8.13

$K'\frac{W}{L} = 2.8\ mA/V^2$

$V_T = 0.5V$

$C_{gs} = 2.8\ pF$

$C_{gd} = 1.8\ pF$

$C_{gd}:\ r_{eq} = r_d // r_L = 1.8K$

$\tau_1 = 1.8 \times 10^{-12} \times 1.8 \times 10^3 = 3.24\ ns$

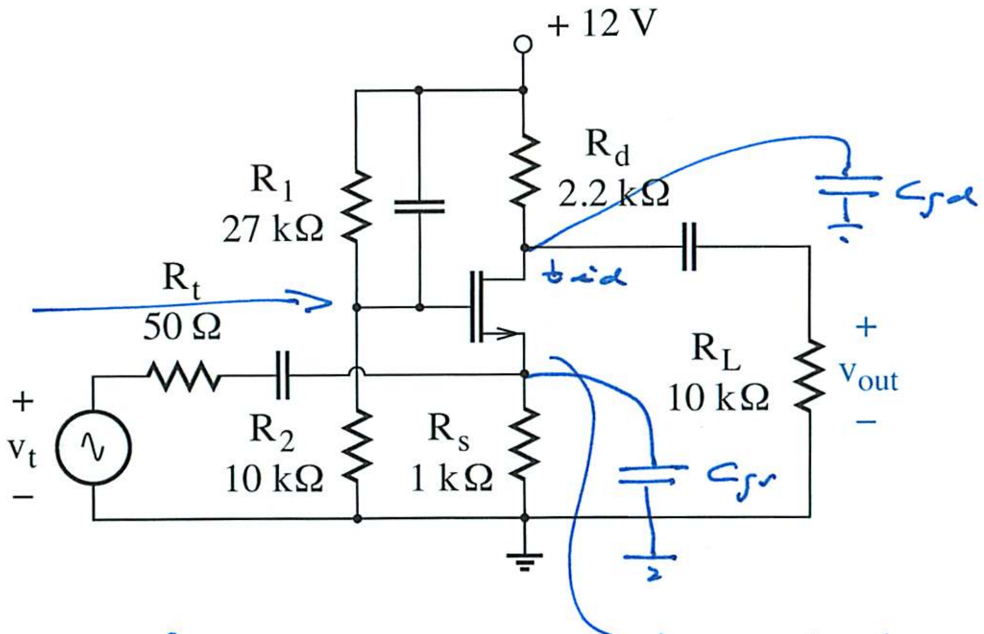
$C_{gs}:\ r_{eq} = r_s // r_t // \frac{1}{g_m} = 41.6\ \Omega$

$\tau_2 = 2.8 \times 10^{-12} \times 41.6 = 0.12\ ns$

$\Sigma\tau = 3.36\ ns \qquad f_h \approx \frac{1}{2\pi\Sigma\tau} = \underline{47\ MHz}$

