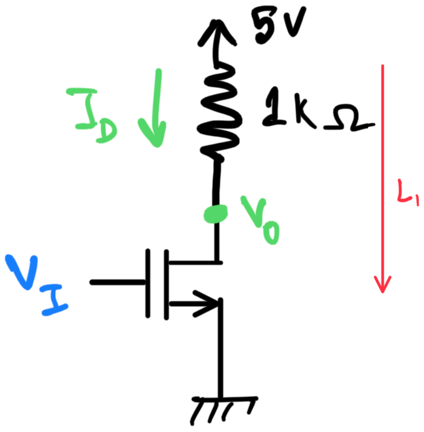
Example 1



The MOSFET is specified as $V_T = 1V$ and $k = 0.5\ mA/V^2$. Find I_D and V_O for $V_I = 2V$.

Solution:

Step 1: Assume the MOSFET in **saturation**

Step 2: $I_D = \frac{k}{2} V_{OV}^2$ Here, $V_{GS} = V_G - V_S = V_G - 0 = V_G = V_I = 2V$

Therefore, $V_{OV} = V_{GS} - V_T = 2 - 1 = 1V$

$$\therefore I_D = \frac{0.5}{2}(1)^2 = 0.25\ mA$$

Again, $V_{DS} = V_D - V_S = V_D - 0 = V_D = V_o$

KVL along L_1: $I_D \times 1k\Omega + V_o = 5 - 0 \Rightarrow V_0 = 5 - I_D \times 1k\Omega$

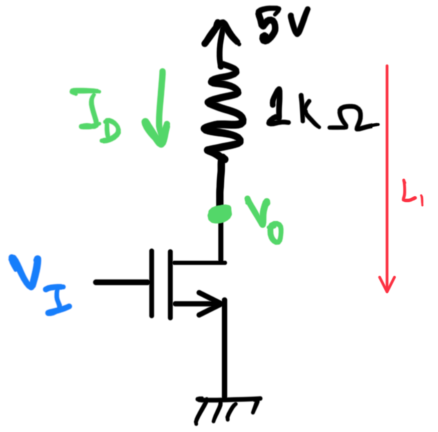
$$\Rightarrow V_o = 5 - 0.25 \times 1 = 4.75\ V = V_{DS}$$

Step 3: $V_{GS} = 2V > V_T$ √ Therefore, **assumption correct**!

$V_{DS} = 1V > V_{OV}$ √

$\boxed{\text{Correct ans: } I_D = 0.25\ mA, V_o = 4.75\ V}$

Example 2



The MOSFET is specified as $V_T = 1V$ and $k = 0.5\,mA/V^2$. Find I_D and V_O for $V_I = 5V$.

Solution:

Step 1: Assume the MOSFET in **saturation**

Step 2: $I_D = \frac{k}{2} V_{OV}^2$

Here, $V_{GS} = V_G - V_S = V_G - 0 = V_G = V_I = 5V$

Therefore, $V_{OV} = V_{GS} - V_T = 5 - 1 = 4V$

$$\therefore I_D = \frac{0.5}{2}(4)^2 = 4\,mA$$

Again, $V_{DS} = V_D - V_S = V_D - 0 = V_D = V_o$

KVL along L_1: $I_D \times 1k\Omega + V_o = 5 - 0 \Rightarrow V_0 = 5 - I_D \times 1k\Omega$

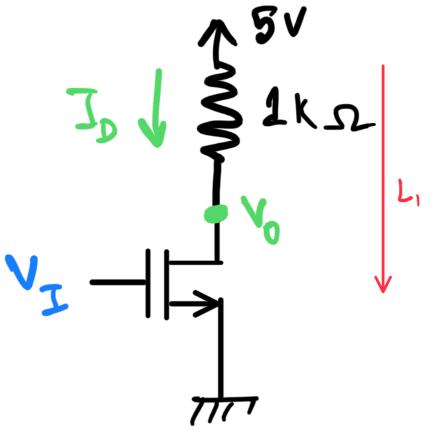
$\Rightarrow V_o = 5 - 4 \times 1 = 1\,V = V_{DS}$

Step 3: $V_{GS} = 5V > V_T$ $\surd$

$V_{DS} = 1V \ngtr V_{OV}$ $\times$

Therefore, **assumption wrong**!

Example 2



The MOSFET is specified as $V_T = 1V$ and $k = 0.5\,mA/V^2$. Find I_D and V_O for $V_I = 5V$.

