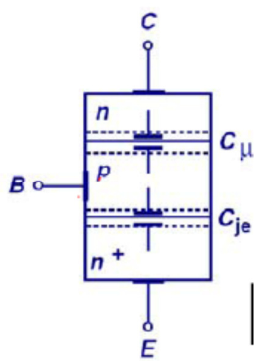
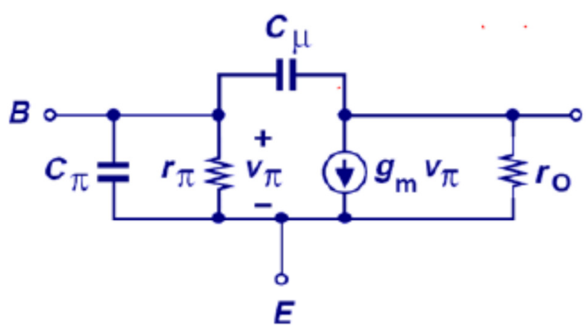
Comportamento del BJT ad alta frequenza:
Legato a caratteristiche reattive delle giunzioni

Zona attiva:
Giunzione di emettitore pol. diretta → Cap. di transizione + Cap. di diffusione
Giunzione di collettore pol. inversa → Capacita' di transizione

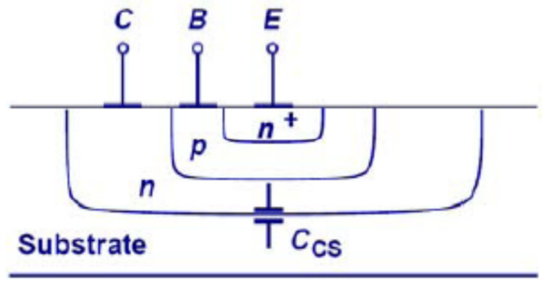


Modello a π ibrido esteso ad elementi reattivi:

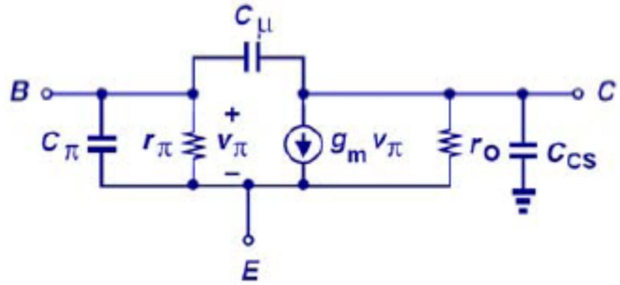


Capacita' effettive delle giunzioni:
$C_\pi = C_{be} + C_{diff}$ transizione + diffusione
$C_\mu = C_{bc}$ transizione

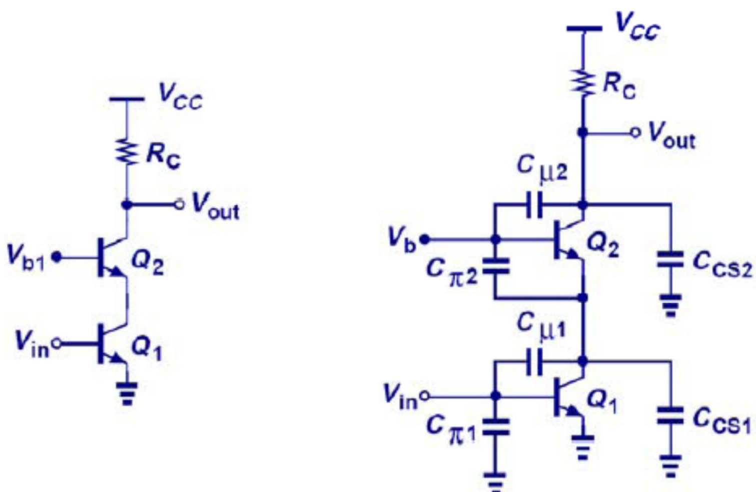
Inoltre, nei circuiti integrati:
C_{cs} capacita' collettore-substrato



Modello completo per BJT in CI:



Es: Capacita' in un circuito specifico ('Cascode', v. dopo)

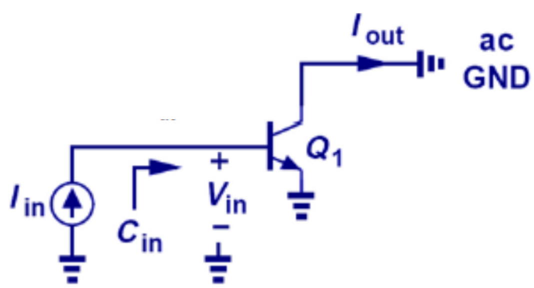


Effetto principale della capacita' C_π:

