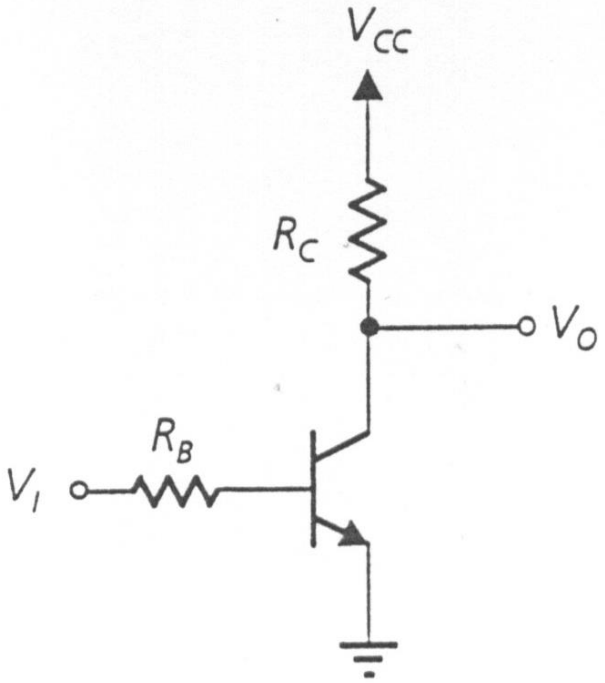
UNIVERSITÀ
DEGLI STUDI DI TRIESTE

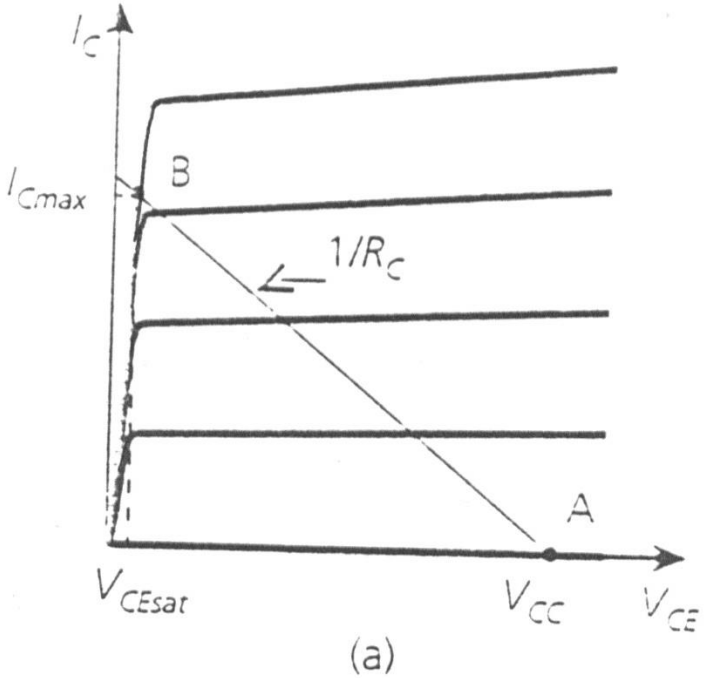
dipartimento
di ingegneria
e architettura

I circuiti bipolari

A.Carini – Elettronica digitale

L’invertitore RTL





L’invertitore RTL

Affinchè in B si sia in saturazione deve essere:

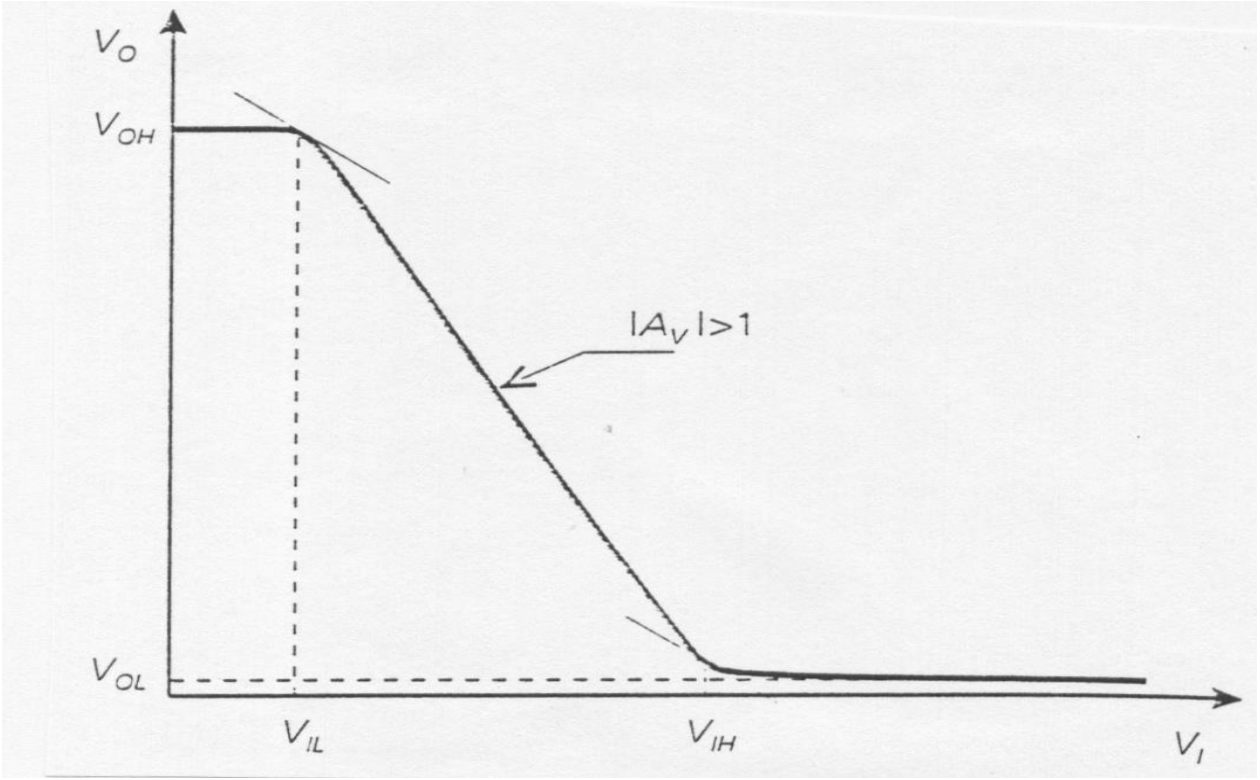
$$I_{C,\max} < \beta_F \; I_{B,\max}$$

$$I_{C,\max} = I_{C,sat} = \frac{V_{CC} - V_{CE,sat}}{R_C} \cong \frac{V_{CC}}{R_C}$$

$$I_{B,\max} = \frac{V_{OH} - V_{BE,sat}}{R_B} = \frac{V_{CC} - V_{BE,sat}}{R_B} \cong \frac{V_{CC}}{R_B}$$

$$\boxed{\frac{R_B}{\beta_F \; R_C} < 1}$$

Caratteristica di trasferimento



Caratteristica di trasferimento

$$V_{IL} < V_I < V_{IH}:$$

$$I_B = \frac{V_I - V_{BE}}{R_B} \cong \frac{V_I - 0.7}{R_B}$$

$$I_C = \frac{V_{CC} - V_O}{R_C}$$

$$I_C = \beta_F \, I_B \quad \Rightarrow \quad \frac{V_{CC} - V_O}{R_C} = \beta_F \frac{V_I - 0.7}{R_B}$$

$$\frac{\Delta V_O}{\Delta V_I} = -\beta_F \frac{R_C}{R_B}$$

Caratteristica di trasferimento

V_{IH} :

$$I_C = \beta_F \; I_B$$

$$V_O = V_{CE,sat}$$

$$\Rightarrow \quad \frac{V_{CC} - V_{CE,sat}}{R_C} = \beta_F \frac{V_{IH} - V_{BEsat}}{R_B}$$

$$V_{IH} = \frac{R_B}{\beta_F \; R_C}\left(V_{CC} - V_{CE,sat}\right) + V_{BE,sat}$$

Invertitore Caricato

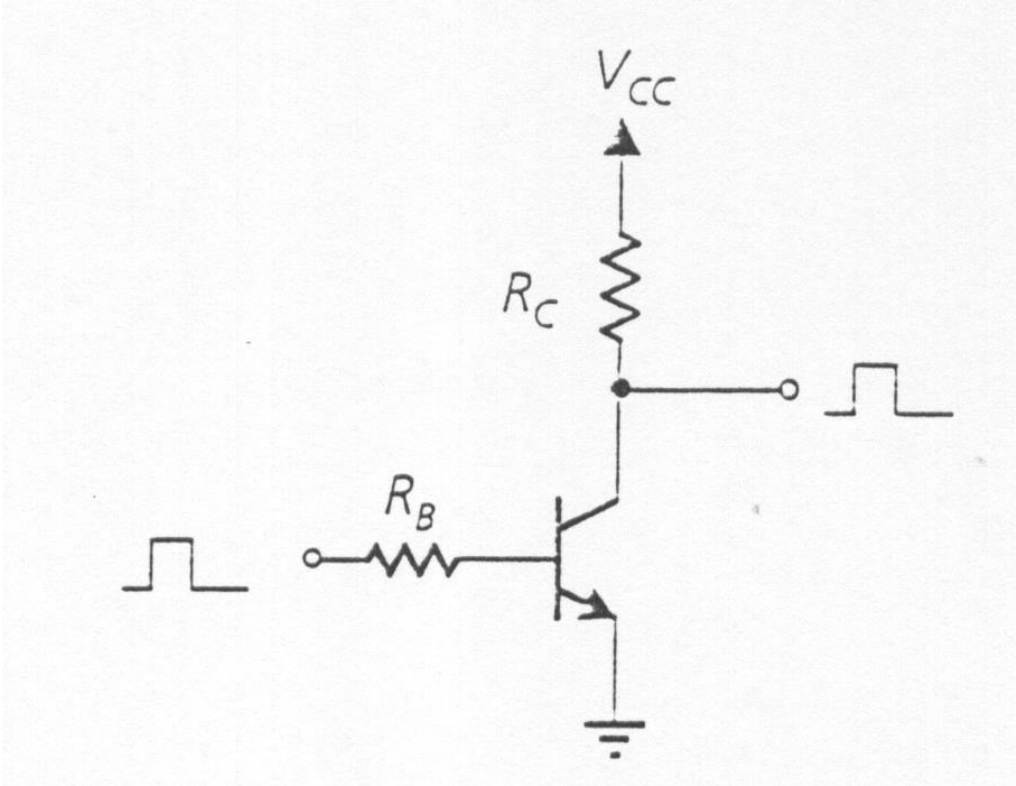
$$V_{OH} = \frac{R_B}{R_B + R_C}\left(V_{CC} - V_{BE,sat}\right) + V_{BE,sat}$$

$$V_{IH} = \frac{R_B}{\beta_F \, R_C}\left(V_{CC} - V_{CE,sat}\right) + V_{BE,sat}$$

