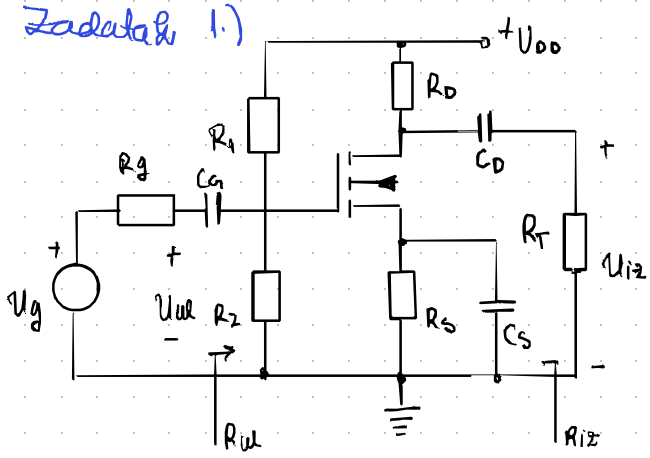
ZADACI: Sklopovi s unipolarnim tranz.

Zadatak 1.)



$U_{DD} = 18V$

$R_g = 500\,\Omega$

$R_1 = 3{,}3\,M\Omega$

$R_2 = 1{,}1\,M\Omega$

$R_D = 2\,k\Omega$

$R_T = 3{,}3\,k\Omega$

n-kanalni

$K = 2{,}25\,mA/V^2$

$U_{GSO} = 0{,}5V$

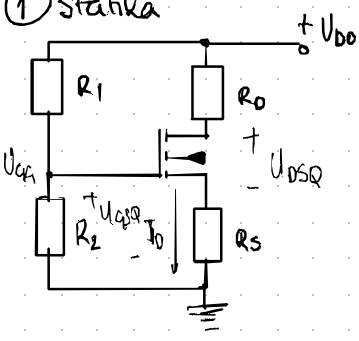
$\lambda = 0{,}0045/V$

a) $R_S = ?$ $\quad I_{DQ} = 2{,}915\,mA$

b) $A_V = \frac{U_{iz}}{U_{ul}}$, $A_{Vg} = \frac{U_{iz}}{U_g} = ?$

c) ulazni otpor R_{ul}, izlazni otpor R_{iz}

① Statika



$$U_{GG} = \frac{R_2}{R_1 + R_2} \cdot U_{DD} \qquad U_{GG} = U_{GSQ} + I_D \cdot R_S$$

$$U_{DD} = U_{DSQ} + I_{DQ}(R_D + R_S)$$

$$I_{DQ} = \frac{K}{2}(U_{GSQ} - U_{GSO})^2$$

$$I_{DQ} = \frac{K}{2}(U_{GSQ}^2 - 2U_{GSQ} \cdot 0{,}5 + 0{,}25)$$

$$\frac{2}{K} I_{DQ} = U_{GSQ}^2 - U_{GSQ} + 0{,}25$$

$$U_{GSQ}^2 - U_{GSQ} + 0{,}25 - \frac{2 \cdot 2{,}915}{2{,}5} = 0$$

n-kanalni → $U_{GSQ} > U_{GSO}$

$U_{GSQ} = 2{,}11$ $\qquad U_{GSQ} = -1{,}03$

$$R_S = \frac{U_{GG} - U_{GSQ}}{I_{DQ}}, \quad U_{GG} = 4{,}5V \longrightarrow R_S = \frac{4{,}5 - 2{,}11}{2{,}915 \times 10^{-3}} \longrightarrow \boxed{R_S = 820\,\Omega}$$

$$U_{DSQ} = U_{DD} - I_{DQ}(R_D + R_S) = 18 - 2{,}915 \times 10^{-3}(2000 + 820)$$

