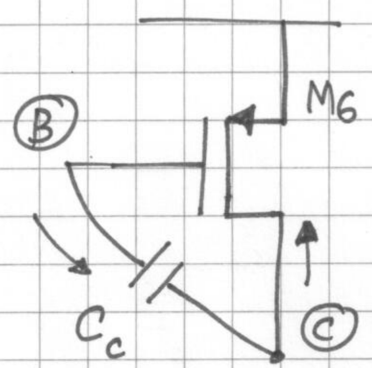
Cause of RHP Zero



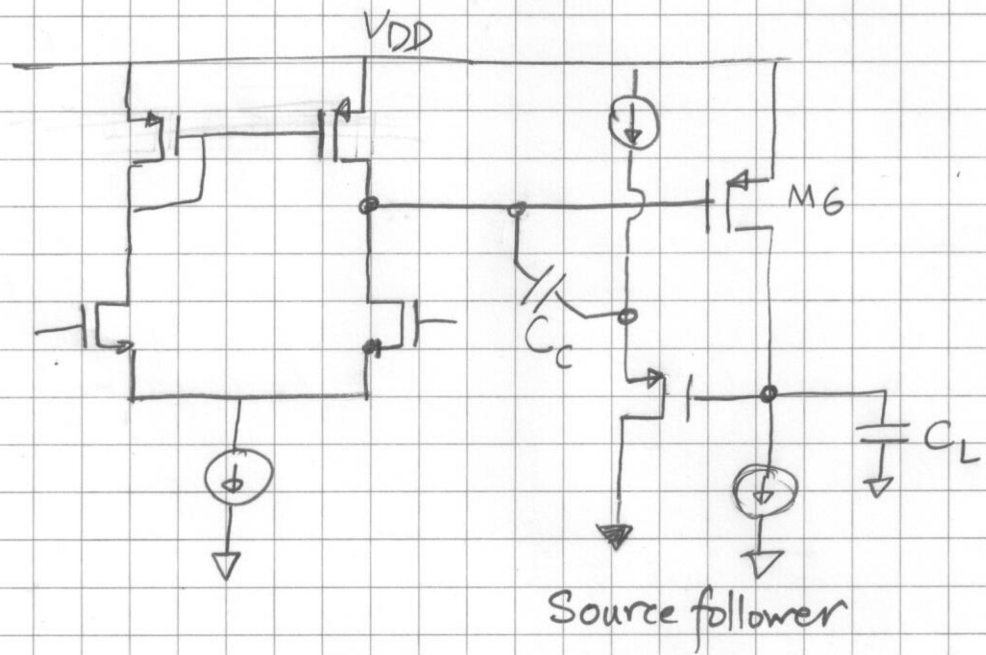
C_c around inverting Stage

$\rightarrow \omega_z C_c V_B = g_{m_6} V_B$ @ zero freq.

$s \Rightarrow \omega_z = \dfrac{g_{m6}}{C_c}$

→ Due to feedforward path.

Sol^n Remove feedforward path.

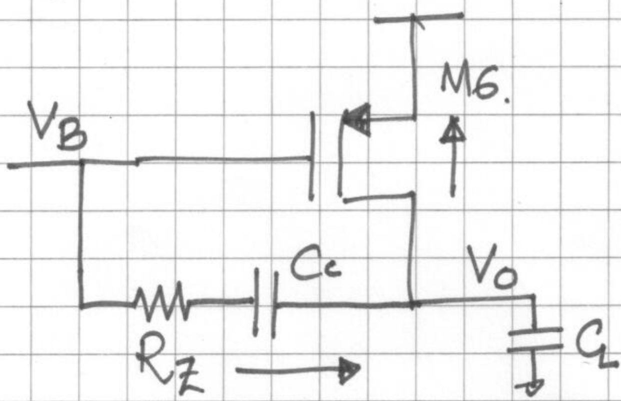


→ P_D & P_{ND} remain same as before.

