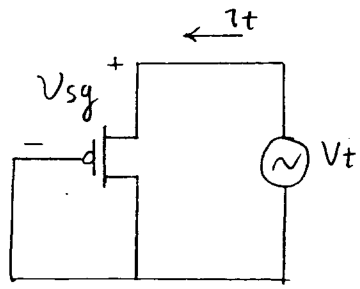
Chapter 22.

Problem 22.1

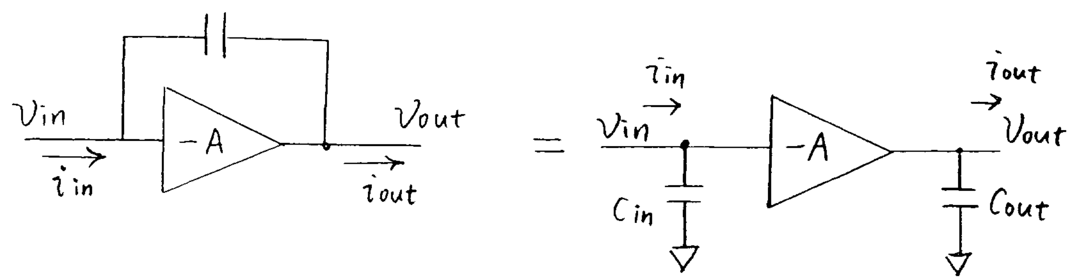


$$R_{eq} = \frac{v_t}{i_t} = \frac{v_{sg}}{g_m v_{sg}} = \frac{1}{g_m}.$$

Problem 22.2

See next page.

Problem 22.3



$$i_{in} = \frac{v_{in} - v_{out}}{\frac{1}{j\omega C}} = \left[v_{in} - (-A)v_{in}\right]j\omega C = v_{in}(1+A)j\omega C$$

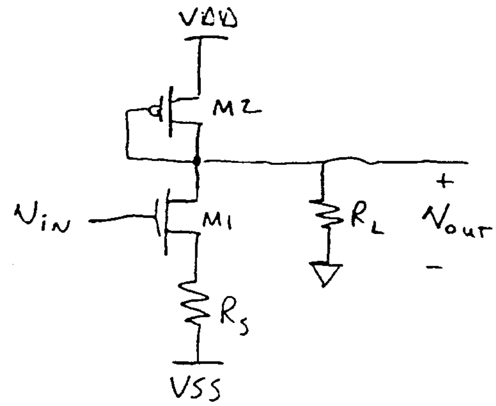
$$\frac{v_{in}}{i_{in}} = \frac{v_{in}}{v_{in}(1+A)j\omega C} = \frac{1}{j\omega(1+A)C} = \frac{1}{j\omega C_{in}} \Rightarrow \underline{\underline{C_{in} = (1+A)C}}$$

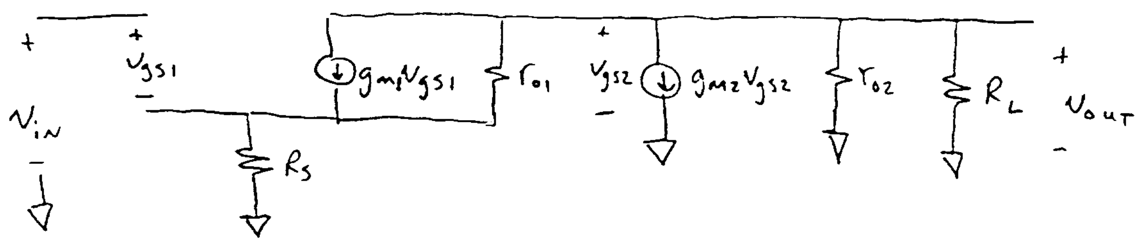
$$i_{out} = \frac{v_{in} - v_{out}}{\frac{1}{j\omega C}} = \left(-\frac{1}{A}v_{out} - v_{out}\right)j\omega C = -\left(1+\frac{1}{A}\right)v_{out}\,j\omega C$$

$$\frac{v_{out}}{-i_{out}} = \frac{v_{out}}{v_{out}\left(1+\frac{1}{A}\right)j\omega C} = \frac{1}{j\omega\left(1+\frac{1}{A}\right)C} = \frac{1}{j\omega C_{out}} \Rightarrow \underline{\underline{C_{out} = \left(1+\frac{1}{A}\right)C}}$$

22.2

Using small signal models, verify that the gain given in Ex. 22.1 is correct.





Assume $\frac{1}{g_{m2}} \ll r_{o1} + r_{o2}$

$$v_o = -g_{m1}v_{gs1}\left(\frac{1}{g_{m2}} \parallel R_L\right)$$

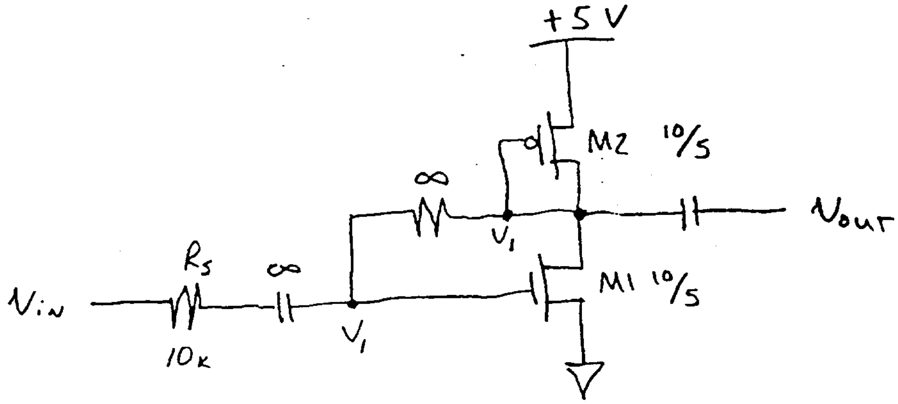
$$v_{IN} = v_{gs1} + g_{m1}v_{gs1}(R_S)$$

$$\frac{v_o}{v_{IN}} = \frac{v_o}{v_{gs1}} \cdot \frac{v_{gs1}}{v_{IN}} = \left(-g_{m1}\left(\frac{1}{g_{m2}} \parallel R_L\right)\right)\left(\frac{1}{1+g_{m1}R_S}\right)$$

$$\frac{v_o}{v_{IN}} = \frac{-\left(\frac{1}{g_{m2}} \parallel R_L\right)}{\frac{1}{g_{m1}} + R_S}$$

checks!

22.4



(a) Determine DC voltages & currents:

$$I_{D1} = I_{D2}$$

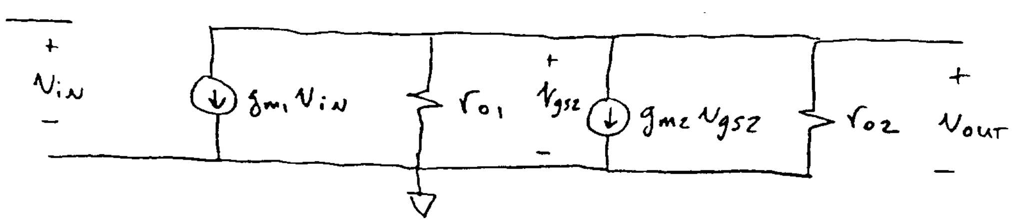
$$\frac{50\,\mu A/V^2}{2}\,\frac{10}{5}(V_1 - .83)^2 = \frac{17\,\mu A/V^2}{2}\,\frac{10}{5}(5 - V_1 - .91)^2$$

$$1.941\,V_1^2 + 3.2979\,V_1 - 14.7019 = 0$$

$$V_1 = \underline{\underline{2.031\,V}}$$

$$I_{D1} = I_{D2} = 50\,\mu A/V^2\,(2.031 - .83)^2 = \underline{\underline{72.12\,\mu A}}$$

