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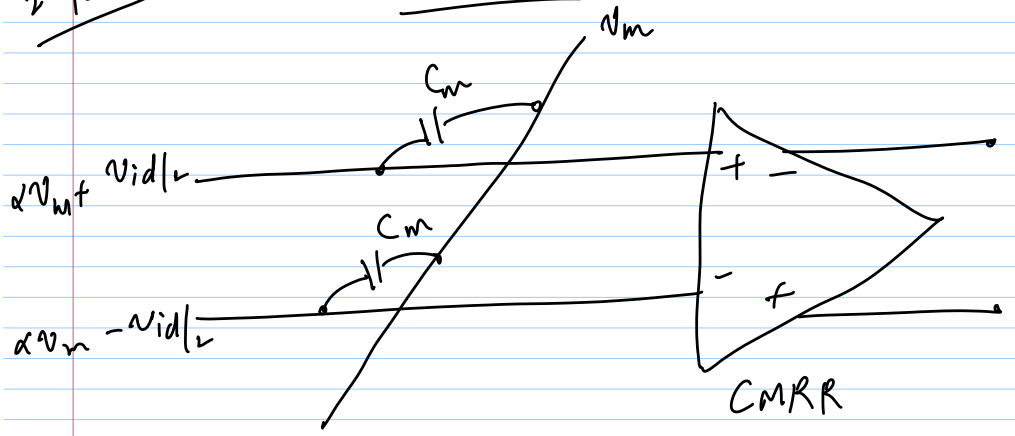
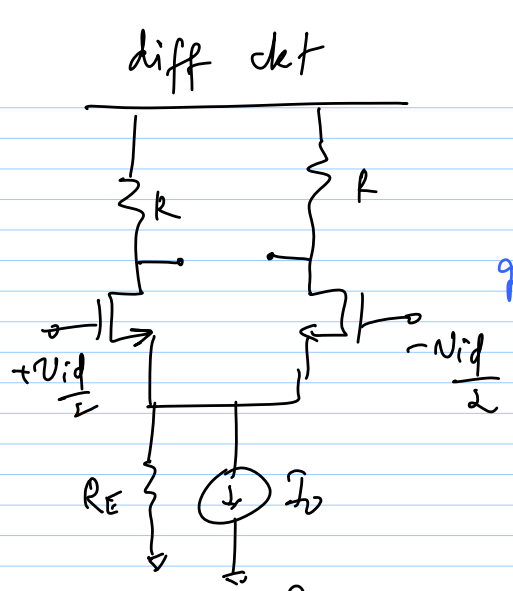
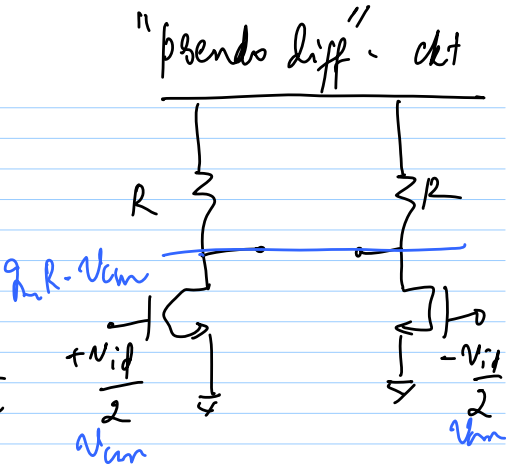


