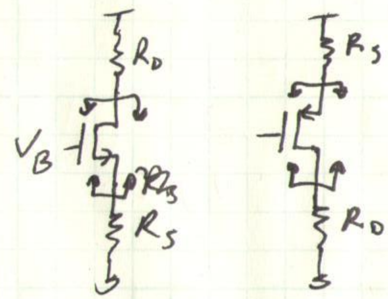
Midterm Friday

G_m

Biasing

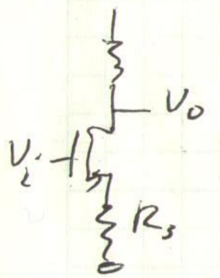
Last time

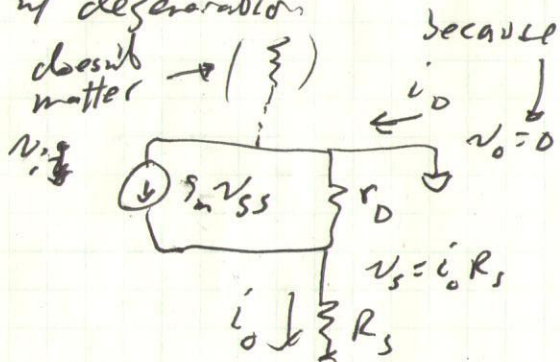


$$R_D = (1+g_m r_o)R_S + r_o$$
$$= g_m r_o R_S + R_S + r_o$$
$$\doteq g_m r_o R_S \quad \text{if } R_S \gg \frac{1}{g_m}$$

$$R_S = \frac{1}{g_m}\left(1 + \frac{R_D}{r_o}\right)$$

G_m for CS w/ degeneration



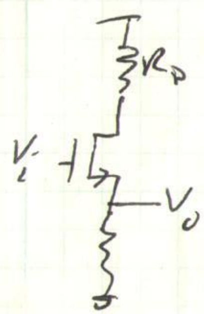


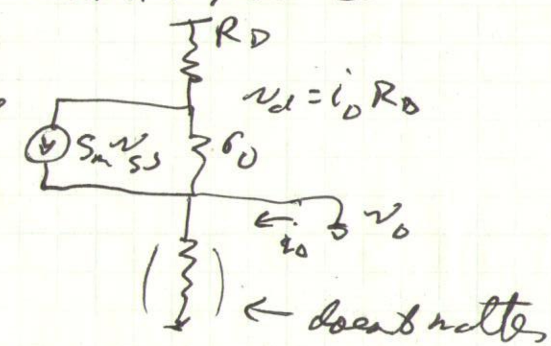
KCL @ v_d $\quad i_o = \cancel{g_m(-i_o R_s)}\; g_m(v_i - i_o R_s) + \frac{1}{r_o}(0 - i_o R_s)$

$$i_o\left[1 + g_m R_s + \frac{1}{r_o}R_s\right] = g_m v_i$$

$$G_m = \frac{i_o}{v_i} = \frac{g_m}{1 + g_m R_s\left(1 + \frac{1}{g_m r_o}\right)} \doteq \frac{g_m}{1 + g_m R_s} = \begin{cases} g_m & R_s \ll \frac{1}{g_m} \\ \frac{g_m}{2} & R_s = \frac{1}{g_m} \\ 1/R_s & R_s \gg \frac{1}{g_m} \end{cases}$$

G_m for CS w/ drain impedance





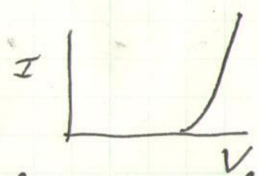
KCL @ v_s $\quad i_o + g_m(v_i) + \frac{1}{r_o}(i_o R_D) = 0$

$$i_o\left[1 + \frac{R_D}{r_o}\right] = -g_m v_i$$

$$G_m = \frac{i_o}{v_i} = \frac{-g_m}{1 + \frac{R_D}{r_o}} = \begin{cases} -g_m & R_D \ll r_o \\ -g_m/2 & R_D = r_o \\ -\frac{g_m r_o}{R_D} & R_D \gg r_o \end{cases}$$

