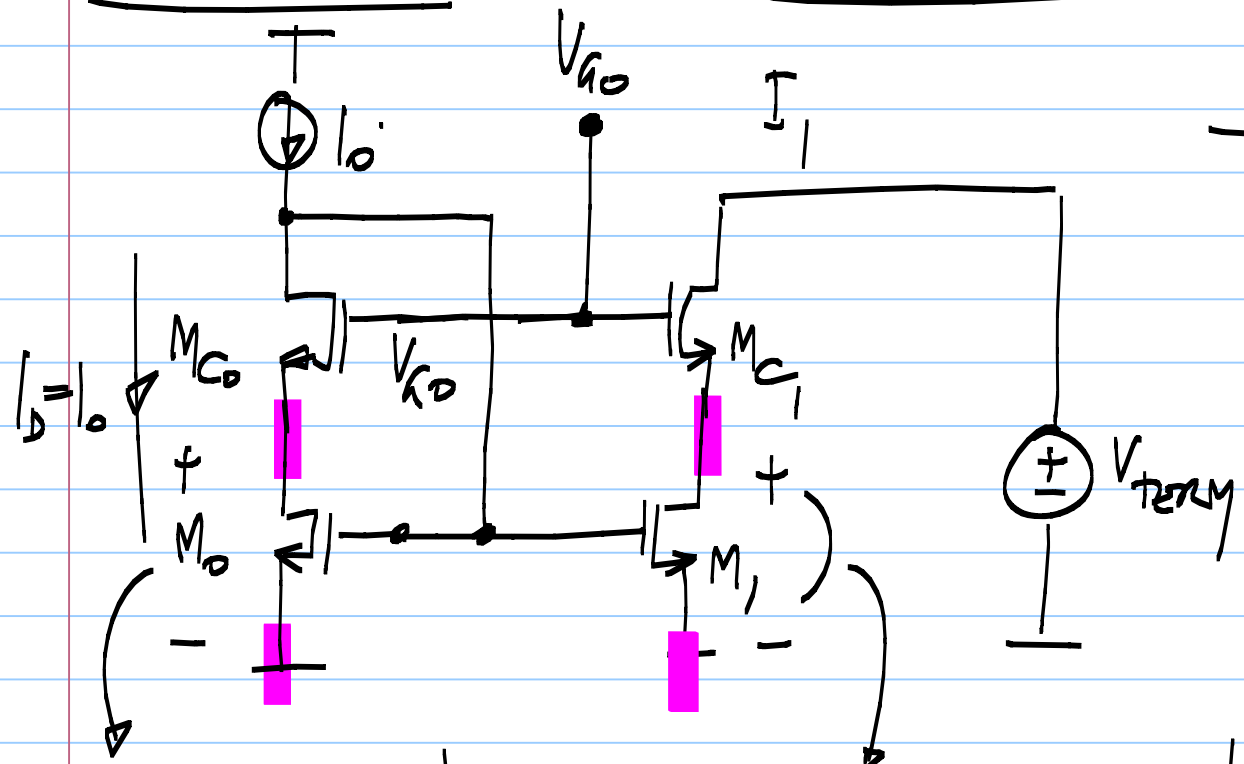
Lecture 33:

