EECS 140

FALL 1996

MIDTERM #2

NAME <u>SOLUTIONS</u>

$k_n' = k_p' = 10^{-4}\ A/V^2$

$\gamma_n = \gamma_p = 0$

$\lambda_n = \lambda_p = .01$

$V_{Tn} = V_{TP} = 1V.$

$C_{gd} = 1ff$

$C_{db} = 10ff$

$C_{gs} = 100ff$

$C_{gb} = 5ff$

$C_{sb} = 10ff$

SHOW YOUR WORK!

1 a 2.1V.

b 220 MΩ

c .45 m℧

d 203 kRAD/SEC

X

a 3700

b 400 RAD/SEC

c 9.4 MRAD/SEC

4 a SHUNT-SERIES

b .01

c X

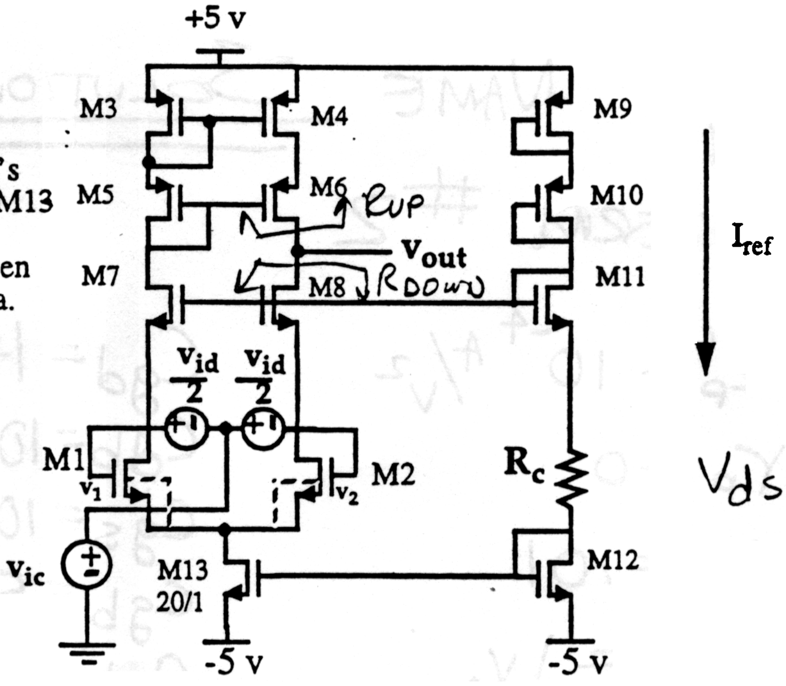
d 25

e 2.5 MΩ

Problem 1)

All transistor W/L's are 10, except for M13

Assume R_c is chosen so that I_{ref}=100μa.



$$V_{dSAT} = \left(\frac{2 I_{DS}}{k' W/L}\right)^{1/2} = \left(\frac{2 \cdot 10^{-4}}{10^{-4} \cdot 10}\right)^{1/2} = .45V.$$

$$r_o = \frac{1}{\lambda I_{DS}} = 1M\Omega$$

$$g_m = .45 m℧$$

a) What is the DC voltage at vout? 2.1V

$$2V_T + 2V_{DSAT} = 2.9$$

$$5 - 2.9 = 2.1V,$$

b) What is Rout (seen at v_{out})? 2.25×10^8

$$R_{UP} = r_o(1 + g_m r_o) = 10^6 \cdot .45 \times 10^{-3} \cdot 10^6 = 4.5 \times 10^8 \Omega$$

$$R_{DOWN} = R_{UP}$$

$$R_{OUT} = R_{UP} \| R_{DOWN}$$

c) What is Gm = i_{out}/vid (i_{out} is the current out if v_{out} is grounded)? .45 m℧

