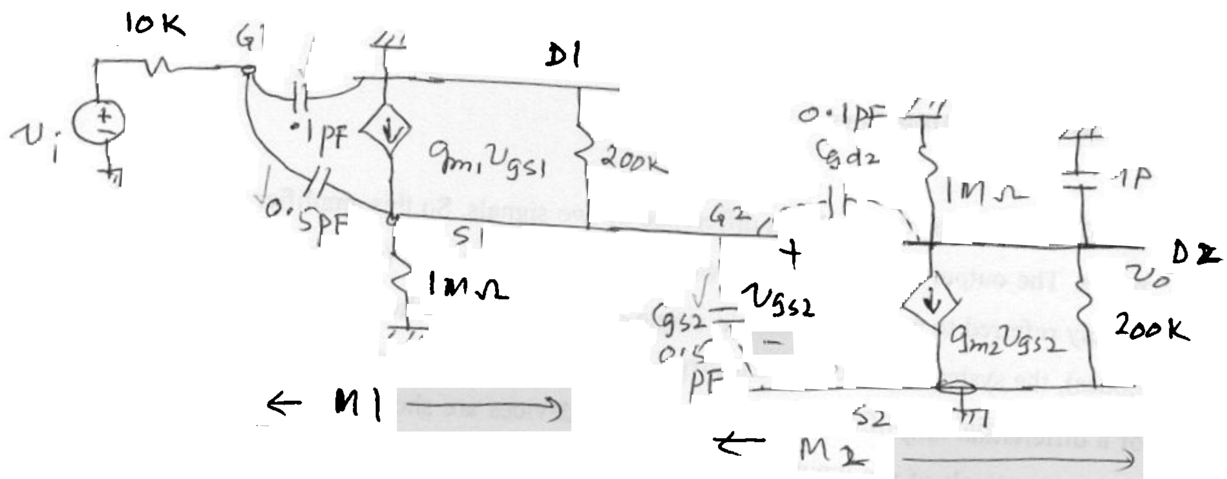
3.8.7
(contd.)

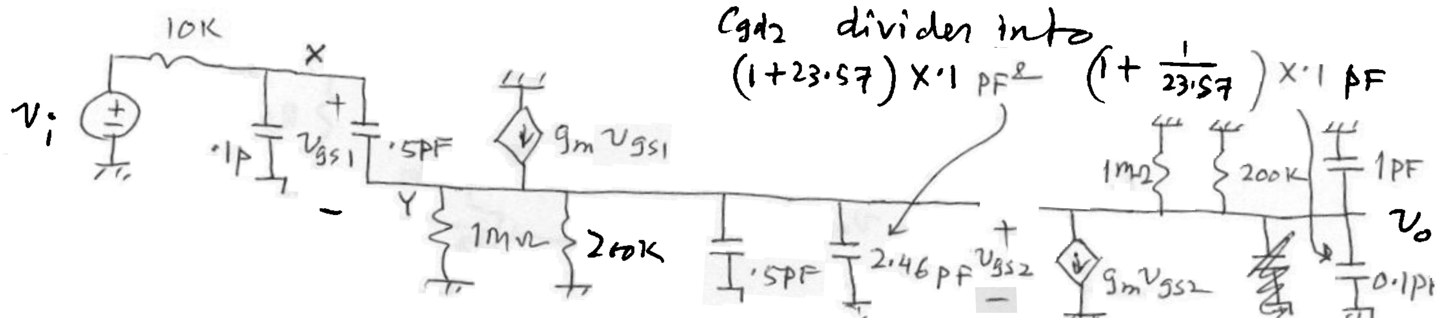


For M_2 we apply Miller's Theorem $\left(-g_{m2}R_D\right) = -141.4\times10^{-6} \times (1M\Omega \,\|\, 200k)$

