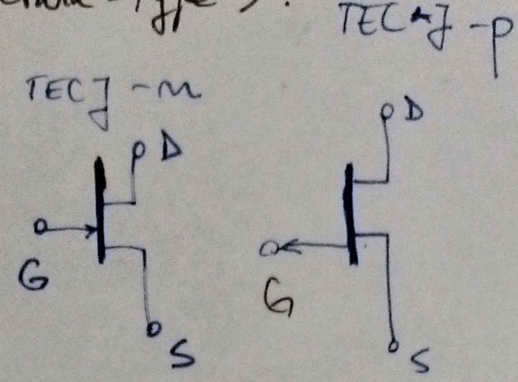
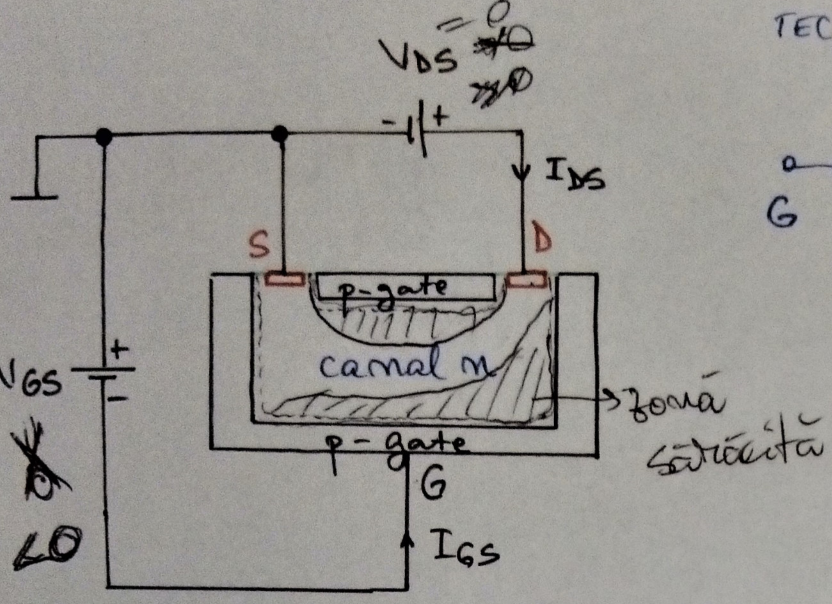
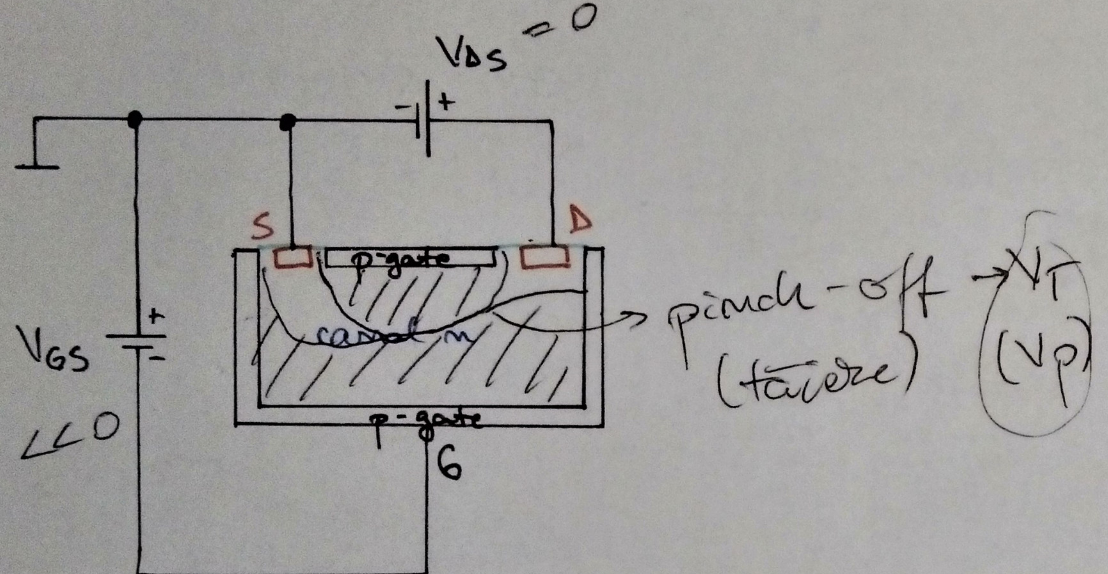
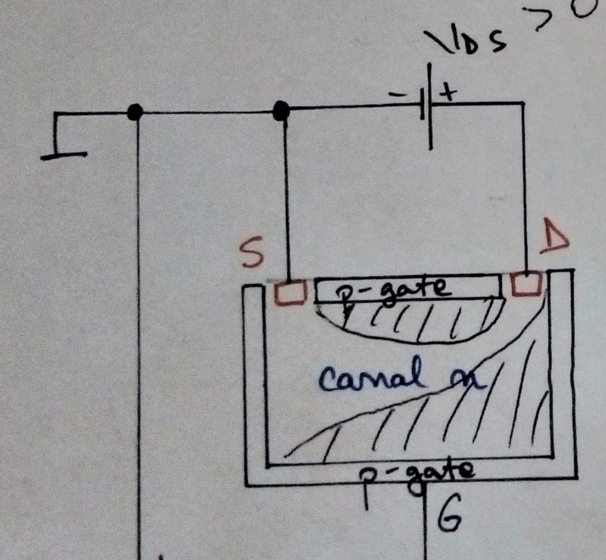
SEMINAR 5 EL.2

JFET cu canal n ("depletion-type").



