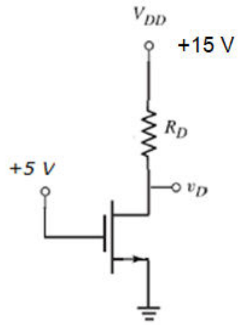
19EEE114 Electronic Circuits

Assignment #5 **SOLUTION** **Due on: 01st June 2022**

Q1. For the circuit shown, find i_D and v_{DS}. For the NMOS, V_t = 1 V and Kn = 0.5 mA/V^2. Consider R_D = 1 kΩ



Solution:

V_{GS} = 5 V > V_t

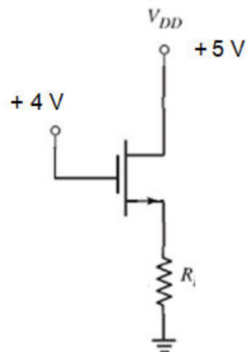
Assume the transistor is in saturation.

$i_D = \frac{1}{2}K_n(V_{GS} - V_t)^2$

$= 0.25 \times (5 - 1)^2 = 4$ mA

$V_{DS} = V_{DD} - i_D R_D = 11$ V

Q2. Design the circuit so that i_D = 1 mA and v_{DS} = 2.5 V. The NMOS has V_t = 1 V. Find k_n.



Solution:

$v_{RS} = V_{DD} - v_{DS} = 2.5$ V

R_S = (2.5 V)/(1 mA) = 2.5 kΩ.

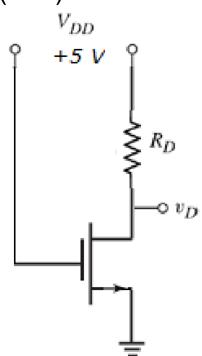
$v_{GS} = V_G - v_{RS}$ = 4 V – 2.5 V = 1.5 V.

$v_{DS} > v_{GS}$ NMOS will be operating in saturation

$i_D = \frac{1}{2}K_n(V_{GS} - V_t)^2$

$K_n = 8$ mA/V^2

Q3. Design the circuit to establish a drain voltage of 0.2 V. What is the effective operating resistance between drain and source at this Q-point? Take V_t = 1 V and k(W/L) = 2mA/V^2.



Solution:

$V_D < V_G$ by 4.8V so MOS operates in triode region.

$I_D = \frac{1}{2}k'_n (W/L)[(V_{GS} - V_T) V_{DS} - V_{DS}/2]$

$= \frac{1}{2} \times 2 \times 10^{-3}[(5 - 1)0.2 - 0.2/2]$

= 0.7 mA

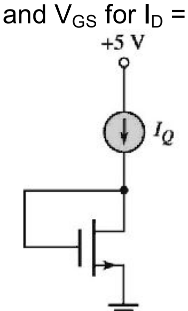
$R_D = V_{DD} - V_D/I_D$

= 5 – 0.2/0.7m = 4.71 kΩ

$r_{DS} = V_{DS}/I_D$

= 0.2/0.7m = 285.71Ω

Q4. The parameters for the transistor below are kn = 0.5 mA/V^2, W/L=1, Vtn = 1.2 V, and λ = 0. Determine V_{DS} and V_{GS} for I_D = 1 mA.



Solution:

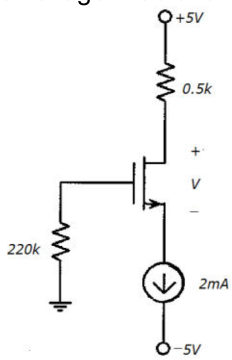
$I_D = \frac{1}{2} k_n(V_{GS} - V_T)^2$

$1 \times 10^{-3} = 0.5 \times 10^{-3} (V_{GS} - 1.2)^2$

V_{GS} = 3.2 V or V_{GS} = -0.8 V

$V_{DS} = V_{GS} = 3.2$ V

Q5. The N-channel enhancement mode MOSFET in this circuit has the following parameters: $K_n'(W/L) = 2mA/V^2$, $V_{tn}=1V$, and $\lambda = 0$. Determine the voltage V as shown.