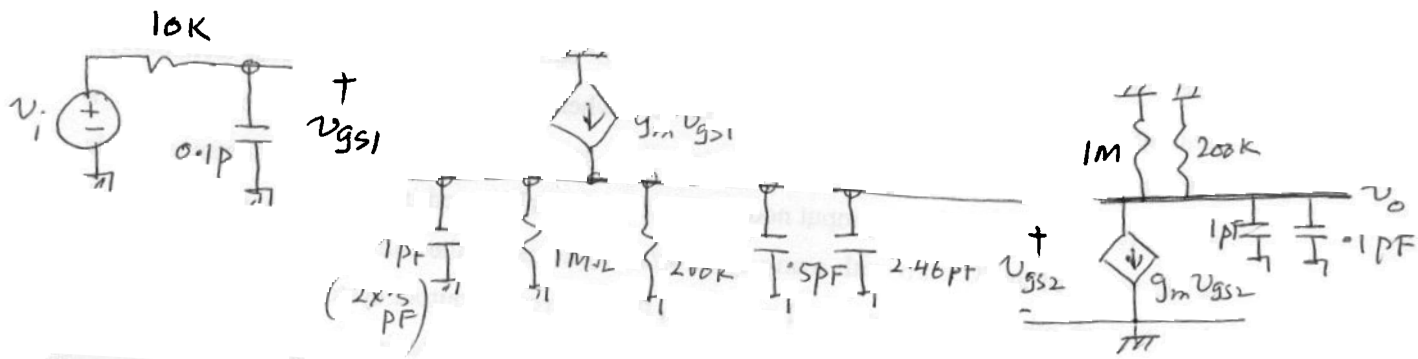
The gain $= -141.4\times10^{-6} \times 166.7K = -23.57$

So

C_{gd2} divides into $(1+23.57)\times.1\text{ pF}$ & $\left(1+\frac{1}{23.57}\right)\times.1\text{ pF}$



Between nodes X and Y, the CD amplifier has a voltage gain of ≈ 1. We can apply Miller's Theorem to convert further



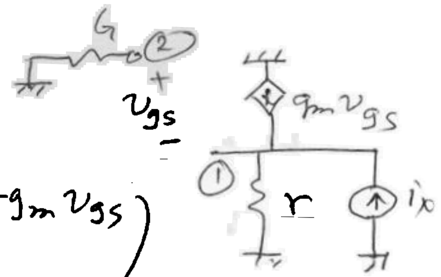
There are ~~three~~ three time constants involved

For the 0.1 pF cap the time constant is $0.1\times10^{-12}\times10K = T_1$

For the $(1pF + .5pF + 2.46pF)$ cap., the time constant is

$$T_2 \quad 3.96\times10^{-12} \times \frac{1M\Omega \,\|\, 200K}{1+g_m\cdot(1M\Omega \,\|\, 200K)}, \quad g_m = 141.4\,\mu\mho$$

3.8.7 proof for τ_3



$R_{TH} = \frac{v_①}{i_x}$

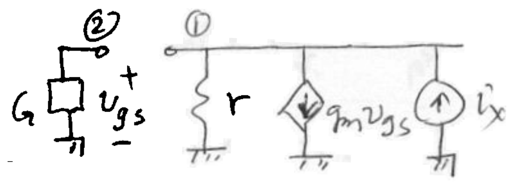
By nodal matrix

$$\begin{pmatrix} g & 0 \\ 0 & G \end{pmatrix}\begin{bmatrix} v_① \\ v_② \end{bmatrix} = \begin{pmatrix} i_x + g_m v_{gs} \\ 0 \end{pmatrix}$$

But v_{gs} $v_② - v_①$. So $\begin{bmatrix} g_m + g & -g_m \\ 0 & g \end{bmatrix}\begin{bmatrix} v_① \\ v_② \end{bmatrix} = \begin{bmatrix} i_x \\ 0 \end{bmatrix}$

Solving for $\frac{v_①}{i_x} \rightarrow \frac{1}{g+g_m} = \frac{r}{1+g_m r} = R_{TH}$

