ECE 515 - Lecture 22

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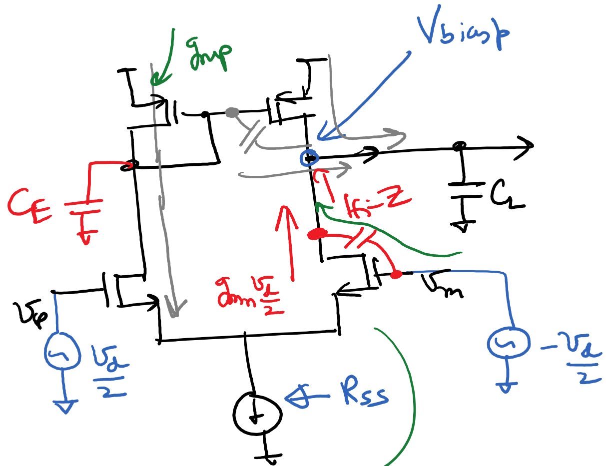
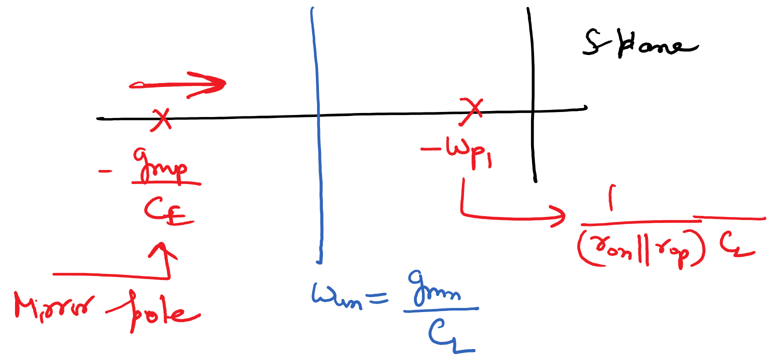




$$\omega_{un} \simeq A_v \cdot \omega_{3dB}$$
$$= g_{mn}(r_{on}||r_{op}) \times \frac{1}{(r_{on}||r_{op})C_L}$$
$$= \frac{g_{mn}}{C_L}$$

at the output node, the current $i_{d2} = g_m \frac{v_d}{2}$ and the signal $\left(-\frac{v_d}{2}\right)$ coupled through C_{gd2} are of opposite polarity

↳ RHP zero

$\omega_T = \frac{g_m}{C_{gs}}$

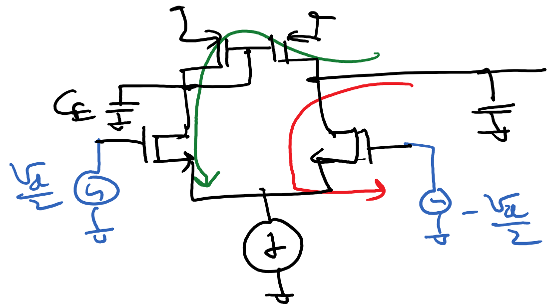
$$\omega_{z2} = +\frac{g_{mn}}{C_{gdn}} \leftarrow > \omega_T$$

very high frequency

$$\omega_{z1} = -\frac{g_{mp}}{C_E} \leftarrow \text{LHP zero}$$

fast path

$$A_{fast}(s) = \frac{A_0}{(1+s/\omega_{p1})}$$



slow path:

$$A_{slow}(s) = \frac{A_0}{(1+s/\omega_{p1})(1+s/\omega_{p2})}$$

$$\frac{v_{out}}{v_{in}}(s) = A_{slow}(s) + A_{fast}(s)$$

$$= \frac{A_0}{(1+s/\omega_{p1})}\left[\frac{1}{(1+s/\omega_{p2})} + 1\right]$$

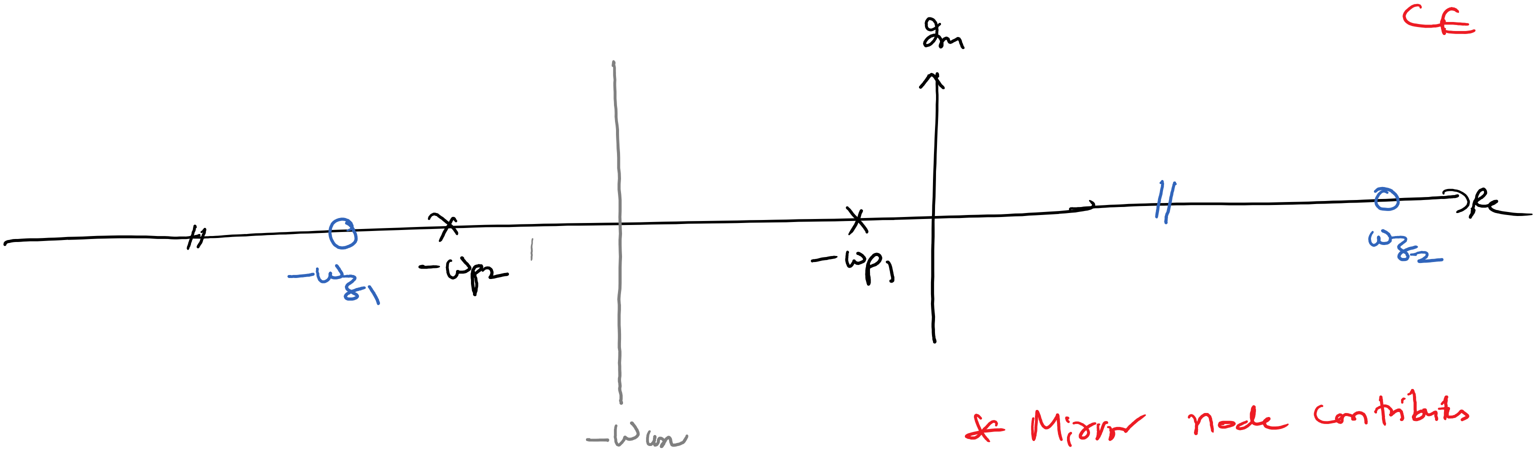
$$= \frac{A_0\,(2+s/\omega_{p2})}{(1+s/\omega_{p1})(1+s/\omega_{p2})}$$

