JFET :

→ ohmic Region : $V_P \le V_{GS} \le 0$, $V_{DS} \le V_{GS} - V_P$ (N-channel)

$$I_D = I_{DSS}\left(2\left(1-\frac{V_{GS}}{V_P}\right)\left(\frac{V_{DS}}{-V_P}\right) - \left(\frac{V_{DS}}{V_P}\right)^2\right)$$

→ Saturation Region : $V_P \le V_{GS} \le 0$, $V_{DS} \ge V_{GS} - V_P$ (N-channel)

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$$

→ Breakdown :

$$V_{DS} >>> V_P$$

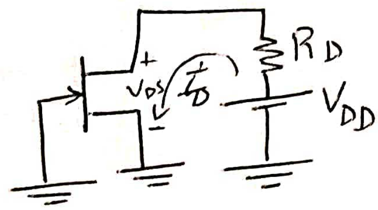
→ cut-off : $V_{GS} < V_P$ (N-channel)

* for p-channel reverse all polarities of the above conditions.

Part 2
sheet 5
(JFET)

1. $V_{GS(off)} = -4V$, $I_{DSS} = 12\ mA$

find min. V_{DD} to put the device in constant-current region.



sol:

$\Rightarrow V_{GS} = 0$

In constant-current (saturation) Region: $V_{DS} \geq V_P$ (at $V_{GS}=0$)

$\Rightarrow$ for min V_{DD} $\Rightarrow V_{DS} = V_P = -V_{GS(off)} = 4\ V$

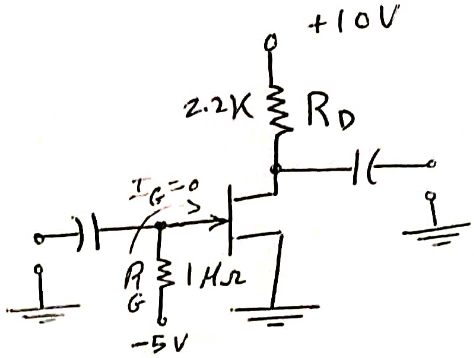
$\Rightarrow V_{DD} = V_{DS} + (560\,\Omega) I_D$

$\Rightarrow I_D = I_{DSS} \left(1 - \cancel{\frac{V_{GS}}{P}}\right)^2$

$= I_{DSS} = 12\ mA$

$\Rightarrow V_{DD} = (4) + 0.56\,(12) = 10.72\ V$

2. A JFET has values of $V_{GS(off)} = -8V$ & $I_{DSS} = 16\,mA$. Find the values of V_{GS}, I_D & V_{DS} for the ct.



Sol:

$\Rightarrow V_{GS(off)} = -8\,V$, $I_{DSS} = 16\,mA$

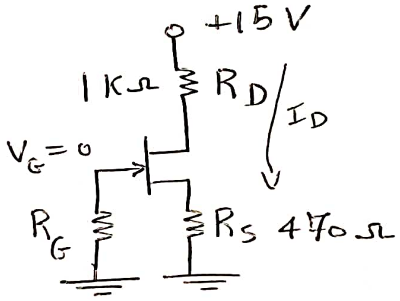
$\because I_G = 0 \Rightarrow V_{GS} = -5\,V$

$$\Rightarrow I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$
$$= 16\left(1 - \frac{(-5)}{(-8)}\right)^2$$
$$= 2.25\ mA$$

$$\Rightarrow V_{DS} = 10 - I_D R_D$$
$$= 10 - (2.25)(2.2) = 5.05\ V$$

---

3. Find V_{DS} & V_{GS} in the ct. shown given $I_D = 5\,mA$.



Sol:

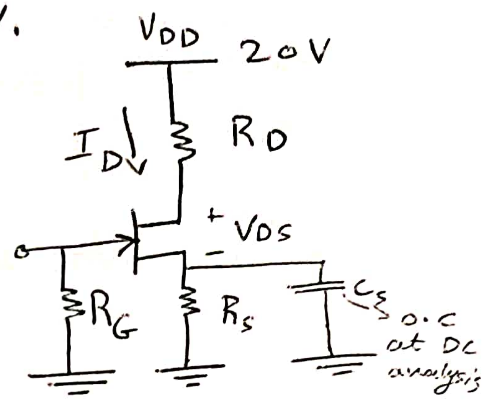
$\Rightarrow$ Applying KVL at o/p loop:

$$\Rightarrow 15 = I_D(R_D + R_S) + V_{DS}$$
$$\Rightarrow V_{DS} = 15 - 5(1 + 0.47)$$
$$= 7.65\ V$$