Similarly for



$$\begin{pmatrix} g & 0 \\ 0 & \end{pmatrix}\begin{pmatrix} v_① \\ v_② \end{pmatrix} = \begin{pmatrix} i_x - g_m v_{gs} \\ 0 \end{pmatrix}$$

but $v_{gs} = v_②$ now

So $$\begin{pmatrix} g & g_m \\ 0 & G \end{pmatrix}\begin{pmatrix} v_① \\ v_② \end{pmatrix} = \begin{pmatrix} i_x \\ 0 \end{pmatrix} \qquad \frac{v_①}{i_x} = \frac{1}{g} = r = R_{TH}$$

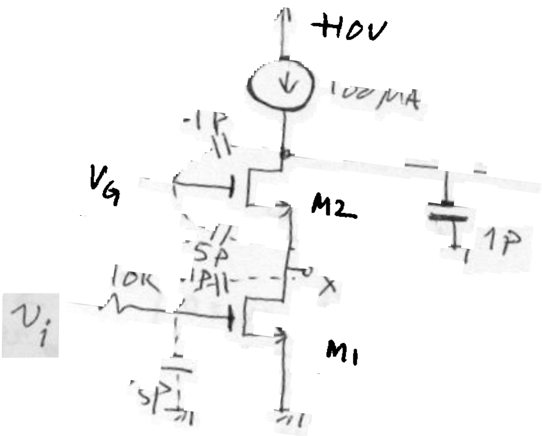
(note $v_{gs2} \rightarrow v_g - v_{s2} \rightarrow 0 - 0 \rightarrow 0$; so $g_m v_{gs2} \rightarrow 0$, open circuit current source)

So the time constant τ_3 for the (1pF+0.1pF) cap. is

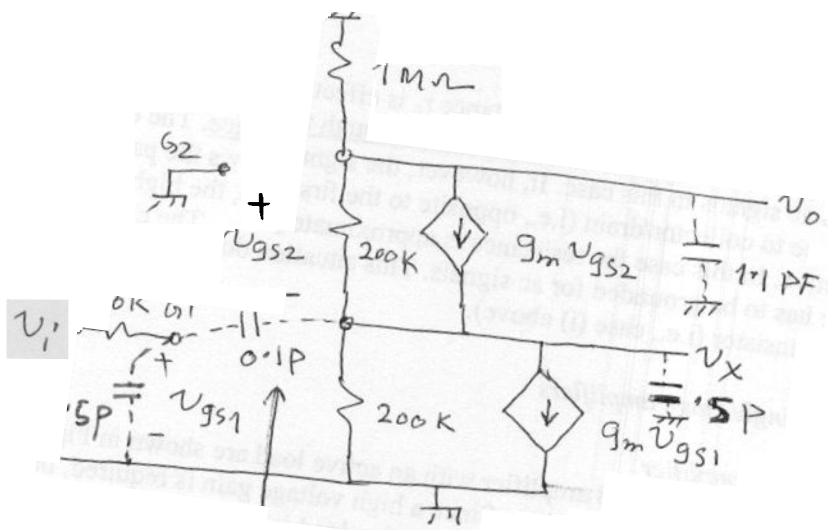
$= 1.1 \times 10^{-12} \times (1M\Omega \parallel 200K)$

Calculate τ_1, τ_2, τ_3, then $\omega_H \approx \frac{1}{\tau_1 + \tau_2 + \tau_3}$ rad/sec

3.8.8

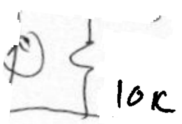


$C_{gd} = 0.1\,pF$
$C_{gs} = 0.5\,pF$
$r_{o1} = r_{o2} = 200\,k\Omega$
$r_I = 1\,M\Omega$

