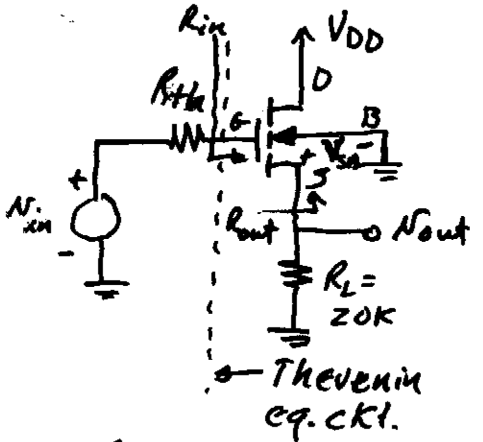
Source Follower with Bulk Effect ($V_{BS} \neq 0$)



Find $\frac{v_{out}}{v_{in}}$, R_{in}, & R_{out}

if $K_n = 500\mu A/V^2$, $V_{TN} = 1V$, $\lambda = 0$

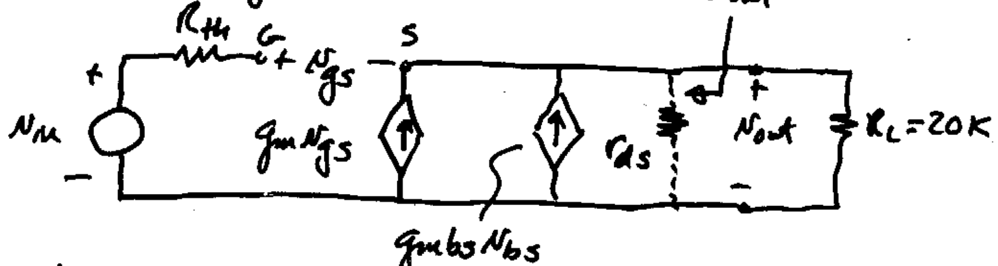
$\gamma = 0.75\ V^{1/2}$ and $2\phi_F = 0.6V$

Also, $I_{DS} = 241\mu A$ & $V_o(DC) = 5V$.

$\frac{5V}{20K} \simeq 0.25mA \simeq 241\mu A$

$R_{th} = R_S + R_1 \| R_2$

1.) Small signal model

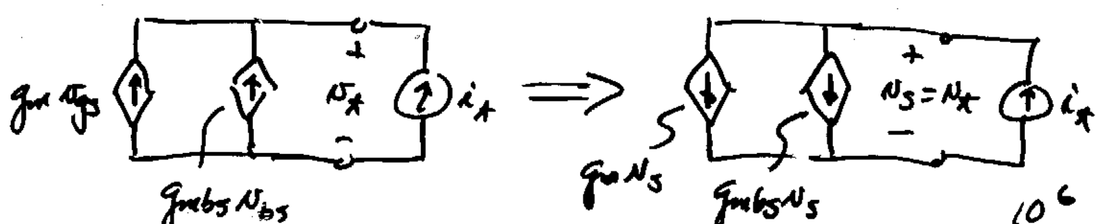


2.) Find g_m, g_{mbs}, and $r_{ds} = \infty$.

$$g_m = \sqrt{2K_N I_D} = \sqrt{2 \cdot 500 \cdot 241} = 491\mu S$$

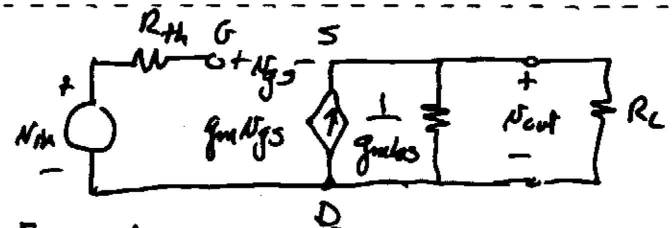
$$g_{mbs} = \frac{g_m \gamma}{2\sqrt{\underbrace{V_{SB} + 2\phi_F}_{\text{Everything is positive}}}} = \frac{(491\mu S)(0.75)}{2\sqrt{5+0.6}} = 77.8\mu S$$

3.) $\underline{R_{in} = \infty}$, $R_{out} = ?$ ($v_{in} = 0 \Rightarrow v_G = 0$) $\Rightarrow v_{gs} = -v_s$



$\sum i = 0 \quad g_m v_x + g_{mbs} v_x = i_x \rightarrow R_{out} = \frac{1}{g_m + g_{mbs}} = \frac{10^6}{491 + 77.8} = \underline{\underline{1.76K\Omega}}$

$$\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{v_{gs}}\right)\left(\frac{v_{gs}}{v_{in}}\right) = ?$$



$$= \left[g_m\left(\frac{1}{g_{mbs}} \| R_L\right)\right]\left[\frac{1}{1+g_m\left(R_L \| \frac{1}{g_{mbs}}\right)}\right]$$