$$U_{DSQ} = 9{,}8V$$

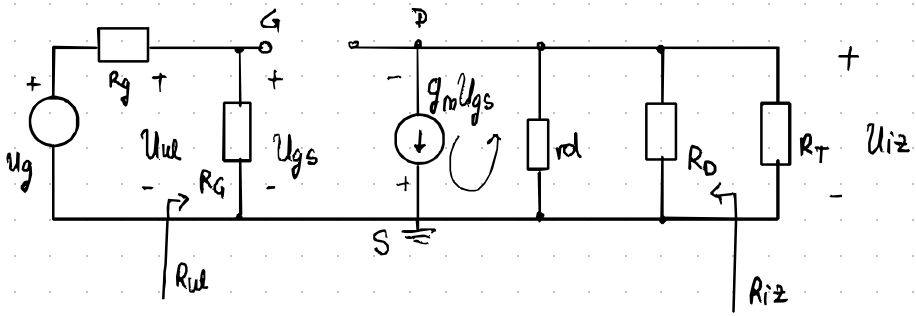
$$i_D = \frac{K}{2}(u_{GS} - U_{GSO})^2 (1 + \lambda u_{DS})$$

$$g_m = \frac{\partial i_D}{\partial u_{GS}} = K(U_{GSQ} - U_{GSO})(1 + \lambda U_{DSQ}) = 2{,}5 \times 10^{-3}(2{,}03 - 0{,}5)(1 + 0{,}0045 \cdot 9{,}7)$$

$$g_m = 3{,}8\,mA/V^2$$

$$\frac{1}{r_d} = \frac{\partial i_D}{\partial u_{DS}} = \frac{K}{2}(U_{GSQ} - U_{GSO})^2 \lambda = I_{DQ} \cdot \lambda = 13{,}12\,\mu S \longrightarrow r_d = 76{,}22\,k\Omega$$

b) A_V, A_{Vg} = ?



$R_G = 825 k\Omega$

$U_{iz} = -g_m U_{gs} \cdot (r_d \parallel R_D \parallel R_T)$

$U_{ul} = U_{gs}$

$A_V = \frac{U_{iz}}{U_{ul}} = -g_m (r_d \parallel R_D \parallel R_T)$

$A_V = -3{,}8 \times 10^{-3} \left(\frac{1}{76{,}22} + \frac{1}{2} + \frac{1}{3{,}3} \right)^{-1}$

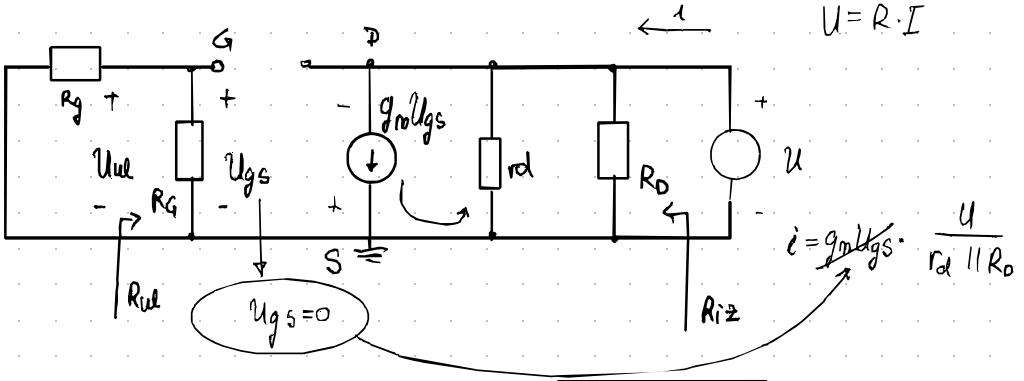
$\boxed{A_V = -4{,}66}$

$A_{Vg} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{ul}} \cdot \frac{U_{ul}}{U_g}$

$A_{Vg} = A_V \cdot \frac{1}{U_g} \cdot \frac{R_G}{R_g + R_G} \cdot U_g \rightarrow \boxed{A_{Vg} = -4.66}$

b) R_{ul}, R_{iz} = ?

