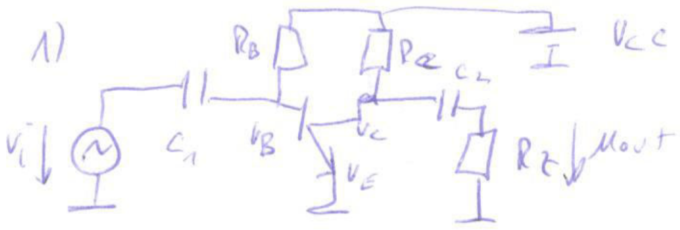
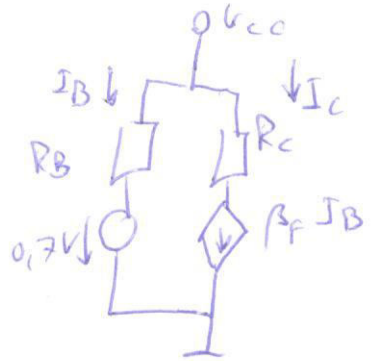
1)





$$I_B = \frac{V_{CC}-0{,}7}{R_B} = \frac{9{,}3}{930k} = 0{,}01\,mA$$

$$I_C = 100\,I_B = 1\,mA$$

$$V_C = V_{CC} - I_C R_C = 10 - 5 = 5V$$

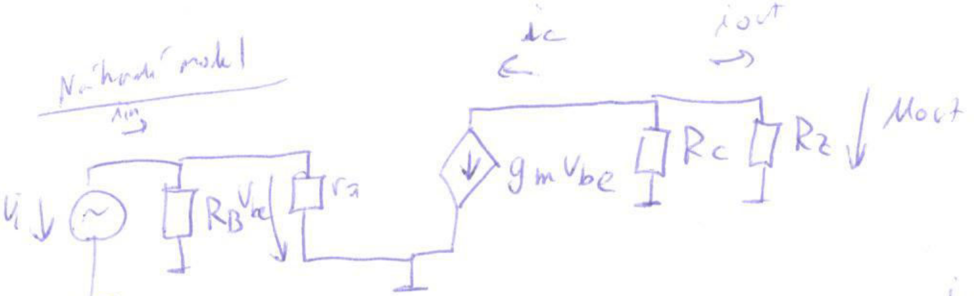
$$V_E = 0V$$

$$V_{CE} = V_C - V_E = 5V \geq 0{,}27V$$ ✓ splněno

~~$V_{BE} = V_B - V_E =$~~

$$g_m = 40\,I_C = 40\,mS \Rightarrow r_\pi = \frac{\beta}{g_m} = \frac{100}{40\,mS} = 2{,}5\,k\Omega$$

Náhradní model



$$v_{be} = v_{in} \qquad g_m v_{be} = g_m v_{in} = +i_c$$

$$i_{out} = -\frac{R_C}{R_C+R_Z}\cdot i_c = -g_m v_{in}\frac{R_C}{R_C+R_Z}$$

$$u_{out} = i_{out}\cdot R_Z = -g_m v_i \frac{R_C R_Z}{R_C+R_Z}$$

~~$A_u = \lim_{R_Z\to\infty}$~~

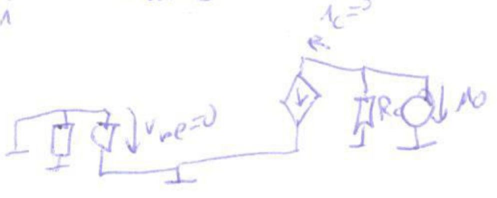
$$A_u = \lim_{R_Z\to\infty}\frac{u_o}{u_i} = \lim_{R_Z\to\infty}\frac{-g_m R_C R_Z}{R_C+R_Z} \overset{L'H}{=} \underline{-g_m R_C}$$

$$i_{in} = i_{R_B} + i_{r_\pi} = \frac{v_i}{R_B} + \frac{v_i}{r_\pi} = v_i\left(\frac{r_\pi+R_B}{r_\pi R_B}\right)$$

$$A_i = \lim_{R_Z\to\infty}\frac{i_o}{i_{in}} = \lim_{R_Z\to\infty}\frac{-g_m\frac{R_C}{R_C+R_Z}}{\frac{r_\pi+R_B}{r_\pi R_B}} = -g_m\frac{r_\pi R_B}{r_\pi+R_B} \underset{R_B\gg r_\pi}{\doteq} -g_m r_\pi = \underline{\underline{-\beta}}$$