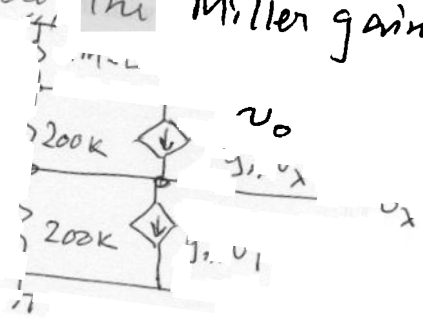


$v_{gs2} = -v_x$

We need to calculate the Miller effect capacitance where the Miller gain $K = \dfrac{v_x}{v_1}$



$i_s = \dfrac{v_i}{10K}$



This is the low-frequency equivalent circuit to calculate approx. K (this ignores all capacitors)

$$\begin{array}{c} \begin{array}{ccc} v_i & v_x & v_o \end{array} \\ \begin{bmatrix} g_s & 0 & 0 \\ 0 & 2g_{o1} & -g_{o1} \\ 0 & -g_{o1} & g_{o1}+g_{o2} \end{bmatrix} \end{array} \begin{bmatrix} v_1 \\ v_x \\ v_o \end{bmatrix} = \begin{bmatrix} i_s \\ -g_m v_1 - g_m v_x \\ g_m v_x \end{bmatrix}$$

3.8.8 (contd.)

$$\begin{bmatrix} g_s & 0 & 0 \\ g_m & g_m+2g_{o1} & -g_{o1} \\ 0 & -g_m-g_{o1} & g_{o1}+g_{o2} \end{bmatrix} \begin{bmatrix} v_1 \\ v_x \\ v_o \end{bmatrix} = \begin{bmatrix} i_s \\ 0 \\ 0 \end{bmatrix}$$

$$v_X = \begin{vmatrix} g_s & i_s & 0 \\ g_m & 0 & -g_{o1} \\ 0 & 0 & g_{o1}+g_{o2} \end{vmatrix} \frac{1}{\Delta}$$

$$v_1 = \begin{vmatrix} i_s & 0 & 0 \\ 0 & g_m+2g_{o1} & -g_{o1} \\ 0 & -g_m-g_{o1} & g_{o1}+g_{o2} \end{vmatrix} \frac{1}{\Delta}$$