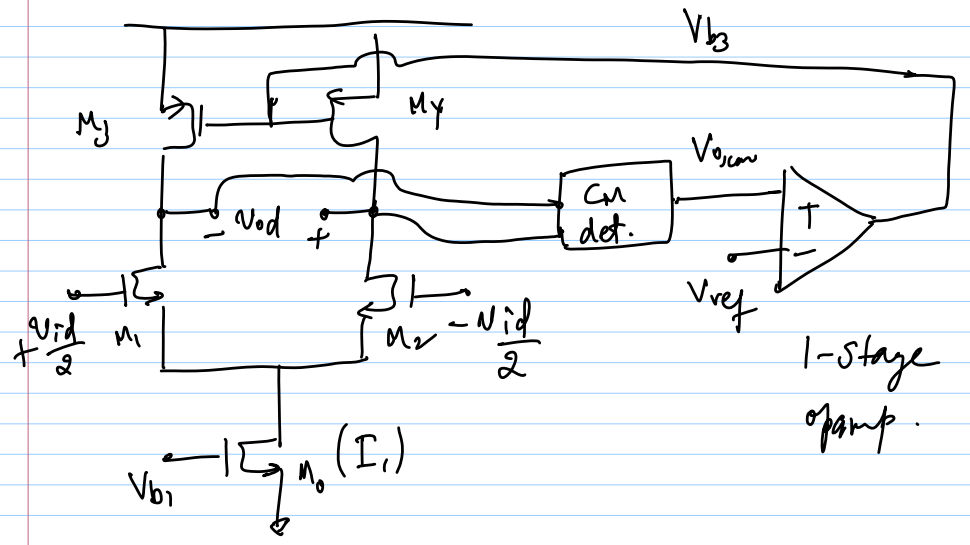


$$\text{CM gain} = \frac{g_m R}{1 + 2 g_m R_E}$$

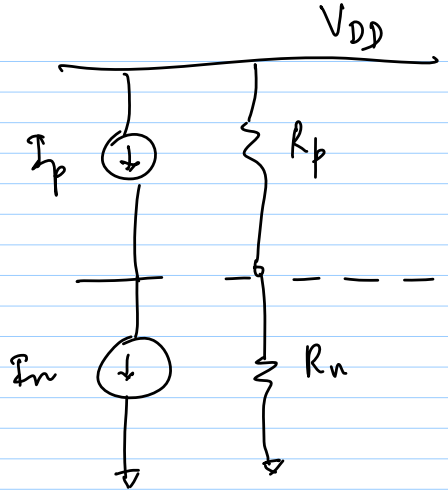


CM gain = $g_m R$

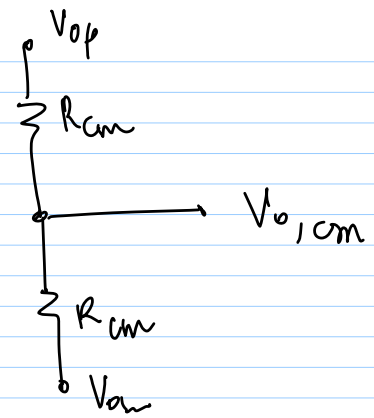
CMRR = 1 or 0 dB



1-stage opamp.



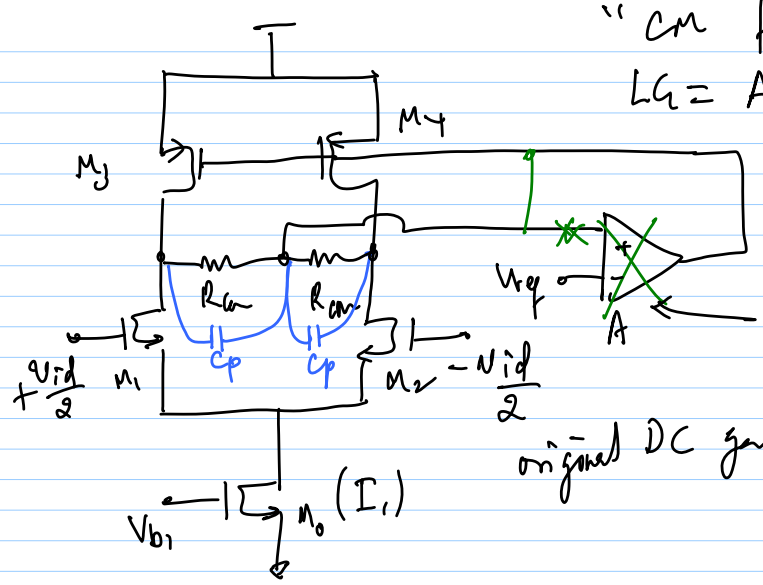
DC not well defined



"cm feedback"

