

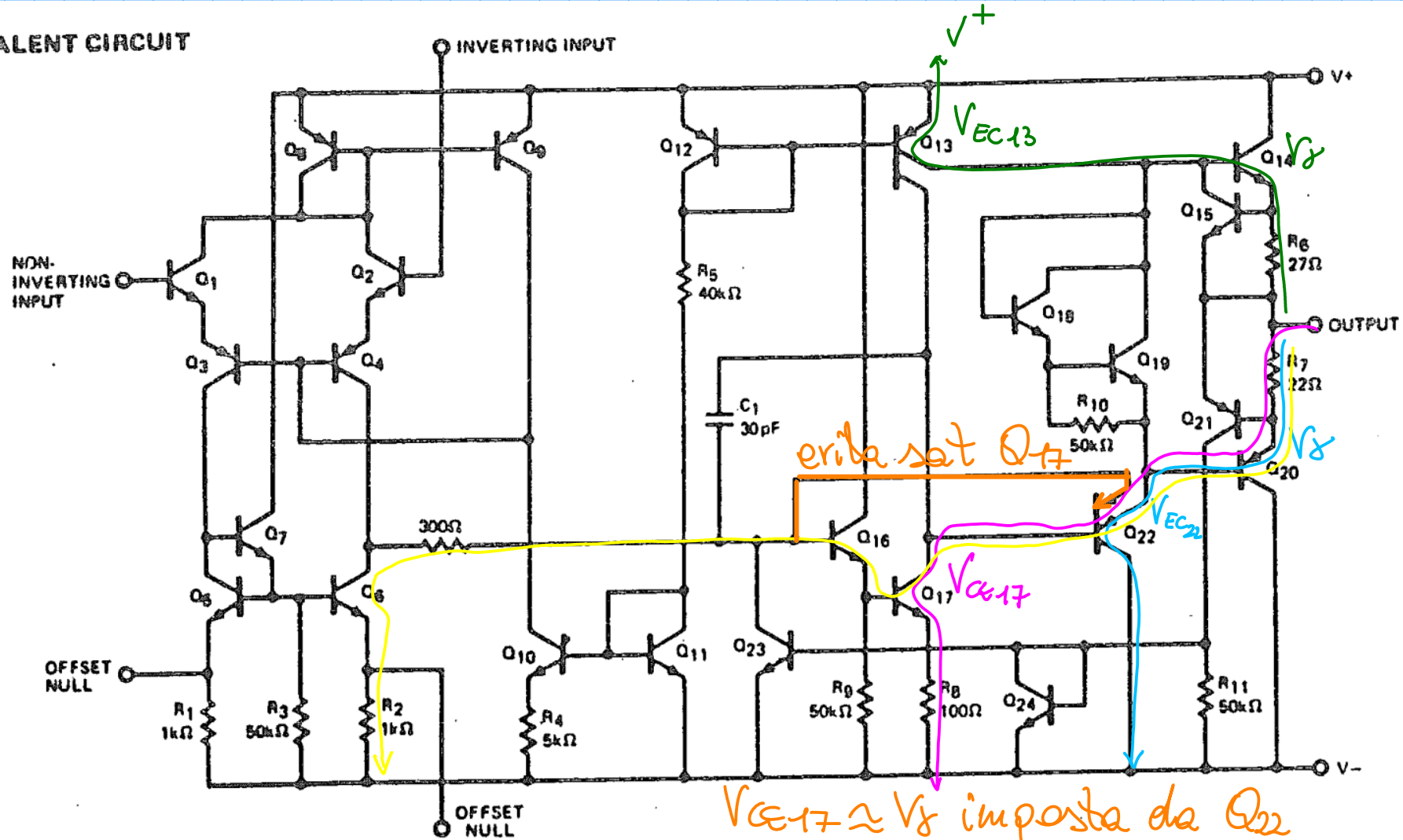
dinamica uscita tensioni

con  $V^+ = -V^- = 15V$

17nov

cerco percorso peggiore  $\rightarrow$  impone limite sull'uscita

### EQUIVALENT CIRCUIT



