7-3-12

Lec 26

For $\geq 45^\circ$ PM, (neglect p_3)

$$p_2 \geq a_0 p_1$$

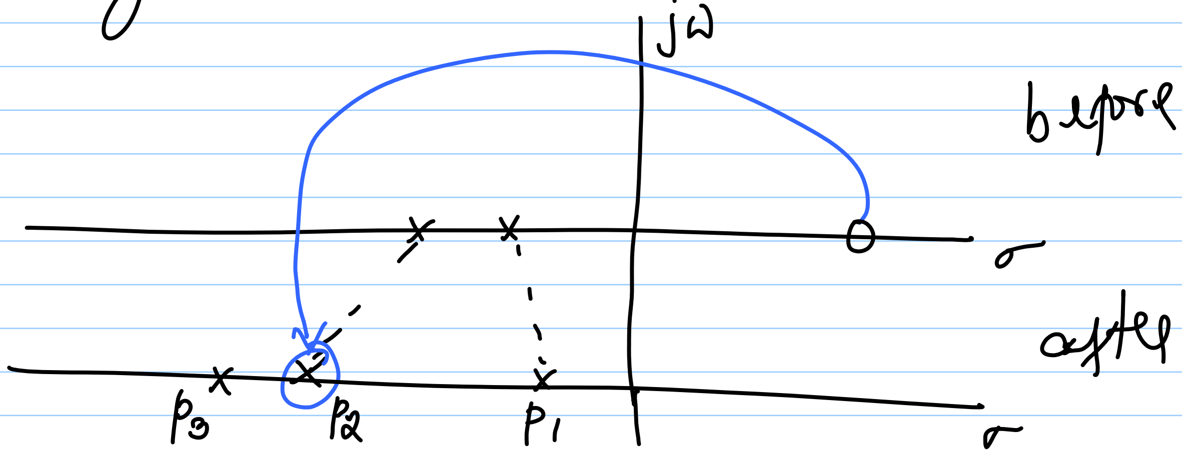
$$\Rightarrow C_F \geq \frac{G_{m1}}{g_{m2}} C_2$$

same value as simple compensation

<u>case (ii)</u> $\quad z_1 = \dfrac{1}{C_F/G_{m2} - R_F C_F}$

If $R_F > \dfrac{1}{G_{m2}}$, zero moves into LHP

$\Rightarrow$ bring z_1 around to cancel p_2



$$z_1 = p_2 \Rightarrow R_F = \frac{1}{G_{m_2}} \left(\frac{C_F + C_2}{C_F} \right)$$

for PM > 45°, $\underline{\underline{p_3}} \geq a_0 p_1$

$$\Rightarrow C_F \geq \frac{G_{m1}}{G_{m2}} \cdot C_1 \cdot \left(\frac{C_F + C_2}{C_F} \right)$$

solve quadratic in C_F

$$\Rightarrow C_F \approx \sqrt{\frac{G_{m1}}{G_{m2}} \cdot C_1 \cdot C_2}$$

$$C_F \approx \underbrace{\frac{G_{m1}}{G_{m2}} \cdot C_2}_{C_F(z_1 = \infty)} \cdot \underbrace{\sqrt{\frac{G_{m2}}{G_{m1}}}}_{\approx 1} \cdot \underbrace{\sqrt{\frac{C_1}{C_2}}}_{\ll 1}$$

Smaller C_F than $z_1 = \infty$

* How do you guarantee exact cancellation?

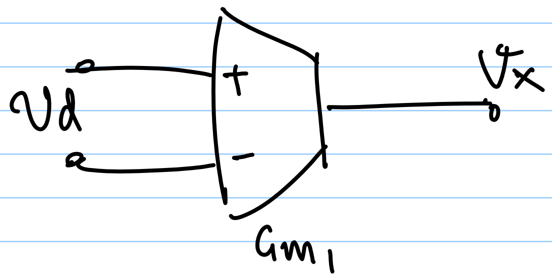
p_2 & z_1 <u>may</u> be below ω_u

* If they don't cancel exactly ⇒ pole-zero doublet...

