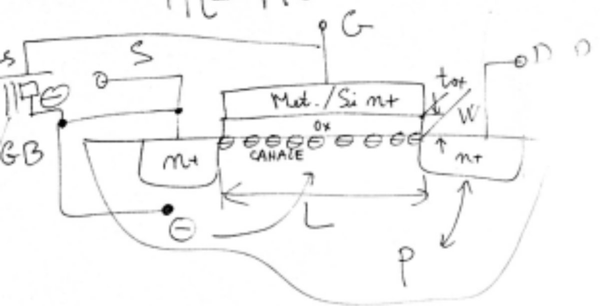
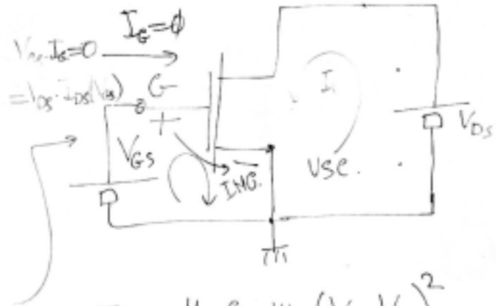
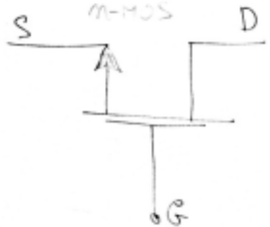
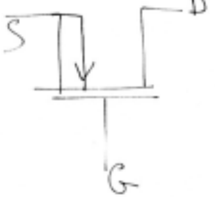
n-MOS









$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} \left(V_{GS} - V_{TH}\right)^2$$

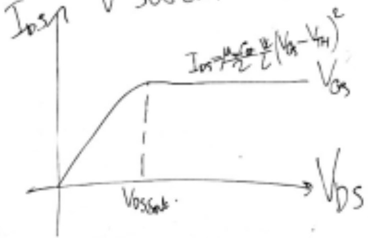
$V_{GS} > V_{TH}$

$V_{THRESHOLD}$

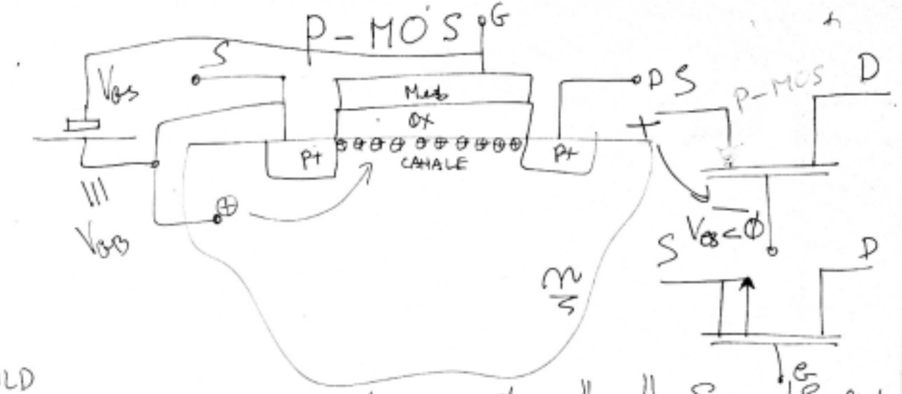
V SOGLIA.

SE $V_{DS} > V_{DS\,sat} = V_{GS} - V_{TH}$

$$I_{DS} = f\left(V_{GS}\right)$$



P-MOS



$V_{GS} < 0$ "+" Source / Sulist.

$V_{GS} < V_{TH}$

$$|V_{GS}| \overset{\Downarrow}{>} |V_{TH}|$$

BATTERIA + SEGNALE "PICCOLO"
(o spina di rete)

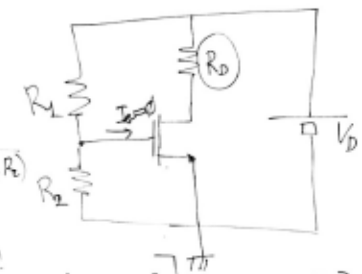
↓ POLARIZZ. PUNTO di LAVORO o di RIPOSO

↓ VARIAZIONI (PICCOLE) → CONTENUTO, INFOR...