$$V_{U\min} = V^- + V_8 + V_8 + V_{CE17} \approx V^- + 3V_8 = -12,9V$$

$$V_{U\max} = V^+ - V_8 - V_{EC13} = V^+ - V_8 - V_{SAT} = 14,1V$$

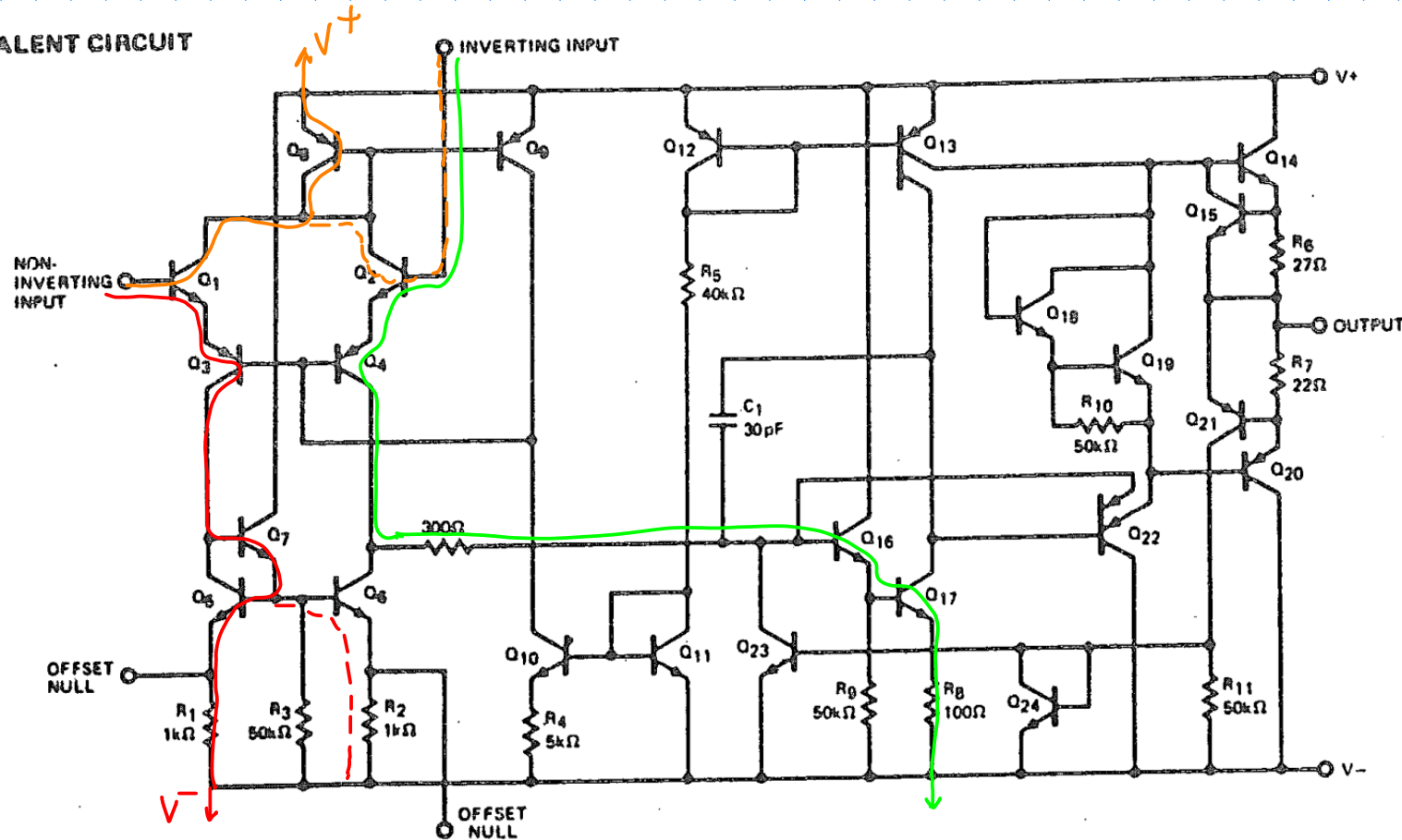
$\uparrow$   $H_p$   $Q_{13}$  sat.