$v_g = 12\,\frac{10}{10+27}$

$= 3.24\ V$



$v_s = 1 \cdot i_d$

$i_d = 1.4\,(v_{gs} - 0.5)^2$

$v_{gs} = 3.24 - i_d$

$v_{gs} = 3.24 - 1.4 v_{gs}^2 + 1.4 v_{gs} - 0.35$

$1.4 v_{gs}^2 - 0.4 v_{gs} - 2.89 = 0$

$v_{gs} = \frac{0.4 \pm \sqrt{0.16 + 16.18}}{2.8} = 1.59\ V,\ -\cancel{1.3}\ V$

$g_m = \sqrt{2 \times 1.66\ mA \times 2.8\ mA/V^2}$

$= 3.05 \times 10^{-3}\ \mho$

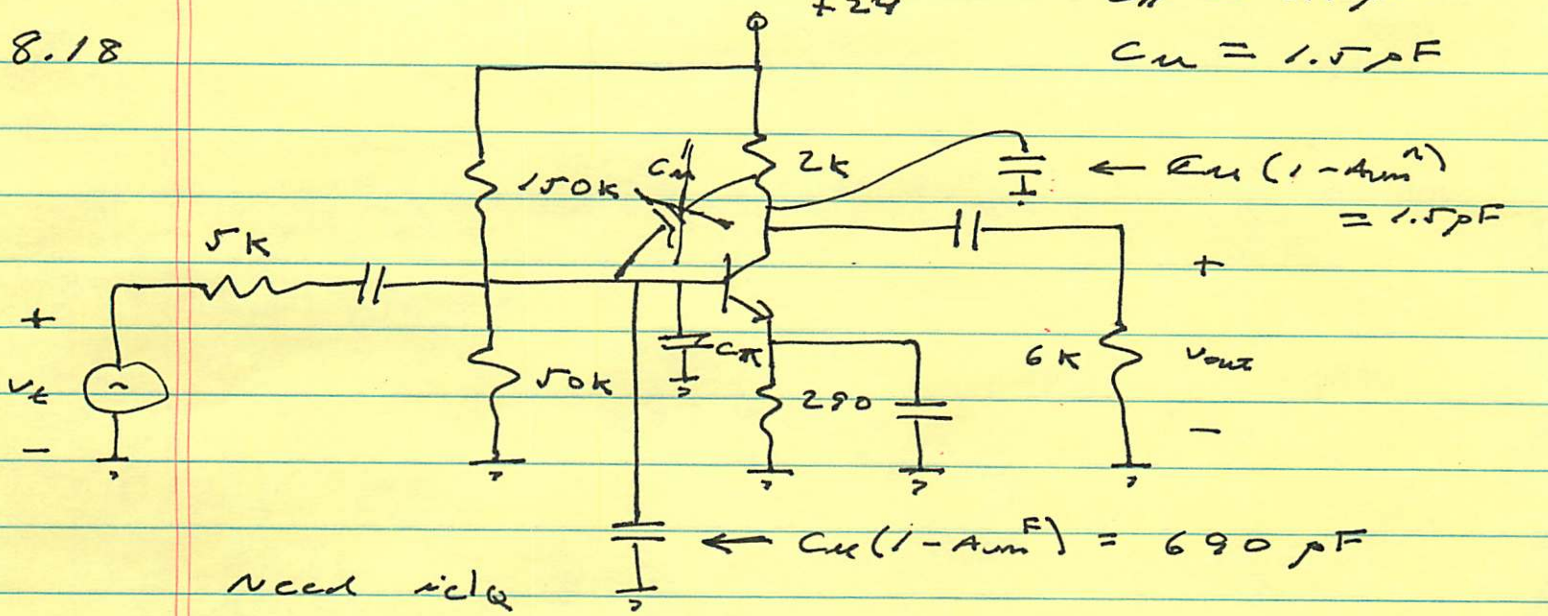
$\longrightarrow i_d|_Q = 1.66\ mA$

8.18

$\beta_F = \beta_0 = 100$

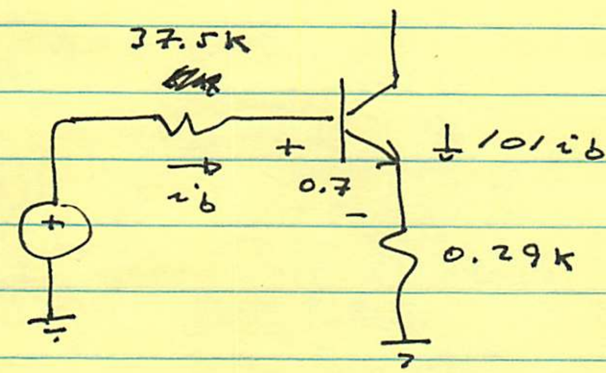
$C_\pi = 2.5\,pF$

$C_\mu = 1.5\,pF$



Need i_{cQ}

$24\left(\frac{50}{150+50}\right) = 6$



$6 = 37.5\,i_b + 0.7 + 29.3\,i_b$

$i_b = \frac{5.3}{66.8} = 79.3\,\mu A$

$i_{cQ} = 7.93\,mA$

$g_m = \frac{7.93\,mA}{25.9\,mV} = 0.306\,℧$

$r_\pi = \frac{\beta_0}{g_m} = 326\,\Omega$

$A_{vm}^F = -g_m(2k \,//\, 6k) = -459$

$A_{vm}^R = 0$

$\tau_1 = \left[\underbrace{C_\pi + C_\mu(1 - A_{vm}^F)}_{692.5\,pF}\right] \times \left(\underbrace{5k \,//\, 150k \,//\, 50k \,//\, r_\pi}_{304\,\Omega}\right) \approx 211\,ns$