$\because V_G = 0 \quad (I_D = 0)$

$$\Rightarrow V_{GS} = 0 - I_D R_S = -5(0.47) = -2.35\ V$$

4. In a self-bias n-channel JFET, The operating point is $I_D = 1.5\,mA$ & $V_{DS} = 10V$.
$I_{DSS} = 5\,mA$ & $V_{GS(off)} = -2V$
find R_S & R_D given $V_{DD} = 20V$.



sol :

$I_D = 1.5\,mA$ & $V_{DS} = 10V$
$I_{DSS} = 5\,mA$ & $V_{GS(off)} = -2V$

$\because I_D = I_{DSS}\left(1 - \dfrac{V_{GS}}{V_{GS(off)}}\right)^2$

$\Rightarrow V_{GS} = V_{GS(off)}\left(1 - \sqrt{\dfrac{I_D}{I_{DSS}}}\right)$

$\Rightarrow V_{GS} = (-2)\left(1 - \sqrt{\dfrac{1.5}{5}}\right) = -0.9045\ V$

$\because I_G = 0 \Rightarrow V_{GS} = 0 - I_D R_S$

$\Rightarrow R_S = -\dfrac{V_{GS}}{I_D} = \dfrac{0.9045}{1.5\,mA} = 0.6\ K\Omega$

* Applying KVL at o/p Loop :

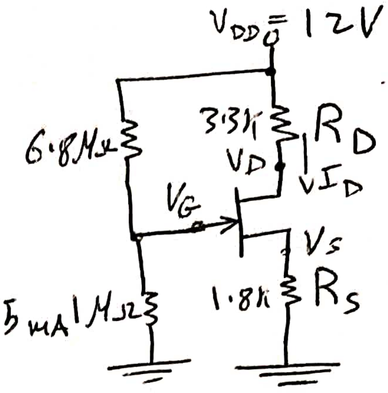
$\Rightarrow 20 = I_D(R_D + R_S) + V_{DS}$

$\Rightarrow 20 = 1.5(R_D + R_S) + 10$

$\Rightarrow R_D + R_S = \dfrac{20}{3}$, $\boxed{R_S = 0.6\ K}$

$\Rightarrow \boxed{R_D = 6.066\ K\Omega}$

5. Determine I_D & V_{GS} for the JFET with voltage divider bias in ct. given that $V_D = 7\,V$.



Sol :

$\because V_D = 7V$ (Drain voltage)

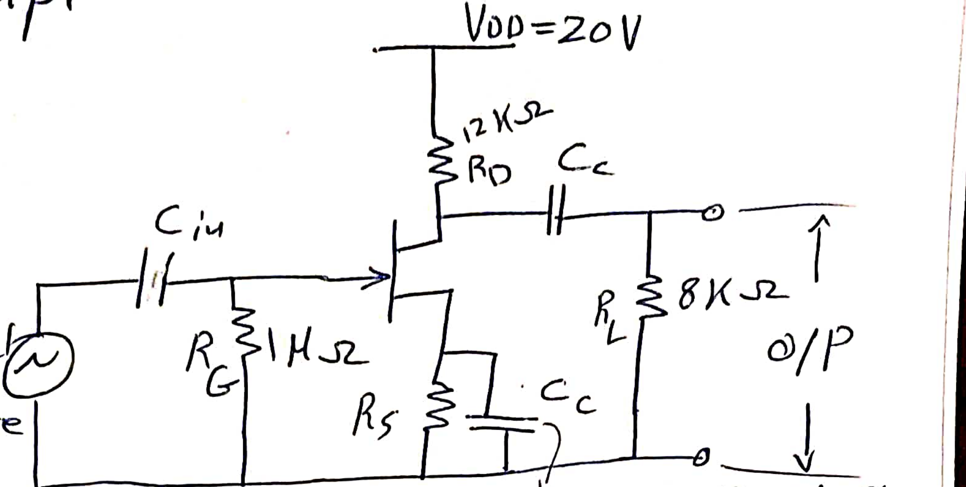
$\Rightarrow I_D = \dfrac{V_{DD} - V_D}{R_D} = \dfrac{12 - 7}{3.3} = 1.515\,mA$

