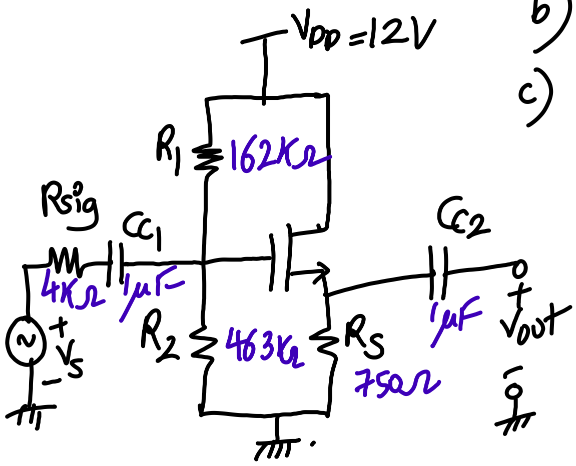
AEC lec 21 28/8/23

Numerical 1: Calculate a) small-slg voltage gain (A_v)
b) I/p impedance (Z_{in})
c) o/p impedance (Z_{out})



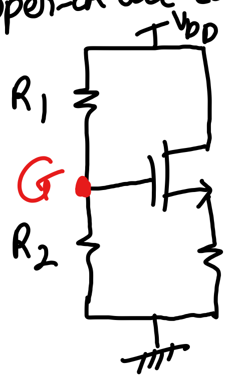
NMOS-E parameters:-
$V_{TN} = 1.5V$
$\lambda = 0.01V^{-1}$
$K_n = 4mA/V^2$

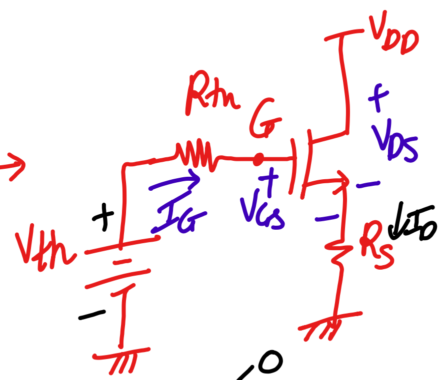
"Common-drain Amplifier"

Solution: ① I_{DQ}, V_{GSQ} 2m ② g_m, r_o 2m ③ A_v, Z_{in}, Z_{out} 6m

① DC Analysis:-

① open-ckt all capacitors





$V_{th} = \frac{R_2}{R_1+R_2} \times V_{DD}$

$V_{th} = \left(\frac{463}{463+162}\right) \times 12$

$V_{th} = \underline{8.89}\ V$

→ Apply KVL to G-S loop, $V_{th} - \overset{0}{I_G} R_{th} - V_{GS} - I_D R_S = 0$

$V_{GS} = V_{th} - I_D R_S$

$V_{GS} = 8.89 - I_D(750)$ — ①

→ Assume given device is working in saturation region

$\therefore I_D = K_n(V_{GS} - V_{TN})^2 = 4\times10^{-3}(V_{GS} - 1.5)^2$ — ②

→ Put ② in ①, we get

$V_{GS} = 8.89 - 3(V_{GS}^2 - 3V_{GS} + 2.25)$

→ $V_{GS} = 8.89 - 3V_{GS}^2 + 9V_{GS} - 6.75$

→ $3V_{GS}^2 - 8V_{GS} - 2.14 = 0$

($\because V_{GS} > V_{TN}$) $V_{GS} = \underline{2.91}\ V$ ✓ $V_{GS} = \underline{-0.245}\ V$ ✗ (Reject)

$$I_{DQ} = k_n(V_{GS}-V_{TN})^2 = 4\times10^{-3}\times(2.91-1.5)^2$$

$$\boxed{I_{DQ} = 7.95\,mA}$$

② Small-s/g parameters (g_m, r_o)

$$g_m = 2k_n(V_{GS}-V_{TN}) = 2\times4\times10^{-3}(2.91-1.5)$$

$$\boxed{g_m = 11.28\ \frac{mA}{V}}$$

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{0.01\times7.95\times10^{-3}}$$

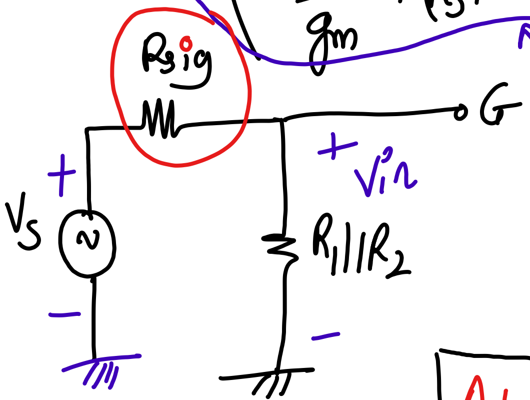
$$\boxed{r_o = 12.578\,K\Omega}$$

③ Av, Zin & Zout

98, 24, 25, 82, 44, 101, 88, 97, 100, 78, 80, 41, 67, 16, 7, 45, 4, 85, 54, 50, 40

$$A_V = \frac{R_S}{\frac{1}{g_m}+R_S} \quad \text{.... w/o '}r_o\text{' \& }R_{sig}$$

$$\boxed{A_V = \left(\frac{(r_o\,||\,R_S)}{\frac{1}{g_m}+(R_S\,||\,r_o)}\right)} \quad \text{.... with } r_o \text{ \& w/o } R_{sig}$$



$$A_{V_T} = \frac{V_{out}}{V_S}$$

$$\frac{V_{in}}{V_S} = \frac{R_1\,||\,R_2}{R_1\,||\,R_2+R_{sig}}$$

$$A_{V_T} = \frac{V_{out}}{V_{in}}\,\frac{V_{in}}{V_S}$$

$$A_{V_T} = A_V\left(\frac{V_{in}}{V_S}\right)$$

$$\boxed{A_{V_T} = A_V\left(\frac{R_1\,||\,R_2}{R_1\,||\,R_2+R_{sig}}\right)} \rightarrow \text{with } R_{sig}$$

$$A_V = \frac{(R_S\,||\,r_o)}{\frac{1}{g_m}+(R_S\,||\,r_o)}$$

$$r_o\,||\,R_S = 12.578K\,||\,750\Omega = 707.8\Omega$$

$$\frac{1}{g_m} = \frac{1}{11.28\times10^{-3}} = 88.615$$

$$A_V = \frac{707.8}{88.615+707.8}\ ; \quad \boxed{A_V = 0.8869}$$

$$A_{V_T} = \left(\frac{R_1\,||\,R_2}{R_1\,||\,R_2+R_{sig}}\right)A_V\ ; \quad R_1\,||\,R_2 = 162K\,||\,463K = 120K\Omega$$

$$A_{V_T} = \left(\frac{120K}{120K + 4K}\right) \times 0.8869 \Rightarrow \boxed{A_{V_T} = 0.86}$$

$$Z_{in} = R_{sig} + R_1 \| R_2 = 4K + 120K = \underline{124K\Omega} \quad (\text{High})$$

$$Z_{out} = R_S \| \frac{1}{g_m} \| r_o \quad \text{---- with } r_o$$

$$Z_{out} = 750 \| 88.615 \| 12.578K$$

$$Z_{out} = \underbrace{R_S \| r_o}_{707.8} \| 88.615$$

$$\boxed{Z_{out} = 78.78\Omega} \quad (\text{low})$$