$M_1 = M_0$

$M_C = MC_0$

$I_1 = I_0$



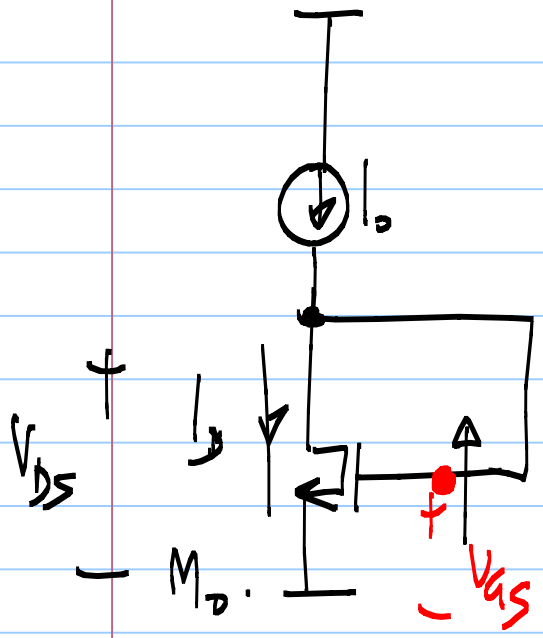
$\Delta V_{transf} \cdot g_{ds_1}$

$\Delta V_{transf} \cdot g_{ds_1} \left(\frac{g_{dsC}}{g_{mC}}\right)$

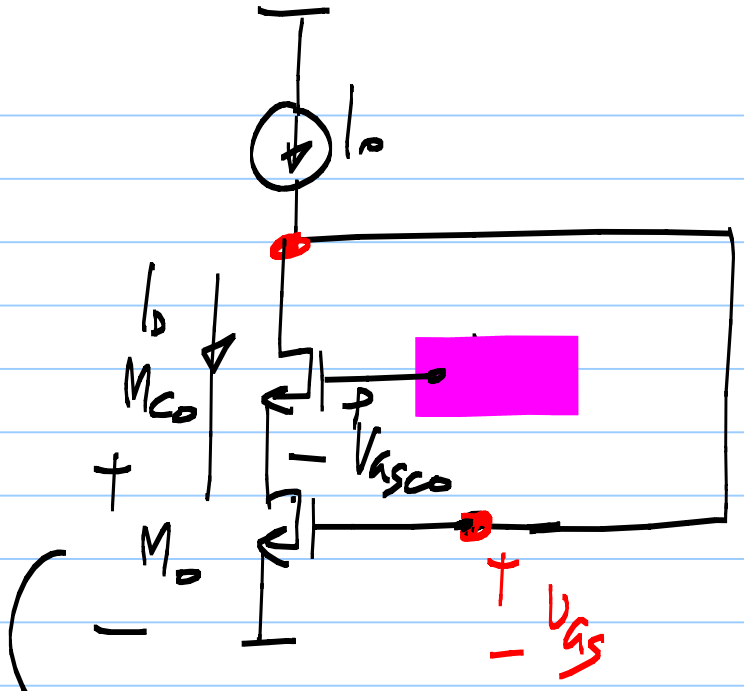
Cascode current mirror

$V_{DS0} = V_{G0} - V_{GSC0}$ | I_0