$$LG = A \cdot \frac{g_{m1,2}}{g_{ds4} + g_{ds2}}$$

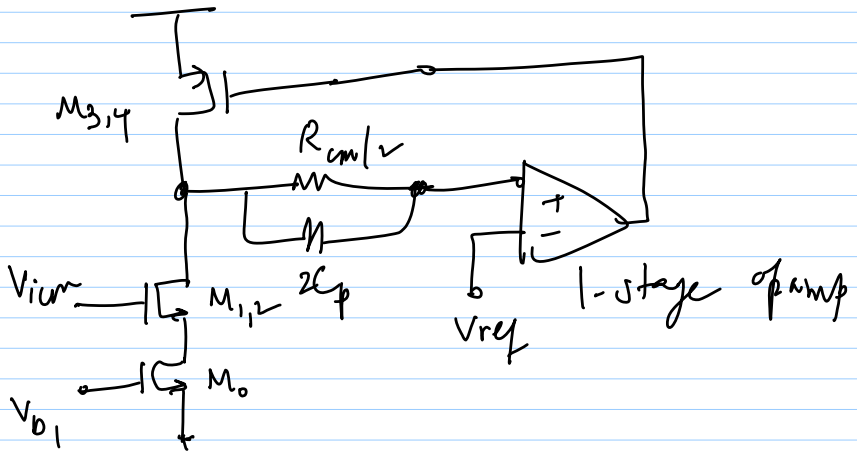
1-stage opamp

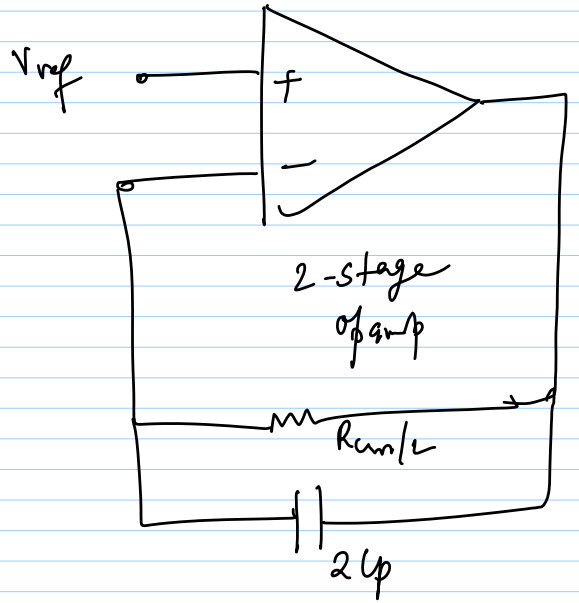


original DC gain $= \dfrac{g_{m1}}{g_{ds4} + g_{ds2}}$

now $= \dfrac{g_{m1}}{g_{ds2} + g_{ds4} + 1/R_{cm}}$

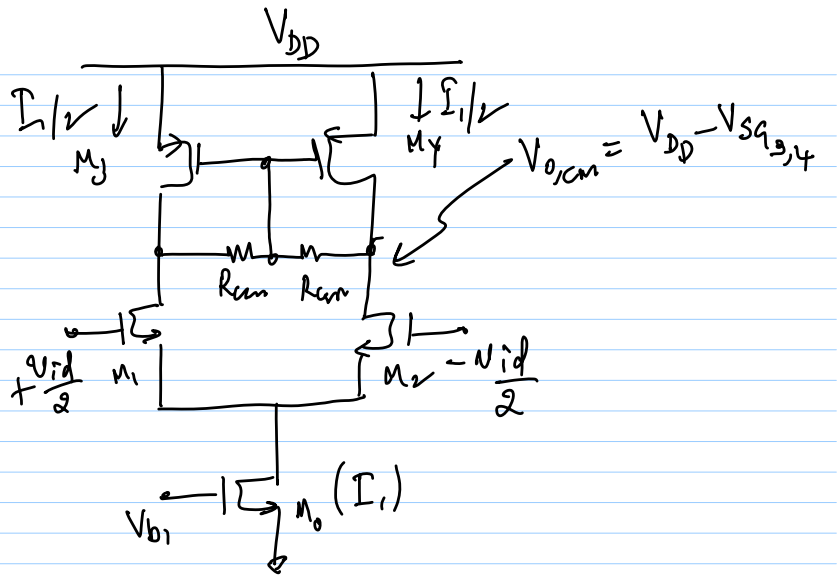