Repeat:

Step 1: Assume the MOSFET in **triode**

Step 2: $I_D = k[V_{OV}V_{DS} - \frac{1}{2}V_{DS}^2]$

Here, $V_{GS} = V_G - V_S = V_G - 0 = V_G = V_I = 5V$

Therefore, $V_{OV} = V_{GS} - V_T = 5 - 1 = 4V$

Again, $V_{DS} = V_D - V_S = V_D - 0 = V_D = V_o$. Assuming $V_{DS} = x$

KVL along L_1: $I_D \times 1k\Omega + V_o = 5 - 0 \Rightarrow I_D = \frac{5 - V_{DS}}{1} = 5 - x$

$\therefore I_D = 0.5\left[4 \times V_{DS} - \frac{1}{2}V_{DS}^2\right] \Rightarrow (5 - x) = 0.5\left[4x - \frac{1}{2}x^2\right]$

$\Rightarrow 5 - x = 2x - 0.25x^2 \Rightarrow 0.25x^2 - 3x + 5 = 0$

Solving, $x = 2V, \cancel{x = 10V}$

Since $V_{DS} = x$ is small in triode, smaller value of x is favorable

Therfore, $V_o = V_{DS} = x = 2V$, and $I_D = 5 - x = 3\,mA$

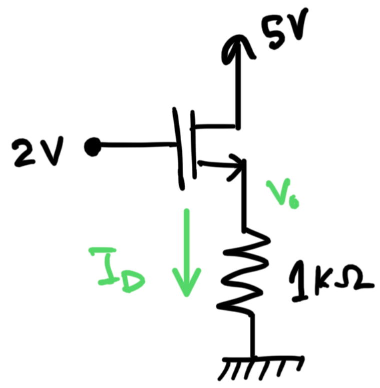
Step 3: $V_{GS} = 5V > V_T$ √

$V_{DS} = 2V < V_{OV}$ √

Therefore, **assumption correct**!

$\boxed{\text{Correct ans: } I_D = 3\,mA, V_o = 2\,V}$

Example 3



The MOSFET is specified as $V_T = 1V$ and $k = 4\,mA/V^2$. Find I_D and V_O

Solution:

Step 1: Assume the MOSFET in **saturation**

Step 2: $I_D = \frac{k}{2}V_{ov}^2$

Let's assume $V_0 = V_S = x$

Here, $V_{GS} = V_G - V_S = V_G - V_o = 2 - x$

Therefore, $V_{OV} = V_{GS} - V_T = (2 - x) - 1 = 1 - x$

Again, $V_{DS} = V_D - V_S = V_D - V_0 = 5 - x$

Ohm's law for the resistor: $I_D = \frac{V_0 - 0}{1k\Omega} = x$

$$\therefore x = \frac{4}{2}(1 - x)^2 \Rightarrow x = 2(1 - 2x + x^2) \Rightarrow x = 2 - 4x + 2x^2$$

$$\Rightarrow 2x^2 - 5x + 2 = 0$$

Solving, $x = 0.5, \cancel{x = 2V}$

Since $V_{DS} = 5 - x$ is large in saturation smaller value of x is favorable

$\therefore V_o = V_S = x = 0.5V, I_D = x = 0.5\,mA,$
$V_{DS} = 5 - x = 4.5V, V_{GS} = 2 - x = 1.5V,$ and $V_{OV} = 1 - x = 0.5V$

Step 3: $V_{GS} = 1.5V > V_T$ √ Therefore, **assumption correct**!

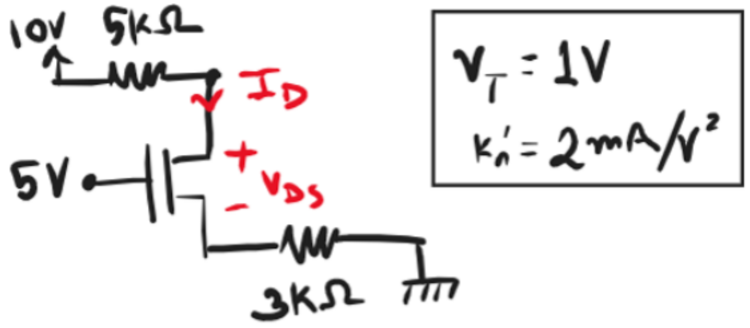
$V_{DS} = 4.5V > V_{OV}$ √

$\boxed{\text{Correct ans: } I_D = 0.5\,mA, V_o = 0.5\,V}$

Practice

Question 4 [CO1, CO4] **10**

Analyze the following circuit to find the values of I_D and V_{DS} **using** the Method of Assumed State. You must **validate** your assumptions. [7 + 3]
Hint: Use I_D as unknown x. Use Ohm's law to represent V_D and V_S in terms of x.



Hint Explanation

Assume $I_D = x$. For $5k\Omega$: $I_D = \frac{10-V_D}{5} \Rightarrow \mathrm{V_D} = 10 - 5\times I_D = 10 - 5x$.

For $3k\Omega$: $I_D = \frac{V_S-0}{3} \Rightarrow \mathrm{V_S} = 3\times I_D = 3x$.

Therefore, $V_{GS} = V_G - V_S = 5 - 3x$, and $V_{OV} = V_{GS} - V_T = (5 - 3x) - 1$

Also, $V_{DS} = V_D - V_S = (10 - 5x) - 3x = 10 - 8x$

Now if you assume saturation:

$$I_D = \frac{k}{2} V_{OV}^2 \Rightarrow x = \frac{2}{2}(4 - 3x)^2$$

And if you assume triode:

$$I_D = k[V_{OV} V_{DS} - \frac{1}{2} V_{DS}^2]$$

$$\Rightarrow x = 2[(4 - 3x)(10 - 8x) - 0.5\times(10 - 8x)^2]$$

Solve for x, take the _______ root