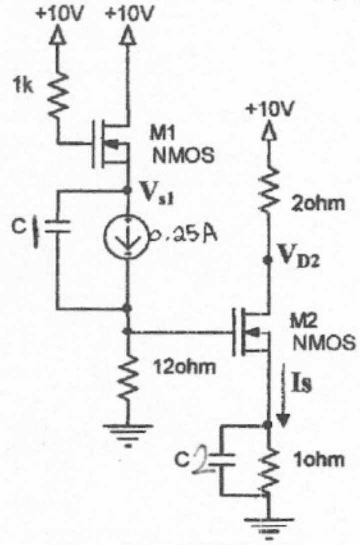


Use: V_t=1V
$k_n'(W/L)=2A/V^2$
λ=0 for all transistors
The 0.25A current source is not ideal and may have a voltage drop across it.
All caps are large.

Solve the circuit for the **DC** values of:
(a) V_{D2}
(b) V_s
(c) Is

$V_{G1} = +10V$

Assume sat:

$I_{D_1} = \frac{1}{2}k_n'(\frac{W}{L})(V_{GS_1} - V_t)^2$

$0.25A = \frac{1}{2}(2)(10 - V_{S1} - 1)^2$

$0.25A = (9 - V_{S1})^2$

$\sqrt{0.25} = 9 - V_{S1}$

$\therefore V_{S1} = 9 \pm \sqrt{0.25} = \boxed{8.84}, 9.5$

if V_{S1}=8.84

$V_{GS} = 10 - 8.84 = 1.16 \geq V_t$ (ON)

if V_{S1}=9.5

$V_{GS} = 10 - 9.5 = 0.5 < V_t$ (off

Q-pt: $V_{GS1} = 10 - 8.84 = \boxed{1.16}$

$V_{D2} = 10 - I_S(2)$

$V_{D2} = 10 - 1(2) = \boxed{8V}$

$V_{DS2} = 8 - 1 = 7V \geq 1 \; (V_{GS} - V_t)$

$\therefore$ saturated

$V_{G2} = 0.25(12) = 3V$

$V_{S2} = I_S(1\Omega)$

$I_{D2} = \frac{1}{2}k_n'(\frac{W}{L})(3 - I_S - V_t)^2$

$I_{D2} = I_S = \frac{1}{2}(2)(2 - I_S)^2$

$I_S = (4 - 4I_S + I_S^2)$

$I_S^2 - 5I_S + 4 = 0 \Rightarrow I_S = \frac{5 \pm \sqrt{25 - 4(4)}}{2} = \frac{5 \pm 3}{2} = 4A, \boxed{1A}$

