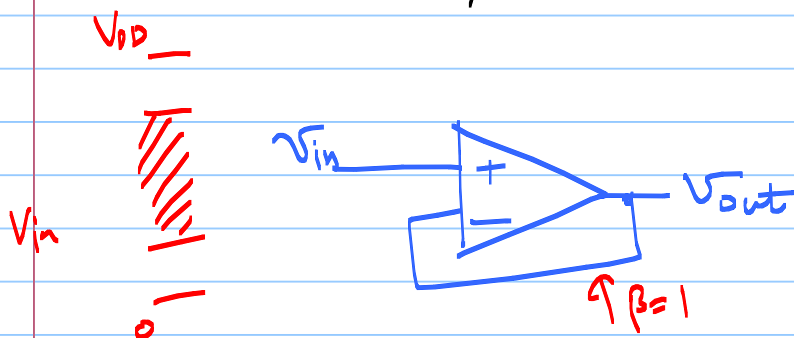
ECE 5411 – Lecture 22

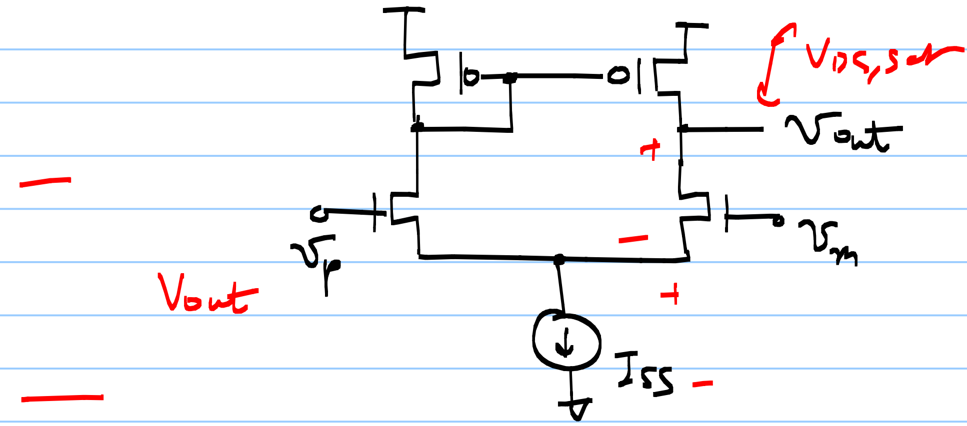
Note Title 4/20/2011

Ex. $V_{DD} = 3V$

$V_{THN} = V_{THP} = 0.7V$

$V_{ov} = V_{DS,sat} = 0.3V$



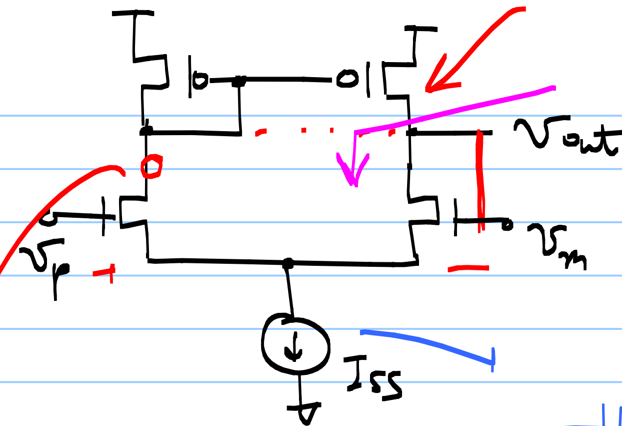


* what is the input CMR = ?

* Closed-loop output impedance

$$V_{in,cm} \in \Big[\overbrace{V_{GS_{1,2}} + V_{DS,sat}}^{V_{in,min}},\ \overbrace{V_{DD} - V_{SG_3} + V_{THN}}^{V_{in,max}}\Big]$$