$V_{DS_1} = V_{G_1} - V_{GSC_1}$ | I_1

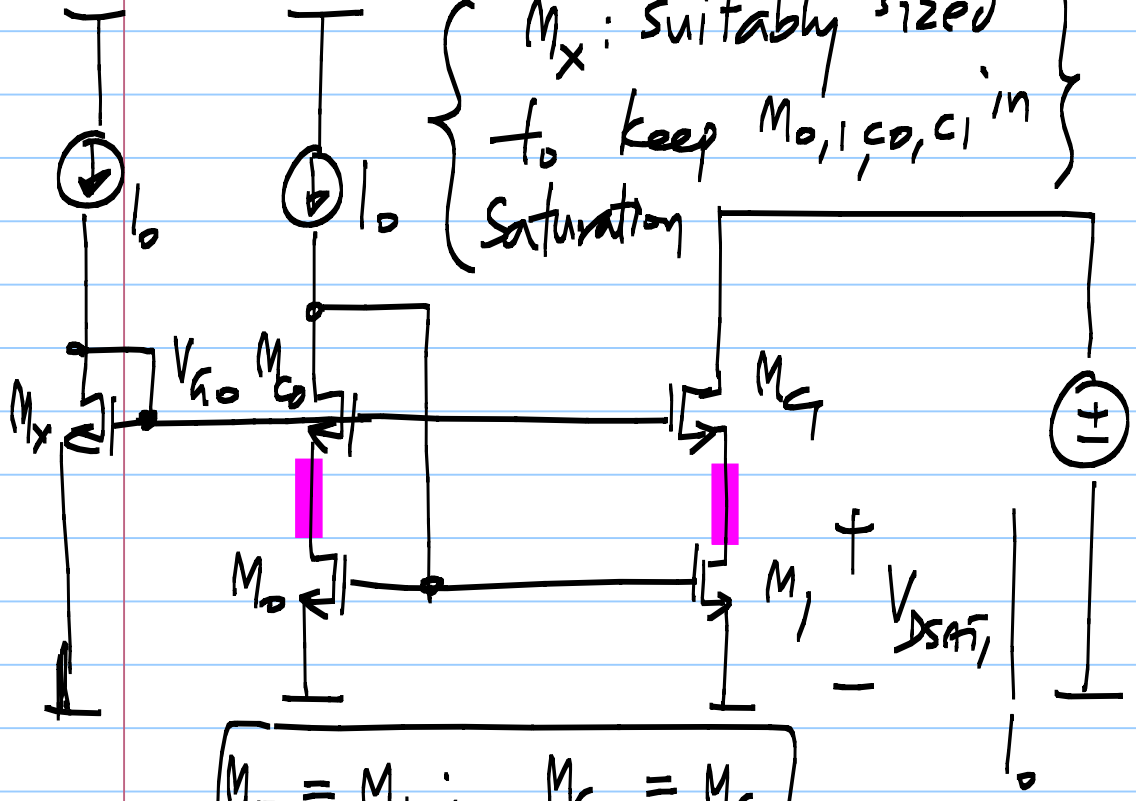


$$V_{DS_0} = V_{GS_0}$$



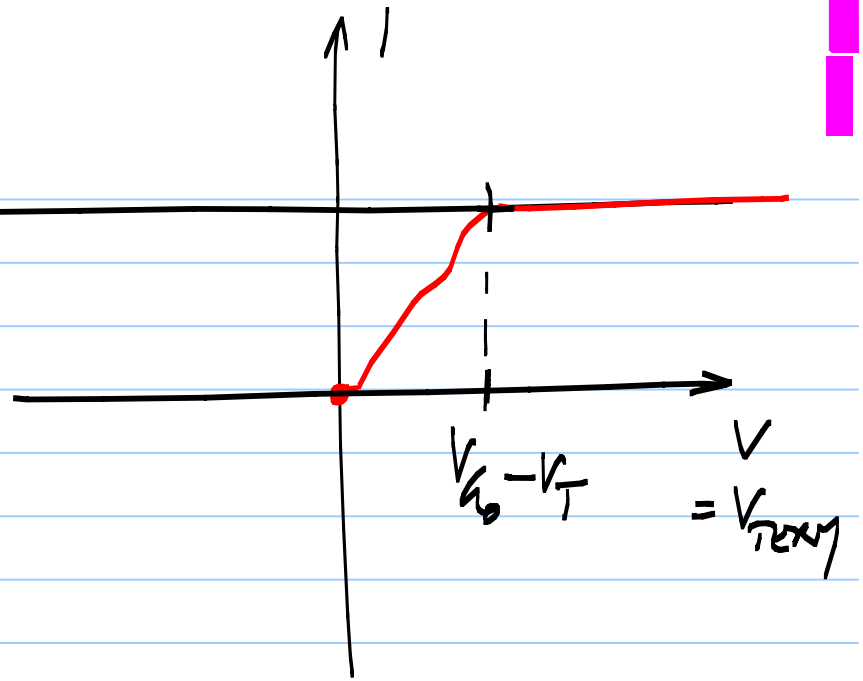
$$V_{DS_0} = V_{G_0} - V_{GSCO}$$

High swing Cascode current mirror



M_X : suitably sized to keep $M_{0,1,C0,C1}$ in saturation

