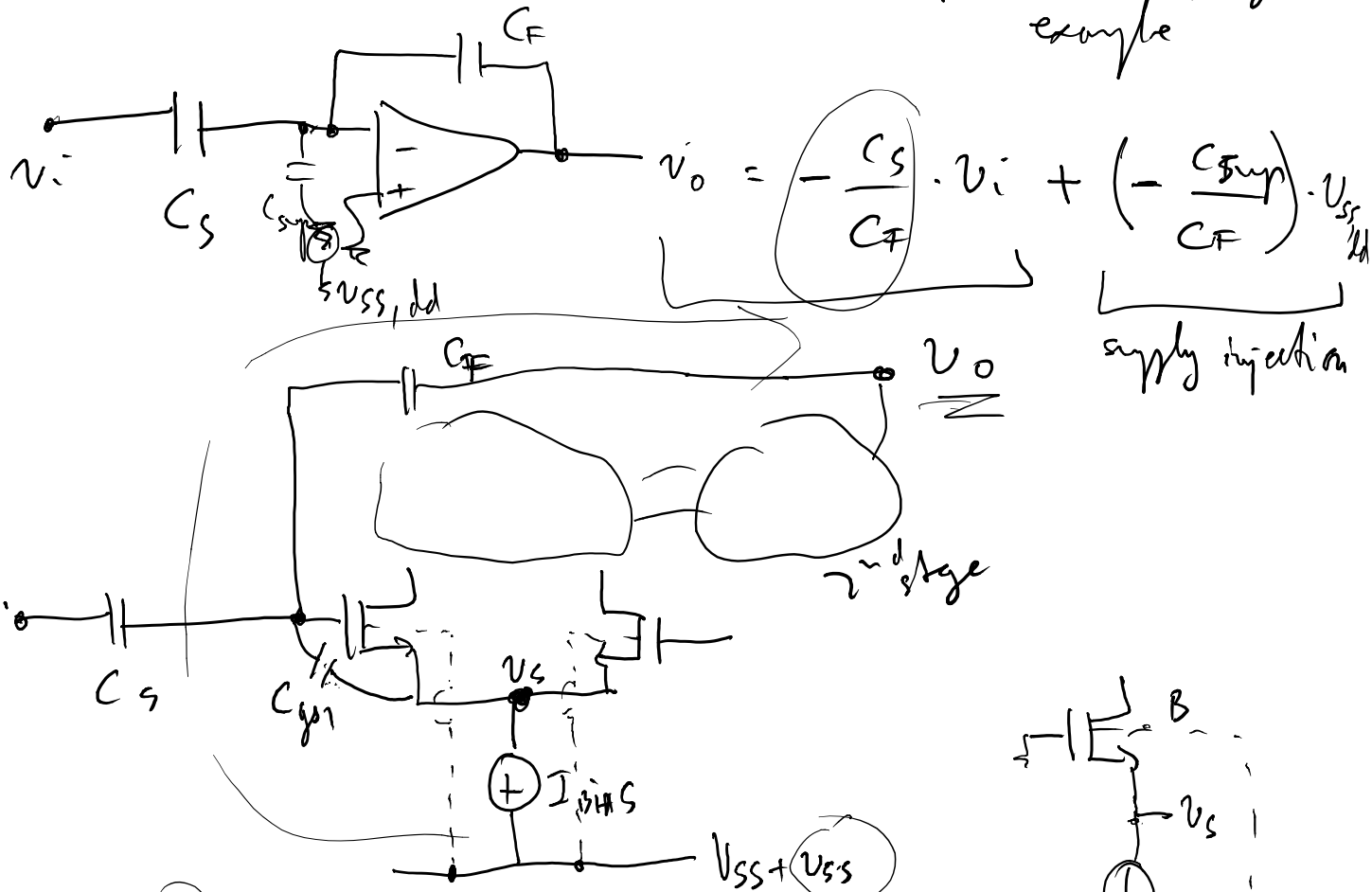
PSRR — 2-stage diff. CMOS g-amp (supply coupling) example



