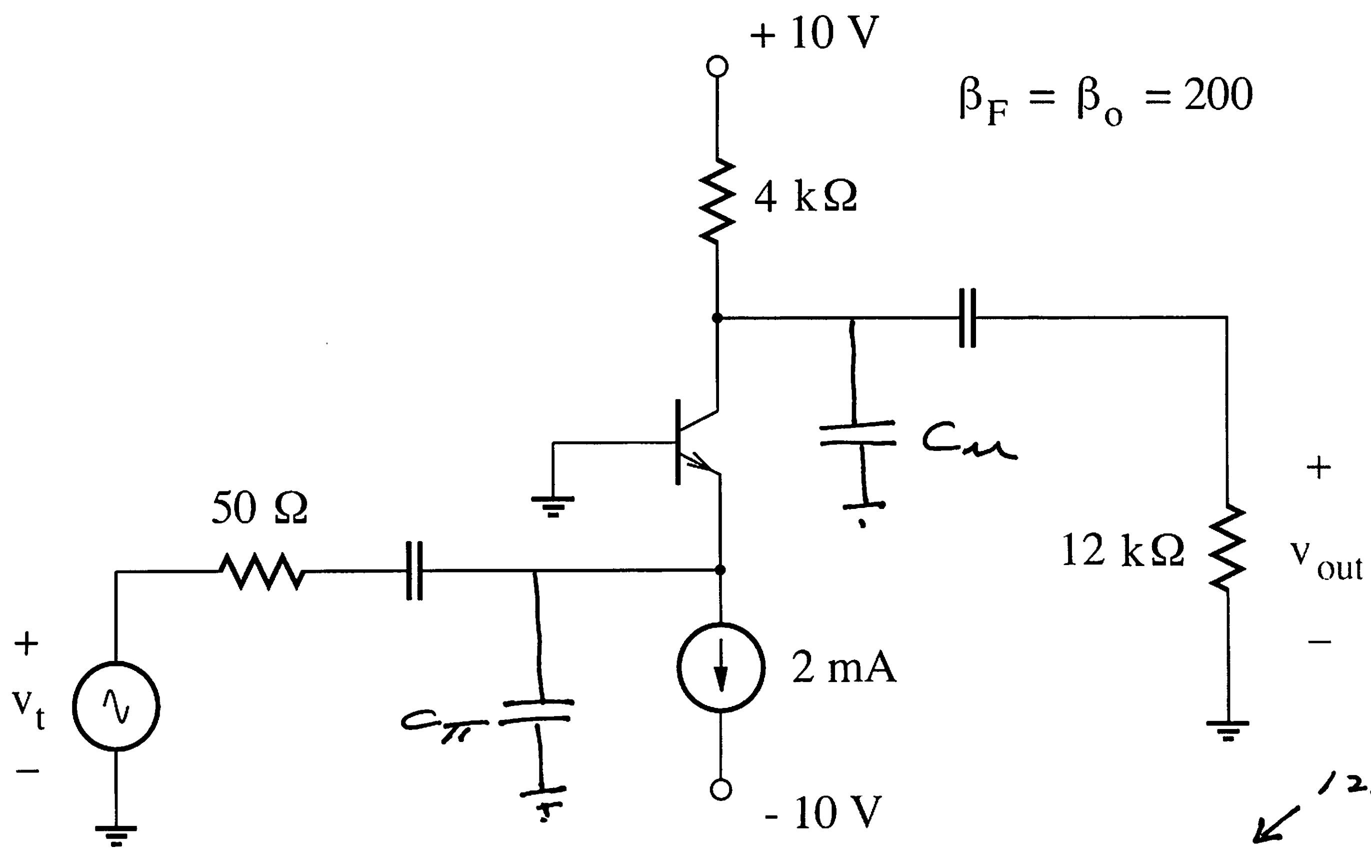
8.12

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

$$g_m = \frac{2\,mA}{25.9\,mV} = 77.2 \times 10^{-3}\ \mho$$

$\tau_1\ (C_\mu)$: $$\tau_1 = 1.5 \times 10^{-12} \times \underbrace{(4k \,//\, 12k)}_{3 \times 10^3} = 4.5\,ns$$



