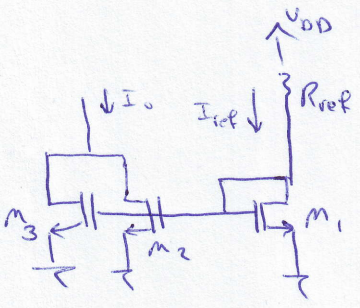


Quiz 2 - Set A)



$$\left. \begin{aligned}
 i) \quad I_0 &= 1 \text{ mA} \\
 \left(\frac{W}{L}\right)_2 &= \left(\frac{W}{L}\right)_3 \\
 V_{GS2} &= V_{GS3}
 \end{aligned} \right\} \Rightarrow I_{D2} = I_{D3} \Rightarrow I_{D2} = I_{D3} = \frac{I_0}{2} = 0.5 \text{ mA}$$

$$\left. \begin{aligned}
 V_{GS1} &= V_{GS2} \\
 \left(\frac{W}{L}\right)_1 &= \left(\frac{W}{L}\right)_2
 \end{aligned} \right\} \Rightarrow I_{D1} = I_{D2} = 0.5 \text{ mA}$$

$$I_G = 0 \Rightarrow I_{D1} = I_{ref} \Rightarrow I_{ref} = 0.5 \text{ mA}$$

$$ii) \quad I_{D1} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_1 (V_{GS1} - V_t)^2$$

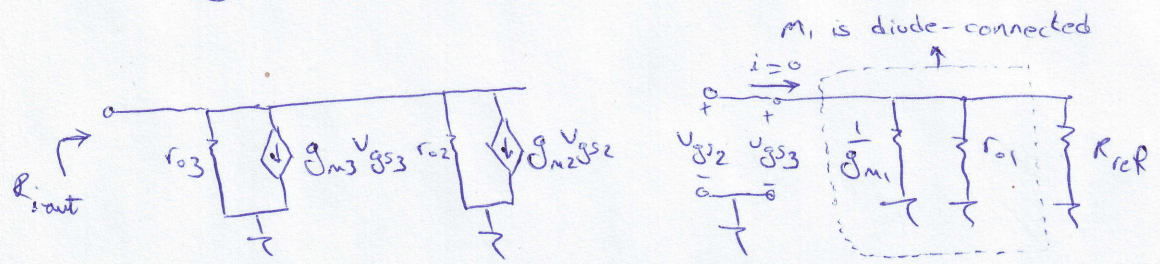
$$0.5 \text{ mA} = \frac{1}{2} \times 100 \mu\text{m} \times 10 (V_{GS1} - V_t)^2$$

$$\Rightarrow V_{GS1} - V_t = \pm 1 \Rightarrow V_{GS1} = \begin{matrix} 0 & \text{not acceptable} \\ 2 \text{ V} & \checkmark \end{matrix}$$

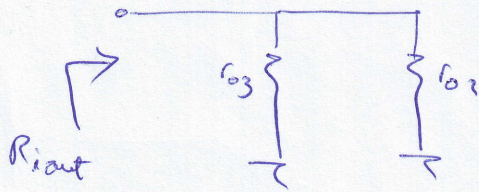
$$V_{S1} = 0 \Rightarrow V_{D1} = V_{G1} = 2 \text{ V}$$

$$R_{ref} = \frac{V_{DD} - V_{D1}}{I_{ref}} = \frac{5 - 2}{0.5 \text{ mA}} = 6 \text{ k}\Omega$$

iii) small-signal model



$i = 0 \Rightarrow V_{GS2} = V_{GS3} = 0 \Rightarrow$ dependent current sources are open-circuit.



$$\Rightarrow R_{iout} = r_{o2} \parallel r_{o3}$$

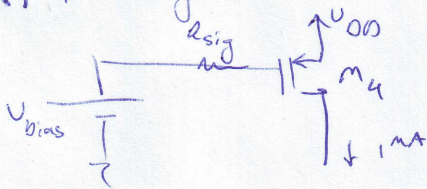
$$r_{o2} = \frac{V_A}{I_{D2}} = \frac{1}{\lambda I_{D2}}$$

$$r_{o3} = \frac{V_A}{I_{D3}} = \frac{1}{\lambda I_{D3}}$$

$$\Rightarrow r_{o2} = r_{o3} = 80 \text{ k}\Omega$$

$$\Rightarrow R_{iout} = r_{o2} \parallel r_{o3} = 40 \text{ k}\Omega$$

iv) DC analysis



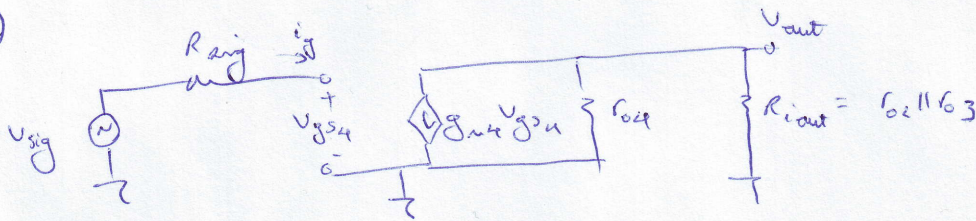
$$I_{D4} = \frac{1}{2} k_p' \left(\frac{W}{L}\right)_4 (V_{GS4} - V_{tp})^2$$

$$1 \text{ mA} = \frac{1}{2} 50 \mu \times 40 (V_{BIAS} - V_{DD} - (-1))^2$$

$$\Rightarrow (V_{BIAS} - 4)^2 = 1$$

$$\Rightarrow V_{BIAS} = \begin{cases} 3 \text{ V} \checkmark \\ 5 \text{ V} \Rightarrow V_{GS4} = 0 \text{ not acceptable} \end{cases}$$

v)



vi)

$$i_g = 0 \Rightarrow V_{sig} = V_{GS4}$$

$$\Rightarrow V_{out} = -g_{m4} V_{GS4} (r_{o4} \parallel R_{iout})$$

$$\Rightarrow \frac{V_{out}}{V_{sig}} = -g_{m4} (r_{o4} \parallel r_{o2} \parallel r_{o3})$$

$$I_{D4} = 1 \text{ mA}$$

$$|V_{GS4} - V_{TP}| = 1 \text{ V}$$

 \Rightarrow

$$g_{m4} = \frac{2I_{D4}}{|V_{GS4} - V_{TP}|} = 2 \text{ mA/V}$$

$$r_{o4} = \frac{1}{\lambda I_{D4}} = 40 \text{ k}\Omega$$

$$\Rightarrow \frac{V_{out}}{V_{sig}} = -2 \text{ mA/V} \times (40 \text{ k}\Omega \parallel 40 \text{ k}\Omega) = -40 \text{ V/V}$$