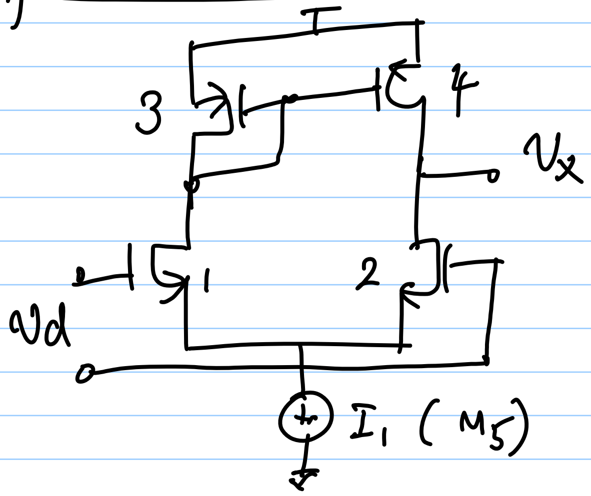
* over PVT variations, $1/G_{m_2}$ & R_F vary differently.

→ We want R_F to track $1/G_{m_2}$

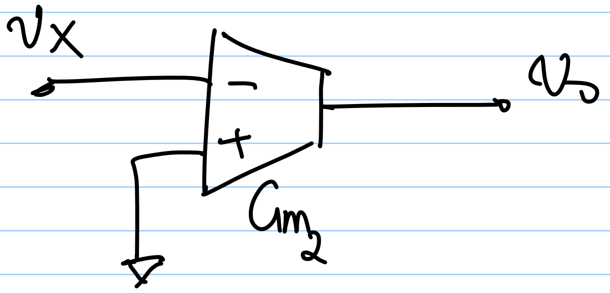
Ckt implementation of blocks



e.g.



* telescopic etc. also possible



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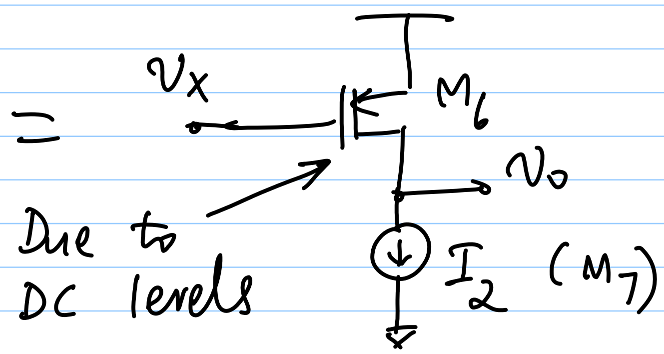
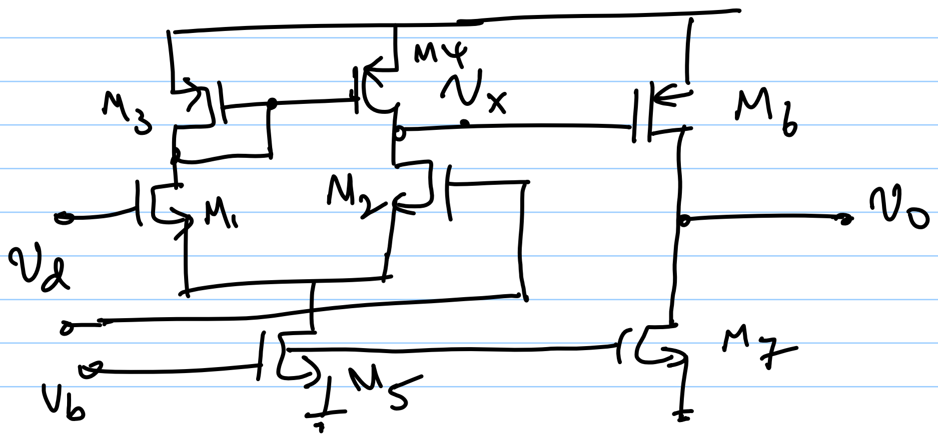
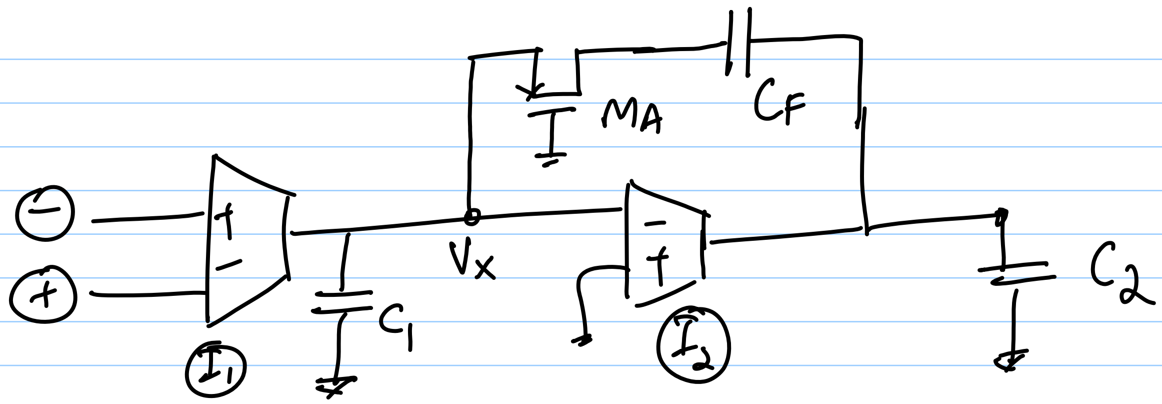