if I_S=4A: $V_{S2} = 4V \Rightarrow V_{GS2} = 3 - 4 = -1 < V_t \therefore$ off

if I_S=1A: $V_{S2} = 1V \Rightarrow V_{GS2} = 3 - 1 = 2 \geq V_t \therefore$ on

$g_{m2} = k_n'(\frac{W}{L})(V_{GS}-V_t) = \sqrt{2k_n'(\frac{W}{L})I_D} = 4m$

$g_{m3} = 1m(3-1) = \sqrt{2(1m)(2m)} = 2m$

$r_{o3} = \infty$

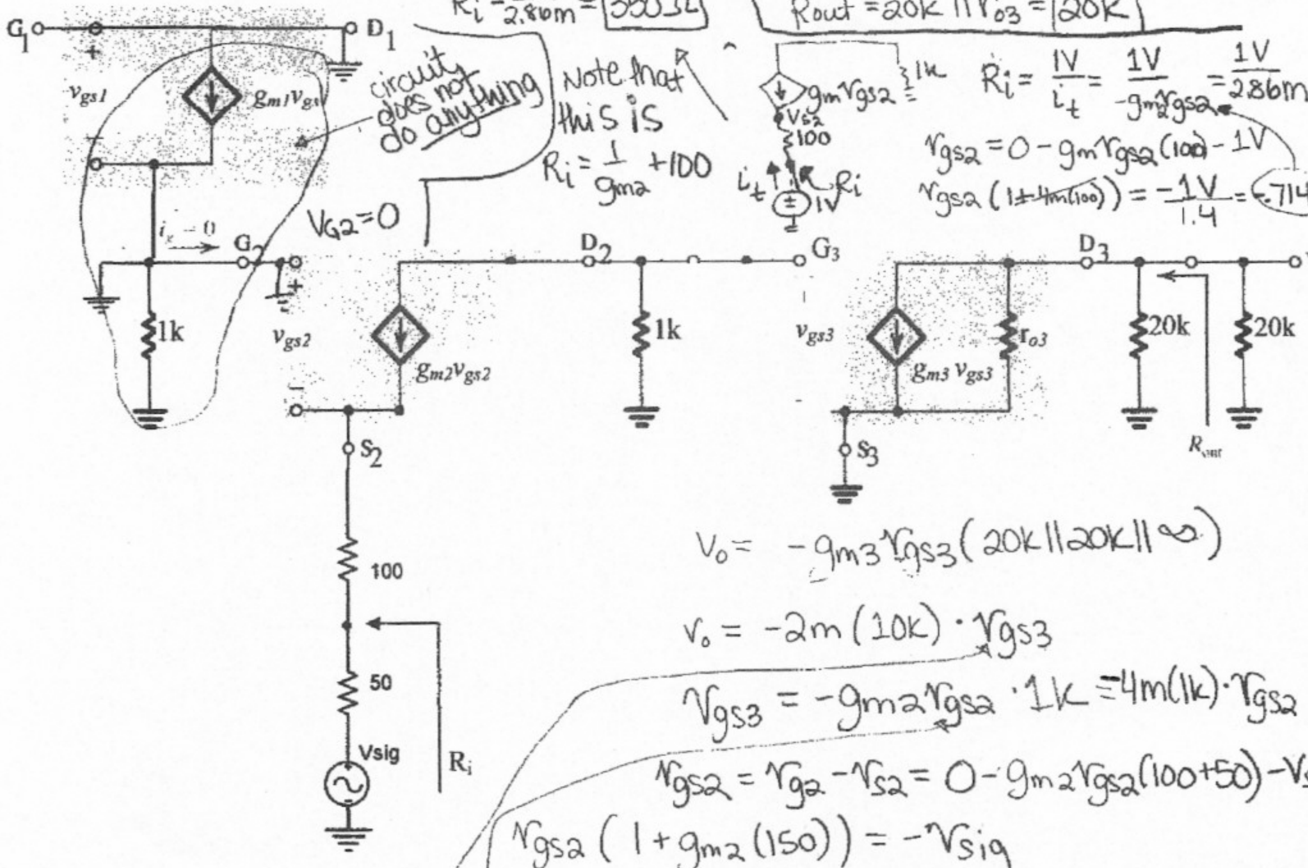
Use: V_t=1V
$k_n'(W/L)$=1mA/V^2
v_{sig} is an AC source
Transistor 1 has DC values: VGS=5V, ID=8mA
Transistor 2 has DC values: VGS=5V, ID=8mA
Transistor 3 has DC values: VGS=3V, ID=2mA
$\lambda = 0$ (for all transistors)

For the following hybrid-π equivalent circuit, find the following values:

(a) R_i (input resistance –ignore the 50ohm and Vsig) $R_i = \frac{1}{2.86m} = \boxed{350\,\Omega}$