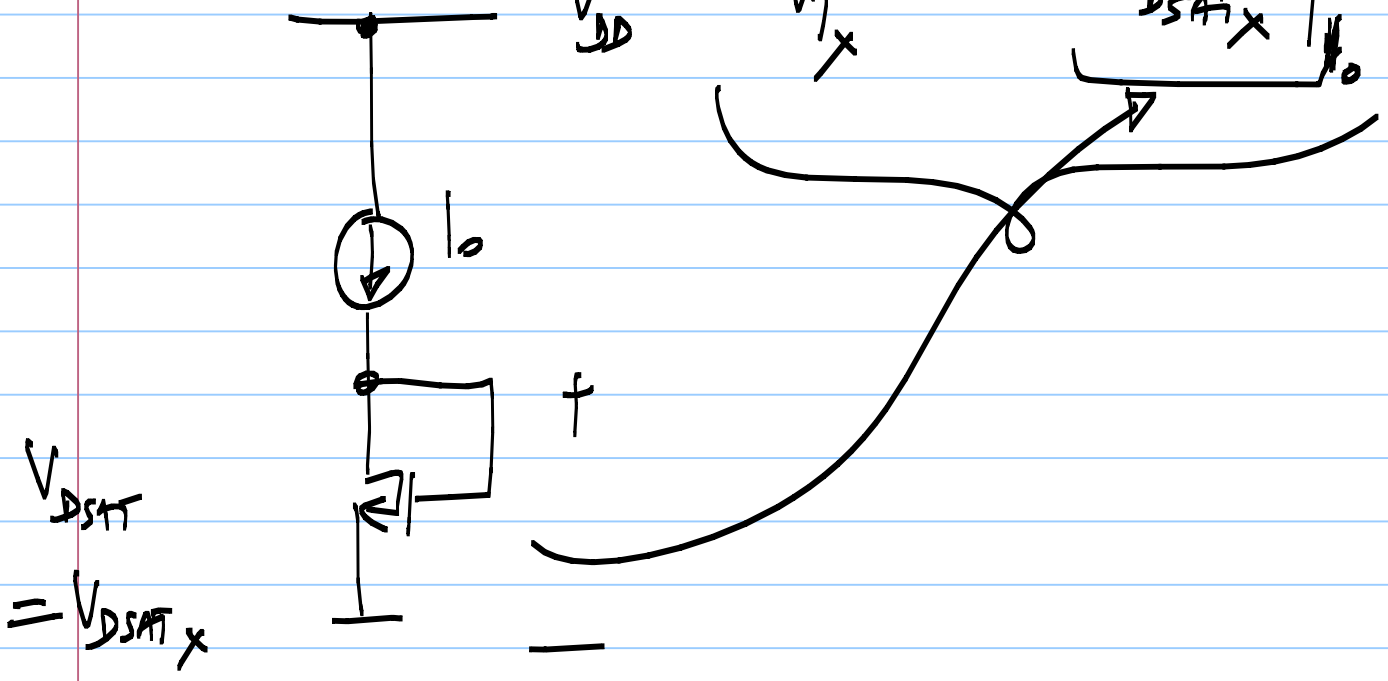
$M_0 = M_1$; $M_{C0} = M_{C1}$

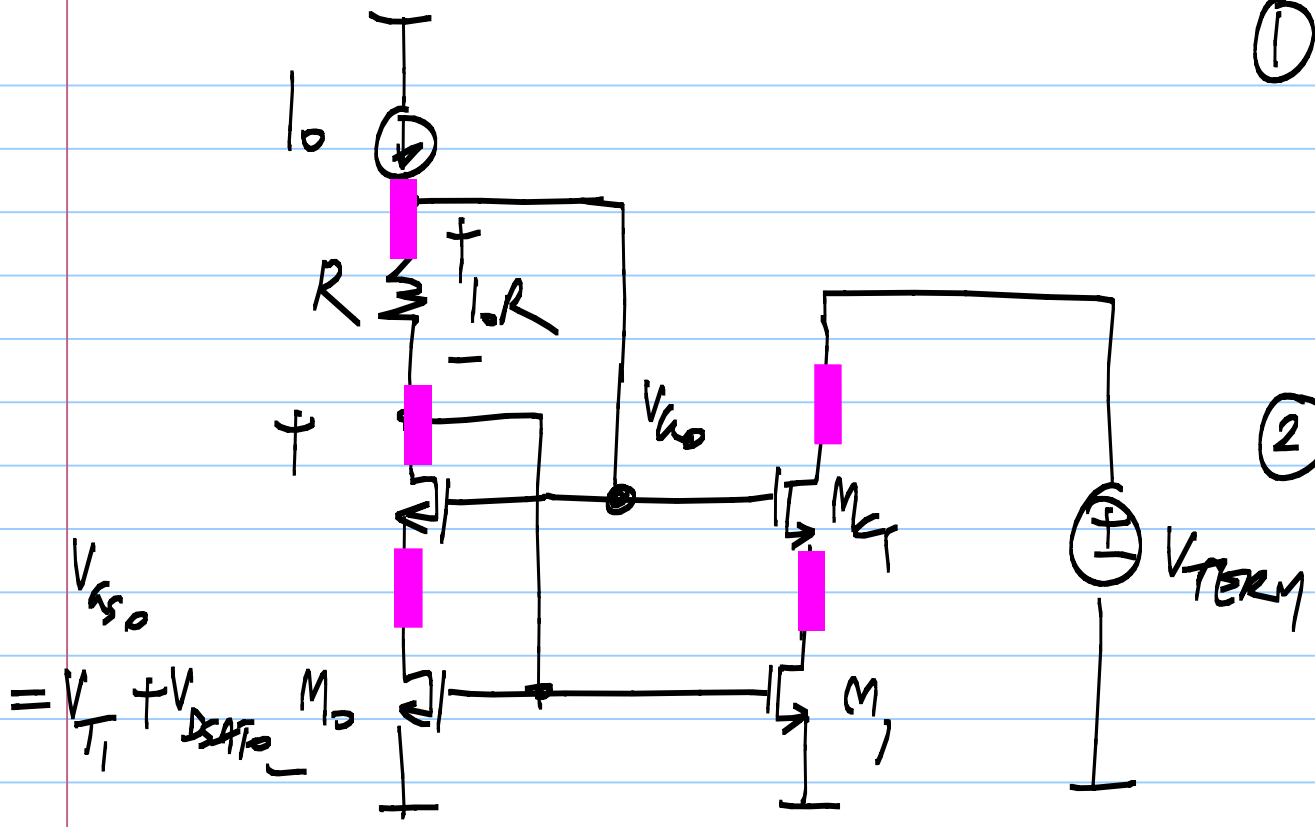


Minimize V_{G0}

$$V_{G0} > V_{DSAT0}\Big|_{I_0} + V_{T_{C0}} + V_{DSAT_{C0}}$$

$$V_{o,min} = V_{T_{co}} + V_{DSAT_{CO}} + V_{DSAT_0} \Big|_{I_0} + V_{T_x} + V_{DSAT_x} \Big|_{I_0}$$