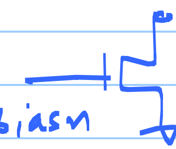
$$= [\underbrace{1.3,\ 2.7}_{1.4V}]$$



$V_{d_{1,2}} \le V_{DD} - V_{SG} + V_{THN}$

$+V_{THN}$

$V_{in,max}$



$$R_{o,CL} = \frac{R_{o,OL}}{1 + \text{loop-gain}}$$

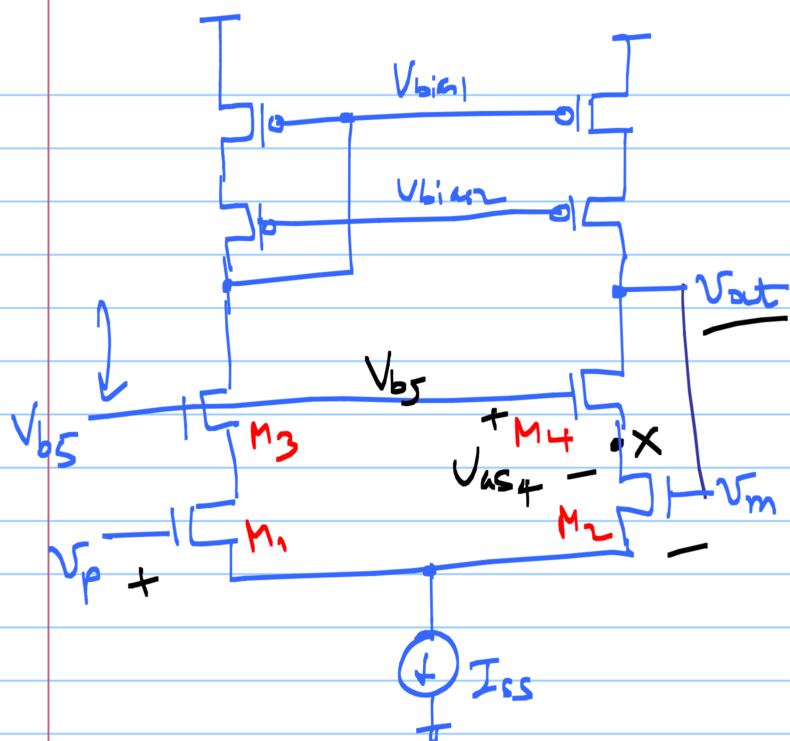
$$= \frac{r_{op} \| r_{on}}{g_{m_{1/2}}(r_{op} \| r_{on})}$$

$$\simeq \frac{1}{g_{m_{1,2}}}$$

$V_{DD} = 3V$

$V_{THN} = V_{THP} = 0.7V$

$V_{ov} = V_{DS,sat} = 0.3V$



× Both M_2 & M_4 must be in SAT.

⇒

M_2: $V_{out} \le V_x + V_{THN}$ ⟶ ①

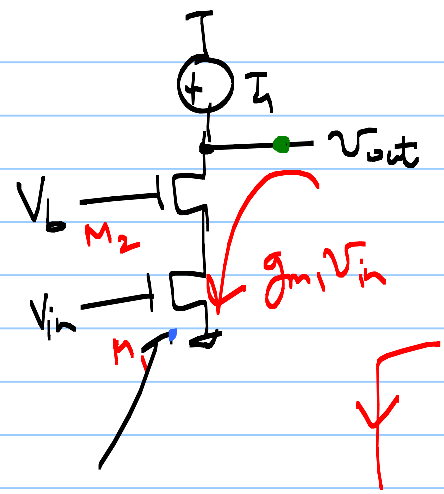
M_4: $V_{out} \ge V_{b5} - V_{THN}$ ⟶ ②

$V_x = V_{b5} - V_{GS4}$ ⟶ ③

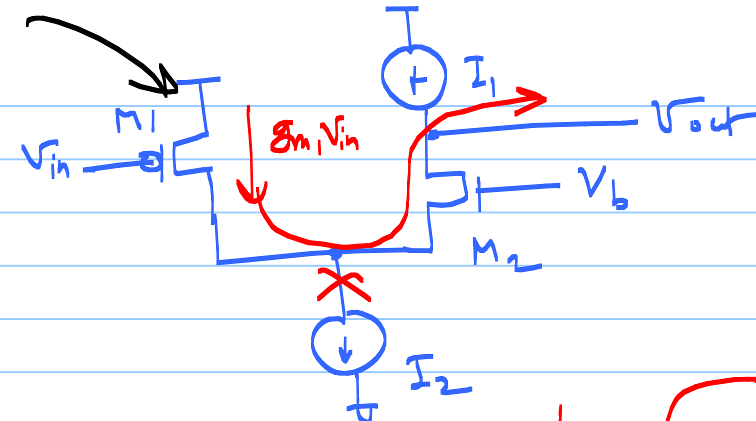
$$\underbrace{V_{b5} - V_{THN}}_{V_{o,min}} \le V_{out} \le \underbrace{V_{b5} - V_{GS4} + V_{THN}}_{V_{o,max}}$$