$\Big\rangle \; \dfrac{v_X}{v_1} = -4.809$

where

$g_m = 141.4\ \mu℧$

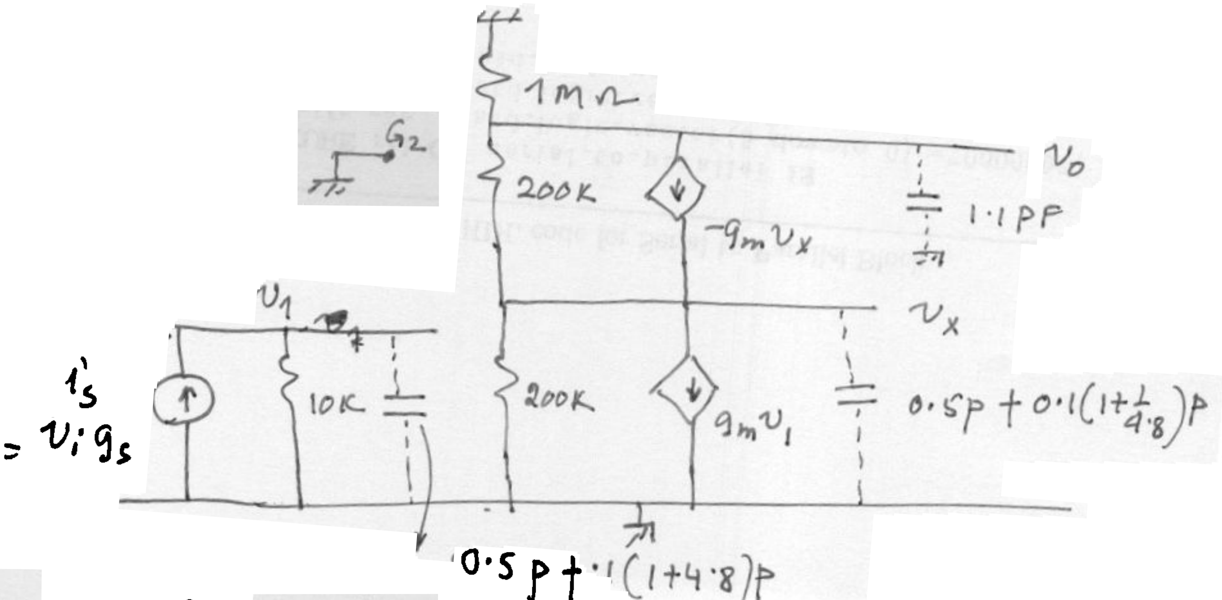
$g_{o1} = \dfrac{1}{200\,k\Omega}$

$g_{o2} = \dfrac{1}{1M\Omega}$

$g_s = \dfrac{1}{10K}$

So Miller gain is $= -4.8$.

Modified ac equivalent circuit is

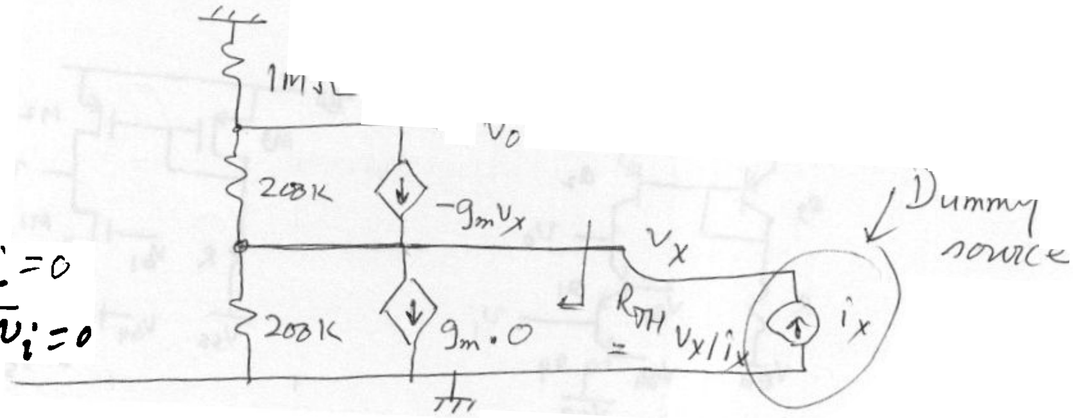


There are 3 possible O.C.T.C values at nodes v_1, v_X, v_o respectively

3.8.8
(contd.)

For v_x node

$v_i = 0$
$\because v_i = 0$



Let $g_{o1} = \dfrac{1}{200K}$; $g_{o2} = \dfrac{1}{1M\Omega}$

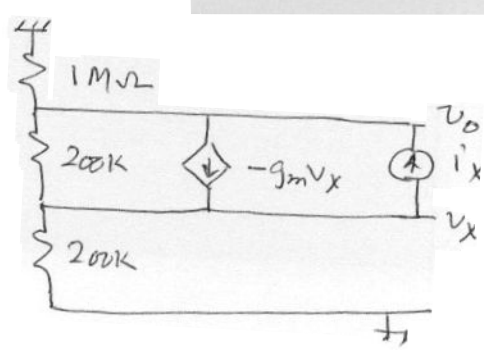
$$\begin{pmatrix} g_{o1}+g_{o1} & -g_{o1} \\ -g_{o1} & g_{o1}+g_{o2} \end{pmatrix} \begin{pmatrix} v_x \\ v_o \end{pmatrix} = \begin{bmatrix} i_x - g_m v_x \\ g_m v_x \end{bmatrix}$$

$$\begin{bmatrix} g_m + g_{o1} + g_{o1} & -g_{o1} \\ -g_{o1} - g_m & g_{o1} + g_{o2} \end{bmatrix} \begin{bmatrix} v_x \\ v_o \end{bmatrix} = \begin{bmatrix} i_x \\ 0 \end{bmatrix}$$

