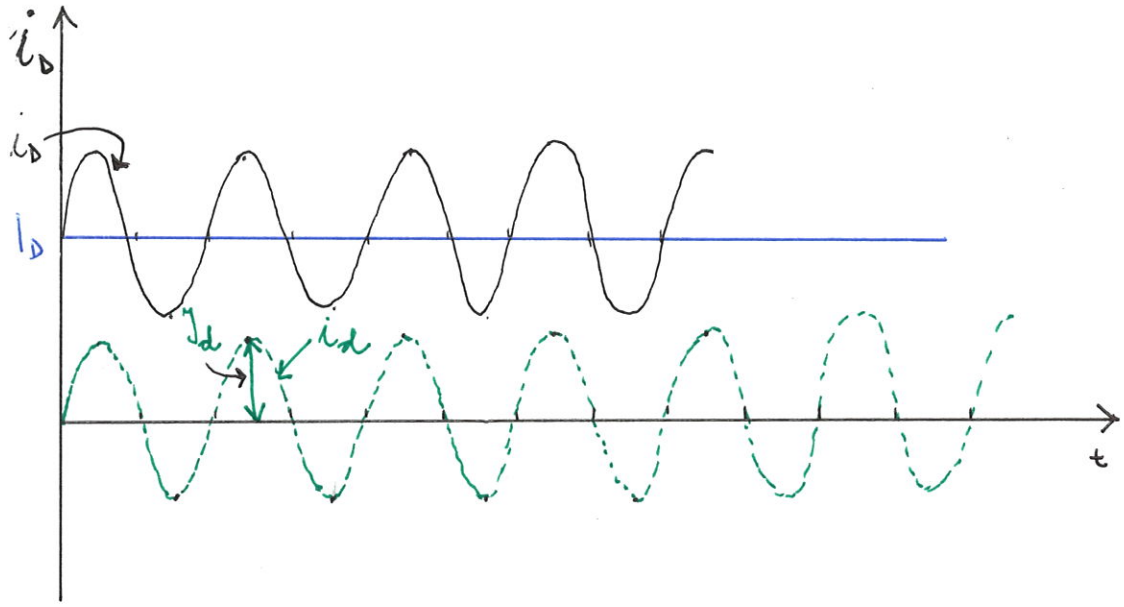
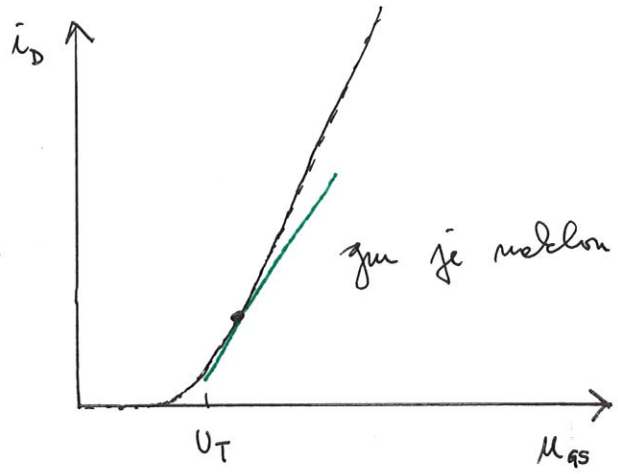


$$i_D = I_D + i_d$$

$$i_d = \hat{I}_d \cdot \sin \omega t$$



g_m je naklon tangente $\quad g_m = \dfrac{\partial i_D}{\partial u_{GS}}$

Zanima nas sprememba toka i_D glede na spremembo u_{GS} v D.T.

$$i_D = K_N \cdot (u_{GS} - U_{T_N})^2$$

TRANSKONDUKTANCA:

$$\left.\frac{\partial i_D}{\partial u_{GS}}\right|_{D.T} = 2 K_N \cdot (u_{GS} - U_{T_N}) \cdot \Big|_{D.T.} = \underline{2 K_N \cdot (U_{GS} - U_{T_N})}$$