$$V_{omax} - V_{omin} = 2V_{THN} - V_{GS4} = V_{THN} - V_{OV4}$$

NMOS Cascode



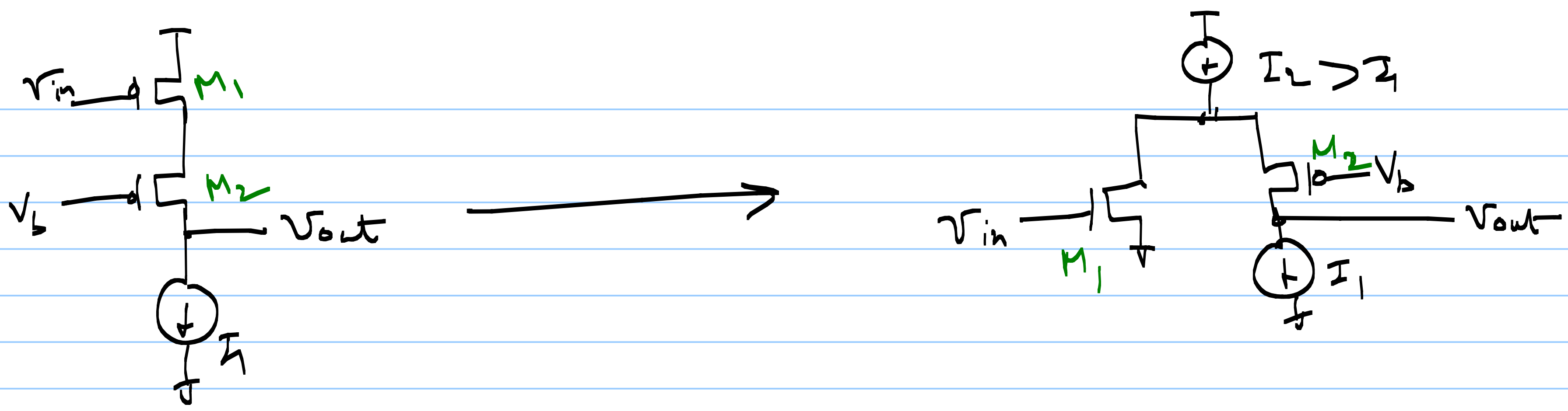
Folded Cascode



* input device is replaced by the opposite

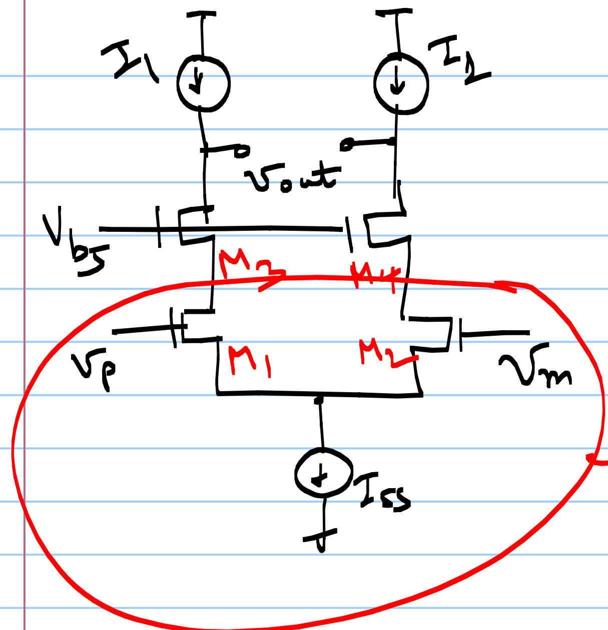
* Small-signal current $g_{m1}v_{in}$ is folded up through M_2

