RW Brodersen
EECS 140
SPRING 1996

NAME SOLUTIONS

SHOW YOUR WORK

1a SHUNT - SHUNT (2)

b $1/R_3$ (3)

c $R_1 \| R_2 \left(\frac{1}{1+x}\right) \frac{g_m(R_4 \| R_3)}{1+g_m(1+x)R_5}$ (3)

d $\frac{R_4 \| R_3}{1+aR_f}$ (3)

60

2 a SERIES-SHUNT (2)

b .1 (3)

c 2.9×10^5 (3)

d 5Ω (3)

3 (10)

4 C_c 1.1 pf (8)

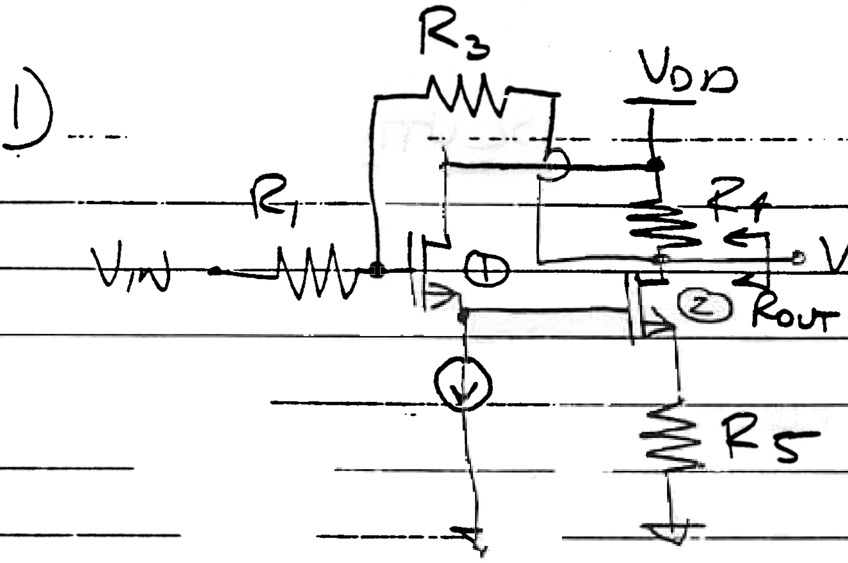
5 ω_{3dB} 35 kRAD/SEC (8)

6 ω_{3dB} 4 kRAD/SEC (5)

$\omega_{90°}$ 4 kRAD/SEC (5)

7 .4 MRAD/SEC, 50 MRAD/SEC 9 GRAD/SEC (8)

1)



$g_{m1} = g_{m2} = g_m$

$\chi_1 = \chi_2 = \chi$

$r_{o1} = r_{o2} = r_o$

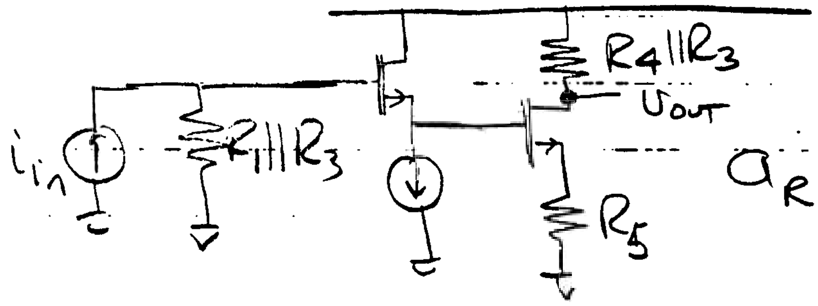
$R_1, R_3, R_4, R_5 \ll r_o$

a) WHAT KIND OF FEEDBACK IS THIS

SHUNT-SHUNT

b) WHAT IS f? $\frac{i_{fb}}{v_{OUT}} = \frac{1}{R_3}$

c) WHAT IS THE GAIN OF THE BASIC AMPLIFIER WITH LOADING?