$$V_{U\min} = -12,9V$$

$$V_{U\max} = 14,1V$$

# dinamica ingresso tensioni → misurata a modo comune

EQUIVALENT CIRCUIT



$$V_{C_{MIN}} = -12,7V$$

$$V_{C_{MAX}} = +14,8V$$

$$V_{C_{MIN}} (\text{ingresso } Q_1) = V_{BE6} + V_{BE7} + V_{EC3} + V_{BE4} + V^-$$

$$= 3V_\gamma + V_{CESAT} - |V^-| = -12,7V$$

$$V_{C_{MIN}} (\text{ingresso } Q_2) = V_{BE2} + V_{BE4} + I_{AT} R_{300} + V_{BE16} + V_{BE17} = -12,7V$$

$$V_{C_{MAX}} = V^+ - V_{EB8} - V_{CB1} = V^+ - V_{EB8} - (V_{CESAT} - V_\gamma) = +14,8V$$

## Range linearità

studio linearità operazionale per  
grandi segnali (elle variazioni linearizzato)

Modello di Ebers Moll

$$i_3 = I_s \left( e^{\frac{V_{EB3}}{V_T}} - 1 \right) \approx I_s e^{\frac{V_{EB3}}{V_T}}$$

$$i_{out} = i_3 - i_4 = I_s e^{\frac{V_{EB3}}{V_T}} - I_s e^{\frac{V_{EB4}}{V_T}}$$

