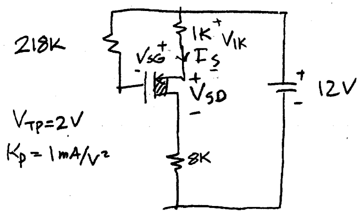
1. (20 points) For the circuit given below, V_{TP}=2V and K_P=1mA/V^2.

a. Find the DC bias (I_{DQ} and V_{DSQ}) of the transistor.

b. Plot the DC load line of the transistor.



a-) $V_{1K} + V_{SG} = 0 \Rightarrow 1000 I_S + V_{SG} = 0 \Rightarrow I_S = \frac{-V_{SG}}{1000}$

assuming saturation

$I_D = K_p (V_{SG} + V_{TP})^2$

$\frac{-V_{SG}}{1000} = \cancel{10^{-3}} (V_{SG}+2)^2 \Rightarrow -V_{SG} = V_{SG}^2 + 4V_{SG} + 4 \Rightarrow$

$V_{SG}^2 + 5V_{SG} + 4 = 0 \Rightarrow$

$V_{SG_{1,2}} = \frac{-b}{2a} \pm \frac{\sqrt{b^2-4ac}}{2a} = -\frac{5}{2} \pm \frac{\sqrt{25-16}}{2} = -\frac{5}{2} \pm \frac{3}{2}$

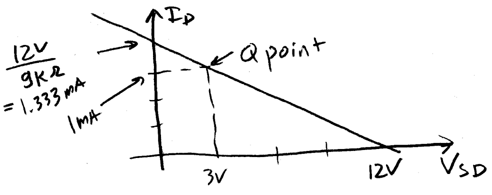
$V_{SG_{1,2}} = -\cancel{4}, -1$ $\quad$ $-4V$ is beyond $V_{TP} \Rightarrow$ not valid $\Rightarrow$

$V_{SG} = -1$Volts. $\Rightarrow I_S = \frac{1V}{1000\Omega} = 1mA$

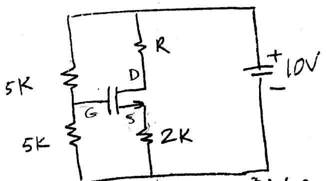
$V_{SD} = -(1K+8K)1mA + 12V = 3V$ $\quad$ $V_{SG}+V_{TP} = -1V+2 = 1V$

$V_{SG}+V_{TP} = 1V < V_{SD} = 3V \Rightarrow$ sat assumption is correct.

b-). DC load line



2. (20 points) For the transistor shown below, $V_{TH}=2V$ and $K_n=2mA/V^2$. Find the value of R to bias the transistor at the edge of saturation and non-saturation region.



$V_{TH}=2V$ $\quad K_n=2\times10^{-3}A/V^2$ $\quad$ Assume <u>SAT</u>

$V_{GS} = 10V\times\frac{5}{5+5} - I_D\times2000 \Rightarrow V_{GS} = 5-2000I_D \Rightarrow$

$I_D = \frac{5-V_{GS}}{2000} = 2\times10^{-3}(V_{GS}-2)^2 \Rightarrow \frac{5-V_{GS}}{4} = V_{GS}^2-4V_{GS}+4$

$5-V_{GS} = 4V_{GS}^2-16V_{GS}+16=0 \Rightarrow 4V_{GS}^2-15V_{GS}+11=0$

$V_{GS1,2} = \frac{-b}{2a}\pm\frac{\sqrt{b^2-4ac}}{2a} = \frac{15}{8}\pm\frac{\sqrt{225-4\times4\times11}}{8}$

$V_{GS1,2} = \frac{15}{8}\pm\frac{\sqrt{225-176}}{8} = \frac{15}{8}\pm\frac{\sqrt{49}}{8} = \frac{15}{8}\pm\frac{7}{8} = \frac{22}{8}, \frac{8}{8}$

$V_{GS1,2} = 2.75V$, ~~1V~~ $\because 1V < V_{TH} \Rightarrow V_{GS}=2.75V$

$I_D = K_n(2.75-2)^2 = 2\times10^{-3}(0.75)^2 = 1.125\times10^{-3}A$

$V_{2K} = 1.125\times10^{-3}\times2\times10^{3} = 2.25V$

$V_{GS} = 5-2.25 = 2.75V \Rightarrow$ solution is correct.

In order to bias the transistor at the edge of saturation

$V_{GS}-V_{TN} = V_{DS} \Rightarrow V_{DS} = 2.75-2 = 0.75V$

$\Rightarrow V_R = 10V-V_{DS}-V_{2K} = 10V-0.75V-[5V-V_{GS}]$

$= 10V-0.75-[5-2.75]V = 10V-0.75V-2.25V$

$V_R = 10-3 = 7V \Rightarrow \boxed{R = \frac{V_R}{I_R} = \frac{7V}{1.125mA} = 6.2\overline{2}K\Omega}$

Alternative solution I

$$\frac{V_S}{2\times10^3} = I_D = 2\times10^{-3}(5 - V_S - V_{TN})^2 = 2\times10^{-3}(3-V_S)^2$$

$$V_S = 4(9 - 6V_S + V_S^2) = 36 - 24V_S + 4V_S^2 \Rightarrow$$

$$\underset{a}{4}V_S^2 \underset{b}{-25}V_S + \underset{c}{36} = 0$$

$$V_{S_{1,2}} = \frac{-b}{2a} \pm \frac{\sqrt{b^2-4ac}}{2a} \rightarrow \frac{25}{8} \pm \frac{\sqrt{625-4\times4\times36}}{8} = \frac{25}{8} \pm \frac{7}{8} = \frac{32}{8}, \frac{18}{8}$$

$$V_{S_{1,2}} = 4, 2\tfrac{1}{8} = 4, 2.25\,V \qquad V_S = 4V \Rightarrow \cancel{V_{GS} = 1V < V_{TH}}$$

$$V_S = 2.25V \Rightarrow V_{GS} = 5 - 2.25 = 2.75V,\ I_D = \frac{2.25V}{2K} = 1.125mA,$$

$$V_{DS} = V_{GS} - V_{TH} = 2.75V - 2.00V = 0.75V$$

Alternative solution II

$$I_D = 2\times10^{-3}[5 - 2000I_D - 2]^2 \text{ assuming SAT}$$

$$I_D = 2\times10^{-3}[3 - 2000I_D]^2 \quad \text{let } \underset{(\text{in mA})}{I_D'} = I_D\times10^3 \Rightarrow \frac{I_D'}{1000} = I_D$$

I_D in Amps

$$\frac{I_D'}{10\cancel{00}} = 2\times\cancel{10^{-3}}[3 - 20\cancel{00}\frac{I_D'}{10\cancel{00}}]^2 \rightarrow I_D' = 2[3 - 2I_D']^2$$

$$I_D' = 2[9 - 12I_D' + 4I_D'^2] = 18 - 24I_D' + 8I_D'^2 \Rightarrow 8I_D'^2 - 25I_D' + 18 = 0$$

$$I'_{D_{1,2}} = \frac{-b}{2a} \pm \frac{\sqrt{b^2-4ac}}{2a} = \frac{25}{16} \pm \frac{\sqrt{625-4\times8\times18}}{16} = \frac{25}{16} \pm \frac{\sqrt{49}}{16} = \frac{25\pm7}{16}$$

$$I_D' = \frac{18}{16}, \frac{32}{16}\,mA = 1.125, 2\,mA$$