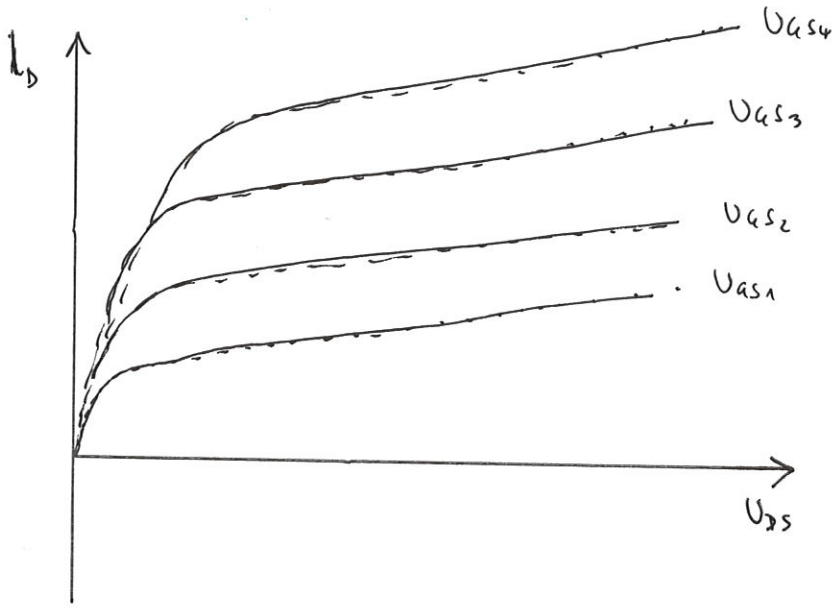
$$I_D = K_N \cdot (U_{GS} - U_{T_N})^2 \Rightarrow \quad U_{GS} - U_{T_N} = \sqrt{\frac{I_D}{K_N}}$$

$$= 2 K_N \cdot \sqrt{\frac{I_D}{K_N}} = \underline{2\sqrt{K_N \cdot I_D}}$$

$$g_m = \left.\frac{\partial i_D}{\partial u_{GS}}\right|_{D.T.}$$

$$i_d = g_m \cdot u_{gs}$$

$$g_m = 2K_N \cdot (U_{GS} - U_{T_N}) = 2\sqrt{K_N \cdot I_D}$$



$$i_D = K_N \cdot (u_{GS} - U_{T_N})^2 (1 + \lambda u_{DS})$$

IZHODNA UPORNOST = R_{izh}

$$\left.\frac{\partial u_{DS}}{\partial i_D}\right|_{D.T.} \qquad \left.\frac{\partial i_D}{\partial u_{DS}}\right|_{D.T.} = R_{izh}^{-1}$$

$$\left.\frac{\partial i_D}{\partial u_{DS}}\right|_{D.T.} = \underbrace{K_N \cdot (U_{GS} - U_{T_N})^2 \cdot \lambda}_{\doteq I_D}$$

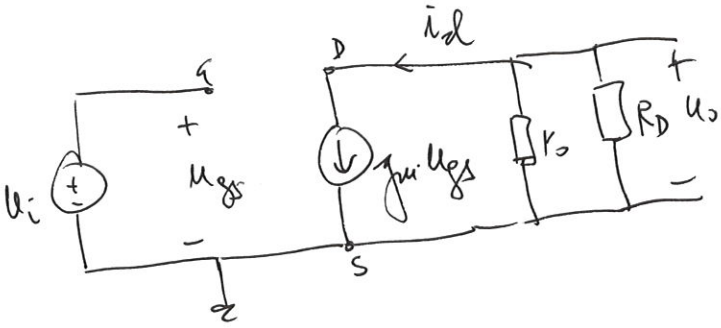
$$\frac{1}{R_{izh}} = \lambda \cdot I_D \Rightarrow R_{izh} = \frac{1}{\lambda \cdot I_D}$$

$$u_o = -g_m \cdot u_{gs} \cdot (r_o \| R_D)$$

$$u_{gs} = u_i$$

$$u_o = -g_m \cdot u_i \cdot (r_o \| R_D)$$

$$A_u = \frac{u_o}{u_i} = -g_m (r_o \| R_D)$$



A_u je negativno !

