Note Title 3/12/2019

ENEE 303
03/12/19

Cascade connection, P. 26, Fig. 1.17

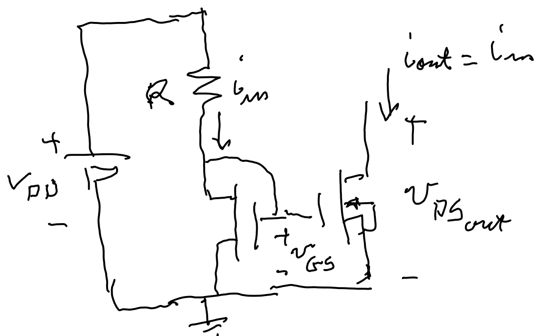
Cascode connection, P. 547, Fig. 8.29

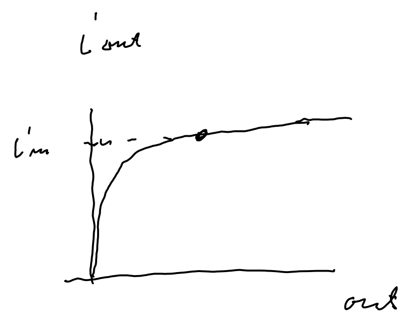
$A_{v_1} = \frac{v_{mid}}{v_1}$

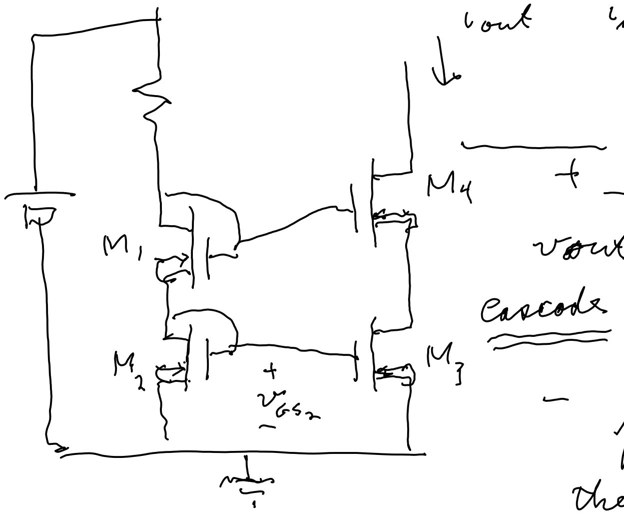
$A_{v_2} = \frac{v_o}{v_{mid}}$

$A_v = \frac{v_o}{v_1} = \frac{v_o}{v_{mid}} \cdot \frac{v_{mid}}{v_1} = A_{v_1} \cdot A_{v_2}$

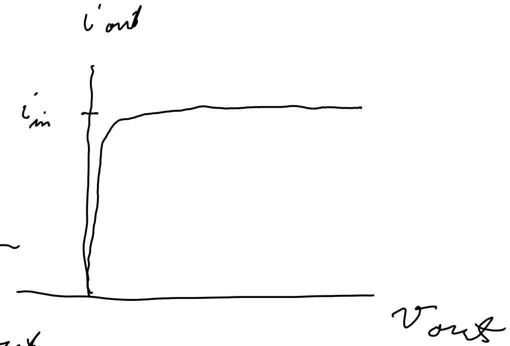
when C_2 is connected







current mirror

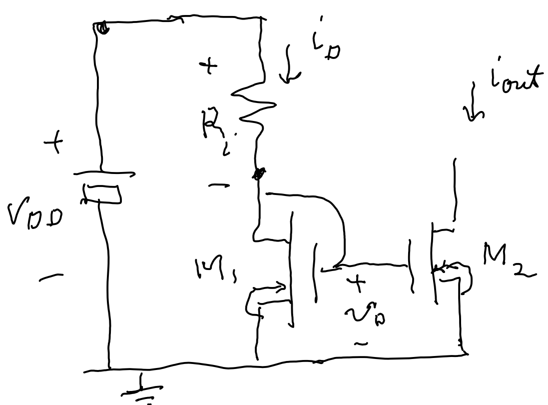


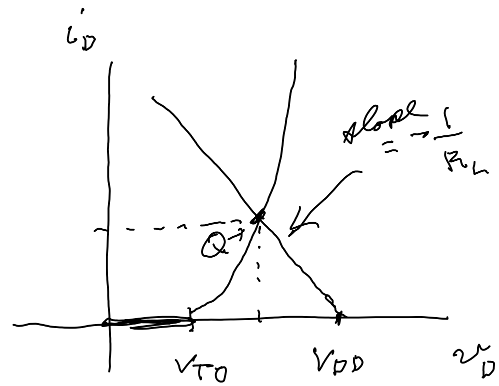
cascode

fix v_{GS_2} to give $i_{out} = i_{in}$

then M_4 allows this current for almost all output voltages

CM





load line

$$i_D = -\frac{1}{R_L} v_D + \frac{V_{DD}}{R_L}$$

$$v_D = v_{DS} = v_{GS} > v_{GS} - V_{TO}$$

$\Downarrow$

$$v_{DS} > v_{GS} - V_{TO}$$

$\Downarrow$

M_1 is in saturation if V_{DD} is big enough to keep $v_{GS} > V_{TO}$

$$i_D = k(v_D - V_{TO})^2 (1 + \lambda v_D) \approx k(v_D - V_{TO})^2, \quad k = \frac{KP}{2} \cdot \frac{W}{L}$$