We want large R_{cm}

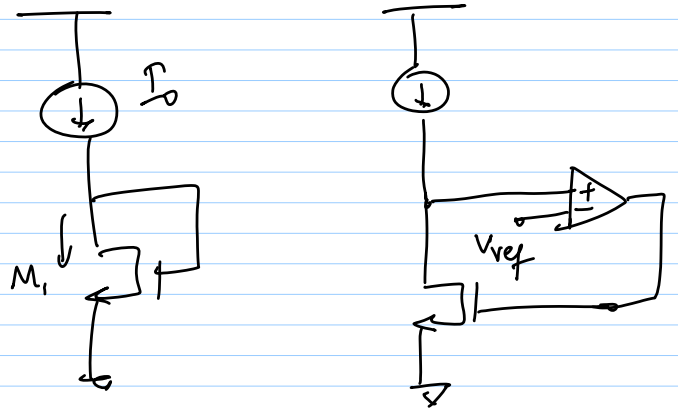


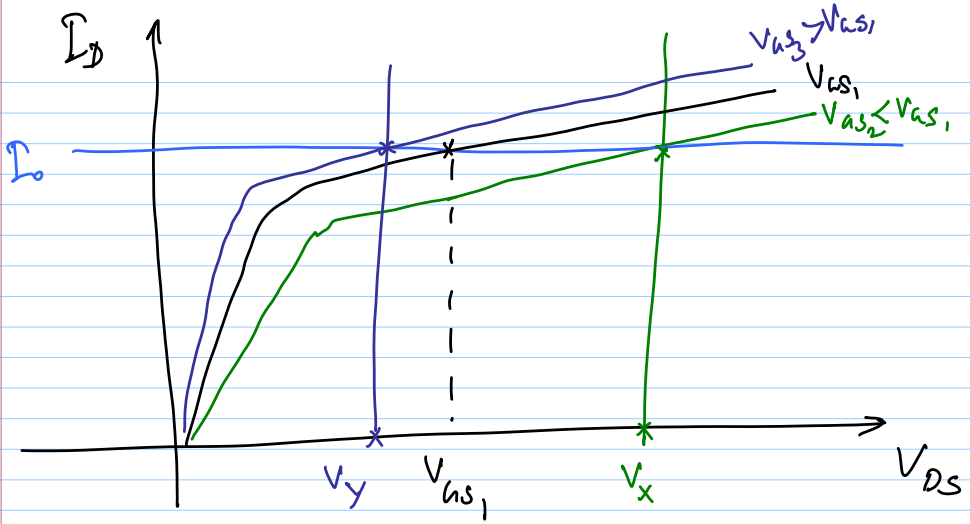


Stability

poles, zeros, VGF, compensation







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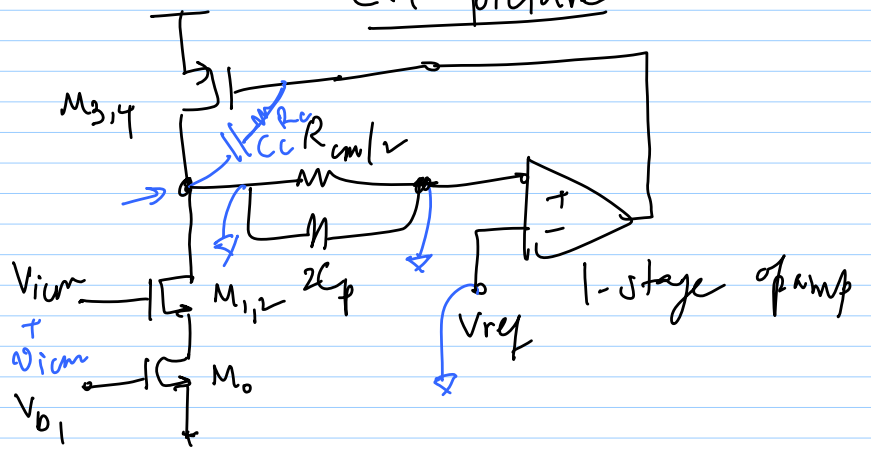
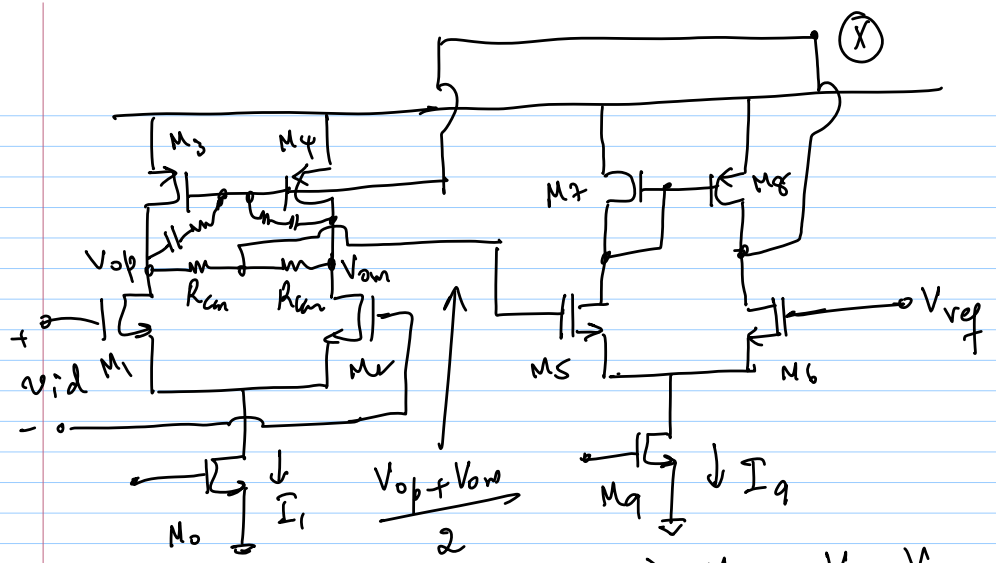
CM picture





