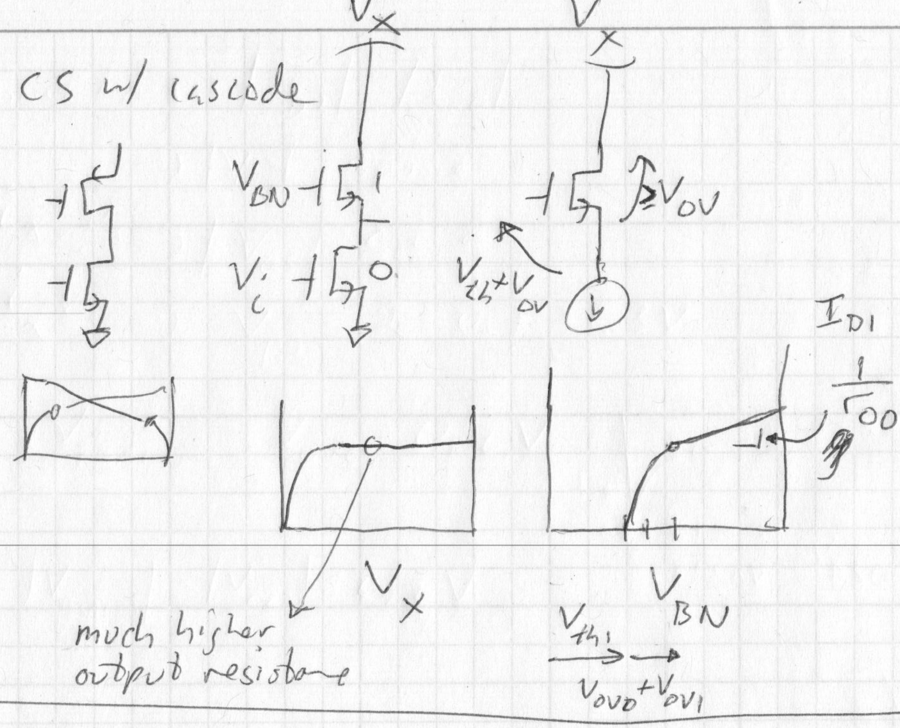
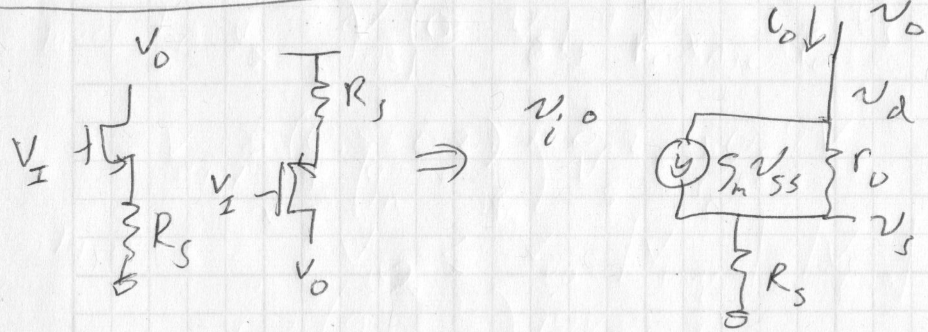
Midterm Friday closed book 1 pg 2 sides notes
no silicon
HW 1-4
Ch 1-3, 6.1, 6.2 eqn 6.21, 6.22

Cascode

CS w/ cascode





① KCL @ v_o

$i_o = g_m v_{gs} + \frac{1}{r_o} v_{ds}$ → some people write $g_o v_{ds}$

② $v_s = i_o R_s$

$v_{gs} = v_i - i_o R_s$ ($v_i \to 0$ for R_o calc.) $\quad v_{ds} = v_o - i_o R_s$

Note: in a sum all terms must have the same units! check that!