$\tau_2 = C_\mu(1 - A_{vm}^R) \times (2k \,//\, 6k) = 2.25\,ns$

$f_h \approx \frac{1}{2\pi\Sigma\tau} \approx 750\,kHz$

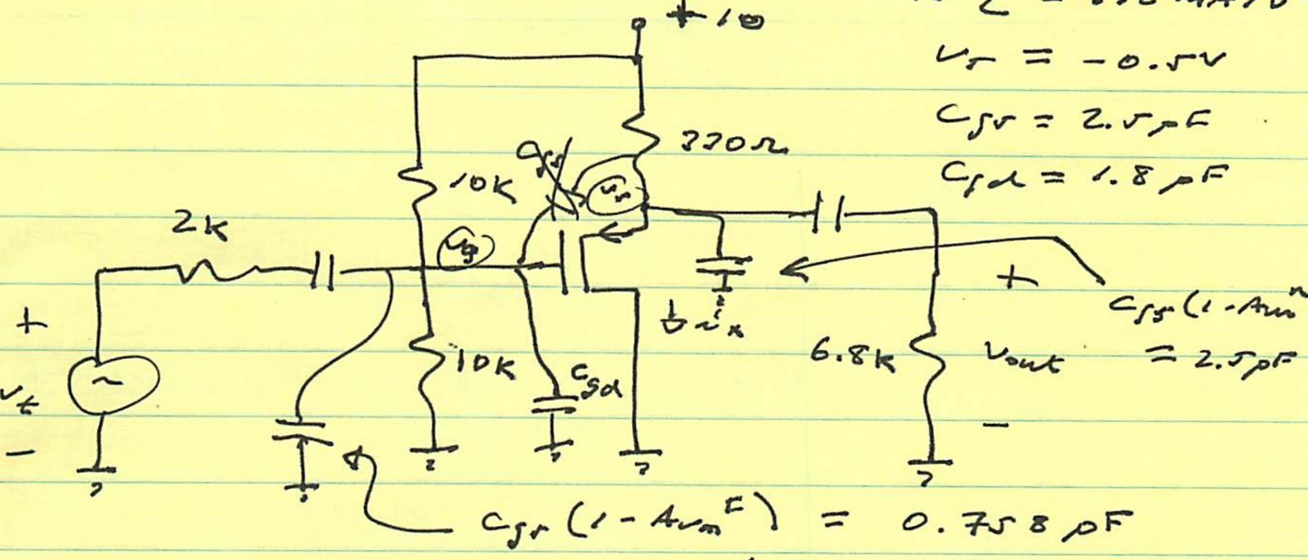
8.25

$K'\frac{W}{L} = 3.6\ mA/V^2$

$V_T = -0.5V$

$C_{gs} = 2.5pF$

$C_{gd} = 1.8pF$



$i_x = -i_d$ $\qquad v_g = 10\left(\frac{10}{10+10}\right) = 5\ V$

$v_s = 10 - 0.33\, i_x$

$$v_{gs} = 5 - (10 - 0.33 i_x) = 0.33 i_x - 5$$

$$-i_d = i_x = 1.8\,(v_{gs} + 0.5)^2$$

$$v_{gs} = 0.6 v_{gs}^2 + 0.6 v_{gs} + 0.15 - 5$$

$$0.6 v_{gs}^2 - 0.4 v_{gs} - 4.85 = 0$$

$$v_{gs} = \frac{0.4 \pm \sqrt{0.16 + 11.64}}{1.2} = \cancel{3.2}, -2.53$$

$$-I_{DQ} = 1.8\,(-2.53 + 0.5)^2 = 7.42\ mA$$

$$g_m = \sqrt{2K'\frac{W}{L}|I_{DQ}|} = 7.31 \times 10^{-3}\ ℧$$

$$A_{vm}^F = \frac{g_m r_s'}{g_m r_s' + 1} = 0.697$$

$(r_s' = 6.8k \parallel 330 = 315\ \Omega$

$$A_{vm}^R = 0$$

$$\tau_1 = \underbrace{\left[C_{gd} + C_{gs}(1 - A_m^F)\right]}_{2.56\ pF} \underbrace{(2k \,//\, 10k \,//\, 10k)}_{1.43\ k}$$