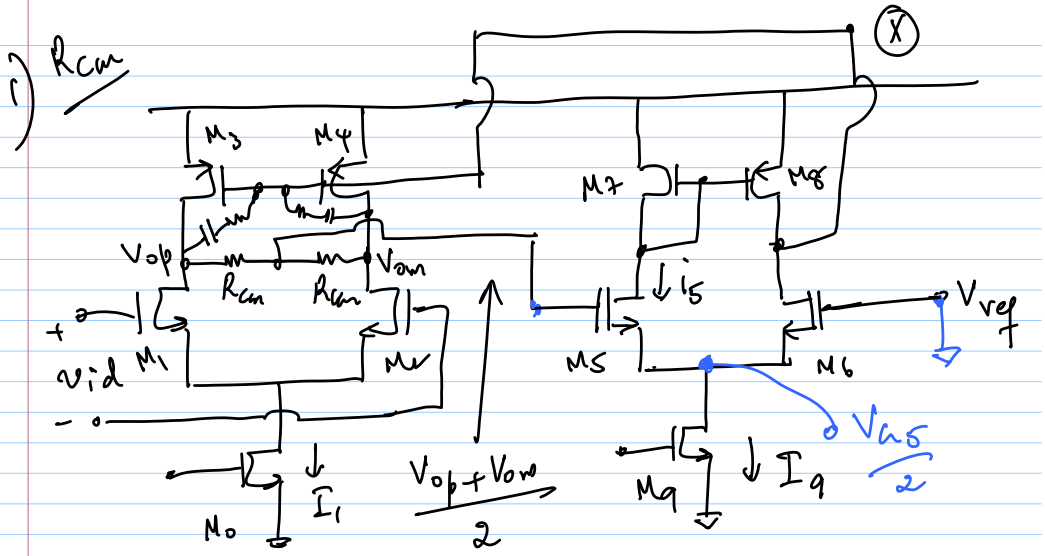
1) $V_x = V_{DD} - V_{SG_{3,4}} \Big|_{I_1/2}$