12.9 Ω

$\tau_2\ (C_\pi)$: $$\tau_2 = 2.5 \times 10^{-12} \times \underbrace{\left(50\,\Omega \,//\, \frac{1}{g_m(1 + 1/\beta_o)}\right)}_{10.2\,\Omega}$$

$= 0.026\ ns$

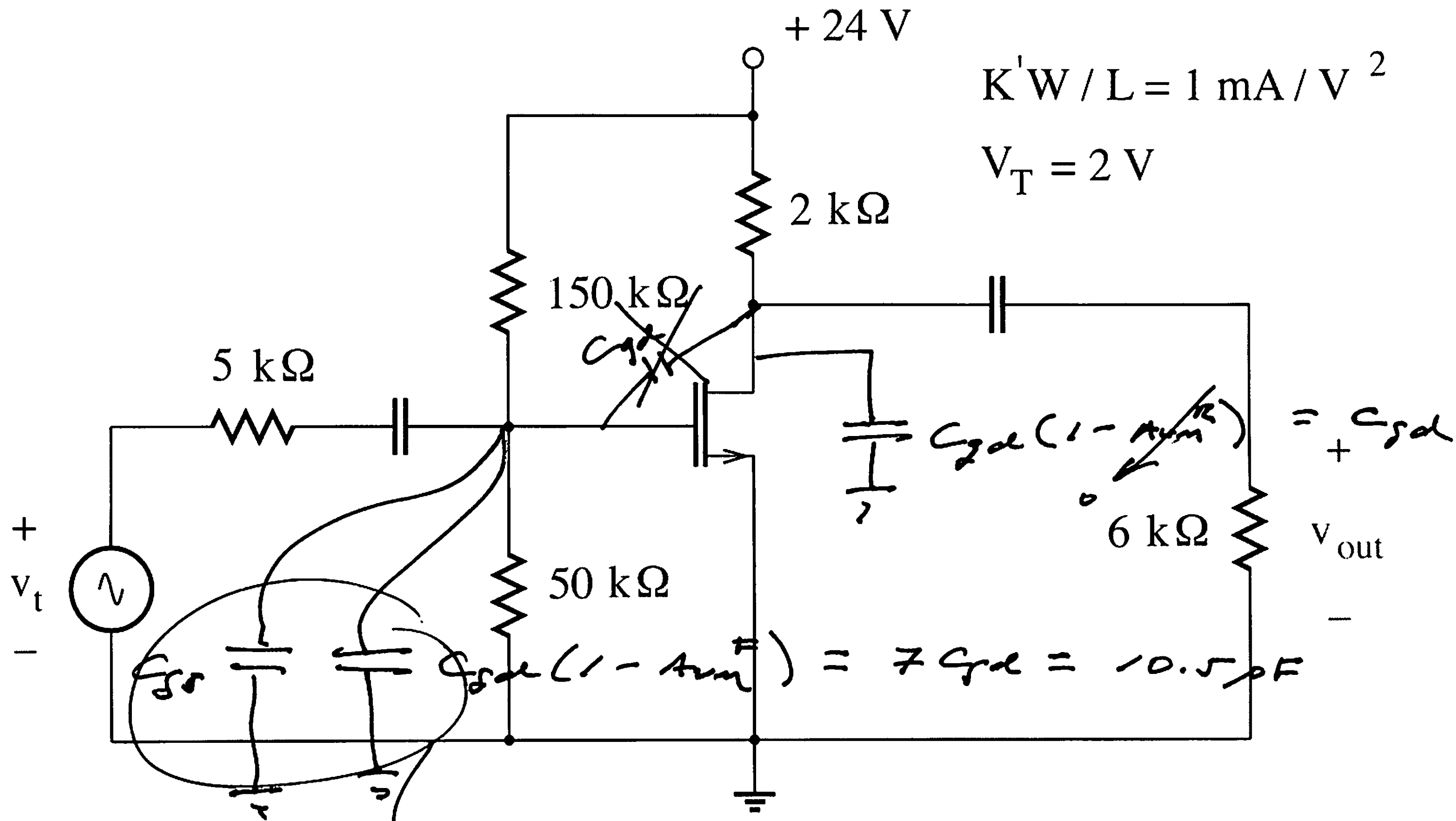
$\Sigma \tau = 4.526\ ns$

$$f_h \simeq \frac{1}{2\pi \Sigma \tau} = \underline{35.2\ MHz}$$

8.17 $C_{gs} = 2.5\,pF$, $C_{gd} = 1.5\,pF$

