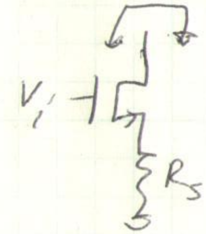
Midterm friday in class
1 page (2 sides) notes
no calculators

Homeworks 1-4
Labs 1, 3 (not cadence)

Cascode
- A_v
- C_{in}
- biasing

Last time



$$R_O = (1 + g_{m2} r_{o2}) R_S + r_{o2}$$

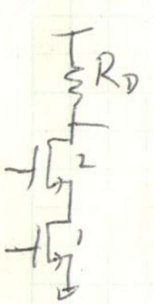
3.66, 67

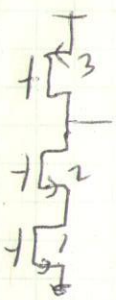
$$= (1 + g_{m2} R_S) r_{o2} + R_S$$

$$\approx \begin{cases} g_{m2} r_{o2} R_S & R_S \gg \frac{1}{g_{m2}} \\ 2 r_{o2} & R_S = \frac{1}{g_{m2}} \\ r_{o2} & R_S \ll \frac{1}{g_{m2}} \end{cases}$$

$R_S = r_{o2} \Rightarrow R_O = g_{m2} r_{o2} r_{o1}$

$G_m \approx g_{m1}$ $\quad A_v = -G_m R_O = g_{m1}(g_{m2} r_{o2} r_{o1} \| R_{up})$





$R_D \ll g_{m2} r_{o2} r_{o1}$

$A_v = -g_{m1} R_D$

$A_v = -g_{m1} r_{o3}$

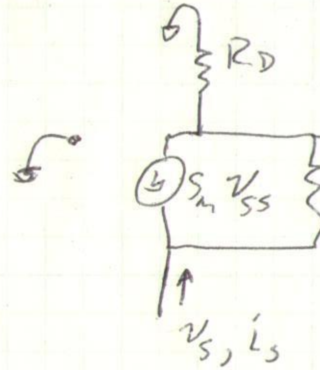
What about C_{in}?

$$C_i = C_{gs1} + (1 - A_{gd1} C_{gd1})$$

A_{gd1} calc:

$G_m = g_{m1}$

$R_O = r_{o1} \| R_{S2,up}$



$v_d = i_s R_D$

find $R_{S,up} = \frac{v_s}{i_s}$

KCL @ v_s: $\quad i_s + g_m(0 - v_s) + \frac{1}{r_o}(v_d - v_s) = 0$

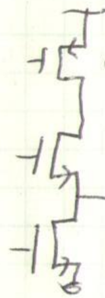
$$i_s + \frac{1}{r_o}(i_s R_D) = \left(g_m + \frac{1}{r_o}\right) v_s$$

$$R_{S,up} = \frac{v_s}{i_s} = \left(1 + \frac{R_D}{r_o}\right) \frac{1}{g_m\left(1 + \frac{1}{g_m r_o}\right)} \approx \frac{1}{g_m}\left(1 + \frac{R_D}{r_o}\right)$$

$$R_{S,UP} = \begin{cases} \frac{1}{g_m} & R_D \ll r_o \\ \frac{2}{g_m} & R_D = r_o \\ \frac{R_D}{g_m r_o} & R_D \gg r_o \end{cases}$$

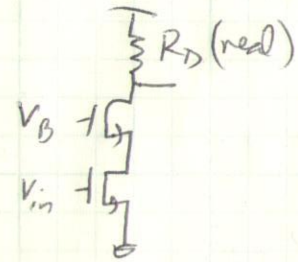
Real Resistor $\Rightarrow R_D \ll r_{o2}$ typ

$A_{VGD1} \approx -g_{m1} \frac{1}{g_{m2}} \approx -1$



$\leftarrow r_{o3} \approx r_{o2}$

$A_{VGD1} \approx -g_{m1} \frac{2}{g_{m2}} \approx -2$



$C_{in} \approx C_{gs1} + 2C_{gd1}$

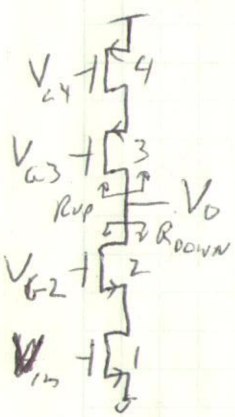
$A_v = -g_{m1} R_D$

$C_{in} \approx C_{gs1} + 3C_{gd1}$

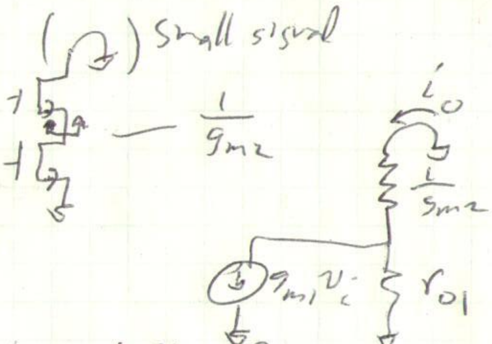
$A_v \approx -g_{m1} r_{o3}$

decouples gain & input capacitance (compared to CS)

some cost in swing



$G_m = \frac{i_o}{v_i}\Big|_{v_o=0}$ doesn't depend on R_{UP} since $v_o = 0$



which way will current flow?