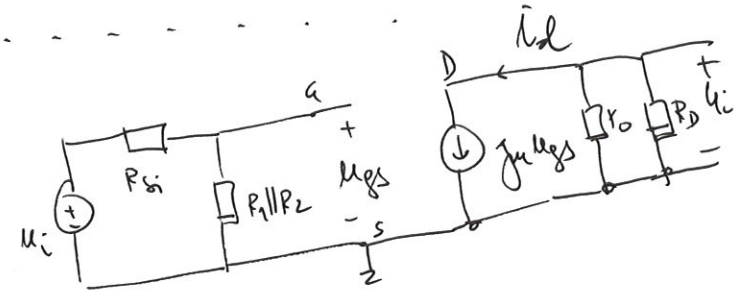
u_o in u_i sta v protifazi

$$u_o = -g_m \cdot u_{gs} \cdot r_o \| R_D$$

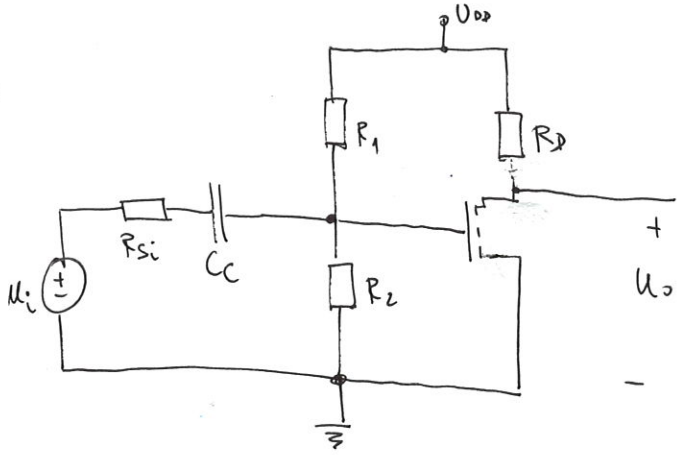
$$u_{gs} = \frac{R_1 \| R_2}{R_1 \| R_2 + R_{Si}} \cdot u_i$$

$$u_o = -g_m \frac{R_1 \| R_2}{R_1 \| R_2 + R_{Si}} \cdot u_i \cdot r_o \| R_D$$

$$A_u = \frac{u_o}{u_i} = -g_m \frac{R_1 \| R_2}{R_1 \| R_2 + R_{Si}} \cdot r_o \| R_D$$



Ex. 4.8



$U_{DD} = 3.3V$

$R_D = 10 k\Omega$

$R_1 = 140 k\Omega$

$R_2 = 60 k\Omega$

$R_{Si} = 4 k\Omega$

$C_C = 10 \mu F$

$U_{TN} = 0.4V$

$K_N = 0.5 \frac{mA}{V^2}$

$\lambda = 0.02 V^{-1}$

$$U_{GS} = \frac{R_2}{R_1 + R_2} \cdot U_{DD} = \frac{60 k\Omega}{140 k\Omega + 60 k\Omega} \cdot 3{,}3V = 0.99V$$

$$I_D = K_N \cdot (U_{GS} - U_{TN})^2 = 0.5 \frac{mA}{V^2} \cdot (0.99V - 0{,}4V)^2 = 0.174 mA$$

$$U_{DS} = U_{DD} - I_D \cdot R_D = 3{,}3V - 0.174mA \cdot 10 k\Omega = 1.56V$$

NASIČENJE ?

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

$1.56V > 0.99V - 0.4V$ ✓

$$g_m = 2\sqrt{K_N \cdot I_D} = 2\sqrt{0.5 \frac{mA}{V^2} \cdot 0.174mA} = 0.59 mS$$

$$r_o = \frac{1}{\lambda \cdot I_D} = \frac{1}{0.02 \frac{1}{V} \cdot 0.174mA} = 287 k\Omega$$

$$A_u = -g_m \cdot \frac{R_1 \| R_2}{R_1 \| R_2 + R_{Si}} \cdot r_o \| R_D$$

$$= -0.59 mS \cdot \frac{42 k\Omega}{42 k\Omega + 4 k\Omega} \cdot 287 k\Omega \| 10 k\Omega = -5.21$$