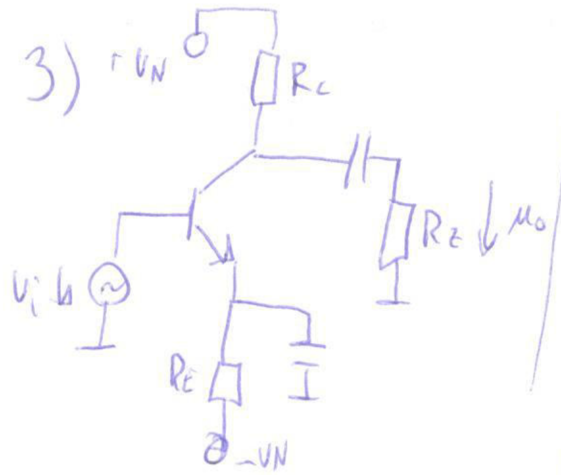
$$R_i = \frac{u_i}{i_i} = \frac{r_\pi R_B}{r_\pi+R_B} \doteq \underline{r_\pi}$$

R_o :

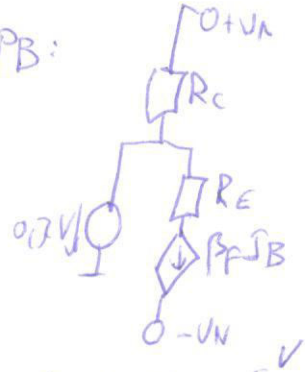


$$R_o = \frac{u_o}{i_o} = \underline{R_C}$$

3)



PB:



$I_C = \frac{U_N - 0{,}7}{R_E} \sim 1mA$

$g_m = 40 I_C = 40mS$

$r_\pi = \frac{\beta}{g_m} = 2{,}5 k\Omega$

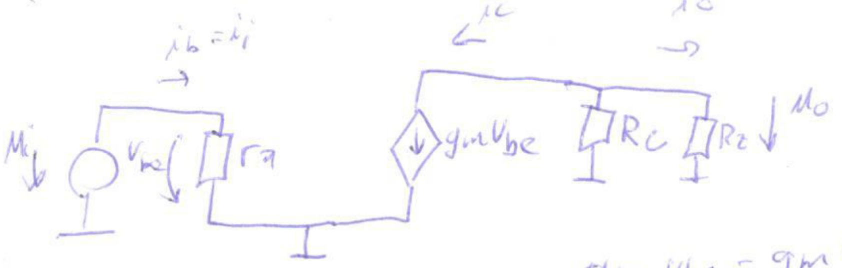
$V_C = U_N - I_E R_C = 5\,V$ $\quad I_E \sim I_C$

$U_E = -U_N + I_C R_E = -0{,}8V$

$\underline{V_{CE} = 5{,}8V} > \underline{0{,}2V}$

splněno

Náhradní model



$v_{be} = u_i - 0 = u_i \Rightarrow g_m v_{be} = g_m v_i = i_c$

$i_o = -i_c \frac{R_C}{R_C + R_Z} = -g_m u_i \frac{R_C}{R_C + R_Z}$ $\quad \Big| \; u_o = i_o R_Z = -g_m u_i \frac{R_C R_Z}{R_C + R_Z}$

$i_i = \frac{u_i - 0}{r_\pi} = \frac{u_i}{r_\pi}$ $\quad \Big| \; u_i \ldots$ známá vel.

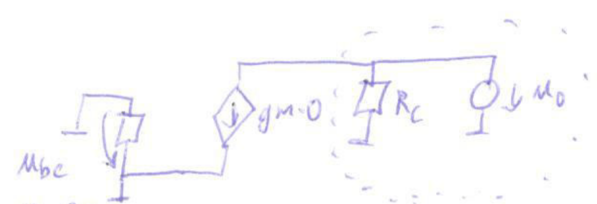
$$A_u = \frac{u_o}{u_i}\Big|_{R_Z \to \infty} = \lim_{R_Z \to \infty} -g_m \frac{R_C R_Z}{R_C + R_Z} \overset{L'H}{=} \underline{-g_m R_C}$$

$$A_i = \frac{i_o}{i_i}\Big|_{R_Z \to 0} = \lim_{R_Z \to 0} \frac{-g_m u_i \left(\frac{R_C}{R_C + R_Z \to 0}\right) \to 1}{\frac{u_i}{r_\pi}} = -g_m r_\pi = -g_m \frac{\beta}{g_m} = \underline{\underline{-\beta}}$$

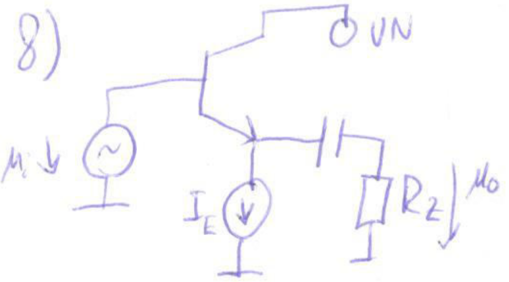
$$R_i = \frac{u_i|_{R_Z \to \infty}}{i_i|_{R_Z \to 0}} = \frac{u_i}{\frac{u_i}{r_\pi}} = \underline{\underline{r_\pi}}$$

R_O: Náhrada $R_Z \to u_o$, $u_i \to$ zem

$R_O = \underline{R_C}$



8)



