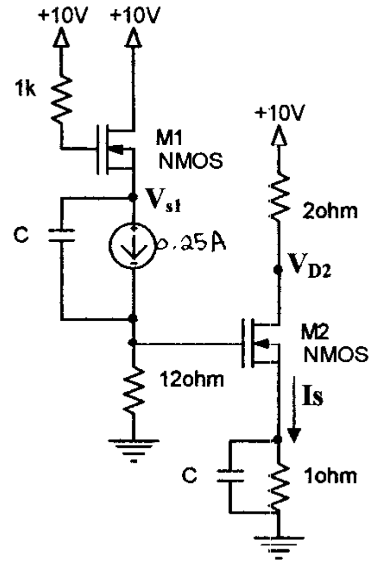
Exam2 – Solution

Problem 1 (35 points)



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_{s1}~~ Transistor M1's Q pt.
(c) Is

$V_{G1} = +10V$

Assume sat:

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

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

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

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

$\therefore V_{S1} = 9 \pm \sqrt{0.25} =$ 8.5, 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} = 10-8.5 = 1.5

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

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

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

$\therefore$ saturated

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

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

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

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

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

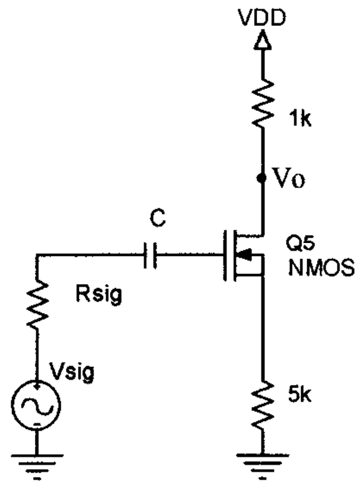
$I_S^2 - 5I_S + 4 = 0 \Rightarrow I_S = \frac{5\pm\sqrt{25-4(4)}}{2} = \frac{5\pm3}{2} = 4A,$ 1A

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

Problem 2 (10 points)

v_{sig} =0.01sin(ωt). Does this circuit operate as an AC amplifier? If so, what is the gain, $\frac{Vo}{Vsig}$, of the following circuit in terms of VDD?



NO, the gate is floating in the DC operation. The transistor is therefore not on or saturated and can not amplify v_{sig}.

Problem 3 (35 points)

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)

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

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

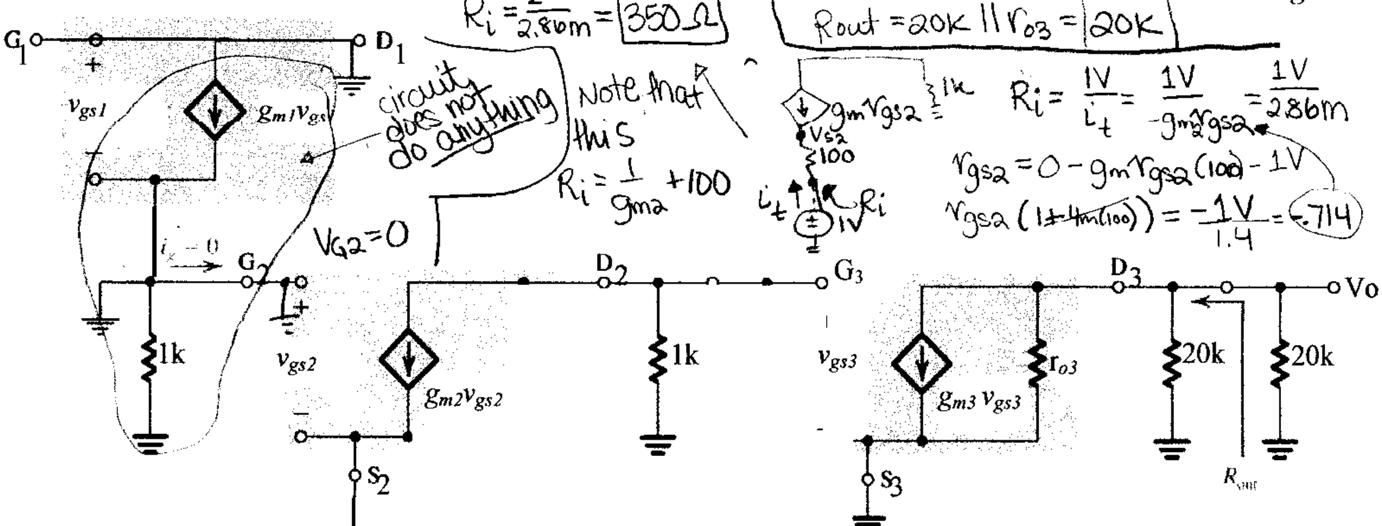
$r_{o3} = \infty$

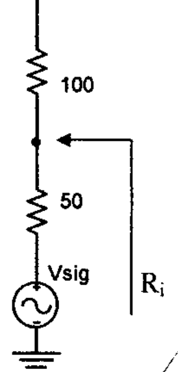
For the following hybrid-π equivalent circuit, find the following values:

(a) R_i (input resistance –ignore the 50ohm and Vsig) (b) Rout (output resistance) (c) gain, $\frac{Vo}{Vsig}$

$R_i = \frac{1}{2.86m} = \boxed{350\,\Omega}$

$\boxed{R_{out} = 20K \,\|\, r_{o3} = 20K}$





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

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

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

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

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

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

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

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

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

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

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

Problem 4 (20 points)

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.