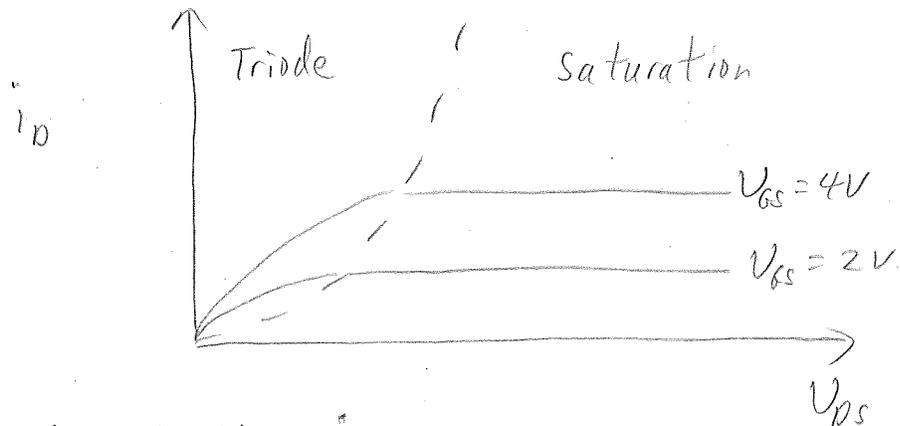


1) More on nMOSFETs or NMOS Trans.



Off: $V_{GS} - V_{TN} \leq 0V$; $i_D = 0A$

Triode: $V_{GS} - V_{TN} \geq 0V$ and $V_{GS} - V_{TN} \geq V_{DS}$

$$i_D = K_n' \left(\frac{W}{L} \right) \left(V_{GS} - V_{TN} - \frac{V_{DS}}{2} \right) V_{DS}$$

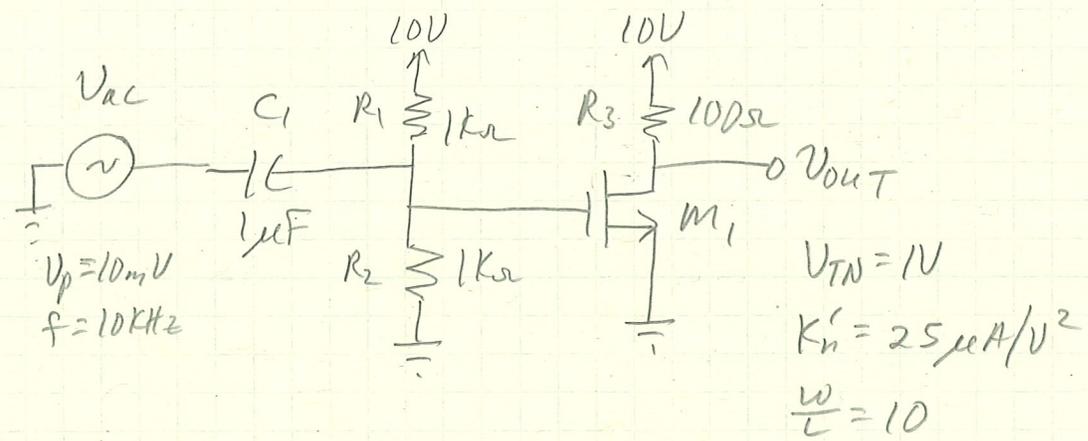
Saturation: $V_{GS} - V_{TN} \geq 0V$ and $V_{GS} - V_{TN} \leq V_{DS}$

$$i_D = \frac{1}{2} K_n' \left(\frac{W}{L} \right) (V_{GS} - V_{TN})^2$$

a. Finding the Q-point

- ① Assume an operating state
- ② Open circuit capacitors
- ③ Perform a DC analysis to find V_{GS} , V_{DS} , I_D
- ④ Verify operating state