Riduzione del guadagno di corrente ad alta frequenza

Def: ω_T frequenza di guadagno unitario

Misura 'concettuale':



$$I_{out} = g_m V_{in}$$

$$V_{in} = Z_{in} I_{in}$$

$$\rightarrow I_{out} = g_m Z_{in} I_{in}$$

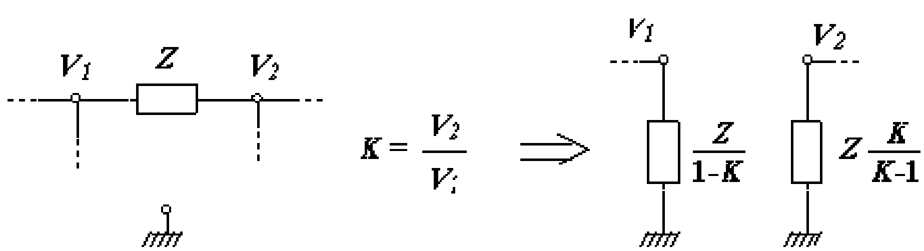
$$\rightarrow \frac{I_{out}}{I_{in}} = g_m Z_{in} = g_m \frac{1}{j\omega C_\pi}$$

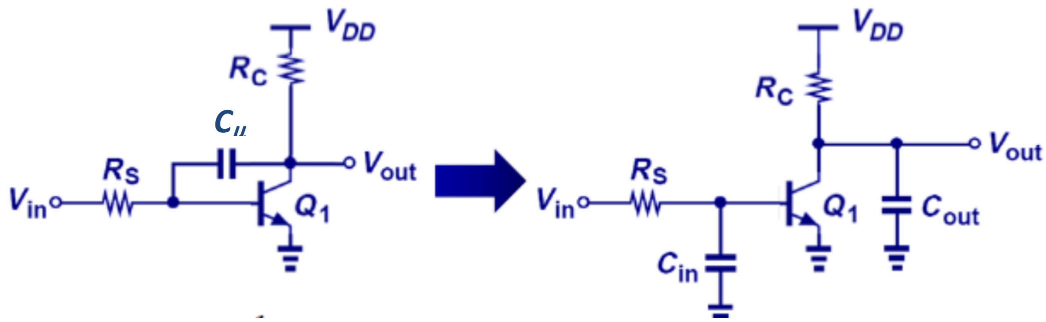
$$\left|\frac{I_{out}}{I_{in}}\right| = 1 \rightarrow \frac{g_m}{\omega_T C_\pi} = 1 \rightarrow \omega_T = \frac{g_m}{C_\pi}$$

Effetto di C_μ: ???

Difficile da visualizzare: Capacita' 'floating', senza terminali a ground

$\rightarrow$ Teorema di Miller (non dimostrato):





$$Z_1 = \frac{\frac{1}{j\omega C_\mu}}{1 - A_v} = \frac{1}{j\omega C_\mu (1 - A_v)}$$

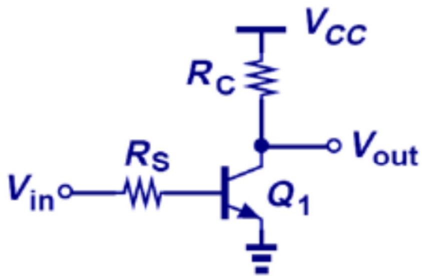
$$Z_2 = \frac{\frac{1}{j\omega C_\mu}}{1 - \frac{1}{A_v}} = \frac{1}{j\omega C_\mu \left(1 - \frac{1}{A_v}\right)}$$

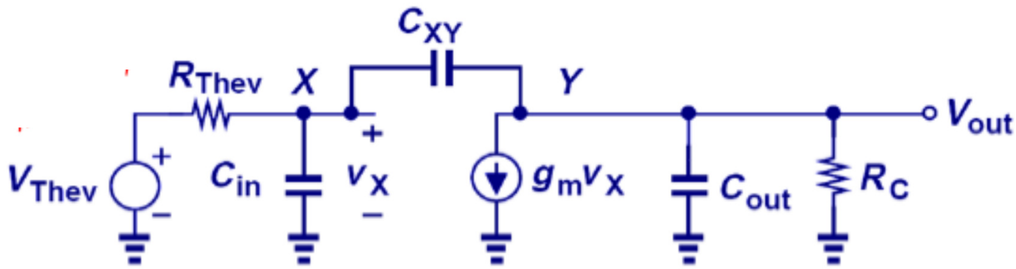
$A_v < 0 \rightarrow C_\mu \nearrow$:

Effetto Miller = Aumento della capacita' floating

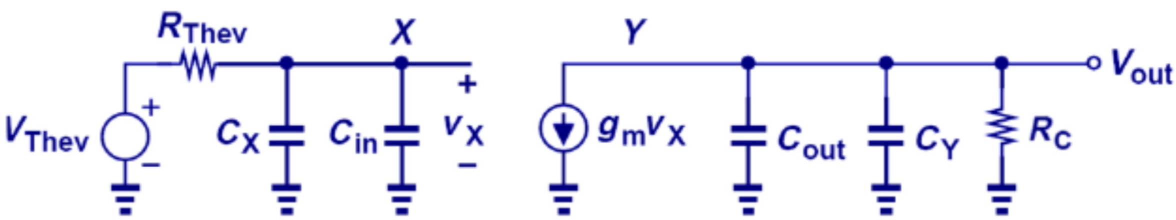
$|A_v| \gg 1 \rightarrow$ Effetto dominante quello di C_{in}

Applicazione a stadio *CE*:





Teorema di Miller:



$$V_{Thev} = V_{in} \frac{r_\pi}{r_\pi + R_S}$$

$$R_{Thev} = R_S \| r_\pi$$

$$C_X = C_\mu (1 + g_m R_C)$$

$$C_Y = C_\mu \left(1 + \frac{1}{g_m R_C}\right)$$

Frequenze di taglio, ingresso e uscita, per guadagno:

$$\omega_{p,in} = \frac{1}{R_{Thev}\left(C_{in} + (1 + g_m R_C) C_\mu\right)}$$

$$\omega_{p,out} = \frac{1}{R_C\left(C_{out} + \left(1 + \frac{1}{g_m R_C}\right) C_\mu\right)}$$

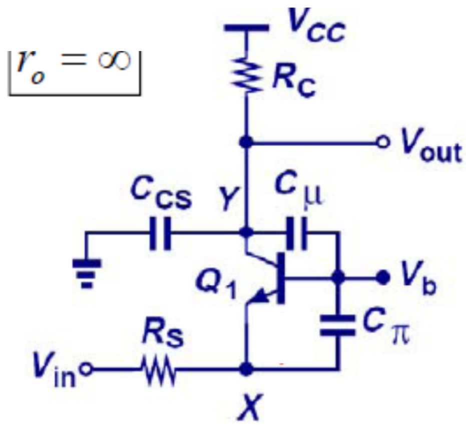
Impedenze di ingresso e uscita:

$$Z_{in} \approx \frac{1}{j\omega\left[C_\pi + \left(1 + g_m (R_C \| r_o)\right) C_\mu\right]} \| r_\pi$$

$$Z_{out} = \frac{1}{j\omega\left[C_\mu + C_{CS}\right]} \| R_C \| r_o$$

Applicazione a stadio a *CB*:
Vantaggi notevoli nella risposta in frequenza

Nessuna capacita' fra in e out
→ Nessuna capacita' floating
→ No effetto Mill a valore fisso!)



$$\omega_{p,Y} = \frac{1}{R_C C_Y}$$

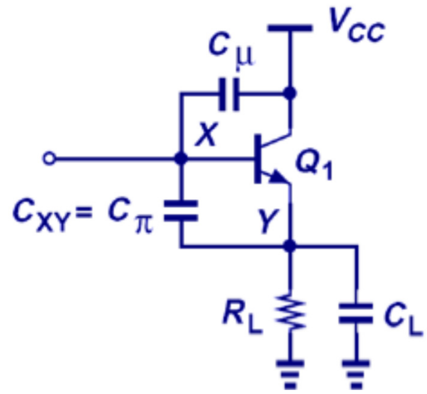
$$C_Y = C_\mu + C_{CS}$$

$$\omega_{p,X} = \frac{1}{\left(R_S \,||\, \frac{1}{g_m}\right) C_X} > \omega_T$$

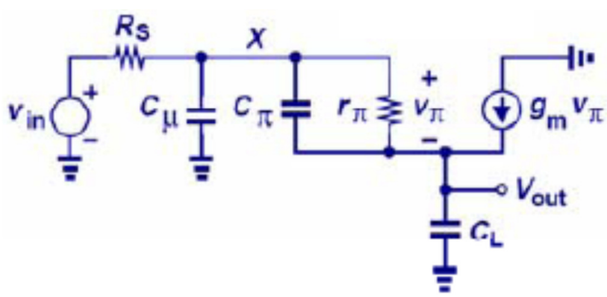
$$C_X = C_\pi$$

→ Frequenze di taglio ~ Essenzialmente indipendenti dal guadagno

Applicazione a stadio a CC (Emitter follower):