(b) Rout (output resistance) $R_{out} = 20K \,||\, r_{o3} = \boxed{20K}$

(c) gain, $\frac{Vo}{Vsig}$



Note that this is $R_i = \frac{1}{g_{m2}} + 100$

$g_m v_{gs2}$ 1k, V_{S2} 100, i_t, 1V, R_i

$R_i = \frac{1V}{i_t} = \frac{1V}{-g_{m2}v_{gs2}} = \frac{1V}{2.86m}$

$v_{gs2} = 0 - g_m v_{gs2}(100) - 1V$

$v_{gs2}(1+4m(100)) = \frac{-1V}{1.4} = -.714$

$V_o = -g_{m3}v_{gs3}(20K \,||\, 20K \,||\, \infty)$

$v_o = -2m(10K) \cdot v_{gs3}$

$v_{gs3} = -g_{m2}v_{gs2} \cdot 1K = -4m(1k) \cdot v_{gs2}$

$v_{gs2} = v_{g2} - v_{s2} = 0 - g_{m2}v_{gs2}(100+50) - v_{sig}$

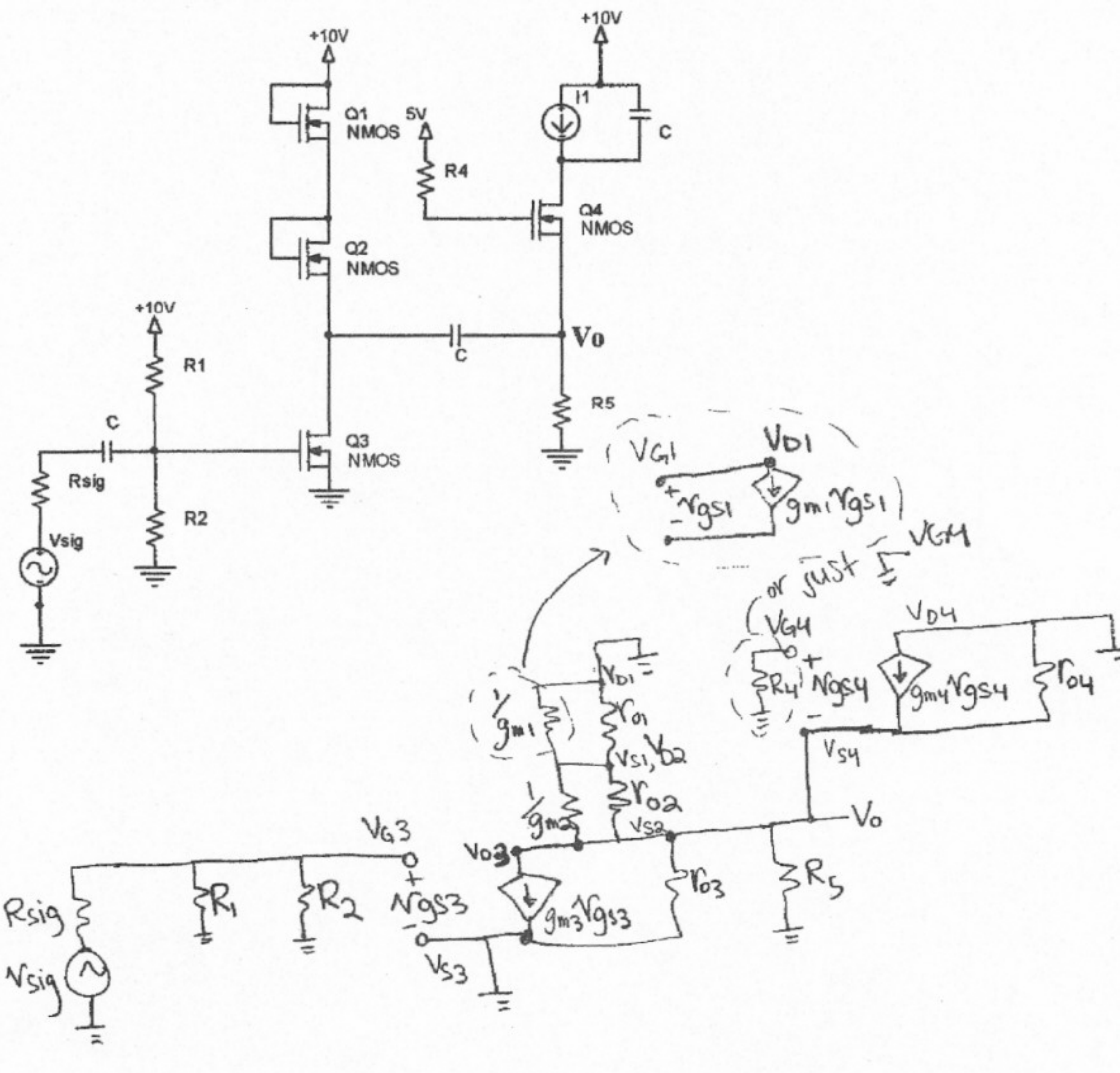
$v_{gs2}(1 + g_{m2}(150)) = -v_{sig}$

$v_{gs2} = \frac{-v_{sig}}{1+4m(150)} = \frac{-v_{sig}}{1.6}$

$v_{gs3} = -4m(1k)\frac{(-v_{sig})}{1.6} = +2.5v_{sig}$

$\frac{v_o}{v_{sig}} = +2.5(-2m)(10k) = \boxed{-50\ V/V}$

For the circuit shown below, draw the AC small-signal equivalent circuit(use hybrid-π or model T). Make sure that everything is labeled in terms of the transistor number. (e.g. g_{m1}, v_{gs2}, etc.). $\lambda \neq 0$ for all transistors. v_{sig} is an AC source.



Let V_t=1V, $k_n'(W/L)$=1mA/V^2, and λ=0.

(a) Solve the DC circuit assuming capacitors are acting as an open.
(b) Draw the small-signal equivalent circuit
(c) Analyze the circuit to find $A_v=V_o/V_{in}$, R_{in} and R_{out}
(d) Find all low frequency pole values
(e) Find ω_H given Cgs= 10pF and C_{gd}=0.1pF.

$\omega_H = \dfrac{1}{R'_{sig}(C_{eq}+C_{gs})}$

$C_{eq} = C_{gd}(1+g_m R'_L)$

$R'_{sig} = 1k \| 5Meg \approx 1k$ (Rsig)

$R'_L = 3k$ (Radd)