given i_{out} set = to $i_D = i_{in}$

" V_{DD}

" M_1

find R_L

KVL $0 = -V_{DD} + R_L i_D + v_D$

$$R_L i_D = V_{DD} - v_D$$

desire v_D given $i_{in} = k(v_D - V_{TO})^2$ $\quad (\times(1+\lambda v_D))$ but λ small

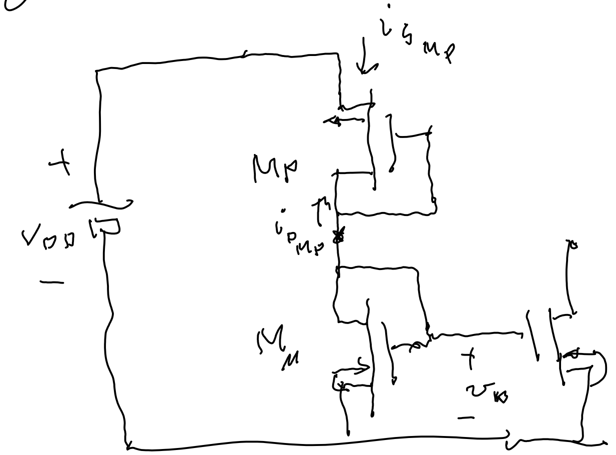
$$v_D = V_{TO} \pm \sqrt{\frac{i_{in}}{k}}$$

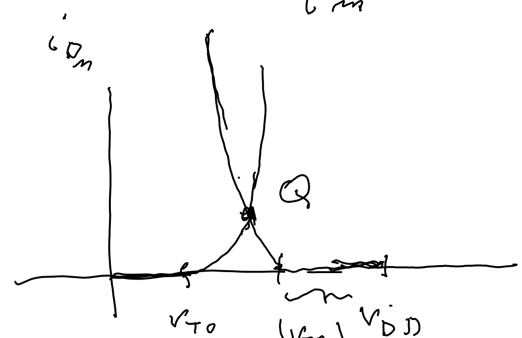
but $v_D = v_{GS} > 0$ as $v_D - V_{TO} > 0$ (as M_1 turned on)

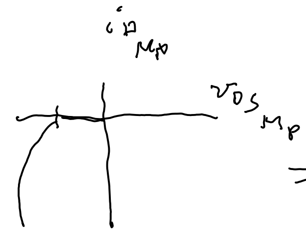
so use $+$ on $\sqrt{\ }$.

$$0 = -V_{DD} + R_L i_{in} + (V_{TO}) + \sqrt{\frac{i_{in}}{k}} \implies R_L = \frac{\left(V_{DD} - V_{TO} - \sqrt{\frac{i_{in}}{k}}\right)}{i_{in}}$$ so know R_L