PB: $I_C \sim I_E = 1mA$ $g_m = 40 I_C$

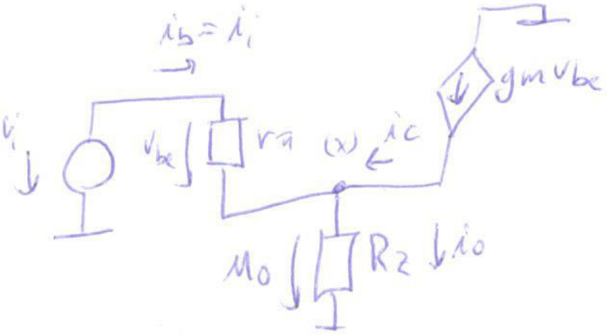
$U_N > 0{,}7V$

$U_{BC} > -0{,}5V$ splněno

$\overset{\shortparallel}{U_N}$

$r_\pi = \frac{\beta}{g_m} = 2{,}5k\Omega$

Náhradní schéma



$i_c = \beta i_b$

proud v uzlu (x): $i_b + \beta i_b - i_o = 0$

$i_o = (\beta+1) i_b$

$u_o = i_o R_Z = R_Z i_b (\beta+1)$

$i_i = i_b$

$u_i = u_{r_\pi} + u_o$ …dělič napětí

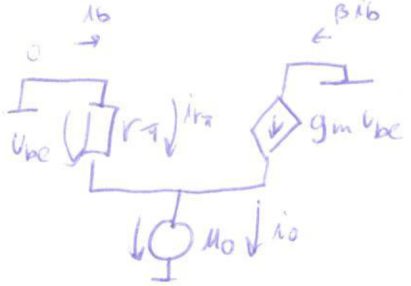
$= i_b r_\pi + R_Z i_b (\beta+1)$

$$A_v = \frac{u_o}{u_i}\bigg|_{R_Z\to\infty} = \frac{R_Z i_b (\beta+1)}{\cancel{i_b} r_\pi + R_Z \cancel{i_b} (\beta+1)}\bigg|_{R_Z\to\infty} = \frac{R_Z(\beta+1)}{r_\pi + R_Z(\beta+1)}\bigg|_{R_Z\to\infty} \overset{L'H}{=} \underline{1}$$

$$A_i = \frac{i_o}{i_i}\bigg|_{R_Z\to 0} = \frac{(\beta+1) i_b}{i_b} = \underline{\beta+1}$$

$$R_i = \frac{u_i}{i_i}\bigg|_{\substack{R_Z\to\infty\\R_Z\to 0}} = \frac{i_b r_\pi + R_Z i_b (\beta+1)}{i_b}\bigg|_{\substack{R_Z\to\infty\\R_Z\to 0}} = r_\pi + R_Z(\beta+1)\bigg|_{\substack{R_Z\to\infty\\R_Z\to 0}} = \begin{cases} \xrightarrow{R_Z\to 0} \underline{r_\pi} \\ \xrightarrow{R_Z\to\infty} \underline{\infty} \end{cases}$$

R_o:



~~$v_{be} = -u_o + g_m v_{be} = -g_m u_o$~~

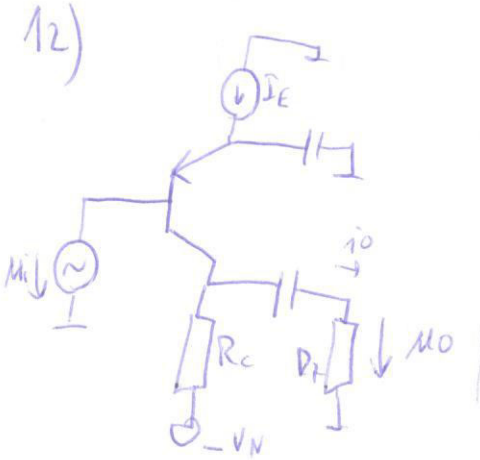
$\underline{u_o = i_b r_\pi}$

~~$i_b = i_{r_\pi} + g_m v_{be} =$~~

$\underline{i_o = (\beta+1) i_b}$

$$R_i = \frac{i_b r_\pi}{(\beta+1) i_b} = \underline{\underline{\frac{r_\pi}{\beta+1}}} \quad (= r_e)$$

12)



PB $I_E \sim I_C = 1\,mA$

$V_B = 0\,V$

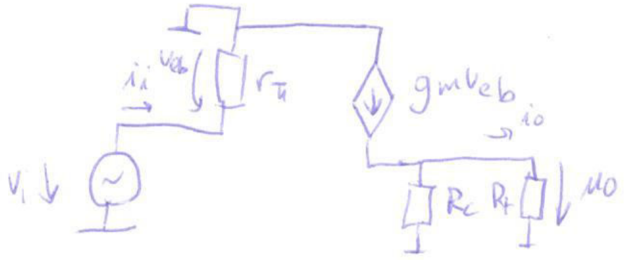
$V_C = \cancel{-10+}\ -V_N + I_C R_C = -10 + 5 = \underline{-5\,V}$

