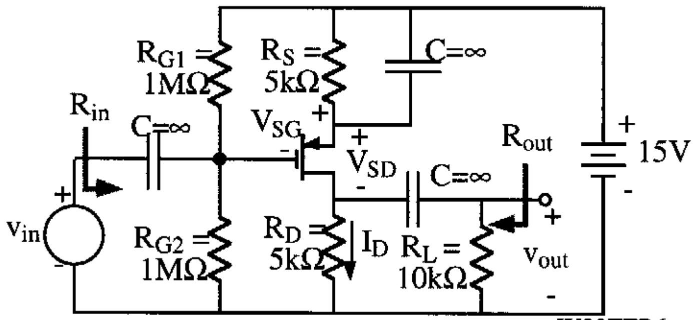
Homework Assignment No. 5 - Solutions

1.) Find the dc operating point, the small signal voltage gain, v_{out}/v_{in}, the small signal input resistance, R_{in}, and the small signal output resistance, R_{out}, if $K = 0.1\text{mA/V}^2$, $V_t = -1\text{V}$, and $\lambda = 0.01\text{V}^{-1}$.



W99FEP6

Solution

Finding the dc Thevenin equivalent circuit looking out the gate gives $V_{GG} = 7.5\text{V}$ and $R_G = 0.5\text{M}\Omega$. Assuming saturation gives $I_D = K(V_{GS}\text{-}V_t)^2$. Combining with

$$V_{GG} = 7.5\text{V} = V_{GS} + I_D R_S$$

gives $7.5 = V_{GS} + 5\text{k}\Omega\cdot 0.1\text{mA/V}^2(V_{GS}\text{-}1)^2 = V_{GS} + 0.5V_{GS}^2 - V_{GS} + 0.5$

which reduces to $V_{GS}^2 = 14 \quad \rightarrow \qquad V_{GS} = \sqrt{14} = 3.74\text{V}$

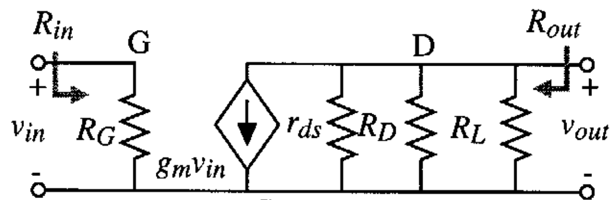
This gives $I_D = 0.1\text{mA}(3.75\text{-}1)^2 = 0.752\text{mA}$. Finally, $V_{DS} = 15 - I_D(R_D + R_S) = 7.48\text{V}$

$\therefore$ $\boxed{V_{SG} = 3.74\text{V},\ I_D = 0.752\text{mA and } V_{SD} = 7.48\text{V}}$

Note that the MOSFET is indeed saturated.

The small signal model parameters are $g_m = 2\sqrt{KI_D} = 2\sqrt{0.1\cdot 0.752} = 0.548\text{mA/V}$ and $r_{ds} = (\lambda\cdot I_D)^{-1} = 100/0.752 = 133\text{k}\Omega$.

The small-signal model for this problem is,



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$$\frac{v_{out}}{v_{in}} = -g_m(r_{ds}||R_D||R_L) = -0.548(133||5||10) = -1.782\text{V/V}, \qquad R_{in} = 500\text{k}\Omega$$

and $R_{out} = r_{ds}||R_D||R_L = 3.25\text{k}\Omega$.

$\therefore$ $\boxed{R_{in} = 500\text{k}\Omega,\ R_{out} = 3.25\text{k}\Omega \text{ and } \frac{v_{out}}{v_{in}} = -1.782\text{ V/V}}$

13.91

$$g_m = \sqrt{2\left(500\frac{\mu A}{V^2}\right)(100\mu A)(1+0.02(5))} = 332\mu S \;|\; r_o = \frac{50+5V}{100\mu A} = 550k\Omega$$

$$A_V = -\left(\frac{6.8M\Omega}{6.8M\Omega + 0.1M\Omega}\right)(332\mu S)(550k\Omega \| 50k\Omega \| 120k\Omega) = -10.9$$

13.100

$$g_m = \frac{2}{3}\sqrt{1mA(1mA)[1+0.015(9)]} = 710\mu S \;|\; r_o = \frac{\frac{1}{0.015}+9V}{1mA} = 75.7k\Omega$$

$$A_V = -\left(\frac{1M\Omega}{1M\Omega + 10k\Omega}\right)(710\mu S)(75.7k\Omega \| 7.5k\Omega \| 160k\Omega) = -4.60$$

13.108

$$R_{IN} = R_G = 6.8M\Omega \;|\; R_{OUT} = 50k\Omega \| r_o$$

$$r_o = \frac{(50+5)V}{0.1mA} = 550k\Omega \;|\; R_{OUT} = 50k\Omega \| 550k\Omega = 45.8k\Omega$$

13.119

$$I_B = \frac{(5-0.7)V}{10000\Omega + 66(1600)\Omega} = 37.2\ \mu A \;|\; I_C = 65I_B = 2.42\ mA \;|\; I_E = 66I_B = 2.46\ mA$$

$$V_{CE} = 10 - 1000I_C - 1600I_E - (-5) = 8.64\ V$$

$$g_m = 40(0.00242) = 0.0968S \;|\; r_\pi = \frac{65}{0.0968S} = 672\Omega \;|\; r_o = \frac{50+8.64}{0.00242} = 24.2k\Omega$$

$$R_{IN} = R_B \| r_\pi = 10k\Omega \| 672\Omega = 630\Omega \;|\; R_{OUT} = 1k\Omega \| 24.2k\Omega = 960\ \Omega$$

$$A_V = -\left(\frac{630}{330+630}\right)(0.0968)(1k\Omega \| 24.2k\Omega \| 220k\Omega) = -60.7$$

Note that the gain has been reduced by 25% by the lower value of R_{IN}. Also note that R_{IN} and R_{OUT} have changed directly with the current.