(b) Determine the small signal low frequency gain:



$$\frac{v_{out}}{v_{in}} = -g_{m1}\left(\frac{1}{g_{m2}} \| r_{o1} \| r_{o2}\right)$$

$$g_{m1} = \sqrt{2(50\mu)\left(\tfrac{10}{5}\right)(72.12\mu)} = 120\,\mu A/V$$

$$g_{m2} = \sqrt{2(17\mu)\left(\tfrac{10}{5}\right)(72.12\mu)} = 70\,\mu A/V$$

$$r_{o1} = r_{o2} = \frac{1}{\lambda I_D} = \frac{1}{.06(72.12\mu)} = 231.1\,k\Omega$$

$$\frac{v_{out}}{v_{in}} = -1.53\ \frac{V}{V}$$

c) Determine C_{sg2}, C_{db2}, C_{gd1}, C_{gs1}, and C_{db1}. Assume the areas of the drains and sources of the MOSFETs measure 6 um X 10 um.

$$C_{sg2} = \frac{2}{3} \cdot C_{ox}' \cdot W_2 \cdot L_2 = \frac{2}{3}\left(800\ aF/um^2\right)\left(10\ um \cdot 5\ um\right)$$
$$= 26.7\ fF$$

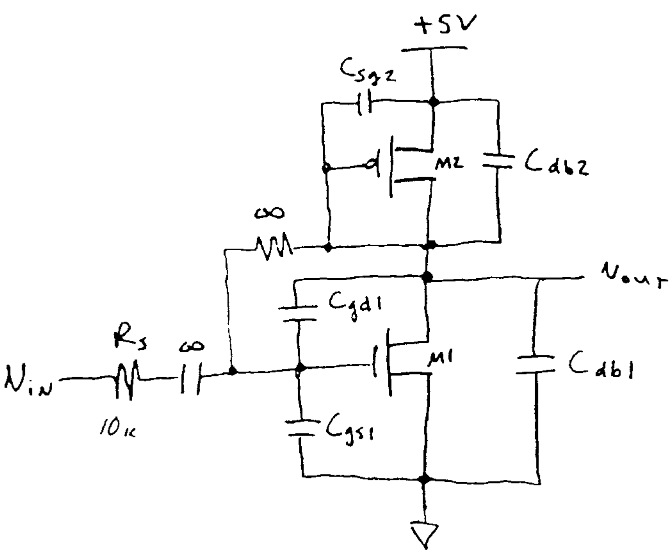
$$C_{db2} = C_{jdep} = C_j \cdot A_d = \left(3.24 \cdot 10^{-4}\ F/m^2\right)\left(6\ um \times 10\ um\right)$$
$$= 19.4\ fF$$

$$C_{gd1} = CGDO \cdot W_1 = \left(0.38\ nF/m\right)\left(10\ um\right)$$
$$= 3.8\ fF$$

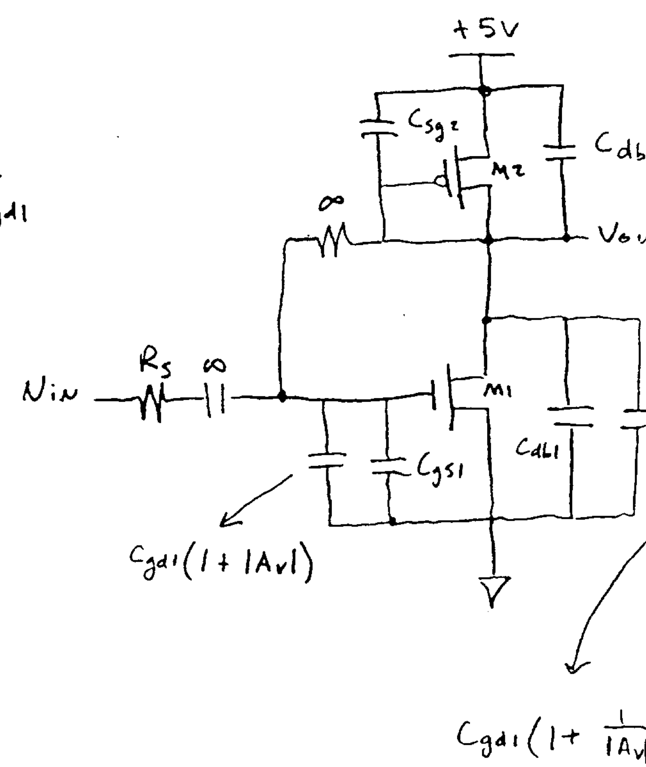
$$C_{gs1} = \frac{2}{3} C_{ox}' \cdot W_1 \cdot L_2 = \frac{2}{3}\left(800\ aF/um^2\right)\left(10\ um \cdot 5\ um\right)$$
$$= 26.7\ fF$$

$$C_{db1} = C_{jdep} = C_j \cdot A_d = \left(1.04 \cdot 10^{-4}\ F/m^2\right)\left(6\ um \times 10\ um\right)$$
$$= 6.24\ fF$$

d) Determine the frequency response:

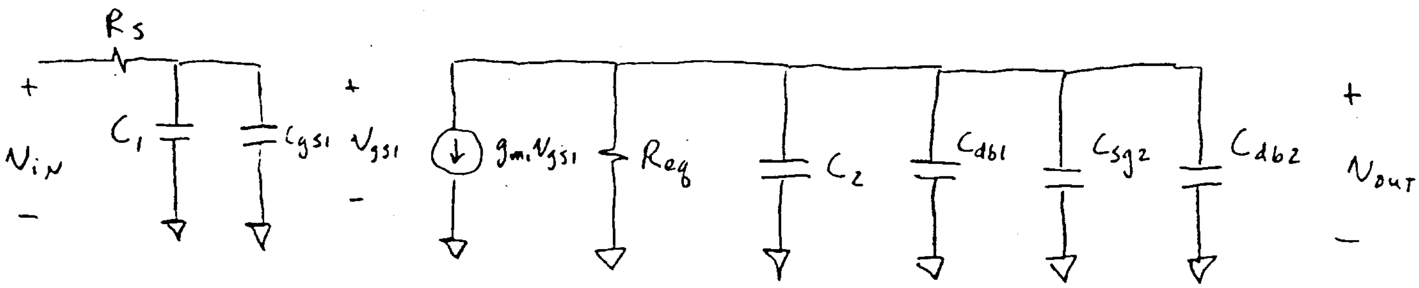


Using Miller's Theorem on C_{gd1} $\Longrightarrow$



* note: Using Miller's Theorem a zero is neglected.

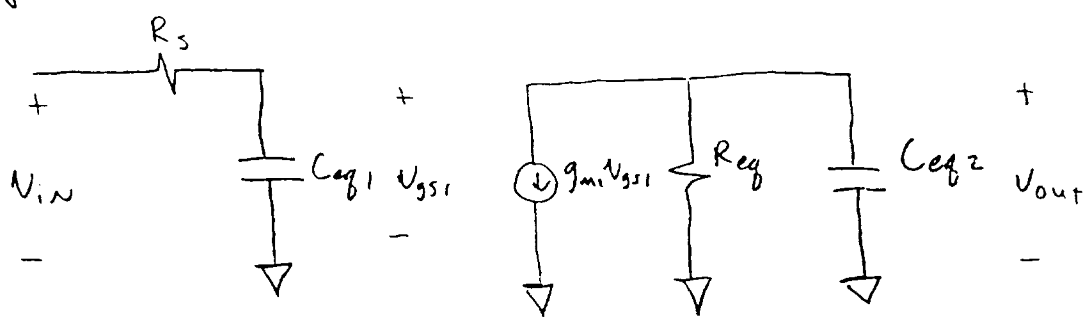
small signal model:



$$C_1 = C_{gd1}(1 + |A_v|) = 9.614\,fF$$

$$C_2 = C_{gd1}\left(1 + \frac{1}{|A_v|}\right) = 6.284\,fF$$

Simplify model



$$C_{eq1} = C_1 + C_{gs1}$$

$$C_{eq2} = C_2 + C_{db1} + C_{sg2} + C_{db2}$$

$$\frac{V_{out}}{V_{gs1}} = -g_{m1}\left(\frac{1}{\frac{1}{R_{eq}} + j\omega C_{eq2}}\right)$$