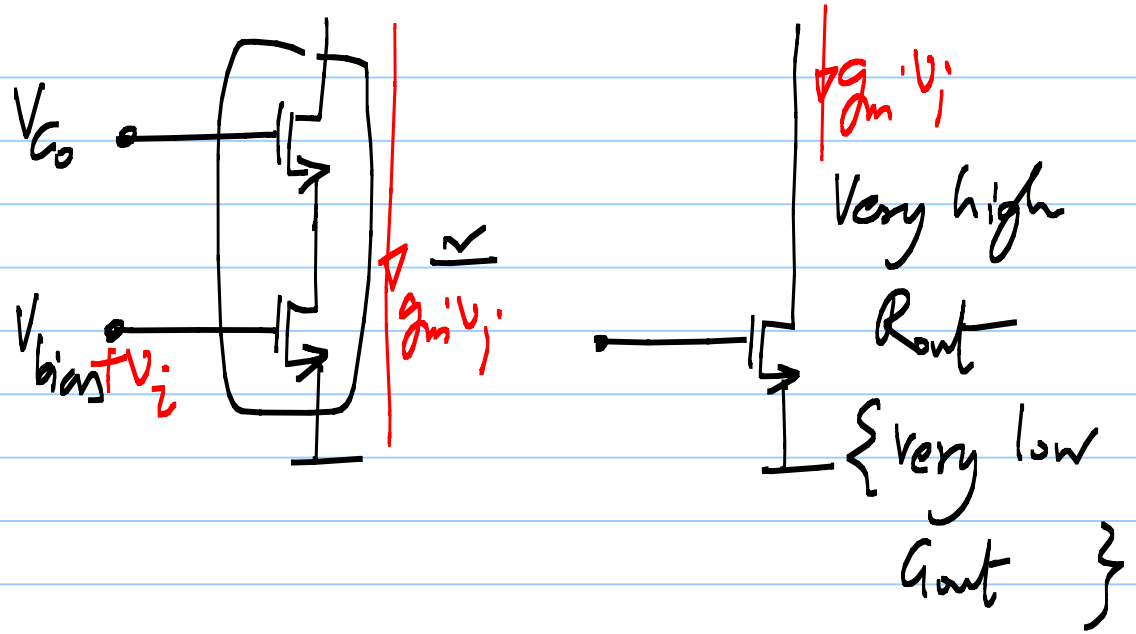


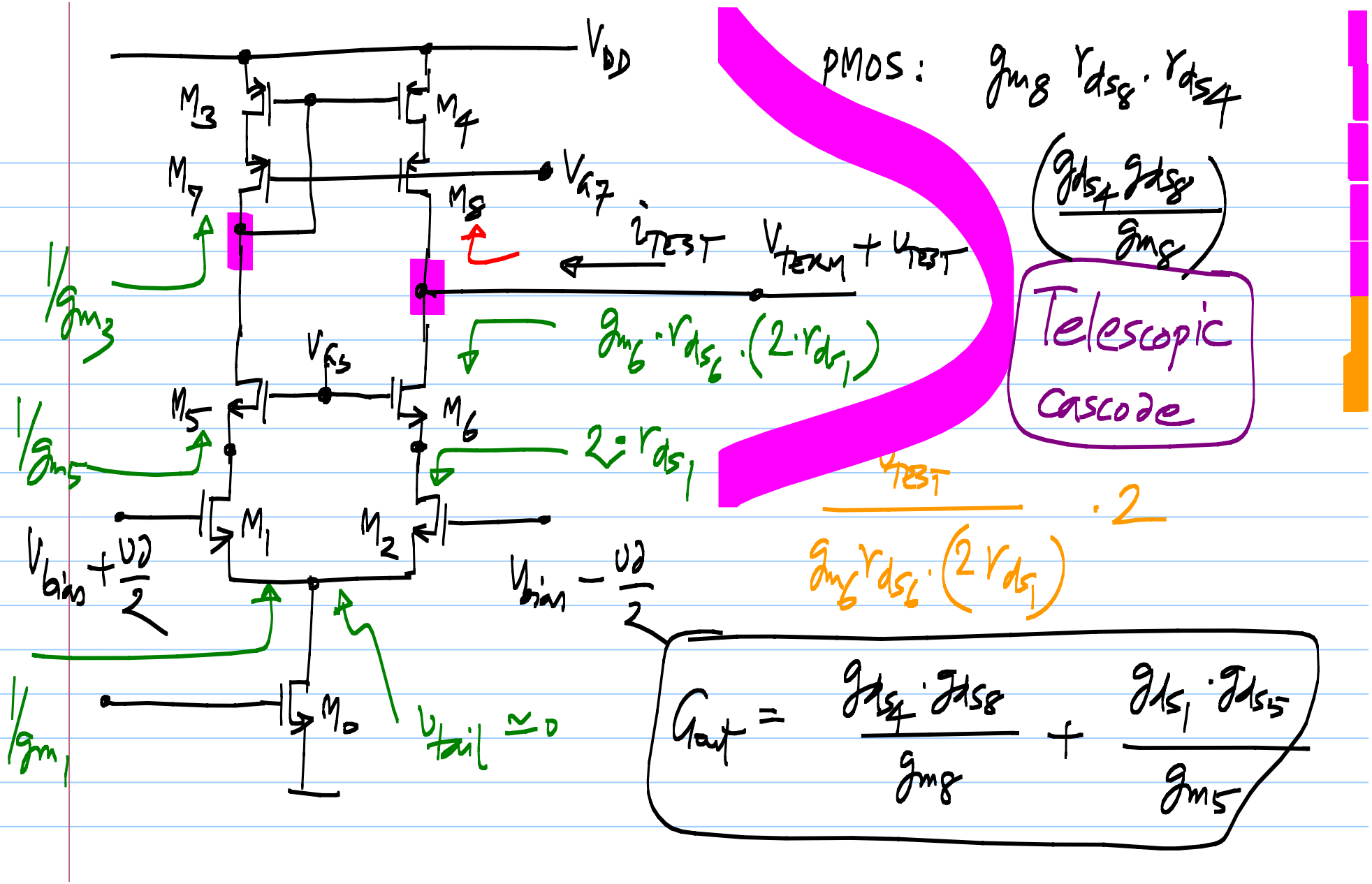


$V_{GS0} = V_{T1} + V_{DSAT0}$

① Calculate ΔV_{DS1} due to a change ΔV_{TERM}

② Range of V_{GS0} so that all transistors are in saturation


V_{CO}
$V_{bias}+v_i$
$-g_m v_i$
$\approx$
$+g_m v_i$
Very high
Rout
{ Very low
Gout }