$$= 3.66\ ns$$

$$\tau_2 = \underbrace{C_{gs}(1 - A_m^{\sim})}_{2.5\ pF} \times \underbrace{(330\,\Omega \,//\, 6.8k \,//\, \overset{137\,\Omega}{\frac{1}{g_m}})}_{95.5\,\Omega}$$

$$= 0.24\ ns$$

$$f_h \approx \frac{1}{2\pi \Sigma \tau} = 41\ MHz$$

8.31

$A_{vm1}^{F} = -g_{m1}\left(10K \,//\, r_{in}^{(2)}\right)$

$= -20$

$r_3 \,//\, r_4 \,//\, \left[\underbrace{r_{\pi 2} + (1+\beta_o)\cdot 50K}_{6.08\text{ meg}}\right]$

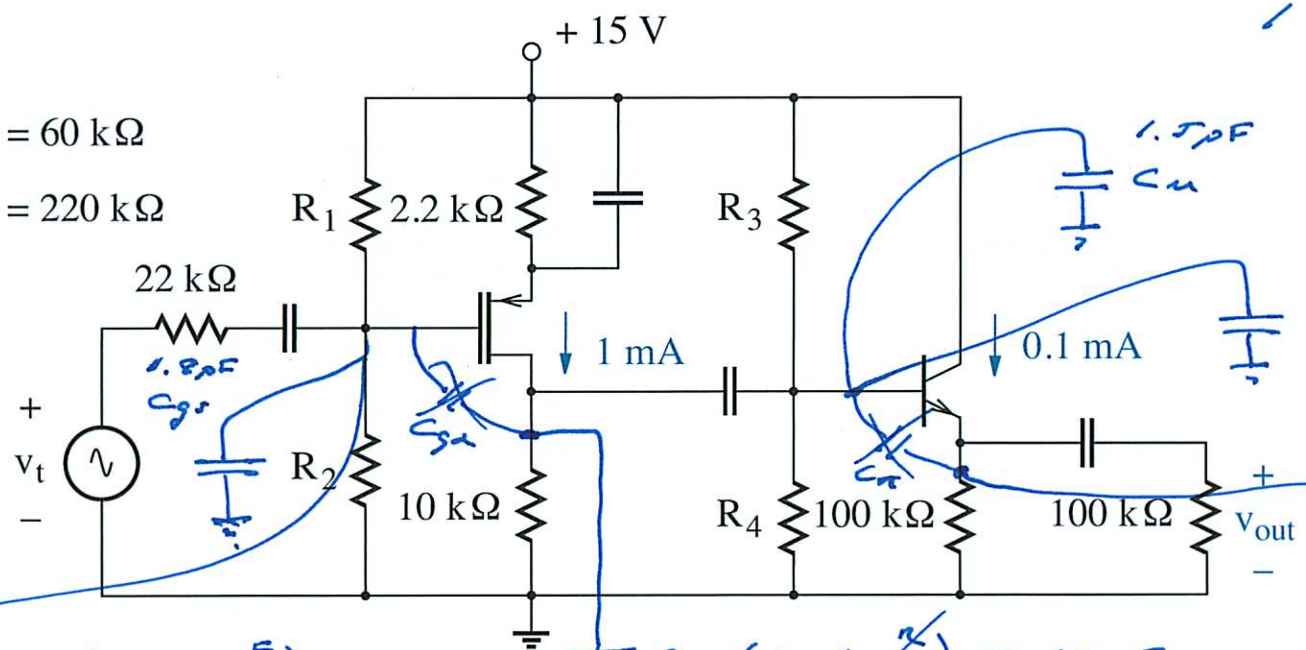
$\underbrace{\qquad}_{212K}$

$\dfrac{g_{m2}(50K)\left(1+\frac{1}{120}\right)}{1+g_{m2}(50K)\left(1+\frac{1}{120}\right)}$