⊖⊖ Power dissipation of SF.

⊖ SF frequency response. (must make sure that it doesn't deteriorate PM).

Another idea



Location of zero.

At zero freq. ω_z

$$\frac{V_B}{\left(R_z + \frac{1}{\omega_z C_c}\right)} = V_B\, g_{m_6}$$

$$g_{m_6}\left(R_z + \frac{1}{\omega_z C_c}\right) = 1$$

$$\frac{g_{m6}}{\omega_z C_c} = \left(1 - g_{m_6} R_z\right) \Rightarrow \omega_z = \frac{g_{m6}/C_c}{\left(1 - g_{m_6} R_z\right)}$$

When $g_{m_6} R_z = 1 \Rightarrow R_z = \frac{1}{g_{m_6}}$

Zero moves to ∞.

Better yet. when $g_m R_z > 1$ $\omega_z \rightarrow$ (-ve) LHP zero.

$\longrightarrow$ cancel out Non-dominant pole..

$$\omega_z = \frac{g_{m6}/C_c}{\left(1 - g_{m_6} R_z\right)} = -\frac{g_{m_6}}{C_L}$$

(LHP Pole) -ve sign.

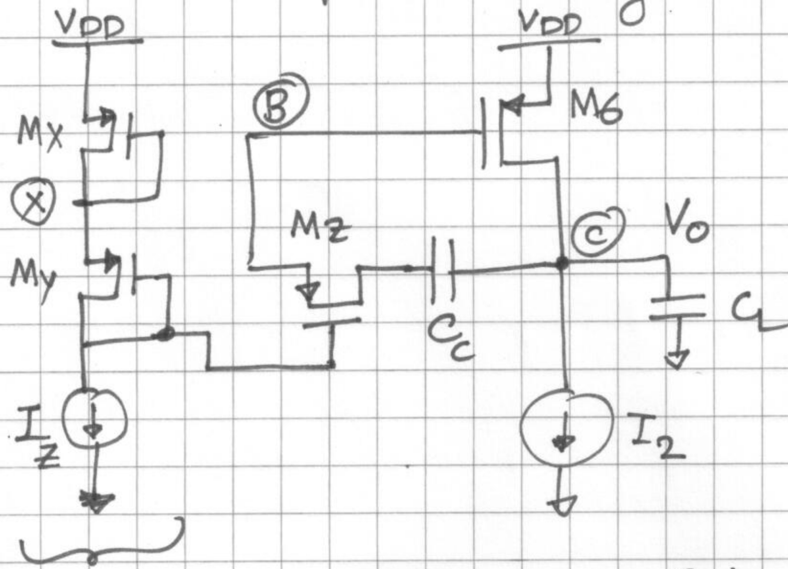
$$\frac{C_L}{C_c} = g_m R_z - 1 \Rightarrow R_z = \frac{1}{g_{m_6}}\left(1 + \frac{C_L}{C_c}\right)$$

Really Cool idea!!

How do you achieve this. over PVT ?

R_z - resistor. - to track $\frac{1}{g_m}$.

$R_Z \rightarrow$ Implement using triode MOSFET.



M_Z – Non Sat.

$$I = \left[(V_{SG} - |V_{Tp}|) V_{SD} - \frac{1}{2} V_{SD}^2 \right] \mu_p C_{ox} \left(\frac{W}{L}\right)_Z$$

$$R_Z = 1 \Big/ \left.\frac{\partial I}{\partial V_{SD}}\right|_{V_{SD}=0} = \frac{1}{\mu_p C_{ox} \left(\frac{W}{L}\right)_Z (V_{SG} - |V_{Tp}|)_Z}$$

Looks like g_m form.