$A_{vm}^{F} = -6$ (see Exercise 7.10)

$\tau_{output} = 1.5 \times 10^{-12} \times (\underbrace{2k // 6k}_{1.5k}) = 2.25\,ns$



$C_{gd}(1 - A_{vm}^{R}) \approx C_{gd}$

C_{gs}, $C_{gd}(1 - A_{vm}^{F}) = 7 C_{gd} = 10.5\,pF$

Total 13 pF

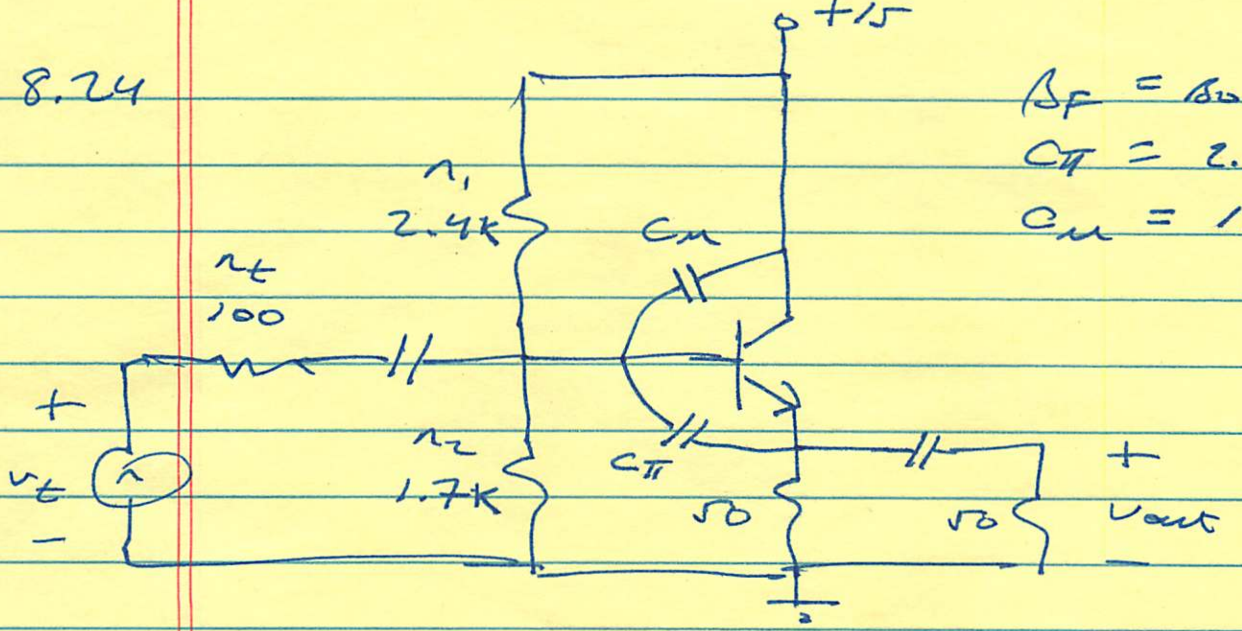
$\tau_{input} = 13 \times 10^{-12} \times (\underbrace{5k // 50k // 150k}_{4.41k})$