$= 0.995$

$R_1 \parallel R_2 = 60\ k\Omega$

$R_3 \parallel R_4 = 220\ k\Omega$



1.8 pF C_{gs}

C_{gd}

1.5 pF C_{μ}

C_{π}

$C_{\pi}\left(1 - A_{vm2}^{F}\right)$

$= 0.0125\ pF$

$C_{\pi}\left(1 - A_{vm2}^{R}\right)$

$= 1.91\ pF$

$C_{gd}\left(1 - A_{vm1}^{F}\right) = 25.2\ pF$

$C_{gd}\left(1 - \cancel{A_{vm1}^{R}}\right) = 1.2\ pF$ (0)

$K'\frac{W}{L} = 2.2\ mA/V^2$

$V_T = -0.6V$

$g_{m1} = \sqrt{2 \times 2.2\ mA/V^2 \times 1\ mA}$

$= 2.1 \times 10^{-3}\ ℧$

$C_{gd} = 1.2\ pF,\ C_{gs} = 1.8\ pF$

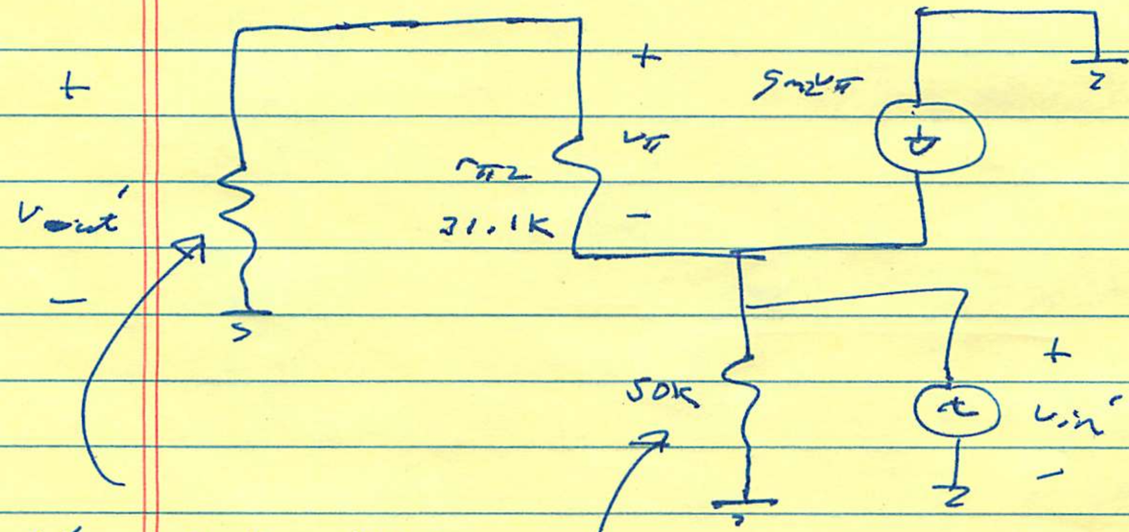
$\beta_F = \beta_o = 120$

$g_{m2} = \dfrac{0.1\ mA}{25.9\ mV} = 3.86 \times 10^{-3}\ ℧$

$r_{\pi 2} = \beta_o/g_m = 31.1\ K$

$C_{\mu} = 1.5\ pF,\ C_{\pi} = 2.5\ pF$

A_{vm2}^{n}



$r' = r_3 \| r_4 \| 10K$

$= 9.56K$

$100K \| 200K$

$$A_{vm2}^{n} = \frac{v_{out}'}{v_{in}} = \frac{r'}{R' + r_{\pi 2}} = 0.235$$

MOSFET gate $\quad C_1 = 1.8\,pF + 25.2\,pF = 27\,pF$

$r_{eq}^{(1)} = 22k \,//\, r_1 \,//\, r_2 = 16.1\,k$

$\tau_1 = 16.1k \times C_1 = 435\,ns$

MOSFET drain $\quad C_2 = 1.2\,pF + 1.5\,pF + 0.0125\,pF$

$= 2.71\,pF$

$r_{eq}^{(2)} = 10k \,//\, r_{in}^{(2)} = 9.55\,k$

$\tau_2 = 9.55k \times C_2 = 25.9\,ns$

BJT emitter $\quad C_3 = 1.91\,pF$

$r_{eq}^{(3)} = 56k \,//\, \dfrac{r_{\pi 2} + r_3 // r_{eq} // 10k}{1 + \beta_0}$ $\quad 336$