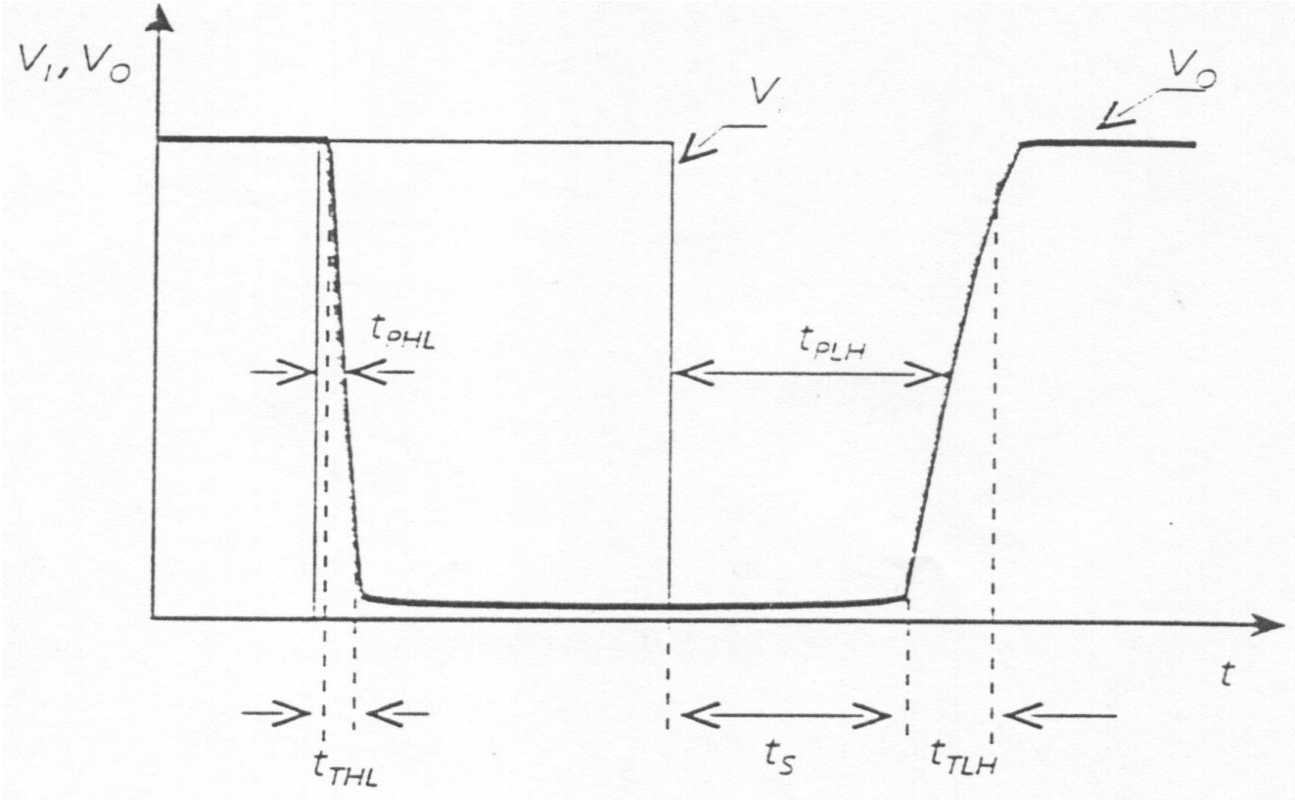
$$V_{IL} = V_{BE,\gamma} \cong 0.6V$$

$$V_{OL} = V_{CE,sat} \cong 0.2V$$

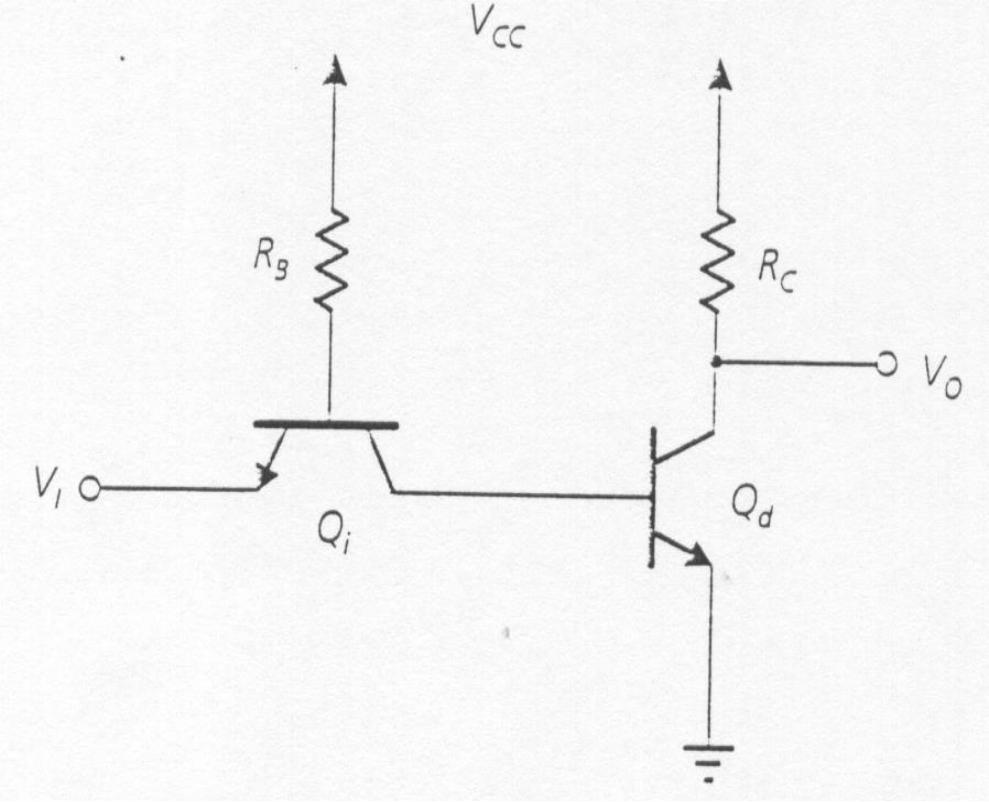
Comportamento dinamico



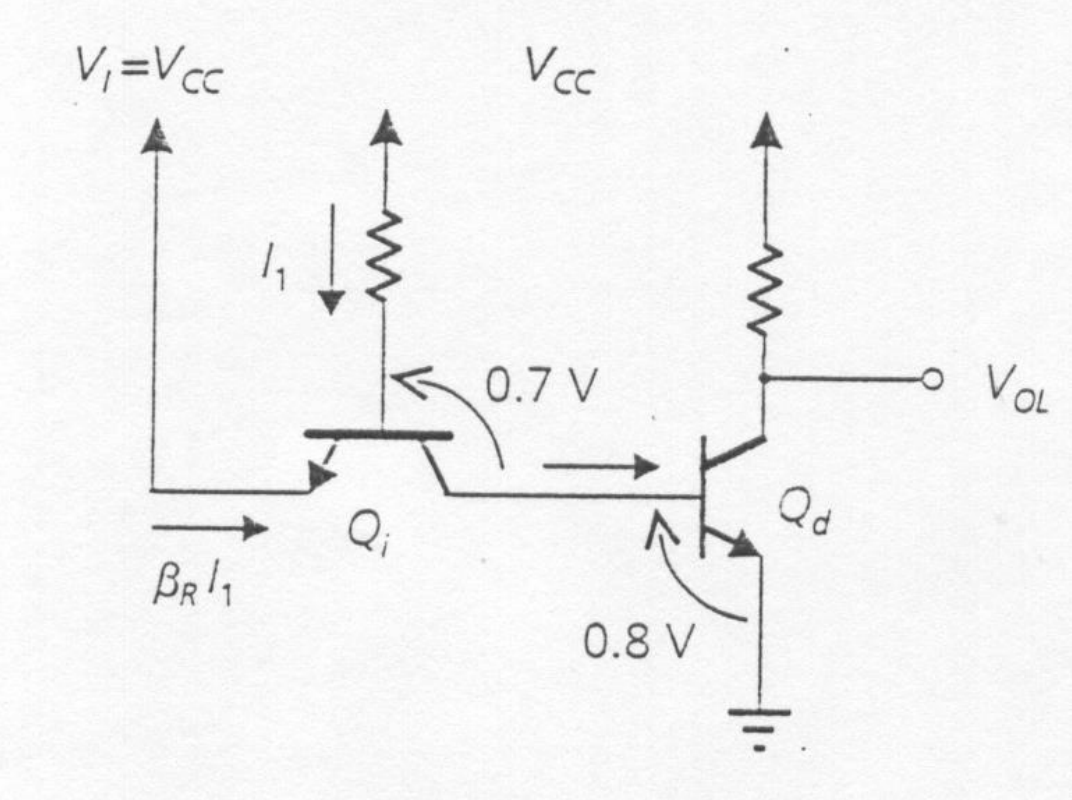