$= 57.3\,ns$

$\Sigma\tau = 59.6\,ns$

$f_h \approx \frac{1}{2\pi \Sigma\tau} = 2.67\,MHz$

8.24

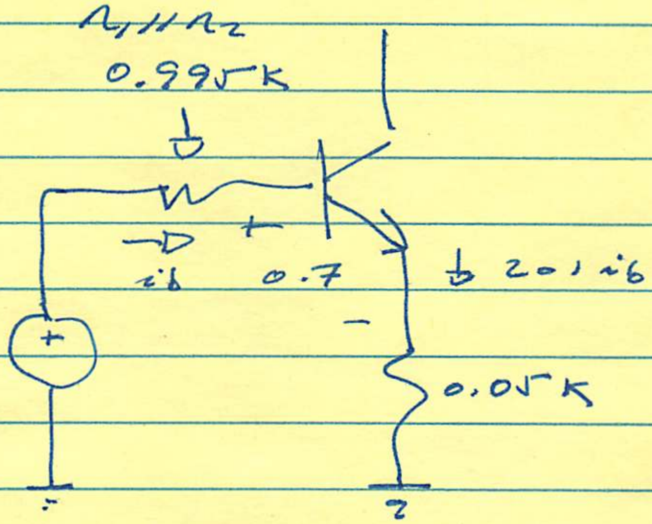


$\beta_F = \beta_0 = 200$

$C_\pi = 2.5\ pF$

$C_\mu = 1.5\ pF$

need the Q point for g_m, r_π, A_{vm}, etc.