↑ Source Follower

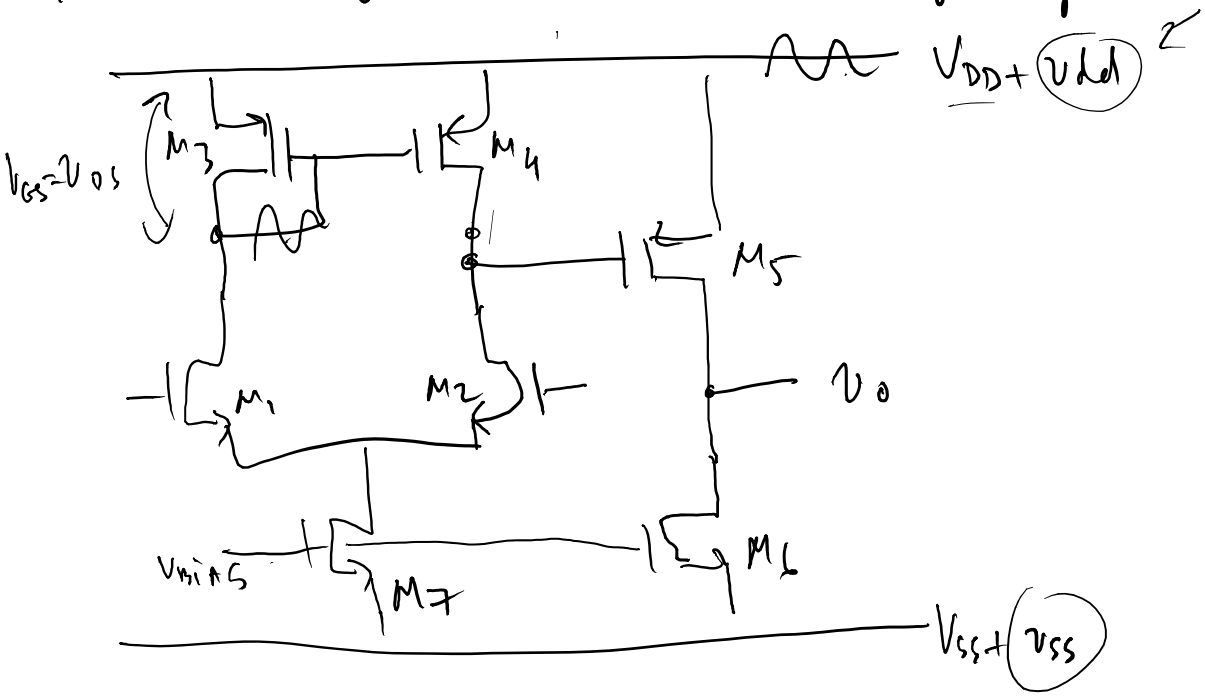
$$\frac{v_o}{v_{SS}} = \frac{v_o}{v_S} \cdot \frac{v_S}{v_{SS}} = -\frac{C_{gs1}}{C_F} \cdot \frac{g_{mb}}{g_m + g_{mb}}$$

$$PSRR = \frac{-\frac{C_S}{C_F}}{-\frac{C_{gs1}}{C_F}} \cdot \frac{g_m + g_{mb}}{g_{mb}} = \frac{C_S}{C_{gs1}} \cdot \frac{g_m + g_{mb}}{g_{mb}}$$