$V_{BC} = \underline{5\,V}$ ... splněno

$g_m = 40 I_C = 40\,mS$

$r_\pi = \frac{\beta}{g_m} = \underline{2{,}5\,k\Omega}$

Náhradní model



$v_{eb} = 0 - v_i = -v_i \Rightarrow g_m v_{eb} = -g_m v_i$

$i_o = g_m v_{eb} \cdot \frac{R_C}{R_C+R_Z} = -g_m v_i \frac{R_C}{R_C+R_Z}$

$u_o = i_o R_Z = -g_m u_i \frac{R_C R_Z}{R_C+R_Z}$

$i_i = \frac{v_i}{r_\pi}$

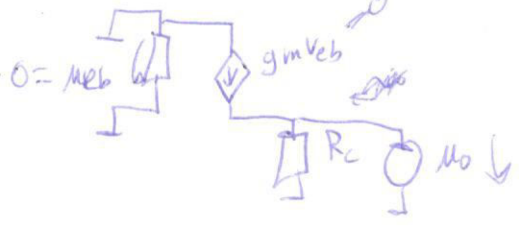
$A_V = \frac{u_o}{u_i}\Big|_{R_Z\to\infty} = -g_m \frac{R_C R_Z}{R_C+R_Z}\Big|_{R_Z\to\infty} \overset{L'H}{=} \underline{-g_m R_C}$

$A_i = \frac{i_o}{i_i}\Big|_{R_Z\to 0} = \frac{-g_m u_i \left(\frac{R_C}{R_C+R_Z}\right)\to 1}{\frac{u_i}{r_\pi}}\Big|_{R_Z\to 0} = -g_m r_\pi = \underline{-\beta}$

$R_i = \frac{u_i}{i_i}\Big|_{R_Z\to\infty}^{R_Z\to 0} = \frac{u_i}{\frac{u_i}{r_\pi}} = \underline{\underline{r_\pi}}$

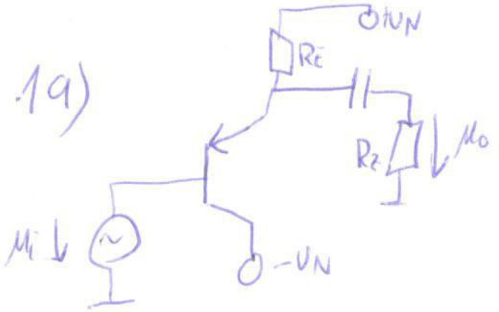
R_o:

$i_o = \frac{u_o}{R_C}$

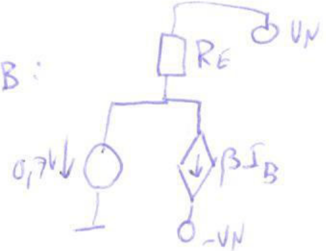


$R_o = \frac{u_o}{i_o} = \frac{u_o}{\frac{u_o}{R_C}} = \underline{\underline{R_C}}$

19)



PB:



$$\beta I_B = \alpha I_E = \frac{\beta}{\beta+1}\,\frac{U_N-0{,}7}{R_E} = \frac{200}{201}\cdot\frac{6{,}3}{8{,}24} \sim 0{,}75\,mA$$

$$U_B = 0$$

$$U_C = -7V$$

$$U_E = 7 - I_E R_E = 7 - 6{,}15 = 0{,}85V$$

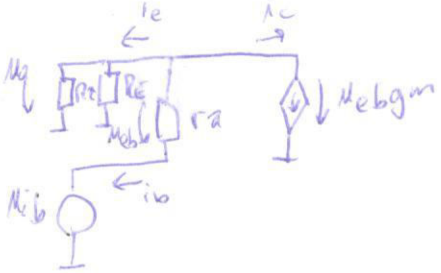
$$\left.\begin{aligned} U_{BC} &= -U_C = \underline{7V} > -0{,}5V \\ U_{EC} &= U_E - U_C = \underline{7{,}85V > 0{,}2V} \end{aligned}\right\}\ \text{splněno}$$

$$I_E \sim I_C \quad \dots \quad g_m = 40 I_C = \underline{30mS}$$

$$r_\pi = \frac{\beta}{30g_m} = \frac{200}{30mS} = 6{,}7k\Omega$$

$$r_e = \frac{r_\pi}{\beta+1} = 33\,\Omega$$

Náhradní model



[illegible] $i_e + i_c + i_b = 0$

$$v_{eb} = i_b r_\pi$$

$$i_c = g_m i_b r_\pi = \beta i_b$$

$$i_e = -(i_c + i_b) = -(\beta+1)\,i_b$$

$$i_o = -(\beta+1)\,i_b\,\frac{R_E}{R_E+R_Z} \qquad u_o = R_Z i_o = -(\beta+1)\,i_b\,\frac{R_E R_Z}{R_E+R_Z}$$