$15 \frac{r_2}{r_1 + r_2}$

$= 6.22$

$6.22 = 0.995\, i_b + 0.7 + 201\,(0.05)\, i_b$

$i_b = \frac{5.52}{11.0}$

$i_{CQ} = \frac{5.52}{11} (200) = 100\ mA$

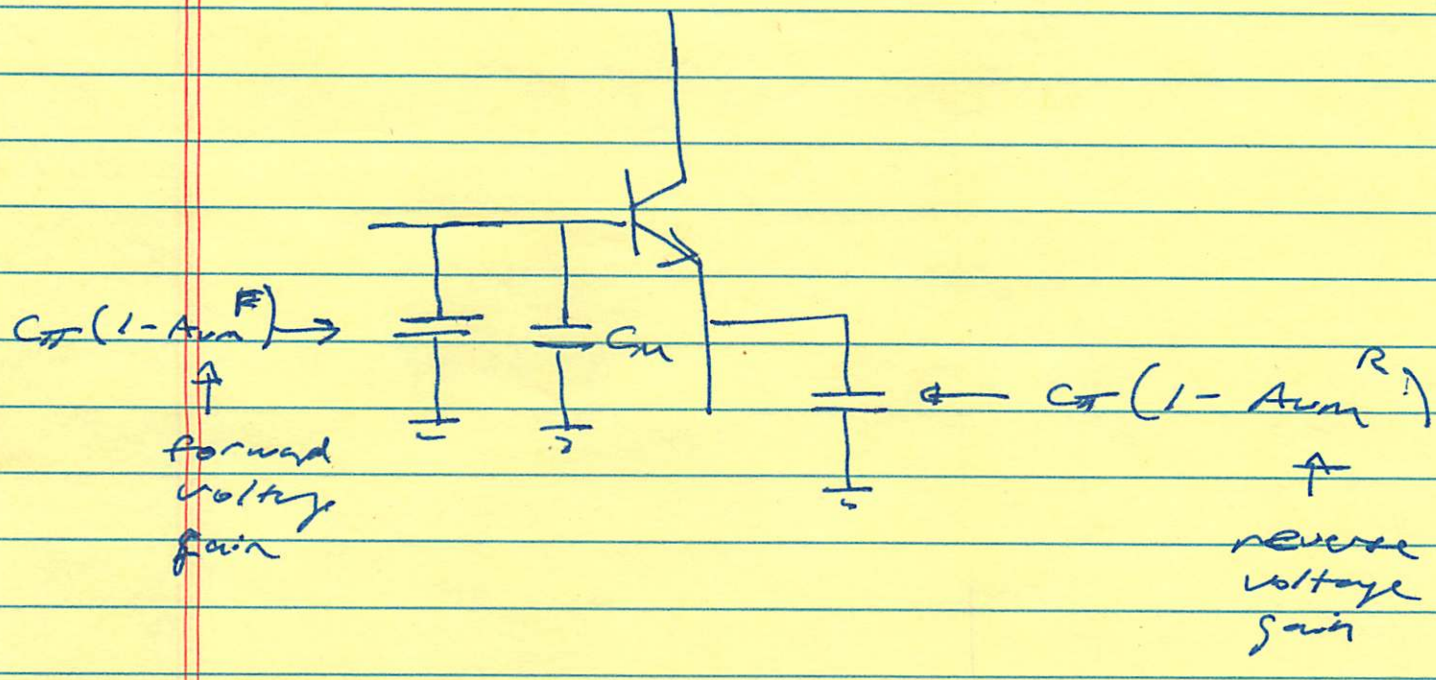
$V_{CEQ} = 15 - (100)(0.05) = 10V$

✓ forward active

$g_m = \frac{i_{CQ}}{kT/q} = \frac{100\ mA}{25.9\ mV} = 3.86\ \mho$

$r_\pi = \beta_0 / g_m = 200 / 3.86 = 51.8\ \Omega$

C_μ connects from base to ac ⏚
C_π is a feedback cap. ⟶ Miller time



A_{vm}^F (common collector) $= \dfrac{g_m R_e'(1+1/\beta_o)}{1+g_m R_e'(1+1/\beta_o)}$

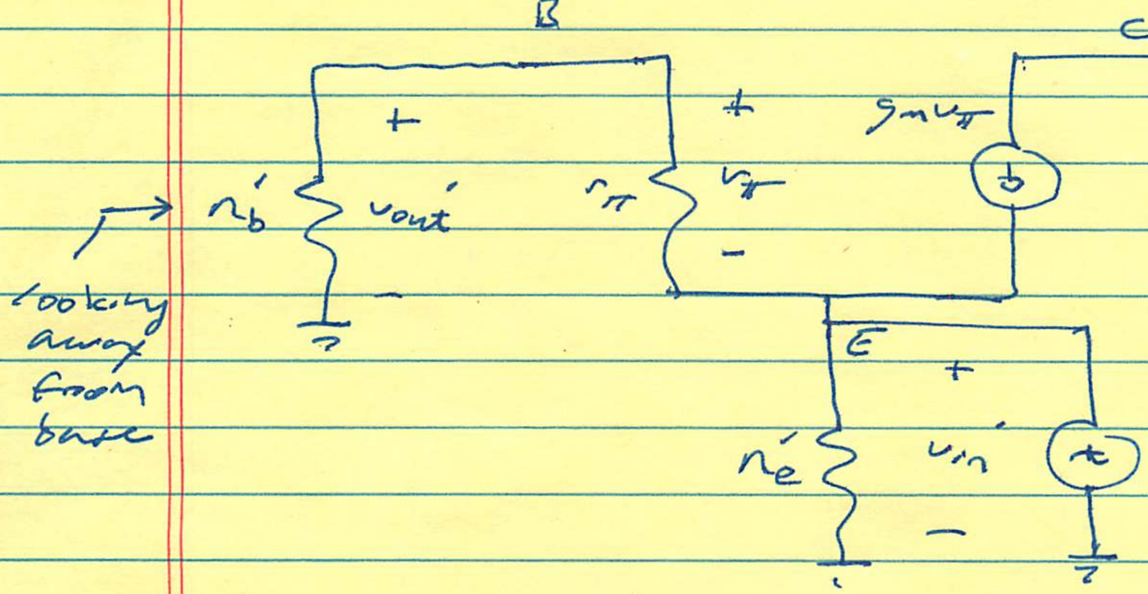
$R_e' = 50\Omega \,//\, 50\Omega = 25\Omega$
(looking away from emitter)