→ LINEARIZZAZIONE delle CARATT. FISICHE del DISPOS.

↓ → ESP. in SERIE di TAYLOR

DATO $V_{GS} > V_{TH}$ (R_1, R_2)



$\rightarrow V_{DS} < V_{GS} - V_{TH}$

$$I_{DS} = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{V_{DS}^2}{2} \right]$$

SE $V_{DS} > V_{DSsat} = V_{GS} - V_{TH}$

$$I_{DS} = I_{DSsat} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS0} - V_{TH})^2$$

POLARIZZ. del MOS.

→ SATURAZ.

$V_{GS} > V_{TH}$ (n-MOS)

$V_{DS} > V_{DSsat} = V_{GS} - V_{TH}$

$\rightarrow I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2$

($V_{BATTERIA}$, per il MOS V_D o V_{DD})

$$V_{GS0} = V_D \cdot \frac{R_2}{R_1 + R_2} \quad (V_{GS0} > V_{TH})$$

$$\rightarrow I_{DS0} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS0} - V_{TH})^2$$

POLARIZZ. del MOS.

→ SATURAZ.

$V_{GS} > V_{TH}$ (n-MOS)

$V_{DS} > V_{DSsat} = V_{GS} - V_{TH}$

$\rightarrow I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2$

($V_{BATTERIA}$, per il MOS V_D o V_{DD})

$$V_{GS0} = V_D \cdot \frac{R_2}{R_1+R_2} \quad (V_{GS0} > V_{TH})$$

$$\rightarrow I_{DS0} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS0} - V_{TH})^2$$

DATO $V_{GS} > V_{TH}$ (R_1, R_2)

$\rightarrow V_{DS} < V_{GS} - V_{TH}$

$$I_{DS} = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{V_{DS}^2}{2} \right]$$

SE $V_{DS} > V_{DSsat} = V_{GS} - V_{TH}$

$$I_{DS} = I_{DSsat} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS0} - V_{TH})^2$$

V_{DS} > o < $V_{DSsat} = V_{GS} - V_{TH}$?

$V_D = R_D I_{DS} + V_{DS}$

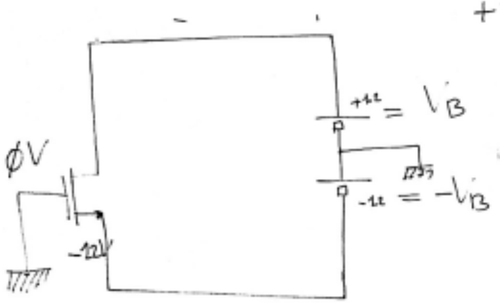
$\rightarrow V_{DS} = V_D - R_D I_{DS}$

$V_{GS0} \rightarrow I_{DS0} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS0} - V_{TH})^2$

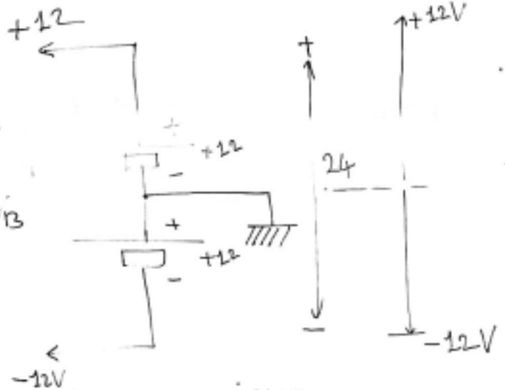
→ CALC. di V_{DS0}, scegliamo R_D : $V_{DS0} > V_{GS0} - V_{TH}$

$\rightarrow V_{GS0}$, I_{DS0} e $V_{DS0} > V_{GS0} - V_{TH}$

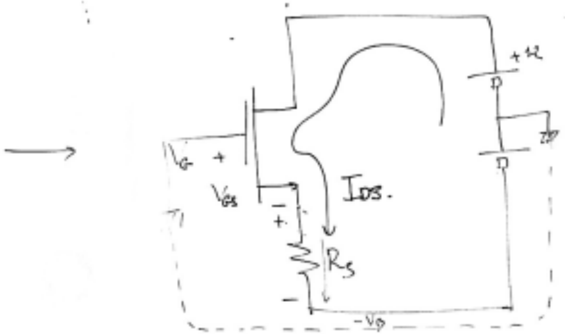
$(R_1, R_2, V_D) \rightarrow$ POLARIZZ.