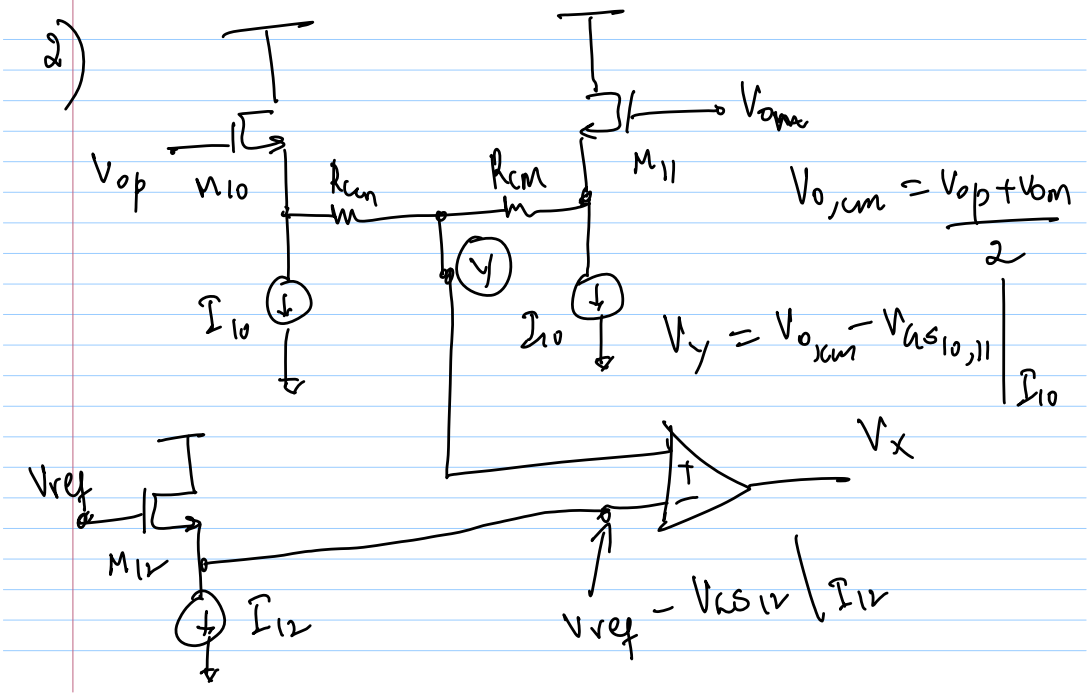
2) $V_{D8} = V_{DD} - V_{SG_{7,8}} \Big|_{\frac{I_q}{2}}$

* Measure $V_{o,cm}$
* -ve f.b. to ensure that $V_{ocm} \to V_{reg}$
* $(V_{ocm} - V_{reg})$ depends on LH$_{CMFB}$
* $V_{DD} - V_{SG_{3,4}} \Big|_{\frac{I_1}{2}} = V_{DD} - V_{SG_{7,8}} \Big|_{\frac{I_q}{2}}$

$\Rightarrow$ equal current densities in M_{3-4} & M_{7-8}

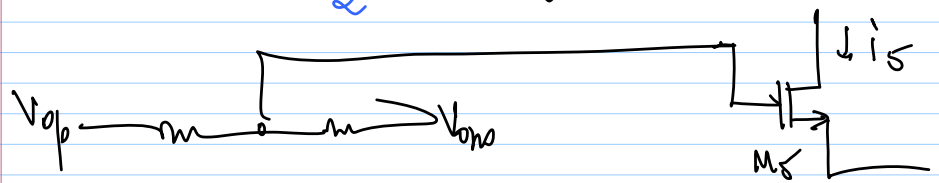
$I_q \ll I_1$

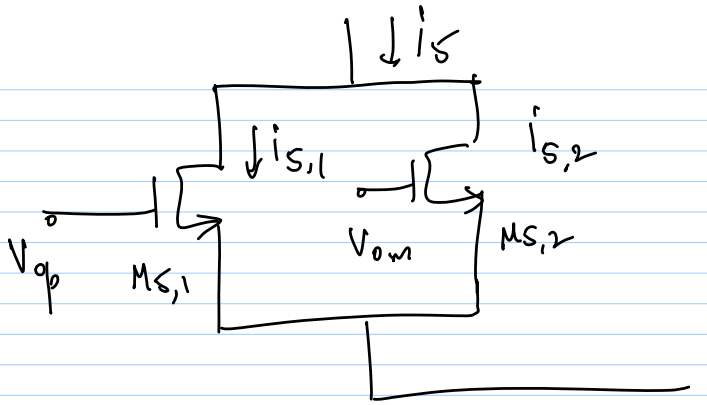




$$V_{GS_{10,11}}\Big|_{I_{10}} = V_{GS_{12}}\Big|_{I_{12}}$$

3) $i_5 = \frac{g_{m5}}{2}\left[\frac{v_{op} + v_{om}}{2}\right]$





$i_{5_1} = \frac{g_{m5}}{2} \cdot V_{op}$; $i_{5_2} = \frac{g_{m5}}{2} \cdot V_{om}$

$i_5 = i_{5_1} + i_{5_2} = \frac{g_{m5}}{2}\left[\frac{v_{op} + v_{om}}{2}\right]$

* (2) & (3) can be used only when swings are low.