Comportamento dinamico



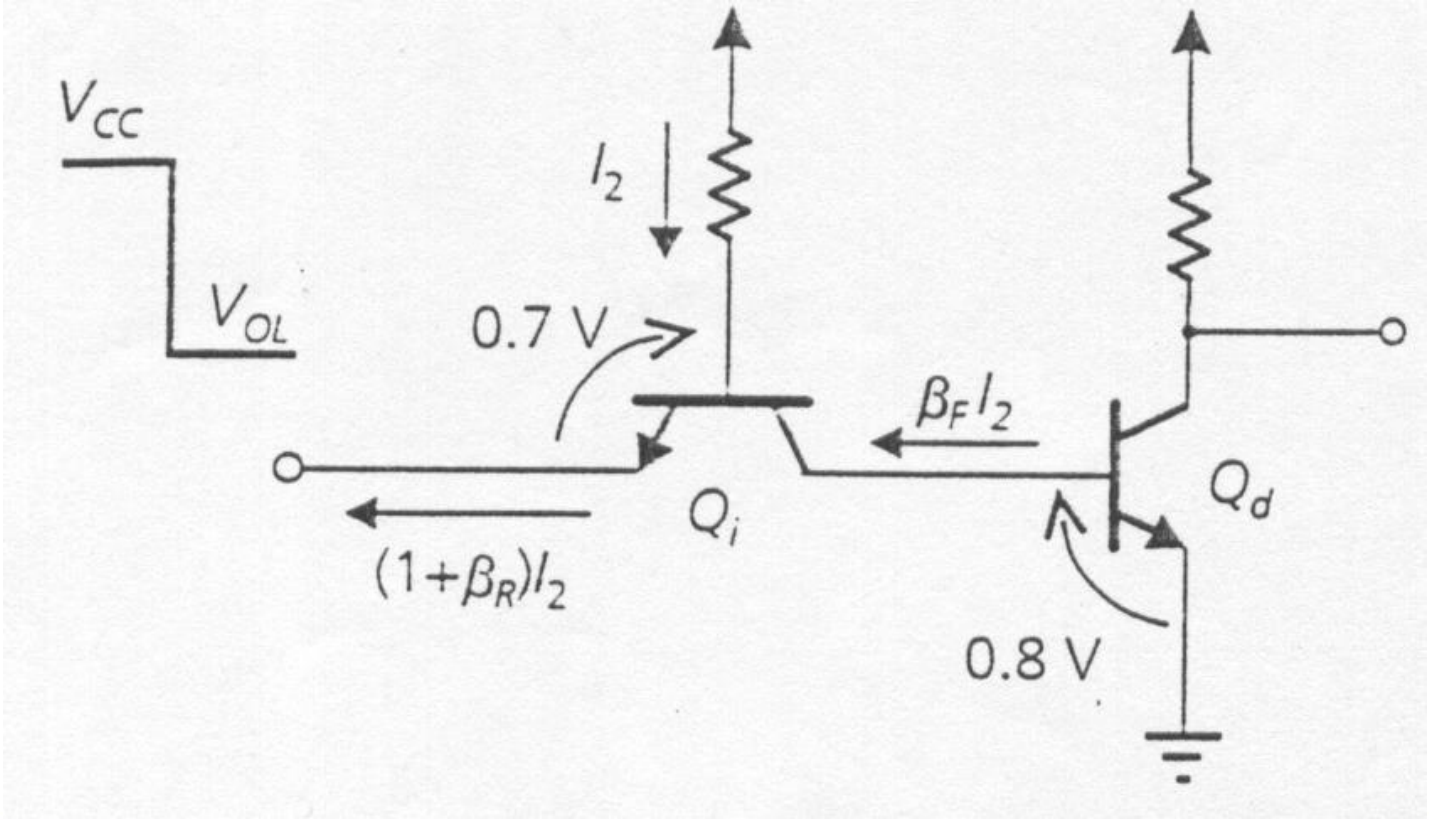
Invertitore Elementare TTL



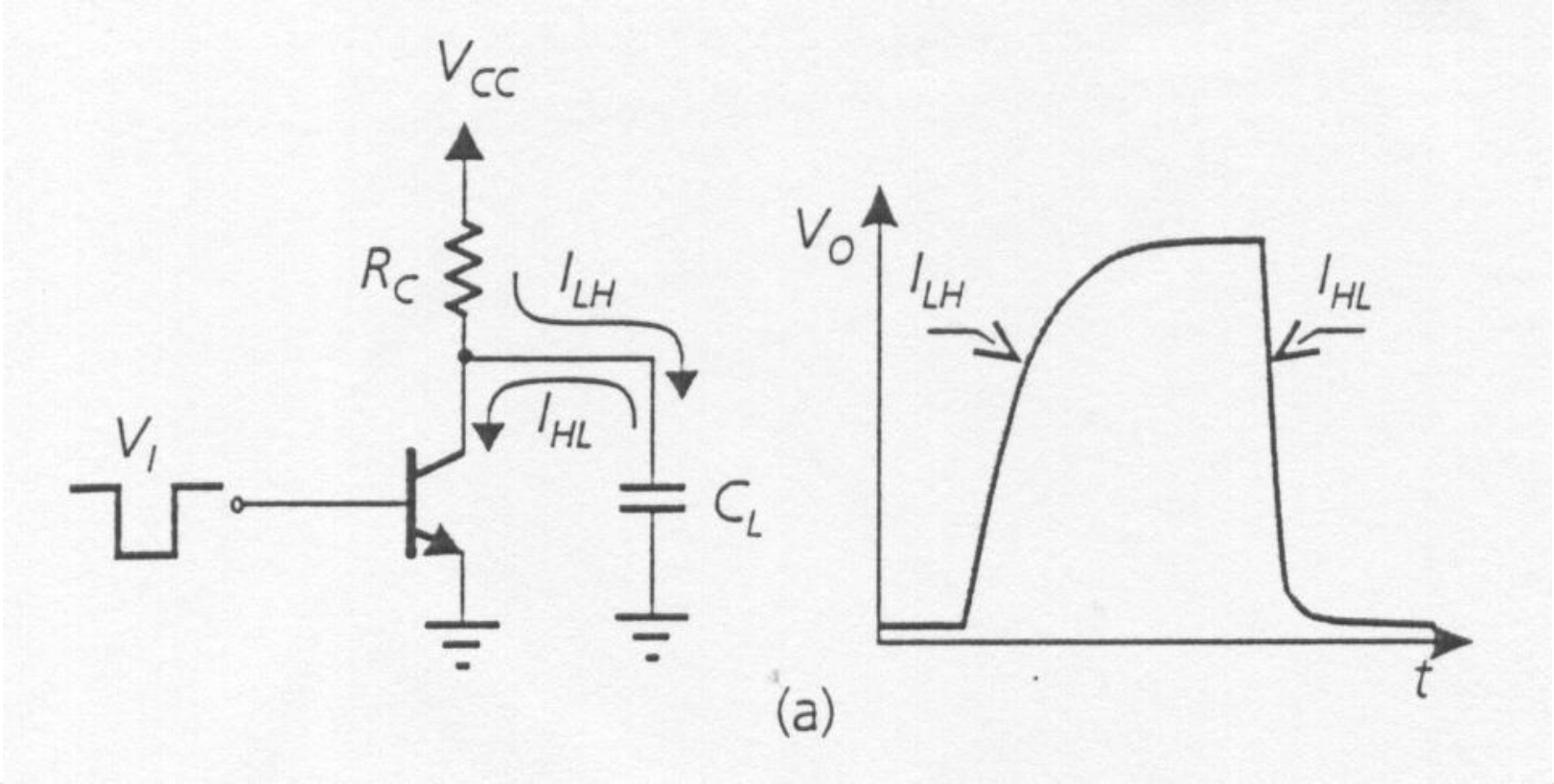
Invertitore Elementare TTL



Invertitore Elementare TTL