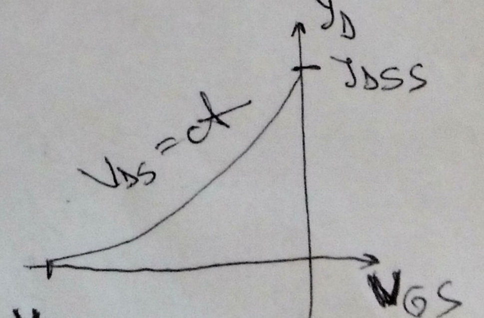






$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_T}\right)^2$$

I_{DSS}, V_T - catalog.



(catalog $|Y_{fs}|$ ←) $g_m = \left(\frac{\Delta I_D}{\Delta V_{GS}}\right)_{V_{DS}=ct}$ - transconduct

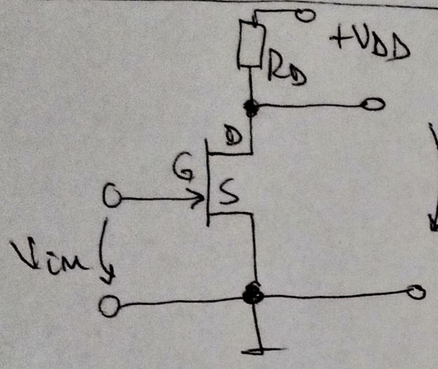
$$r_d = \left(\frac{\Delta V_{DS}}{\Delta I_D}\right)_{V_{GS}=ct.}$$ - rez. de ieșire (rez. de drenă)

(↪ catalog $|Y_{OS}| = \frac{1}{r_d}$).

$$U_{DSsat} = U_{GS} - U_T$$

·) conexiuni ale TECJ:

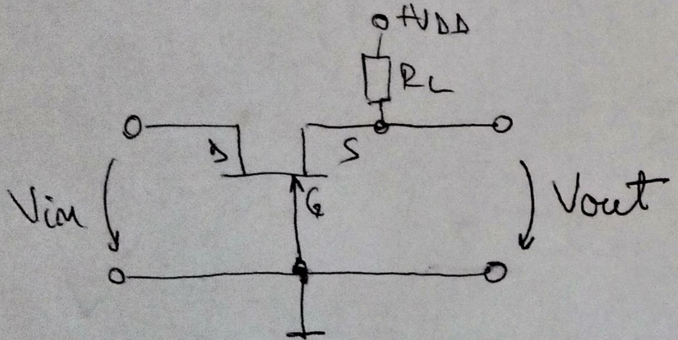
1.) Sursă comună:



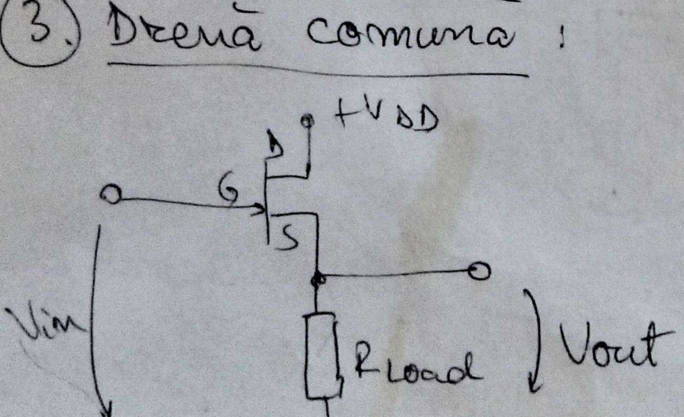
Z_{in} mare

$\Delta\varphi = 180°$

2.) Poartă comună:



3.) Drenă comună:

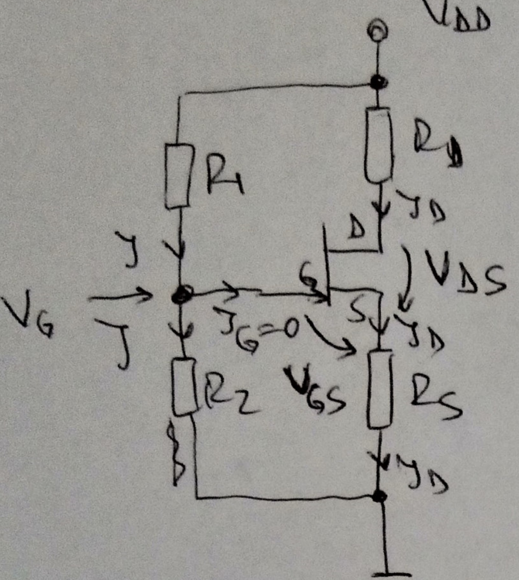


„buffer"

„voltage follower"

Polarizarea TEC J.

1) cu divitor de tensiune în poartă.



$V_{DD} = I(R_1 + R_2)$

$V_{DD} = I_D R_D + I_D R_S + V_{DS}$.

$I R_2 = V_{GS} + I_D R_S$.

$R_1, R_2 \rightarrow M\Omega$

$R_D, R_S \rightarrow k\Omega$

Ex: Pentru circuitul de mai sus, găsiți valorile rezistențelor astfel încât $I_D = 2mA$.

Determinați regimul în care se află TEC J.