$R_{ul} = \frac{U_{ul}}{i_{ul}} = R_G \longrightarrow \boxed{R_G = 825 k\Omega}$

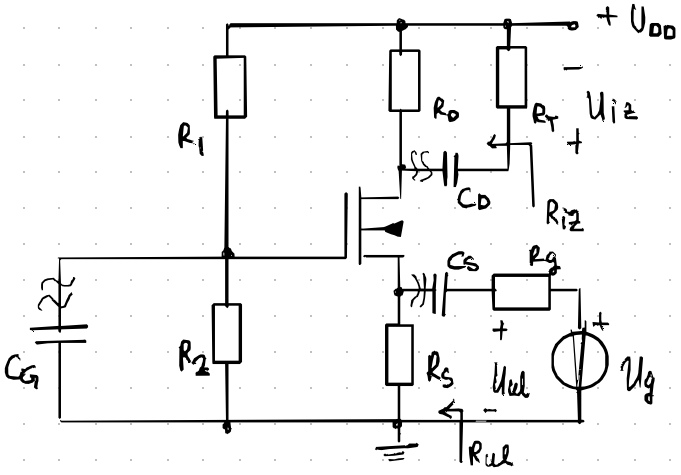


$U = R \cdot I$

$i = g_m U_{gs} \cdot \frac{U}{r_d \parallel R_D}$

$R_{iz} = \frac{U}{i} = \frac{U}{\frac{U}{r_d \parallel R_D}} = r_d \parallel R_D \longrightarrow \boxed{R_{iz} = 1948{,}9 \Omega}$

Zadatak 3.)



$U_{DD} = 12V$

$R_g = 500\,\Omega$

$R_1 = 3{,}9\,M\Omega$

$R_2 = 1{,}2\,M\Omega$

$R_D = 1\,k\Omega$

$R_T = 4{,}7\,k\Omega$

$R_S = 560\,\Omega$

$K = 2{,}2\,mA/V^2$

$U_{GSO} = -2V$

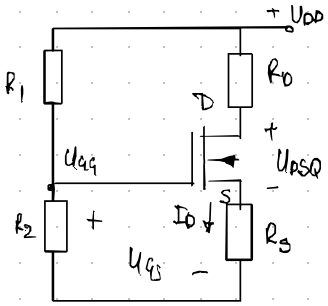
$\lambda = 0{,}004/V$

a) statička radna točka ?

b) naponsko pojačanje $A_V = \frac{U_{iz}}{U_{ul}}$

c) $R_{ul} = ?$ $R_{iz} = ?$

(1) Statika → STR U_{GSQ}, U_{DSQ}, I_{DQ}



$U_{GG} = U_{GSQ} + I_{DQ} \cdot R_S$

$U_{GG} = \frac{R_2}{R_1 + R_2} \cdot U_{DD}$

$I_{DQ} = \frac{K}{2}\left(U_{GSQ} - U_{GSO}\right)^2$

$U_{DD} = U_{DSQ} + I_{DQ}\left(R_D + R_S\right)$

$U_{GG} = 2{,}82\,V$

$\frac{U_{GG} - U_{GSQ}}{R_S} = \frac{K}{2}\left(U_{GSQ} - U_{GSO}\right)^2$

$\frac{2}{K \cdot R_S} U_{GG} - \frac{2}{K \cdot R_S} \cdot U_{GSQ} = U_{GSQ}^2 - 2U_{GSQ} \cdot U_{GSO} + U_{GSO}^2$

$U_{GSQ}^2 - 2\left(U_{GSO} - \frac{1}{K \cdot R_S}\right) + U_{GSO}^2 - \frac{2}{K \cdot R_S} \cdot U_{GG} =$

$U_{GSQ}^2 - 2\left(-2 - \frac{1}{2{,}2 \cdot 560}\right) U_{GSQ} + 4 - \frac{2}{2{,}2 \cdot 560} \cdot 2{,}82 = 0$