$\therefore \omega_H = \dfrac{1}{1k(.4p+10p)} = 96M \frac{rad}{sec}$

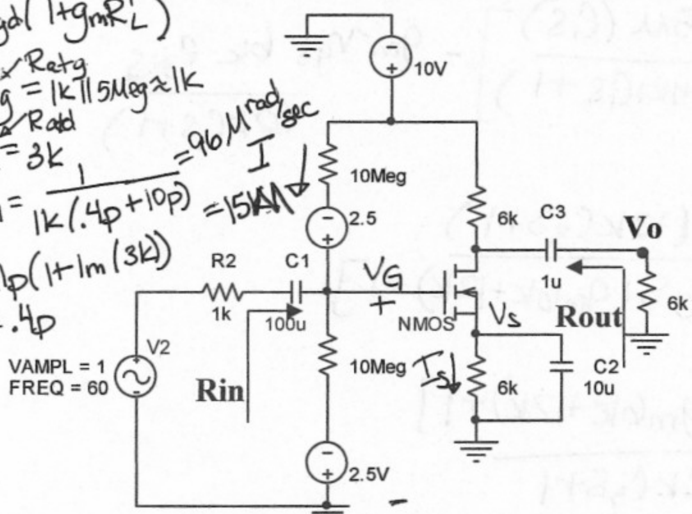
$C_{eq} = .1p(1+1m(3k)) = .4p$

pole values: $C_1 \Rightarrow \dfrac{1}{C_1 * (1k+5M)} \cong 2m \frac{rad}{sec}$

$C_2 \Rightarrow \dfrac{1}{C_2(6k \| \frac{1}{g_m})} \cong 117 \frac{rad}{sec} \cong 19Hz$

$\frac{\omega}{2\pi} = f$

$C_3 \Rightarrow \dfrac{1}{C_3(6k \| 6k)} = 333 \frac{rad}{sec} = \boxed{53Hz}$



$+10 - I(10Meg) + 2.5 - I(10Meg) + 2.5 = 0$

$I = \dfrac{15}{20Meg} = .75\mu A$

$+V_G - I(10Meg) + 2.5 = 0$

$V_G = 7.5 - 2.5 = \underline{5V}$

$+V_S - I_S(6k) = 0$

$V_S = I_S(6k)$

$V_{GS} = 5 - I_S(6k)$

$I_D = \frac{1}{2}k_n'(\frac{W}{L})(V_{GS}-V_t)^2 = \frac{1}{2}(1m)(5 - I_D(6k) - 1)^2$