By design ⓧ tracks Ⓑ (DC bias)

$\Rightarrow V_{SG_X} = V_{SG_6} \longrightarrow$ choose I_Z & $\left(\frac{W}{L}\right)_X$

$$R_Z = \frac{1}{g_{m6}}\left(1 + \frac{C_L}{C_C}\right) = \frac{1}{\mu_p C_{ox} \left(\frac{W}{L}\right)_Z \underbrace{(V_{SG} - |V_{Tp}|)_Z}_{= (V_{SG} - |V_{Tp}|)_Y}}$$

$$\frac{\left(1 + \frac{C_L}{C_C}\right)}{\mu_p C_{ox} \left(\frac{W}{L}\right)_6 (V_{SG} - |V_{Tp}|)_6} = \text{''}$$

$$\left(\frac{W}{L}\right)_Z = \left(\frac{W}{L}\right)_6 \cdot \frac{(V_{SG} - |V_{Tp}|)_6}{(V_{SG} - |V_{Tp}|)_Y} \cdot \left(\frac{C_C}{C_C + C_L}\right)$$

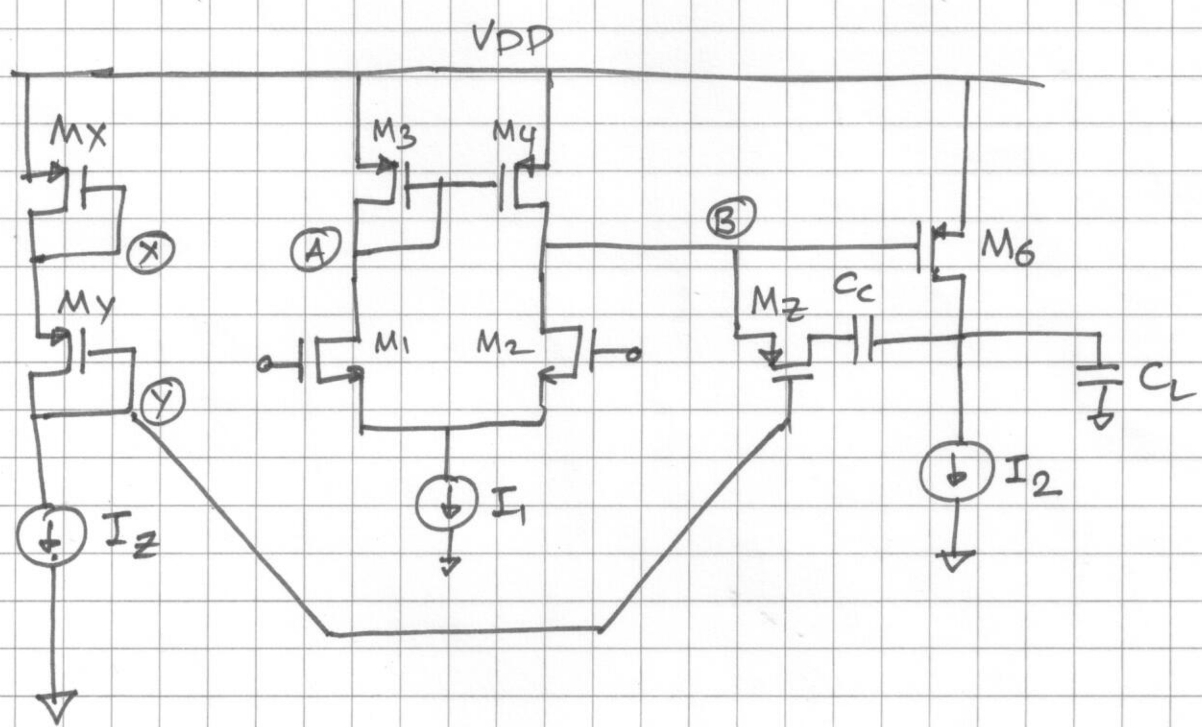
$$\left(\frac{W}{L}\right)_Z = \left(\frac{W}{L}\right)_6 \sqrt{\frac{2 I_6}{(W/L)_6 \cdot \mu_p C_{ox}}} \times \sqrt{\frac{(\frac{W}{L})_y \mu_p C_{ox}}{2 I_Z}} \cdot \left(\frac{C_c}{C_c + C_L}\right)$$

$$= \sqrt{\frac{I_6}{I_Z}} \sqrt{\left(\frac{W}{L}\right)_6 \cdot \left(\frac{W}{L}\right)_y} \cdot \left(\frac{C_c}{C_c + C_L}\right)$$