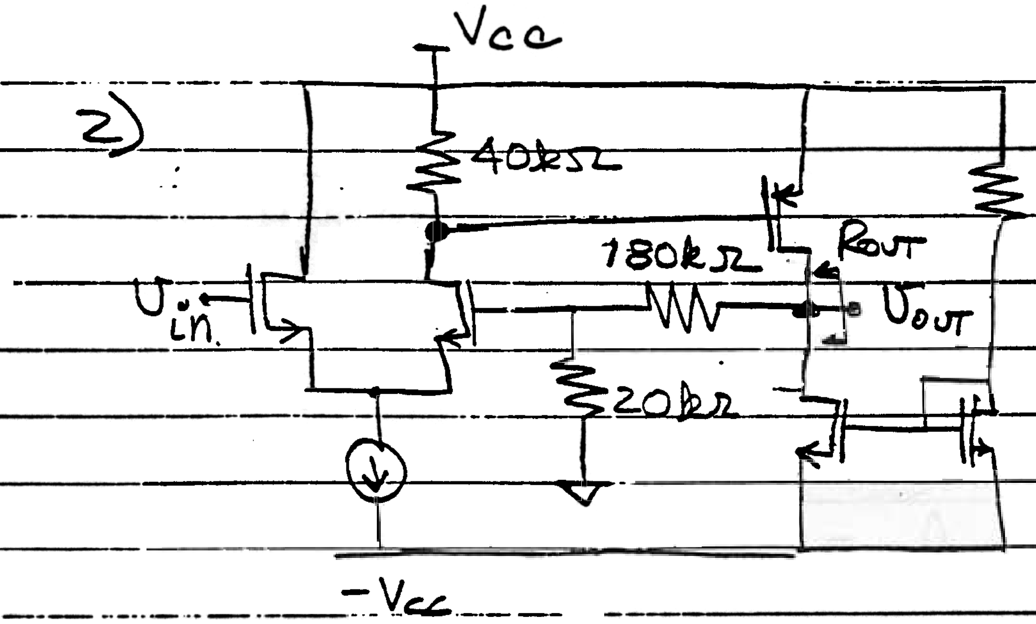
$$a_R = \frac{v_{OUT}}{i_{in}} = R_1 \| R_3 \left(\frac{1}{1+\chi}\right) \frac{g_m(R_4 \| R_3)}{1 + g_m(1+\chi) R_5}$$

d) WHAT IS ROUT?

$$\frac{R_4 \| R_3}{1 + a_R f}$$

✓

2)



$g_m = .01$

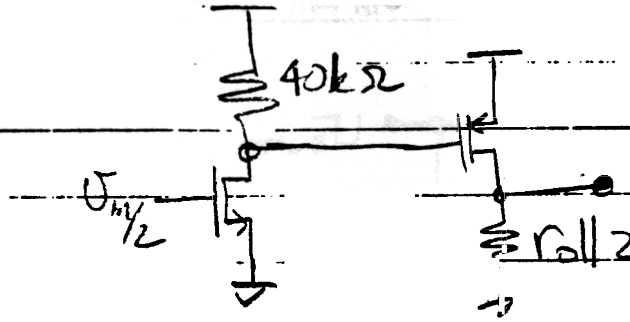
$\chi =$

$r_o = 1M\Omega$

a) WHAT KIND OF FEEDBACK? SERIES-SHUNT

b) WHAT IS f? .1

c) WHAT IS THE GAIN OF THE BASIC AMPLIFIER WITH LOADING? 2.9×10^5



$$a_v = \frac{g_m 40k}{2} \; g_m (r_o \| 200k \| r_o)$$

200k

$r_o \| 200k \| r_o$ $= (200)(1430) = a_v$

$= 2.9 \times 10^5$

d) WHAT IS THE OUTPUT RESISTANCE, R_{OUT}?