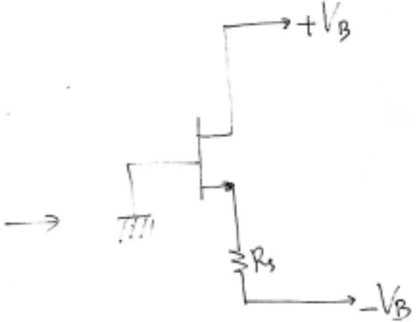


$V_{GS} = +V_B$



ALIMENTAZIONE
DUALE





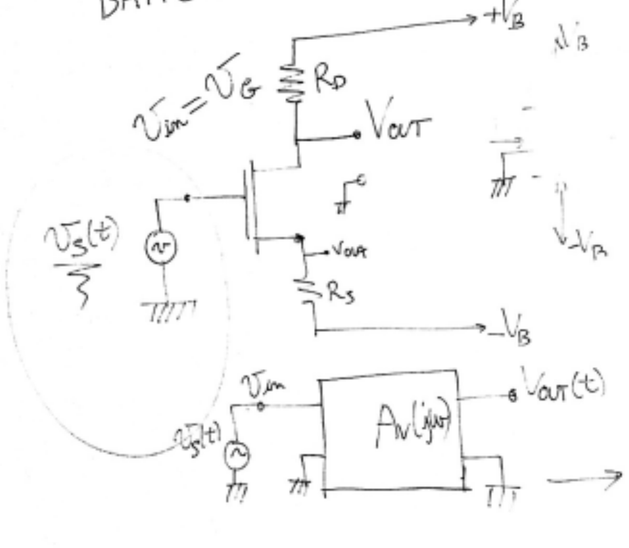
$$V_G = V_{GS} + R_S I_{DS} - V_B$$

$$0 = V_{GS} + R_S I_{DS} - V_B \longrightarrow V_{GS0} = V_B - R_S I_{DS0}$$

$$V_{GS0} = V_B - R_S \left[\frac{\mu_n C_{ox}}{2} \frac{W}{L} \left(V_{GS0} - V_{TH} \right)^2 \right]$$

$$\Rightarrow V_{GS0}(V_B, R_S)$$

BATTERIA + SEGNALE



$v_S(t) = V_M \sin(\omega t + \vartheta)$:

ETTERA MIN.

PICCOLO SEGNALE

$\rightarrow V_M \ll V_B$

$H(S) = \dfrac{V_{OUT}(j\omega)}{V_{in}(j\omega)}$

$H(j\omega)$

$\longrightarrow$

$A_V(j\omega) = \dfrac{V_{OUT}(j\omega)}{V_{in}(j\omega)}$

BATTERIE

$\rightarrow V_{GS0}, I_{DS0} \quad (V_B, R_S, R_D)$

$DS0$, V_{OUT0}

$V_B = R_D I_{DS0} + V_{OUT0}$

$V_{OUT0} = V_B - R_D I_{DS0}$

$\Delta V_{OUT}(t) = -R_D \, \Delta I_{DS}(t)$

$v_{OUT}(t) = -R_D \, i_{DS}(t)$

$I_{DS}(t) = \dfrac{\mu_n C_{ox}}{2} \left[V_{GS}(t) - V_{TH} \right]^2$

$+ \quad v_S(t) = V_M \sin(\omega t + \vartheta)$

SEGNALE

$V_M \ll V_B$

$\downarrow$

$I_{DS}(t) = I_{DS0} + i_{DS}(t)$

$\boxed{i_{DS}(t) = \Delta I_{DS}(t)} = I_{DS}(t) - I_{DS0}$

$V_{OUT}(t) = V_B - R_D I_{DS}(t)$

$$\begin{aligned}
v_{OUT}(t) &= V_{OUT}(t) - V_{OUT0} = \\
&= V_B - R_D I_{DS}(t) - \left[V_B - R_D I_{DS0} \right] \\
&= \cancel{V_B} - R_D I_{DS}(t) - \cancel{V_B} + R_D I_{DS0} \\
&= -R_D \left(I_{DS}(t) - I_{DS0} \right) = -R_D \, i_{DS}(t)
\end{aligned}$$