→ All dependent on ratios – Not abs values

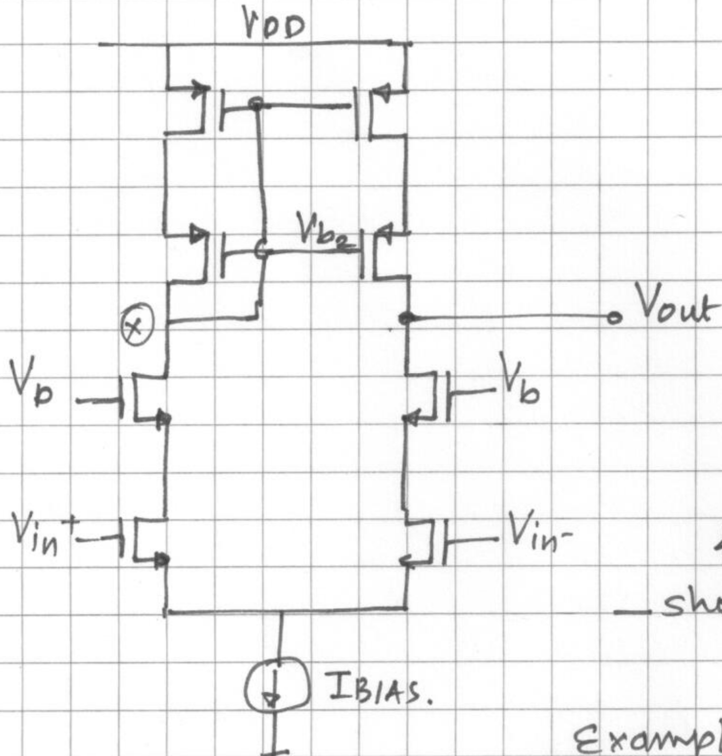
→ Tracking compensation

* Black, Allstot, Reed. – JSSC Dec 83



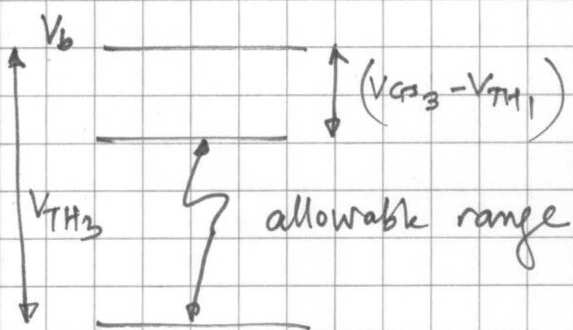
Opamp Architectures

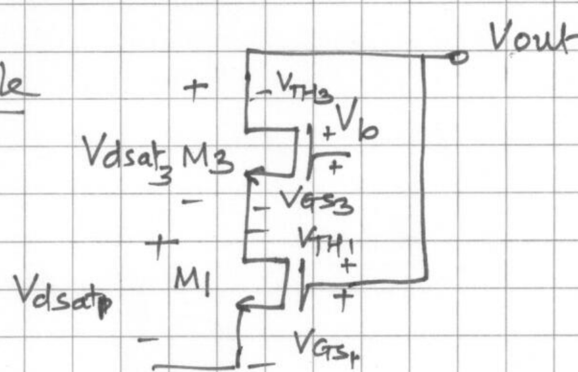
Telescopic Cascode Opamp.