$$G_m = g_m = .45 m℧$$

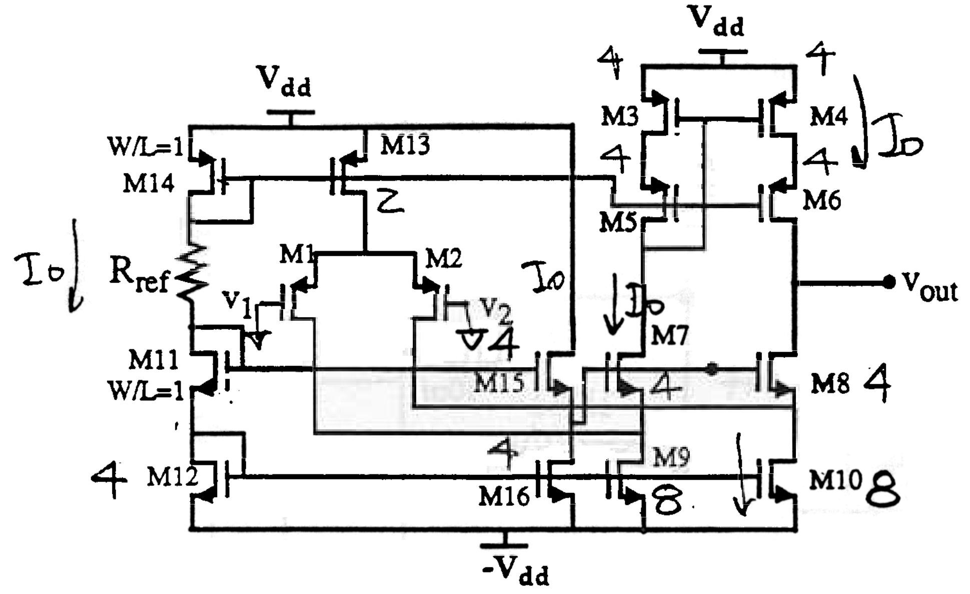
c) What isthe -3db freq of the gain,v_{out}/v_{id}? 2.03×10^5 RAD/SEC

$$\omega_{3dB} = \frac{1}{22 \times 10^{-15} \times 2.2 \times 10^8} = 2.03 \times 10^5 \frac{rad}{s}$$

AT THE V_{OUT} NODE

$$C_{OUT} = C_{db6} + C_{gd6} + C_{db8} + C_{gd8} = 22 fF$$

Problem 2)



Choose the values of the W/L's for all the transistors (except for M11 and M14 which are 1), so that the currents in all transistors have the same value, Io, except for M9, M10 and M13 which are twice that value or 2Io. Also, choose those sizes so that M3,M4, M9 and M10 are biased at the edge of saturation. $\lambda=0$ for this problem.

M1 ANY VALUE

M2 SAME AS M1

M3 4

M4 4

M5 4

M6 4

M7 4

M8 4

M9 8

M10 8

M12 4

M13 2

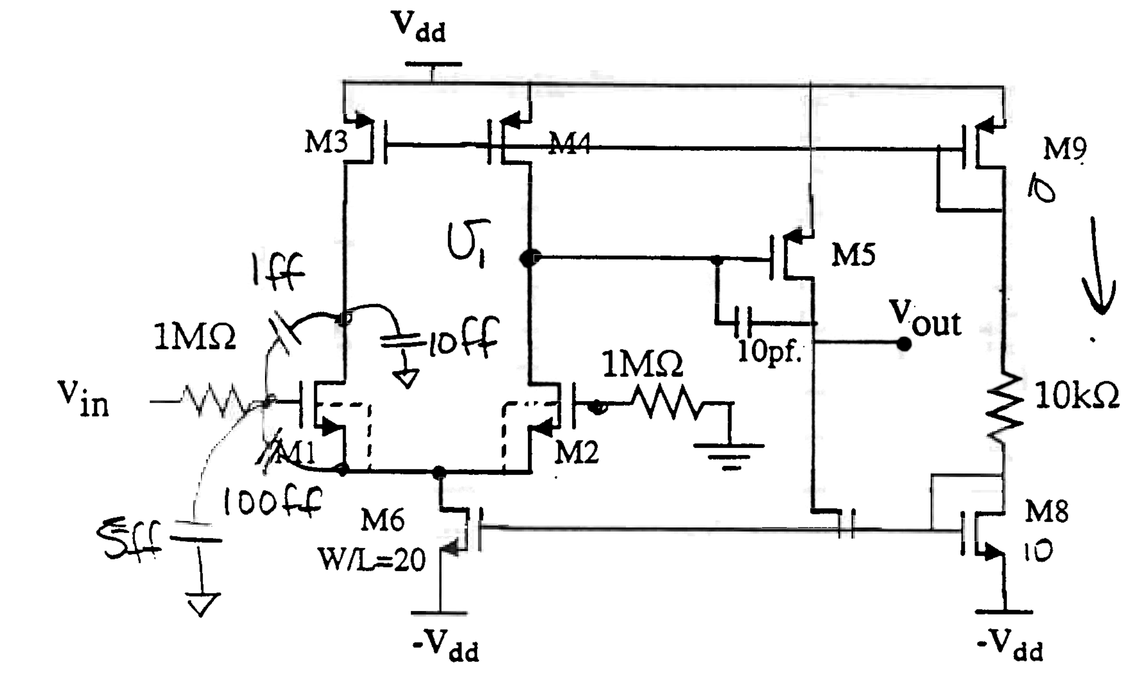
M15 4

M16 4

Problem 3)

All W/L's=10 except for M6=20.