Stadio d'uscita



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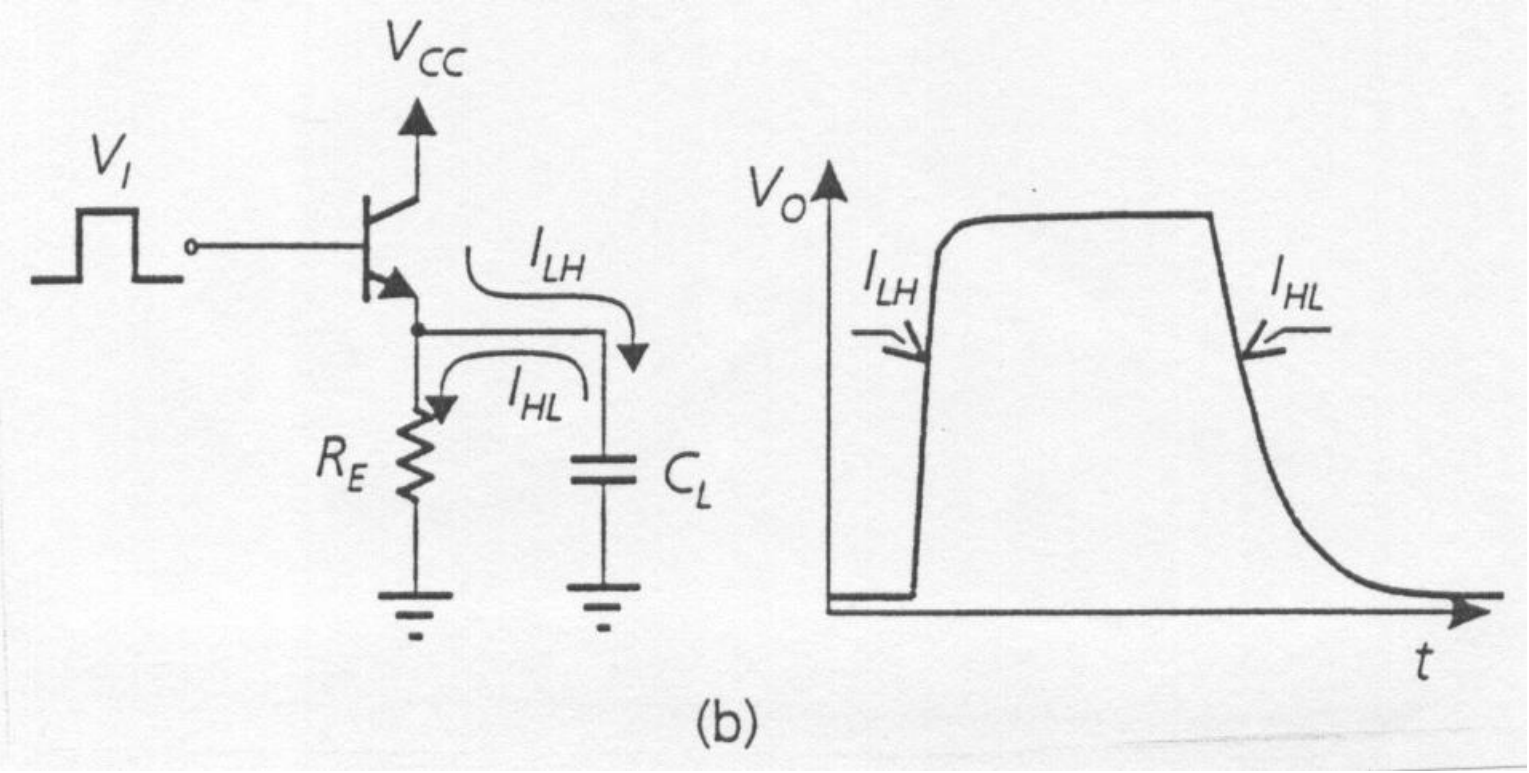
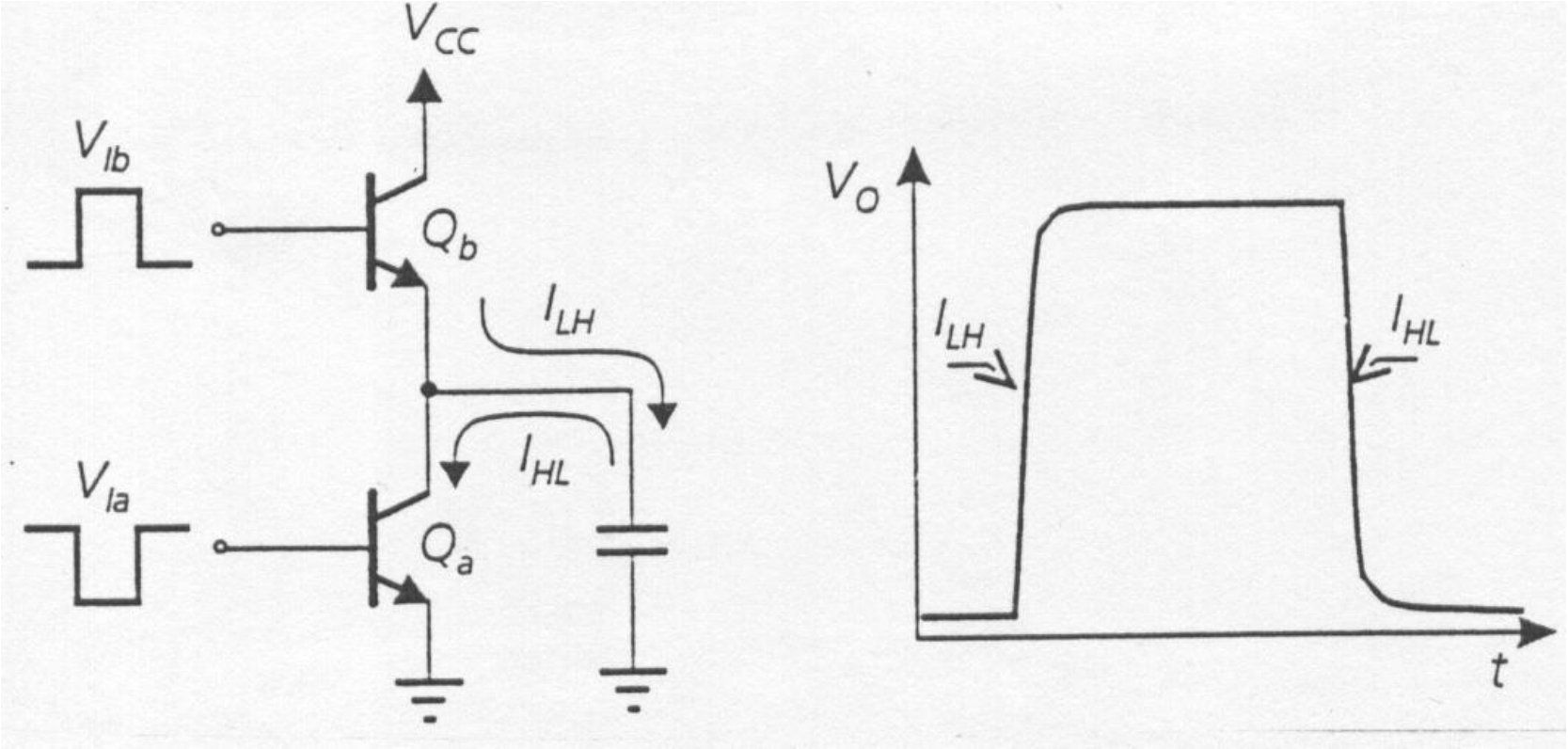
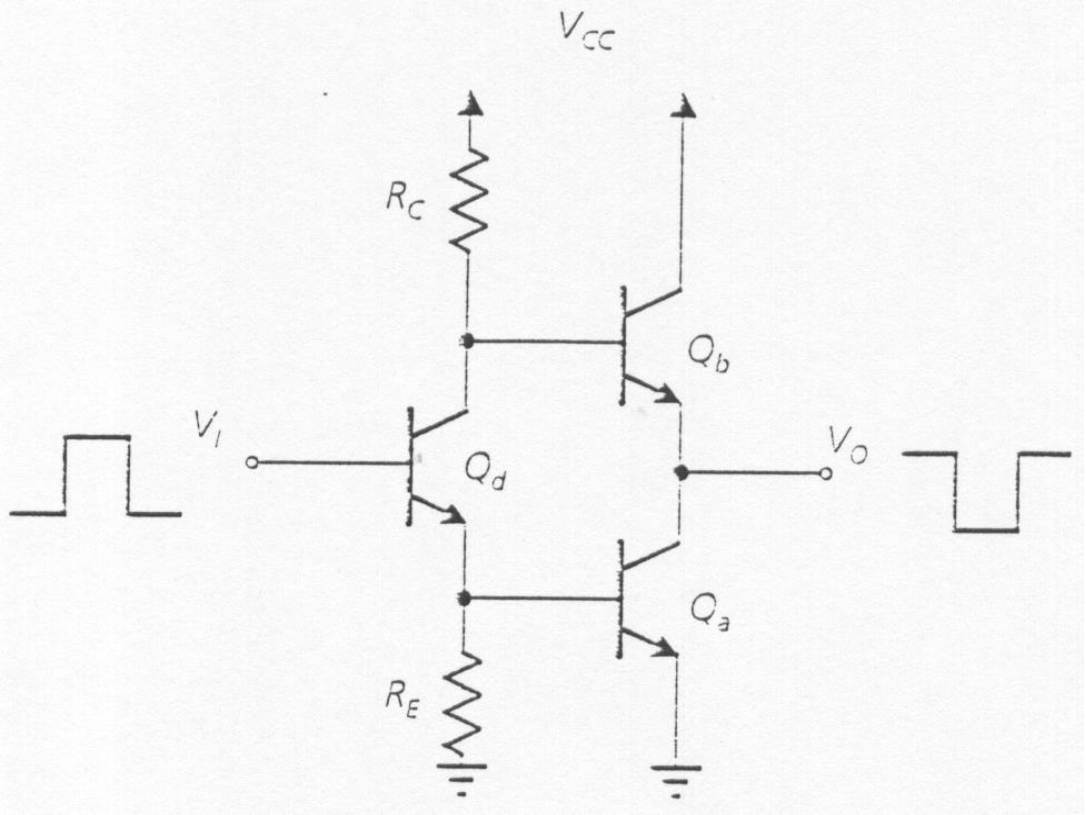