5Ω

$$\frac{143k}{(1 + .1 a_v)} = \frac{143k}{2.9 \times 10^4} = 5$$

3) DESIGN A CIRCUIT WHICH MEETS THE FOLLOWING SPECIFICATIONS

$R_{IN} = 10k\Omega$

$R_{OUT} < .1\Omega$

$A_v = \frac{v_{OUT}}{v_{in}} = 2$

ASSUME YOU CAN'T USE MORE THAN 6 10 kΩ RESISTORS AND 3 TRANSISTORS WITH THE FOLLOWING SPECIFICATIONS (NMOS)

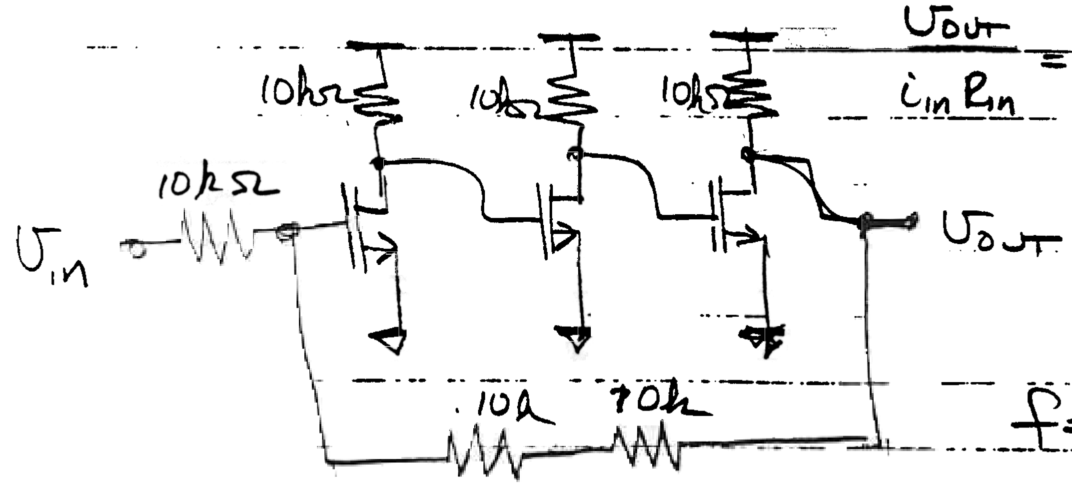
$g_m = .01$

$r_o = 1M\Omega$

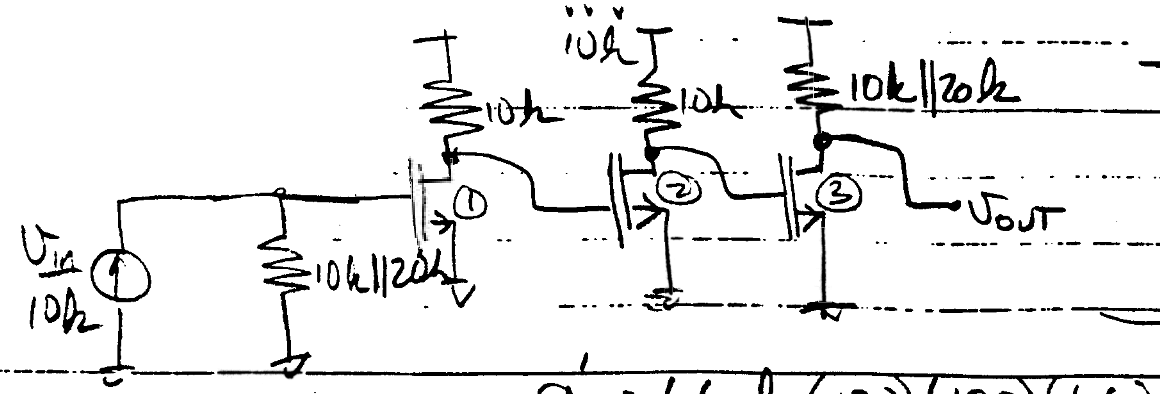
$\chi = 0$

$\frac{v_{OUT}}{i_{in}} = \frac{1}{f}$