current divider says $\frac{r_{o1}}{r_{o1} + \frac{1}{g_{m2}}}$ goes to i_o

$\Rightarrow G_m \approx g_{m1}$

$R_o = R_{up} \| R_{DOWN}$

$R_{DOWN} \approx g_{m2} r_{o2} r_{o1}$

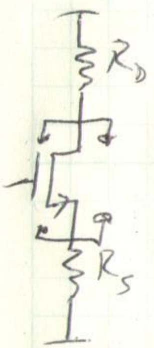
$R_{UP} \approx g_{m3} r_{o3} r_{o4}$

$A_v = -g_{m1} R_o \approx \frac{1}{2}(g_m r_o)^2$

input capacitance:

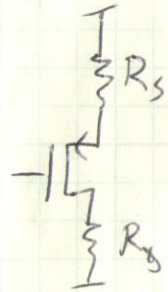
$$A_{VGD1} = -g_{m1}\left(r_{o1} \| \frac{R_{UP}}{g_{m2} r_{o2}}\right) \approx -\frac{g_m r_o}{2}$$

So, same input cap as simple common source but much higher gain ($g_m r_o$ bigger)



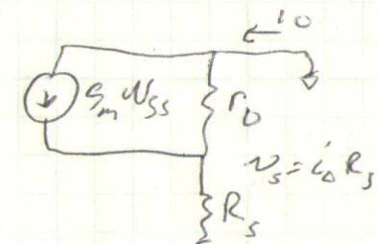
$R_O = (1 + g_m R_S) r_O$

$R_O = \frac{1}{g_m}\left(1 + \frac{R_D}{r_O}\right)$ ← or R_i



G_m for source degen CS

v_i v_o

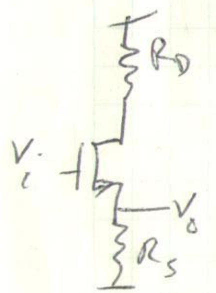


KCL @ v_d $\quad i_o = g_m(v_i - i_o R_s) + \frac{1}{r_o}(0 - i_o R_s)$

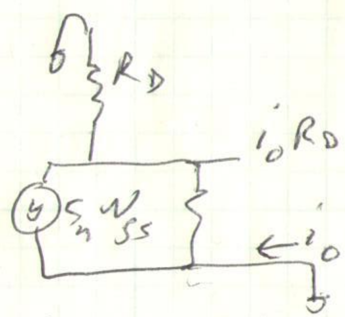
$i_o\left[1 + g_m R_s + \frac{R_s}{r_o}\right] = g_m v_i$

$G_m = \frac{i_o}{v_i} = \frac{g_m}{1 + g_m R_s + \frac{R_s}{r_o}} = \frac{g_m}{1 + g_m R_s\left(1 + \frac{1}{g_m r_o}\right)}$

G_m for source follower w/ drain load



v_i v_o

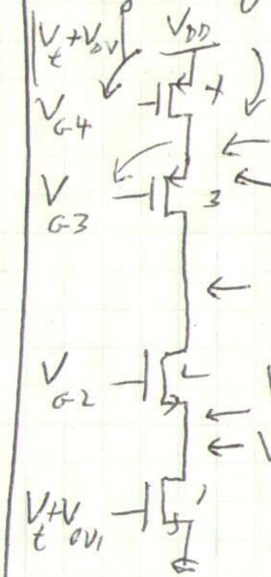


KCL @ v_s: $i_o + g_m v_i + \frac{1}{r_o}(i_o R_D) = 0$

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

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

Biasing for quadratic devices in saturation



$|V_{ov}|$

$V_{D4,max} = V_{DD} - |V_{ov}|$

$V_{S3} = V_{G3} + |V_{tp}| + |V_{ov3}|$

$V_{O,max} = V_{S3} - |V_{ov}| = V_{G3} + |V_{tp}|$

$V_{O,min} = V_{S2} + V_{ov2} = V_{G2} - V_{tn}$

$V_{S2} = V_{G2} - V_{tn} - V_{ov2}$

$V_{D1,min} = V_{ov1}$