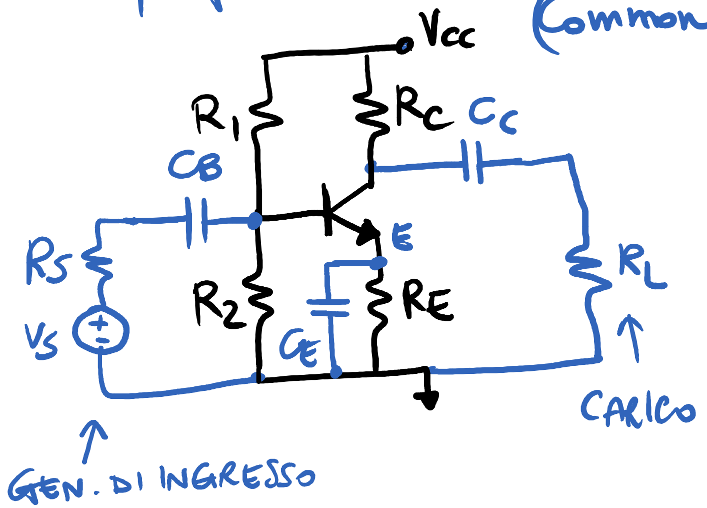
Amplificatori con BJT

Thursday, March 16, 2017 9:47 AM

→ Amplificatore a EMETTITORE COMUNE (Common Emitter) CE



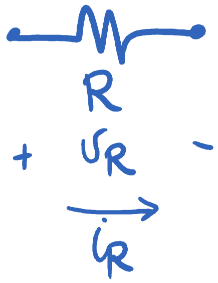
C_B, C_C capacità di accoppiamento

C_E capacità di bypass

il valore di C_B, C_C, C_E è tale che alla frequenza del segnale si comportino come un corto circuito