$= 334\,\Omega$

$\tau_3 = 0.334k \times C_3 = 0.64\,ns$

$\sum \tau = 462\,ns$

$f_h \approx \dfrac{1}{2\pi \sum \tau} = \underline{344\,kHz}$

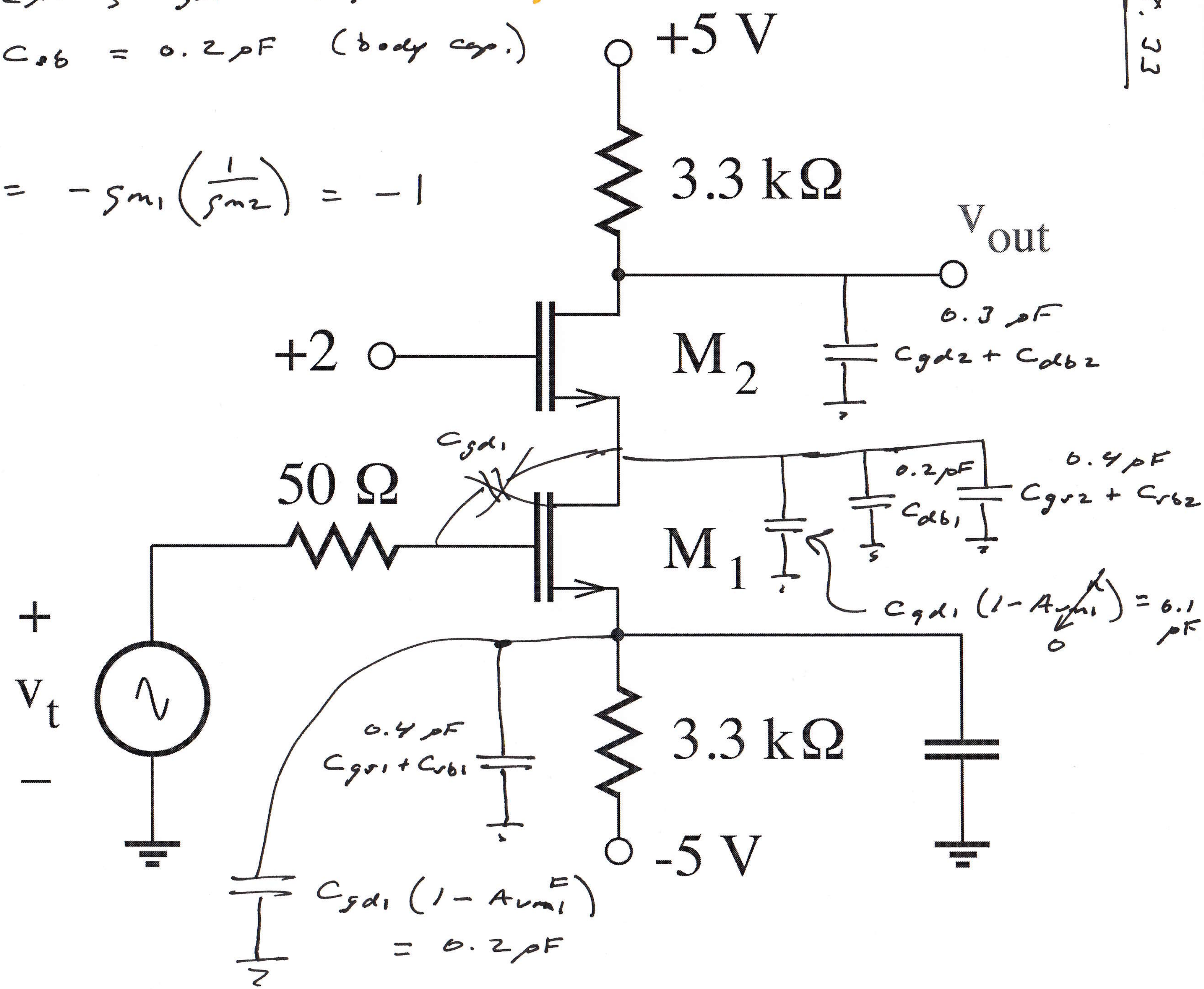
8.33

$K'\frac{W}{L} = 2\,mA/V^2 \qquad V_T = 0.7V$

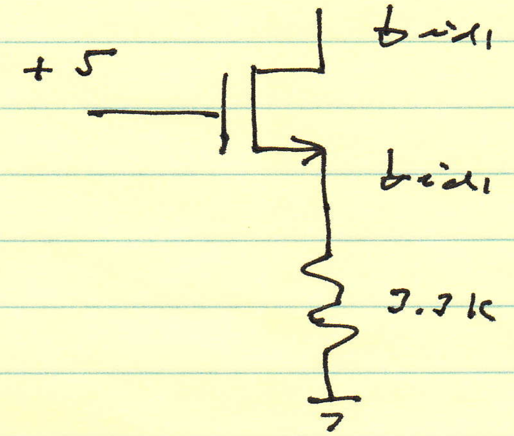
$C_{gs} = 0.2\,pF\,, \quad C_{gd} = 0.1\,pF$

$C_{db} = C_{sb} = 0.2\,pF$ (body cap.)

$A_{vm_1}^{F} = -g_{m_1}\left(\frac{1}{g_{m2}}\right) = -1$



m_1 biasing



$$v_{gs} = 5 - 3.3\, i_{d1}$$

$$i_{d1} = \tfrac{1}{2}(2)(v_{gs} - 0.7)^2$$

$$v_{gs} = 5 - 3.3\, v_{gs}^2 + 4.62\, v_{gs} - 1.62$$

$$3.3\, v_{gs}^2 - 3.62\, v_{gs} - 3.38 = 0$$

$$v_{gs} = \frac{3.62 \pm \sqrt{13.1 + 44.6}}{6.6}$$

$$= 1.7\,V, \; \cancel{-0.6\,V}$$

$$i_{d1}|_Q = \tfrac{1}{2}(2)(1.7 - 0.7)^2 = \underline{1\,mA}$$