2- stage opamp





* Use MOSFET as a resistor

→ PMOS, NMOS, T-gate

→ Use PMOS ∵ Gm_1 is a PMOS

→ MA operates in triode region

If I_2 (bias current through Gm_2) ↑ due to PVT variations

$$p_2 = \frac{Gm_2}{C_2} \uparrow$$

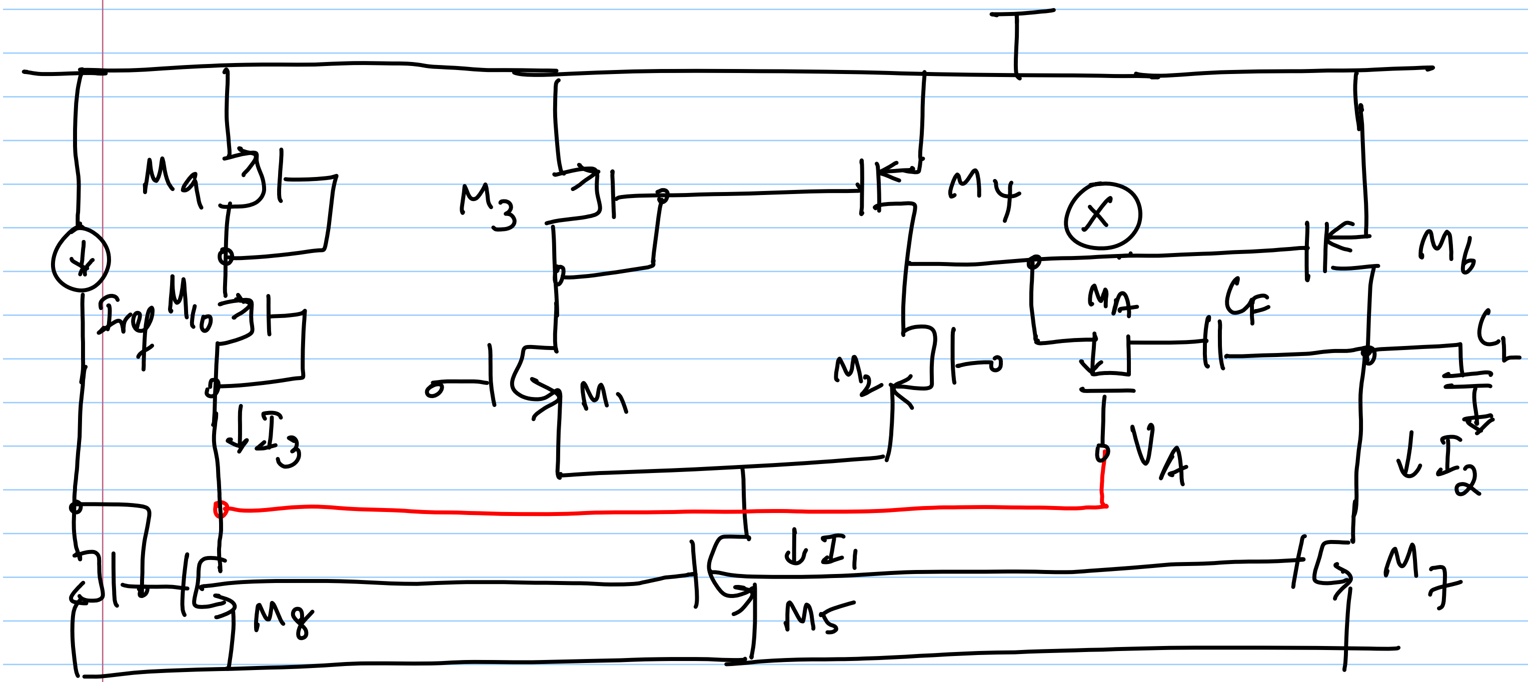
$$z_1 \propto \frac{1}{R_F C_F}$$ as $I_2 \uparrow \Rightarrow V_x \downarrow \Rightarrow R_F \uparrow$

