

Exam2 - Solution

Problem 1 (35 points)

Use: $V_t = 1V$

$$k_n'(W/L) = 2A/V^2$$

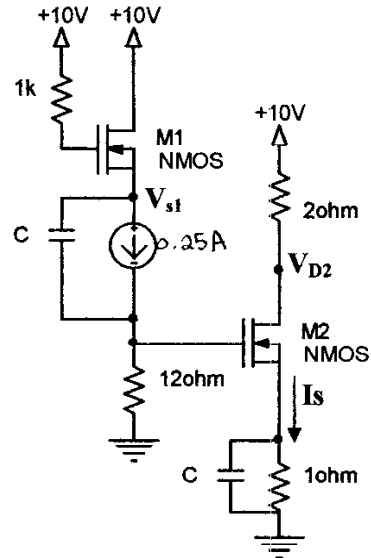
$\lambda = 0$ for all transistors

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:

- V_{D2}
- V_{S1} Transistor M1's Q pt.
- I_S



$V_{G1} = +10V$
 Assume sat: $I_{D1} = \frac{1}{2} k_n' \left(\frac{W}{L}\right) (V_{GS1} - V_t)^2$
 $0.25A = \frac{1}{2} (2) (10 - V_{S1} - 1)^2$
 $0.25A = (9 - V_{S1})^2$
 $\sqrt{0.25} = 9 - V_{S1}$
 $\therefore V_{S1} = 9 \pm \sqrt{0.25} = \boxed{8.5}, 9.5$
 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: $V_{GS1} = \frac{10 - 8.5}{1} = \boxed{1.5}$

$V_{D2} = 10 - I_S (2)$
 $V_{G2} = 10 - 1(2) = \boxed{8V}$
 $V_{DS2} = 8 - 1 = 7V \geq 1 (V_{GS} - V_t)$
 \therefore saturated

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

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

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

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

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

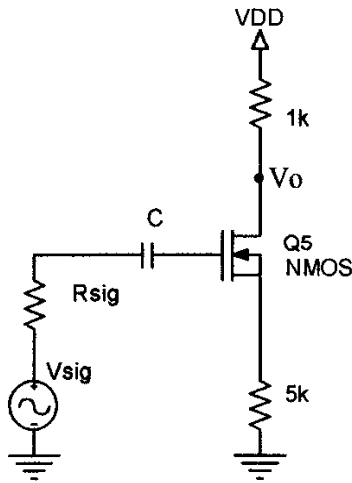
$$I_S^2 - 5I_S + 4 = 0 \Rightarrow I_S = \frac{5 \pm \sqrt{25 - 4(4)}}{2} = \frac{5 \pm 3}{2} = 4A, \boxed{1A}$$

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

Problem 2 (10 points)

$v_{sig} = 0.01\sin(\omega t)$. Does this circuit operate as an AC amplifier? If so, what is the gain, $\frac{V_o}{V_{sig}}$, 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: $V_{GS} = 5V, I_D = 8mA$
 Transistor 2 has DC values: $V_{GS} = 5V, I_D = 8mA$
 Transistor 3 has DC values: $V_{GS} = 3V, I_D = 2mA$
 $\lambda = 0$ (for all transistors)