①+②

$i_o = g_m(v_i - i_o R_s) + \frac{1}{r_o}(v_o - i_o R_s)$ ③

for R_o calc: $v_i = 0$ $\quad R_o = \frac{v_o}{i_o}$

for g_m calc: $v_o = 0$ $\quad g_m = \frac{i_o}{v_i}$

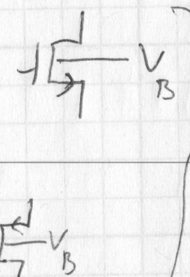
expect when $R_s = 0 \Rightarrow g_m, r_o$
when $R_s = \infty \Rightarrow 0, \infty$
when $g_m = 0 \Rightarrow ?, r_o + R_s$

} check

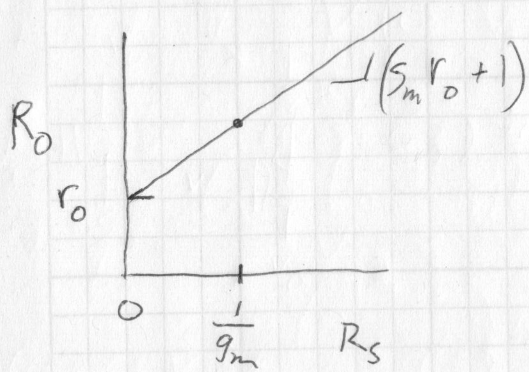
② ③ w/ $v_i = 0$ $\quad i_o + g_m R_s i_o + i_o \frac{R_s}{r_o} = \frac{1}{r_o} v_o$

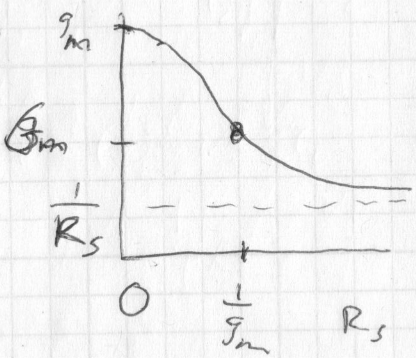
$$R_o = \frac{v_o}{i_o} = r_o\left[1 + g_m R_s + \frac{R_s}{r_o}\right]$$

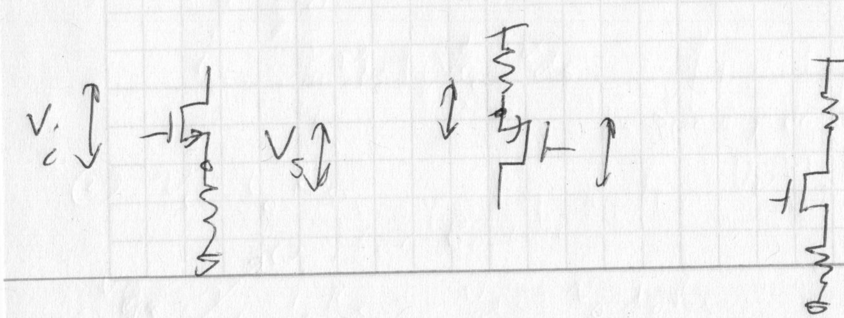
$$= r_o + R_s + g_m r_o R_s$$



$\Rightarrow R_o = r_o + R_s + (g_m + g_{mb}) r_o R_s$





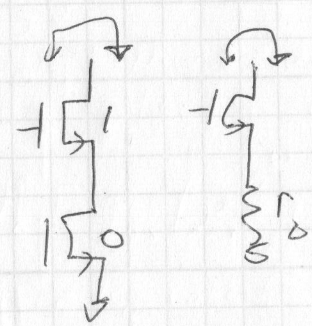


$A_v = \frac{-R_D}{R_s}$ if $R_s \gg \frac{1}{g_m}$

③ w/ $v_o = 0$ $\quad i_o = g_m v_i - g_m R_s i_o - i_o \frac{R_s}{r_o}$

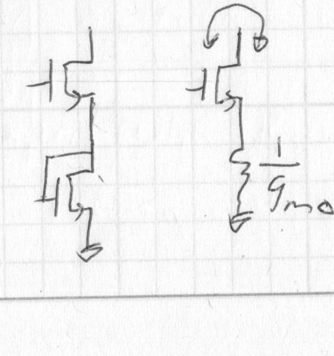
$$G_m = \frac{i_o}{v_i} = \frac{g_m}{1 + g_m R_s + \frac{R_s}{r_o}}$$

w/ body effect $\Rightarrow g_m + g_{mb}$



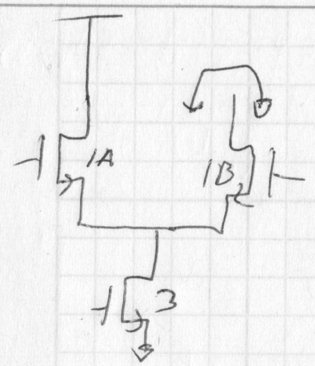
$R_o = r_{o1} + (1 + g_{m1} r_{o1}) r_{o0} \approx g_m r_o^2$

