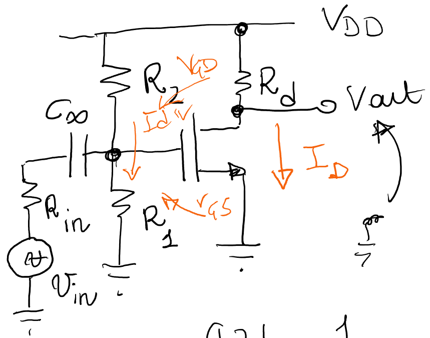
Lezione 9b: stadio source a massa e source a massa degenerato

mercoledì 8 aprile 2020 10:33

STADIO SOURCE A MASSA



V_{DD} gen. tensione DC

v_{in} gen. di segnale

$$C_\infty \begin{cases} |Z| = \frac{1}{\omega C_\infty} = \infty & \omega = 0 \text{ in DC} \\ |Z| = \frac{1}{\omega C_\infty} = 0 & \forall \omega \neq 0 \end{cases}$$

Ⓐ POLARIZZAZIONE : tensioni a tutti i nodi e correnti in tutti i rami

1. capacità circuiti aperti perché in DC
2. generatori di segnali spenti
3. |Hp| MOS operi in saturazione

↑ DA VERIFICARE

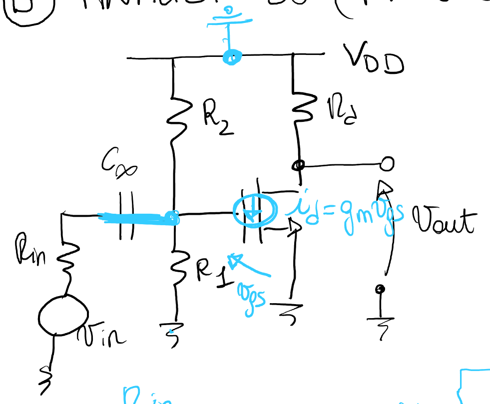
$$V_G = V_{GS} = \frac{R_1}{R_1+R_2} V_{DD} \Rightarrow I_D = k_n (V_{GS} - V_{Tn})^2$$

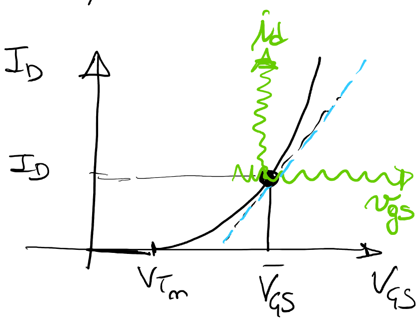
$$V_D = V_{out} = V_{DD} - I_D R_d \; ; \; I_{div} = \frac{V_{DD}}{R_1+R_2}$$

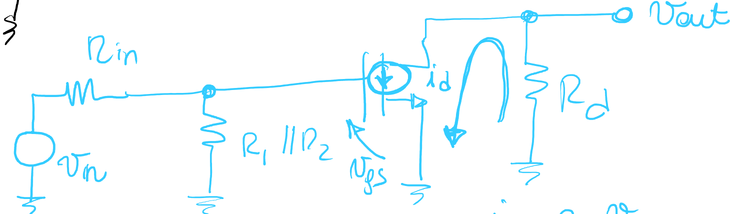
$V_{GD} = V_G - V_D$ se $V_{GD} < V_{Tn}$ ⟹ ok MOS saturo