$\rightarrow A_{vm}^F = 0.990$

$C_\pi(1-A_{vm}^F) = 0.025\ pF$ small

$C_\mu + C_\pi(1-A_{vm}^F) = 1.525\ pF$

A_{vm}^{r}



$$\frac{v_{out}'}{v_{in}'} = A_{vm}^{r} = \frac{r_b'}{r_\pi + r_b'}$$

(This situation — BJT, feedback from emitter, is the only $A_{vm}^{r} \neq 0$.)

$$r_b' = r_1 \| r_2 \| r_t = 90.9\ \Omega$$

$$\rightarrow A_{vm}^{r} = \frac{90.9}{51.8 + 90.9} = 0.637$$

$$C_\pi (1 - A_{vm}^{r}) = 0.908\ pF$$

r_1 = resistance to $\frac{1}{2}$ "seen" by $C_\mu + C_\pi[1 - A_{vm}^F]$

$= \underbrace{r_1 \| r_2 \| r_t}_{90.9\,\Omega} \| r_b'$

↑ resistance looking into base

$r_b' = r_\pi + (1+\beta_0) r_e' = 5.08\,K$

r_e': 25 Ω ← Table 8.1

↳ $r_1 \cong 89.3\ \Omega$

$\tau_1 = 1.525 \times 10^{-12} \times 89.3 = 0.136\ ns$

r_2 = resistance to $\frac{1}{2}$ "seen" by $C_\pi[1 - A_{vm}^2]$

$= 50 \| 50 \| r_e'$

↑ resistance looking into emitter

$r_e' = \frac{r_\pi + r_b'}{1+\beta_0}$ ⟵ see Table 8.1

$= \frac{51.8\,\Omega + 90.9\,\Omega}{201} = 0.71\ \Omega$

↳ $r_2 = 0.69\ \Omega$

$\tau_2 = 0.908 \times 10^{-12} \times 0.69 = \underbrace{0.62\ ps}_{\text{negligible}}$