$$u_i = -v_{eb} + u_o$$

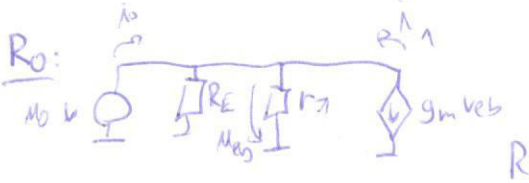
$$i_i = -i_b$$

$$A_V = \left.\frac{u_o}{u_i}\right|_{R_Z\to\infty} = \left.\frac{-i_b(\beta+1)\frac{R_E R_Z}{R_E+R_Z}}{-i_b r_\pi - i_b(\beta+1)\frac{R_E R_Z}{R_E+R_Z}}\right|_{R_Z\to\infty} = \frac{(\beta+1)\frac{R_E R_Z}{R_E+R_Z}}{r_\pi + (\beta+1)\frac{R_E R_Z}{(R_E+R_Z)}} = \left| r_\pi \ll (\beta+1)\frac{R_E R_Z}{R_E+R_Z} \right| = \underline{\underline{1}}$$

$$A_i = \left.\frac{i_o}{i_i}\right|_{R_Z\to 0} = \left.\frac{-i_b(\beta+1)\frac{R_E}{R_E+R_Z}}{-i_b}\right|_{R_Z\to 0} = \underline{\underline{\beta+1 \sim \beta}}$$

$$R_i = \left.\frac{u_i}{i_i}\right|_{\substack{R_Z\to 0\\ R_Z\to\infty}} = \left.\frac{-i_b r_\pi - i_b(\beta+1)\frac{R_E R_Z}{R_E+R_Z}}{-i_b}\right|_{R_Z\to 0,\infty} = r_\pi + (\beta+1)\frac{R_E R_Z}{R_E+R_Z} \;\Bigg|\; = \begin{cases} \xrightarrow{R_Z\to 0} \underline{r_\pi} \\ \xrightarrow{R_Z\to\infty} \underline{r_\pi + (\beta+1)R_E} \end{cases}$$

$\underline{R_O}$:

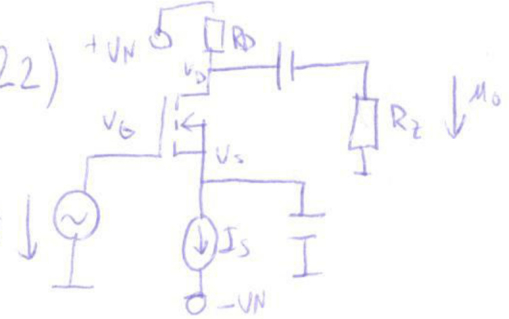


[illegible]

$$i_o = i_{R_E} + i_{r_\pi} + g_m v_{eb} = \frac{u_o}{R_E} + \frac{u_o}{r_\pi} + g_m v_o$$

$$R_o = \frac{u_o}{i_o} = \frac{1}{\frac{1}{R_E}+\frac{1}{r_\pi}+g_m} = \frac{1}{\frac{R_E + r_\pi + R_E g_m r_\pi}{R_E r_\pi}} = \frac{R_E r_\pi}{R_E + r_\pi + \beta R_E} = \frac{R_E \frac{r_e}{\cancel{\beta+1}}(\beta+1)}{R_E(\beta+1) + \frac{r_e}{\cancel{\beta+1}}(\beta+1)} = \underline{\frac{R_E r_e}{R_E + r_e}}$$

22)



$I_S = I_D$

$U_G = 0$

$U_D = U_N - R_D I_S = 10-5 = 5V$

$i_d = \frac{1}{2} k_p \frac{W}{L} (U_g - U_S - U_{T0})^2 = \frac{1}{2} \cdot 0{,}0016 \cdot 16 (-U_S - 1{,}9)^2$

$0{,}001 = 0{,}0128 (-U_S - 1{,}9)^2$

$0{,}078 = (-U_S - 1{,}9)^2 = (U_S + 1{,}9)^2 = U_S^2 + 3{,}8U_S + 3{,}61$

$U_S^2 + 3{,}8U_S + 3{,}532 = 0$

$U_S = \begin{cases} -2{,}18\ V \\ -1{,}62\ V \end{cases}$ | $U_{GS} > U_{T0} \Rightarrow$ | $\frac{2{,}18 > 1{,}9}{1{,}62 \not> 1{,}9}$