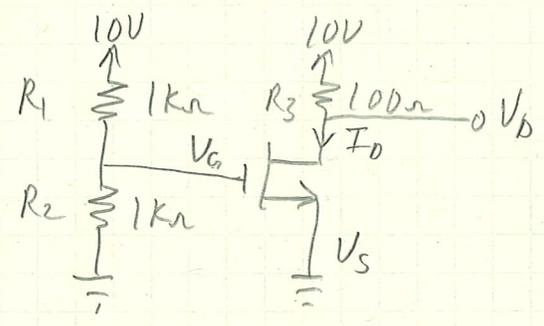
Example 1 : Find Q-Point



∴ open circuit C_1 and do a DC analysis to find operating mode and V_{GS}, V_{DS}, I_D

→ Pick operating state : \neq choose Saturation

→ $I_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right) (V_{GS} - V_{TN})^2$ → don't need to know V_{DS} to solve



$$I_G = 0A \rightarrow \therefore V_G = 10 \frac{R_2}{R_1 + R_2} = 10 \left(\frac{1}{1+1}\right) = 5V$$

$$V_{GS} = 5 - 0 = 5V$$

$$V_{GS} - V_{TN} = 5 - 1 = 4V \rightarrow > 0V \therefore M_1 \text{ is on}$$

→ if M_1 was off : $I_D = 0A$

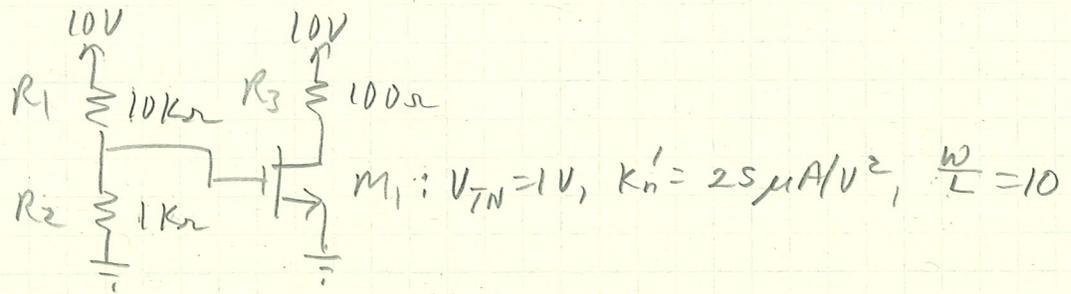
$$I_D = \frac{1}{2} (25 \times 10^{-6}) (10) (5 - 1)^2 = 2mA$$