* Make $\frac{C_S}{C_{gs1}}$ ↑ increased noise from M_1

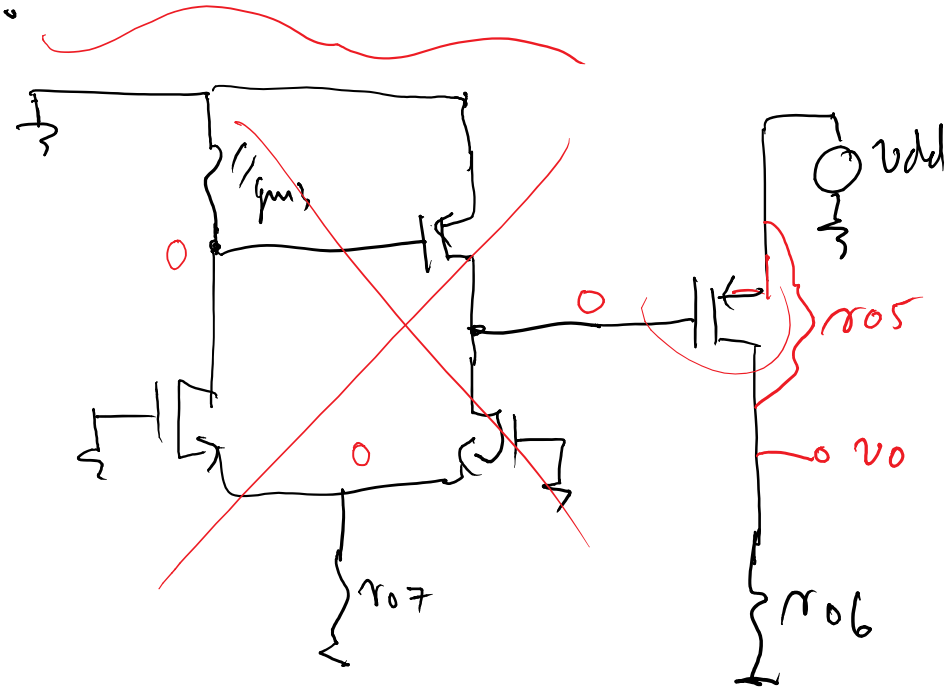
* Tie M_1 B to S ⇒ affects CMRR (↓)

PSRR for 2-stage CMOS op-amp



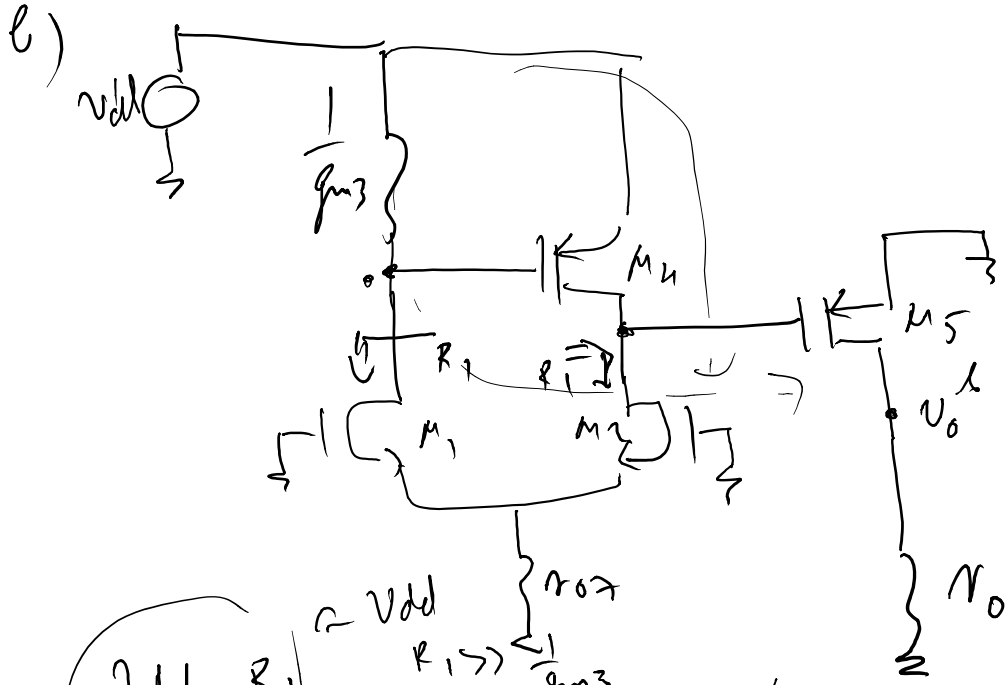
PSRR$^+$:

a)



$$\frac{v_o^a}{v_{dd}} = \frac{r_{O6}}{r_{O5}+r_{O6}}$$

c)



$$\frac{v_{dd}\cdot R_1}{\frac{1}{g_{m3}}+R_1}\left(-g_{m4}\left(r_{o4}\|R_1\right)\right)\left(-g_{m5}\cdot\left(r_{o5}\|r_{o6}\right)\right)+$$