Stadio d'uscita



Stadio d'uscita

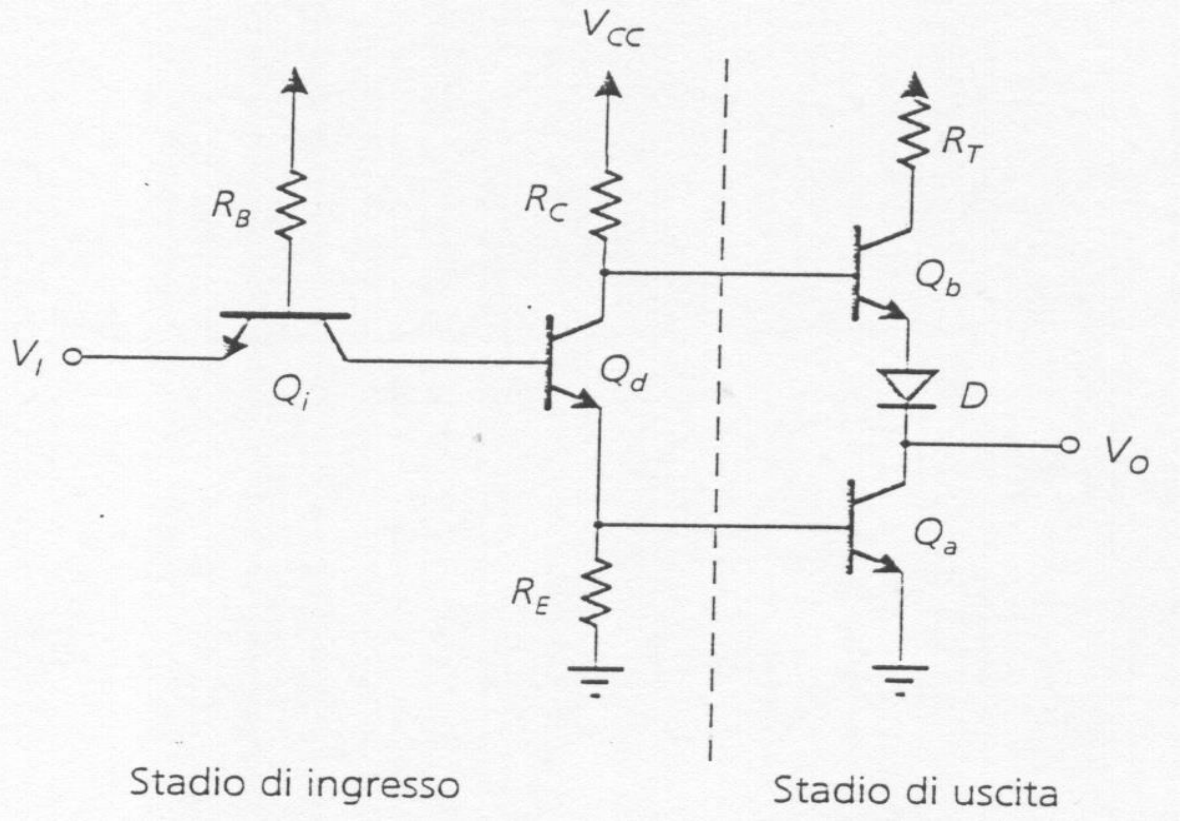


$$V_{B,a} = R_E \; I_E$$

$$V_{B,b} = V_{CC} - R_C \; I_C$$

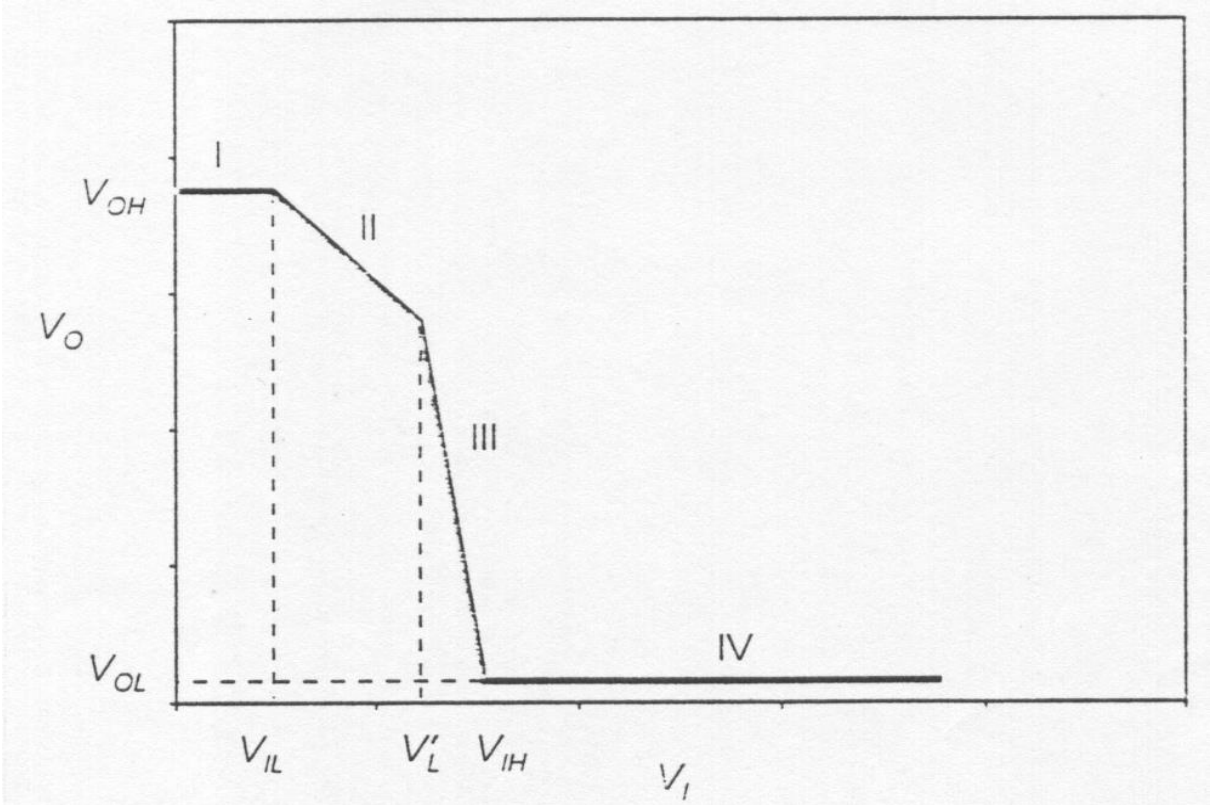
$$I_C \cong I_E$$

Invertitore TTL standard

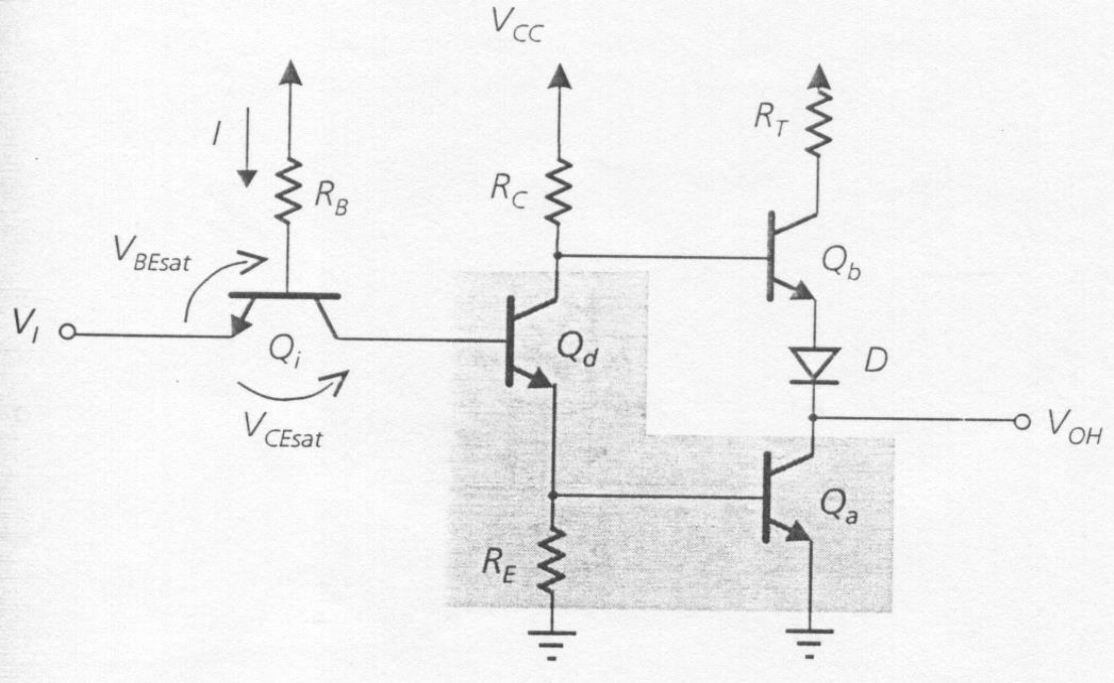


$$R_B = 4\ k\Omega$$
$$R_C = 1{,}6\ k\Omega$$
$$R_E = 1\ k\Omega$$
$$R_T = 130\ \Omega$$