$\Rightarrow |z_1| \downarrow$

∴ z_1 changes in the wrong direction

Tracking Compensation

1) MOS in triode region



* For two identically biased transistors

→ sat: $g_m = \mu C_{ox}\left(\frac{W}{L}\right)(V_{GS} - |V_T|)$

→ non-sat: $g_{ds} = \mu C_{ox}\left(\frac{W}{L}\right)(V_{GS} - |V_T|)$

We want $R_F = \frac{1}{g_{m6}}\left(1 + \frac{C_L}{C_F}\right)$

$$\frac{1}{\mu C_{ox}\left(\frac{W}{L}\right)_A (V_{SG_A} - |V_T|)} = \frac{1}{\mu C_{ox}\left(\frac{W}{L}\right)_6 (V_{SG_6} - |V_T|)} \cdot \left(1 + \frac{C_L}{C_F}\right)$$

$$V_{SG_A} - |V_T| = V_X - V_A - |V_T|$$

$$= (V_{DD} - V_{SG_6}) - (V_{DD} - V_{SG_9} - V_{SG_{10}}) - |V_T|$$

$$= V_{SG_{10}} + (V_{SG_9} - V_{SG_6}) - |V_T|$$

If M_9 & M_6 are identically biased,

$$V_{SG_9} = V_{SG_6}$$

$$\Rightarrow \quad V_{SG_A} - |V_T| = V_{SG_{10}} - |V_T|$$

$$\Rightarrow \left(\frac{W}{L}\right)_A \left[V_{SG_{10}} - |V_T|\right] = \left(\frac{W}{L}\right)_6 \left(V_{SG_6} - |V_T|\right) \cdot \frac{C_F}{C_L + C_F}$$

$$\left(\frac{W}{L}\right)_A = \left(\frac{W}{L}\right)_6 \cdot \frac{V_{SG_6} - |V_T|}{V_{SG_{10}} - |V_T|} \cdot \frac{C_F}{C_L + C_F}$$

$$= \left(\frac{W}{L}\right)_6 \frac{\sqrt{\dfrac{2I_2}{\mu_p C_{ox} (W/L)_6}}}{\sqrt{\dfrac{2I_3}{\mu_p C_{ox} (W/L)_{10}}}} \cdot \frac{C_F}{C_L + C_F}$$

$$\left(\frac{W}{L}\right)_A = \left[\left(\frac{W}{L}\right)_i \left(\frac{W}{L}\right)_{10} \cdot \frac{I_2}{I_3}\right]^{1/2} \cdot \frac{C_F}{C_L + C_F}$$