* Single Stage.
  Low power - current reuse
* Limited output swing.
  $\left(V_{DD} - 2V_{dsat_n} - 2|V_{dsat_p}| - V_{IBIAS}\right)$
* unity gain buffer difficult — shorting -ve i/p to O/P.

Example

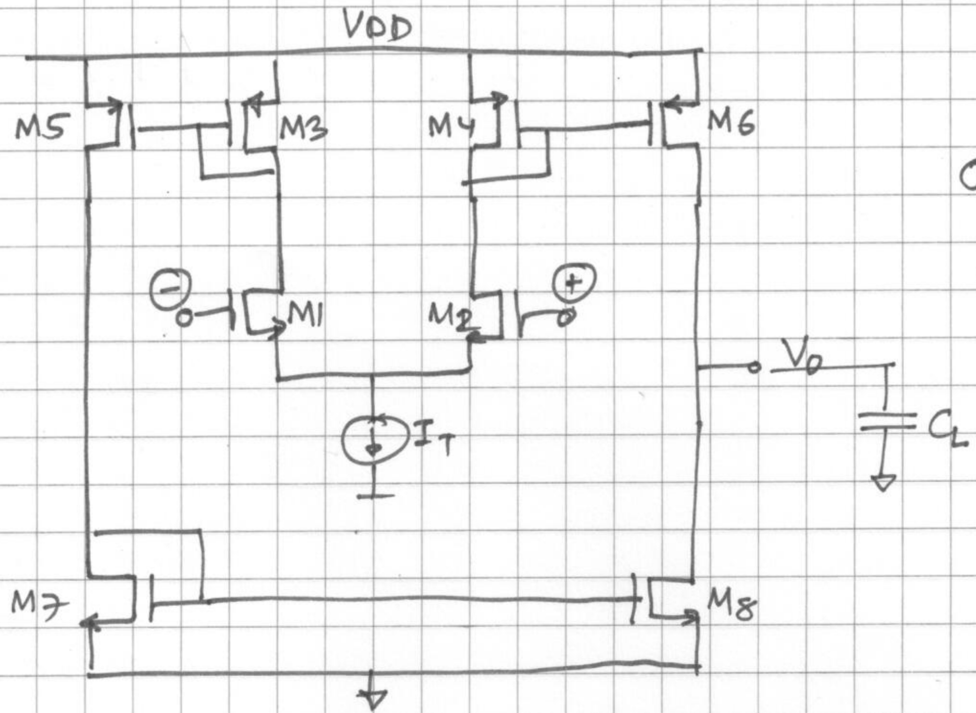




$$\text{Gain} = g_{m_N}\left[g_{m_N} r_{o_N}^2 \parallel g_{m_P} r_{o_P}^2\right]$$