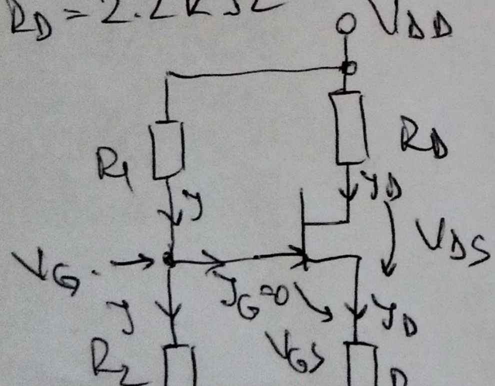
$V_G = 5V$; $V_{DD} = 20V$

$I_{DSS} = 4mA$

$V_T = -2V$

$R_D = 2.2 k\Omega$

$R_1, R_2, R_S = ?$



$V_G = 5V = V_{DD} \cdot \frac{R_2}{R_1 + R_2}$

$5 = 20 \cdot \frac{R_2}{R_1 + R_2} \Leftrightarrow$

$\Leftrightarrow \frac{1}{4} = \frac{R_2}{R_1 + R_2} \Leftrightarrow$

$R_1 = 3M\Omega$
$R_2 = 1M\Omega$

$R_2 = \frac{R_1}{3} \Leftarrow 4R_2 = R_1 + R_2 \Rightarrow 3R_2 = R_1$

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

$$2mA = 4mA\left(1-\frac{V_{GS}}{-2}\right)^2$$

~~$\frac{1}{2}\left(1+\frac{V_{GS}}{2}\right)^2$~~

~~$\frac{1}{\sqrt{2}} = 1+\frac{V_{GS}}{2} \Rightarrow \frac{V_{GS}}{2} = \frac{1}{\sqrt{2}} - 1 \quad \frac{\sqrt{2}}{2} - 1$~~

$$\frac{1}{2} = \left(1-\frac{V_{GS}}{V_T}\right)^2$$

$$\frac{1}{\sqrt{2}} = 1-\frac{V_{GS}}{V_T} \Rightarrow -\frac{V_{GS}}{V_T} = \frac{1}{\sqrt{2}} - 1 \Rightarrow$$

$$\Rightarrow \frac{V_{GS}}{V_T} = 1-\frac{1}{\sqrt{2}} \Rightarrow V_{GS} = V_T\left(1-\frac{\sqrt{2}}{2}\right) =$$

$$= 0.29 \cdot V_T = -0.29 \cdot 2 =$$

$$\boxed{V_{GS} = -0.58V}$$

$$V_{DS\,sat} = V_{GS} - V_T =$$
$$= -0.58 + 2 =$$
$$= \boxed{1.42V}$$

$$V_{DD} = I_D(R_D + R_S) + V_{DS}$$

$$V_{DS} = \frac{V_{DD}}{I_D(R_D+R_S)} = \boxed{2V}$$

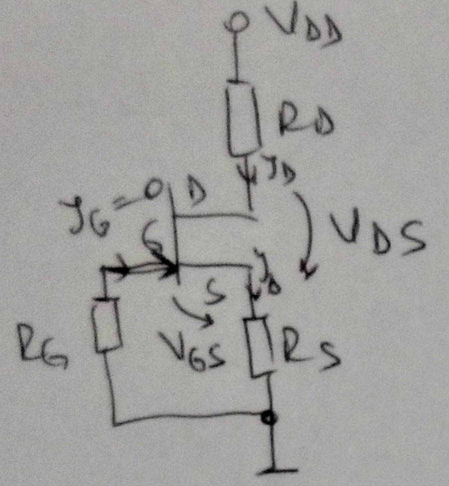
activa (sat.)

$$5 = V_{GS} + I_D R_S$$

$$I_D R_S = 5 + 0.58$$

$$R_S = \frac{5.58}{I_D} = \frac{5.58V}{2mA} = \boxed{2.79k\Omega}$$

•) Poarta conectată la masă:



$$V_{DD} = I_D(R_D + R_S) + V_{DS}.$$

$$\cancel{I_G} R_G = V_{GS} + I_D R_S \quad (I_G = 0)$$

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

Ex: Pentru schema de mai sus, determinați R_D astfel încât TECJ să lucreze în regim de saturație.

$R_G = 1M\Omega$ $\quad$ $I_{DSS} = 9mA$

$R_S = 250\,\Omega$ $\quad$ $V_T = -3V$

$V_{DD} = 16V$

$$V_{GS} = -I_D \cdot R_S = -250\, I_D.$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_T}\right)^2 = 9\cdot 10^{-3}\,(1 - 83.33\cdot I_D)^2 =$$

$$= 9\cdot 10^{-3}\,(1 - 166.67\cdot I_D + 6943.89\cdot I_D^2)$$

$$I_D = 9\cdot 10^{-3} - 1.503\, I_D + 62.495\, I_D^2$$

$$62.495\, I_D^2 - 2.503\, I_D + 9\cdot 10^{-3} = 0.$$

$$I_D^2 - 0.04\, I_D + 0.144\cdot 10^{-3} = 0.$$

$$\Delta = 0.04\cdot 0.04 - 4\cdot 0.144\cdot 10^{-3} = 16\cdot 10^{-4} - 5.76\cdot 10^{-4} =$$

$$= 10.24\cdot 10^{-4}.$$

$$I_D = \frac{0.04 \pm \sqrt{10.24 \cdot 10^{-4}}}{2} = 0.02 \pm \frac{1}{2}\sqrt{10.24} \cdot 10^{-2} =$$

$$= 0.02 \pm 1.6 \cdot 10^{-2} = 0.02 \pm 0.016 \text{ A} =$$

$$= 20 \pm 16 \text{ mA}$$

$(I_{DSS} = 9 \text{ mA})$.