$U_{GSQ}^2 + 5{,}62\,U_{GSQ} - 0{,}58 = 0$

~~$U_{GSQ} = -5{,}72V$~~ $U_{GSQ} = 0{,}1V$ → $I_{DQ} = \frac{K}{2}(0{,}1+2)^2$

$I_{DQ} = 4{,}85\,mA$

$U_{DSQ} = U_{DD} - I_{DQ} \cdot (R_D + R_S)$ → $U_{DSQ} = 4{,}43V$

provjera radi li u području zasićenja

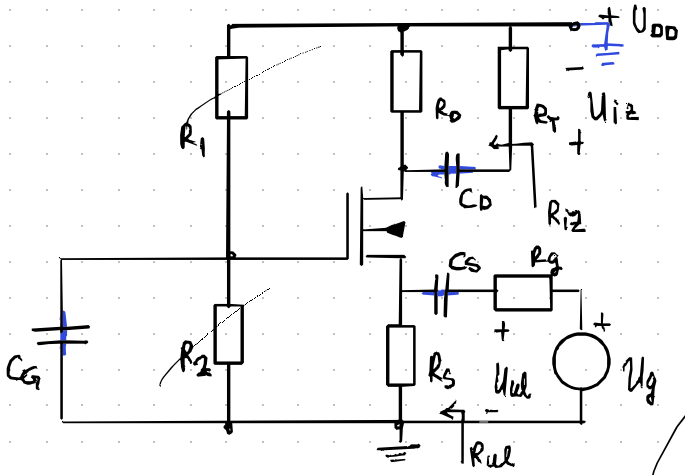
$U_{DSQ} = 4{,}43V > U_{GSQ} - U_{GSO} = 0{,}1 + 2$ → $4{,}43 > 2{,}1V$

b) naponsko pojačanje $A_v = \frac{u_{iz}}{u_{ul}}$

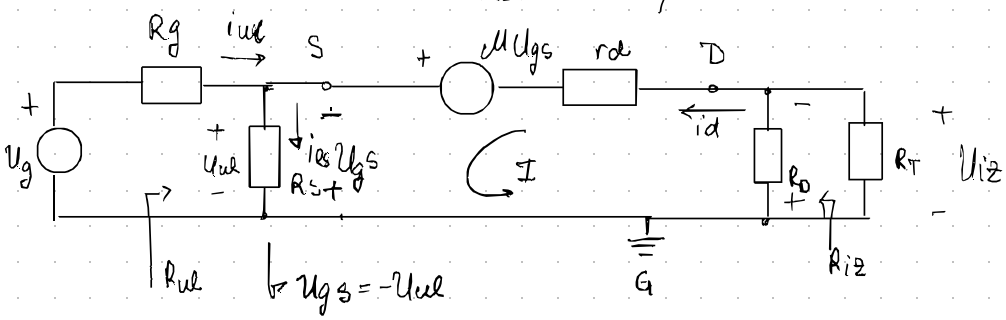
$$i_D = \frac{K}{2}(u_{GS} - u_{GSO})^2(1+\lambda u_{DS})$$

$$g_m = \frac{\partial i_D}{\partial u_{GS}} = K(u_{GSQ} - u_{GSO})(1+\lambda u_{DSQ}) \longrightarrow g_m = 4{,}7\,mA/V^2$$

$$\frac{1}{r_d} = \frac{\partial i_D}{\partial u_{GS}} = \frac{K}{2}(u_{GSQ} - u_{GSO})^2 \lambda = I_{DQ}\cdot\lambda \longrightarrow r_d = 51.55\,k\Omega$$