Caratteristica di Trasferimento



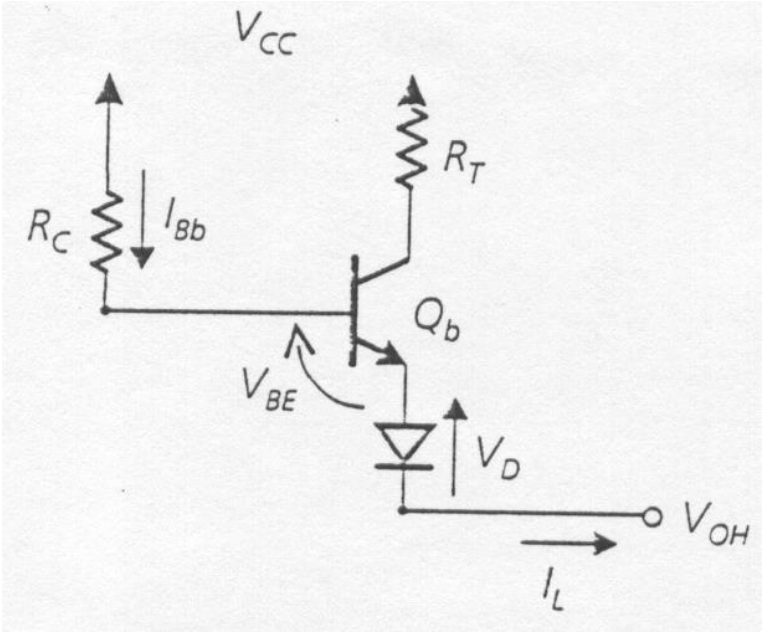
Regione I: $0 < V_I < V_{IL}$



$$V_{B,d} = V_I + V_{CE,sat} = V_I + 0{,}1V$$

$$V_{IL} \cong 0.5V$$

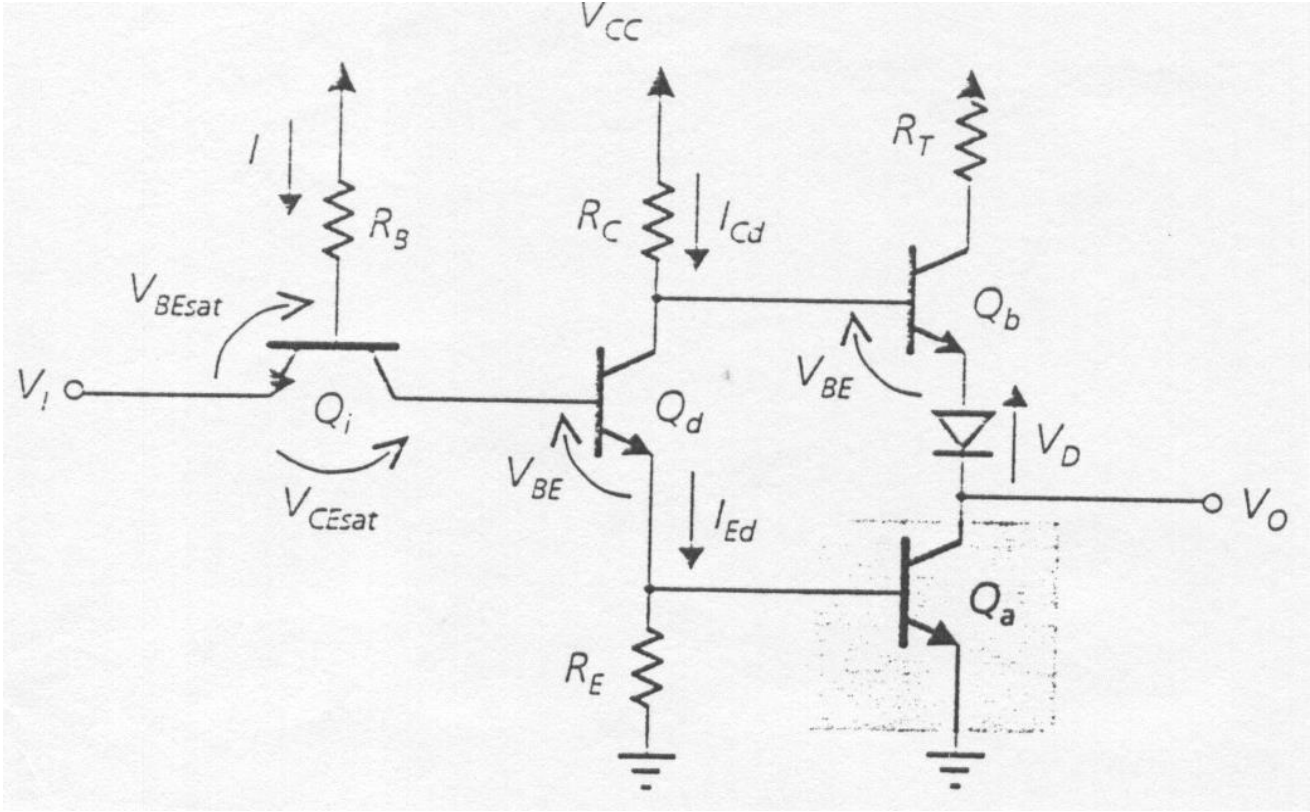
Regione I: $0 < V_I < V_{IL}$



$$I_L \cong 0 \quad \Rightarrow \quad I_{B,b} \cong 0$$

$$V_{OH} = V_{CC} - V_{BE} - V_D$$
$$= V_{CC} - 0.6 - 0.6 = 3.8V$$

Regione II: $V_{IL} < V_I < V_L'$

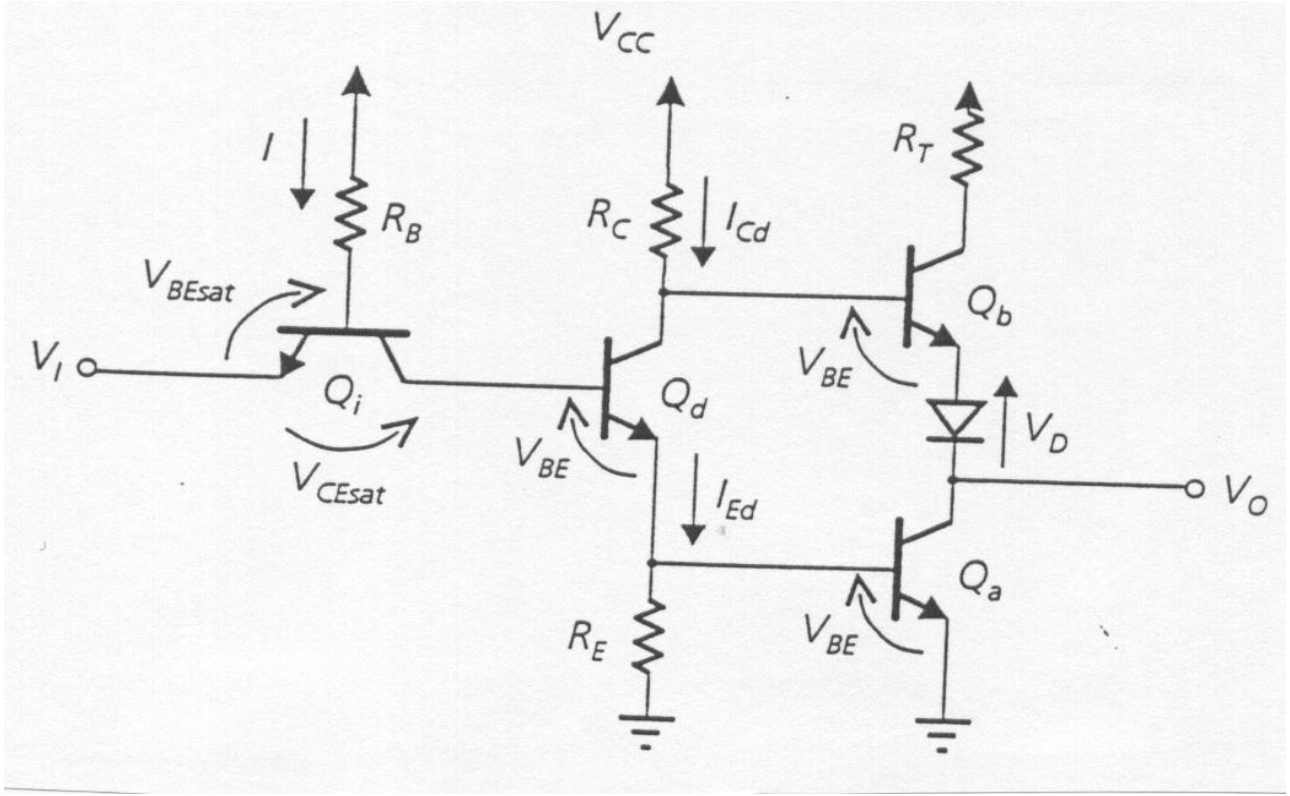


Regione II: $V_{IL} < V_I < V_L'$

$$V_{IL} = V_{BEd\gamma} - V_{CEsat} \cong 0.6 - 0.1 \cong 0.5V$$

$$V_L' = V_{BEa\gamma} + V_{BE} - V_{CEsat} = 0.6 + 0.7 - 0.1 \cong 1.2V$$

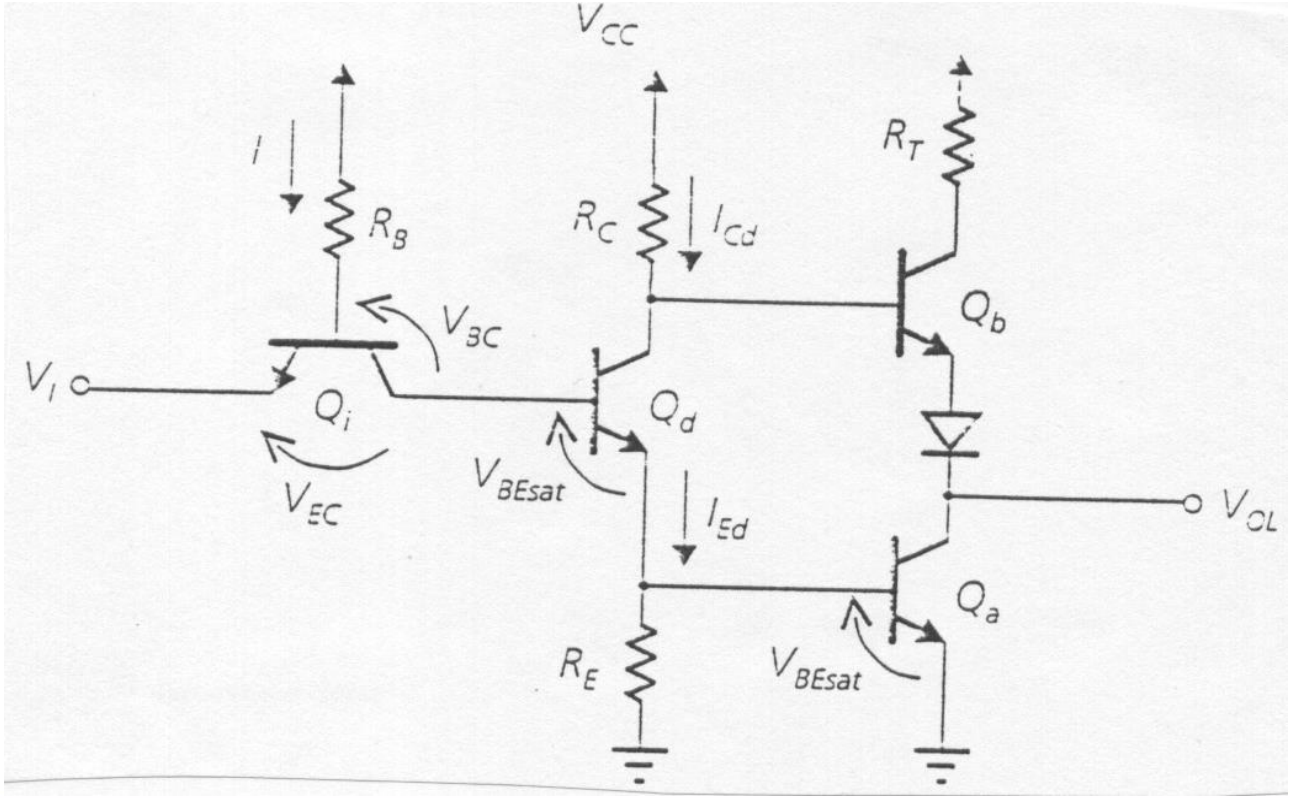
Regione III: $V_L' < V_I < V_{IH}$



Regione III: $V_L' < V_I < V_{IH}$

$$V_{IH} = V_{BEsat} + V_{BE,d} - V_{CE,sat}$$
$$\cong 0.8 + 0.7 - 0.0 \cong 1.5V$$