$g_m = k_p \frac{W}{L} |U_{GS} - U_{T0}| =$

$= 0{,}0016 \cdot \frac{160}{10} |2{,}18 - ~~0,~~ 1{,}9| =$

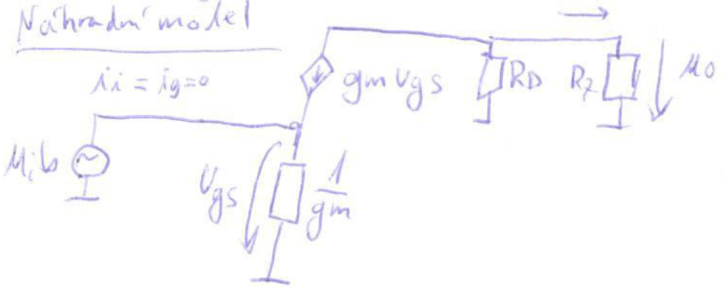
$= 0{,}0072 S = 7{,}2 mS$

$U_{DS} > U_{GS} - U_{T0}$

$U_D > U_g - U_{T0}$ | $5 > 0 - 1{,}9$ V splněno

Náhradní model

$i_i = i_g = 0$



$u_{gs} = u_i - 0 = u_i$

$g_m u_{gs} = g_m u_i$

$i_o = -g_m u_i \frac{R_D}{R_D + R_Z}$ | $i_i = 0$

$u_o = -g_m u_i \frac{R_D R_Z}{R_D + R_Z}$ | u_i ... zadáno

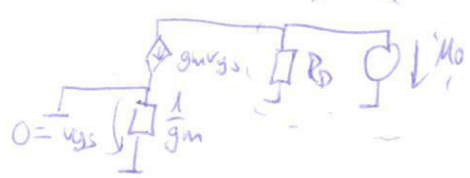
$$A_U = \frac{u_o}{u_i}\Big|_{R_Z \to \infty} = -g_m \frac{R_D R_Z}{R_D + R_Z}\Big|_{R_Z \to \infty} = -g_m R_D$$

$$A_i = \frac{i_o}{i_1}\Big|_{R_Z \to 0} = \left| \frac{-g_m u_i \frac{R_D}{R_D + R_Z}}{0} \right| = -\infty$$

$$R_i = \frac{u_i}{i_i}\Big|_{\substack{R_i \to 0 \\ R_Z \to \infty}} = \left| \frac{u_i}{0} \right| = \infty$$

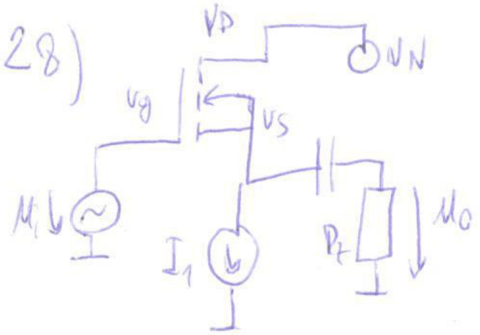
zdroj umístěn na gate (není postačující podmínka)

R_o :



$\Rightarrow R_o = \underline{R_D}$

28)



$V_g = 0$

$U_D = V_N$

$V_S = ?$

PB:

$I_D = I_S = \frac{1}{2} k_p \frac{W}{L} (V_{GS} - V_{T0})^2 =$

$(V_g - V_S - V_{T0})^2 =$

$\Rightarrow 0{,}001 = \frac{1}{2} \cdot 0{,}0016 \cdot \frac{160}{10}$

$\Rightarrow 0{,}0781 = (V_S + \overset{1{,}9}{\overset{\shortparallel}{V_{T0}}})^2$

$V_S^2 + 3{,}8 V_S + 3{,}61 - 0{,}078 = 0$

$V_S = \begin{cases} -2{,}18\ V \\ -1{,}62\ V \end{cases}$ | $V_{GS} > V_{T0}$ | $\underline{2{,}18 > 1{,}9}$ / $1{,}62 \not> 1{,}9$

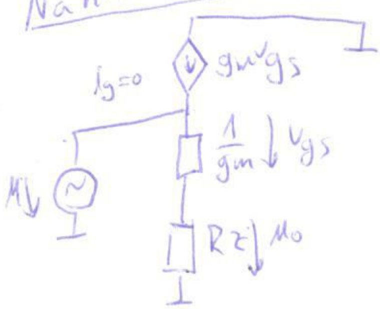
$U_{DS} > U_{GS} - U_{T0}$

$V_D > V_g - V_{T0}$

$\underline{10 > -1{,}9}$ ..splněno

$g_m = k \frac{W}{L} |V_{GS} - V_{T0}| = 0{,}0016 \cdot \frac{160}{10} \underbrace{|-V_S - V_{T0}|}_{2{,}18 - 1{,}9} = 0{,}0072\ S = \underline{7{,}2\ mS}$

Náhradní zapojení



$\frac{u_i}{R_z + \frac{1}{g_m}} = i_1$

$U_{GS} = i_1 \cdot \frac{1}{g_m} = \frac{u_i}{R_z g_m + 1}$ | $\rightarrow g_m v_{gs} = \frac{u_i g_m}{R_z g_m + 1}$