$N(s)=0$

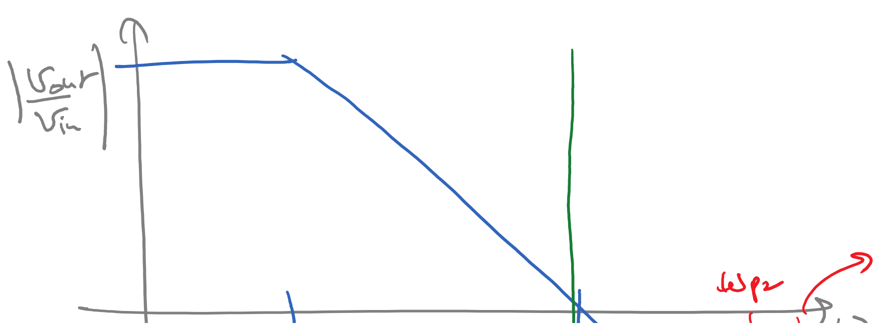
$\Rightarrow s_z = -2\omega_{p2}$

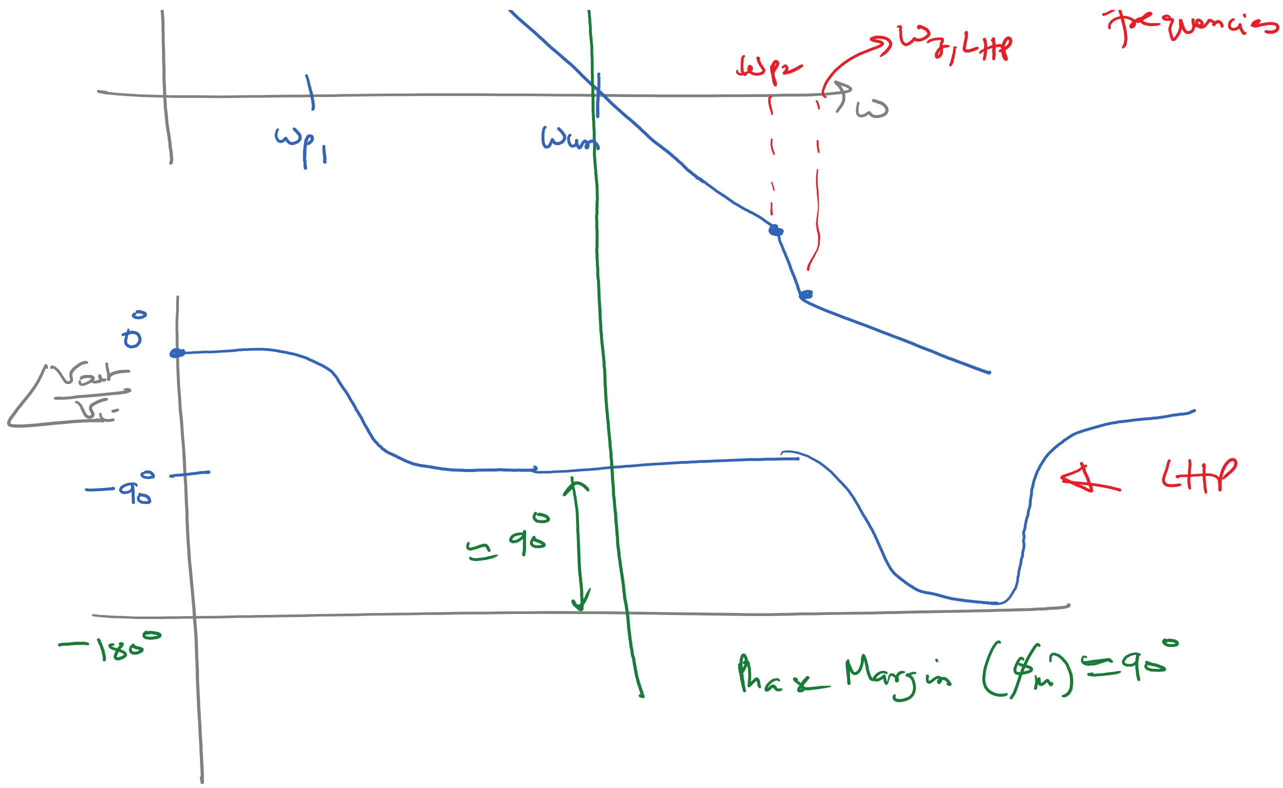
$\Rightarrow \omega_z = -2\omega_{p2}$

$= -\frac{2g_{mp}}{C_E}$



& Mirror node contributes Mirror pole & LHP zero at $\frac{g_{mp}}{C_E}$ & $\frac{2g_{mp}}{C_E}$ frequencies




frequencies
ω_z, LHP
ω_{p2}
ω
ω_{p1}
ω_{um}
0°
$\angle \frac{V_{out}}{V_{in}}$
-90°
$\simeq 90^\circ$
LHP
-180°
Phase Margin $(\phi_M) \simeq 90^\circ$

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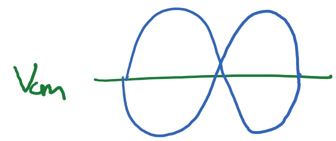
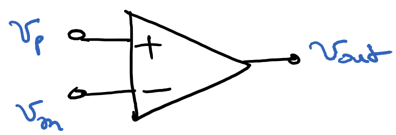
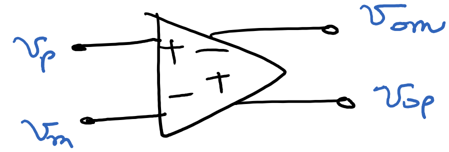
Operational Amplifiers (opamps):