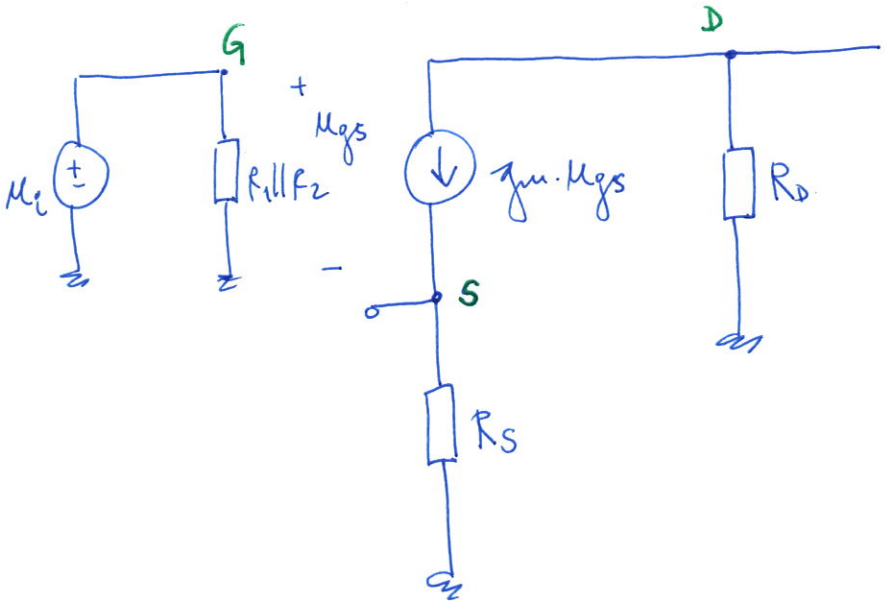
$R_i = R_1 \| R_2 = 42 k\Omega$

$R_o = r_o \| R_D = 287 k\Omega \| 10 k\Omega = 9.66 k\Omega$

$$u_{gs} = \frac{R_i}{R_i + R_s} \cdot u_i$$

$$u_{gs} = \frac{42 k\Omega}{42 k\Omega + 4 k\Omega} \cdot u_i = 0.91$$

LOADING EFFECT



$$u_i = u_{gs} + g_m \cdot u_{gs} \cdot R_S$$

$$u_i = (1 + g_m \cdot R_S) \cdot u_{gs}$$

$$u_{gs} = \frac{u_i}{1 + g_m \cdot R_S}$$

$$u_{izh} = -g_m \cdot u_{gs} \cdot R_D$$

$$u_{izh} = -g_m R_D \cdot \frac{u_i}{1 + g_m R_S}$$

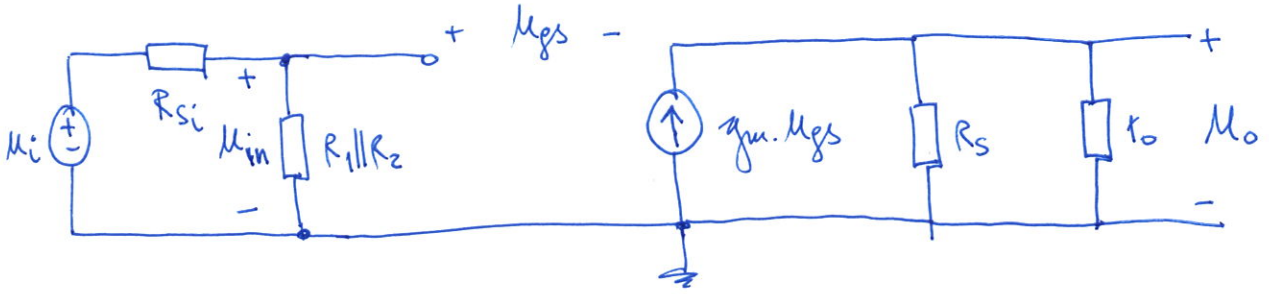
$$A_u = \frac{u_{izh}}{u_{vh}} = -\frac{g_m R_D}{1 + g_m R_S}$$