Solution:

$I_D = \frac{1}{2}k_n(V_{GS} – V_T)^2$

$2 \times 10^{-3} = \frac{1}{2} \times 2 \times 10^{-3} (V_{GS} – 1)^2$

$V_{GS} = 2.414$ V

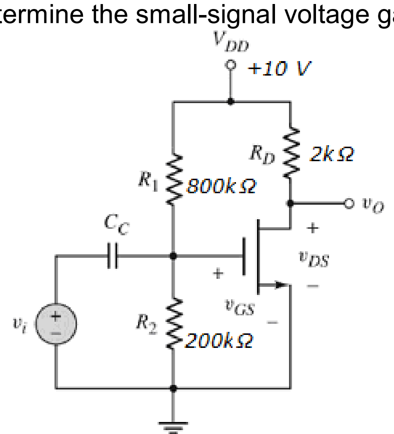
$V_S = -2.414$ V

$V_D = 5 – 2m \times 0.5k = 4$ V

$V_{DS} = V_D – V_S = 4 – (-2.414) = 6.414$ V

V = 6.414 V

Q6. The n-channel MOSFET in this circuit has $K_n'(W/L) = 2mA/V^2$ and $V_{tn}=1V$. Neglect λ.
a) Determine the dc operating point.
b) Draw the small signal model for the circuit.
c) Determine the small-signal voltage gain.



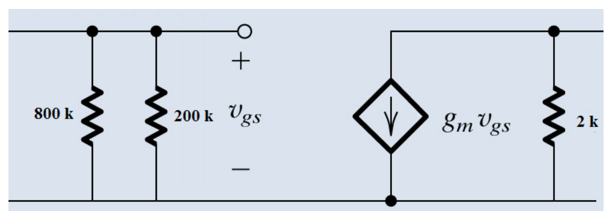
Solution:

(a) $V_{GS} = 2V$

$I_D = 1$ mA, $V_{DS} = 8$ V

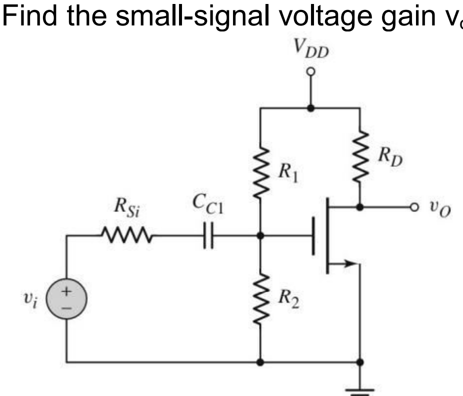
MOS is in saturation region

(b) $g_m = 2I_D/V_{ov} = 2/1 = 2$ mA/V



(c) Voltage gain = $- g_m R_D = - 2$ mA x 2 k = - 4 V/V

Q7. The parameters of the circuit shown below are $V_{DD} = 5$ V, $R_1 = 520$ kΩ, $R_2 = 320$ kΩ, $R_D = 10$ kΩ, and $R_{Sig} = 0$. Assume transistor parameters $V_{tn} = 0.8V$, $K_n = 0.20 mA/V^2$, and $\lambda= 0$.
(a) Determine the small-signal parameters g_m and r_o.
(b) Find the small-signal voltage gain v_o/v_i.



Solution:

(a) $V_{GS} = \left(\frac{R_2}{R_1 + R_2}\right)V_{DD} = \left(\frac{320}{520+320}\right)(5) = 1.905$ V

$I_{DQ} = 0.20(1.905 - 0.8)^2 = 0.244$ mA

$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{(0.2)(0.244)} = 0.442$ mA/V

$r_o = \infty$

(b) $A_v = -g_m R_D = -(0.422)(10) = -4.22$