BATTERIA + SEGNALE

$$I_{DS}(t) = I_{DS0} + \partial I_{DS}\big| (V_{GS}(t) - V_{GS0}) + O_2$$

$I_{DS}(t)$ MOLTO "VICINA" a I_{DS}

$\rightarrow v_g(t) << V_B$

$\downarrow V_M << V_B$

$$I_{DS} = f(V_{GS}(t))$$

$$f(x) = f_0 + \frac{\partial f}{\partial x}\Big|_{x_0} (x - x_0) + O_2$$

$$I_{DS}(V_{GS}(t)) = I_{DS0} + \frac{\partial I_{DS}}{\partial V_{GS}}\Big|_{V_{GS0}} (V_{GS}(t) - V_{GS0})$$

$$I_{DS}(t) - I_{DS0} = \frac{\partial I_{DS}}{\partial V_{GS}}\Big|_{V_{GS0}} v_{GS}(t)$$

$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2 \qquad \frac{\partial I_{DS}}{\partial V_{GS}}\Big|_{V_{GS0}} = \mu_n C_{ox} \frac{W}{L} (V_{GS0} - V_{TH})$$

$$\frac{\partial I_{DS}}{\partial V_{GS}}\Big|_{V_{GS0}} = \mu_n C_{ox} \frac{W}{L} (V_{GS0} - V_{TH}) = g_m$$

$$\rightarrow I_{DS}(t) - I_{DS0} = g_m (V_{GS}(t) - V_{GS0})$$

$$i_{DS}(t) = g_m v_{GS}(t) \longrightarrow$$

$$\Delta V_{OUT}(t) = -R_D \, \Delta I_{DS}(t)$$

$$v_{OUT}(t) = -R_D \, i_{DS}(t)$$

$$I_{DS}(t) = \frac{\mu_n C_{ox}}{2} \left[V_{GS}(t) - V_{TH} \right]^2$$

$$\uparrow v_g(t)$$

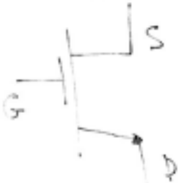
$$V_{GS}(t) = V_{GS0} + \underline{v_g(t)}$$

MOS LINEARIZZATO

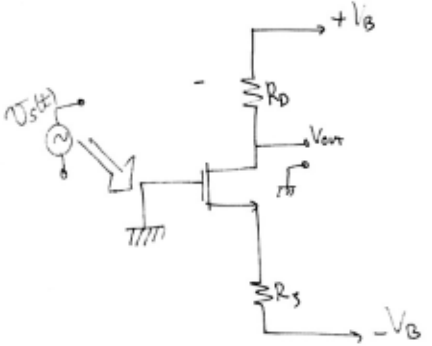
in $V_{GS0}, I_{DS0} \rightarrow g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS0} - V_{TH})$

NEL PUNTO DI POLARIZZ, o di RIPOSO (V_B, R_S, R_D)

≡



g_m: PARAMETRO LINEARIZZ.
PARAMETRO DIFF.
PARAMETRO per PICCOLO SEGNALE



$v_S = 0$

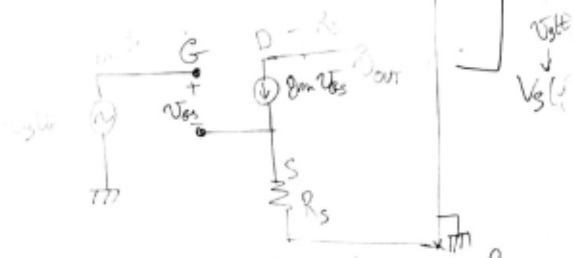
BATTERIE: POLARIZZ.