$v_{out} = A(v_p - v_m)$

$(v_{op} - v_{om}) = A(v_p - v_m)$

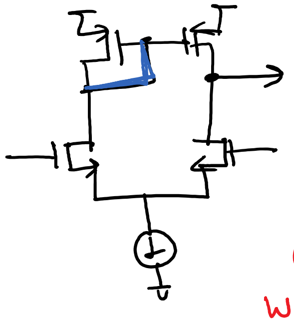
Ideally $A \to \infty \Rightarrow$ for finite v_{out}
$v_p \simeq v_m$
↳ only in a negative feedback loop

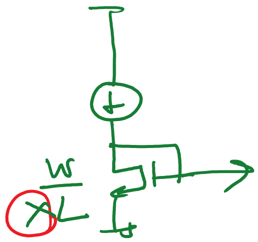
$\frac{v_{op} + v_{om}}{2} = V_{CM}$

Need to stabilize the output common-mode
(CCM feedback loop)
CMFB.

Opamps → { $A \to \infty$ → Need high-gain
$R_{in} \to \infty$ → Not a problem with CMOS
$R_{out} \to 0$ → We will see about this

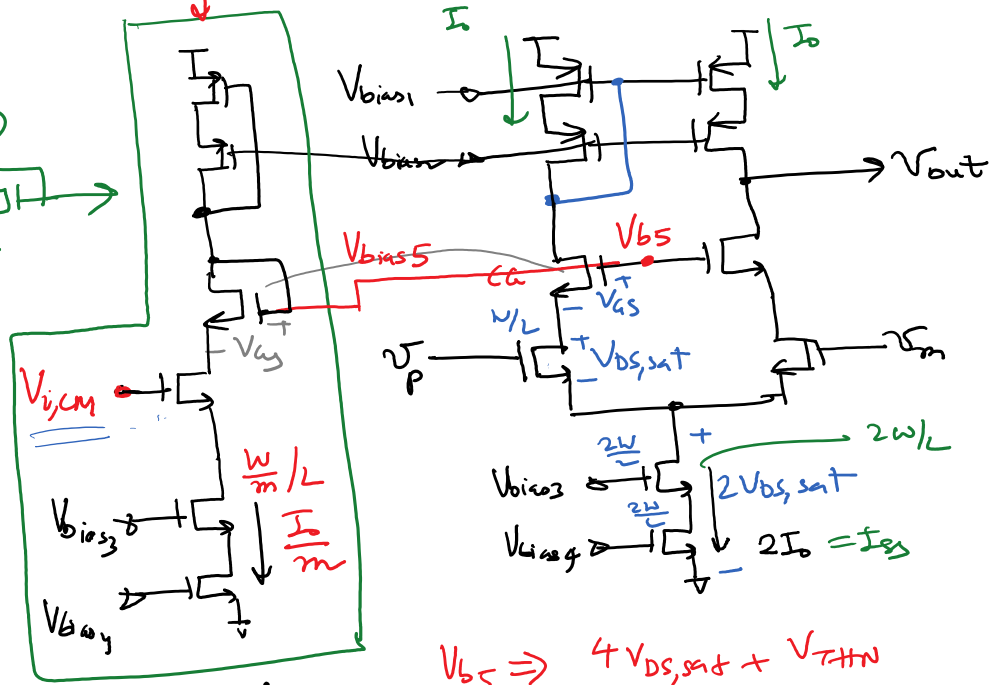
Diff amp with CM-load





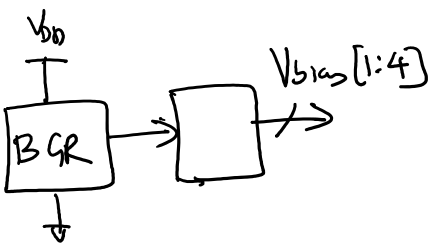
Ideally $\frac{W}{16L}$

transistors should have the same current density $(J = \frac{I}{W})$ as the main circuit



$V_{b5} \Rightarrow 4V_{DS,sat} + V_{THN}$

Multifinger layout of the MOSFET.