$\frac{v_{OUT}}{i_{in} R_{in}} = \frac{1}{f R_{in}} = \frac{20k}{10k} = 2$



$f = \frac{1}{5k}$



$T = a_R f$

$R_{OUT} = \frac{3.3k}{1+T}$

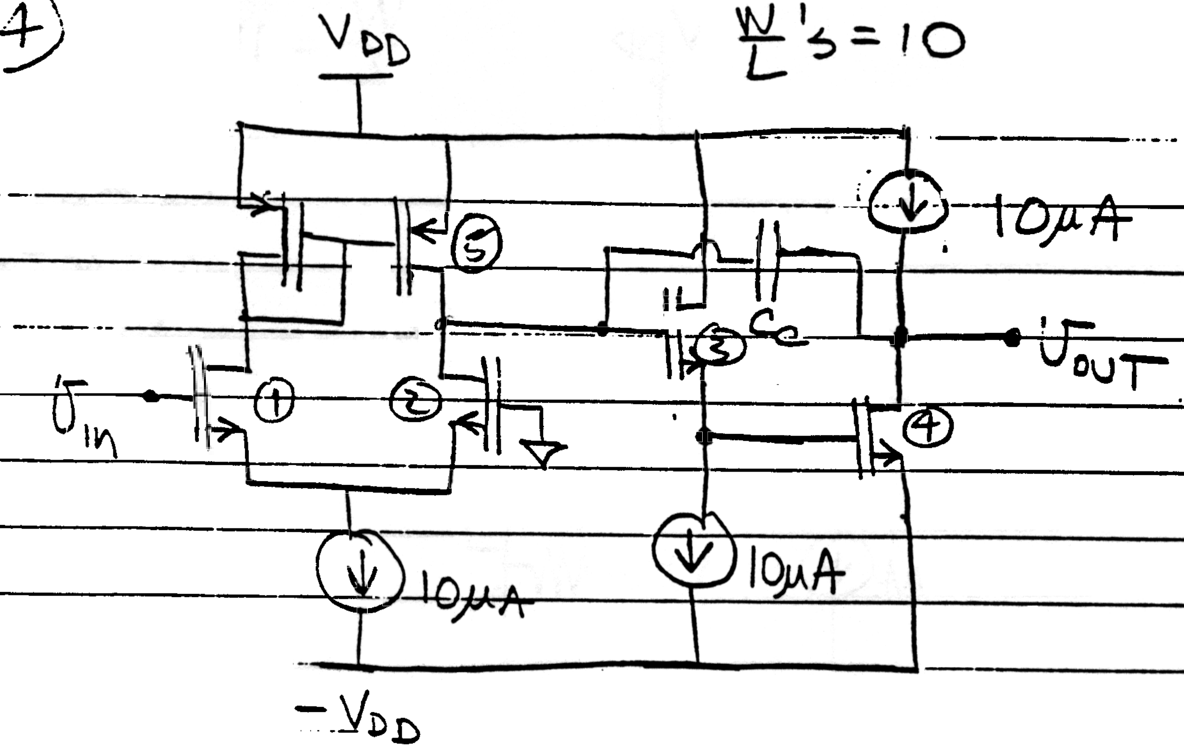
$= \frac{3.3k}{8.7\times10^5}$

$\approx 3.8 m\Omega$

$a_R' = 6.6k(100)(100)(66)$

4)

$\frac{W}{L}$'s = 10



$C_{gd} = .1pf$ $\quad k_n' = k_p' = 100\mu A/V^2$

$C_{gs} = 1pf$

$C_{db} = .1pf$ $\quad V_{Tn} = V_{Tp} = 1V.$

$C_{sb} = .1pf$ $\quad \lambda_n = \lambda_p = .1$

$\gamma_n = \gamma_p = 0$

CALCULATE THE VALUE OF C_c WHICH WILL GIVE A 3dB FREQUENCY OF 1kHz.