$\longrightarrow V_{GS\phi}, I_{DS\phi}, V_{DS0}, V_{OUT\phi}$

$\Delta V_{GS}(t), \Delta I_{DS}(t), \Delta V_{OUT}(t)$

$v_{GS}(t), i_{DS}(t), v_{OUT}(t)$

$\Delta V_B(t) = \phi, \; v_B(t) = 0$



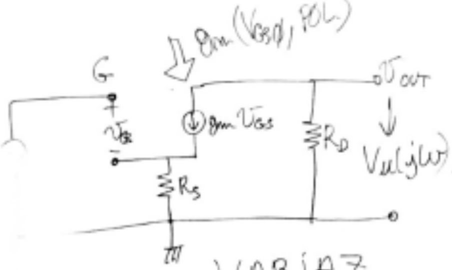
PARAMETRI DIFF.

CIRCUITO per le VARIAZIONI

$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS\phi} - V_{TH})$

NEL PUNTO di POLARIZZ.

$(V_{GS\phi})$



per le VARIAZ.

$$\Delta V_{OUT}(t) = -R_D \, \Delta I_{DS}(t)$$

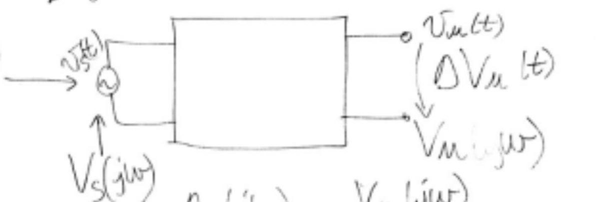
$$v_{OUT}(t) = -R_D \, i_{DS}(t)$$

$$I_{DS}(t) = \frac{\mu_n C_{ox}}{2} \left[V_{GS}(t) - V_{TH} \right]^2$$

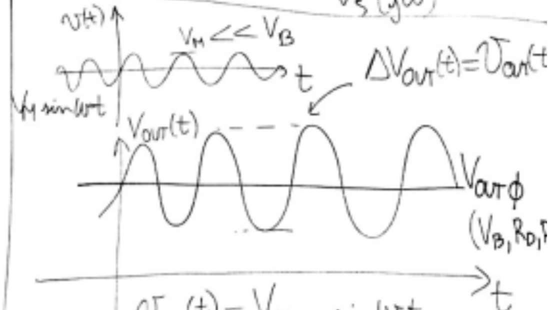
$$\uparrow v_S(t)$$

$$V_{GS}(t) = V_{GS\phi} + v_S(t)$$

$\Delta V_G(t) = v_S(t)$



$$A_V(j\omega) = \frac{V_u(j\omega)}{V_S(j\omega)}$$



$\Delta V_{OUT}(t) = v_{OUT}(t$

$v_{OUT}(t) = V_{MOUT} \sin \omega t$

$\rightarrow V_{MOUT} > V_M$ AMPLIF

$V_u(j\omega) = -g_m V_{GS}(j\omega) \cdot R_D$

$V_S(j\omega) = V_{GS}(\quad + R_S I_{DS}(j\omega)$

$V_S(j\omega) = V_{GS} + R_S\, g_m V_{GS}$

$V_S = V_{GS}(1 + R_S g_m)$

$V_{GS} = \dfrac{V_S}{1 + R_S g_m}$

$A_V(j\omega) = -\dfrac{g_m}{1+g_m R_S} \cdot R_D$

Si $\cdot R_S \gg 1$

(caso [illegible] vol.)

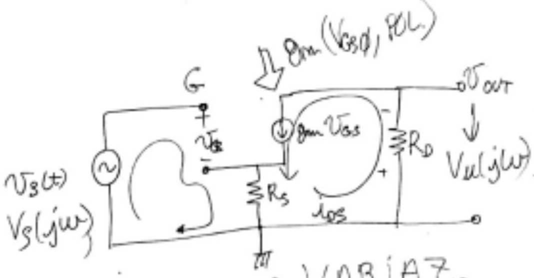
$\hookrightarrow A_V = -\dfrac{g_m R_D}{g_m R_S} \simeq$ [illegible]

$V_u = -g_m V_{GS} R_D$

$V_u = -g_m \dfrac{V_S}{1+g_m R_S} \cdot R_D$

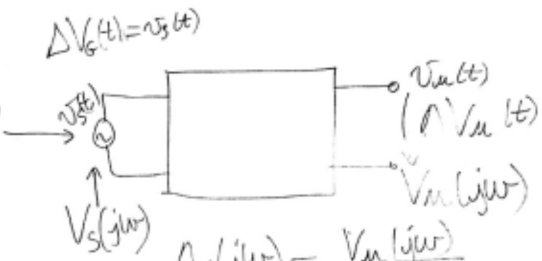
$A_V(j\omega) = \dfrac{V_u(j\omega)}{V_S(j\omega)} = -\dfrac{g_m}{1+g_m R_S} \cdot R_D$

$(H(j\omega))$



CIRC. per le VARIAZ.