ZMANJŠAMO VPLIV SPREMEMB GEOMETRIJE (PARAMETROV) TRANZ. NA A_u

K_N	g_m	A_u
0.72	0.912	−2.44
0.80	0.974	−2.48
0.88	1.03	−2.52

$\pm 10\% \longrightarrow \pm 1.8\%$

Vendar manjše A_u!



$$u_o = g_m . u_{gs} . (R_S \| r_o)$$

$$u_{in} = u_{gs} + u_o = u_{gs} + g_m . u_{gs} (R_S \| r_o)$$

$$u_{in} = \left(1 + g_m (R_S \| r_o)\right) . u_{gs}$$

$$u_{gs} = \frac{u_{in}}{1 + g_m (R_S \| r_o)} = \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_S \| r_o} \cdot u_{in}$$

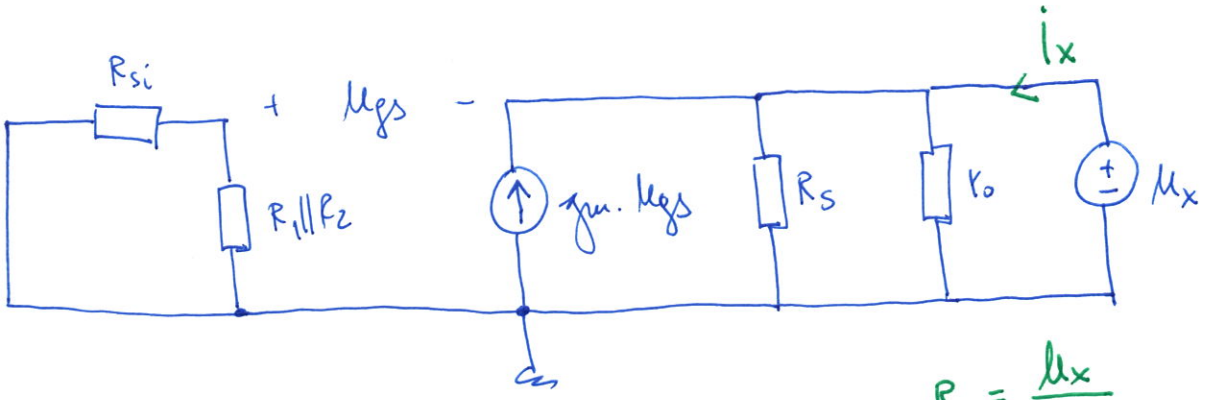
$$u_o = g_m . (R_S \| r_o) \cdot \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_S \| r_o} \cdot u_{in}$$

$$u_{in} = \frac{R_1 \| R_2}{R_1 \| R_2 + R_{Si}} u_i$$

$$= \frac{R_i}{R_i + R_{Si}} \cdot u_i$$

$$u_o = \frac{R_S \| r_o}{\frac{1}{g_m} + R_S \| r_o} \cdot \frac{R_i}{R_i + R_{Si}} \cdot u_i$$

$$A_u = \frac{u_o}{u_i} = \underbrace{\frac{R_S \| r_o}{\frac{1}{g_m} + R_S \| r_o}}_{< 1} \cdot \underbrace{\frac{R_i}{R_i + R_{Si}}}_{< 1} \Rightarrow A_u < 1$$