10, 100, ... ?



$$R_o = r_{o1} + (1 + g_{m1} r_{o1}) \frac{1}{g_{m0}}$$

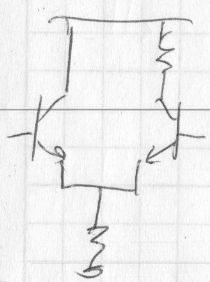
$$\approx r_{o1}\left(1 + \frac{g_{m1}}{g_{m0}}\right)$$



$$R_o = r_o + (1 + g_{m1B} r_o) R_s$$

$$R_s = \frac{1}{g_{m1A}} \| r_{o3} \approx \frac{1}{g_{m1A}}$$

$$R_o \approx r_o + \frac{g_{m1B}}{g_{m1A}} r_o \approx 2 r_o$$

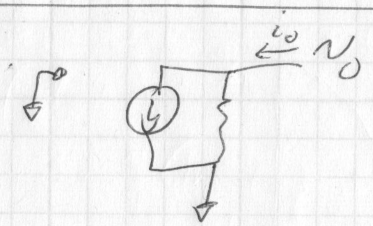


Q: What small signal current flows in i_{d1A} if v_{d1B} increases?

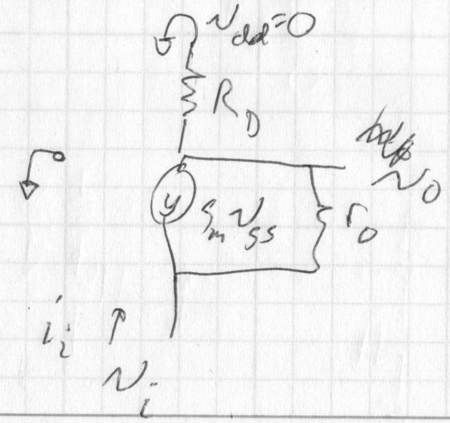
A: $i_{d1A} \approx -i_{d1B} = \dfrac{v_{d1B}}{2 r_{o1B}}$

$$R_o = \frac{v_o}{i_o}\Big|_{v_i=0}$$

$$= r_o$$

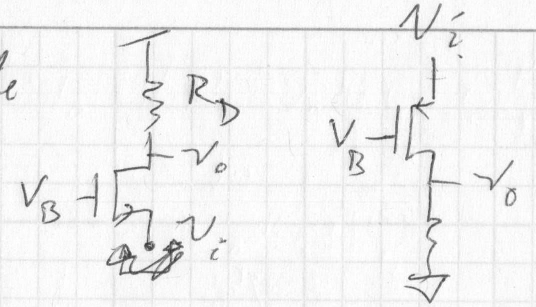


$$R_i = \frac{v_i}{i_i}\Big|$$



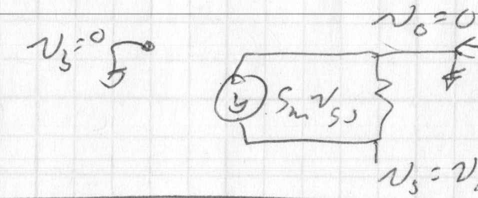
$$v_o = i_i R_D$$

common gate



$G_m,\ R_o,\ R_i$

$$G_m = \frac{i_o}{v_i}\Big|_{v_o=0} = -\left(g_m (+ g_{mb}) + \frac{1}{r_o}\right)$$



$$i_o = -g_m v_i - \frac{1}{r_o} v_i$$

KCL @ v_i $\quad i_i + g_m v_{gs} + \frac{1}{r_o}(v_o - v_i) = 0$

$$i_i + g_m(-v_i) + \frac{1}{r_o}(i_i R_D - v_i) = 0$$

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

$$R_i = \frac{v_i}{i_i} = \frac{1 + R_D/r_o}{g_m\left(1 + \frac{1}{g_m r_o}\right)} \approx \frac{1}{g_m}\left(1 + \frac{R_D}{r_o}\right)$$

$$= \frac{R_D}{g_m r_o} \quad \text{iff } R_D \gg r_o$$