·) Presup. $I_D = 36 \text{ mA}$

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

$$\frac{36}{9} = \left(1 + \frac{V_{GS}}{3}\right)^2 \Leftrightarrow \frac{4}{3} = 1 + \frac{V_{GS}}{3} \Rightarrow$$

$$\Rightarrow \frac{V_{GS}}{3} = \frac{1}{3}$$

$$\boxed{V_{GS} = 1V}$$

·) Presup. $\boxed{I_D = 4 \text{ mA}}$ ✓

$$\frac{2}{3} = 1 + \frac{V_{GS}}{3} \Rightarrow \frac{V_{GS}}{3} = -\frac{1}{3}$$

$$\boxed{V_{GS} = -1V}$$ ✓

$$V_{DSsat} = V_{GS} - V_T = -1 - (-3) = 2V.$$

TECJ activ $V_{DS} > V_{DSsat}$

$V_{DS} > 2V$

$$V_{DD} = I_D(R_D + R_S) + V_{DS}$$

$$V_{DD} = I_D R_D + I_D R_S + V_{DS}.$$

$$V_{DS} = V_{DD} - I_D R_D - I_D R_S > 2$$

$$V_{DD} - I_D R_D - I_D R_S > 2$$

$$-I_D R_D > 2 + I_D R_S - V_{DD}.$$

$$R_D < \frac{-2}{I_D} - R_S + \frac{V_{DD}}{I_D}$$

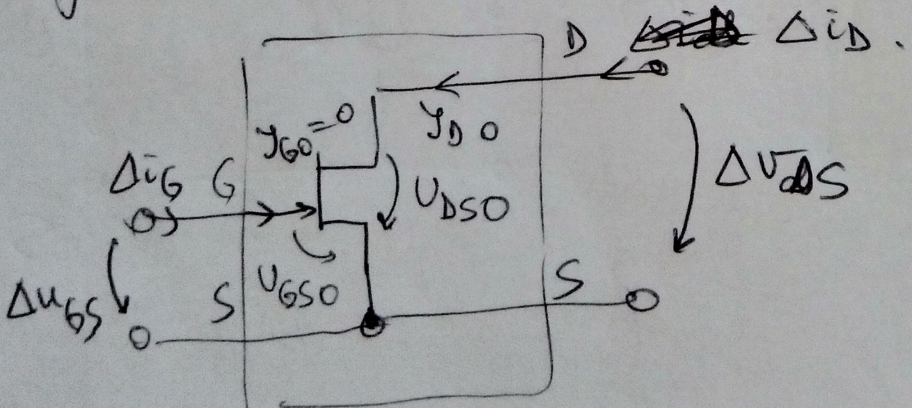
$(I_D = 4\,mA)$ $$R_D < \frac{-2}{4} \cdot 10^3 - 250 + \frac{16}{4} \cdot 10^3$$

$$R_D < -500 - 250 + 4000$$

$$R_D < 3250\,\Omega$$

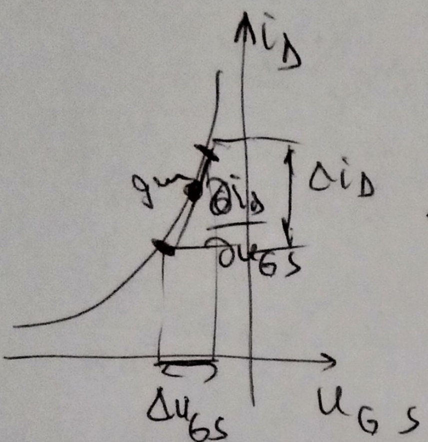
$$\boxed{R_D < 3.25\,k\Omega}$$

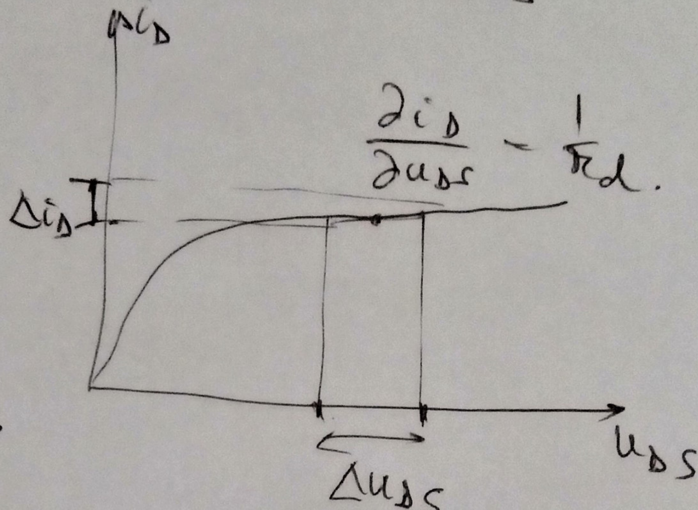
Regimul dinamic al TECJ!



$$i_d = f(u_{GS}, u_{DS})$$

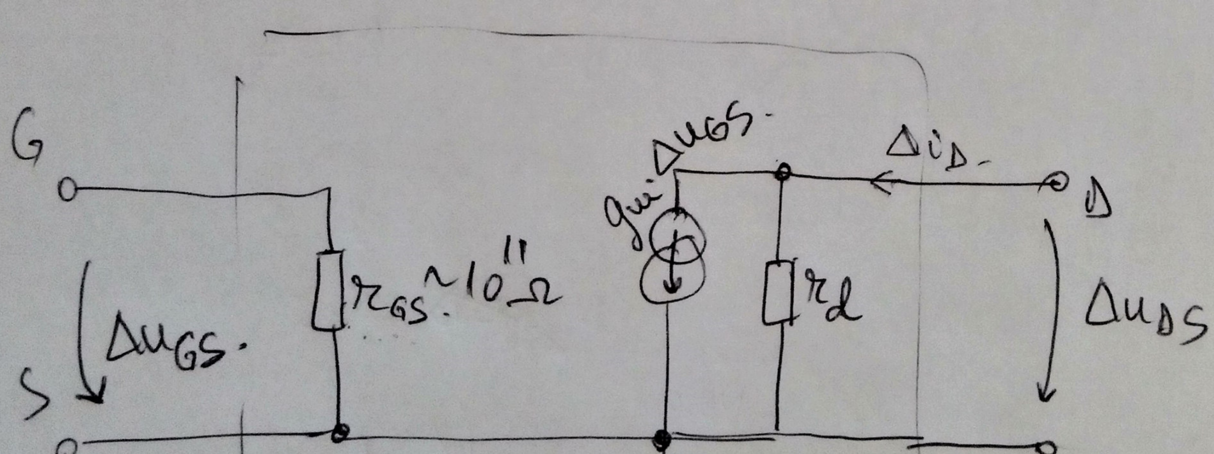
$$\Delta i_D = \underbrace{\left.\frac{\partial i_D}{\partial u_{GS}}\right|_{\Delta u_{DS}=0}}_{g_m} \cdot \Delta u_{GS} + \underbrace{\left.\frac{\partial i_D}{\partial u_{DS}}\right|_{\Delta u_{GS}=0}}_{\frac{1}{r_d}} \cdot \Delta u_{DS}$$