$$R_o = \frac{u_x}{i_x}$$

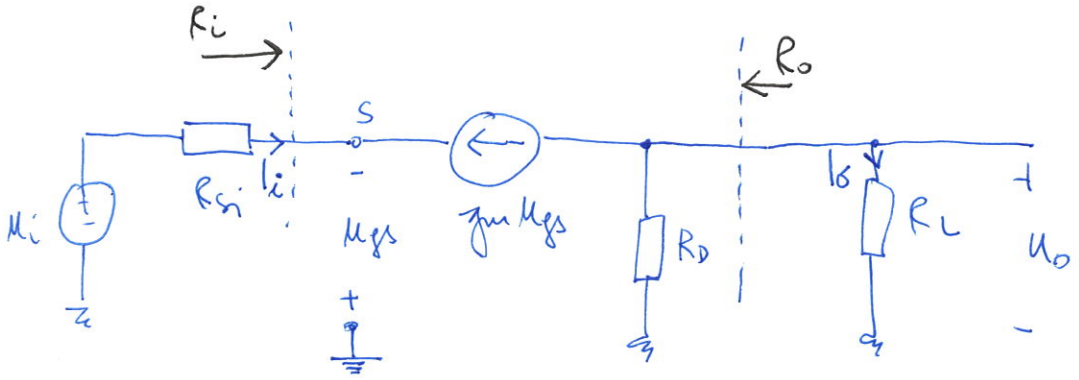
$$i_x + g_m . u_{gs} = \frac{u_x}{R_S} + \frac{u_x}{r_o} \qquad u_{gs} = -u_x$$

$$i_x = u_x . \left(g_m + \frac{1}{R_S} + \frac{1}{r_o} \right)$$

$$\frac{i_x}{u_x} = \frac{1}{R_o} = g_m + \frac{1}{R_S} + \frac{1}{r_o} \Longrightarrow R_o = \frac{1}{g_m} \| R_S \| r_o$$

$\sim \Omega$

R_o je nízká ↓



$$R_i = \frac{-u_{gs}}{i_i} = \frac{-u_{gs}}{-g_m u_{gs}} = \frac{1}{g_m}$$ NIZKA !

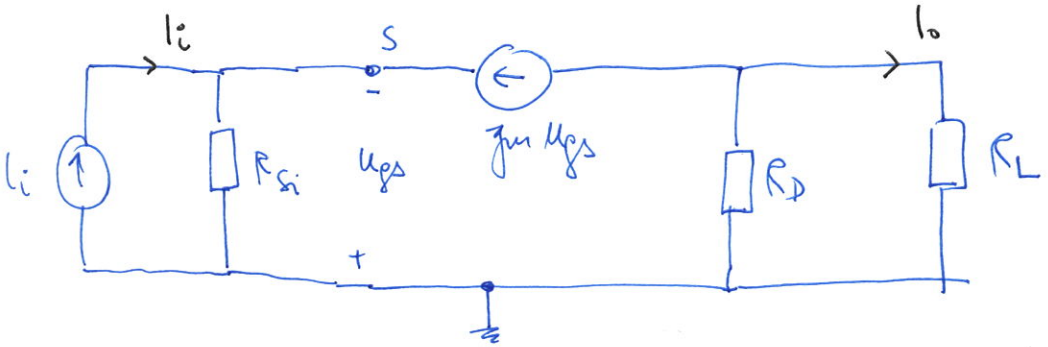
R_o

$u_i = 0$

$u_{gs} = -g_m u_{gs} R_{si} \Rightarrow u_{gs} = 0$

$g_m u_{gs} = 0 \Rightarrow R_o = R_D$

TOKOVNO OJAČANJE



$$i_o = \frac{R_D}{R_D + R_L} \cdot (-g_m u_{gs})$$

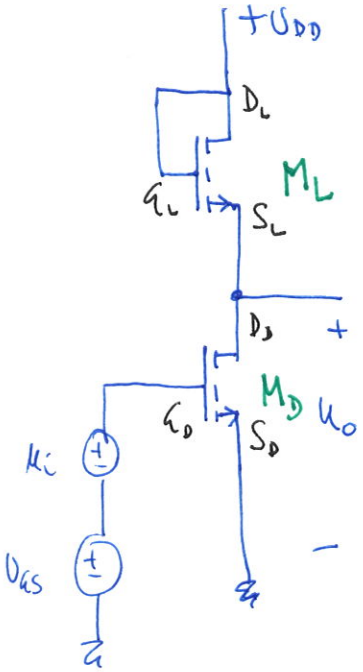
$$i_i + g_m u_{gs} + \frac{u_{gs}}{R_{si}} = 0$$