$\Rightarrow V_G = (12)\left(\dfrac{1}{1 + 6.8}\right) = 1.538\ V$

$\Rightarrow V_{GS} = V_G - I_D R_S = 1.538 - (1.515)(1.8)$

$\Rightarrow V_{GS} = -1.189\ V.$

6. The JFET Amp. has $g_m = 1\,mA/V$. If the source Resistance as compared to R_G, find the voltage gain of the Amp.



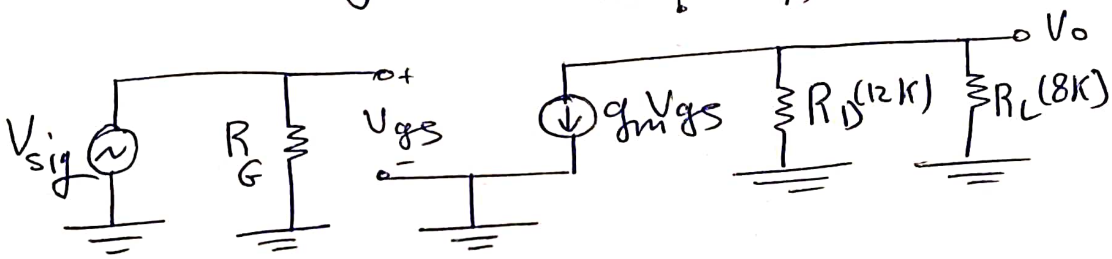
(This cap. will short R_s in Ac-analysis)

Sol:

$g_m = 1\,mA/V$

so, the transconductance is already given, we don't need Dc Analysis

Ac (small-signal) Analysis:



$$\Rightarrow A_V = \frac{V_o}{V_{sig}}$$

$$\because V_o = -g_m V_{gs} (R_D \parallel R_L)$$

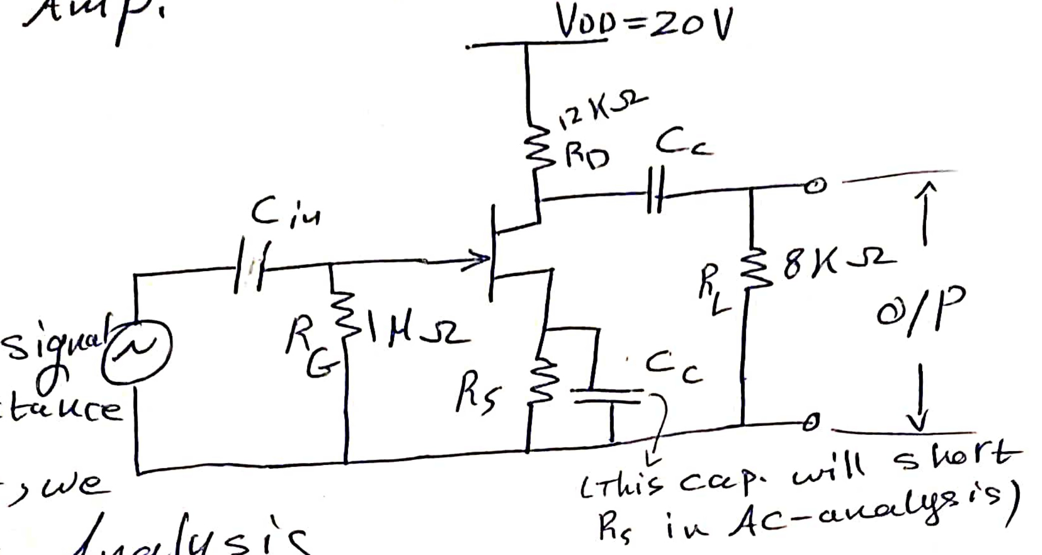
$$\because V_{gs} = V_{sig}$$

$$\Rightarrow V_o = -g_m V_{sig} (R_D \parallel R_L)$$

$$\Rightarrow \frac{V_o}{V_{sig}} = A_V = -g_m (R_D \parallel R_L)$$

$$= -(10^{-3}) \left[\frac{12 \times 10^3 \times 8 \times 10^3}{(12+8) \times 10^3} \right] = -4.8$$