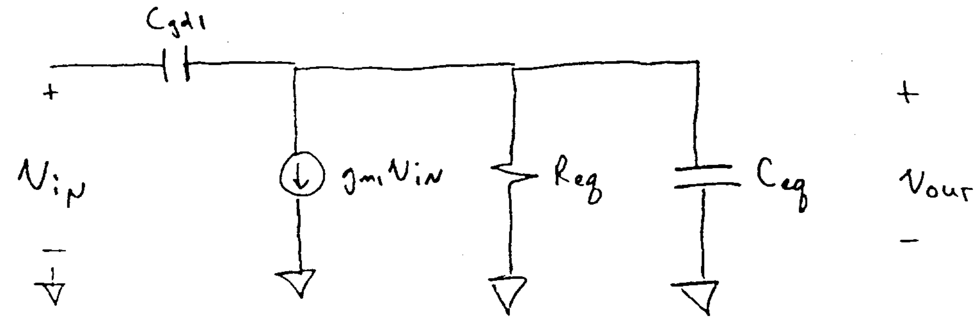
$$\frac{V_{gs1}}{V_{in}} = \frac{\frac{1}{j\omega C_{eq1}}}{\frac{1}{j\omega C_{eq1}} + R_S} = \frac{1}{1 + j\omega C_{eq1} R_S}$$

$$\frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_{gs1}} \cdot \frac{V_{gs1}}{V_{in}} = -g_{m1}\left(\frac{1}{\frac{1}{R_{eq}} + j\omega C_{eq2}}\right)\left(\frac{1}{1 + j\omega C_{eq1} R_S}\right)$$

$$\frac{V_{out}}{V_{in}} = \left(\frac{-g_{m1} R_{eq}}{1 + j\omega C_{eq2} R_{eq}}\right)\left(\frac{1}{1 + j\omega C_{eq1} R_S}\right)$$

e) The location of the zero

To determine the location of the zero use the following small signal model:



$$R_{Leq} = r_{o1} \,\|\, \frac{1}{g_{m2}} \,\|\, r_{o2}$$

$$C_{eq} = C_{sg2} + C_{db1} + C_{db2}$$

$$V_{out} = \left[(V_{in} - V_{out})\, j\omega C_{gd1} - g_{m1} V_{in} \right] \frac{1}{\frac{1}{R_{Leq}} + j\omega C_{eq}}$$

$$V_{out}\left(1 + \frac{j\omega C_{gd1}}{\frac{1}{R_{Leq}} + j\omega C_{eq}}\right) = V_{in}\left(j\omega C_{gd1} - g_{m1}\right) \frac{1}{\frac{1}{R_{Leq}} + j\omega C_{eq}}$$

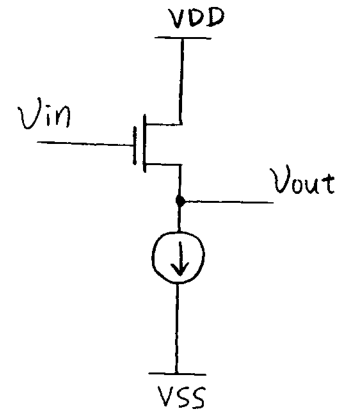
$$\frac{V_{out}}{V_{in}} = \frac{(j\omega C_{gd1} - g_{m1})\left(\frac{1}{\frac{1}{R_{Leq}} + j\omega C_{eq}}\right)}{\left(1 + \frac{j\omega C_{gd1}}{\frac{1}{R_{Leq}} + j\omega C_{eq}}\right)}$$

$$= \frac{j\omega C_{gd1} - g_{m1}}{\frac{1}{R_{Leq}} + j\omega C_{eq} + j\omega C_{gd1}}$$

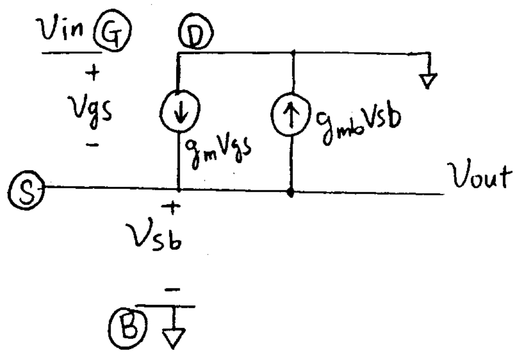
$$= \frac{-g_{m1} R_{Leq}\left(j\omega \frac{C_{gd1}}{g_{m1}} - 1\right)}{1 + j\omega (C_{eq} + C_{gd1}) R_{Leq}}$$

$$\omega_z = \frac{g_{m1}}{C_{gd1}}$$

Problem 22.5



replaced by Small Signal Values $\Rightarrow$



Notice, usually r_o is very big $r_o \gg \frac{1}{g_m}$. So, ignore the r_o (treat it as infinite).

Obviously, $g_m V_{gs} = g_{mb} V_{sb}$

$$V_{gs} = V_{in} - V_{out}, \quad V_{sb} = V_{out} \text{ and } g_{mb} = \eta g_m$$

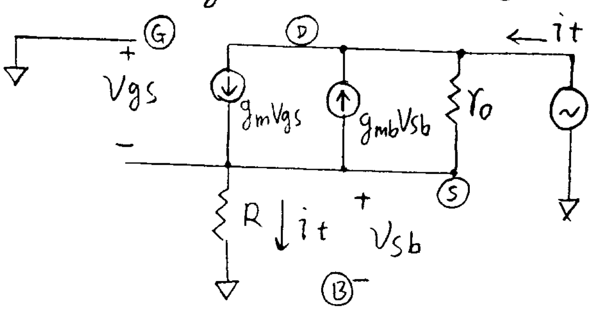
$$\Rightarrow g_m (V_{in} - V_{out}) = \eta g_m V_{out}$$

$$\Rightarrow (g_m + \eta g_m) V_{out} = g_m V_{in}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{g_m}{g_m + \eta g_m} = \frac{1}{1+\eta}$$

Problem 22.6

Small signal Model is shown below (Test source V_t is used):



$$V_t = (i_t - g_m V_{gs} + g_{mb} V_{sb}) r_o + i_t R$$

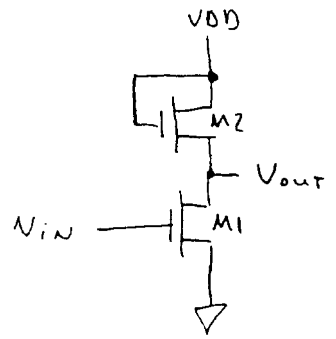
$$V_{sb} = i_t R; \quad V_{gs} = -V_{sb} = -i_t \cdot R; \quad g_{mb} = \eta g_m$$

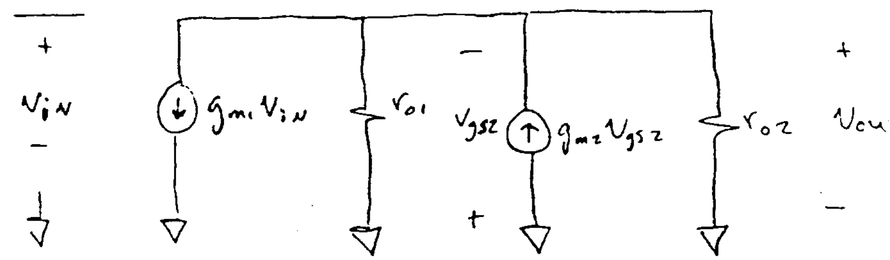
$$\Longrightarrow V_t = (i_t + g_m i_t R + \eta g_m i_t R) r_o + i_t R$$

$$R_o = \frac{V_t}{i_t} = [1 + (1+\eta) g_m R] r_o + R \approx \underline{\underline{[1 + (1+\eta) g_m R] r_o}}$$