* $A_v = -G_m R_{out} = -g_{m1} \cdot (g_{m2} r_{o2} r_{o1})$

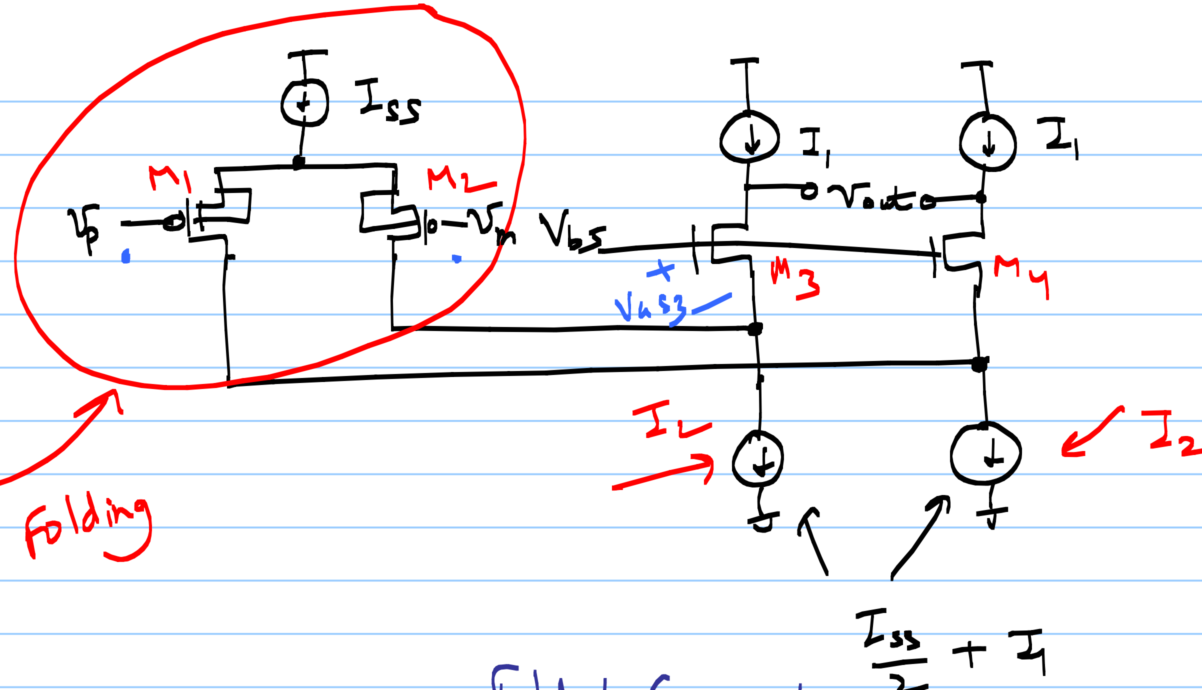


Vin
M1
Vb
M2
Vout
I1
I2 > I1
Vin
M1
M2
Vb
Vout
I1

FD representation CMFB not shown



Telescopic



Folded-Cascode

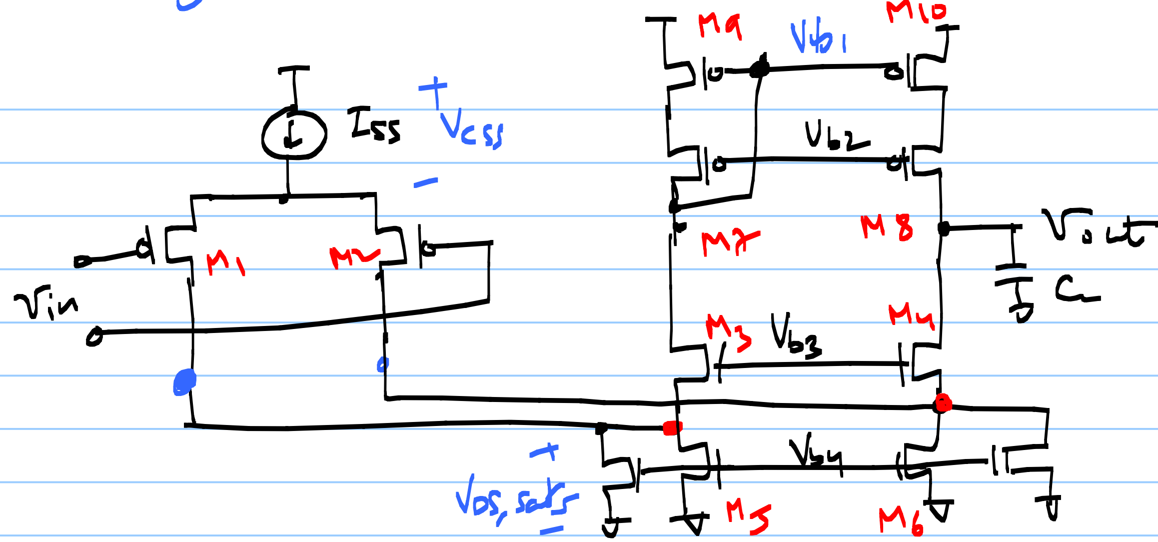
$V_{in,min} = ?$

$V_{cm,in} \le V_{b5} - V_{GS} + V_{THN} = V_{in,max}$

$V_{cm,in} \ge V_{b5} - V_{GS_3} - V_{THP}$

⇒ Possible to short Input & Output

Single-Ended Folded-Cascode Diffamp.