$$i_8 = i_3 + i_4 = I_s e^{\frac{V_{EB3}}{V_T}} + I_s e^{\frac{V_{EB4}}{V_T}}$$

$$I_s = \frac{i_8}{e^{\frac{V_{EB3}}{V_T}} + e^{\frac{V_{EB4}}{V_T}}}$$

cerco  $i_3, i_4$  in funzione della tensione di ingresso

$$\text{CON } V_I = V_{BE1} + V_{EB3} - (V_{BE2} + V_{EB4}) = 2(V_{EB3} - V_{EB4})$$

$$V_I = V_{IN}^+ - V_{IN}^-$$

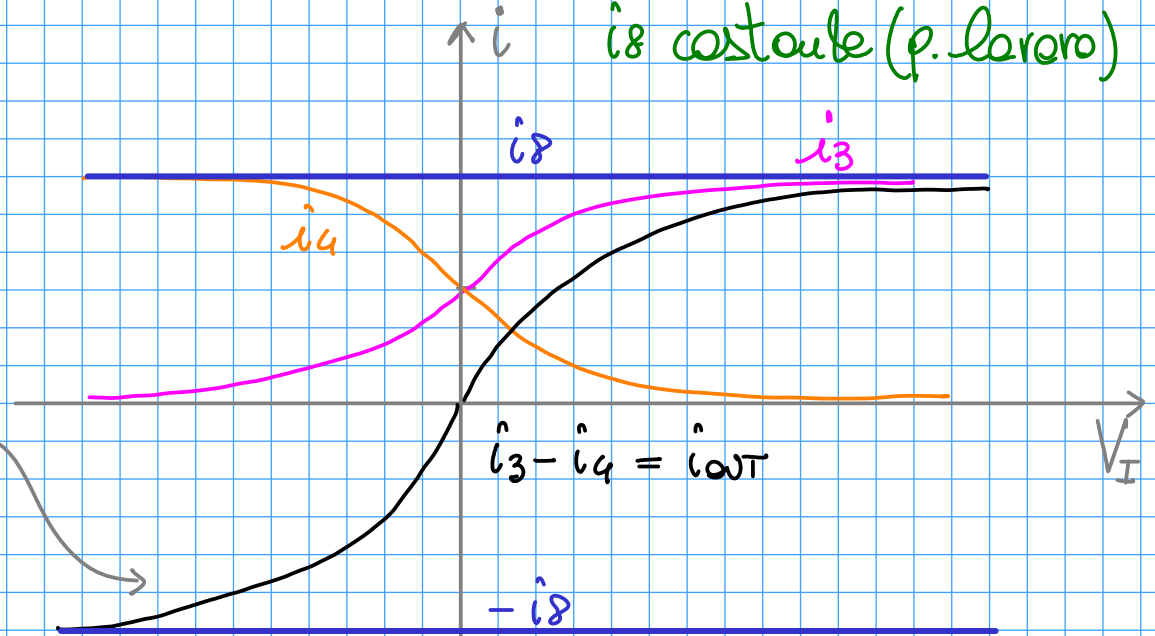
$$i_3 = \frac{i_8}{e^{\frac{V_{EB3}}{V_T}} + e^{\frac{V_{EB4}}{V_T}}} e^{\frac{V_{EB3}}{V_T}} = \frac{i_8}{1 + e^{\frac{V_{EB4} - V_{EB3}}{V_T}}} = \frac{i_8}{1 + e^{-\frac{V_I}{2V_T}}}$$

$$i_4 = \frac{i_8}{e^{\frac{V_{EB3}}{V_T}} + e^{\frac{V_{EB4}}{V_T}}} e^{\frac{V_{EB4}}{V_T}} = \frac{i_8}{1 + e^{\frac{V_{EB3} - V_{EB4}}{V_T}}} = \frac{i_8}{1 + e^{+\frac{V_I}{2V_T}}}$$

$$i_{out} = i_3 - i_4 = \frac{1 + e^{\frac{V_I}{2V_T}} - 1 - e^{-\frac{V_I}{2V_T}}}{\left(1 + e^{\frac{V_I}{2V_T}}\right)\left(1 + e^{-\frac{V_I}{2V_T}}\right)} \cdot i_8$$

$$i_{out} = i_8 \cdot \frac{e^{\frac{V_I}{2V_T}} - e^{-\frac{V_I}{2V_T}}}{\left(1 + e^{\frac{V_I}{2V_T}}\right)\left(1 + e^{-\frac{V_I}{2V_T}}\right)}$$

studio andamento corrente con  $V_I$   
 $i_8$  costante (p. lavoro)



in un intorno dell'origine si ha andamento lineare

→ pendenza dovrebbe essere  $g_m/2$

verifico pendenza, due passi

1) sviluppo di Taylor esponenziale

$$e^x = 1 + x + \frac{x^2}{2} + \dots$$

$$\left| \begin{array}{l} e^{\frac{V_I}{2V_T}} = 1 + \frac{V_I}{2V_T} \\ e^{-\frac{V_I}{2V_T}} = 1 - \frac{V_I}{2V_T} \end{array} \right.$$

$$i_{out} \Big|_{V_I \rightarrow 0} \approx \frac{1 + \frac{V_I}{2V_T} - 1 + \frac{V_I}{2V_T}}{\left(1 + 1 + \frac{V_I}{2V_T}\right)\left(1 + 1 - \frac{V_I}{2V_T}\right)} i_8 = \frac{V_I}{V_T} \frac{1}{\left(2 + \frac{V_I}{2V_T}\right)\left(2 - \frac{V_I}{2V_T}\right)} i_8 =$$

$$= i_8 \cdot \frac{V_I}{V_T} \cdot \frac{1}{4 - \left(\frac{V_I}{2V_T}\right)^2}$$