$$g_m = 2k_n (V_{GS} - V_{Tn})$$

Ⓑ ANALISI SU (PICCOLO) SEGNALE







$i_d = g_m v_{gs}$, $v_{gs} << 2 (V_{GS} - V_{Tn})$

$i_d = g_m v_{gs}$ ← $v_{gs} << 2(V_{GS} - V_{Tn})$

$$v_{gs} = \frac{R_1 // R_2}{R_{in} + R_1 // R_2} \Rightarrow i_d = g_m v_{gs}$$

$$v_{out} = -i_d R_d = -g_m R_d v_{gs} =$$

$$= -g_m R_d \frac{R_1 // R_2}{R_{in} + R_1 // R_2} v_{in}$$

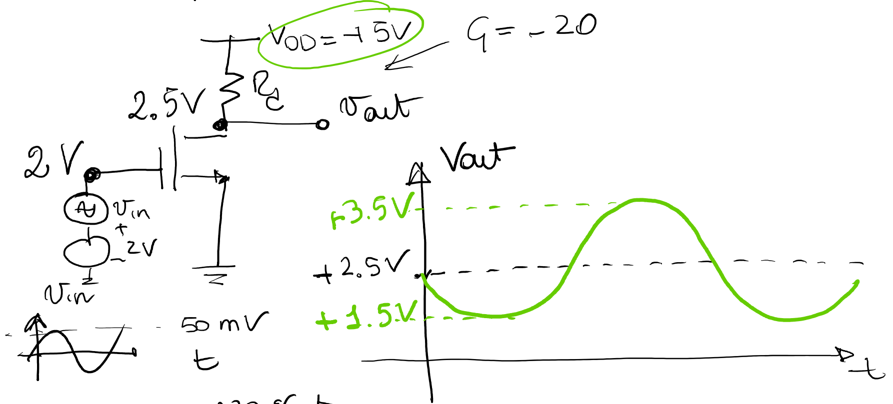
$$G \triangleq \frac{v_{out}}{v_{in}} = -g_m R_d \underbrace{\frac{R_1 // R_2}{R_{in} + R_1 // R_2}}_{\text{partiz. in ingresso}}$$

↑ GUADAGNO DI TENSIONE

• stadio invertente

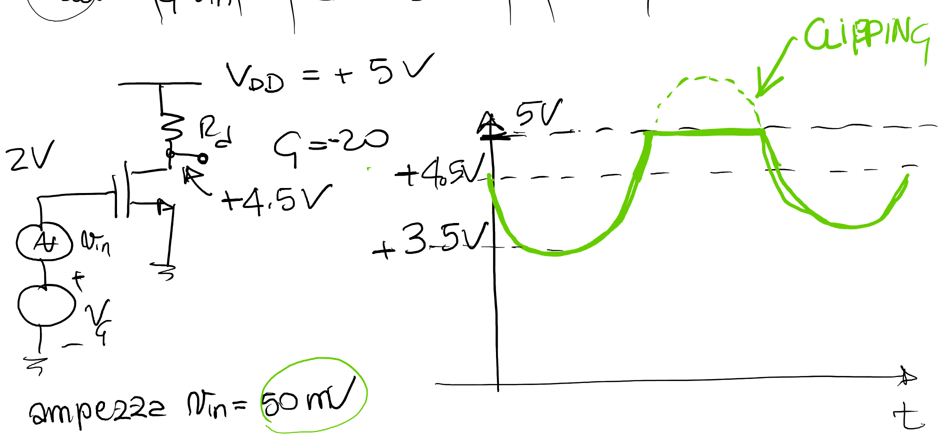
ERRORE DI LINEARITÀ

$$\varepsilon = \frac{v_{gs}}{2(V_{GS} - V_{Tn})}$$



ampiezza Vout ↙

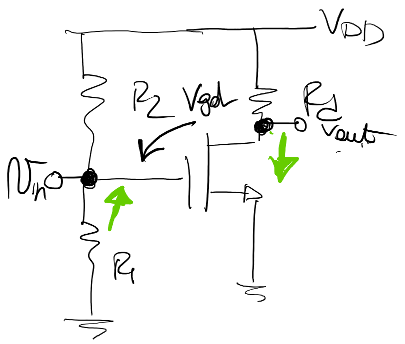
$V_{out} = |G v_{in}| = |20 \times 50mV| = |-1V| = 1V$



ampezza v_{in} = 50 mV

DINAMICA DI USCITA: massima variazione positiva o negativa del nodo di uscita, rispetto al punto di lavoro perché i transistori operino nella corretta zona di funzionamento

Vout può salire fino



V_{out} può salire fino a V_{DD}

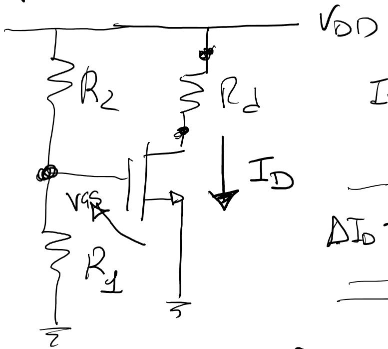
$V_{out} < V_{DD}$

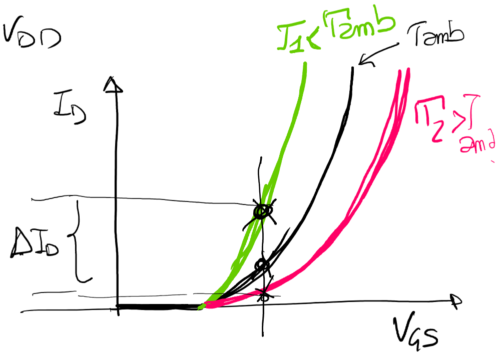
$\Delta V_{out}^{\oplus} = V_{DD} - V_{out}$ ← in polarizz.