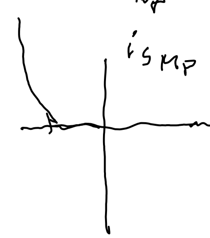
if don't like resistors



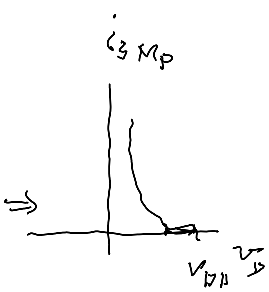




$\Rightarrow$



$v_{DS_{MP}} = V_{DD} - v_D \Rightarrow$



$i_{S_p} = k_p (V_{DD} - v_D - |V_{TO_p}|)^2 = i_{D_n} = k_n (v_D - V_{TO_n})^2$

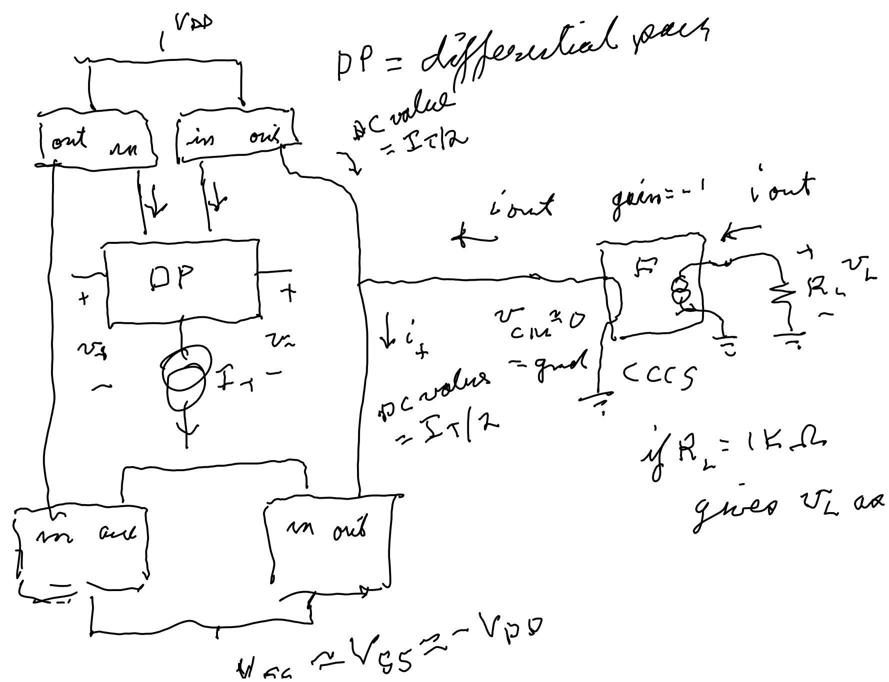
take V_I $\Rightarrow \sqrt{\frac{k_p}{k_n}} (V_{DD} - |V_{TO_p}| - v_D) = v_D - V_{TO_n}$

if M_p & M_n are complementary then $k_p = k_n$, $|V_{TO_p}| = V_{TO_n}$

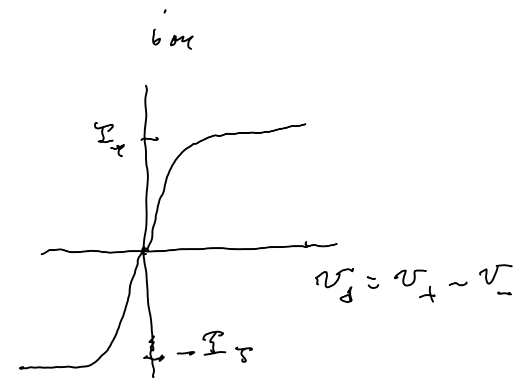
for complementary $1(V_{DD} - v_D) = v_D \Rightarrow v_D = \frac{1}{2} V_{DD}$

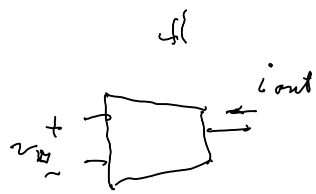
---

testing OTA



if $R_L = 1k\Omega$
gives v_L as current in mA

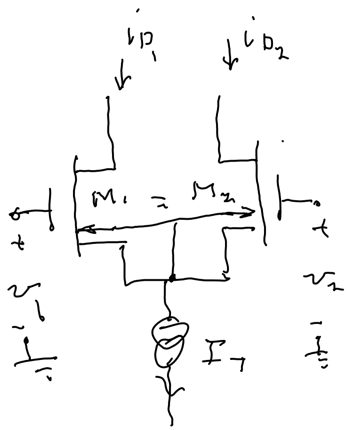




If the DP = differential pair is from BJTR then $i_o = I_T \cdot \tanh\left(\frac{v_D}{2V_T}\right)$ $V_T = \frac{kT}{|q|}$

Eqs for MOS OTA

p. 266 NMOS
p. 617 for DP, i_{D_1} i_{D_2} eq. (9.45)



KVL GS $0 = -v_1 + v_{GS_1} - v_{GS_2} + v_2 \Rightarrow v_1 - v_2 = v_{GS_1} - v_{GS_2} = v_d$ input

in saturation $i_{D_1} = k(v_{GS_1} - V_{TO})^2$, $i_{D_2} = k(v_{GS_2} - V_{TO})^2$

$$\sqrt{\frac{i_{D_1}}{k}} = v_{GS_1} - V_{TO}, \quad \sqrt{\frac{i_{D_2}}{k}} = v_{GS_2} - V_{TO} \Longrightarrow v_d = v_{GS_1} - v_{GS_2} = (v_{GS_1} - V_{TO}) - (v_{GS_2} - V_{TO}) = \sqrt{\frac{i_{D_1}}{k}} - \sqrt{\frac{i_{D_2}}{k}}$$

$$v_d^2 = \frac{i_{D_1}}{k} + \frac{i_{D_2}}{k} - 2\sqrt{\frac{i_{D_1} i_{D_2}}{k^2}} = \frac{I_T}{k} - \frac{2}{k}\sqrt{i_{D_1}(I_T - i_{D_1})}$$ solve for i_{D_1}

$$\left(v_d^2 - \frac{I_T}{k}\right)^2 = -\frac{4}{k^2}\left(i_{D_1}^2 - I_T i_{D_1}\right) \Rightarrow i_{D_1}^2 - I_T i_D + \frac{k^2}{4}\left(v_D^2 - \frac{I_T}{k}\right)^2 = 0$$

$$i_{D_1} = \frac{I_T}{2} \pm \frac{1}{2}\sqrt{I_T^2 - \frac{4k^2}{4}\left(v_D^2 - \frac{I_T}{k}\right)^2}$$

now know i_{D_1} (use +)

i_{D_2} (use −)