$18I_D^2 - 25I_D + 8 = 0$

$I_D = .89m, \boxed{0.5m} \rightarrow$

$V_S = .89m(6k) = 5.34$

$V_{GS} = 5 - 5.34 = -0.34 < V_t \therefore$ OFF

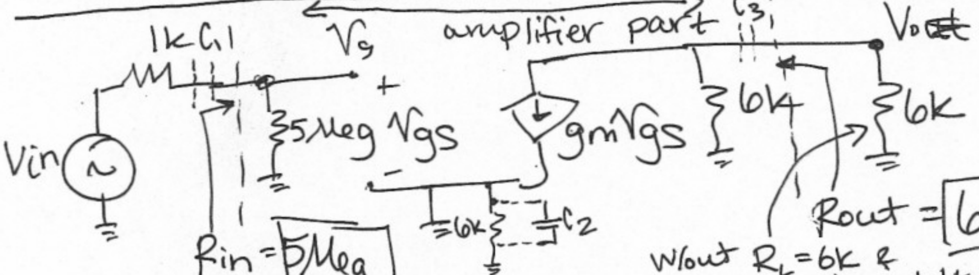
$V_S = 0.5m(6k) = 3V$

$V_{GS} = 5 - 3 = 2V$

$V_D = 10 - I(6k) = 10 - 6k(.5m)$

$V_D = 7V$

$4 = (7-3) = V_{DS} \geq (V_{GS} - V_t) = 2 - 1 = 1$



Rin = $\boxed{5Meg}$

Rout = $\boxed{6K}$

w/out R_L = 6K & input 1k

$A_{vo} = \dfrac{V_o}{V_g} \Rightarrow -g_m V_g 6k = -6 V/V$

$g_m = \sqrt{2k_n'(\frac{W}{L})I_D}$

$= \sqrt{2(1m)(.5m)}$

$g_m = 1mA/V^2$

$g_m = k_n'(\frac{W}{L})(V_{GS}-V_t)$

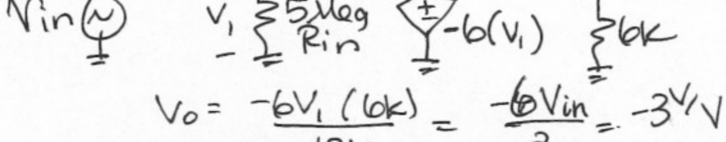
$= 1m(2-1) = 1m A/V^2$

$V_o = -g_m V_{gs}(6k \| 6k)$

$V_{gs} = V_g - 0 = \dfrac{V_{in}(5Meg)}{5Meg + 1k} \cong V_{in}$

$\therefore \dfrac{V_o}{V_{in}} = -g_m \cancel{V_{in}} (3k)$

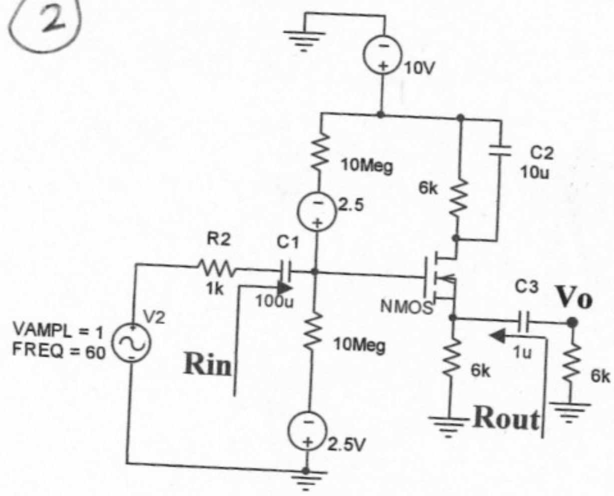
$= -1m(3k) = \boxed{-3 V/V}$



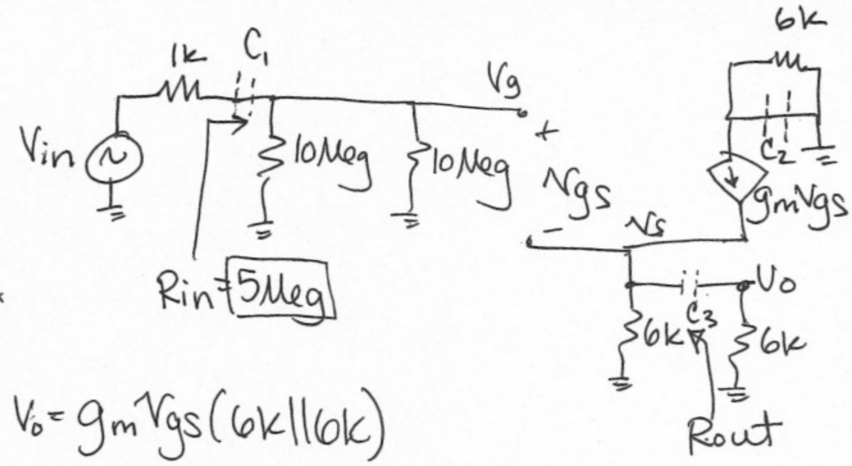
$V_o = \dfrac{-6V_1(6k)}{12k} = \dfrac{-6V_{in}}{2} = -3 V/V$

same

(2)



$I_D = .5m,\ V_{GS} = 2V,\ g_m = 1m\,A/V^2$



$R_{in} = \boxed{5Meg}$

$V_o = g_m V_{gs}(6k \| 6k)$

$V_o = 1m(3k)V_{gs}$

$= 1m(3k)\dfrac{V_{in}}{4}$

$\dfrac{V_o}{V_{in}} = \boxed{0.75 \cancel{V/V}}$

$R_{out} = 6k \| \dfrac{1}{g_m}$

$R_{out} \approx \boxed{857}$

$V_{gs} = V_g - V_s$

$V_g = \dfrac{V_{in}(5Meg)}{5Meg + 1k} \cong V_{in}$

$V_s = g_m V_{gs}(3k)$

$V_{gs} = V_{in} - g_m V_{gs}(3k)$

$V_{gs} + g_m V_{gs}(3k) = V_{in}$

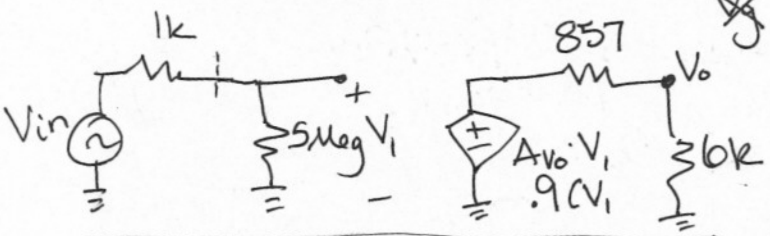
$\therefore V_{gs} = \dfrac{V_{in}}{(1 + g_m(3k))}$

$A_{vo} = \dfrac{V_{o\_w/o\ 6k)}}{V_g} = \dfrac{g_m V_{gs}(6k)}{V_g}$

$V_{gs} = V_g - g_m V_{gs}(6k)$

$V_{gs} = \dfrac{V_g}{1 + (1m)(6k)} = \dfrac{V_g}{7}$

$\therefore \dfrac{V_{o(-6k)}}{\cancel{V_g}} = \dfrac{g_m \cancel{V_g}(6k)}{7} \cong 0.9\,V/V$