$$v_x = \begin{vmatrix} i_x & -g_{o1} \\ 0 & g_{o1}+g_{o2} \end{vmatrix} \Bigg/ \begin{vmatrix} g_m+g_{o1}+g_{o1} & -g_{o1} \\ -g_m - g_{o1} & g_{o1}+g_{o2} \end{vmatrix}$$

$$R_{TH_x} = \frac{v_x}{i_x} = \frac{g_{o1}+g_{o2}}{\begin{vmatrix} g_m+g_{o1}+g_{o1} & -g_{o1} \\ -g_m-g_{o1} & g_{o1}+g_{o2} \end{vmatrix}} \simeq 34013\ \Omega \rightarrow$$

Next for v_o node, the measurement set up changes to



$$R_{TH_o} = \frac{v_o - v_x}{i_x}$$

3.8.8.
(contd.)

The NAM changes to

$$\begin{bmatrix} 2g_{01} & -g_{01} \\ -g_{01} & g_{01}+g_{02} \end{bmatrix} \begin{bmatrix} v_x \\ v_o \end{bmatrix} = \begin{bmatrix} -i_x - g_m v_x \\ i_x + g_m v_x \end{bmatrix}$$

$$\begin{bmatrix} g_m + 2g_{01} & -g_{01} \\ -g_m - g_{01} & g_{01}+g_{02} \end{bmatrix} \begin{bmatrix} v_x \\ v_o \end{bmatrix} = \begin{bmatrix} -i_x \\ i_x \end{bmatrix}$$

Let $\Delta = \begin{vmatrix} g_m + 2g_{01} & -g_{01} \\ -g_m - g_{01} & g_{01}+g_{02} \end{vmatrix} = 0.1764 \times 10^{-9}$

$$v_o = \frac{1}{\Delta} \begin{vmatrix} g_m + 2g_{01} & -i_x \\ -g_m - g_{01} & i_x \end{vmatrix} = \frac{1}{\Delta} \cdot i_x = \frac{5 \times 10^{-5}}{\Delta} i_x$$

$$v_x = \frac{1}{\Delta} \begin{vmatrix} -i_x & -g_{01} \\ i_x & g_{01}+g_{02} \end{vmatrix} = \frac{1}{\Delta} \cdot i_x. = -0.1 \times 10^{-5} \frac{i_x}{\Delta}$$

So $v_o - v_x = \dfrac{0.6 \times 10^{-5}}{\Delta} i_x$; $\dfrac{v_o - v_x}{i_x} = R_{TH_o} = \dfrac{.6 \times 10^{-5}}{\Delta}$

$= 34013.6\ \Omega$

It appears that both R_{TH_x} & R_{TH_o} are about equal

Time constant at v_x node

$$= 34013 \times [.5 + .1 \underbrace{(1 + \tfrac{1}{\cancel{.047}\ 4.8})]}_{2.98} \times 10^{-12} = \cancel{10^{?} \times 10 \text{ sec}}$$

$= 2.11 \times 10^{-8}$ sec.

Time constant at v_o node

$$= 34013 \times 1.1 \times 10^{-12} = 3.74 \times 10^{-8}$$

So $\omega_H \approx \dfrac{1}{3.74 \times 10^{-8} + \cancel{1.1 \times 10^{-?}}\ 2.11 \times 10^{-8}} = \cancel{[illegible]}$

$\cancel{[illegible]\ \text{MHz}}$

$= 2\pi f_H$ so, $f_H \approx \cancel{1.15\ \text{MHZ}}$ 2.72 MHZ

3.8.8 (contd.)

Time constant at v_1 node

$= 10k \times (.5 + 5.8 \times .1)\,p$

$= 10.8 \times 10^{-9}$ sec

Then $\omega_H \approx \dfrac{1}{2.11 \times 10^{-8} + 3.74 \times 10^{-8} + 10.8 \times 10^{-9}} = 14.43 \times 10^{6}$

$f_H = \dfrac{\omega_H}{2\pi} = 2.297$ MHZ