$A_v = \frac{u_{iz}}{u_{ul}}$



I) $i_d[r_d + (R_D \| R_T)] - u_{gs}\cdot\mu - u_{gs} = 0$

$u_{gs}(\mu+1) = i_d[r_d + (R_D \| R_T)]$

$$-u_{ul}(\mu+1) = i_d[r_d + (R_D \| R_T)] \longrightarrow i_d = -\frac{u_{ul}(\mu+1)}{r_d + (R_D \| R_T)}$$

$$\Rightarrow u_{iz} = -i_d\cdot(R_D \| R_T) = +\frac{u_{ul}(\mu+1)}{r_d + (R_D \| R_T)}(R_D \| R_T)$$

$$\Rightarrow A_v = \frac{u_{iz}}{u_{ul}} = (\mu+1)\cdot\frac{R_D \| R_T}{r_d + (R_D \| R_T)}$$

$\mu = g_m \cdot r_d \rightarrow 4{,}7\times10^{-3}\cdot 51{,}55\times10^{3}$

$\mu = 242.3 > 1$

$$A_v = g_m\left(r_d \,\frac{R_D \| R_T}{r_d + (R_D \| R_T)}\right) \longrightarrow A_v = g_m(r_d \| R_D \| R_T) \rightarrow \boxed{A_v = 3{,}8}$$

c) Ulazni otpor

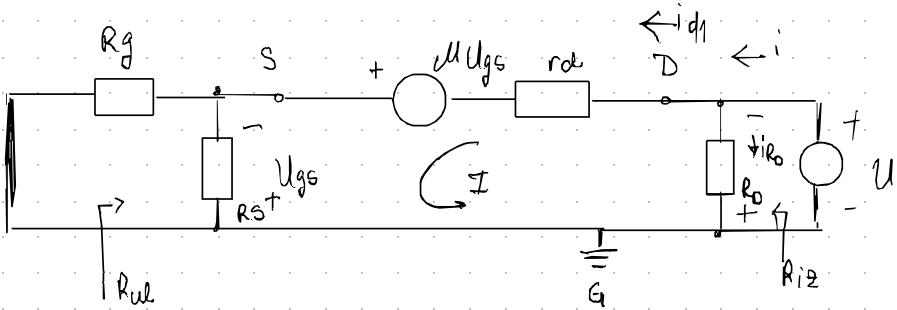
$$R_{ul} = \frac{u_{ul}}{i_{ul}}$$

$i_{ul} = i_{RS} - i_d$

$i_{RS} = \frac{-u_{gs}}{R_S} \longrightarrow i_{ul} = \frac{-u_{gs}}{R_S} - \frac{u_{gs}(\mu+1)}{r_d + (R_D \| R_T)}$

$$i_{ul} = \frac{+u_{ul}}{R_S} + u_{ul}\frac{g_m\cdot r_d}{r_d + (R_D \| R_T)} = u_{ul}\left(\frac{\mu}{r_d + R_D \| R_T} + \frac{1}{R_S}\right)$$

$$R_{ul} = \frac{1}{\frac{\mu}{r_d + R_D \| R_T} + \frac{1}{R_S}} = R_S \| \frac{r_d + R_D \| R_T}{242} \Rightarrow \boxed{R_{ul} = 156{,}1\,\Omega}$$



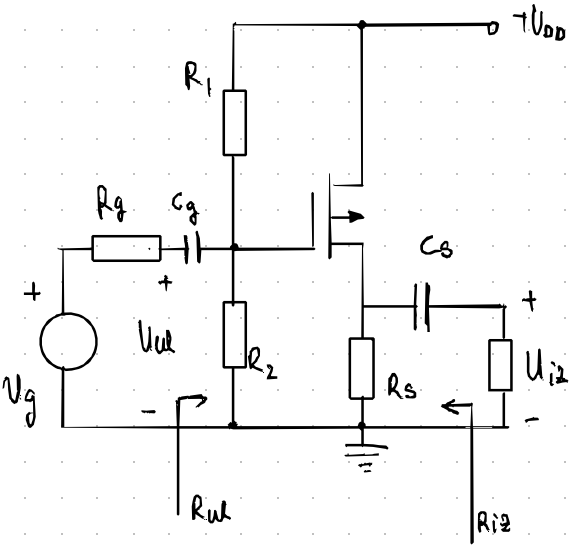
$$R_{iz} = \frac{u}{i} \qquad i = i_{d_1} + i_{R_D} \qquad i_{R_D} = \frac{u}{R_D}$$