$\Rightarrow V_o = \dfrac{A_{vo} \cdot V_1 \cdot 6k}{6k + 857}$

$\dfrac{V_o}{V_{in}} = \dfrac{.9 \cancel{V_{in}}(6k)}{6k + 857} \approx \boxed{.79}$

same

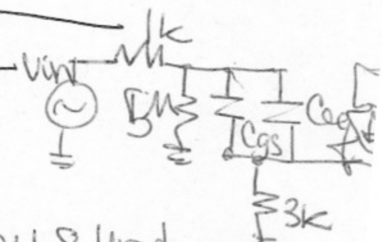
$C_1 \Rightarrow \dfrac{1}{C_1(1k + 5Meg)} = 2m\,\dfrac{rad}{sec.}$

$C_2 \Rightarrow \dfrac{1}{10\mu(6k)} = 17\,\dfrac{rad}{sec.}$

$C_3 \Rightarrow \dfrac{1}{1\mu(6k \| \frac{1}{g_m} + 6k)} = \boxed{146\,\frac{rad}{sec.}}$

23Hz

$\omega_H = \dfrac{1}{(3k + \underbrace{1k \| 5Meg}_{1k})(C_{eq} + 1p)}$



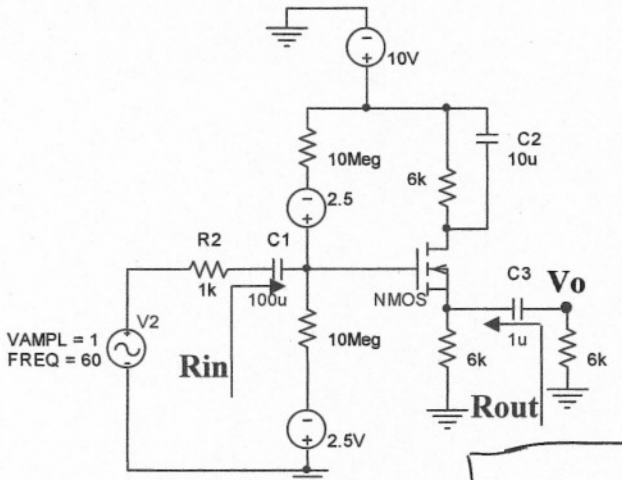
$C_{eq} = C_{gd}(1 + g_m(0))$

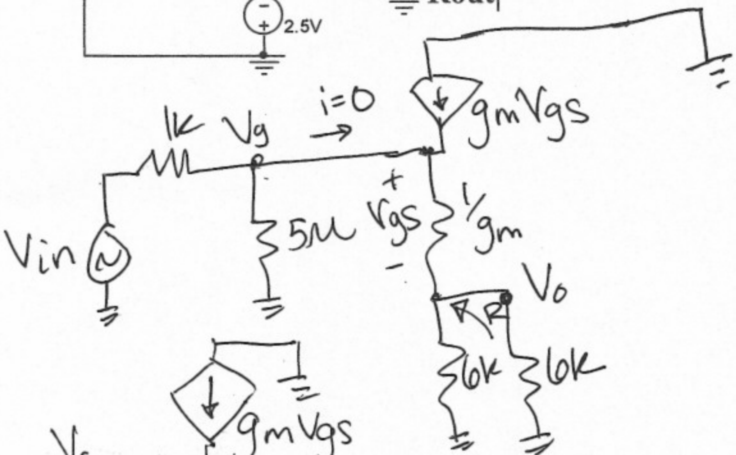
$.1p$

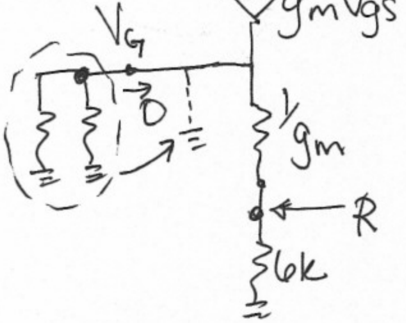
$\omega_H = \dfrac{1}{(3k + 1k)(C_{gd} + C_{gs})} =$