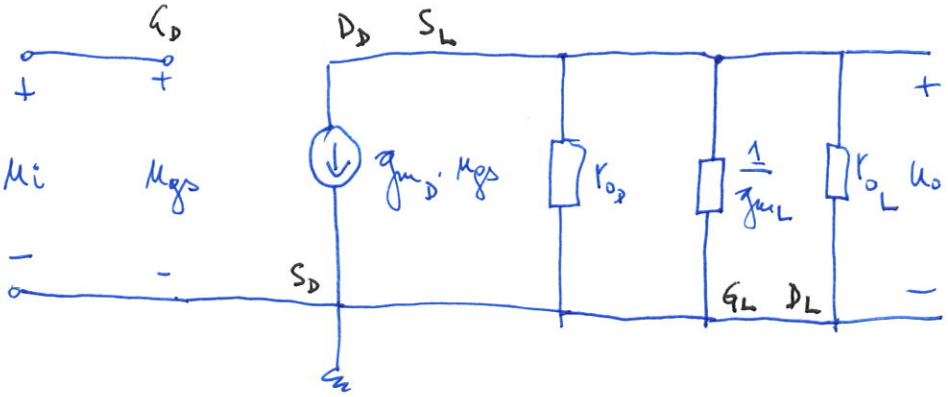
$$i_i = -u_{gs} \cdot \left(g_m + \frac{1}{R_{si}}\right) = -u_{gs}\left(\frac{1 + g_m R_{si}}{R_{si}}\right)$$

$$i_o = \frac{R_D}{R_D + R_L} \cdot \frac{g_m R_{si}}{1 + g_m R_{si}} \cdot i_i$$

$$u_{gs} = -i_i \frac{R_{si}}{1 + g_m R_{si}}$$

$$A_i = \frac{i_o}{i_i} = \frac{R_D}{R_D + R_L} \cdot \frac{g_m R_{si}}{1 + g_m R_{si}}$$



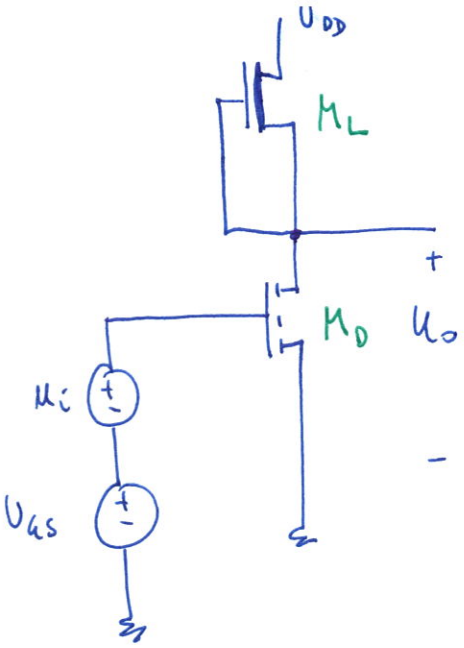


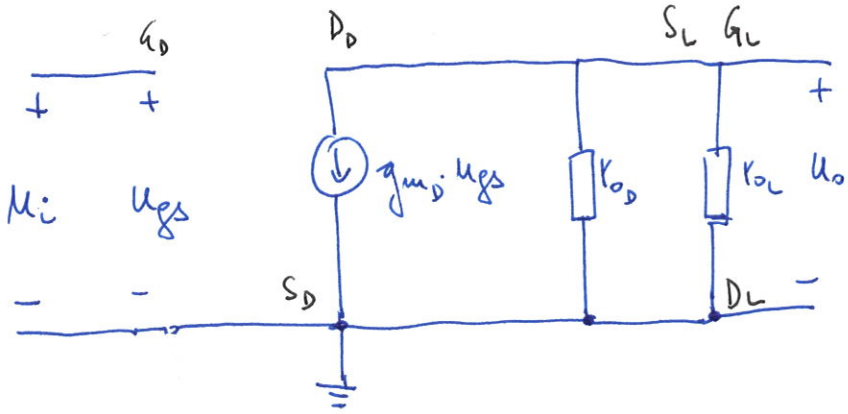
$$U_o = - g_{mD} \cdot U_{gs} \cdot \left(r_{DD} \parallel \frac{1}{g_{mL}} \cdot r_{DL} \right)$$