$$u = i_{d_1}(r_d + R_g \| R_S) - U_{gs}(\mu + 1) \qquad U_{gs} = -i_{d_1} \cdot R_S \| R_g$$

$$\Rightarrow i_{d_1} = \frac{u}{r_d + (1+\mu)\cdot R_S \| R_g} \qquad i = \frac{u}{R_D} + \frac{u}{r_d + (1+\mu)\cdot R_S \| R_g} = u\left(\frac{1}{R_D} + \frac{1}{r_d + (1+\mu)\cdot R_S \| R_g}\right)$$

$$R_{iz} = \frac{u}{i} = \frac{1}{\frac{1}{R_D} + \frac{1}{r_d + (1+\mu)\cdot R_S \| R_g}} = 991{,}4\ \Omega$$

Zadatak 4)



$U_{DD} = -15V$

$R_g = 500\Omega$

$R_1 = 2M\Omega$

$R_2 = 1M\Omega$

$R_s = 2k\Omega$

p-kanalni MOSFET

$U_{GSO} = 1V$

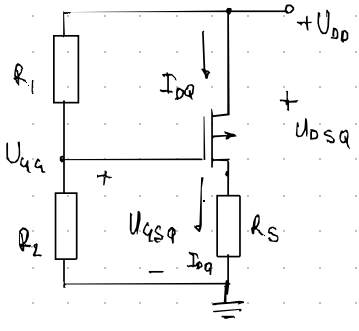
$K = -2mA/V^2$

$\lambda = -0,0055/V$

a) SRT? b) $A_V = \frac{U_{iz}}{U_{ul}}$ c) R_{ul}, R_{iz} = ?

1) Statika

- gasimo izmjenične izvore
- odspajamo C → $\frac{1}{\omega C} = \infty$



$U_{GG} = U_{DD} \cdot \frac{R_2}{R_1 + R_2} = -15V \cdot \frac{1}{3}$

$U_{GG} = -5V$

$U_{GG} = U_{GSQ} + I_{DQ} \cdot R_S$

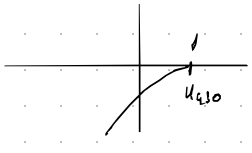
$U_{DD} = U_{DSQ} + I_{DQ} \cdot R_S$

$I_D = \frac{K}{2}(U_{GSQ} - U_{GSO})^2$

$I_{DQ} = \frac{U_{GG} - U_{GSQ}}{R_S}$

$U_{DSQ} = U_{DD} - I_{DQ} \cdot R_S$

* p-kanalni MOSFET:



$$\Rightarrow \frac{U_{GG} - U_{GSQ}}{R_S} \cdot \frac{2}{K} = U_{GSQ}^2 - 2U_{GSO} \cdot U_{GSQ} + U_{GSO}$$

$$\frac{U_{GG}}{R_S} \cdot \frac{2}{K} - \frac{2 \cdot U_{GSQ}}{R_S \cdot K} = U_{GSQ}^2 - 2U_{GSQ} + 1 \rightarrow U_{GSQ}^2 - 2 \cdot U_{GSQ}\left(1 - \frac{1}{R_S \cdot K}\right) - \frac{3}{2} = 0$$

~~$U_{GSQ} = 3V$~~

$U_{GSQ} = -\frac{1}{2}V$

* Za p kanalni MOSFET $U_{GSQ} < U_{GSO}$!

$$I_{DQ} = \frac{-5 + \frac{1}{2}}{2000} \rightarrow I_{DQ} = -2,25mA$$

$$\Rightarrow U_{DSQ} = U_{DD} - I_{DQ} \cdot R_S = -15 + 2,25 \cdot 2 \rightarrow U_{DSQ} = -10.5V$$