DC Replica Biasing Circuit

Telescopic Amplifier

$$A_v = g_{mn} \cdot (g_{mn} r_{on}^2) \| (g_{mp} r_{op}^2)$$

$$\simeq g_m \cdot \frac{g_m r_o^2}{2}$$

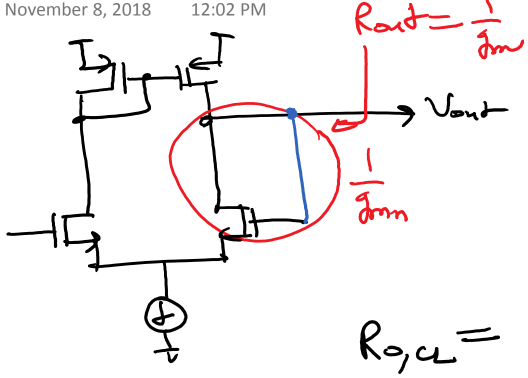
$$= \frac{(g_m r_o)^2}{2}$$

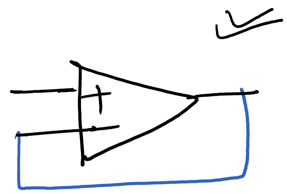
If $g_m r_o$ in nanoCMOS is 25

$\rightarrow A_v = 312.5$

$\Rightarrow 3 \times 100$

$40 + 5 = 45\,dB$





$$R_{o,CL} = \frac{R_{o,CL}}{1+\text{loop gain}}$$ → small output impedance

$$\rightarrow \frac{r_{op}||r_{on}}{g_{mn}\times(r_{op}||r_{on})} = \frac{1}{g_{mn}}$$

* We should be able to short V_{out} to V_{in} of a Telescopic Opamp (single-stage)

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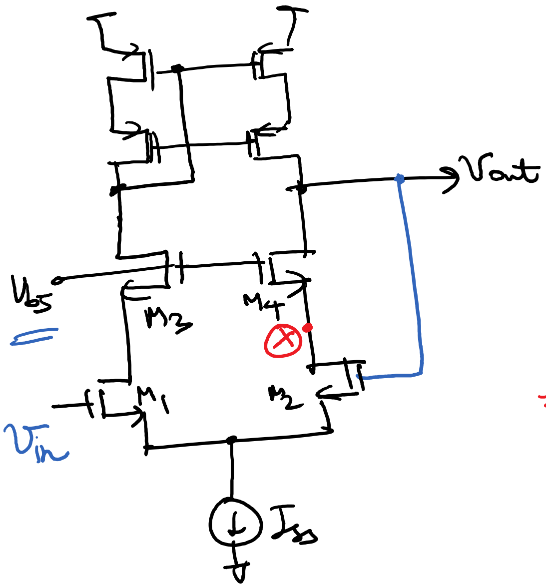

Both M_2 & M_4 must be in saturation

for M_2: $V_{DS_2} > V_{DS,sat_2}$

$V_{D_2} > V_{G_2} - V_{THN}$

$V_x > V_{out} - V_{THN}$

$\Rightarrow \boxed{V_{out} \leq V_x + V_{THN}} \rightarrow (1)$

for M_4: $V_{DS_4} > V_{GS_4} - V_{THN}$

$\Rightarrow V_{D_4} > V_{G_4} - V_{THN}$

$\Rightarrow \boxed{V_{out} > V_{b5} - V_{THN}} \rightarrow (2)$

from (1) & (2):

$V_{b5} - V_{THN} \leq V_{out} \leq$