2) derivo risultato trovato in  $\partial V_I$

trovo

$$\frac{\partial i_{out}}{\partial V_I} = i_8 \frac{\frac{1}{V_T} \left[ 4 - \left( \frac{V_I}{2V_T} \right)^2 \right] + \frac{V_I}{V_T} \left[ +2 \frac{1}{2V_T} \left( \frac{V_I}{2V_T} \right) \right]}{\left[ 4 - \left( \frac{V_I}{2V_T} \right)^2 \right]^2} =$$

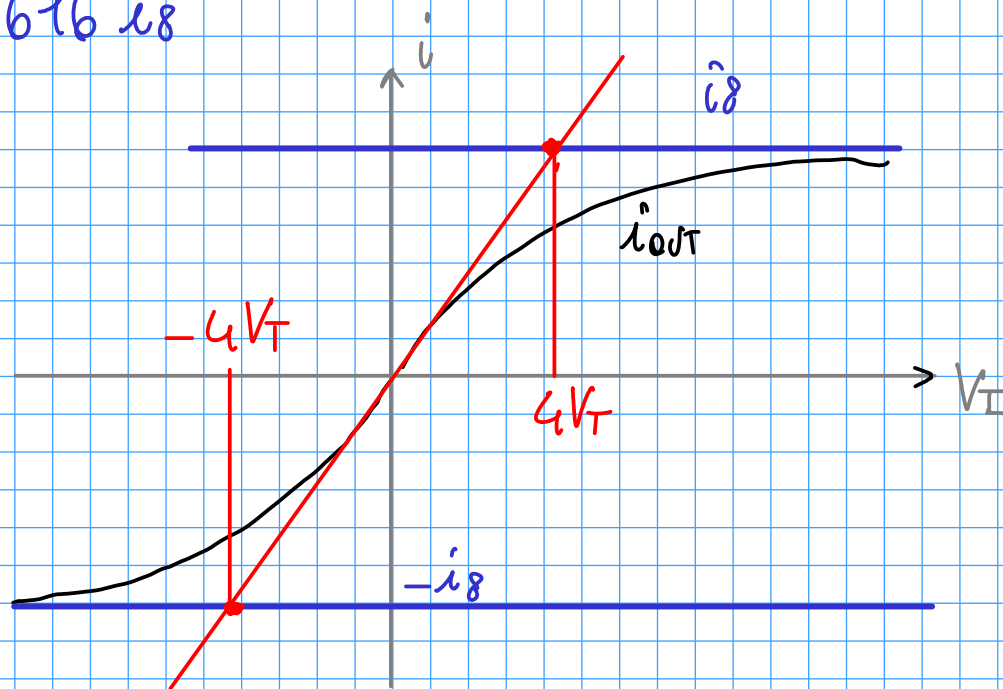
a questo punto  
impago  $V_I \rightarrow \emptyset$

$$\left. \frac{\partial i_{out}}{\partial V_I} \right|_{V_I \rightarrow \emptyset} = \frac{\frac{i_8}{2}}{V_T} \frac{1}{2} = \frac{g_m}{2} !$$