PMOS: $g_{m8} r_{ds8} \cdot r_{ds4}$

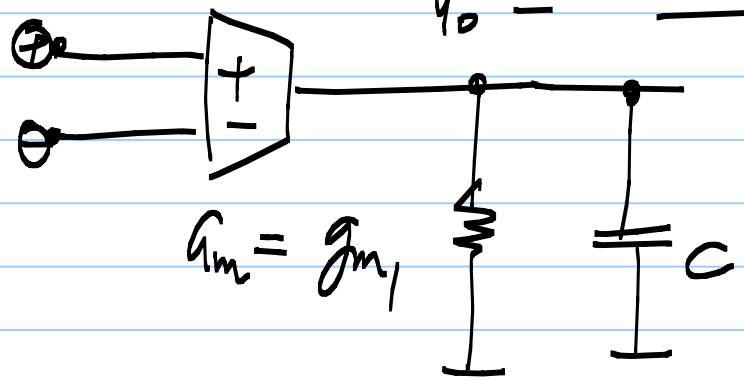
$\left(\frac{g_{ds4} g_{ds8}}{g_{m8}}\right)$

Telescopic cascode

$\frac{v_{TEST}}{g_{m6} r_{ds6} \cdot (2 r_{ds1})} \cdot 2$

$$G_{out} = \frac{g_{ds4} \cdot g_{ds8}}{g_{m8}} + \frac{g_{ds1} \cdot g_{ds5}}{g_{m5}}$$