* Mirror pole @ x

OPAMP using current mirrors



Output pole dominant

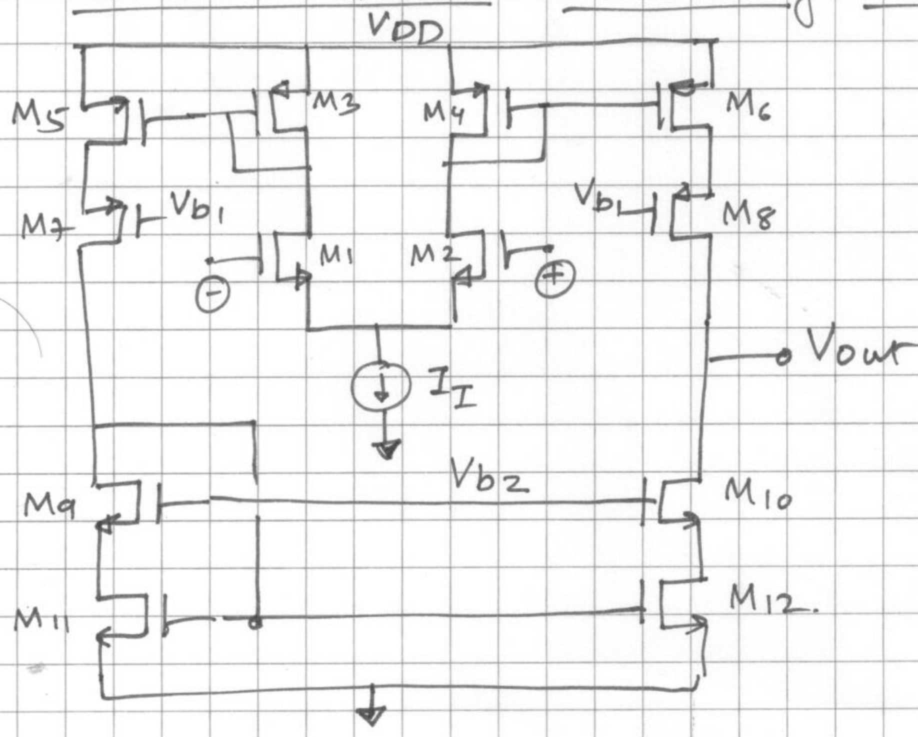
unloaded may become unstable.

$$\text{Slew rate} = \frac{I_T}{C_L} \quad \text{(if all mirrors are unity gain)}$$