$V_{gd} < V_{Tn}$ per garantire la saturazione del MOS

$$V_{gd} = V_G + v_g - (\underbrace{V_D + v_d}_{V_d}) = V_G + v_g - V_D - v_d < V_{Tn}$$

SENSIBILITÀ DELLA POLARIZZAZIONE ALLE VARIAZIONI DEI PARAMETRI DEL MOS DI UNO STADIO SOURCE A MASSA





$$I_D = k_n (V_{GS} - V_{Tn})^2$$

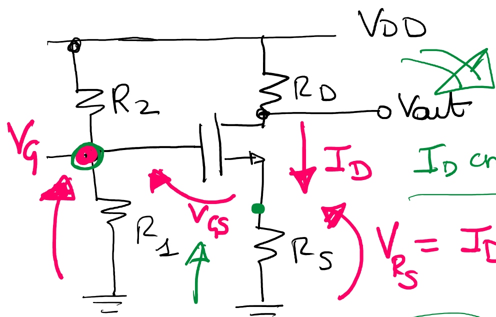
$$k_n = \frac{1}{2} \mu_n C_{ox} \frac{W}{L}$$

$1\% / °C$

$$\Delta I_D = \Delta k_n \underbrace{(V_{GS} - V_{Tn})^2 \cdot \frac{k_n}{k_n}}_{I_D}$$

$$\boxed{\frac{\Delta I_D}{I_D} = \frac{\Delta k_n}{k_n}}$$

STADIO CON DEGENERAZIONE DI SOURCE



~~I_D diminuisce~~ ④ $I_D = k(V_{GS} - V_{Tn})^2$

I_D cresce ①

$V_{R_S} = I_D R_S$ } caduta su R_S cresce ②

③ V_{GS} diminuisce $\quad V_G = V_{GS} + I_D R_S$ (↑ fisso)

(A) POLARIZZAZIONE

③ V_{GS} diminuisce $V_G = V_{GS} + I_D R_S$
↑ fisso

Ⓐ POLARIZZAZIONE

$I_D = k_m (V_{GS} - V_{Tm})^2$ (sotto le hp che MOS saturo)

$V_{GS} > V_{Tm}$ acceso
$V_{GD} < V_{Tm}$ pinch off al drain

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

$$\begin{cases} I_D = k_m (V_{GS} - V_{Tm})^2 \\ V_G = V_{GS} + I_D R_S \end{cases} \Rightarrow I_D, V_{GS}$$

sola una fisicamente accettabile!!

$V_{out} = V_D = V_{DD} - I_D R_D$

$V_{GD} < V_{Tm}$? sì ⇒ ok MOS saturo

$I_D = k_m (V_{GS} - V_{Tm})^2 = k_m [V_{GS}(k_m) - V_{Tm}]^2$

V_{GS} dipende da k_m

$V_{GS} = V_G - I_D R_S$

$$\Delta I_D = \Delta k_m [V_{GS}(k_m) - V_{Tm}]^2 + \underbrace{k_m 2 (V_{GS} - V_{Tm})}_{g_m} \Delta V_{GS}$$