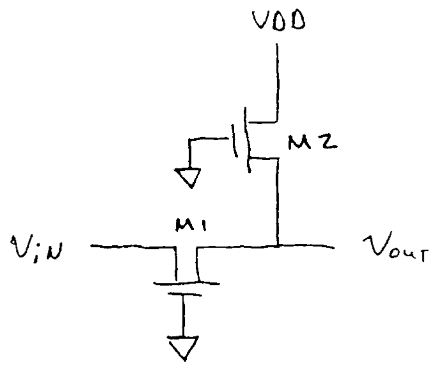
22.7

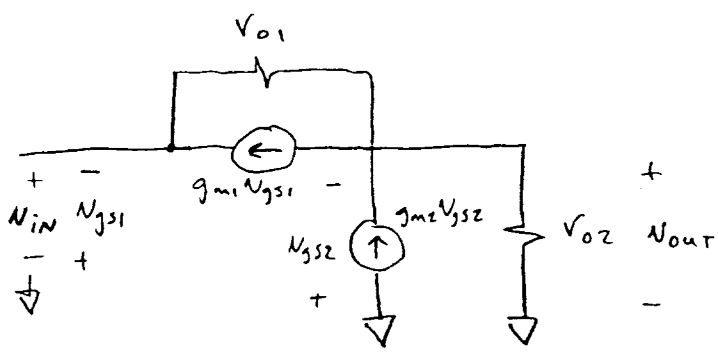
For the amplifiers shown in Fig P22.7, derive the small signal voltage gains using small signal models. Assume the MOSFETs used in these amplifiers are biased in the saturation region.





$$\frac{v_{out}}{v_{in}} = -g_{m1}\left(\frac{1}{g_{m2}} \| r_{o1} \| r_{o2}\right)$$

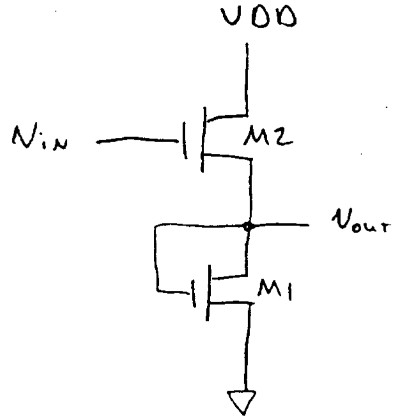


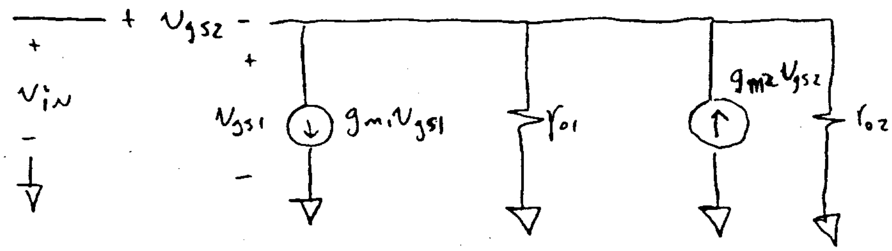


$$v_{in} = \left(\frac{v_{out}}{\frac{1}{g_{m2}} \| r_{o2}} - g_{m1} v_{in}\right) r_{o1} + v_{out}$$

$$v_{in}(1 + g_{m1} r_{o1}) = v_{out}\left(\frac{r_{o1}}{\frac{1}{g_{m2}} \| r_{o2}} + 1\right)$$

$$\frac{v_{out}}{v_{in}} = \frac{1 + g_m r_{o1}}{\frac{r_{o1}}{\frac{1}{g_{m2}} \| r_{o2}} + 1}$$





$$v_{out} = g_{m2} v_{gs2} \left(\frac{1}{g_{m1}} \,\|\, r_{o1} \,\|\, r_{o2} \right)$$

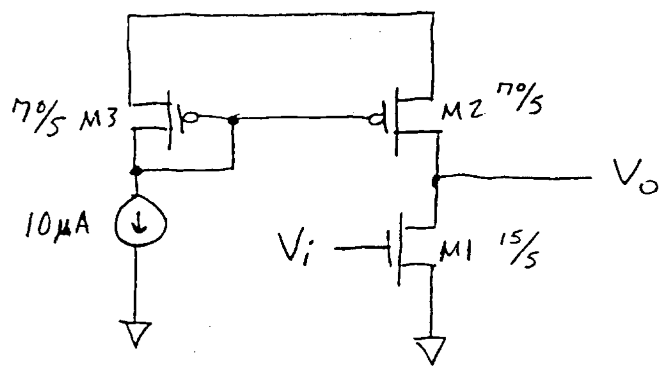
$$v_{gs2} = v_{in} - v_{out}$$

$$v_{out} = g_{m2} (v_{in} - v_{out}) \left(\frac{1}{g_{m1}} \,\|\, r_{o1} \,\|\, r_{o2} \right)$$

$$\frac{v_{out}}{v_{in}} = \frac{g_{m2} \left(\frac{1}{g_{m1}} \,\|\, r_{o1} \,\|\, r_{o2} \right)}{1 + g_{m2} \left(\frac{1}{g_{m1}} \,\|\, r_{o1} \,\|\, r_{o2} \right)}$$

22.8

Estimate the small signal voltage gain of the amplifier shown in Fig. 22.13 assuming that both M1 and M2 are biased in the saturation region.



$$\frac{V_o}{V_i} \simeq -\frac{\text{resistance in the drain}}{\text{resistance in the source}}$$

$$\simeq -\frac{r_{o2}}{\frac{1}{g_{m1}}} \simeq -g_{m1} r_{o2}$$

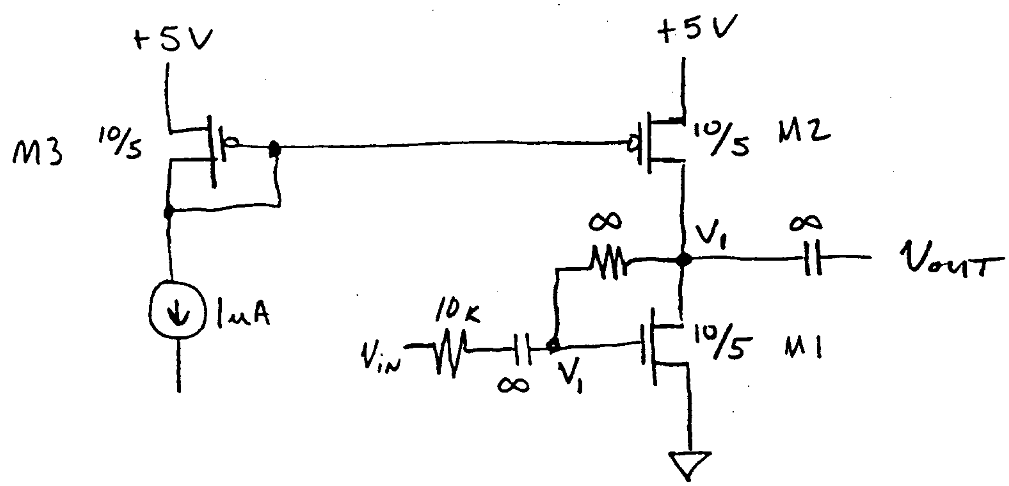
$$g_{m1} = \sqrt{2(50\mu)(15/5)(10\mu)} = 55\ \mu A/V$$

$$r_{o2} = \frac{1}{\lambda I_D} = \frac{1}{(.06)(10\mu)} = 1.67 M\Omega$$

$$\frac{V_o}{V_i} \simeq \underline{\underline{-91.85\ V/V}}$$

22.9

Repeat Problem 4 for the amplifier shown in Fig. P22.9



(a) Determine the AC voltages + currents.