Regione IV: $V_I > V_{IH}$



Regione IV: $V_I > V_{IH}$

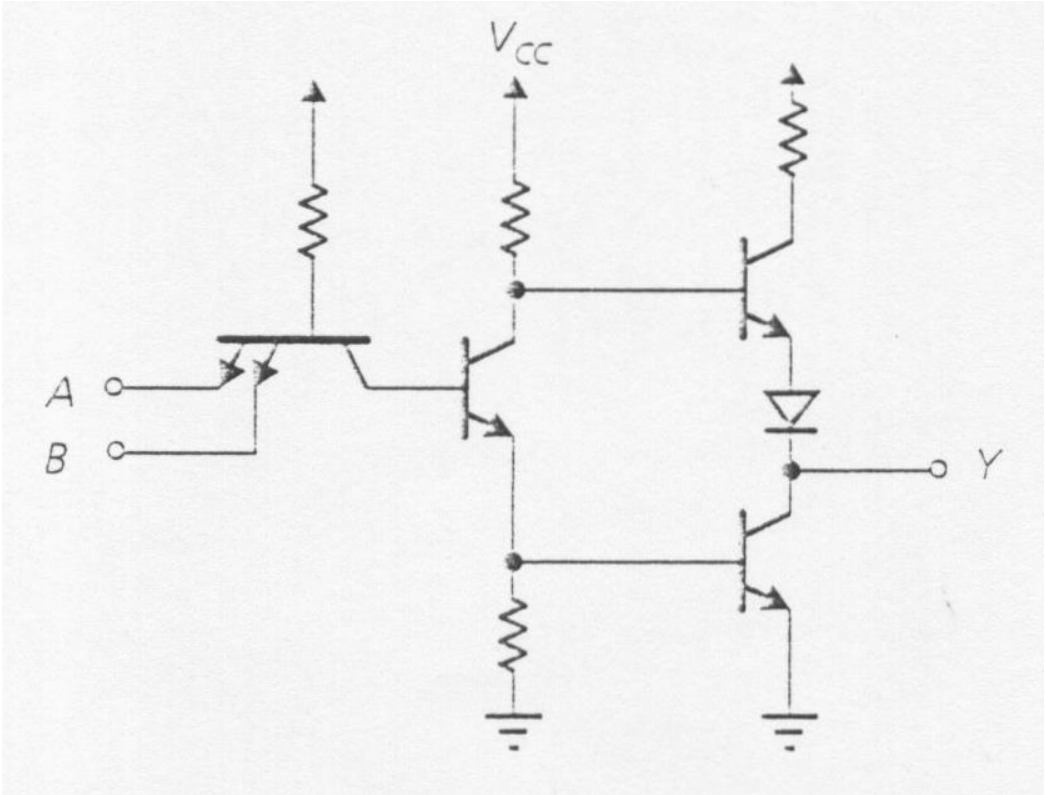
$$V_{OL} = 0.2V$$

$$V_B = V_{BE,sat} + V_{CE.sat} = 1V$$

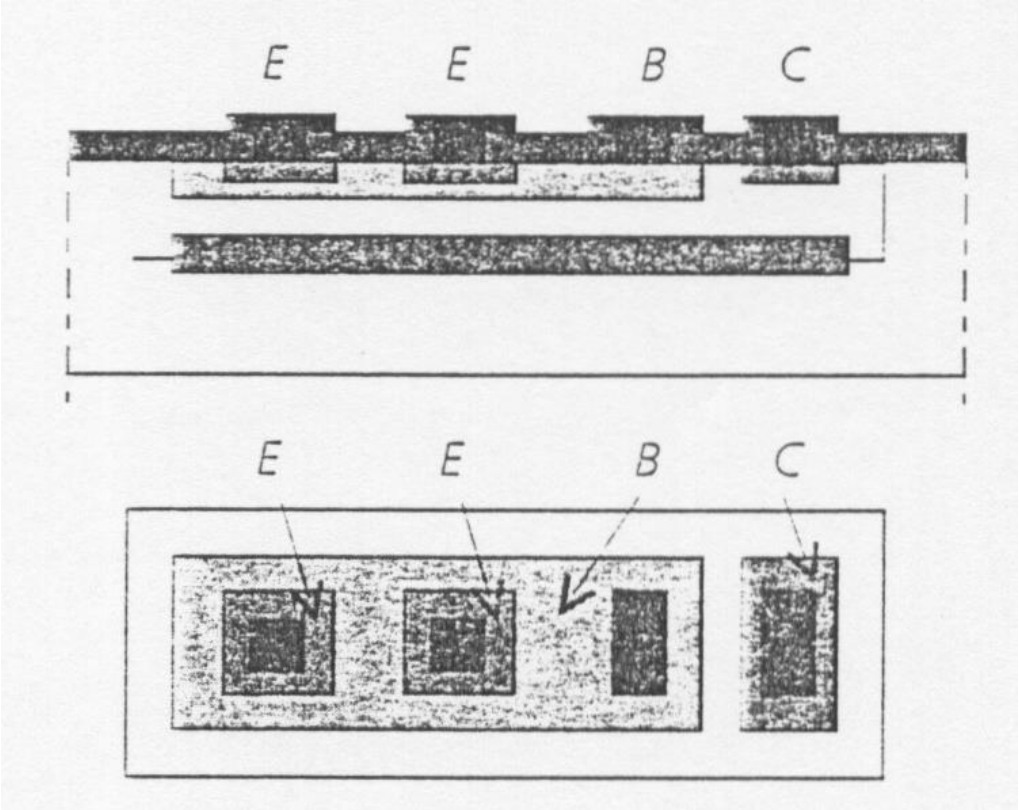
$$NM_L = V_{IL} - V_{OL} \cong 0.5V - 0.2V = 0.3V$$