C_c 1.1 pf

$$g_{m4} = \left(2k'I\frac{W}{L}\right)^{1/2} = \left(2\times10^{-4}\times10\times10^{-6}\times10\right)^{1/2} = 1.41\times10^{-4}$$

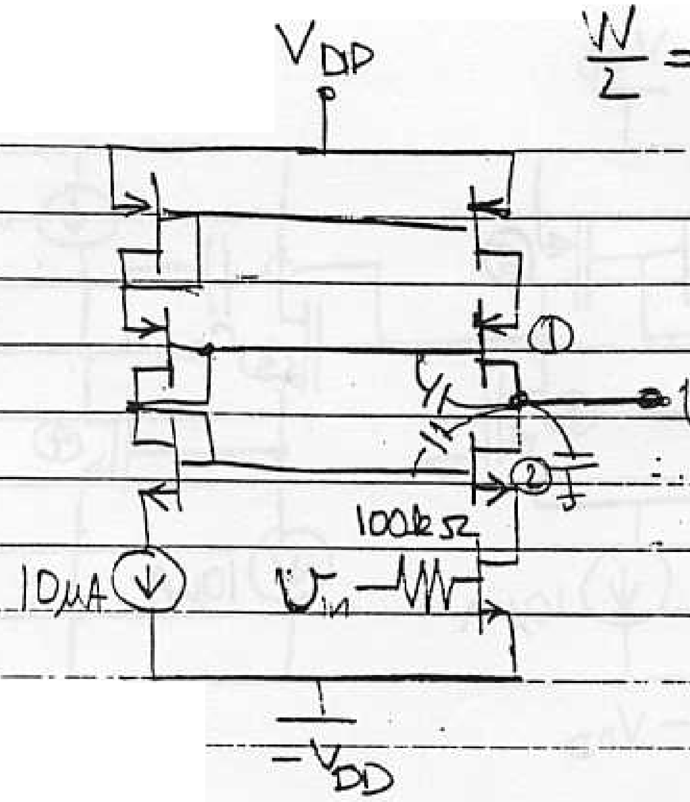
$$r_{o4} = \frac{1}{.1\times10^{-5}} = 1M\Omega \qquad r_{o2} = r_{o5} = \frac{1}{.1\times5\times10^{-6}} = 2M\Omega$$

$$C_m = C_c(1 + g_{m4}r_{o4})$$

$$1kHz = \frac{1}{2\pi\times(r_{o5}\|r_{o2})C_M} \qquad C_c = \frac{1}{2\pi\times10^3\times10^6(g_{m4}r_{o4})}$$

$$= 1.1\ pf$$

5)