$$I_{D1} = I_{D2} = \underline{1uA}$$

$$1uA = \frac{50uA/V^2}{2}(2)(V_1 - .83)^2$$

$$.02 = V_1^2 - 1.66V_1 + .6889$$

$$0 = V_1^2 - 1.66V_1 + .6689$$

$$V_1 = \underline{\underline{0.97\ V}}$$

Find V_{G2}

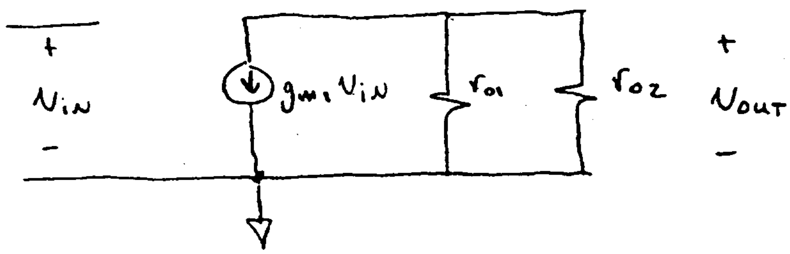
$$1uA = \frac{17uA/V^2}{2}(2)(5 - V_{G2} - .91)^2$$

$$.0588 = V_{G2}^2 - 8.18V_{G2} + 16.7281$$

$$0 = V_{G2}^2 - 8.18V_{G2} + 16.6693$$

$$V_{G2} = \underline{3.85\ V}$$

(b) Determine the small signal low frequency gain



$$\frac{v_{OUT}}{v_{IN}} = -g_{m1}(r_{o1} \| r_{o2})$$

$$g_{m1} = \sqrt{2B_1 I_{D1}} = \sqrt{2(50\mu)(2)(1\mu)} = 14.1\ \mu A/V$$

$$r_{o1} = r_{o2} = \frac{1}{\lambda I_D} = \frac{1}{.06(1\mu)} = 16.7 M\Omega$$

$$\frac{v_{OUT}}{v_{IN}} = \underline{-117.85\ V}$$

(c) Determine C_{sg1}, C_{db2}, C_{gd2}, C_{gd1}, C_{gs1}, & C_{db1}. Assume the areas of the drains and sources measure $6\mu m \times 10\mu m$.

$$C_{sg2} = \frac{2}{3} \cdot C_{ox}' \cdot W \cdot L = \frac{2}{3}(800\ aF/\mu m^2)(10\mu m \cdot 5\mu m) = 26.7\ fF$$

$$C_{db2} = C_{jdep} = \frac{cj \cdot Ad}{\left(1 - \frac{V_{db2}}{pb}\right)^{mj}} + \frac{cjsw \cdot Pd}{\left(1 - \frac{V_{db2}}{pbsw}\right)^{mjsw}}$$

$$= \frac{3.25(10)^{-4} F/m\ (10\mu m \cdot 6\mu m)}{\left(1 - \frac{4.03}{.8}\right)^{.604}} + \frac{2.54(10)^{-10}\ F/m\ (32\mu m)}{\left(1 - \frac{4.03}{.8}\right)^{.24}} = 11.8$$

$$C_{gd2} = CGDO \cdot W = .5026\ nF/m\ (10\mu m) = 5.03\ fF$$

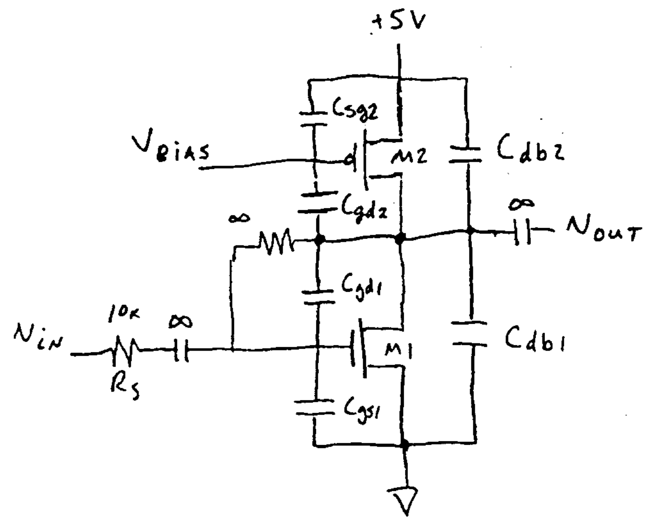
$$C_{gd1} = CGDO \cdot W = .380\ nF/m\ (10\mu m) = 3.8\ fF$$

$$C_{gs1} = \frac{2}{3} C_{ox}' \cdot W \cdot L = \frac{2}{3}(800\ aF/\mu m^2)(10\mu m \cdot 5\mu m) = 26.7\ fF$$

$$C_{db1} = C_{jdep} = \frac{cj \cdot Ad}{\left(1 - \frac{V_{db1}}{pb}\right)^{mj}} + \frac{cjsw \cdot Pd}{\left(1 - \frac{V_{db2}}{pbsw}\right)^{mjsw}}$$

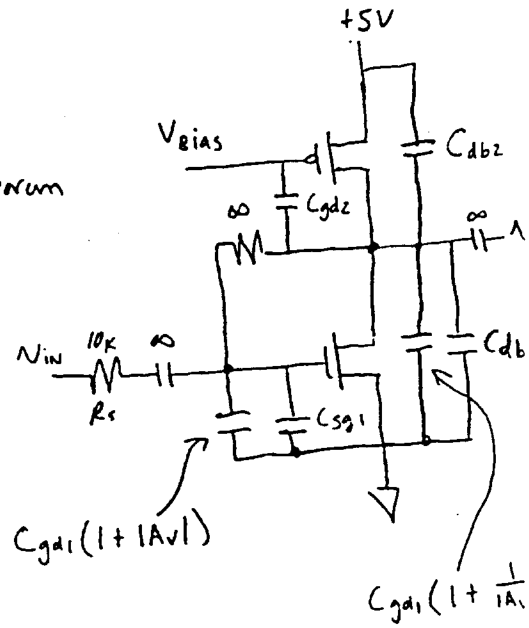
$$= \frac{1.04(10)^{-4}\ F/m^2\ (10\mu m \cdot 6\mu m)}{\left(1 + \frac{.97}{.8}\right)^{.68}} + \frac{2.17\ (10)^{-10}\ F/m\ (32\mu m)}{\left(1 + \frac{.97}{.8}\right)^{.179}} = 9.71\ fF$$

d) Determine the frequency response

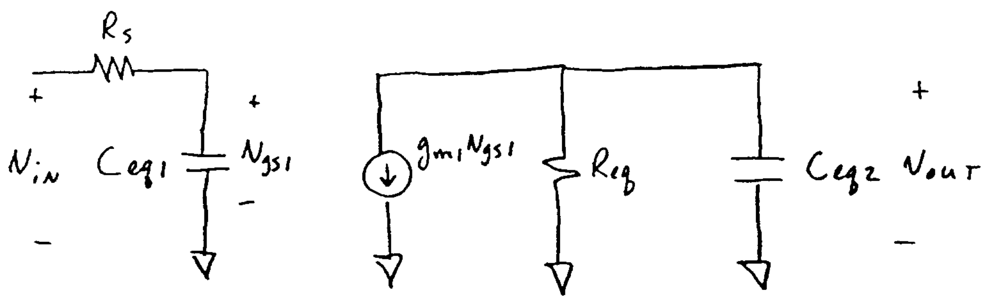


Use Miller's Therem on C_{gd1}

$\Longrightarrow$



* note: using Miller's Theorem neglects a zero



$$C_{eq1} = C_{gs1} + C_{gd1}(1+|A_v|) = 478.33 \text{ fF}$$

$$C_{eq2} = C_{db1} + C_{gd1}\left(1+\frac{1}{|A_v|}\right) + C_{gd2} + C_{db2} = 30.4 \text{ fF}$$

$$R_{eq} = r_{o1} \| r_{o2} = 8.35 \text{ M}\Omega$$

$$\frac{N_{OUT}}{N_{gs1}} = -g_{m1}\left(\frac{1}{\frac{1}{R_{eq}} + j\omega C_{eq2}}\right) = -g_{m1}R_{eq}\left(\frac{1}{1+j\omega C_{eq2}R_{eq}}\right)$$

$$\frac{N_{gs1}}{N_{IN}} = \frac{\frac{1}{j\omega C_{eq1}}}{R_S + \frac{1}{j\omega C_{eq1}}} = \frac{1}{1+j\omega C_{eq1}R_S}$$