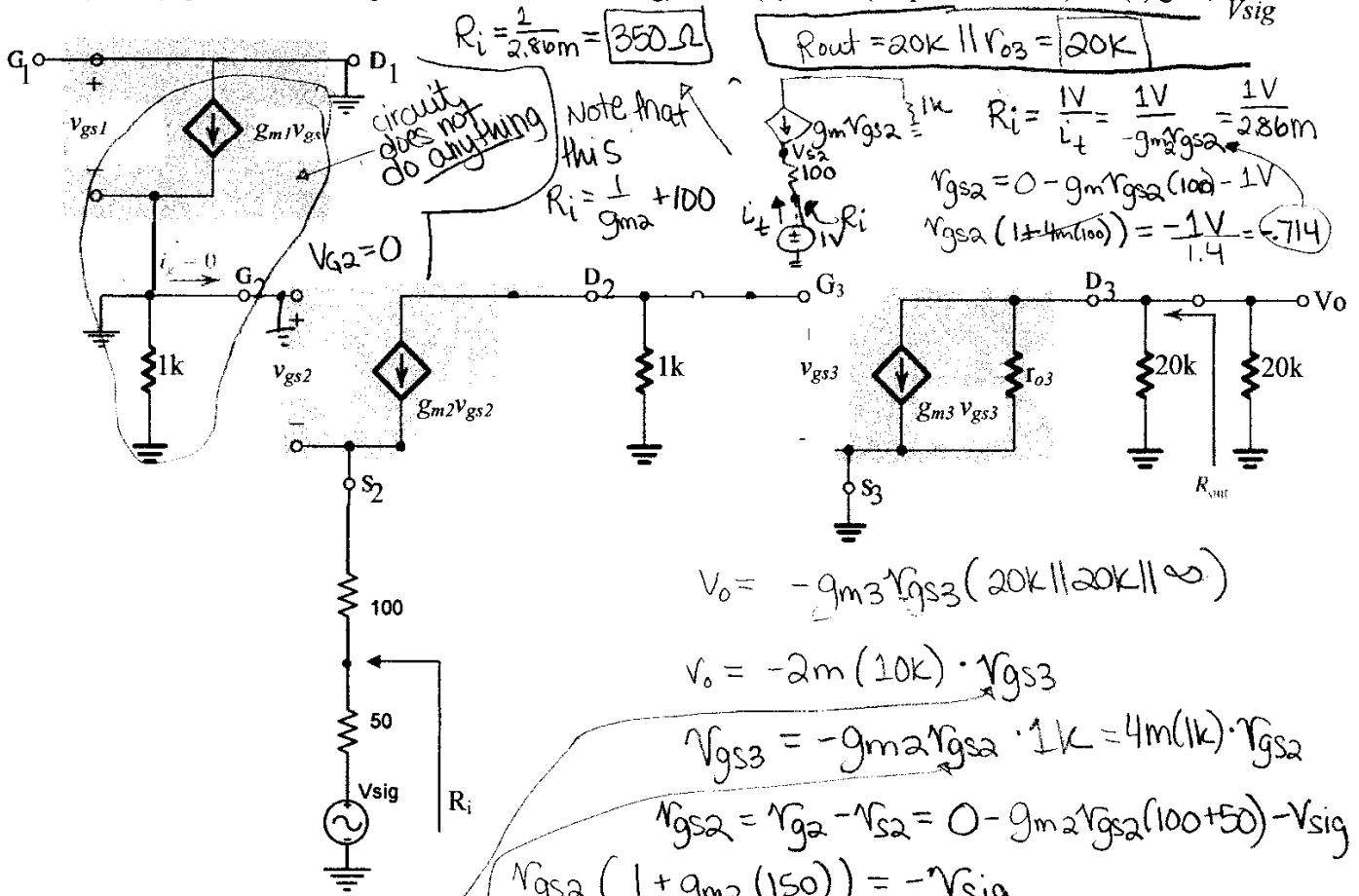
$$g_{m2} = k_n' \left(\frac{W}{L}\right) (V_{GS} - V_t) = \sqrt{2k_n' I_D} = 4m$$

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

$$r_{o3} = \infty$$

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

- (a) R_i (input resistance - ignore the 50ohm and V_{sig}) (b) R_{out} (output resistance) (c) gain, $\frac{V_o}{V_{sig}}$



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

$$R_{out} = 20k \parallel r_{o3} = 20k$$

circuit does not do anything

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

$$R_i = \frac{1V}{I_t} = \frac{1V}{-g_{m2} v_{gs2}} = 286m$$

$$v_{gs2} = 0 - g_{m1} v_{gs1} (100) - 1V$$

$$v_{gs2} (1 + 4m(100)) = \frac{-1V}{1.4} = -0.714$$

$$V_o = -g_{m3} v_{gs3} (20k \parallel 20k \parallel \infty)$$

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

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

$$v_{gs2} = v_{gs2} - v_{s2} = 0 - g_{m1} v_{gs1} (100 + 50) - v_{sig}$$

$$v_{gs2} (1 + g_{m1} (150)) = -v_{sig}$$

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

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

$$\frac{V_o}{V_{sig}} = -2.5 (-2m)(10k) = 50 \frac{V}{V}$$

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.