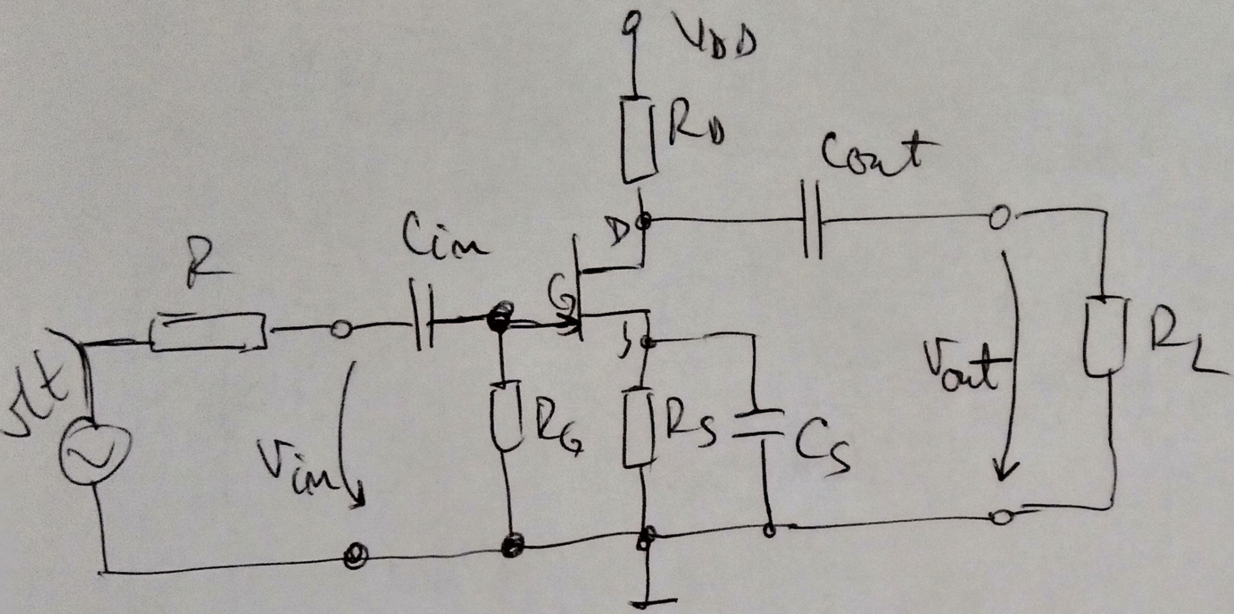


$$\Delta i_D = g_m \cdot \Delta u_{GS} + \frac{1}{r_d} \cdot \Delta u_{DS}$$

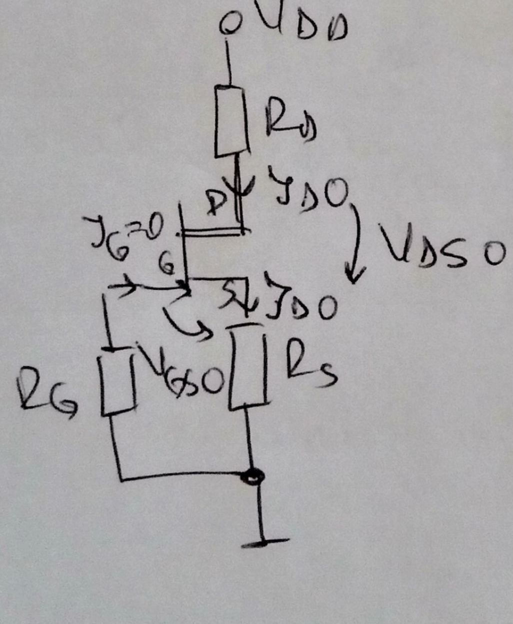
schema ech. de semnal mic.



Amplificatorul TECJ cu SC



c) Schema echivalentă DC → PSF.