Radi li MOSFET u području zasićenja $\Rightarrow |U_{DSQ}| > |U_{GSQ} - U_{GSO}|$?

$$|-10,5| > \left|-\frac{1}{2} - 1\right| \rightarrow 10.5 > \frac{3}{2}V$$

Da, MOSFET radi u području zasićenja

Dinamički parametri: $i_D = \frac{K}{2}(u_{GS} - u_{GS0})^2 (1 + \lambda u_{DS})$

$$g_m = \left.\frac{\partial i_D}{\partial u_{GS}}\right|_Q = \left. K(u_{GS} - u_{GS0})(1+\lambda u_{DS})\right|_Q = K(u_{GSQ} - u_{GS0})(1+\lambda u_{DSQ})$$

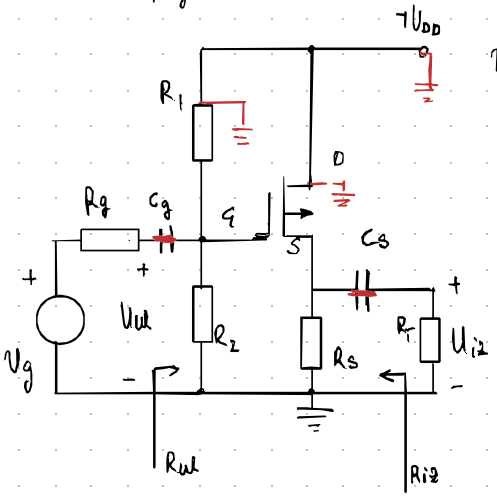
$$g_m = -2\times10^{-3}(-0{,}5 - 1)(1 + 0{,}0055 \cdot 10{,}5)$$

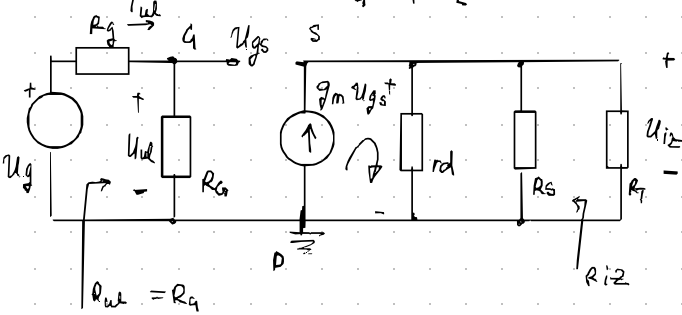
$$\boxed{g_m = 3.173\,mA/V^2}$$

$$\frac{1}{r_d} = \frac{\partial i_D}{\partial u_{DS}} = \frac{K}{2}(u_{GSQ} - u_{GS0})^2 \cdot \lambda = I_{DQ} \cdot \lambda \rightarrow \boxed{r_d = 80.81\,k\Omega}$$

2) Dinamika $A_V = \frac{u_{iz}}{u_{ul}} = ?$ $R_{ul} = ?$ $R_{iz} = ?$

- gasimo istosmjerne izvore
- kratko spajamo C





$R_G = R_1 \| R_2$

$u_{ul} = u_{gs} + u_{iz}$

$u_{iz} = g_m \cdot u_{gs} \cdot (r_d \| R_S \| R_T)$

$u_{ul} = u_{gs}[1 + g_m(r_d \| R_S \| R_T)]$

$$A_V = \frac{u_{iz}}{u_{ul}} = \frac{g_m u_{gs}(r_d \| R_S \| R_T)}{u_{gs}[1 + g_m(r_d \| R_S \| R_T)]}$$

x

$x = 4.127$

$$A_V = \frac{4.127}{5.127} \rightarrow \boxed{A_V = 0.805}$$

$R_{ul} = R_G \Rightarrow R_G = R_1 \| R_2 = \left(\frac{1}{2} + \frac{1}{1}\right) = \frac{2}{3}\,M\Omega$