trovo intercetta  $i_{out} = \frac{g_m}{2} V_I$  e  $i_8$

range linearità stadio di ingresso  
 $V_I \in [-4V_T, 4V_T]$

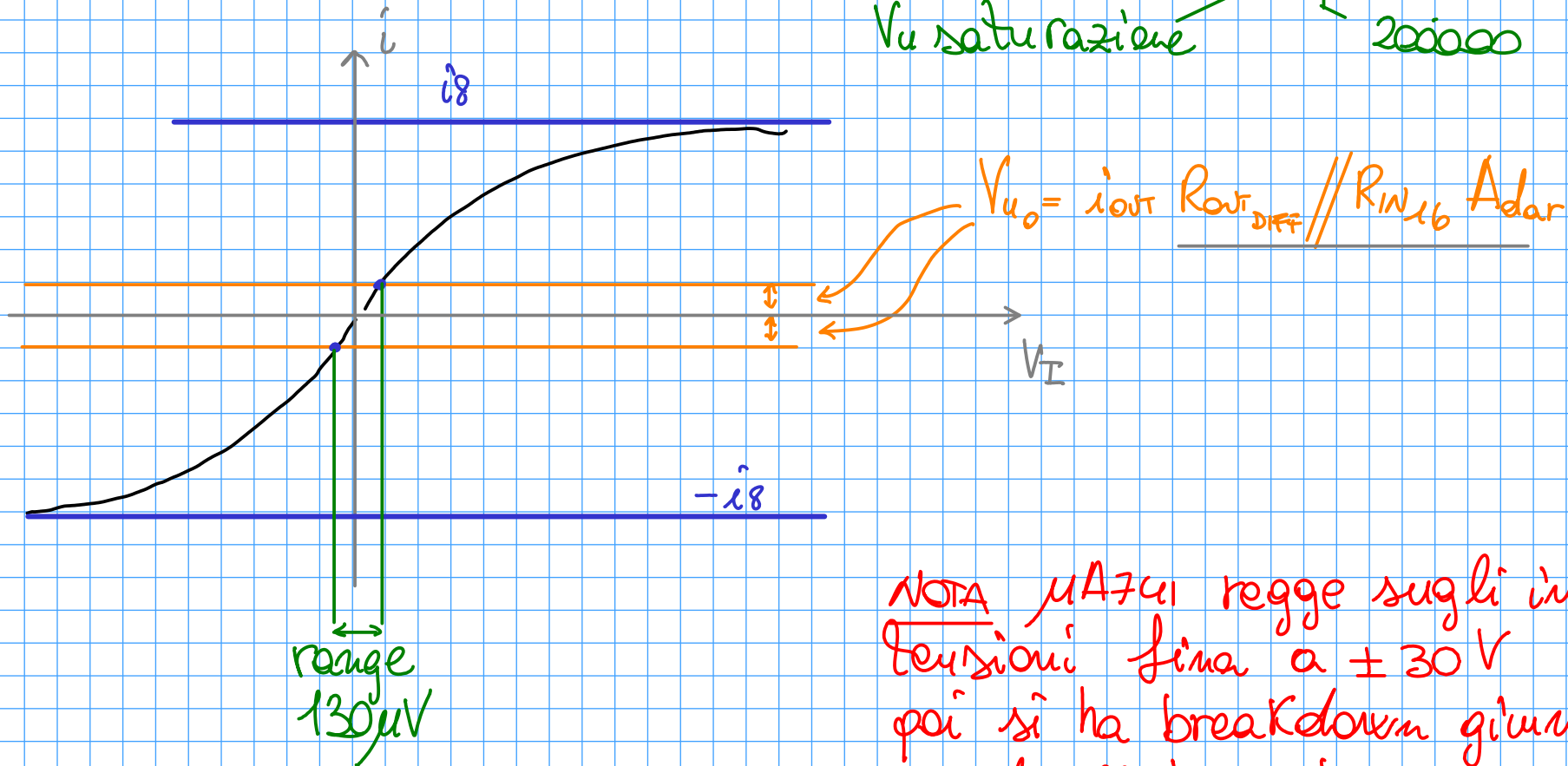
$$\left. i_{out} \right|_{V_I = 4V_T} = 0,7616 i_8$$



estendo ragionamento all'operazionale completo

Range linearità  $\mu A741$  completo

$V_I \in [-65\mu V, +65\mu V]$  ← stimolo con  $V_u = A_v V_I$   
 $V_u$  saturazione  $\uparrow$  200000



NOTA  $\mu A741$  regge sugli ingressi  
tensioni fino a  $\pm 30 V$   
poi si ha breakdown giunzione  
BE degli ingressi