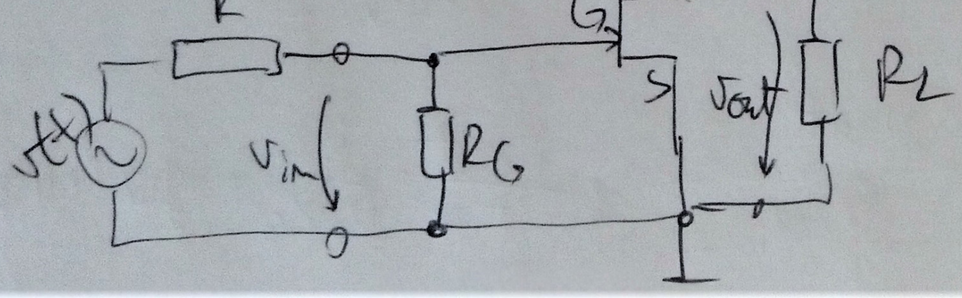


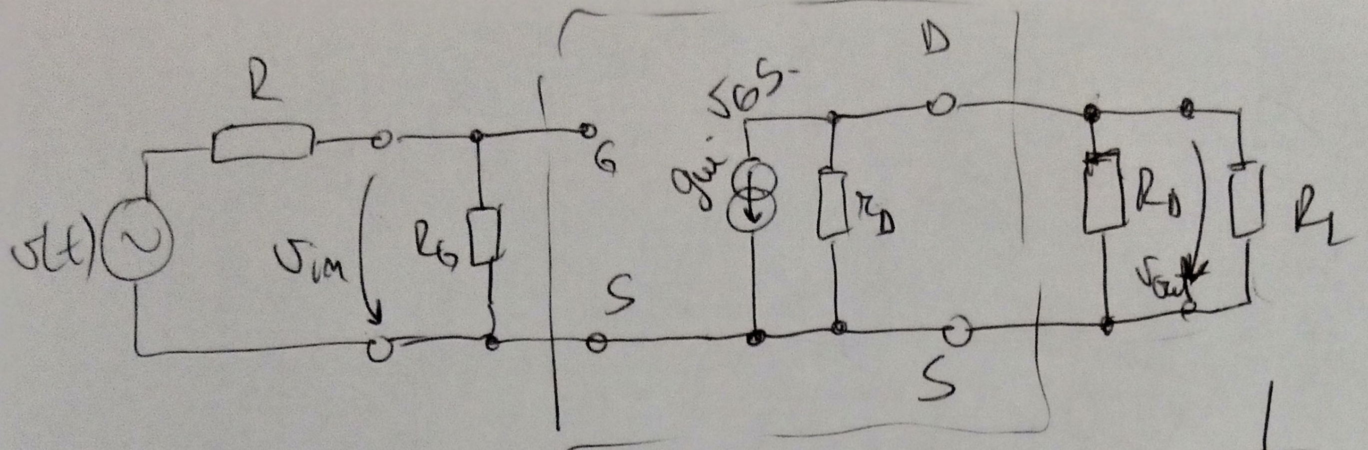
Se cunosc:

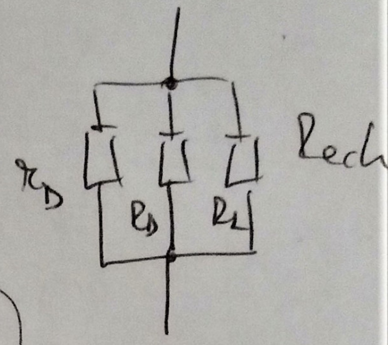
I_{DSS}

V_T.

c) Schema echivalentă AC:







$$\boxed{R_{in} = R_G} = \frac{v_{in}}{i_{in}}$$

$$R_{out} = r_d \parallel R_D = \boxed{\frac{1}{\frac{1}{r_D} + \frac{1}{R_D}} = R_{out}}$$

câștigul în tensiune

$$\boxed{A_v = \frac{v_{out}}{v_{in}} = \frac{-g_m \cdot v_{gs} \cdot R_{ech}}{v_{gs}} = -g_m \cdot R_{ech}}$$

câștigul efectiv în tensiune

$$A_{vs} = \frac{v_{out}}{v}$$

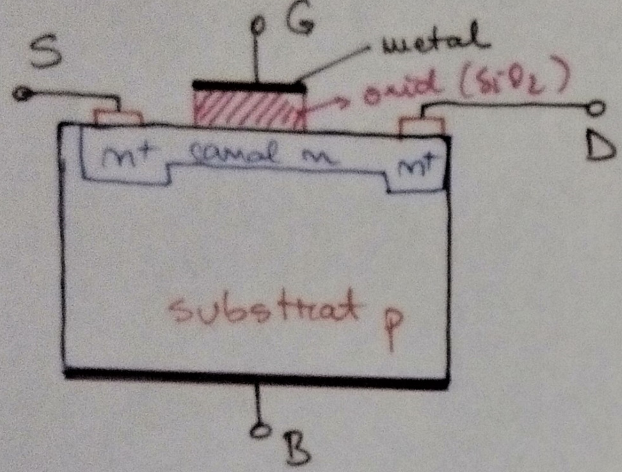
$$v_{in} = \frac{R_G}{R+R_G} \cdot v \Rightarrow v = \frac{v_{in}}{\frac{R_G}{R+R_G}}$$

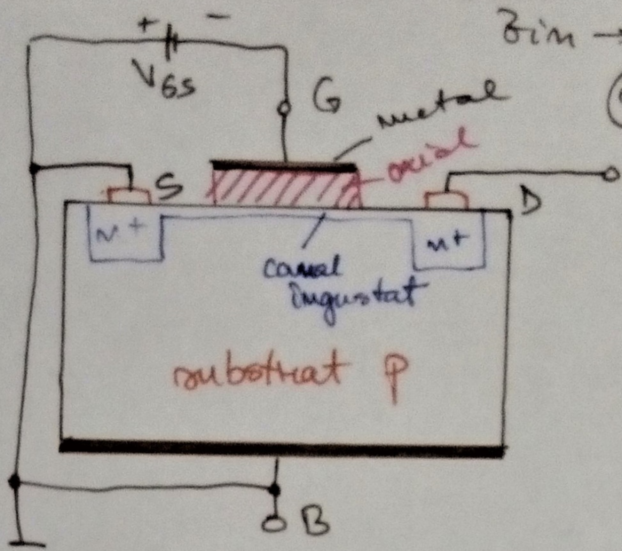
$$A_{vs} = \frac{v_{out}}{\frac{v_{in}}{\frac{R_G}{R+R_G}}} = \frac{v_{out}}{v_{in}} \cdot \frac{R_G}{R+R_G} = \boxed{-g_m \cdot R_{ech} \frac{R_G}{R+R_G}}$$

MOSFET cu canal inițial (mai rare).
("depletion-type").

