EE232-INTRODUCTION TO ELECTRONICS-FALL 2009
EXERCISE-M2

For the MOS transistors in Figure-1a
$\beta_1=\beta_2=10mA/V^2$, $\beta_3=1.8mA/V^2$, $\beta_4=0.2mA/V^2$,
$V_{TH1}=V_{TH2}=V_{TH3}=-1V$ and $V_{TH4}=1V$ are given.
(All transistors are in saturation mode.)

a) Find I_{D1} and I_{D2} for Vi=0V. (10Points)
(Note that the circuit given in Figure-1b is used in order to get V_{G3} and all transistors in Figure-1b have the same properties.)

b) Find ac gain of the circuit (vo/vi). (10Points)

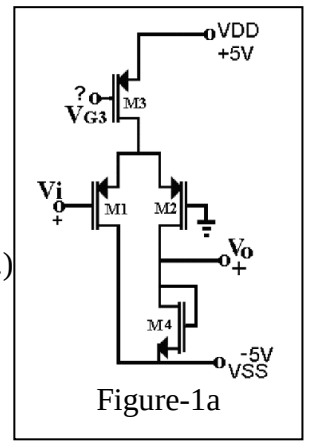

Figure-1a

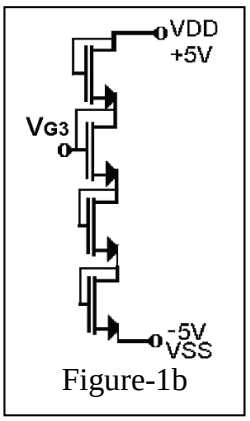

Figure-1b

Solution:
In Figure-1b, the transistors are the same.
On the other hand, one sees from the configuration that
their drain currents are the same, too. And their gates and drains are short-circuit ($V_{GD}=0V<V_{TH}=1V$, so they are in saturation mode). Therefore, their gate-source voltages should be the same.
(Everything is the same!)

$$V_{G3}=\frac{V_{DD}-V_{SS}}{4}=\frac{10}{4}=2.5V$$

$I_{D1}=I_{D2}$ when Vi=0, since M1 and M2 have the same properties and the same V_{GS}, and they are in saturation mode (in saturation I_D is independent from drain voltage).

$$I_{D1}=I_{D2}=\frac{I_{D3}}{2}=\frac{1}{2}\frac{\beta_3}{2}(V_{GS3}-V_{TH3})^2=\frac{1}{2}\frac{1.8mA/V^2}{2}(2.5V-5V-(-1V))^2\cong 1mA$$

b)

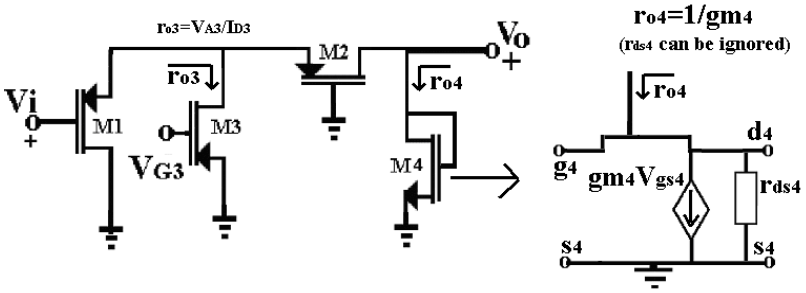

Figure-S21 ac case of the circuit.

$$\frac{v_O}{v_i}=\frac{v_{s1}}{v_{g1}}\frac{v_{d2}}{v_{s2}}=\frac{g_{m1}R_{s1}}{1+g_{m1}R_{s1}}g_{m2}R_{d2} \qquad g_{m1}=g_{m2}=\sqrt{2\beta_2 I_{D2}}=4.47mS$$

$$R_{s2}=r_{O3}\,//\,r_{i2}=\frac{V_{A3}}{I_{D3}}\,//(\frac{1}{g_{m2}})=\frac{50V}{2mA}\frac{1}{\sqrt{2\beta_2 I_{D2}}}\cong 25k\,//\,\frac{1}{4.47mS}\cong 225$$

$$R_{d2}=r_{o4}=1/g_{m4}=1/\sqrt{2\beta_4 I_{D4}}=1/0.63mS\cong 1.6k$$

$$\frac{v_O}{v_i}=\frac{v_{s1}}{v_{g1}}\frac{v_{d2}}{v_{s2}}=\frac{g_{m1}R_{s1}}{1+g_{m1}R_{s1}}g_{m2}R_{d2}\cong\frac{1}{2}7.2\cong 3.6$$