$I_{bias} = \frac{I_{SS}}{2}$

$V_{cm,in} \leq V_{DD} - V_{CSS} - V_{SG_{1,2}}$

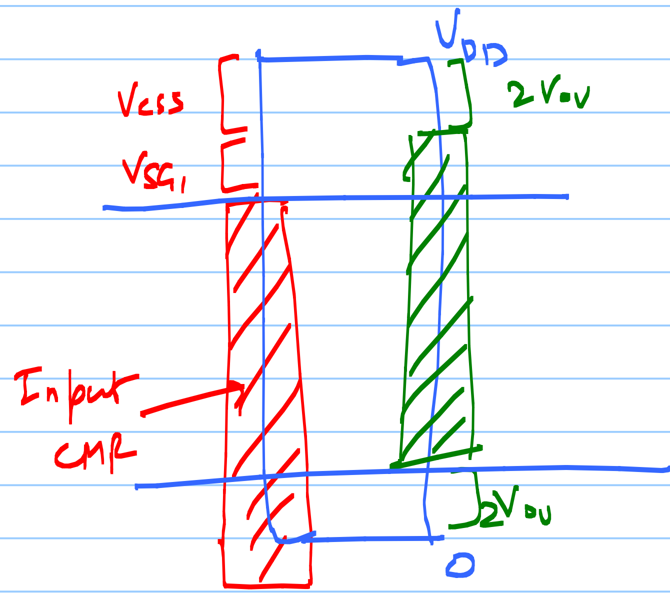
$V_{d_1} \geq V_{DS,sat_5} - V_{THP}$

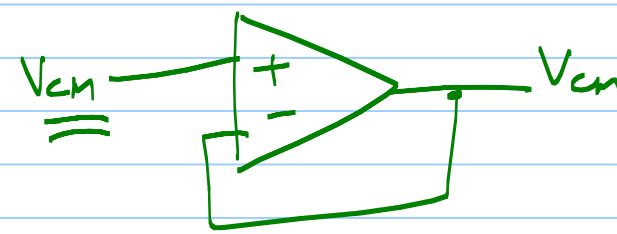
$-V_{THP}$

$V_{cm,in} \geq \overbrace{V_{DS,sat_5}}^{V_{ov_5}} - V_{THP} < 0$

$V_{CM,in} \in \left[V_{DS,sat} - V_{THP},\ V_{DD} - \underline{V_{CSS}} - \underline{V_{SG_{1,2}}} \right].$

$V_{out} \in \left[2V_{DS,sat},\ V_{DD} - 2V_{SD,sat} \right]$





Fully-Diff Circuits

Odd function

v_{o1} $\qquad$ v_{o2}

$$y = \frac{f(x) - f(-x)}{2}$$

$x = a$

$$= \cancel{f(a)} + \frac{f'(a)}{\lfloor 1}(x-a) + \cancel{\frac{f''(a)}{\lfloor 2}(x-a)^2} + \cdots$$

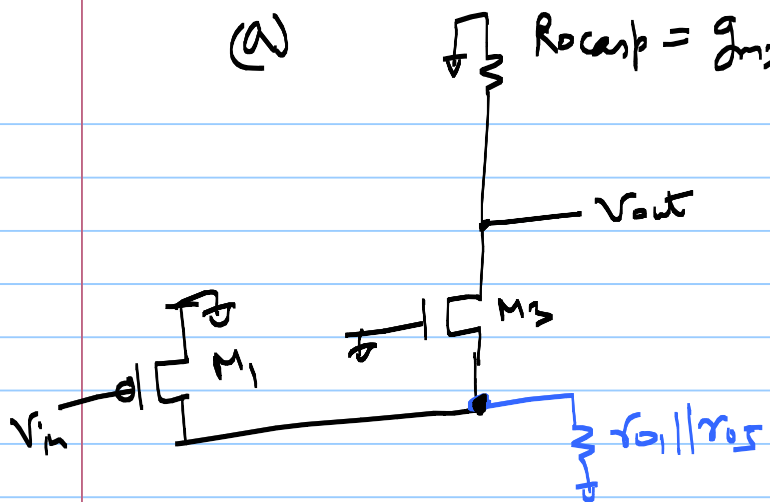
$$- \left[\cancel{f(a)} - \frac{f'(a)}{\lfloor 1}(x-a) + \cancel{\frac{f''(a)}{\lfloor 2}(x-a)^2}\right]$$