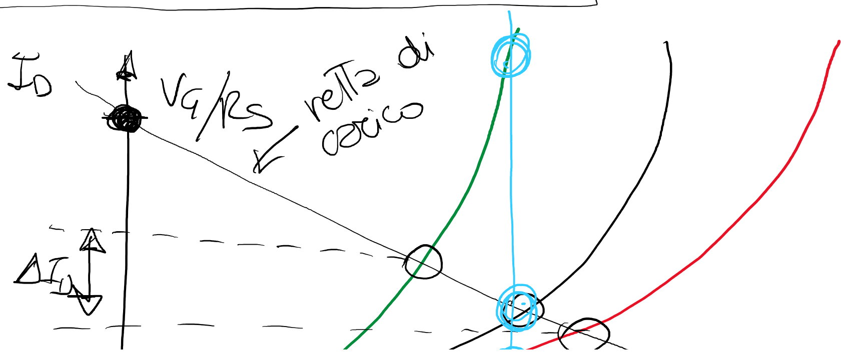
$\Delta V_{GS} = -\Delta I_D R_S$

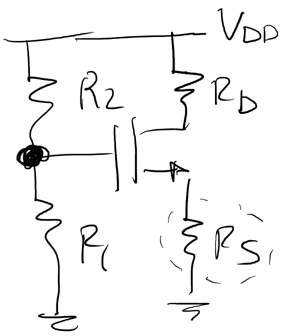
$$\Delta I_D = \Delta k_m [V_{GS} - V_{Tm}]^2 + g_m (-\Delta I_D R_S)$$

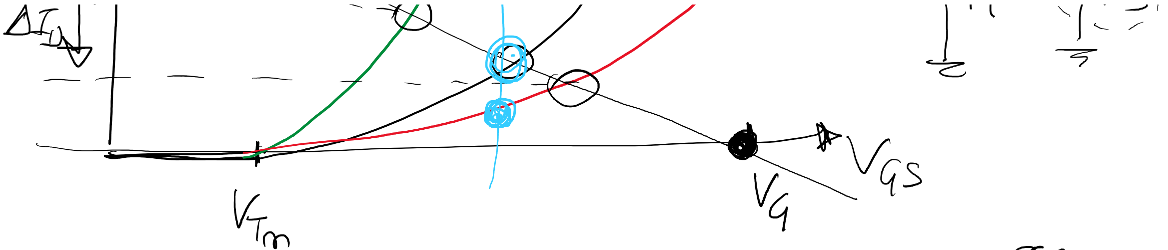
$$\Delta I_D (1 + g_m R_S) = \Delta k_m (V_{GS} - V_{Tm})^2 \frac{k_m}{k_m} \quad [I_D]$$

$$\frac{\Delta I_D}{I_D} = \frac{\Delta k_m}{k_m} \frac{1}{1 + g_m R_S}$$

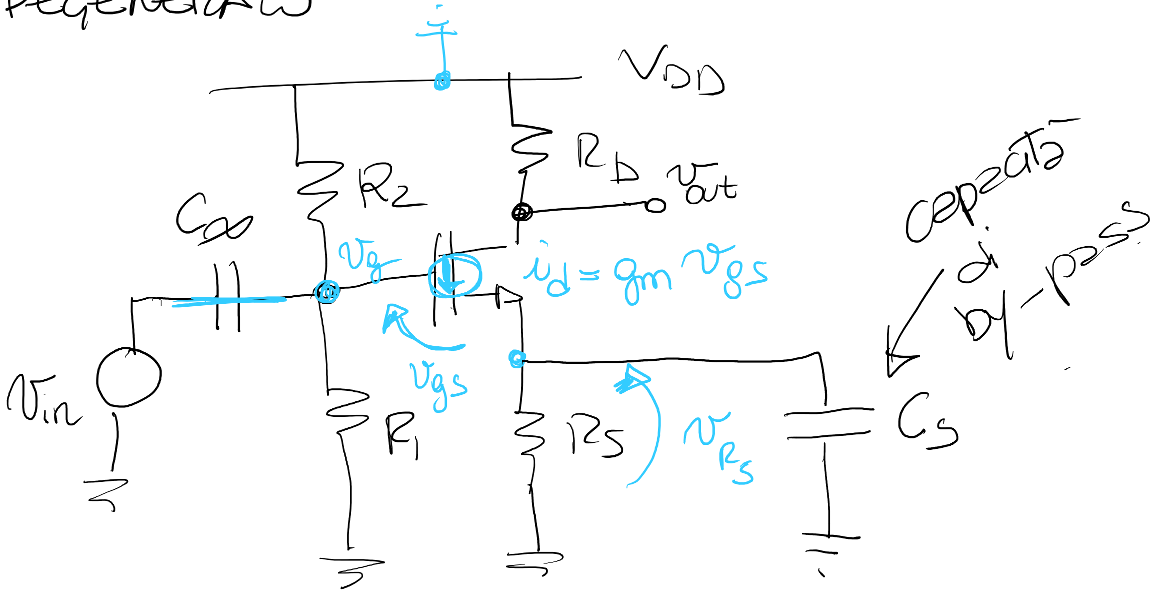
$R_S \gg 1/g_m$ $\quad 1 + g_m R_S \gg 1$