$24.8\,M\dfrac{rad}{sec}$

$\boxed{3.9\,MHz}$







$V_g \simeq V_{in}$

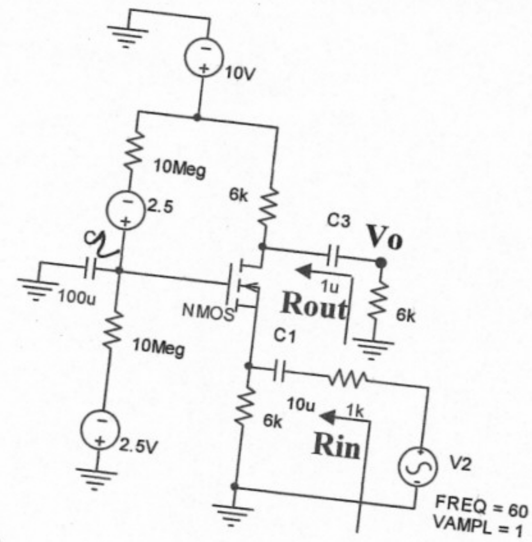
$V_o = g_m V_{gs}(3k)$

$V_{gs} = V_g - V_s = V_{in} - g_m V_{gs}(3k)$

$V_{gs} + g_m V_{gs}(3k) = V_{in}$

$V_{gs} = \dfrac{V_{in}}{(1+g_m(3k))} = \dfrac{V_{in}}{4}$

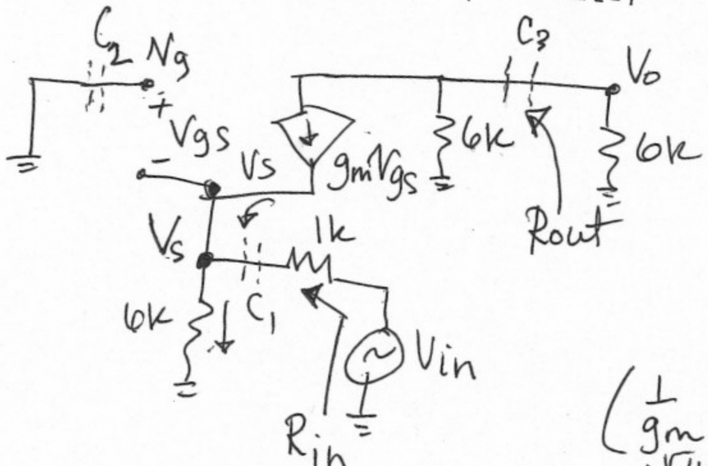
$\dfrac{V_o}{V_{in}} = \dfrac{3}{4}$ V/V



$g_m = 1m\ A/V^2$

$V_o = -g_m V_{gs}(3k)$

$V_{gs} = V_g - V_s = 0 - V_s$



$g_m(-V_s) + \frac{V_{in} - V_s}{1k} + \frac{-V_s}{6k} = 0$

$+V_s\left(\underbrace{\overbrace{g_m + \frac{1}{1k} + \frac{1}{6k}}^{2.2m}}_{}\right) = \frac{V_{in}}{1k}$

$V_s = \frac{1}{g_m} \| 1k \| 6k$

$\frac{V_{in}(\cancel{\frac{1}{g_m}} \| \cancel{1k})}{1k(2.2m)}$

$\frac{V_s}{V_{in}} = \boxed{.46\ V/V}$

$V_s = .45 V_{in}$

$\frac{V_o}{V_{in}} = 3(.45)\cancel{V_{in}} = \boxed{1.35\ V/V}$

$\left(\frac{1}{g_m} \| 6k \| 1k\right)$
(461)

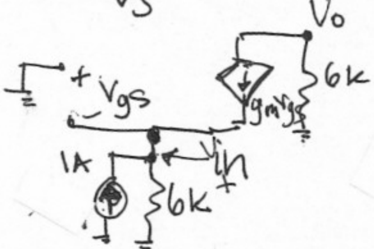
$\boxed{R_{out} = 6k}$ $R_{in} = 6k \| \frac{1}{g_m} = \boxed{857}$