6. The JFET Amp. has $g_m = 1\,mA/V$. If the source Resistance as compared to R_G, find the voltage gain of the Amp.

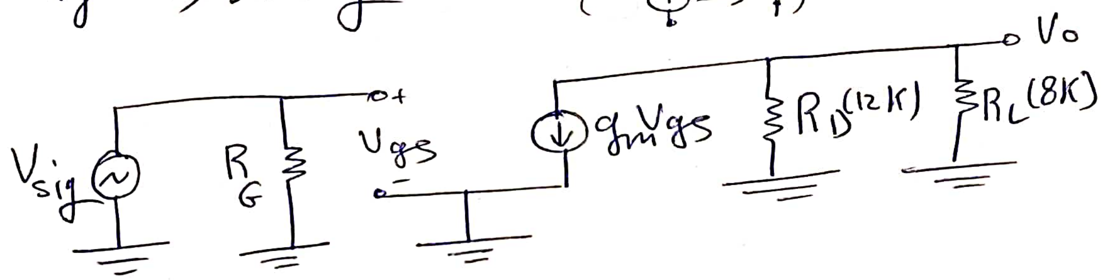


Sol:

$g_m = 1\,mA/V$

so, the transconductance is already given, we don't need Dc Analysis

Ac (small-signal) Analysis:



$$\Rightarrow A_V = \frac{V_o}{V_{sig}}$$

$$\because V_o = -g_m V_{gs} (R_D // R_L)$$

$$\because V_{gs} = V_{sig}$$

$$\Rightarrow V_o = -g_m V_{sig} (R_D // R_L)$$

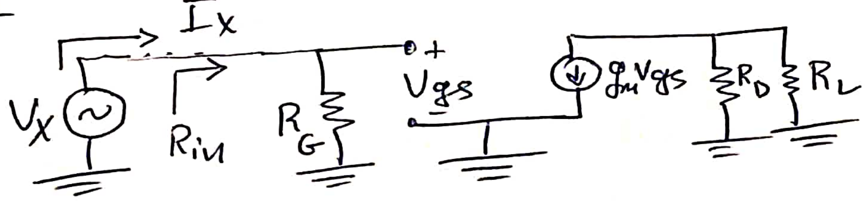
$$\Rightarrow \frac{V_o}{V_{sig}} = A_v = -g_m (R_D // R_L)$$

$$= -(10^{-3}) \left[\frac{12 \times 10^{3} \times 8 \times 10^{3}}{(12+8) \times 10^{3}} \right] = -4.8$$

* If we need to get R_{in} & R_{out} :

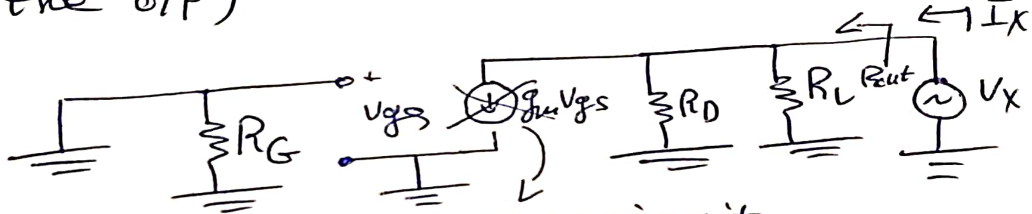
↳ (not Required in this problem)

* R_{in} : → (Replace the source by a test source)



$$\Rightarrow R_{in} = \frac{V_x}{I_x} = R_G$$

* R_{out} : → (short the source & add a test source at the o/P)



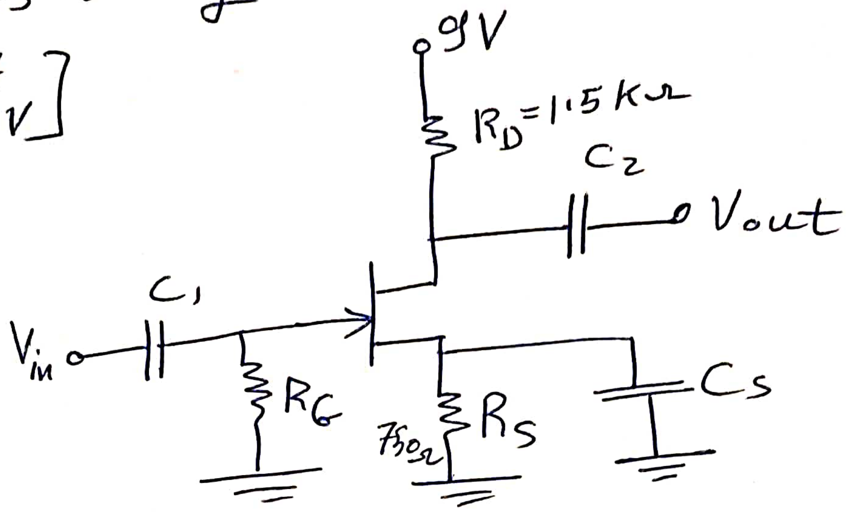
$$\Rightarrow R_{out} = \frac{V_x}{I_x} = R_L // R_D$$

open circuit

↳ since $V_{gs} = 0$.

