Midterm Friday 3:10 - 4:30

- previous examples online

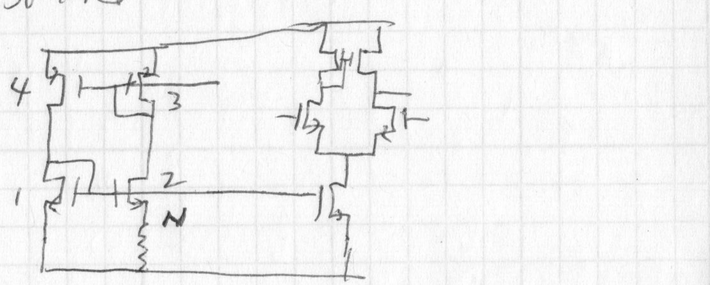
$G_{m2} = \frac{g_{m1}}{2}$ if $K=4$

$$\frac{i_o}{v_{dd}} = \frac{1}{r_{o4}}\left[\underbrace{\frac{2g_{m1}}{g_{m2}}}_{2K} - \underbrace{\frac{g_{m4}}{g_{m3}}}_{1}\right]^{-1}$$

$$= \frac{1}{r_{o4}(2K-1)}$$

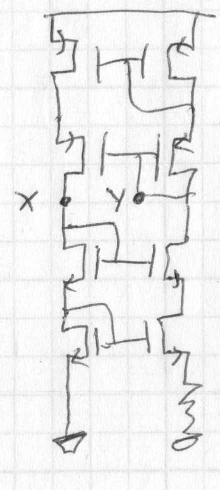
make $L_{3,4}$ <u>long</u> or if you have room (at least the top cascode)

Last time

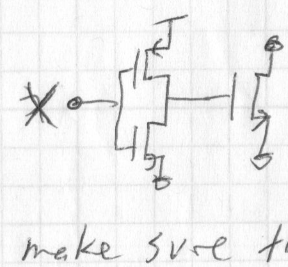


$$I_{D2} = \frac{2}{\mu_n C_{ox}\left(\frac{W}{L}\right)_1} \frac{1}{R_S^2}\left(1 - \frac{1}{\sqrt{K}}\right)^2$$

$$\frac{\partial I_{out}}{\partial V_{DD}} = \frac{i_o}{v_{dd}} \cong \frac{1}{r_{o4}}\left[\frac{1}{G_{m2}\left(r_{o4} \parallel \frac{1}{g_{m1}}\right)} - \frac{g_{m4}}{g_{m3}}\right]^{-1}$$

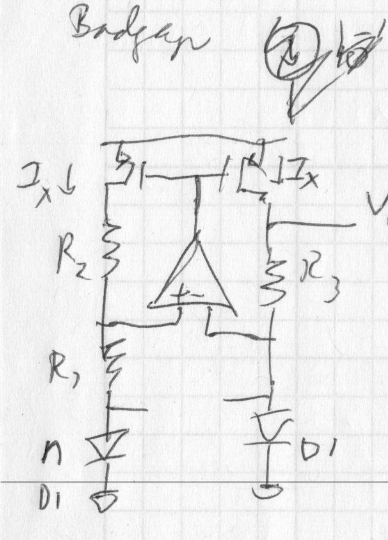


Startup: if $X=0$ pull y low else let y go



make sure that the inverter N and P are sized so that it turns the pull down <u>off</u> when the reference is operating normally

Badgap



say $n=10$

$I_X = 1mA$

let $I_{S1} = 10^{-13} A$ for D1

@25C $I_{D1} = I_{S1}(e^{V_{D1}/V_{TH}} - 1)$

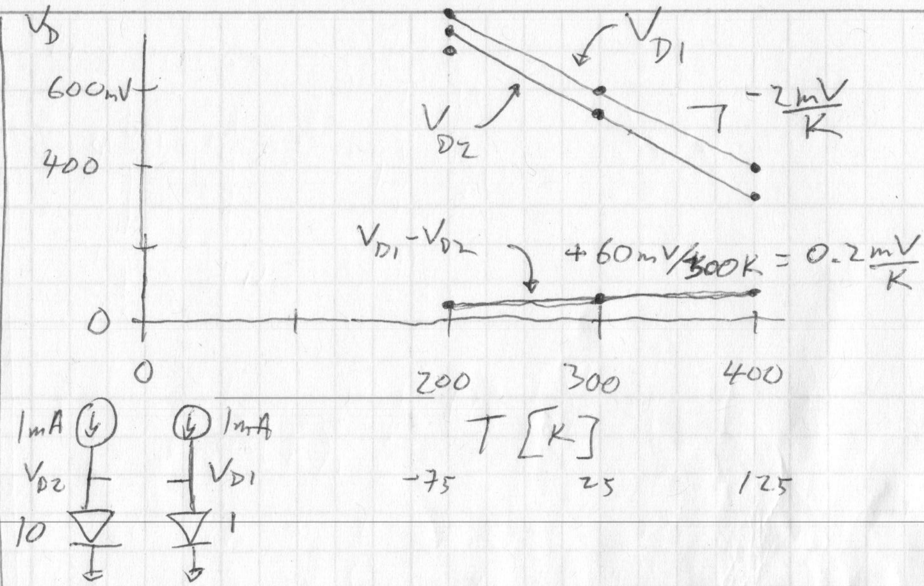
@25C $\frac{60mV}{decade}$

predict 600mV

$V_{D1} = \ln\left(\frac{I_{D1}}{I_{S1}}\right) V_{TH} = 600mV$

$V_{D2} = \ln\left(\frac{I_{D2}}{n I_{S1}}\right) V_{TH} = 600mV - 60mV$

$= \left[\ln\left(\frac{1}{n}\right) + \ln\frac{I_{D2}}{I_{S1}}\right] V_{th}$



Feedback circuit

polarity

stability

If $I_{D1} = I_{D2}$ then $V_{D1} > V_{D2}$

in fact $V_{D1} = V_{D2} + \ln(n) V_{th}$

$V_{D1} - V_{D2} = \underbrace{\ln(n)\frac{k_B}{q}}T$

if $n=10$ $\quad 0.2\frac{mV}{K} = \frac{60mV}{300K}$

true at <u>any</u> <u>current</u> $I_X = 1\mu A, 1mA$

let $R_1 = 60\,\Omega$

If $I_x = 1mA$ $\quad V_{R1} = (1mA)(60\Omega) = 60mV$

@25C, now $V_+ = V_-$

What if I_x is 2mA? $\quad V_+ > V_-$

V_{out} increases, V_{GP} increases,

I_X decreases

until $V_+ = V_-$