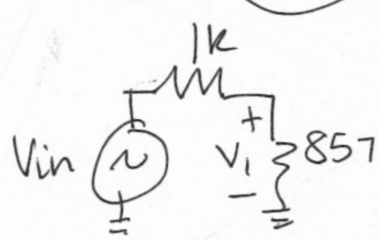
$A_{vo} \Rightarrow \frac{V_o}{V_s}$

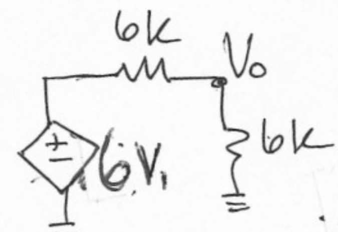
$V_o = -g_m V_{gs}(6k)$

$V_{gs} = V_g - V_s = -V_s$

$\frac{V_o}{V_s} = +g_m(6k) = 6$







$V_1 = \frac{V_{in}(857)}{1{,}857} = V_{in}(.46)$

$V_o = \frac{6V_1(6k)}{12k} = 3V_1 = 3(.46)V_{in}$

$\frac{V_o}{V_{in}} = 1.38\ V/V$

same

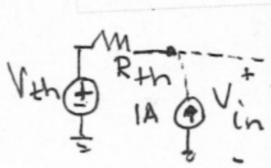
$R_{th} = 6k \| \frac{1}{g_m} = 857$

$V_{in} = R_{th}(1A) + V_{th}$

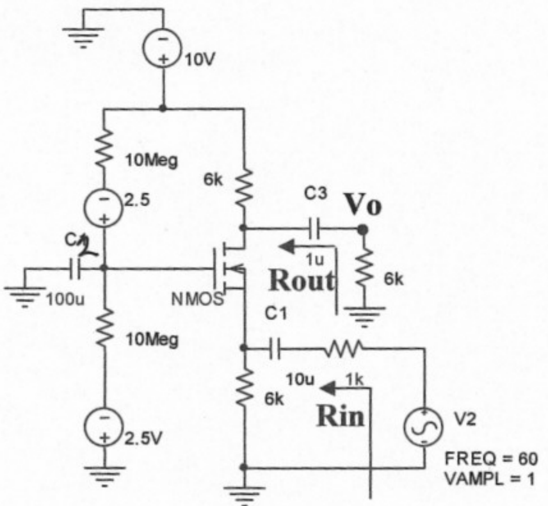
$V_{th} = (V_{in} - R_{th})$

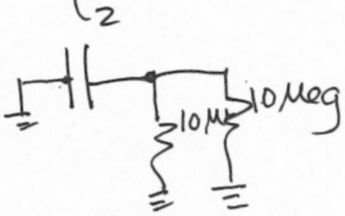
$1A - \frac{V_{in}}{6k} + g_m(-V_{in}) = 0$

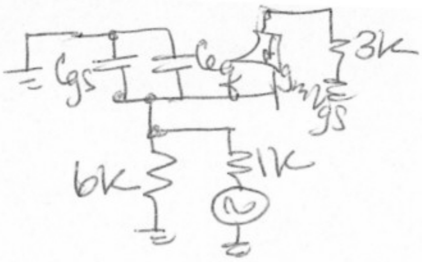
$V_{in} = \frac{1}{\frac{1}{6k} + g_m} = 857$



$\frac{V_{in} - V_{th}}{R_{th}} = 1$







$R_L' = 3k$

$R_{sig}' = 857$

$\omega_H = 112\,M \frac{rad}{sec}$

$\boxed{17.9\,MHz}$

$\frac{1}{C_2(5Meg)} = 2m \frac{rad}{sec.}$

$\frac{1}{C_3(6k+6k)} = \boxed{83 \frac{rad}{sec.}}$

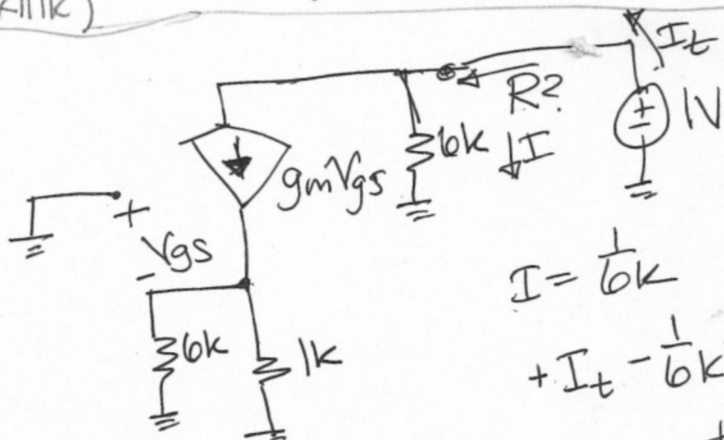
$\approx 13\,HZ$

$\frac{1}{C_1(1k + \underbrace{6k \| \frac{1}{g_m}}_{857})} = 18.57m$

$\omega_H = \frac{1}{R_{sig}'(C_{eq.} + C_{gs})}$

$(0 + 6k \| 1k)$

$C_{eq.} = C_{gd}(1 + g_m R_L') = .4p$



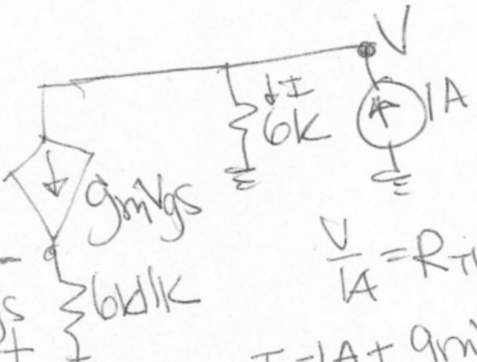
$\frac{1V}{I_t} = R_{th}$

$R_{th} = \frac{1V}{1/6k} = \underline{6k}$

$I = \frac{1}{6k}$

$+I_t - \frac{1}{6k} - g_m V_{gs} = 0$

$I_t = +\frac{1}{6k} + g_m V_{gs}$ $=0$



$\frac{V}{1A} = R_{TH}$

$I - 1A + g_m V_{gs} = 0$

$0 = -\cancel{V_{gs}} = g_m V_{gs}(6k \| 1k) + V_{gs}$

$\therefore V_{gs} = 0$

Easiest way to see

$i_{sc} = -g_m V_{gs}$

$V_{th} = -g_m V_{gs}(6k)$

$R_{th} = \frac{V_{th}}{i_{sc}}$

$= \frac{\cancel{-g_m V_{gs}}(6k)}{\cancel{-g_m V_{gs}}}$