MOS = Metal-oxid-semiconductor

R_{canal} → f. mic.
R_{in} → f. mare
(sensibile)





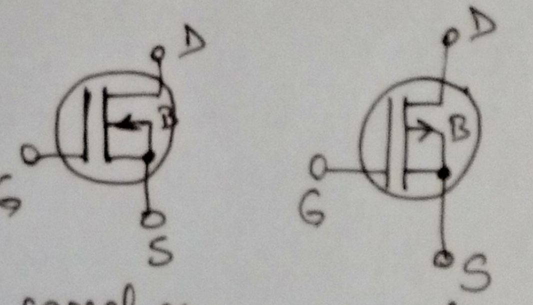
$V_{GS} = 0$.

$V_{GS} < 0$

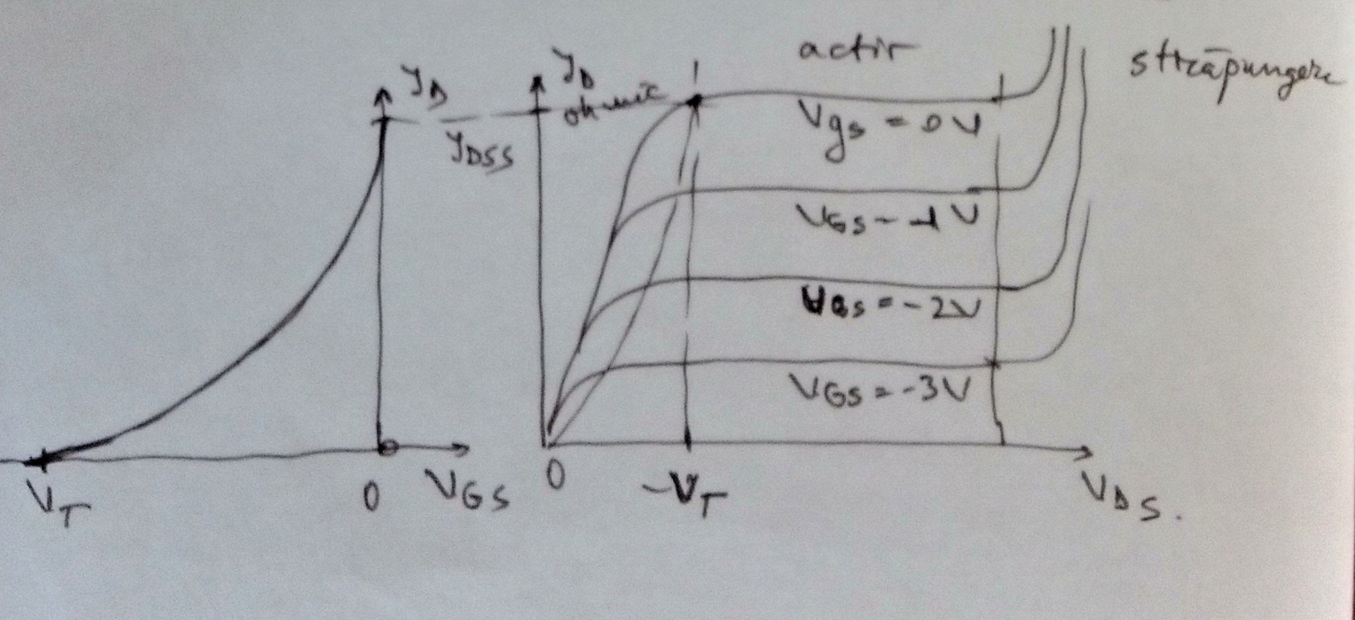
"depletion" sau "sărăcire"

S - sursă (source)
D - drenă (drain)
G - grilă (gate)
B - bază (base) body

simboluri.

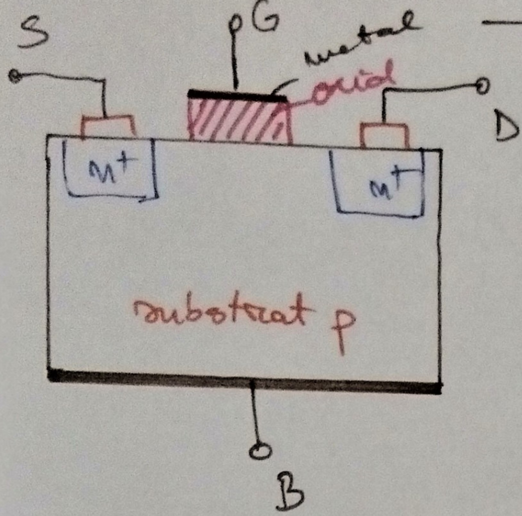


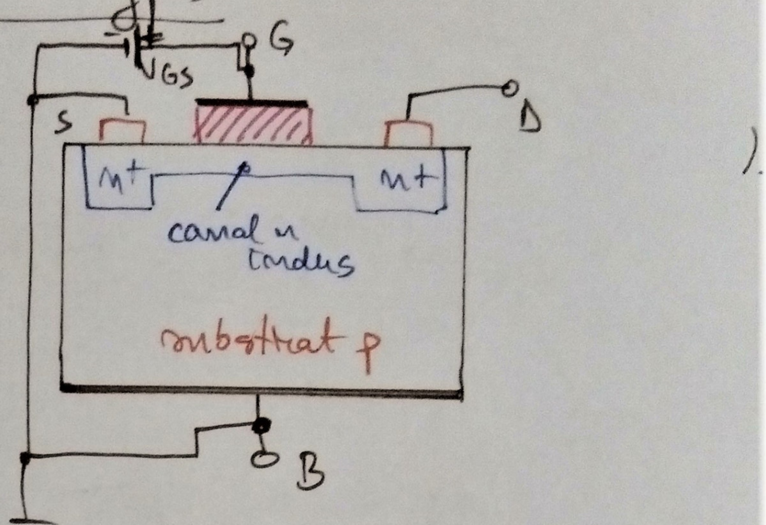
"normally-ON"



MOSFET cu canal indus:

("enhancement type")