Vdd=5



$$I_{REF} = \frac{10 - 2V_T - 2V_{DSAT}}{10k\Omega}$$

$= .8\,ma - .141\,ma\ (I_{cmin})$

$I_{REF} = .68\,ma$

$g_m = 1.17 \times 10^{-3}$

$r_o = 147\,k\Omega$

a) What is the DC gain 3.7×10^3

$$\frac{v_{OUT}}{v_{in}} = \underbrace{\left(\frac{g_m}{2}\left(\frac{r_o}{2}\right)\right)}_{1^{ST}\ STAGE}\underbrace{\left(g_m\frac{r_o}{2}\right)}_{2^{ND}\ STAGE} = \frac{(g_m r_o)^2}{8}$$

FOR PARTS b) & c) USE $g_m = 10^{-3}$ & $r_o = 1M\Omega$ FOR ALL TRANSISTORS

b) What is the lowest frequency pole 400 RAD/SEC

M5: $C_{gs} = 10pf$

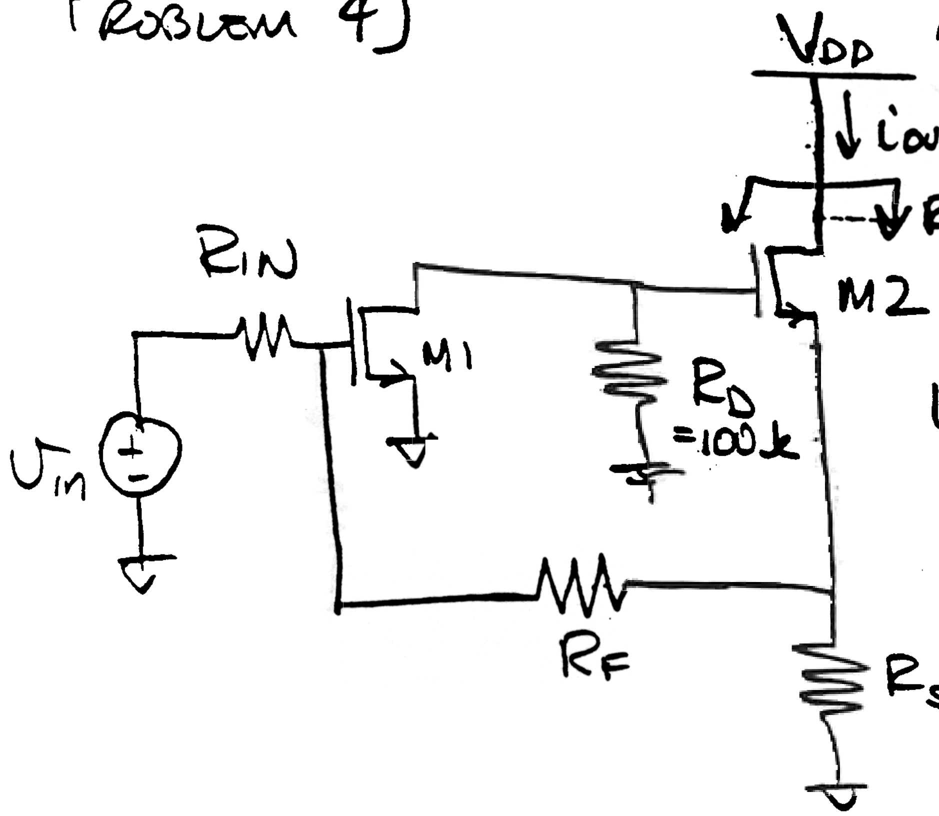
$$W_1 = \frac{1}{r_o/2 \cdot 10^{-11} \cdot \frac{g_m r_o}{2}} = 400\ RAD/SEC$$

CHECK C_{MILLER} ON M2 $\left(\frac{g_m r_o}{4}\right) 1ff = 172ff$ SMALL WITH SAME r_o

c) What is next lowest frequency pole 9.4×10^6 RAD/SEC

SINCE M5 AND THE 10pf CAP LOOK LIKE $1/g_m$ at $W \gg W_1$ THE GAIN AT v_1 IS SMALL THUS NO MILLER MULT. THE EFFECTIVE CAPACITANCE AT THE GATE OF M2 IS $\approx C_{gs_2} + C_{gd_2} + C_{gb_2} \approx 106\,ff$. $W_2 = \frac{1}{10^6 \cdot 1.06 \times 10^{-13}}$ -- [illegible] RAD/SEC