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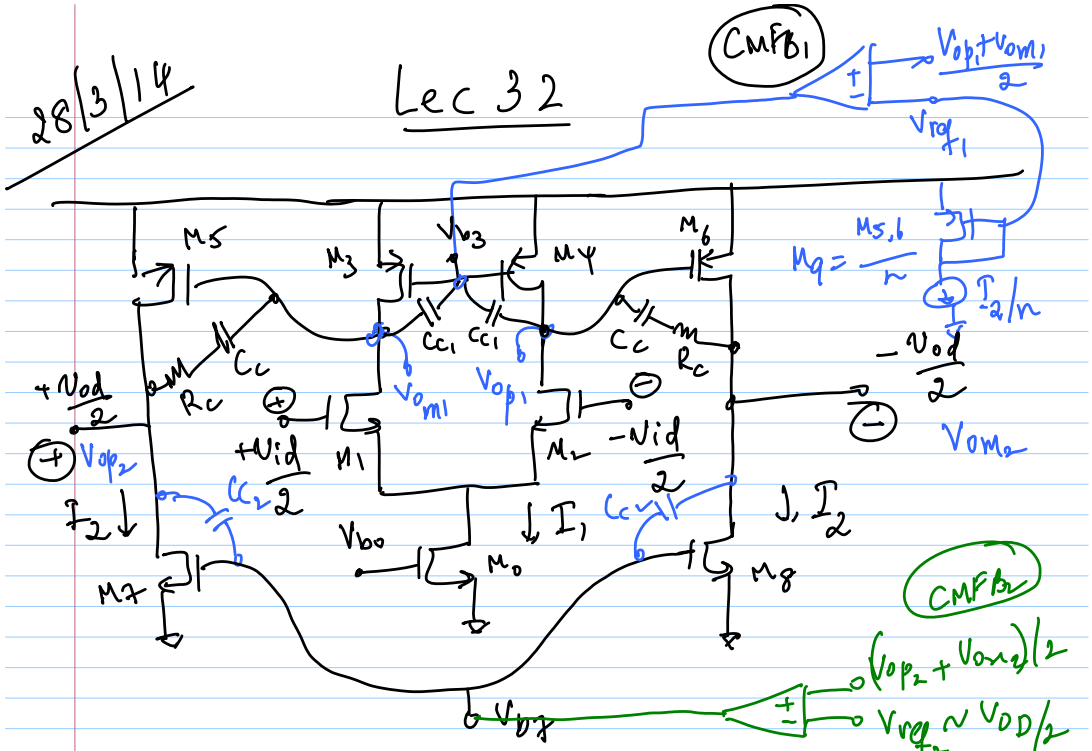


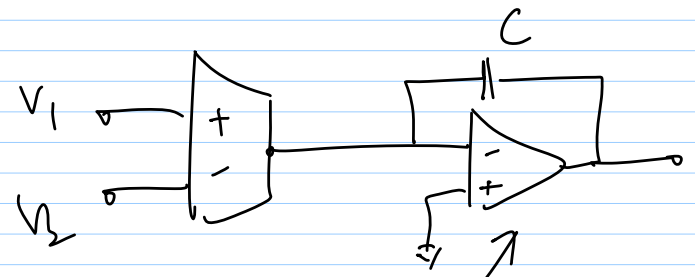
$$V_{o,cm_1} = V_{DD} - V_{SG_{3,4}}\Big|_{I_1/2} = V_{DD} - V_{SG_{5,6}}\Big|_{I_2}$$

$$V_{o,cm_2} = \frac{V_{DD}}{2} \quad \text{(usually)}$$

* M_9 & $M_{5,6}$ have same current density
* Resistive CM detector for 2nd stage
  - → large swings
  - → DC gain from the 1st stage
* Active CM det. for 1st stage
  - → small swings
  - → DC gain

* V_{ocm_1} → set by gates of M_0 or M_{3-4}
* V_{ocm_2} → set by gates of M_{7-8}, M_{5-6} or M_{3-4}
* Single CMFB loop to set both V_{ocm_1} & V_{ocm_2} is possible
* Single $R_c - C_c$ to compensate both CM & DM

* $CMFB_1$ opamp → nmos i/p stage, same I density ← pmos active CM load as M_{3-4}
* $CMFB_2$ opamp → pmos i/p stage same I density ← nmos CM load as M_{7-8}



ideal VCVS
2-stage opamp