$\frac{W}{L} = 10$

$k_n' = k_p' = 100\ \mu A/V^2$

$\lambda_n = \lambda_p = .1$

$\gamma_n = \gamma_p = 0$

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

$C_{gs} = 1pf$

$C_{gd} = .1pf$

$C_{sb} = .1pf$

$C_{db} = .1pf$

WHAT IS THE 3dB FREQ. OF THIS CIRCUIT? 35 KRAD/SEC

$g_m = 1.4 \times 10^{-4}$

$r_o = \frac{1}{10^{-5} \times .1} = 1M\Omega$

$R_{OUT} = \frac{r_o (g_m r_o)}{2} = 70 \times 10^6 \Omega$

$C_{out} = C_{gd,1} + C_{gd,2} + C_{db1} + C_{db2}$
$= .4pf$

$\omega_{3db} = \frac{1}{R_{OUT} C_{OUT}}$

$= \frac{1}{70 \times 10^6 \times .4 \times 10^{-12}}$

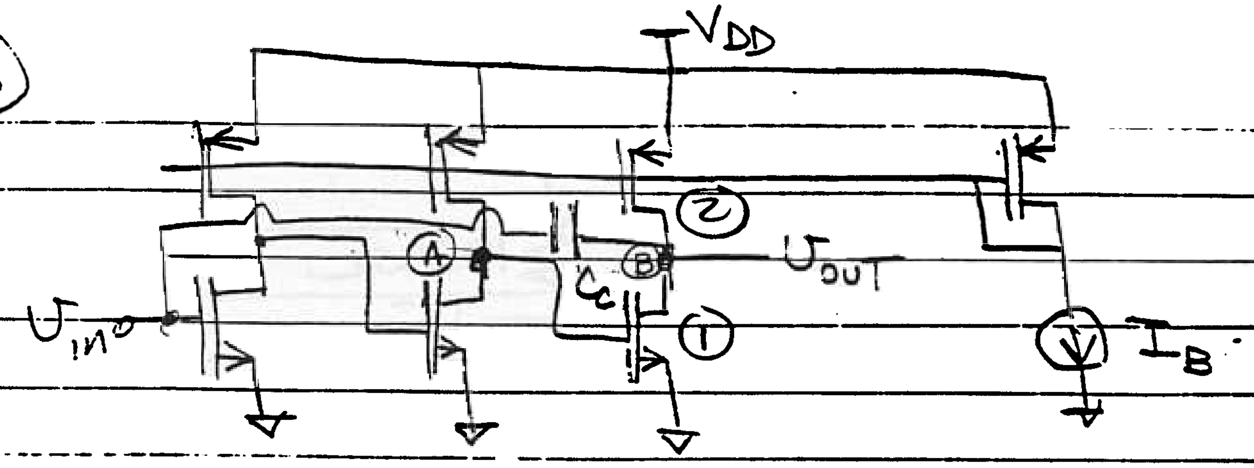
$= 35 \times 10^3$ RAD/SEC

AT INPUT $100k\Omega \ll R_{OUT}$

$C_{IN} = C_{GS} + 2C_{gd} \approx 1.2pf$

MUCH HIGHER FREQ.

6)



$g_m = .01$

$r_o = 1M\Omega$

$\lambda = .1$

$C_{gs} = 1pf$

$C_{gd} = .1pf$

$C_{db} = .1pf$

$C_{ds} = .1pf$

a) WHAT IS THE 3db FREQUENCY IF $C_c = 1pf$?