ANALISI SU SEGNALE DELLO STADIO SOURCE DEGENERATO



$$\begin{cases} v_{in} = v_{gs} + i_d R_S \\ i_d = g_m v_{gs} \end{cases} \Longrightarrow v_{in} = v_{gs} + g_m v_{gs} R_S$$

$$v_{in} = (1 + g_m R_S)\, v_{gs}$$

$$v_{gs} = \frac{v_{in}}{1 + g_m R_S}$$

$$i_d = g_m \frac{v_{in}}{1 + g_m R_S}$$

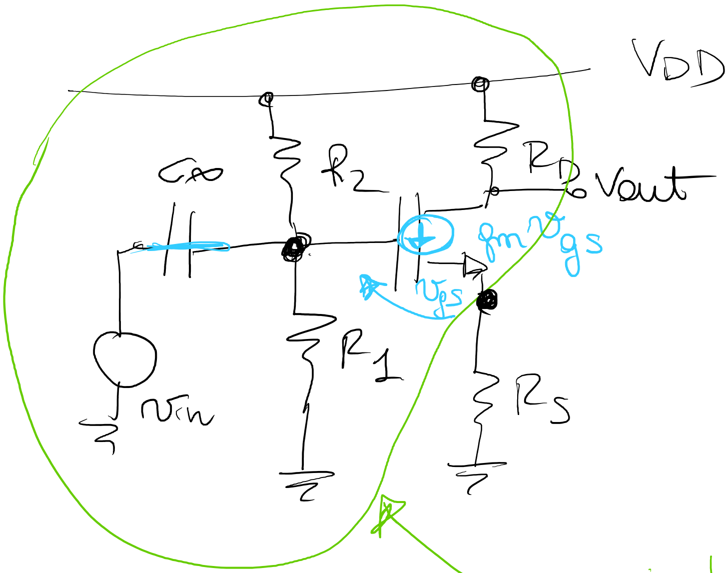
$$v_{out} = -i_d R_D = -\frac{g_m R_D}{1 + g_m R_S} v_{in}$$

⇓ ← GUADAGNO DI TENSIONE DI UNO STADIO SOURCE DEGENERATO

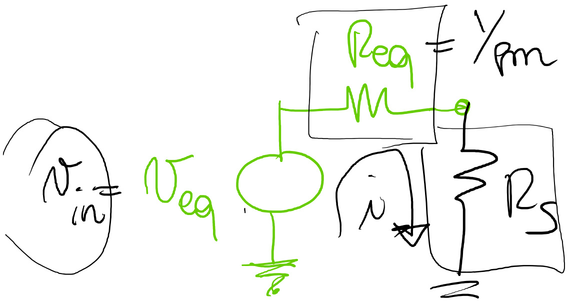
$$G \triangleq \frac{v_{out}}{v_{in}} = -\frac{g_m R_D}{1 + g_m R_S} \underset{R_S \gg 1/g_m}{\simeq} -\frac{R_D}{R_S}$$

$$1 + g_m R_S \simeq g_m R_S$$

GUADAGNO SOURCE AMASSA

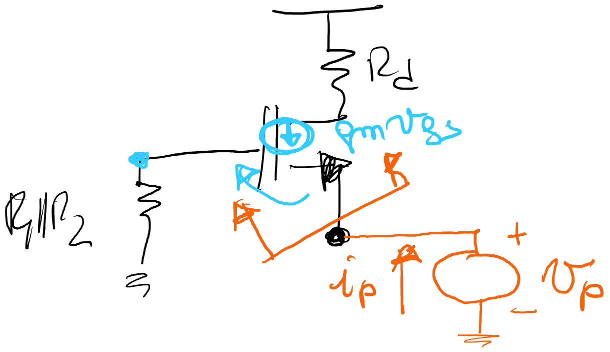


equivalente Thevenin tra source e massa



$$i = i_d = \frac{v_{in}}{\frac{1}{g_m} + R_s}$$

Resistenza vista al source del transistor.