$$V_D = 10 - I_D R_3 = 10 - (2 \times 10^{-3}) (100) = 9.8V = V_{DS}$$

since $V_{DS} > V_{GS} - V_{TN} \rightarrow$ in Saturation

∴ Q-point : $V_{GS} = 5V, V_{DS} = 9.8V, I_D = 2mA$

Example 2: Find the Q-Point



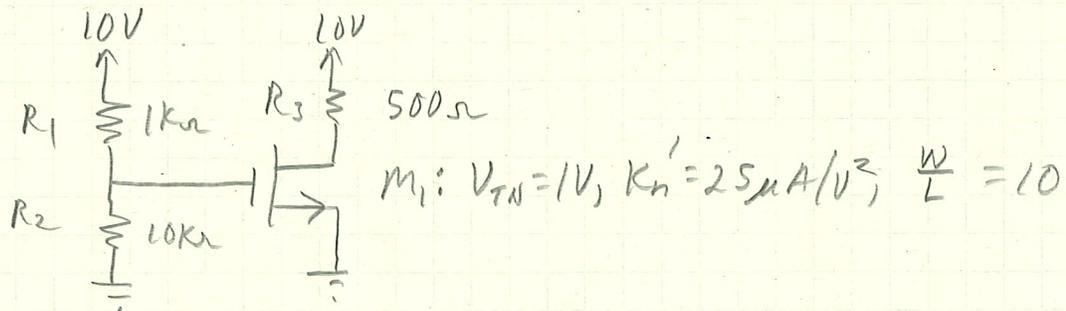
Assume Saturation mode and solve

$$V_G = 10 \left(\frac{1}{10+1} \right) = 0.91V = V_{GS}$$

$$V_{GS} - V_{TN} = 0.91 - 1 = -0.09V < 0 \quad \therefore M_1 \text{ is off}$$

$$Q\text{-Point: } V_{GS} = 0.91V, V_{DS} = 10V, I_D = 0A$$

Example 3: Find the Q-Point



Assume Saturation mode and solve

$$V_{GS} = 10 \left(\frac{10}{1+10} \right) = 9.09V$$

$$V_{GS} - V_{TN} = 9.09 - 1 = 8.09V > 0 \quad \therefore M_1 \text{ is on}$$

$$\begin{aligned} I_D &= \frac{1}{2} K_n' \left(\frac{W}{L} \right) (V_{GS} - V_{TN})^2 \\ &= \frac{1}{2} (25 \times 10^6) (10) (9.09 - 1)^2 \\ &= 8.18 \text{ mA} \end{aligned}$$

$$V_D = 10 - I_D R_3 = 10 - (8.18 \times 10^{-3}) (500) = 5.91V = V_{DS}$$

$$\text{Is } V_{DS} \geq V_{GS} - V_{TN}? \quad \therefore V_{DS} = 5.91V, V_{GS} - V_{TN} = 8.09V \rightarrow V_{DS} < V_{GS} - V_{TN}$$

$\therefore M_1$ is not in Saturation mode

∴ Resolve for Triode mode

$$I_D = K_n' \left(\frac{W}{L} \right) (V_{GS} - V_{TN} - \frac{V_{DS}}{2}) V_{DS}$$

$$V_{GS} = 9.09V \text{ from before}$$

$$\begin{aligned} \therefore I_D &= 2.5 \times 10^{-6} (10) \left(9.09 - 1 - \frac{V_{DS}}{2} \right) V_{DS} \\ &= 2.5 \times 10^{-4} \left(8.09 - \frac{V_{DS}}{2} \right) V_{DS} \end{aligned}$$

need a 2nd equation

$$\rightarrow \text{Since } V_D = V_{DS} \rightarrow V_{DS} = 10 - 500 I_D$$

$$\text{or } I_D = \frac{10}{500} - \frac{V_{DS}}{500}$$

$$\therefore \frac{10}{500} - \frac{V_{DS}}{500} = 2.5 \times 10^{-4} \left(8.09 - \frac{V_{DS}}{2} \right) V_{DS}$$

$$\frac{10}{500} - \frac{V_{DS}}{500} = 2.02 \times 10^{-3} V_{DS} - 1.25 \times 10^{-4} V_{DS}^2$$

$$0 = 0.02 - 4.02 \times 10^{-3} V_{DS} + 1.25 \times 10^{-4} V_{DS}^2$$

use quadratic formula to solve for V_{DS}

$$ax^2 + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\therefore V_{DS} = \frac{4.02 \times 10^{-3} \pm \sqrt{(4.02 \times 10^{-3})^2 - 4(1.25 \times 10^{-4})(0.02)}}{2(1.25 \times 10^{-4})}$$

$$= \frac{4.02 \times 10^{-3} \pm 2.48 \times 10^{-3}}{0.25 \times 10^{-3}}$$

$$= 26V \text{ or } 6.16V \rightarrow \text{cannot physically be } 26V$$

$$\text{Then } I_D = \frac{10}{500} - \frac{6.16}{500} = 7.68 \text{ mA}$$

Is $V_{GS} - V_{TN} > V_{DS}$? $\rightarrow 8.08 > 6.16V \rightarrow$ in Triode mode

$$\therefore \text{Q-Point: } V_{GS} = 9.09V, V_{DS} = 6.16V, I_D = 7.68 \text{ mA}$$