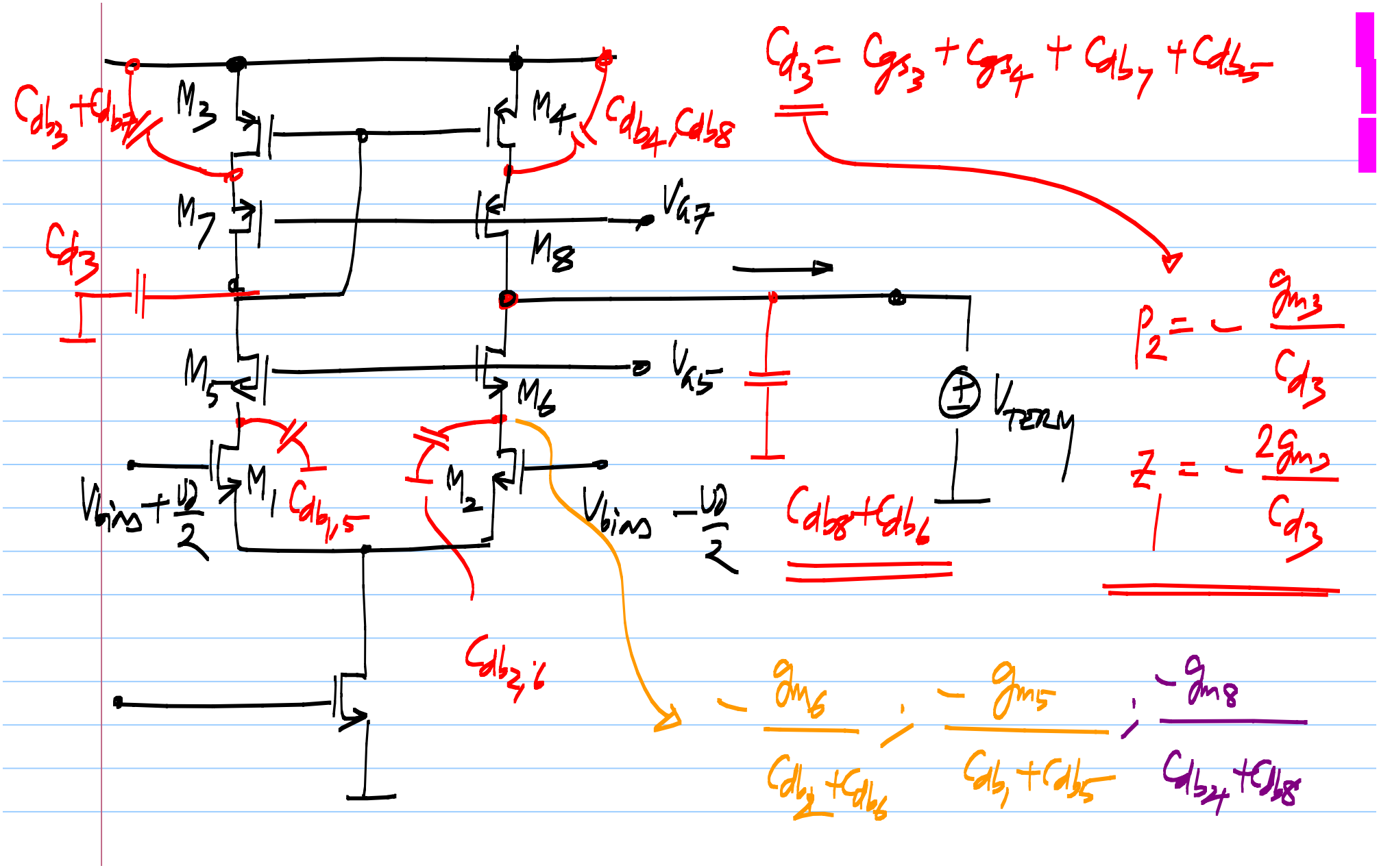
Single stage cascode opamp

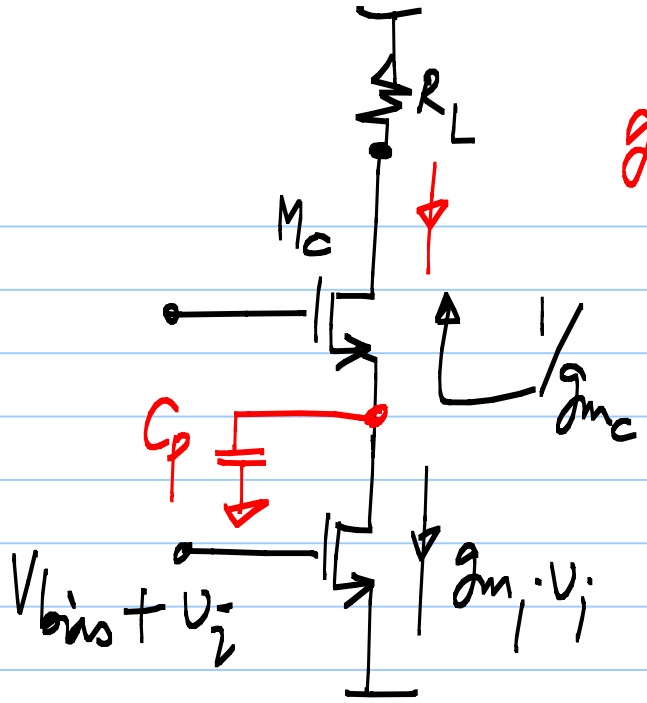


$$G_o = \frac{g_{ds_1} g_{ds_5}}{g_{m_5}} + \frac{g_{ds_3} g_{ds_7}}{g_{m_7}}$$

} Much smaller than $g_{ds_1} + g_{ds_3}$

$$\frac{g_{m_1}}{g_{ds_1} + g_{ds_3}} \sim \left(\frac{g_m}{g_{ds}}\right); \quad \frac{g_{m_1}}{\frac{g_{ds_1} \cdot g_{ds_5}}{g_{m_5}} + \frac{g_{ds_3} g_{ds_7}}{g_{m_7}}} \sim \left(\frac{g_m}{g_{ds}}\right)^2$$


$C_{db3}+C_{db7}$
M_3
M_4
C_{db4},C_{db8}
M_7
V_{G7}
M_8
C_{d3}
M_5
V_{G5}
M_6
V_{TEST}
M_1
M_2
$C_{db1,5}$
$V_{bias}+\frac{V_D}{2}$
$V_{bias}-\frac{V_D}{2}$
$C_{db8}+C_{db6}$
$C_{db2,6}$
$C_{d3}=C_{gs3}+C_{gs4}+C_{db7}+C_{db5}$
$p_2=-\frac{g_{m3}}{C_{d3}}$
$z=-\frac{2g_{m3}}{C_{d3}}$
$-\frac{g_{m6}}{C_{db2}+C_{db6}}$
$-\frac{g_{m5}}{C_{db1}+C_{db5}}$
$-\frac{g_{m8}}{C_{db4}+C_{db8}}$



$$g_{m1} \cdot V_i(s) \frac{g_{mc}}{g_{mc} + sC_p} = g_{m1} \cdot V_i(s) \cdot \frac{1}{1 + \frac{sC_p}{g_{mc}}}$$

Pole: $-\frac{g_{mc}}{C_p}$