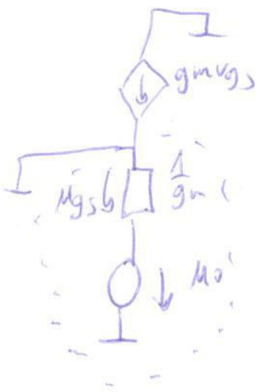
$u_0 = \underbrace{g_m v_{gs}}_{i_0} \cdot R_z = \frac{u_i g_m R_z}{R_z g_m + 1}$

$A_V = \frac{u_0}{u_i}\Big|_{R_z \to \infty} = \frac{g_m R_z}{g_m R_z + 1}\Big|_{R_z \to \infty} = \underline{\underline{1}}$

$A_i = \frac{i_0}{i_1}\Big|_{R_t \to 0} = \left|\frac{g_m v_{gs}}{0}\right| = \underline{\infty}$ } (zdroj na gate není postačující podmínka)

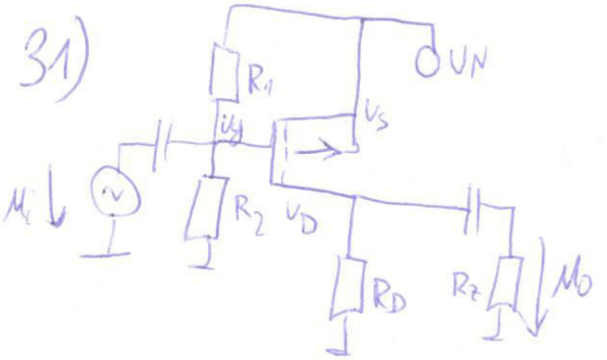
$R_i = \frac{u_i}{i_i} = \frac{u_i}{0} = \underline{\infty}$

Ro:



$R_0 = \underline{\underline{\frac{1}{g_m}}}$

31)



PB: $U_S = U_N$

$$U_g = U_N \cdot \frac{R_2}{R_1+R_2}$$

$$U_{gS} = U_N\left(\frac{R_2}{R_1+R_2} - 1\right) = U_N\left(\frac{-R_1}{R_1+R_2}\right) = 10\left(-\frac{200}{920}\right)$$

$$i_d = \frac{1}{2} k_p \frac{W}{L}\left(U_{gS} - U_{T0}\right)^2 = \frac{1}{2} \cdot 0{,}0016 \cdot 16 \cdot \left(+2{,}17 - 1{,}9\right)^2 =$$

$= ~~0{,}21\,mA~~ ~~= I_S~~ \sim \underline{1\,mA}$

~~$J_S \cdot R_D = 0{,}21 \cdot 5000 =$~~

$U_D = J_D R_D = \underline{5\,V}$

$U_{gS} < U_{T0}$ $\quad \underline{-2{,}17 < 1{,}9}$ splněno

$U_{DS} < U_{gS} - U_{T0}$

~~5~~ $-U_N < -2{,}17 + 1{,}9$

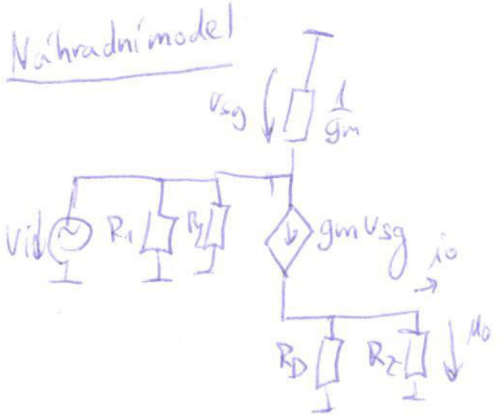
$-5 <$ ~~$4{,}07$~~ $\underline{-0{,}27}$ splněno

$$g_m = k_p \frac{W}{L}\left|U_{gS} - U_{T0}\right| =$$

$$= 0{,}0016 \frac{100}{10}\left|-2{,}17 + 1{,}9\right| =$$

$= ~~0{,}1S = 100\,mS~~ = 7\,mS$

Náhradní model



$u_{Sg} = -u_i$

$g_m u_{Sg} = -g_m u_i$

$i_o = -g_m u_i \cdot \frac{R_D}{R_D + R_Z}$ $\quad \Big| \quad u_o = -g_m u_i \frac{R_D R_Z}{R_D + R_Z}$

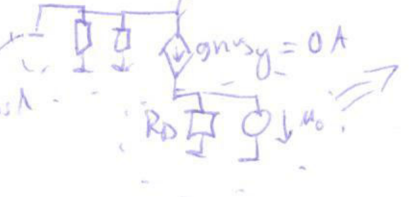
$i_i = \frac{u_i}{R_1} + \frac{u_i}{R_2} + \underbrace{i_g}_{0} = u_i\left(\frac{R_1+R_2}{R_1 R_2}\right)$ $\quad \Big| \quad u_i \ldots$ ~~zadáno~~ (ref. val)

$$A_U = \frac{u_o}{u_i}\Big|_{R_Z\to\infty} = -g_m \frac{R_D R_Z}{R_D + R_Z}\Big|_{R_Z\to\infty} = \underline{-g_m R_D}.$$

$$A_i = \frac{i_o}{i_i}\Big|_{R_Z\to 0} = \frac{-g_m u_i \left(\frac{R_D \cancel{R_Z}}{R_D + R_Z}\right)}{u_i\left(\frac{R_1+R_2}{R_1 R_2}\right)}\Bigg|_{R_Z\to 0} = \underline{-g_m \frac{R_1 R_2}{R_1 + R_2}}$$

$$R_i = \frac{u_i}{i_i}\Big|^{R_Z\to 0}_{R_Z\to\infty} = \frac{u_i}{u_i\left(\frac{R_1+R_2}{R_1 R_2}\right)} = \underline{\frac{R_1 R_2}{R_1 + R_2}}$$