4 kRAD/SEC

$C_{OUT} = C_c + C_{GD1} + C_{GD2} + C_{DB1} + C_{DB2} = 1.4pf$

$C_{M_1} = (.01)\frac{r_o}{2} C_{gd} = 5\times10^3 \times .1pf = 500pf$

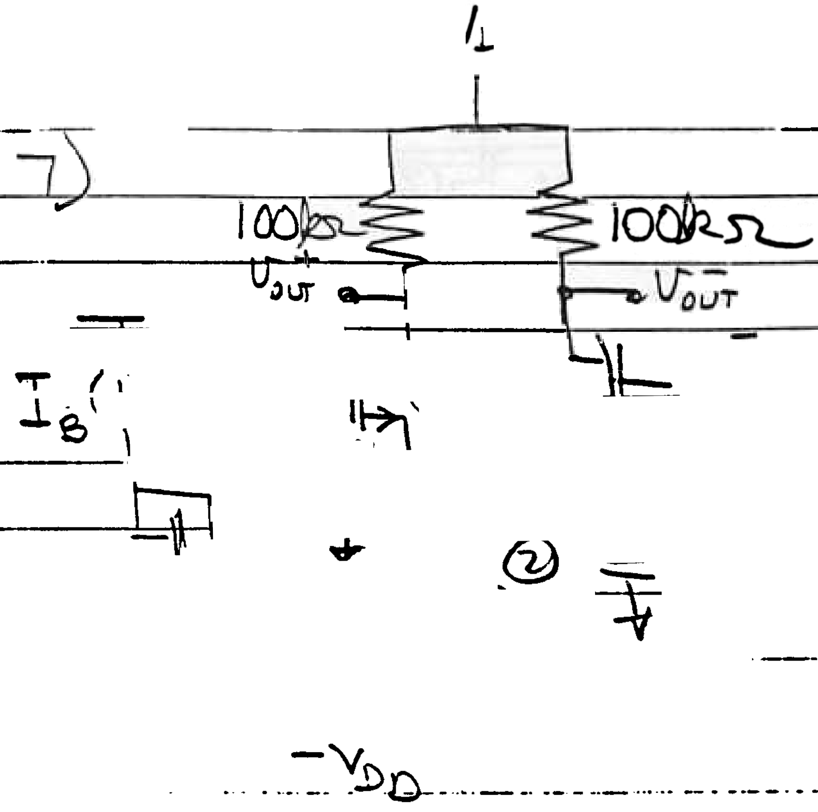
$R_{OUT} = 500k$

$\omega_{3dB} = \frac{1}{500k \times 5\times10^{-10}} = 4 \text{ kRAD/SEC}$

b) IF $C_c = 0pf$ AT WHAT FREQUENCY IS THE PHASE SHIFT OF $U_{OUT}/U_{in} = -90°$?

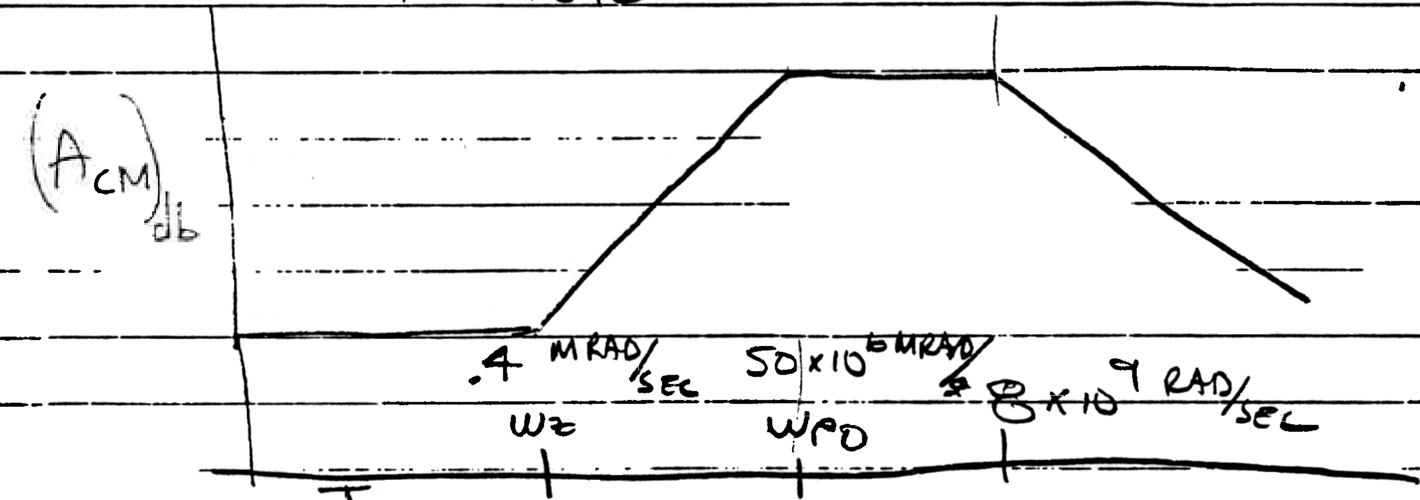
4 kRAD/SEC   NODES A & B HAVE $-45°$ AT ω_{3dB}