$$U_o = - g_{mD} \cdot \frac{1}{g_{mL}} \cdot U_i$$

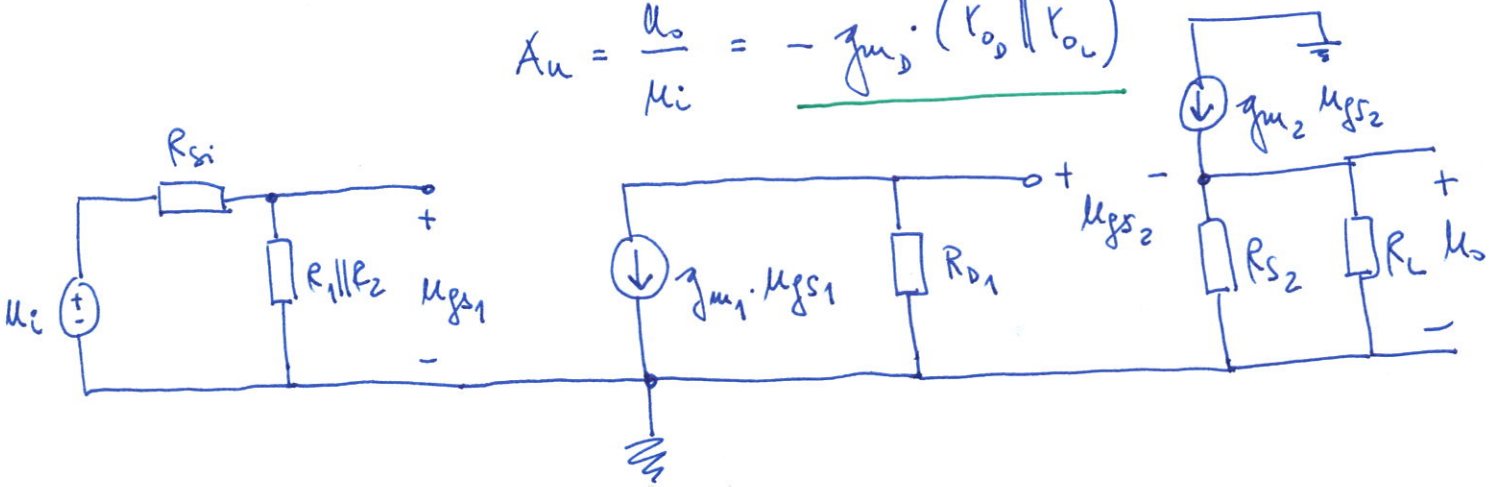
$$A_u = \frac{U_o}{U_i} = - \frac{g_{mD}}{g_{mL}} = - \sqrt{\frac{K_{ND}}{K_{NL}}} = - \sqrt{\frac{\left(\frac{W}{L}\right)_D}{\left(\frac{W}{L}\right)_L}}$$

$$A_u = - \sqrt{\frac{W_D}{W_L}}$$





$$A_u = \frac{u_o}{u_i} = -g_{m_D} \cdot (r_{o_D} \| r_{o_L})$$



$$u_o = g_{m_2} u_{gs_2} (R_{S_2} \| R_L)$$

$$-g_{m_1} \cdot u_{gs_1} \cdot R_{D_1} = u_{gs_2} + u_o \Rightarrow u_{gs_2} = -g_{m_1} u_{gs_1} R_{D_1} - u_o$$

$$u_o = g_{m_2} (R_{S_2} \| R_L) \cdot (-g_{m_1} \cdot u_{gs_1} R_{D_1} - u_o)$$

$$u_o (1 + g_{m_2} (R_{S_2} \| R_L)) = -g_{m_1} g_{m_2} (R_{S_2} \| R_L) R_{D_1} \cdot \frac{R_1 \| R_2}{R_1 \| R_2 + R_{Si}} \cdot u_i$$

$$A_u = \frac{u_o}{u_i} = -\frac{g_{m_1} \cdot g_{m_2} \cdot (R_{S_2} \| R_L) \cdot R_{D_1} \cdot R_1 \| R_2}{1 + g_{m_2} (R_{S_2} \| R_L) \cdot (R_1 \| R_2 + R_{Si})}$$