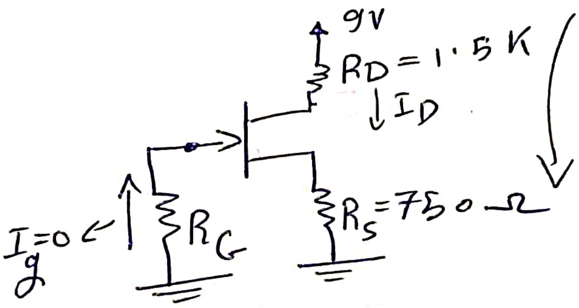
7. For the JFET ampilifier shown, calculate the voltage gain with i) R_S bypassed by a capacitor
ii) R_S un-bypassed.

[given: $I_{DSS} = 10mA$
$V_{GS(off)} = -3.5V$]



sol: first we need to do DC Analysis since

DC- Analysis :



$\dashv\vdash \equiv$ —o o—

$\therefore I_g = 0$

$\Rightarrow V_G = 0$

$\Rightarrow V_{GS} = 0 - V_S$

$V_{GS} = - I_D R_S \quad (1)$

$\therefore I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$

$\Rightarrow I_D = 10 * 10^{-3}\left(1 - \frac{V_{GS}}{(-3.5)}\right)^2$

$\Rightarrow$ from (1):

$I_D = - \frac{V_{GS}}{R_S}$

$\Rightarrow - \frac{V_{GS}}{R_S} = 10^{-2}\left[1 - 2\frac{V_{GS}}{V_{GS(off)}} + \frac{V_{GS}^2}{V_{GS}^2}\right]$

$\Rightarrow - \frac{V_{GS}}{750} = 10^{-2} - \frac{2(10^{-2})}{(-3.5)} V_{GS} + \frac{V_{GS}^2}{(-3.5)^2}(10^{-2})$

$\Rightarrow 0.8163 * 10^{-3} V_{GS}^2 + 0.0070476 V_{GS} + 10^{-2} = 0$

$\Rightarrow V_{GS} = -6.84$ or $V_{GS} = -1.79 > V_{GS(off)}$

(Refused) $\leftarrow$ $\underset{(cut-off)}{-6.8} < \underset{V_{GS(off)}}{-3.5}$

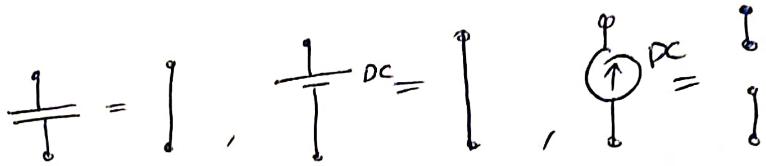
$$\Rightarrow g_m = -\frac{2 I_{DSS}}{V_{GS(off)}}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$$

$$= \cancel{-}\frac{2(10 \times 10^{-3})}{\cancel{-}3.5}\left(1 - \frac{(-1.7)}{(-3.5)}\right)$$

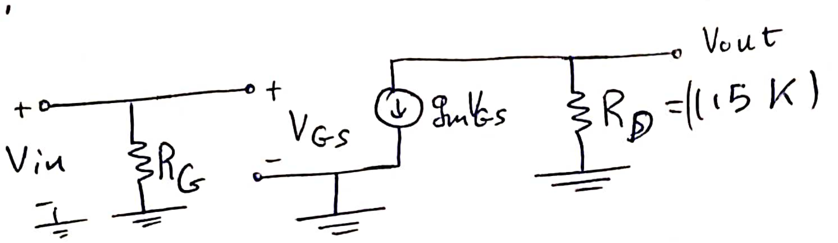
$$= 2.938 * 10^{-3} \ A/V$$

$$= 2.938 \ mA/V$$

#Ac Analysis:



i) R_s bypassed;