$f_h \approx \frac{1}{2\pi \Sigma \tau} = \underline{1.2\ GHz}$

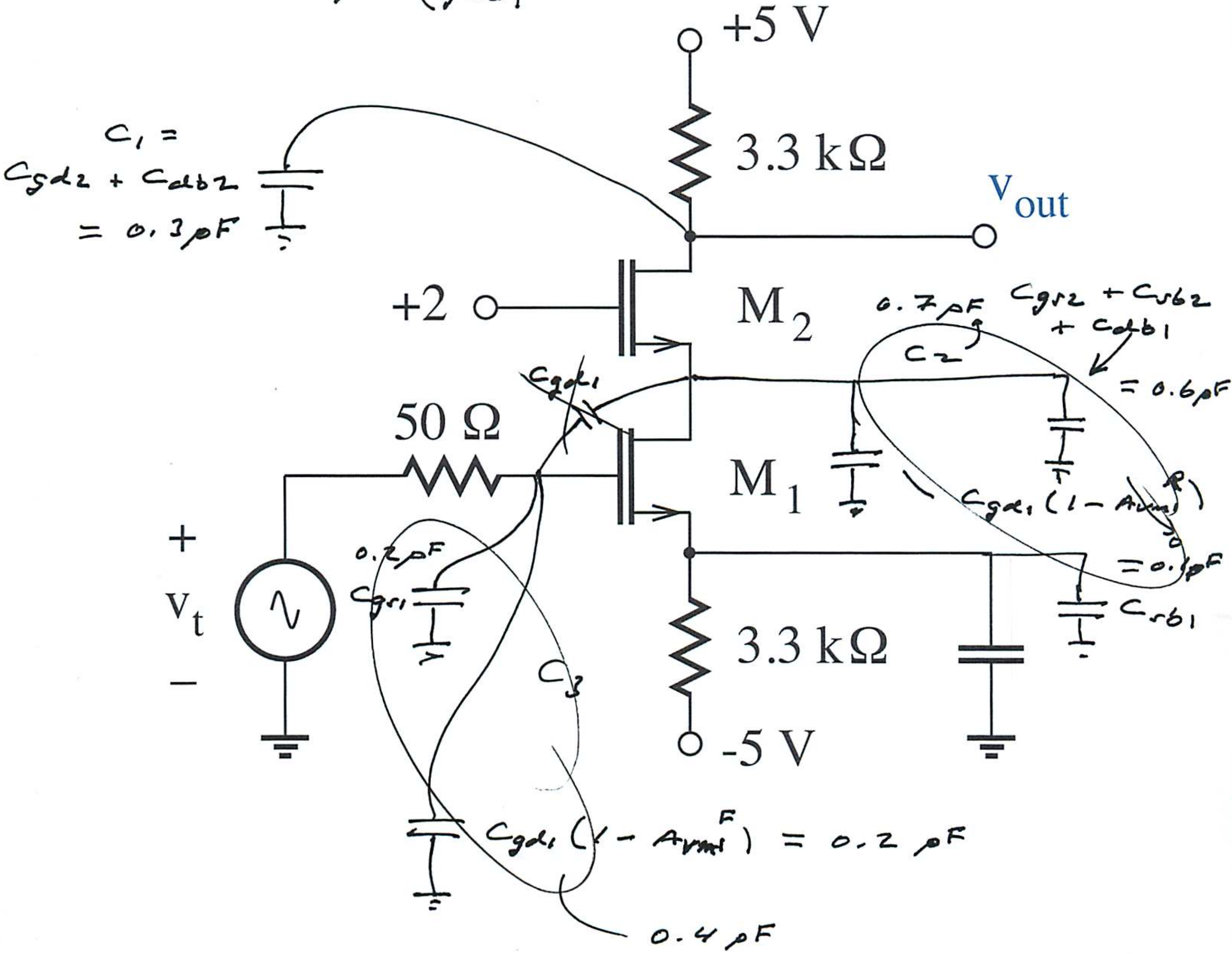
8.33

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

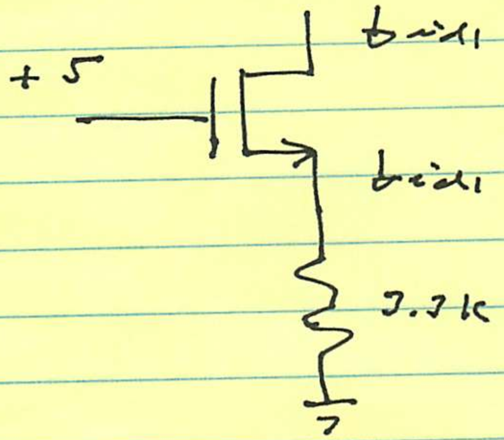
$C_{gs} = 0.2\,pF, \quad C_{gd} = 0.1\,pF$

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

$A_{vm1}^F = -g_{m1}\left(\frac{1}{g_{m2}}\right) = -1$ ← same size M_1, M_2



m_1 biasing



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

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

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

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

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

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

$i_{d1Q} = \frac{1}{2}(2)(1.7 - 0.7)^2 = \underline{1\,mA}$

$= i_{d2Q}$

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

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

M_2 drain: $C_1 = 0.3\ pF$

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

M_2 source: $C_2 = 0.7\ pF$

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

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

M_1 gate: $C_3 = 0.4\ pF$

$r_{eq}^{(3)} = 50\ \Omega$

$\tau_3 = 0.4\ pF \times 0.05\ k = 0.02\ ns$

$\sum \tau = 1.36\ ns$

$f_h \approx \frac{1}{2\pi} \frac{1}{\sum \tau} = 11.7\ MHz$