$$v_{gs} = v_g - v_s = v_{in} - g_m\left(R_L \| \frac{1}{g_{mbs}}\right)v_{gs}$$

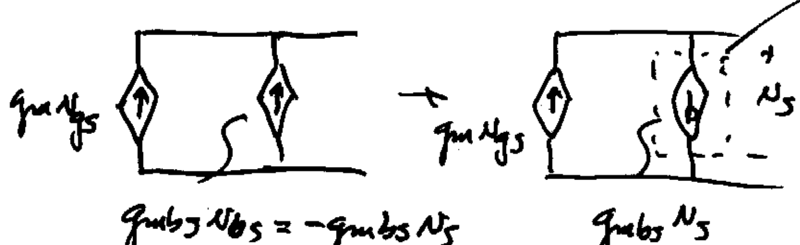
$$v_{gs}\left[1+g_m\left(R_L \| \frac{1}{g_{mbs}}\right)\right] = v_{in}$$

$$\frac{R_L \frac{1}{g_{mbs}}}{R_L + \frac{1}{g_{mbs}}} = \frac{R_L}{1+g_{mbs}R_L}.$$

$$\therefore \frac{v_{out}}{v_{in}} = \frac{\frac{g_m R_L}{1+g_{mbs}R_L}}{1+\frac{g_m R_L}{1+g_{mbs}R_L}} = \frac{g_m R_L}{1+g_m R_L + g_{mbs}R_L} = \frac{(0.491)(20)}{1+(0.491 \cdot 20)+(0.0}$$

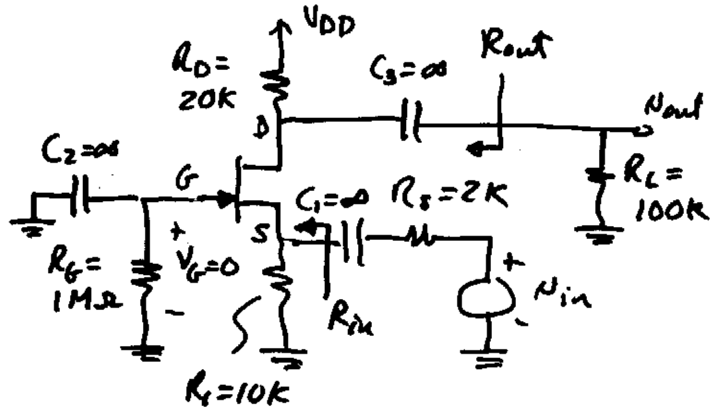
$$= \frac{(0.491)(20)}{1+(0.491\times 20)+(0.077E\times 20)} = \frac{9.82}{12.38} = \underline{\underline{0.793\ V/V}}$$

Question -



$$\frac{\cancel{v_s}}{g_{mbs}\cancel{v_s}} = \frac{1}{g_{mbs}}$$

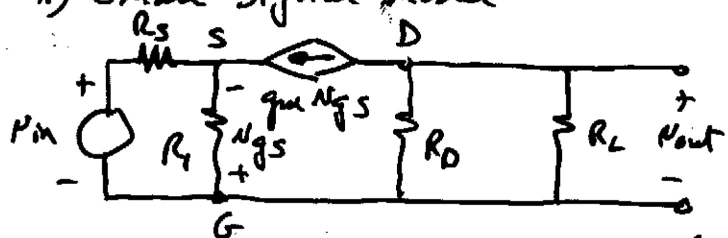
Common Gate JFET Amplifier



If $I_{DS} = 1mA$ and $I_{DSS} = 5mA$, $V_p = -2V$ and $\lambda = 0$, find R_{in}, R_{out}, and $\frac{v_{out}}{v_{in}}$.

1.) Small-signal model

$$i_D = I_{DSS}\left(1 - \frac{v_{GS}}{V_p}\right)^2$$

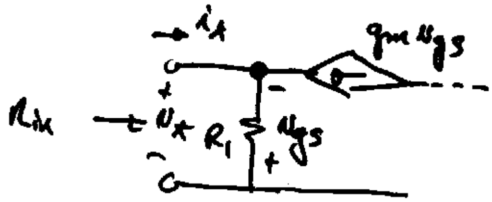


$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q$$

2.) $g_m = \frac{2}{|V_p|}\sqrt{I_{DS} I_{DSS}(1+\lambda V_{DS})} = \frac{2}{2}\sqrt{5 \cdot 1} = 2.236mS$

$r_{ds} = \infty$

3.) $R_{out} = \underline{\underline{R_D = 20k}}$ $R_{in} = ?$



$$i_x + \frac{v_{gs}}{R_1} + g_m v_{gs} = 0$$

But $v_{gs} = -v_x$

$\therefore$ $i_x = \frac{v_x}{R_1} + g_m v_x \rightarrow \frac{v_x}{i_x} = R_{in} = \frac{1}{g_m + \frac{1}{R_1}} = \frac{1}{g_m} \| R_1 = \underline{\underline{428\Omega}}$

$$\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{v_{gs}}\right)\left(\frac{v_{gs}}{v_{in}}\right) = \left(-g_m R_D \| R_L\right)\left(\frac{-R_{in}}{R_s + R_{in}}\right)$$

$$= \left[-2.236(20 \| 100)\right]\left[\frac{-428}{2428}\right] \cong (-37.27)\left(\frac{-1}{6}\right) \approx \underline{\underline{+6\ V/V}}$$

Common Nothing