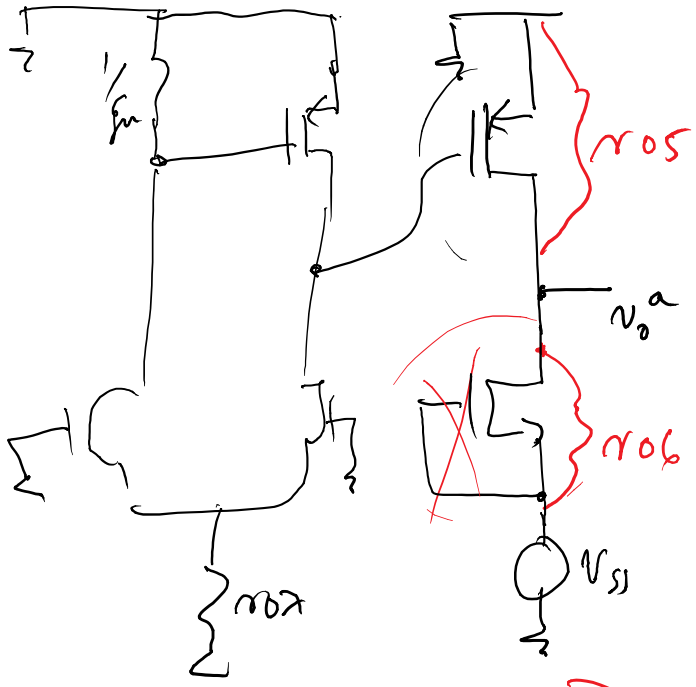
$R_1 \gg \frac{1}{g_{m3}} \Rightarrow \frac{v_{dd}\cdot R_1}{\frac{1}{g_{m3}}+R_1} \simeq v_{dd}$

$$v_{dd}\cdot g_{m4}\cdot\left(r_{o4}\|R_1\right)\cdot\left(-g_{m5}\left(r_{o5}\|r_{o6}\right)\right)\simeq 0$$

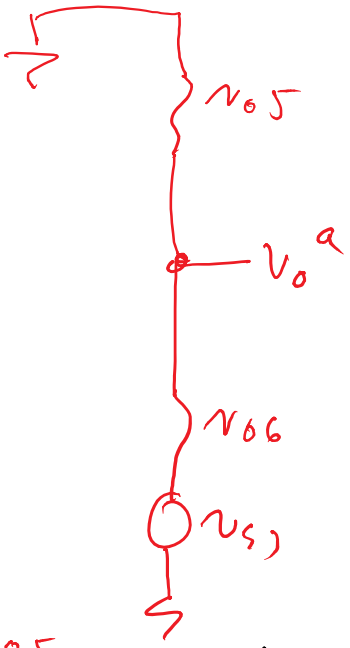
$$\frac{v_o}{v_{dd}} = \frac{v_o^a + v_o^b}{v_{dd}} \simeq \frac{v_o^a}{v_{dd}} = \frac{r_{o6}}{r_{o5}+r_{o6}} \simeq \frac{r_{o5}\|r_{o6}}{r_{o5}}$$

PSRR⁻ :