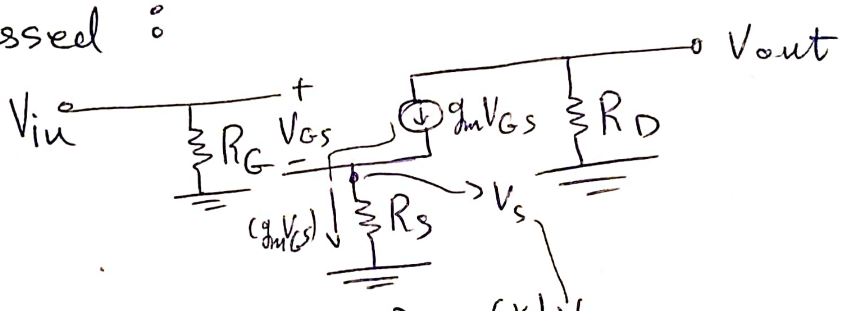
$$\Rightarrow V_o = -g_m V_{GS} R_D$$

$$V_{GS} = V_{in}$$

$$\Rightarrow V_o = -g_m V_{in} R_D$$

$$\Rightarrow A_v = \frac{V_o}{V_{in}} = -g_m R_D = -(2.938)(1.5K) = -4.407$$

ii) R_s unbypassed:



$$\Rightarrow V_{out} = -g_m V_{GS} R_D \quad (*)$$

$$V_s = (g_m V_{GS}) R_s$$

$$\Rightarrow V_{in} = V_{GS} + V_s = V_{GS} + g_m V_{GS} R_s$$

$$\Rightarrow V_{in} = V_{GS}(1 + g_m R_s)$$

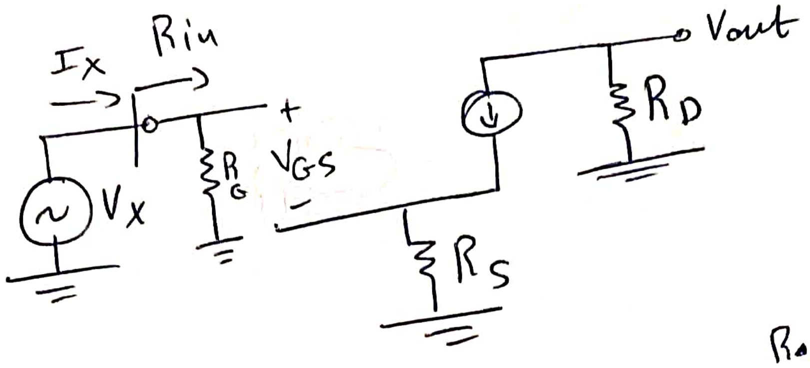
$$\Rightarrow V_{GS} = \frac{V_{in}}{1 + g_m R_s} \Rightarrow \text{sub. in } (*)$$

$$\Rightarrow V_{out} = \frac{-g_m R_D}{1 + g_m R_s} \cdot V_{in}$$

$$\Rightarrow A_v = \frac{V_{out}}{V_{in}} = \frac{-g_m R_D}{1 + g_m R_s} = 1.3756$$

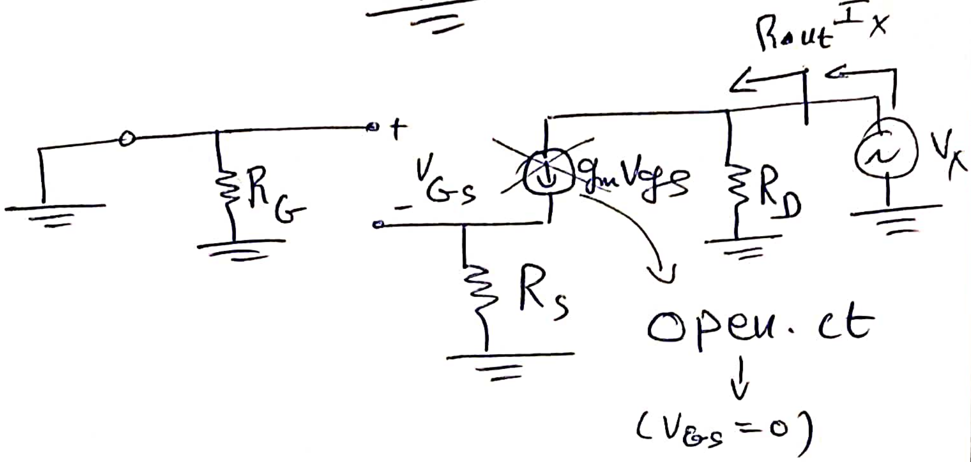
* If we want to find R_{in} & R_{out} :

R_{in} :



$\Rightarrow R_{in} = R_G$

R_{out} :



$\Rightarrow R_{out} = R_D$