$$NM_H = V_{OH} - V_{IH} \cong 3.8V - 1.5V = 2.3V$$

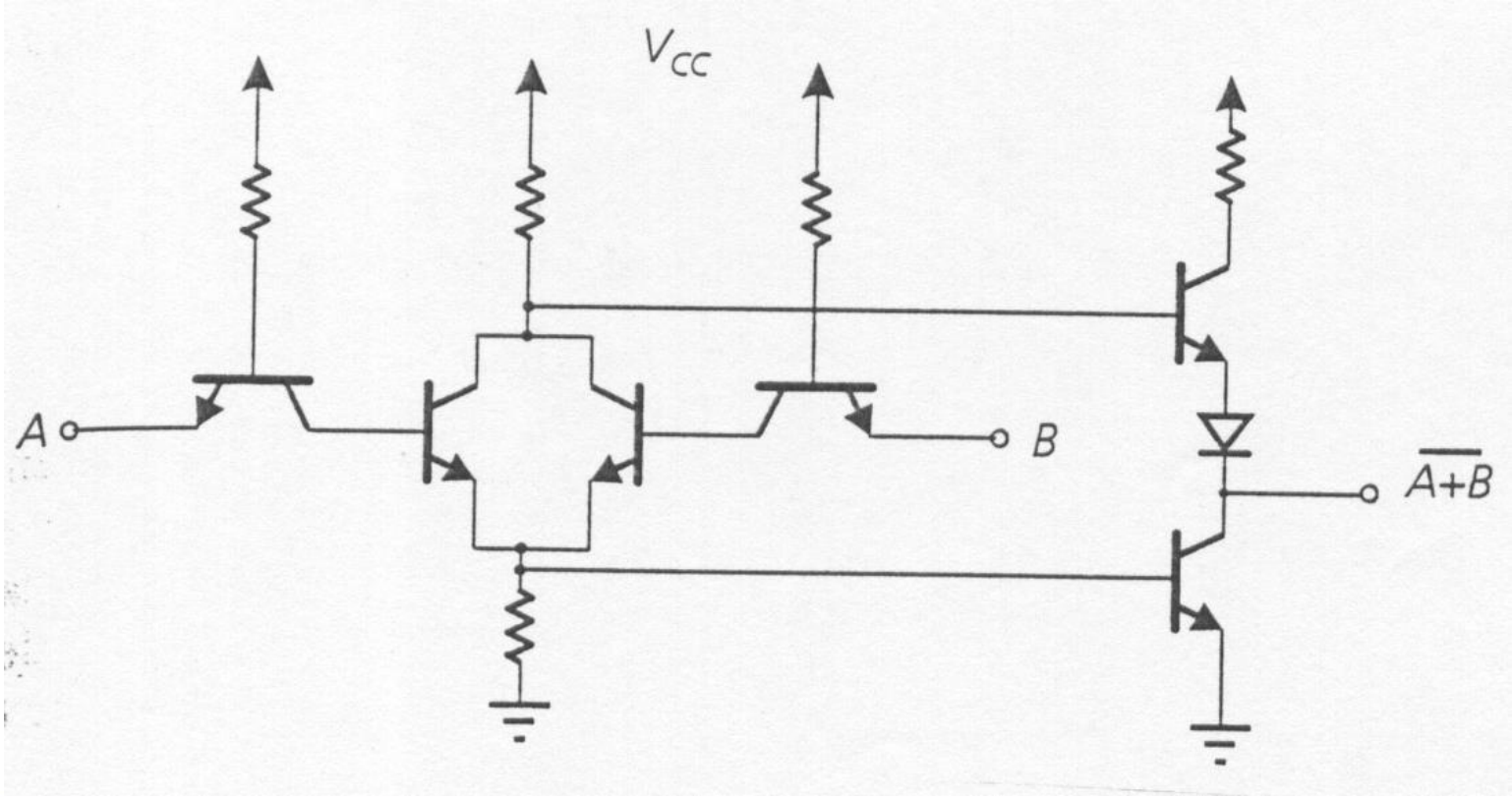
Porta NAND TTL



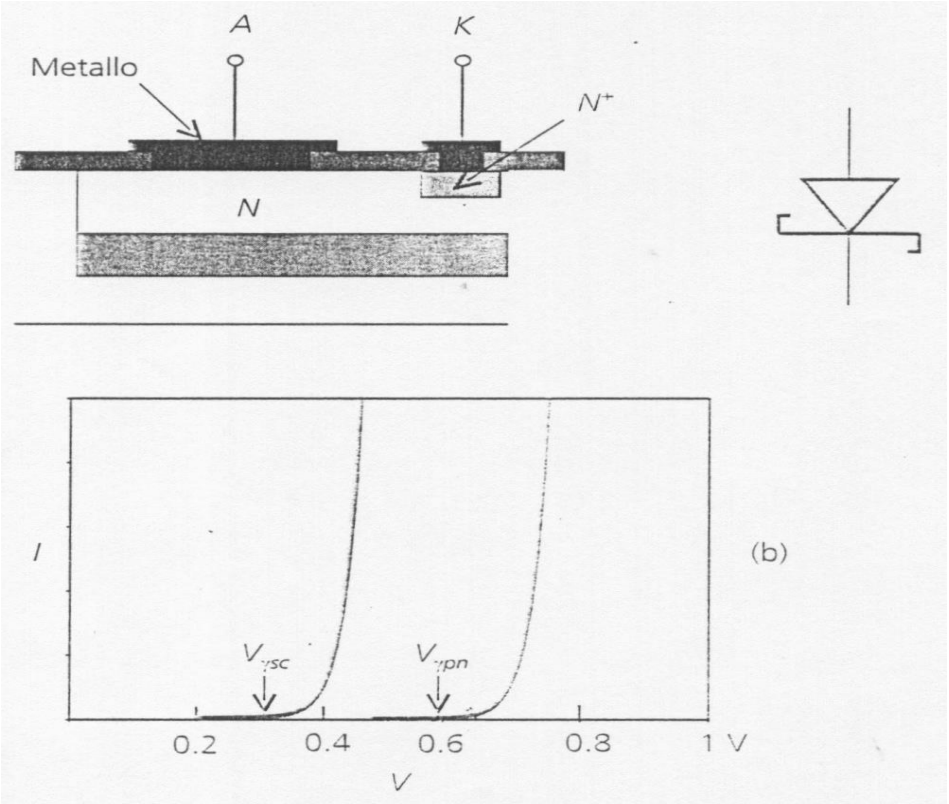
Transistore Multi-Emettitore



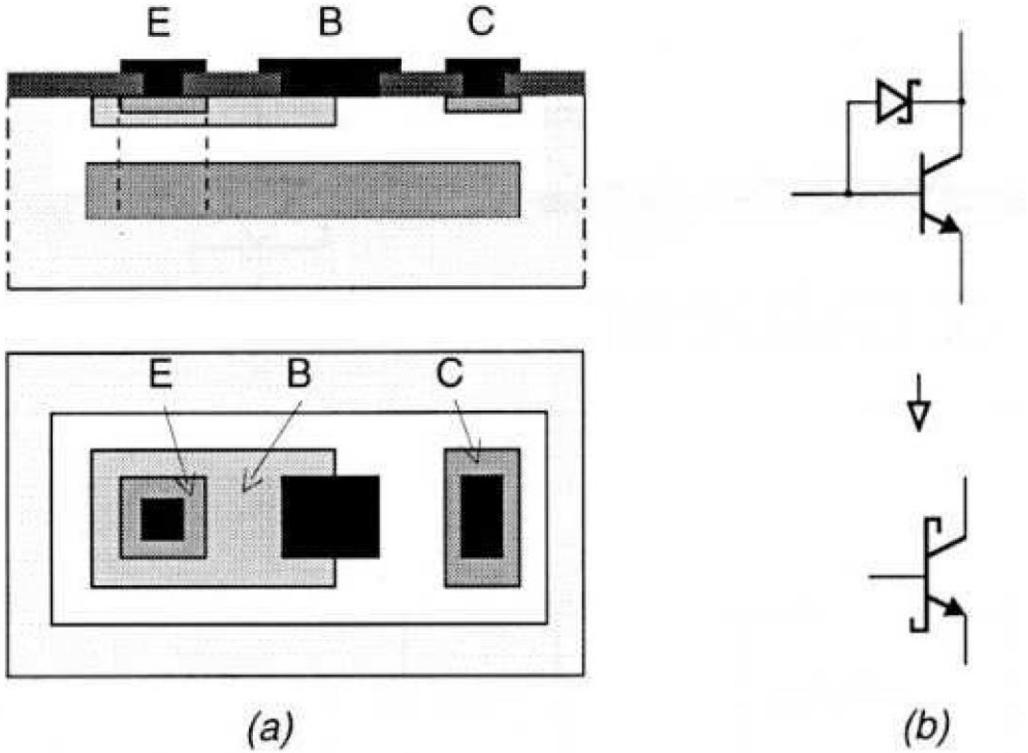
Porta NOR TTL



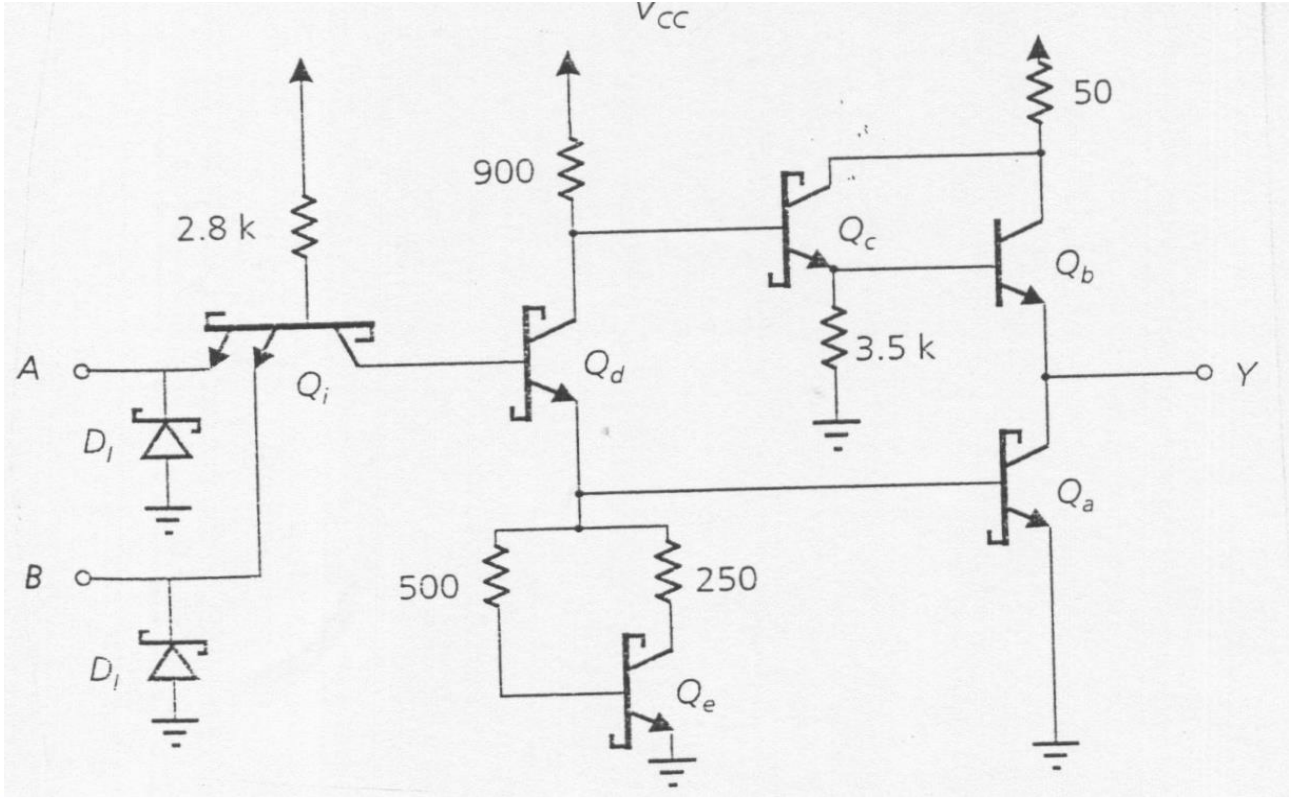
Diodo Schottky



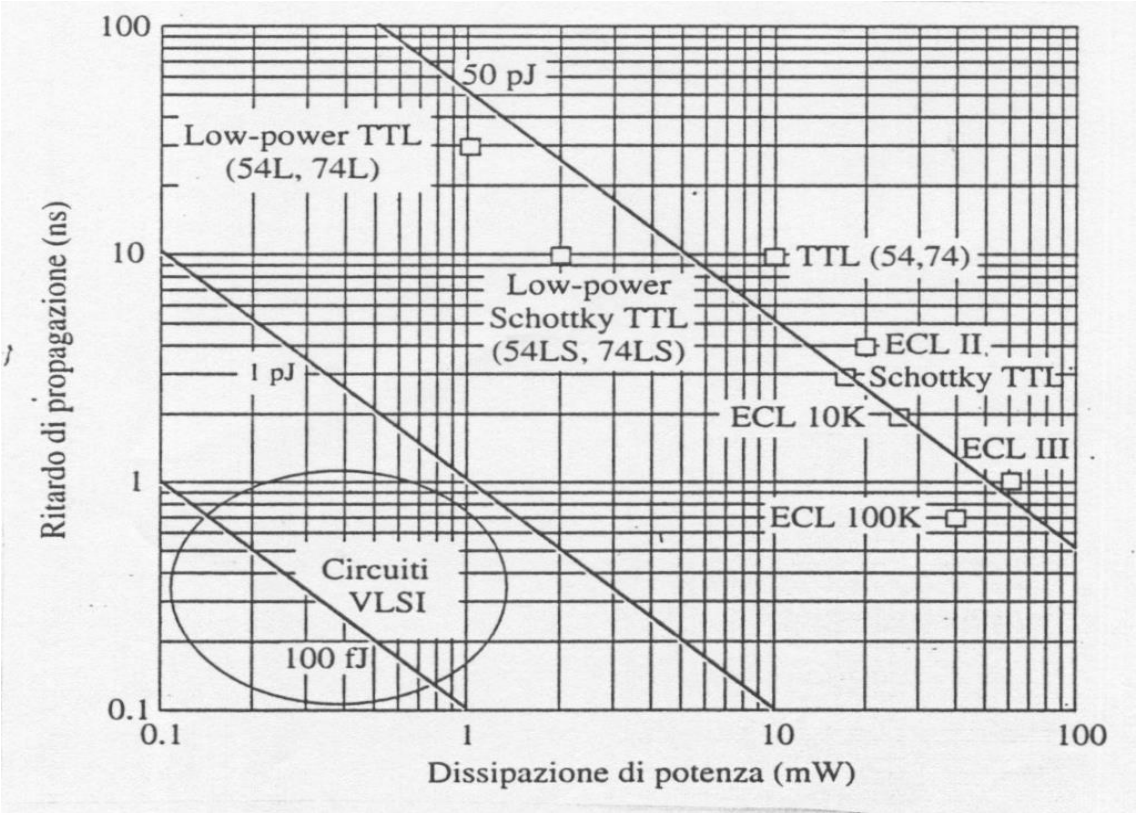
Transistore Schottky



NAND TTL Schottky



Confronto tra famiglie logiche



Vedere:

- Paolo Spirito, “Elettronica Digitale”, Ed. McGraw-Hill
  - Cap. 7.1-7.3, 7.5 (p.194)
  - Cap. 8.1-8.4, 8.8, 8.10