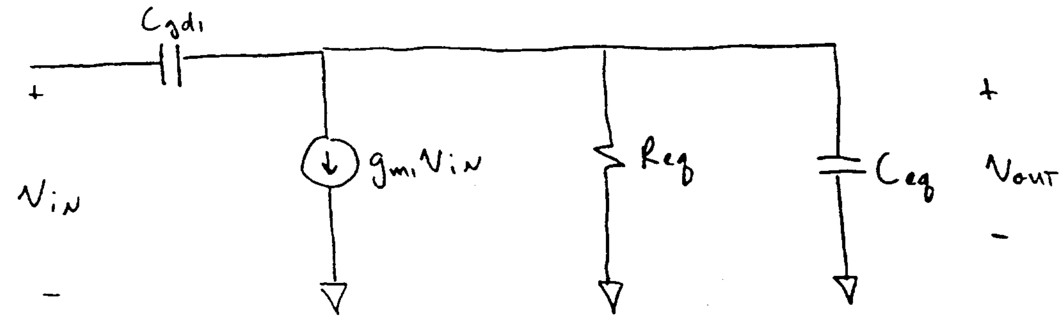
$$\frac{N_{OUT}}{N_{IN}} = \frac{N_{OUT}}{N_{gs1}} \cdot \frac{N_{gs1}}{N_{IN}} = -g_{m1}R_{eq}\left(\frac{1}{(1+j\omega C_{eq2}R_{eq})(1+j\omega C_{eq1}R_S)}\right)$$

$$\omega_{P1} = \frac{1}{C_{eq2}R_{eq}} = \underline{3.94(10)^6 \text{ rad/s}} \Longrightarrow f_{P1} = \underline{627 \text{ kHz}}$$

$$\omega_{P2} = \frac{1}{C_{eq1}R_S} = \underline{209.06(10)^6 \text{ rad/s}} \Longrightarrow f_{P2} = \underline{33.27 \text{ MHz}}$$

e) Determine the location of the zero in the frequency response.

Use the following small signal model ignoring C_{gs1}.



$$R_{eq} = r_{o1} \| r_{o2} = 8.35\ M\Omega$$

$$C_{eq} = C_{db1} + C_{db2} + C_{gd2}$$

$$V_{OUT} = \left[(V_{IN} - V_{OUT}) j\omega C_{gd1} - g_{m1} V_{IN} \right] \frac{1}{\frac{1}{R_{eq}} + j\omega C_{eq}}$$

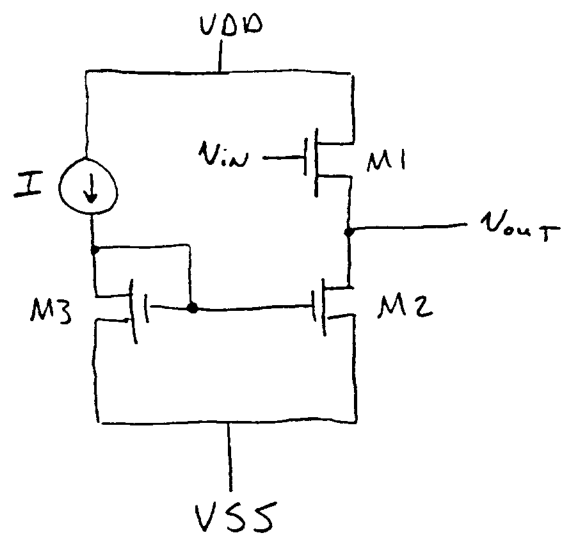
$$\frac{V_{OUT}}{V_{IN}} = \frac{\dfrac{j\omega C_{gd1} - g_{m1}}{\frac{1}{R_{eq}} + j\omega C_{eq}}}{1 + \dfrac{j\omega C_{gd1}}{\frac{1}{R_{eq}} + j\omega C_{eq}}} = \frac{j\omega C_{gd1} - g_{m1}}{\frac{1}{R_{eq}} + j\omega C_{eq} + j\omega C_{gd1}}$$

$$= \frac{-g_{m1} R_{eq} \left(1 - j\omega \frac{C_{gd1}}{g_{m1}}\right)}{1 + j\omega (C_{eq} + C_{gd1}) R_{eq}}$$

$$\omega_{Z1} = \frac{g_{m1}}{C_{gd1}} = 3.710(10)^9\ \text{rad/s}$$

22.10

With respect to Fig. 21.17a, what is the small-signal resistance looking into the source of M1? the drain of M2? What is the small signal resistance from the gate of M2 to ground?



- Source of M1

$$R_{INS1} = \frac{1}{g_{m1}}$$

- Drain of M2

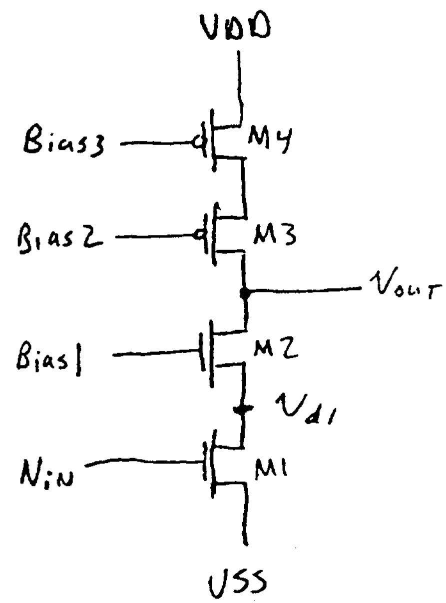
$$R_{IND2} = r_{o2}$$

- The Gate of M2 to ground

$$R_{ING3} = \frac{1}{g_{m3}}$$

22.11

Verify that Eq. (22.51) is correct. With respect to Fig. 22.20, what is the small signal resistance looking into the drain of M4 (in terms of g_{mn}, g_{mp}, r_{on}, and r_{op})? the source of M3? the drain of M3? the source of M2? the drain of M1? the drain of M2? the total small-signal resistance at the output?



$$R_{inD4} = r_{op}$$

$$R_{inS3} = \frac{r_{op} + R_{inD2}}{1 + g_{mp} r_{op}}$$

$$R_{inD3} = r_{op}(1 + g_{mp} r_{op}) + r_{op}$$

$$R_{inS2} = \frac{r_{on} + R_{inD3}}{1 + g_{mn} r_{on}}$$

$$R_{inD1} = r_{oN}$$

$$R_{inD2} = r_{oN}(1 + g_{mn} r_{oN}) + r_{oN}$$

$$R_{OUT} = R_{inD2} \parallel R_{inD3}$$

$$R_{OUT} = \underline{\left[r_{on} + r_{oN}(1 + g_{mn} r_{oN})\right] \parallel \left[r_{op}(1 + g_{mp} r_{op}) + r_{op}\right]}$$

$$\frac{v_{d1}}{v_{in}} = -\frac{\cancel{R_{inS2} \parallel R_{inD1}}}{\frac{1}{g_{m1}}} \cdot \frac{R_{inD2} \parallel R_{inD3}}{\cancel{R_{inS2} \parallel R_{inD1}}}$$

$$\frac{v_{OUT}}{v_{d1}} = \underline{-g_{m1} \cdot R_{OUT}}$$

Problem 22.12

Choosing sizes, M1, M2 $\rightarrow$ $15\mu/5\mu$, M3, M4 $\rightarrow$ $70\mu/5\mu$

$$g_{mn} = \sqrt{2\beta_n I} = \sqrt{2 \times 50\,\mu A/V^2 \times \frac{15\mu}{5\mu} \times 5\,\mu A} = 5\sqrt{60}\,\mu A/V = 38.7\,\mu A/V$$

$$g_{mp} = \sqrt{2\beta_p I} = \sqrt{2 \times 17\,\mu A/V^2 \times \frac{70\mu}{5\mu} \times 5\,\mu A} = 48.8\,\mu A/V$$

$$r_{on} = r_{op} = \frac{1}{\lambda I} = \frac{1}{0.06 \times 5\,\mu A} = \frac{10}{3}\,M\Omega$$