$\Delta V_G(t) = v_S(t)$

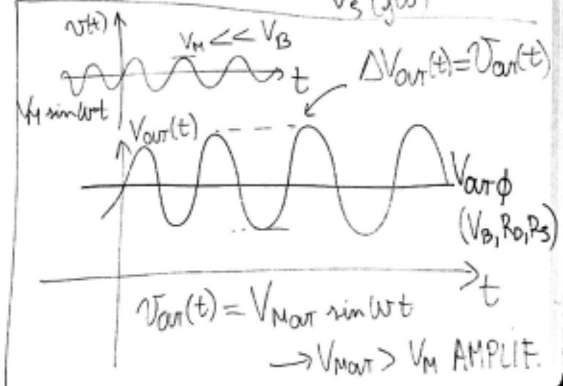


$A_V(j\omega) = \dfrac{V_u(j\omega)}{V_S(j\omega)}$

$A_V(j\omega) = \text{cost}(\omega) = \dfrac{V_{MOUT}}{V_{M\,ing.}}$

ing. $v_S(t) = V_M \sin\omega t$

usc. $\Delta V_{OUT}(t) = V_{MOUT} \sin\omega t$

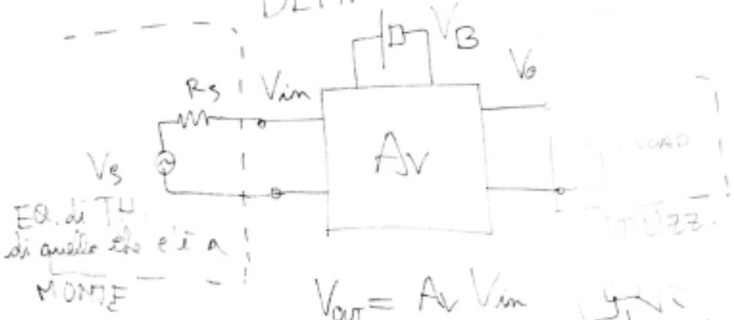


$v_{OUT}(t) = V_{MOUT} \sin\omega t$

$\rightarrow V_{MOUT} > V_M$ AMPLIF.

AMPLIF. di TENSIONE

DEFINIZIONE



$V_{OUT} = A_V V_{in}$ ($R_L \approx 8/4\,\Omega$)

1) V_{OUT} PROP. a V_{in}

2) A_V <u>NON</u> dipende da (V_S, R_S) né da R_L in uscita.

P_{in}, se $R_{in} = \infty$ $P_{in} = V_{in} \cdot I_{in} = 0$

se $R_{OUT} = 0$ $P_{OUT} = \frac{(A_V \cdot V_{in})^2}{R_L}$ GRANDE se R_L PICCOLA

$\rightarrow P_{OUT} \gg P_{IN}$

$V_{OUT} = A_V V_{in} \cdot \frac{R_L}{R_{OUT} + R_L}$

$R_{in} \rightarrow +\infty$

$R_{OUT} \rightarrow 0$

$V_{OUT} = A_{V0} V_S \cdot \frac{R_{in}}{R_S + R_{in}} \cdot \frac{R_L}{R_{OUT} + R_L}$

$V_{OUT} = A_{V0} \frac{R_{in}}{R_S + R_{in}} \cdot \frac{R_L}{R_{OUT} + R_L} \cdot V_S$

$A_V = \frac{V_{OUT}}{V_S} = A_{V0} \frac{R_{in}}{R_S + R_{in}} \cdot \frac{R_L}{R_{OUT} + R_L}$

SE $R_{in} \gg R_S$ $(R_{in} \rightarrow +\infty)$

E $R_{OUT} \ll R_L$ $(R_{OUT} \rightarrow 0)$ $\rightarrow A_V = A_{V0}$ $\forall R_S$ e R_L