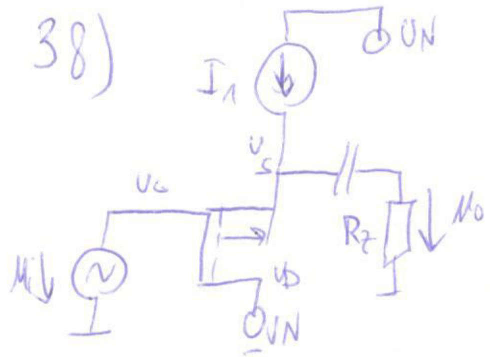
Ro:



neteče [illegible]

$\underline{R_o = R_D}$

38)



$v_g = 0$

$v_S = ?$

$v_D = -10V$

PB: $i_D = I_S = 1mA$

$$i_d = \frac{1}{2} k_p \frac{W}{L} (\underbrace{-v_g}_{0} + v_S - V_{T0})^2 =$$

$$\Rightarrow v_S = \begin{cases} +1{,}62V \\ +2{,}18V \end{cases}$$

$$v_{GS} = \begin{cases} -2{,}18\ V \\ -1{,}62\ V \end{cases}$$ | $v_{GS} < \underbrace{V_{T0}}_{-1{,}9V} \Rightarrow v_{GS} = 2{,}18V$

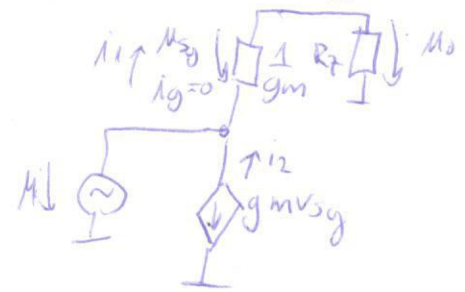
$$g_m = k_p \frac{W}{L} |v_g - v_S - V_{T0}| =$$
$$= 0{,}0016 \cdot \frac{160}{10} |0 - 2{,}18 + 1{,}9| =$$
$$= 0{,}0016 \cdot 16 \cdot 0{,}28 = \underline{7{,}2mS}$$

$v_{DS} < v_{GS} - V_{T0}$

$-10 - 2{,}18 < 0 - 2{,}18 - 1{,}9$

$-12{,}18 < -4{,}08$ splněno

Náhradní model



$$i_1 = \frac{u_i - 0}{\frac{1}{g_m} + R_Z}$$ | $$u_{sg} = \frac{1}{g_m} \cdot i_1 = -\frac{1}{g_m} \frac{u_i}{\frac{1}{g_m} + R_Z} = -\frac{u_i}{1 + g_m R_Z}$$

$$g_m u_{sg} = \frac{-g_m u_i}{1 + g_m u_i}$$

$$i_2 = -g_m u_{sg} = \frac{g_m u_i}{1 + g_m u_i}$$

$$i_o = i_2 = \frac{g_m u_i}{1 + g_m R_Z}$$ | $$u_o = i_o R_Z = \frac{g_m u_i R_Z}{1 + g_m R_Z}$$

| u_i … zadáno

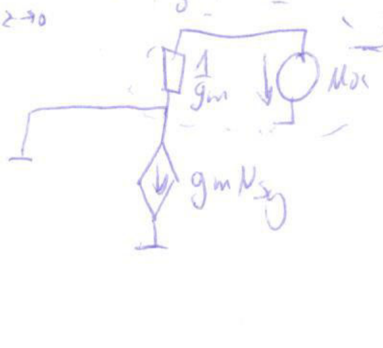
$$A_V = \frac{u_o}{u_i}\Big|_{R_Z \to \infty} = \frac{g_m R_Z}{g_m R_Z + 1}\Big|_{R_Z \to \infty} \overset{L'H}{=} \underline{\underline{1}}$$

$i_i = 0$

$$A_i = \frac{i_o}{i_i}\Big|_{R_Z \to 0} = \underline{\infty}$$

$$R_i = \frac{u_i}{i_i}\Big|_{R_Z \to 0}^{R_Z \to \infty} = \left|\frac{u_i}{0}\right| = \infty$$

Ro:



$$\Rightarrow R_o = \frac{1}{g_m}$$