$$= M\frac{I_T}{C_L} \quad (\text{Mirror gain} = M)$$

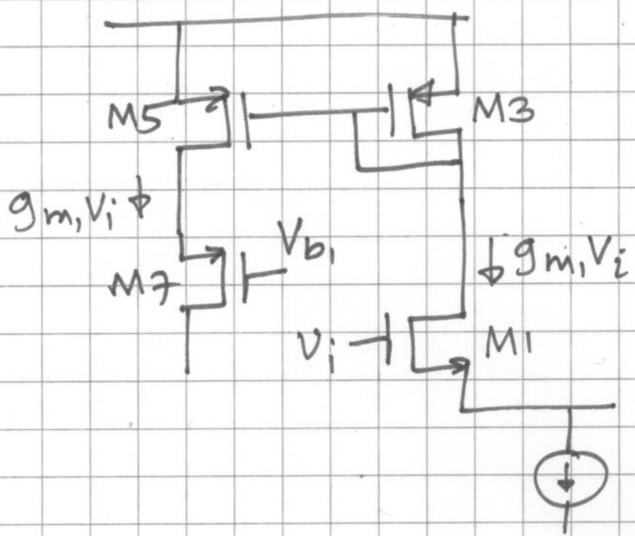
Low gain $\frac{g_m r_o}{2}$

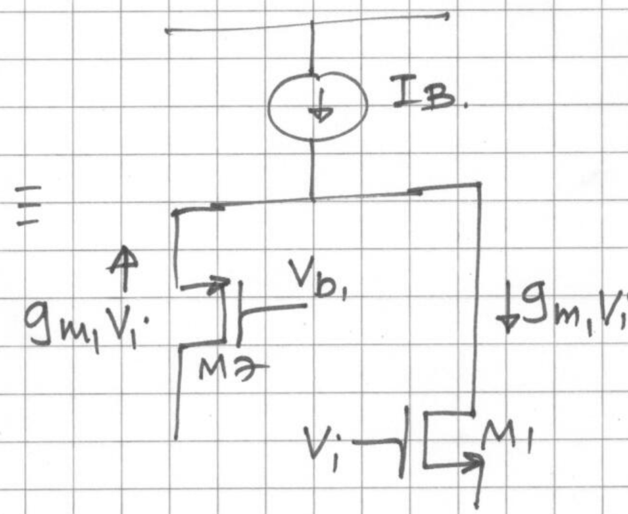
Gain Improvement using cascodes

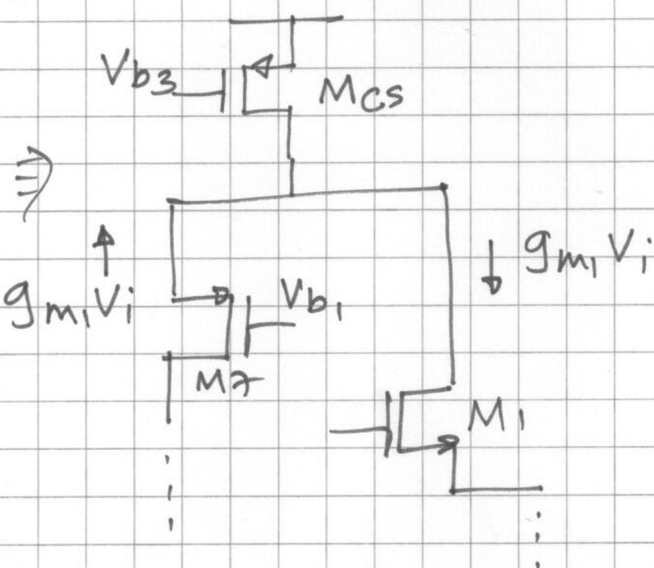


Gain $\frac{(g_m r_o)^2}{2}$

Consider PMOS mirror



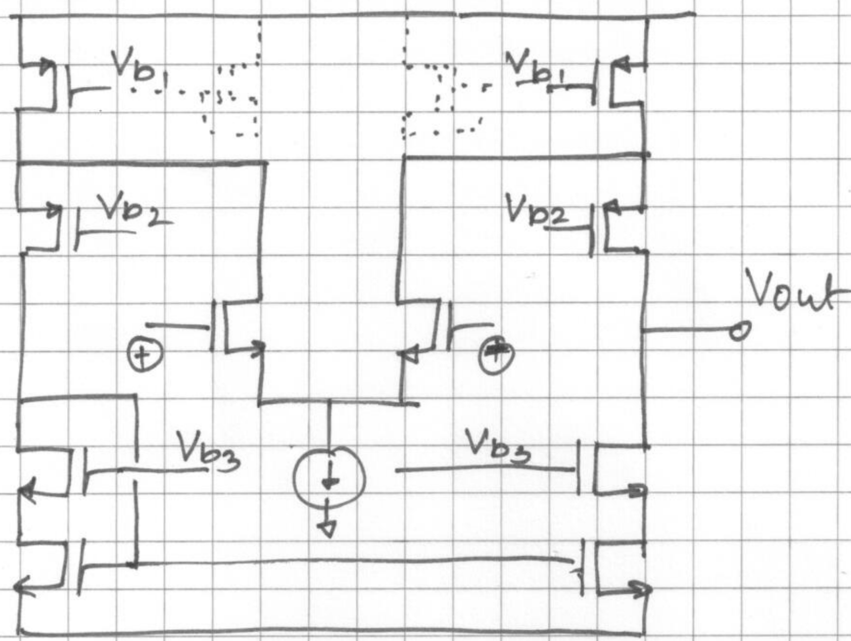




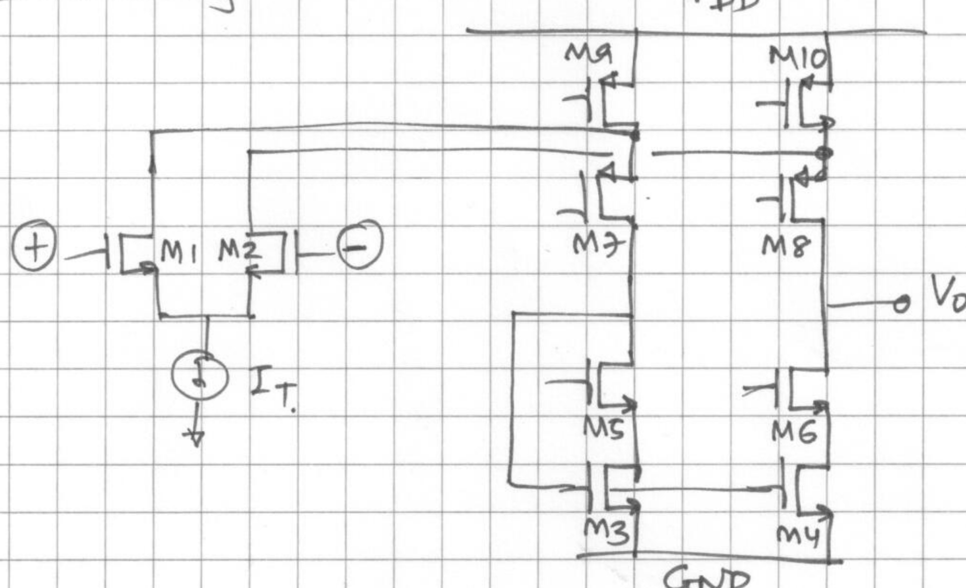
Signal Current flows to o/p.
<u>only sign change</u>

Key Concept of folded Cascode opamp
Avoid Mirror pole. <u>M3/M5</u> & M4/M6

Folded Cascode OPAMP



Redrawing



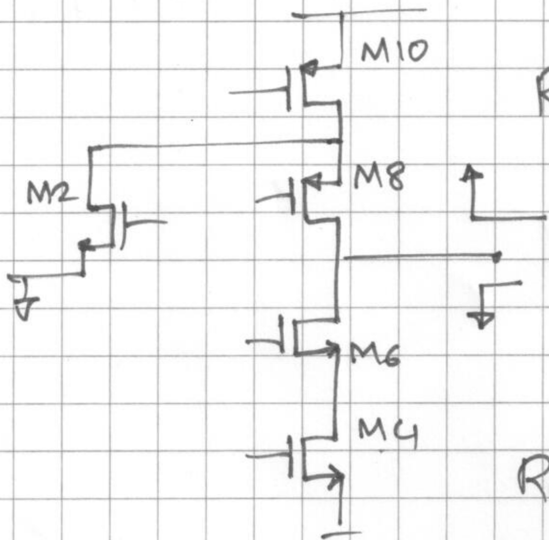
Advantage – No stacking of cascode on top of i/p devices.

Large o/p swing ($V_{DD} - 4V_{dsat}$)

Calculate gain How?

short o/p to DC $\Rightarrow$ $G_m = g_{m1}$

Output impedance $\underline{R_{out}}$.



