

**EE232-INTRODUCTION TO ELECTRONICS-FALL 2009**  
**EXERCISE-M2**

For the MOS transistors in Figure-1a

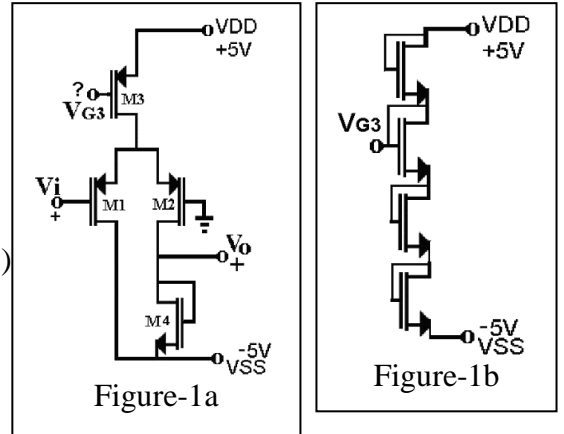
$\beta_1=\beta_2=10\text{mA/V}^2$ ,  $\beta_3=1.8\text{mA/V}^2$ ,  $\beta_4=0.2\text{mA/V}^2$ ,  
 $V_{TH1}=V_{TH2}=V_{TH3}=-1\text{V}$  and  $V_{TH4}=1\text{V}$  are given.

(All transistors are in saturation mode.)

a) Find  $I_{D1}$  and  $I_{D2}$  for  $V_i=0\text{V}$ . (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 ( $v_o/v_i$ ). (10Points)



**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 ( $V_{GD}=0\text{V} < V_{TH}=1\text{V}$ , so they are in saturation mode). Therefore, their gate-source voltages should be the same.

**(Everything is the same!)**

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

$I_{D1}=I_{D2}$  when  $V_i=0$ , 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).

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

b)

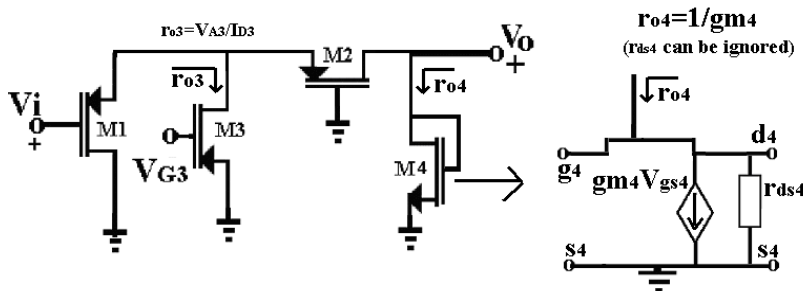


Figure-S21 ac case of the circuit.

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

$$R_{s2} = r_{o3} \parallel r_{i2} = \frac{V_{A3}}{I_{D3}} \parallel \left( \frac{1}{g_{m2}} \right) = \frac{50\text{V}}{2\text{mA}} \parallel \frac{1}{4.47\text{mS}} \cong 25\text{k} \parallel \frac{1}{4.47\text{mS}} \cong 225$$

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

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