Therefore, from problem 22.4, we have

$$R_{d1} = r_{on} = 3.33\,M\Omega \qquad R_{d4} = r_{op} = 3.33\,M\Omega$$

$$R_{d2} = g_{mn} r_{on}^2 = 38.7\,\mu A/V \times \left(\frac{10}{3}\,M\Omega\right)^2 = 430\,M\Omega$$

$$R_{s2} = \frac{g_{mp}}{g_{mn}} \cdot \frac{r_{op}^2}{r_{on}} = \frac{48.8}{38.7} \times \frac{10}{3}\mu = 4.20\,M\Omega$$

$$R_{d3} = g_{mp} r_{op}^2 = 48.8 \times \left(\frac{10}{3}\right)^2 = 542.22\,M\Omega$$

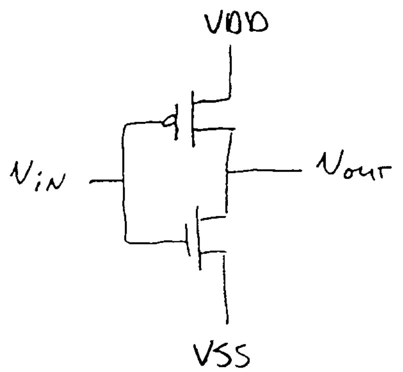
$$R_{s3} = \frac{g_{mn}}{g_{mp}} \frac{r_{on}^2}{r_{op}} = \frac{38.7}{48.8} \times \frac{10}{3}M = 2.64\,M\Omega$$

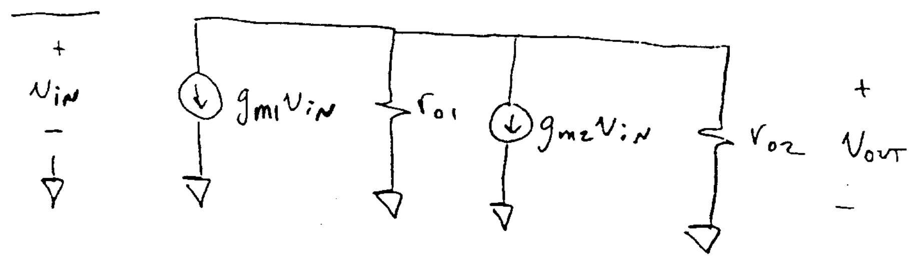
$$R_o = \frac{g_{mn} g_{mp} r_{on}^2 r_{op}^2}{g_{mn} r_{on}^2 + g_{mp} r_{op}^2} = \frac{38.7 \times 48.8}{38.7 + 48.8} \times \left(\frac{10}{3}\right)^2 = 239.82\,M\Omega$$

$$A_v = -g_{m1} R_o = -38.7\mu \times 239.82\,M = \underline{\underline{-9281\ V/V}}$$

22.13

Using the small signal models, verify that Eq. (22.62) is correct.





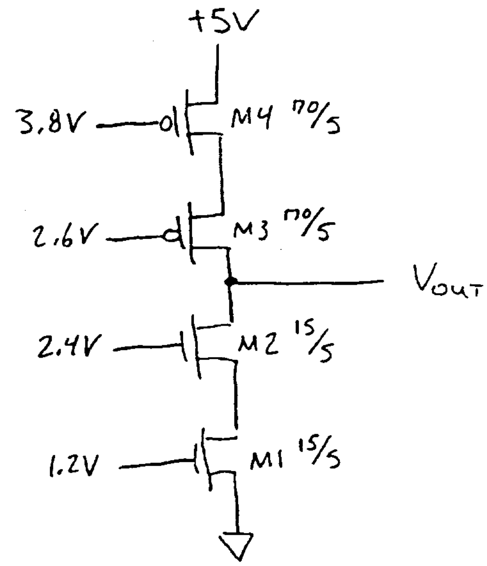
$$v_{OUT} = -(g_{m1} + g_{m2})\, v_{IN}\, (r_{o1} \| r_{o2})$$

$$\frac{v_{OUT}}{v_{IN}} = -(g_{m1} + g_{m2})(r_{o1} \| r_{o2})$$

checks!

22.14

For the amplifier section shown in Fig. P22.14, estimate the minimum and maximum voltages allowable on the output in order to keep all MOSFETs in the saturation region.



Find $V_{OUT}(min)$:

$$V_{DS2} \geq V_{GS2} - V_{THN}$$

$$V_{OUT(min)} = 2.4 - .83$$

$$V_{OUT(min)} = \underline{\underline{1.57\ V}}$$

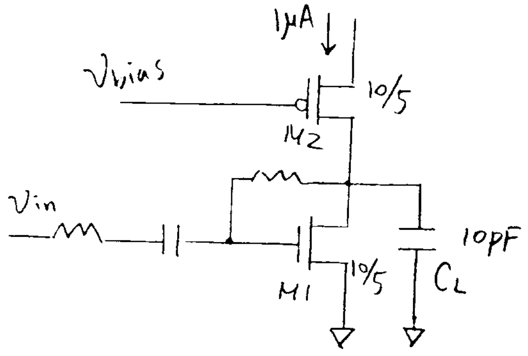
Find $V_{OUT}(max)$:

$$V_{SD3} \geq V_{SG3} - |V_{THP}|$$

$$V_{OUT(MAX)} = 2.6 + .91$$

$$V_{OUT(max)} = \underline{\underline{3.51\ V}}$$

Problem 22.15



The maximum rate the load capacitance can be charged is:

$$SR = \frac{1\mu A}{10\,pF} = \underline{\underline{0.1\,V/\mu s}}$$

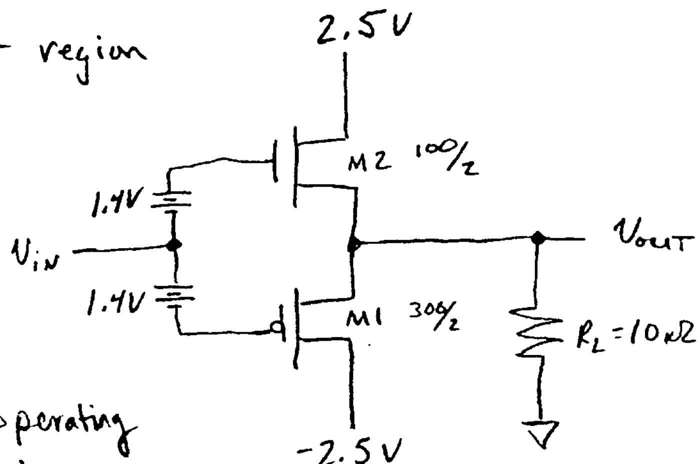
Since the voltage on gate of M1 is not fixed, there is no slew-rate limitation for discharging the capacito

22.16

For the circuit shown in Fig. P22.16, use SPICE to plot the output voltage against the input voltage. What limits the minimum and maximum output voltage swing? Also plot the current through M1 + M2 against the input voltage.

If we dont care what region M1 + M2 are operating:

$V_{O(max)}$ + $V_{O(min)}$ are limited by VDD + VSS.



Keeping both M1 + M2 operating in the saturation region:

$V_{O(max)}$ is limited by the point where M2 becomes nonsat.

$$V_{DS1} = V_{GS1} - V_{THN}$$
$$2.5 \simeq V_{IN} + 1.4 - .83$$

$V_{IN} \simeq \underline{1.93\ V}$ ← this is neglecting the bulk effect so this value is little low

$V_{O(min)}$ is limited by the point wher M1 becomes nonsat.