$$= i_{d2}|_Q$$

$$g_{m1} = g_{m2} = g_m = \sqrt{2 \times 2mA/V^2 \times 1mA}$$

$$= 2 \times 10^{-3}\ \mho$$

$\underline{M_2 \text{ drain}}$ $C_1 = 0.3\,pF$

$r_{eq}^{(1)} = 3.3\,k$

$\tau_1 = 0.3\,pF \times 3.3k = 0.99\,ns$

$\underline{M_2 \text{ source}}$ $C_2 = 0.1\,pF + 0.2\,pF + 0.4\,pF$
$= 0.7\,pF$

$r_{eq}^{(2)} = \frac{1}{g_{m2}} = 0.5\,k$

$\tau_2 = 0.7\,pF \times 0.5\,k = 0.35\,ns$

$\underline{M_1 \text{ source}}$ $C_3 = 0.4\,pF + 0.2\,pF = 0.6\,pF$

$r_{eq}^{(3)} = \frac{1}{g_{m1}} \,//\, 3.3k = 0.434\,k$

$\tau_3 = 0.6\,pF \times 0.434\,k = 0.26\,ns$

$\Sigma\tau = 1.6\,ns$

$f_h \approx \frac{1}{2\pi}\frac{1}{\Sigma\tau} \approx \underline{100\,MHz}$

<u>M_3 source</u> $\quad C_4 = 0.7\ pF$

$r_{eq}^{(4)} = \frac{1}{g_{m3}} = 500\ \Omega$

(see Prob. 8.37)