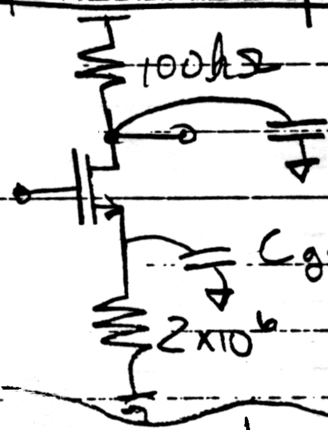
7)



$C_{gs} = 1\,pf$

PLOT $A_{CM}^{(db)}$ VS. ω AND LABEL THE BREAKPOINTS





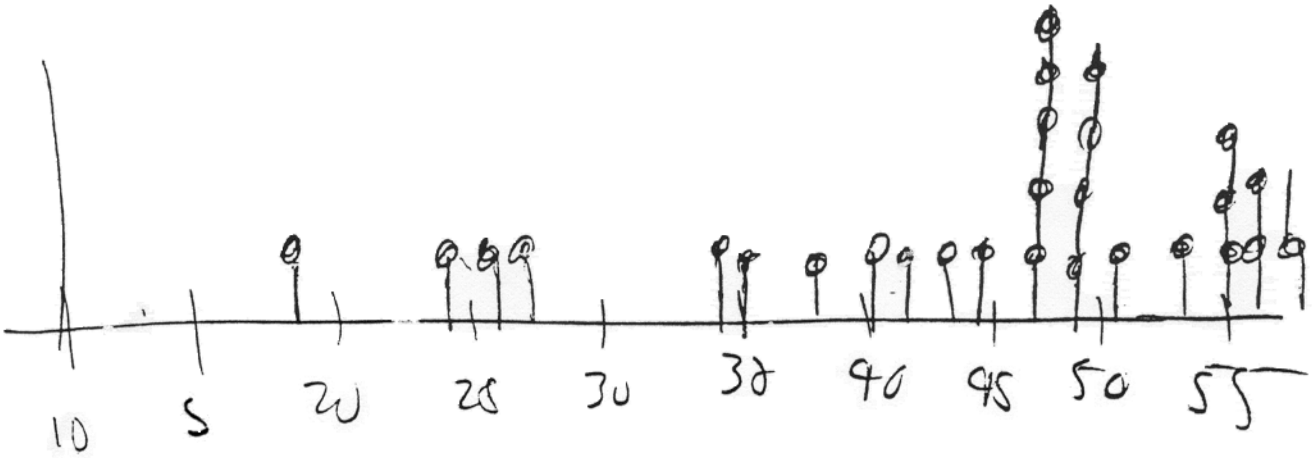
$C_{gd}+C_{db} = .2pf$

$C_{gs_1}+C_{sb_1}+\frac{C_{db2}}{2}+\frac{C_{gd2}}{2} = 1.2pf = C_T$

$\omega_{P_0} = \frac{1}{10^5 \times .2\times10^{-12}} = 50$ MRAD/SEC

$\omega_Z = \frac{1}{2\times10^6 \times 1.2pf} = \frac{1}{2.4\times10^{-6}} = .4$ MRAD/SEC

$\omega_P = \frac{1}{(1/g_m \| R_T)\,C_T} = \frac{1}{100\times1.3\times10^{-12}}$
$= 8$ GRAD/SEC



$$\frac{g_m \quad 10^5 \,\|\, \frac{1}{j\omega C_{OUT}})}{+ \; g_m \left(R_4 \,\|\, \frac{1}{j\omega C_4}\right)}$$

$$+ \; \frac{g_m R_T}{1 + j\omega R_T C_T} \qquad = \frac{1 + j\omega R_T C_T}{1 + j\omega R_T C_T + g_m R_T}$$

$$= \frac{1 + j\omega R_T C_T}{(1 + g_m R_T)\left(1 + \frac{j\omega R_T C_T}{1 + g_m R_T}\right)}$$

X 45

< 2

$$\omega_p = \left[\left(\frac{1}{g_m} \,\|\, R_T\right) C_T\right]^{-1}$$