$V_{GS} = 0$

$V_{GS} > 0$

"enhancement" sau "îmbogățire"

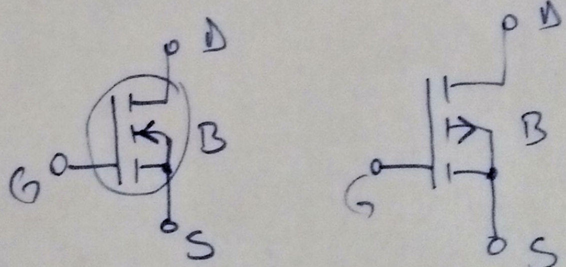
S - sursă

D - drenă

G - grilă

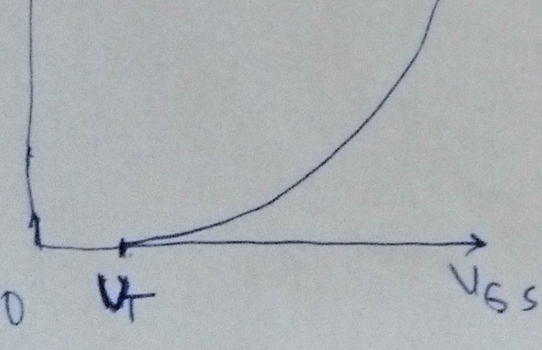
B - bază (body)

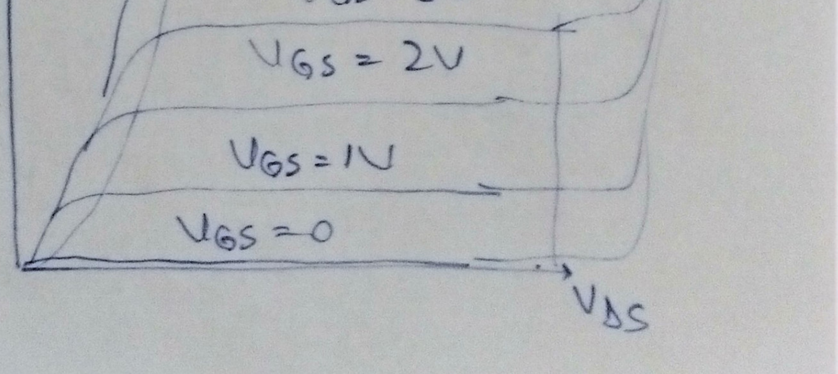
Simboluri:



canal n   canal p

"normally - OFF"

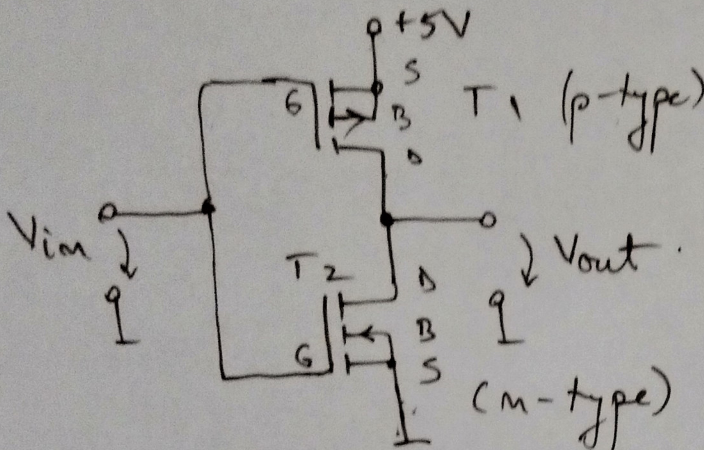




enh mode	$V_{GS} > 0$	$V_{GS} < 0$	$V_{GS} = 0$
n-type	ON	OFF	OFF
p-type	OFF	ON	OFF

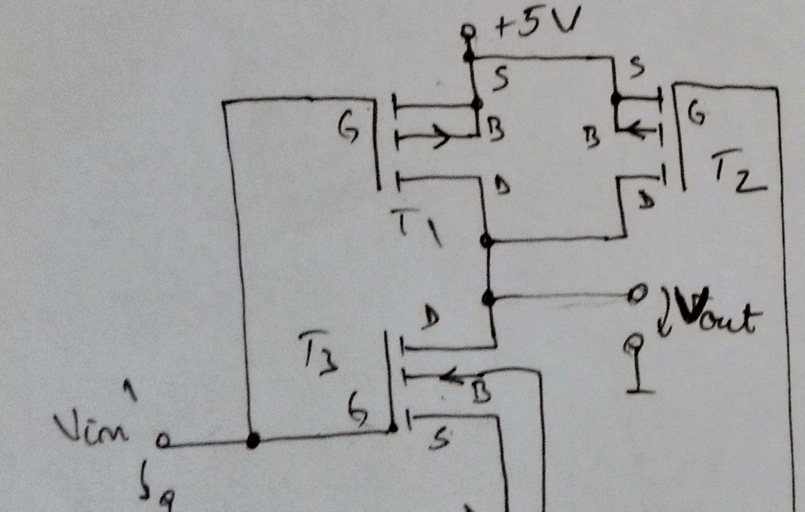
ON = short
OFF = open

CMOS "NOT":



V_{in}	T_1	T_2	V_{out}
5V	OFF	ON	0V
0V	ON	OFF	5V

CMOS "NAND":



~~Vin Vout T1 T2 T3 T4~~

V_{in}^{1}	V_{in}^{2}	V_{out}	T_1	T_2	T_3	T_4
0V	0V	5V	ON	ON	OFF	OFF
0V	5V	5V	ON	OFF	OFF	ON
5V	0V	5V	OFF	ON	OFF	OFF
5V	5V	0V	OFF	OFF		

$T_1, T_2 \rightarrow$ p-type
$T_3, T_4 \rightarrow$ n-type