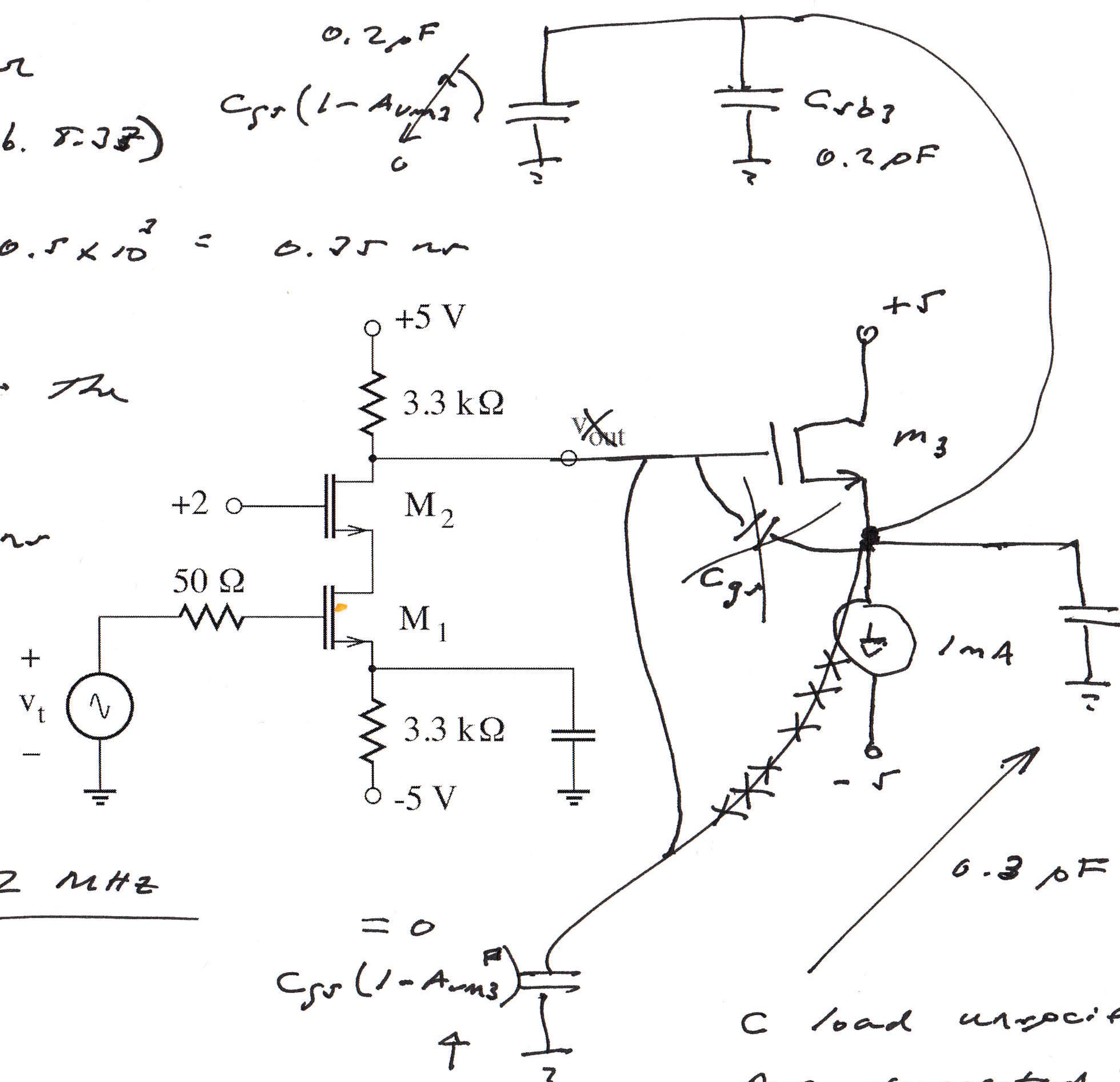
$\tau_4 = 0.7 \times 10^{-12} \times 0.5 \times 10^{3} = 0.35\ ns$

Other time constants the same as in 8.33

$\tau_1 + \tau_2 + \tau_3 = 1.6\ ns$

$\rightarrow \sum \tau = 1.95\ ns$

$f_h \approx \frac{1}{2\pi} \frac{1}{\sum \tau} = \underline{82\ MHz}$



$A_{vm3} = 1$

$\frac{g_m \cdot \infty}{1 + g_m \cdot \infty}$

C load unspecified

A.C. suggested the same cap. load at the M_2 drain in Problem 8.33