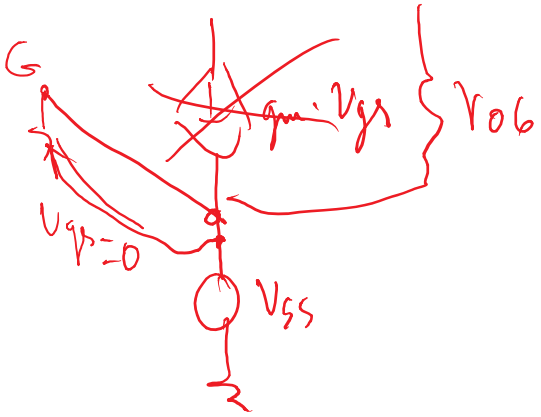
a) 2nd stage



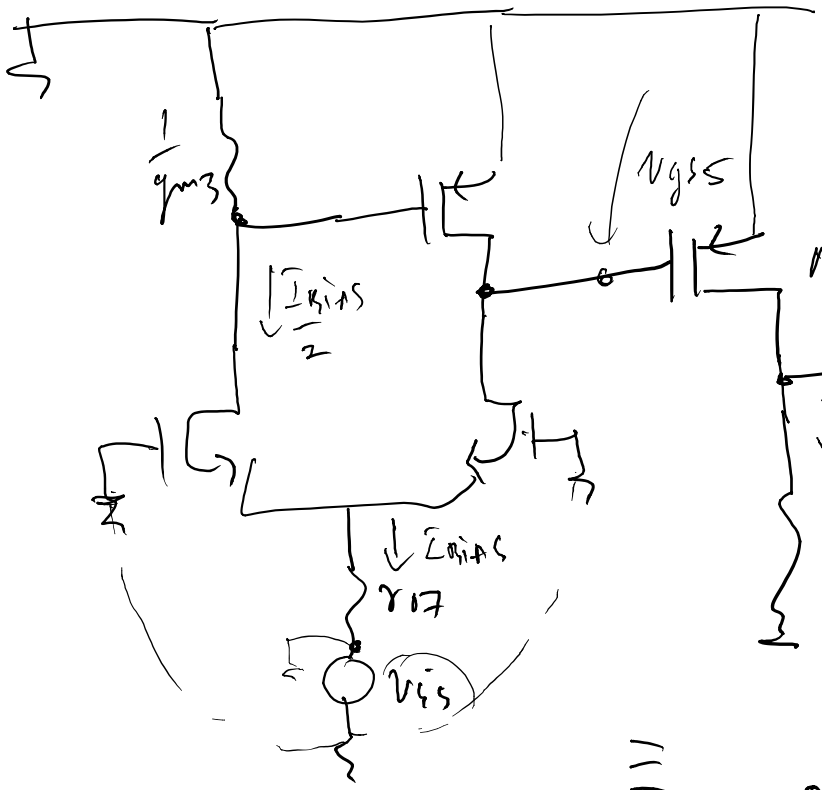
$\equiv$



$$\frac{v_o^a}{v_{SS}} = \frac{r_{O5}}{r_{O5}+r_{O6}} \simeq \frac{1}{2}$$



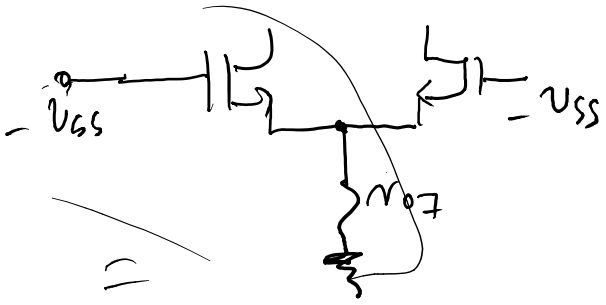
b) v_{ss} in 1st stage.



$$\frac{v_o^b}{v_{ss}} = \frac{v_{gs5}}{v_{ss}} \cdot \frac{v_o^b}{v_{gs5}}$$

$$\frac{v_o^b}{v_{gs5}} = -g_{m5} \cdot r_{05} \| r_{06}$$

$\equiv$



$$\frac{v_{gs5}}{v_{ss}} = \frac{g_{m2}(r_{02} \| r_{04})}{2 g_{m2} \cdot r_{07} \cdot g_{m3} \cdot r_{01} \| r_{03}}$$

$$\cong \frac{1}{2 g_{m3} r_{07}}$$

$$\frac{v_o^b}{v_{ss}} = -\frac{g_{m5} \cdot r_{05} \| r_{06}}{2 g_{m3} \cdot r_{07}} = -\frac{g_{m5}}{2 g_{m3}} \cdot \frac{r_{05} \| r_{06}}{r_{07} \cdot \frac{V_A}{I_{BIAS}}} \cong -\frac{1}{2}$$

($g_{m5} = k$; $\frac{V_A}{I} = \frac{V_A}{2kI_{BIAS}}$)

$$\frac{v_o}{v_{GS}} \geq \frac{v_o^a + v_o^b}{v_{GS}} \cong 0$$

Quick summary:

$V_{OV} \downarrow$ (reducing I_{BIAS} for same $\frac{W}{L}$) $\Rightarrow$

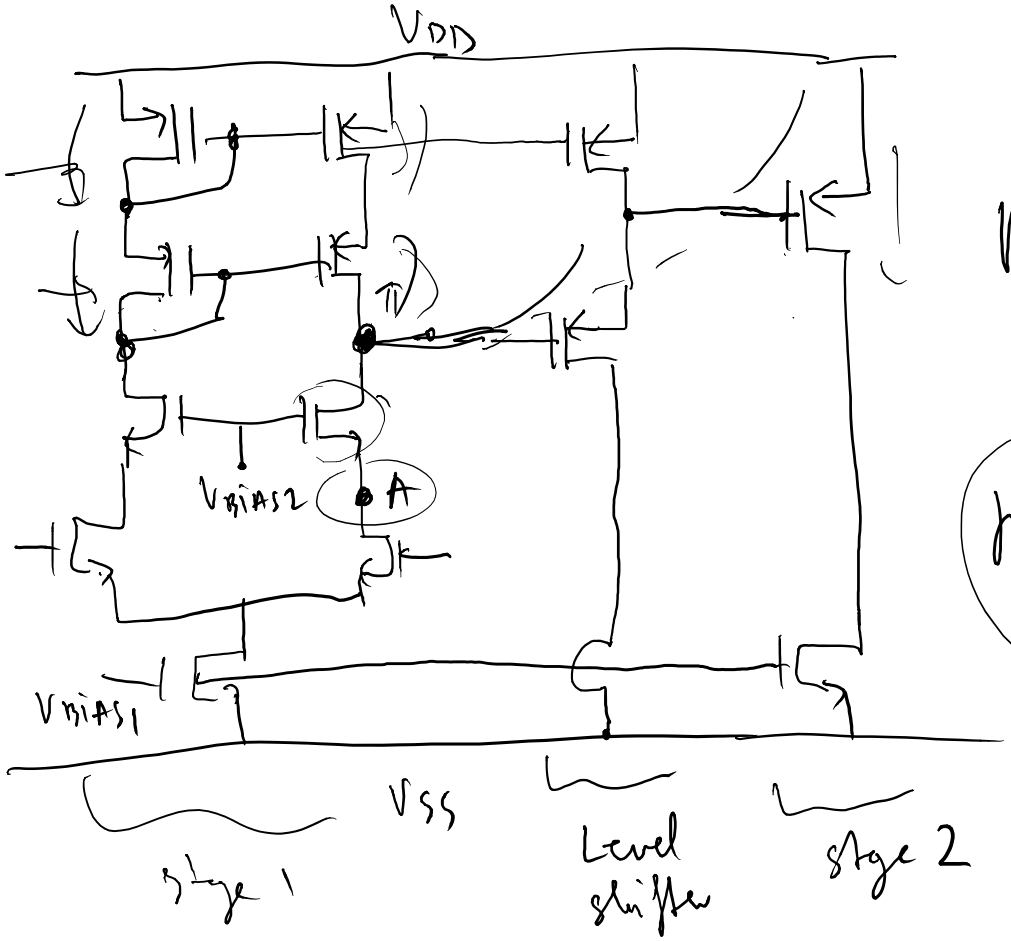
$\Rightarrow$ $A_{dm} \uparrow$, $\Delta V_O \uparrow$, $V_{OS}^{1H} \downarrow$, CMRR $\uparrow$,
PSRR $\uparrow$, CMR $\uparrow$

$L \uparrow \Rightarrow$ $A_{dm} \uparrow$, CMRR $\uparrow$, PSRR $\uparrow$

But $f_T \sim \frac{V_{OV}}{L^2}$ $\quad V_{OV} \downarrow \rightarrow f_T \downarrow$ $\quad L \uparrow \quad f_T \downarrow$

Fundamental trade-off: speed vs. everything else

Increasing Adm: - cascode diff pair
- cascode mirror
} Telescopic cascode



$Adm \sim (g_m \cdot r_o)^2$

$f_1^{1\text{-stage}} = \frac{1}{R_{out_B} \cdot C_B}$

$\uparrow g_m r_o^2$

$f_2^{1\text{-stage}} = \frac{1}{\frac{1}{g_{m_n}} \cdot C_x}$

negligible.

$Adm \cong g_m \cdot \underbrace{(g_m r_o) \cdot r_o}_{R_{out_B}} \cdot \frac{g_m r_o \| r_o}{1 + g_m r_o \| r_o} \cdot g_{m_p} \cdot (r_o \| r_o)$

$\hat{\sim} 1$

$G_{m_{1\text{-stage}}}$

- Level shift minimizes systematic offset