Diode connected

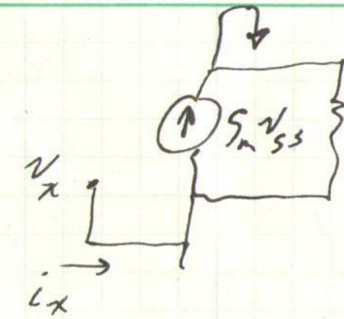
all look like



turn on depends on <u>scale</u>

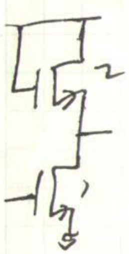
for diode, BJTs it's <u>near</u> 0.6, 0.7 almost scales

for MOS, near V_t



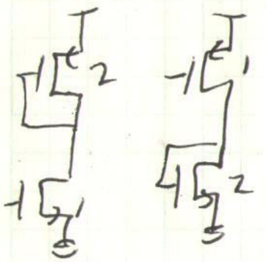
$$i_x = g_m(v_x - 0) + \frac{1}{r_0}(v_x - 0) = \left(g_m + \frac{1}{r_0}\right) v_x = g_m v_x \left(1 + \frac{1}{g_m r_0}\right)$$

$$R_d = \frac{v_x}{i_x} \doteq \frac{1}{g_m}$$



$$A_v = -G_m R_0 = -g_{m1}\left(r_{01} \,\|\, \frac{1}{g_{m2}}\right)$$

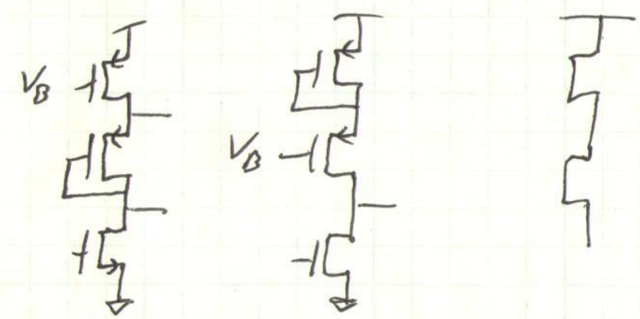
$$= -\frac{g_{m1}}{g_{m2}} = -\frac{\frac{2I_D}{V_{ov1}}}{\frac{2I_D}{V_{ov2}}} = -\frac{V_{ov2}}{V_{ov1}}$$



if $V_{ov2} = 2V_{ov1}$

and $I_{d2} = I_{d1}$

what is $\left(\frac{W}{L}\right)_2 / \left(\frac{W}{L}\right)_1$?

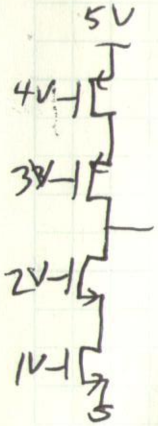


G_m ? $\qquad$ G_m

R_0 ? $\qquad$ R_0

why?

Biasing



$V_{tn} = |V_{tp}| = -0.5$ $\quad \mu_n C_{ox} = 2\mu_p C_{ox}$

All have same $\frac{W}{L}$. No gain. Why?

Change $\left(\frac{W}{L}\right)_p = 2\left(\frac{W}{L}\right)_n$

Bias points? $V_{S2} = 1$

$V_{S3} = 4$

$V_{OUT} = 2.5$? very tough to hit exactly

output swing? $1.5 - 3.5$

gain? $g_{m1}\left(\frac{g_m r_o^2}{2}\right) = \frac{1}{2}\left(\frac{2I_D}{V_{ov}} \cdot \frac{1}{\lambda I_D}\right)^2 = 2\left(\frac{V_A}{V_{ov}} \frac{L}{L_{min}}\right)^2$

How low could V_{S2} go?

What if I double W everywhere?

double $\frac{W}{L}$ everywhere?

drop V_{ov} to $0.1V$?