$$= (x-a), \quad \frac{(x-a)^3}{\lfloor 3},$$

$\Rightarrow$ only odd order terms remain in the output

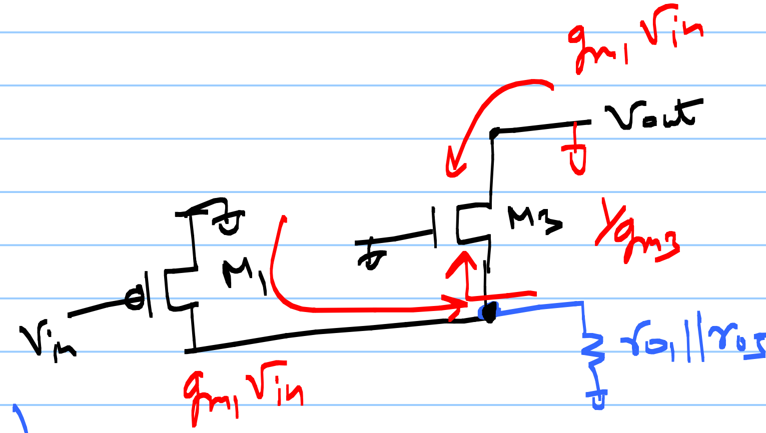
(a)

$R_{ocasp} = g_{m7} r_{o7} r_{o9}$



(b)

$\boxed{G_m = g_{m1}}$



(c) $R_{out} = \underbrace{(g_{m7} r_{o7} r_{o9})}_{g_{mp} r_{op}^2} \,||\, g_{m3} r_{o3} (r_{o1} || r_{o5})$

$\frac{1}{g_{m3}} \ll r_{o1} || r_{o5}$

$A_v = + G_m R_{out}$

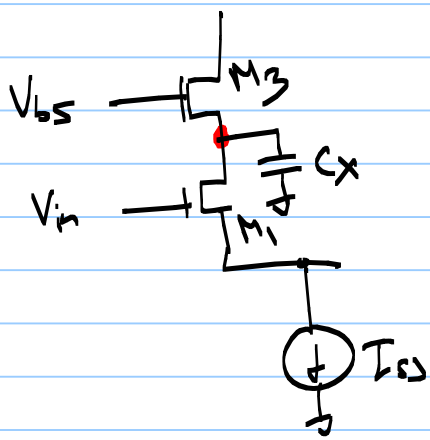
$$A_v = g_{m1}\left\{ \underbrace{g_{m3} r_{o3} (r_{o1} \| r_{o5})}_{\underbrace{g_{mn} r_{on} \| \frac{r_{on}}{2}}_{< g_{mn} r_{on}^2}} \| \underbrace{g_{m7} r_{o7} r_{o9}}_{g_{mp} r_{op}^2} \right\}$$

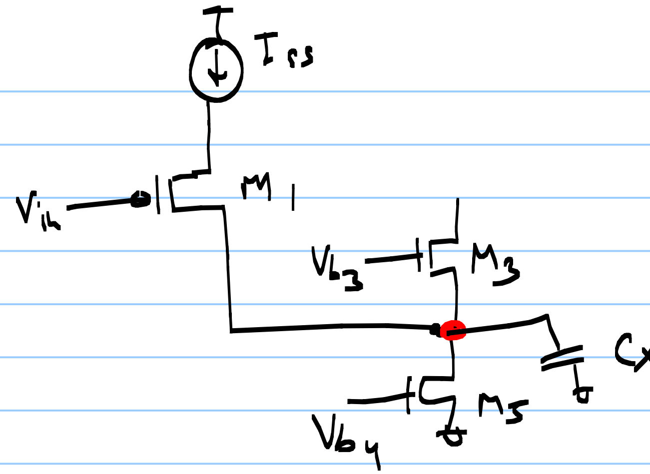
↳ gain is roughly 2-3x lower than Telescopic Diffamp.

Pole location.

* Output pole ⇒ $\omega_{p1} = \frac{1}{R_{out} C_L}$ ← roughly the same as Telescopic

* Mirror pole ⇒ ω_{p2} ⇒ same





* ω_{px} is lower for FC