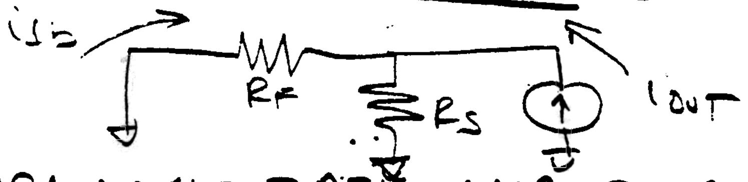
PROBLEM 4)



LET
$g_{m1} = g_{m2} = 10^{-3}\ \mho$
$r_{o1} = r_{o2} = 10^{6}\ \Omega$
$R_S = 1k\Omega$
$R_{IN} = R_F = 100k\Omega$

a) WHAT KIND OF FEEDBACK? SHUNT-SERIES

WHAT IS f? $-\frac{R_S}{R_F+R_S}$



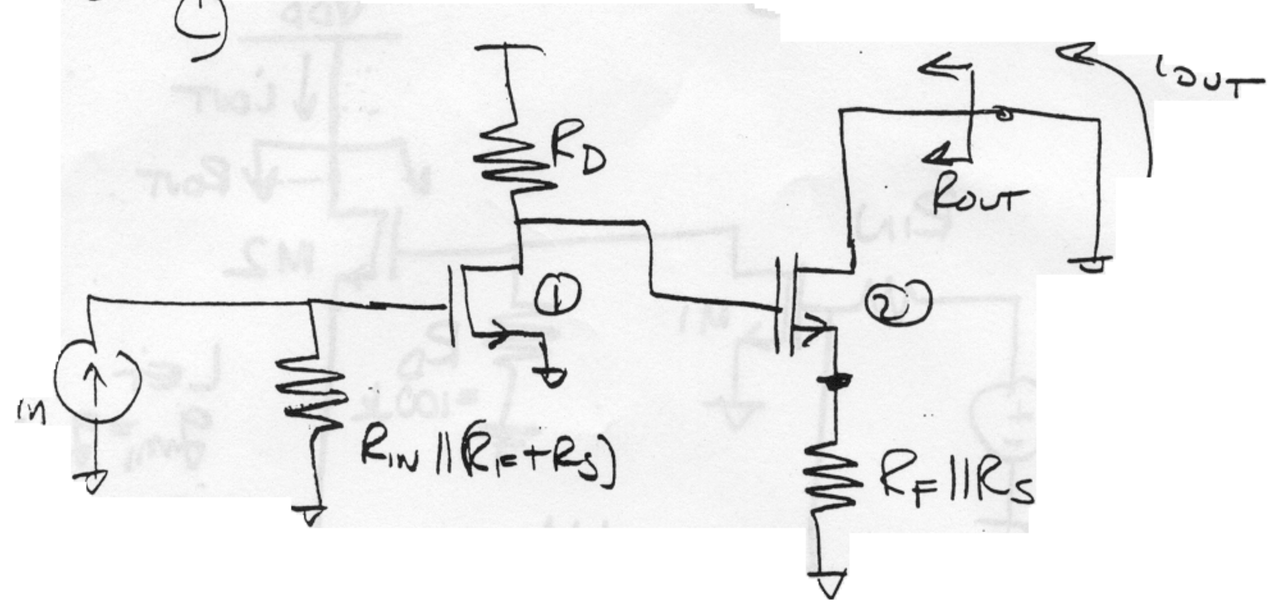
DRAW THE BASIC AMPLIFIER, WITH LOADING OF THE FEEDBACK NETWORK, ON THE NEXT PAGE.

d) CALCULATE THE GAIN OF THE BASIC AMPLIFIER WITH LOADING.

WHAT IS ROUT?

4)

c)



d)

$$a_i = g_{m1}\left[R_{IN} \| (R_F + R_S)\right](R_D \| r)\left[\frac{g_{m2}}{1 + g_{m2}(R_F \| R_S)}\right]$$

$$10^{-3}(50k)\,91k\ \frac{10^{-3}}{(1 + 10^{-3}/1k)}$$

$$= 2300$$

e) r_{OUT}'

$$(R_F \| R_S) + r_{o2}(1 + g_{m2}(R_F \ R_S))$$

$$k\Omega + 10^6(1 + 1) \quad 2 \times 10^6\,\Omega$$

$$R_{OUT} = (1 + T')\,r_{OUT}' = (1 + 23)(2 \times 10^6)\,\Omega$$

$$48 \times 10^6\,\Omega$$

$$T \quad af = 23$$