Modello a π ibrido (trascurando r_0):



Legge di Kirchoff al nodo X e al nodo di out

+

un po' (..) di algebra:

$$\frac{v_{out}}{v_{in}} \cong \frac{1+\frac{C_\pi}{g_m}(j\omega)}{a(j\omega)^2+b(j\omega)+1}$$

$$a = \frac{R_S}{g_m}\left(C_\mu C_\pi + C_\mu C_L + C_\pi C_L\right)$$

$$b = R_S C_\mu + \frac{C_\pi}{g_m} + \left(1+\frac{R_S}{r_\pi}\right)\frac{C_L}{g_m}$$

In questo caso la capacita' floating e' C_π!

Guadagno dello stadio CC:

$$A_v = \frac{R_L}{R_L + \frac{1}{g_m}}$$

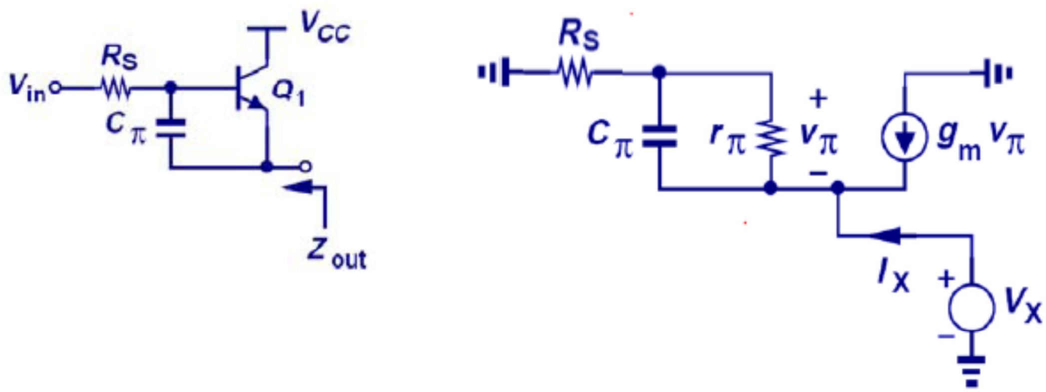
→ Cap. equivalenti di Miller:

$$C_X = (1 - A_v)C_\pi = \frac{C_\pi}{1 + g_m R_L}$$

$$C_Y = \left(1 - \frac{1}{A_v}\right)C_\pi = \frac{-C_\pi}{g_m R_L}$$

$$\boxed{C_{in} = C_\mu + \frac{C_\pi}{1 + g_m R_L}}$$

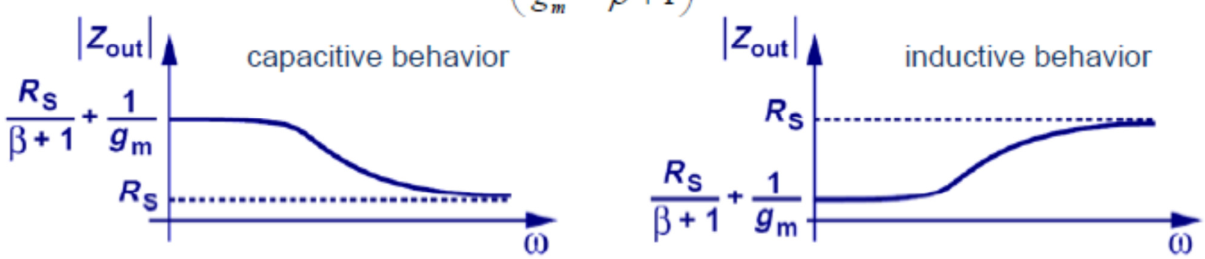
Impedenza di uscita:



$$Z_{out} \equiv \frac{v_X}{i_X} = \frac{R_S r_\pi C_\pi (j\omega) + r_\pi + R_S}{r_\pi C_\pi (j\omega) + \beta + 1} = \left(\frac{r_\pi + R_S}{\beta + 1}\right) \cdot \frac{1 + \dfrac{j\omega}{(r_\pi + R_S)/R_S r_\pi C_\pi}}{1 + \dfrac{j\omega}{(\beta+1)/r_\pi C_\pi}}$$

$$\swarrow \left(\frac{1}{g_m} + \frac{R_S}{\beta + 1}\right)$$

CASE 1: $R_S < 1/g_m$ — **CASE 2**: $R_S > 1/g_m$



→ Nella situazione standard $R_S > \dfrac{1}{g_m}$

→ Emitter follower $\sim$ 'Induttore attivo'