$$V_{SD2} = V_{SG2} - V_{THP}$$
$$2.5 \simeq -V_{IN} + 1.4 - .91$$

$V_{IN} \simeq \underline{-2.01}$ ← neglecting bulk effect

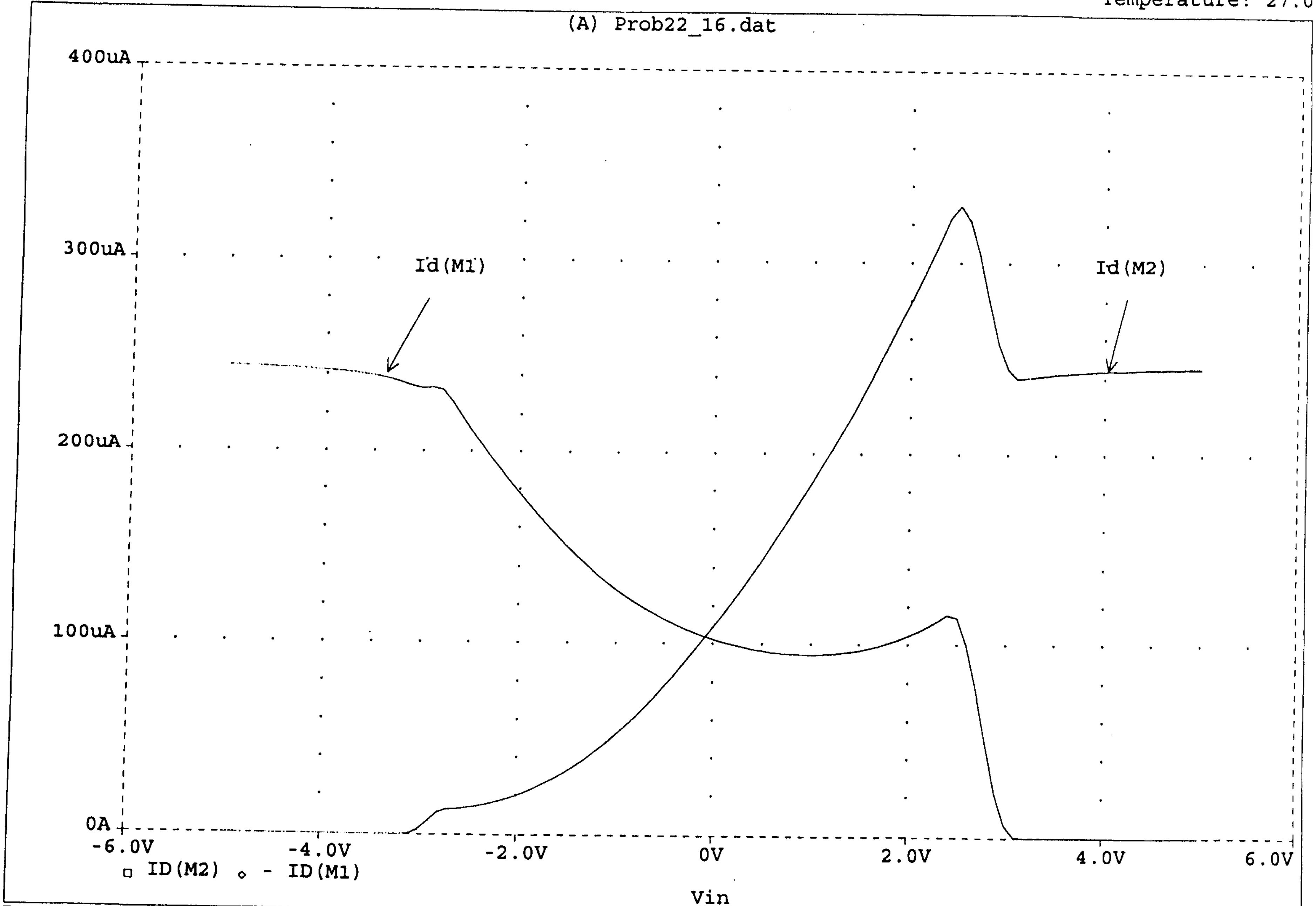
```
* Problem 22.16

M1 1 2 3 4 CMOSPB L=2U W=300U
M2 4 5 3 1 CMOSNB L=2U W=100U
V1 5 6 DC 1.4
V2 6 2 DC 1.4
Vin 6 0 DC 0
RL 3 0 10k
VDD 4 0 DC 2.5
VSS 1 0 DC -2.5

* BSIM model for n-channel CN20
.MODEL CMOSNB NMOS LEVEL=4

* BSIM model for p-channel CN20
.MODEL CMOSPB PMOS LEVEL=4

.probe
.DC Vin -5 5 .1
.end
```

* Problem 22.16

Date/Time run: 03/04/98 09:45:52

Temperature: 27.0

(A) Prob22_16.dat



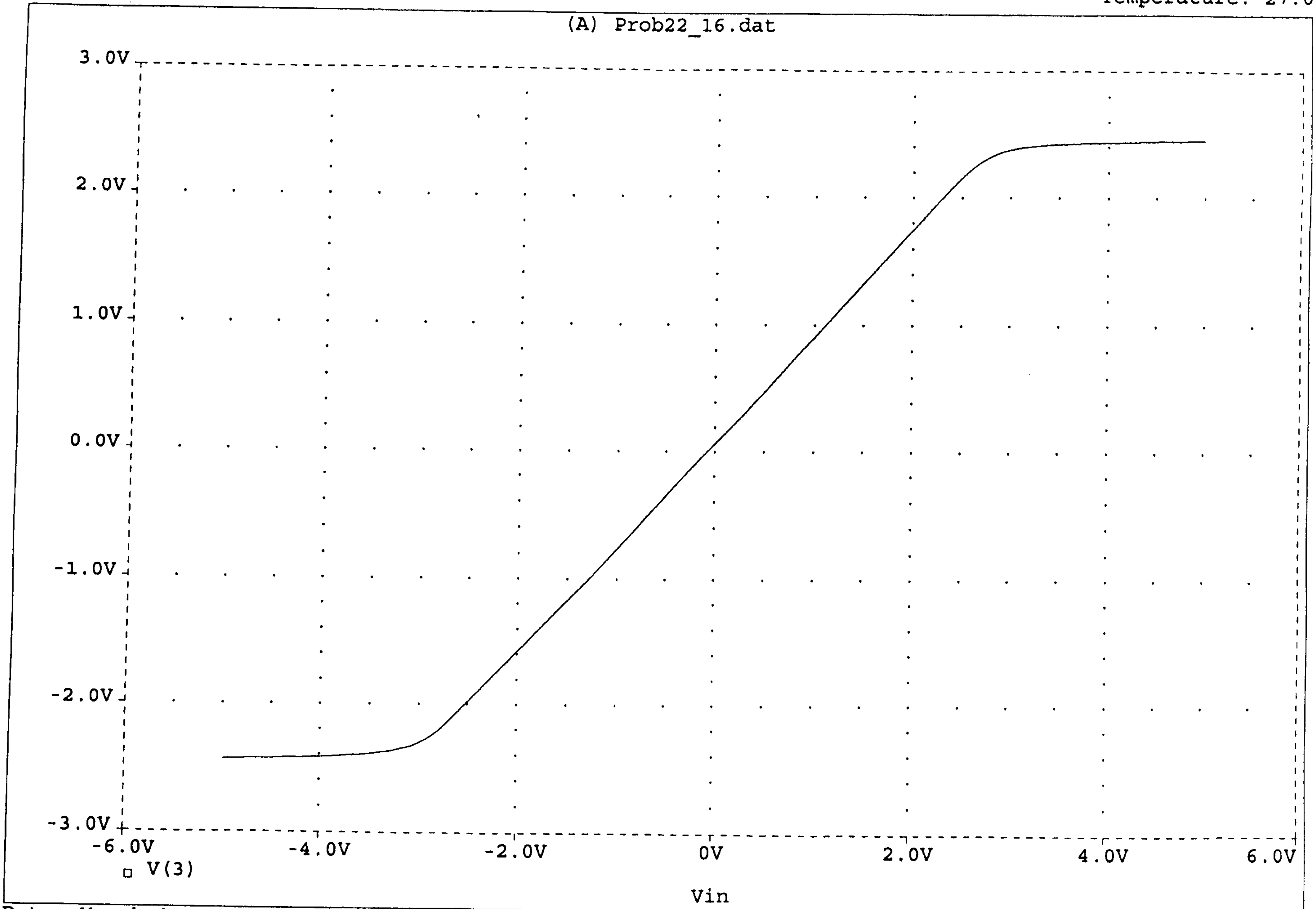
Date: March 04, 1998

Time: 09:52:06

* Problem 22.16

Date/Time run: 03/04/98 09:45:52

Temperature: 27.0



Date: March 04, 1998

Time: 09:49:31