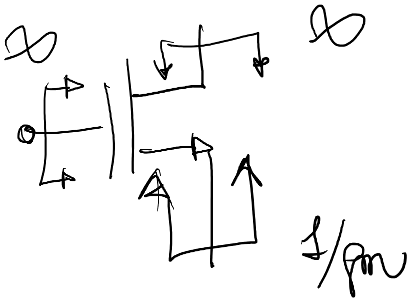
$$R_{eq} = \frac{v_p}{i_p} = \frac{v_p}{g_m v_p} = 1/g_m$$

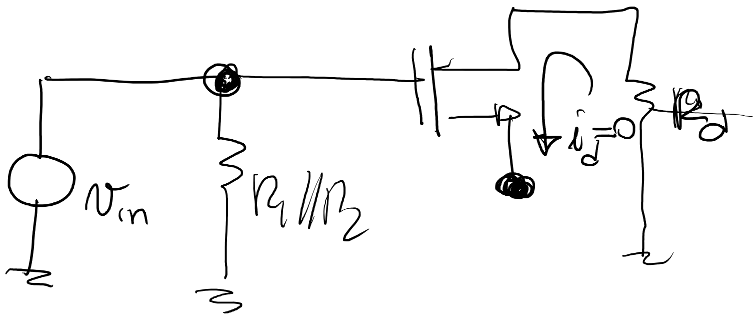
$$v_{gs} = -v_p$$

$$i_d = g_m v_{gs} = -i_p$$

$$\Downarrow$$

$$i_p = +g_m v_p$$



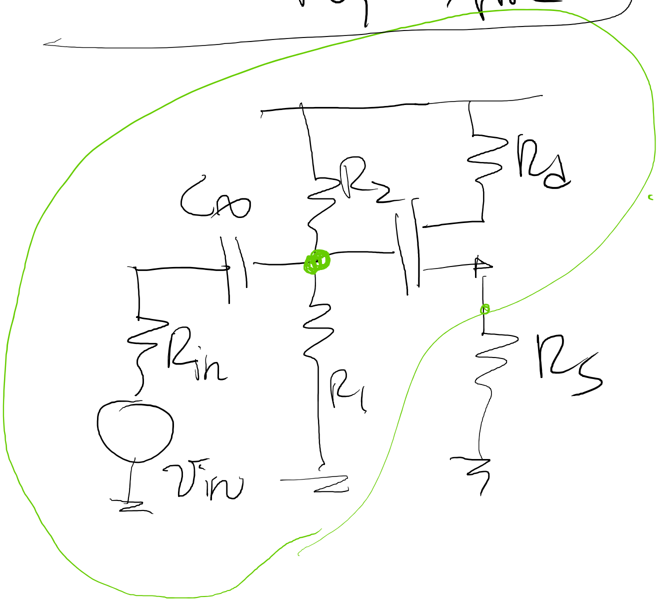


$i_d = g_m v_{gs} \Longleftrightarrow v_{gs} = 0$
$g_m \neq 0$

$v_{gs} = 0 \Rightarrow v_s = v_g = v_{in}$

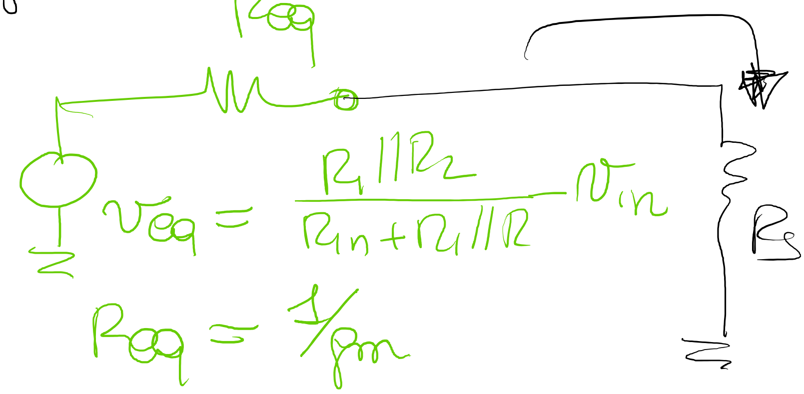
$\hookrightarrow v_{eq} = v_{in}$

$R_{eq} = 1/g_m$



in presenza di generatore di ingresso reale

i_d



$v_{eq} = \frac{R_1 // R_2}{R_{in} + R_1 // R} v_{in}$

$R_{eq} = 1/g_m$

$$i_d = \frac{R_1 // R_2}{R_{in} + R_1 // R_2} v_{in} \frac{1}{1/g_m + R_s}$$