$$R_{out}\uparrow = g_{m8} r_{o8} \left[r_{o10} \parallel r_{o2} \right]$$

$$R_{out}\downarrow = \left(g_{m6} \cdot r_{o6}\right) r_{o4}$$

$$R_{out} = R_{out}\uparrow \parallel R_{out}\downarrow$$

$\parallel$ impedances lets use g.

$$g_{out}\uparrow = \frac{\left(g_{ds2} + g_{ds10}\right)}{g_{m8} \cdot r_{o8}}$$

$$g_{out}\downarrow = \frac{g_{ds4}}{g_{m6} \cdot r_{o6}}$$

diff pair

$$\text{Gain} = \frac{G_m}{g_{out}} = \frac{g_{m1} \cdot}{\frac{\left(g_{ds2} + g_{ds10}\right)}{g_{m8}\, r_{o8}} + \frac{g_{ds4}}{g_{m6} \cdot r_{o6}}}$$

Extreme Simplification all g_ms equal. all g_{ds} equal.

$$\text{Gain} = \frac{g_m}{\frac{2 g_{ds}}{g_m r_o} + \frac{g_{ds}}{g_m r_o}} = \frac{g_m}{3 g_{ds}} \cdot g_m r_o$$

$$= \underline{\underline{\frac{1}{3}}} \left(g_m r_o\right)^2.$$