CIRCUITO DI PICCOLO SEGNALE

Thursday, March 16, 2017 9:56 AM



$$v_R = R\, i_R$$

$$(V_R + v_r) = R(I_R + i_r)$$

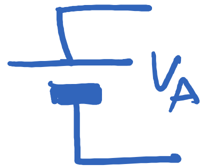
componente continua $V_R = R I_R$

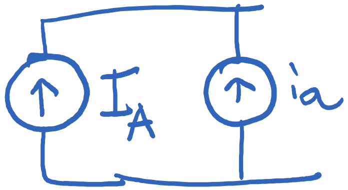
piccolo segnale $v_r = R i_r$

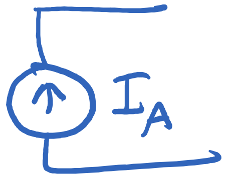
$V_A = v_a + V_A$

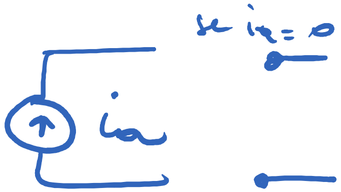
IN CONTINUA

per il piccolo segnale



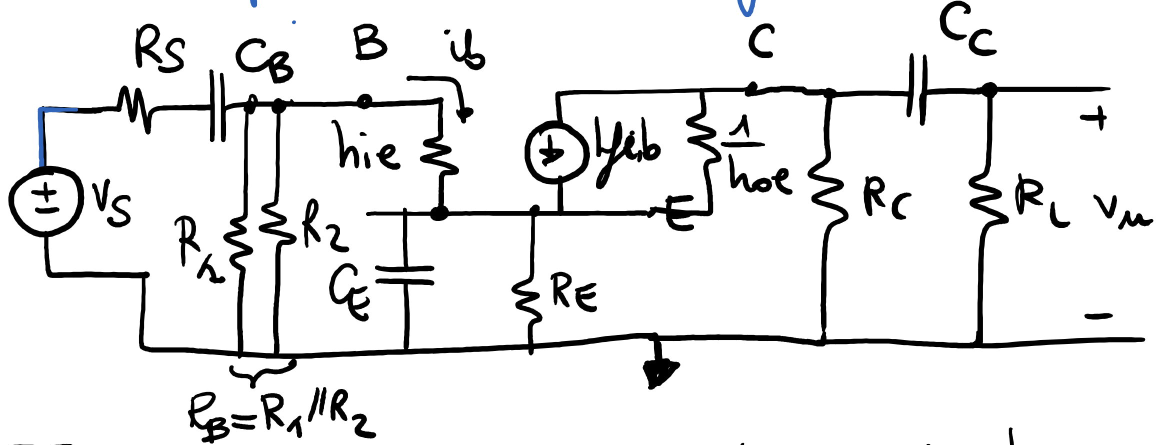






Circuito equivalente di piccolo segnale

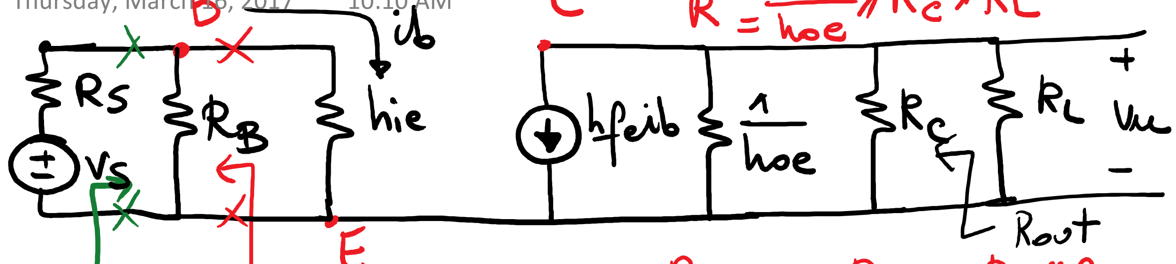
Thursday, March 16, 2017 10:02 AM



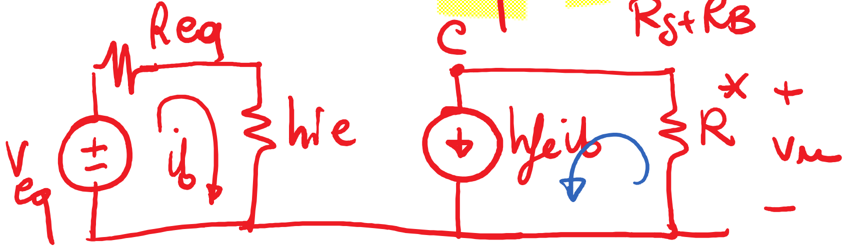
Hp alla frequenza del piccolo segnale, le capacità (C_B, C_E, C_C) sono un corto circuito

[alla f. del piccolo segnale le capacità interne del transistore sono considerabili come un circuito aperto]

$$R^* = \frac{1}{h_{oe}} /\!/ R_C /\!/ R_L$$



$$V_{eq} = V_s \frac{R_B}{R_S + R_B} \qquad R_{eq} = R_S /\!/ R_B$$



$$i_b = \frac{V_{eq}}{R_{eq} + h_{ie}}$$

$$v_u = -h_{fe} i_b R^*$$

$$A_{CB} = \frac{v_u}{v_s} = \frac{-h_{fe} R^*}{R_{eq} + h_{ie}} \left(\frac{R_B}{R_S + R_B} \right)$$

← AMPLIFICAZIONE DI TENSIONE A CENTRO BANDA DI UN AMPLIFICATORE CE

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- Amplificazione intrinseca a VUOTO
  [A_{vs} con generatore di ingresso ideale $(R_S = 0)$
  e impedenza di carico infinita $(R_L \to \infty)$

$$A_{vo} = -\frac{h_{fe}}{h_{ie}}\left(\frac{1}{h_{oe}} // R_C\right)$$

- Impedenza di ingresso [impedenza vista dal generatore di ingresso]

$$R_{in} = R_B // h_{ie}$$

- Impedenza di uscita [impedenza eq. di Thevenin vista dal carico

$$R_{out} = R_C // \frac{1}{h_{oe}}$$

Circuito equivalente di un Amplificatore

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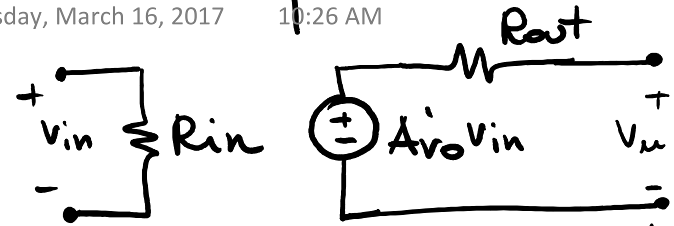
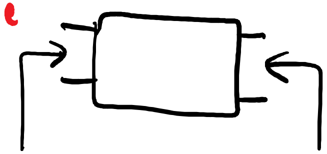
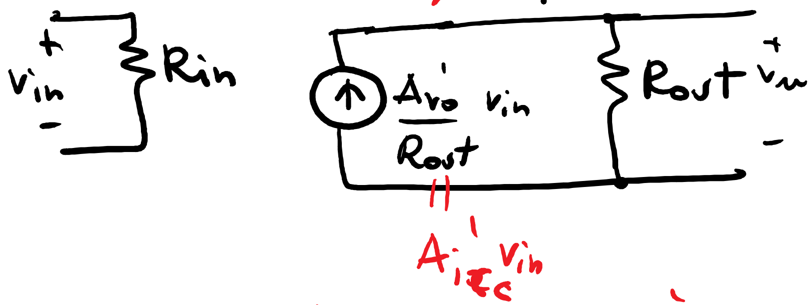




↑ Equivalente di Thevenin

Equivalente di Norton



$$A'_{i_{cc}} = \frac{A'_{vo}}{R_{out}}$$

È RIGOROSO SE L'AMPLIFICATORE È UNIDIREZIONALE

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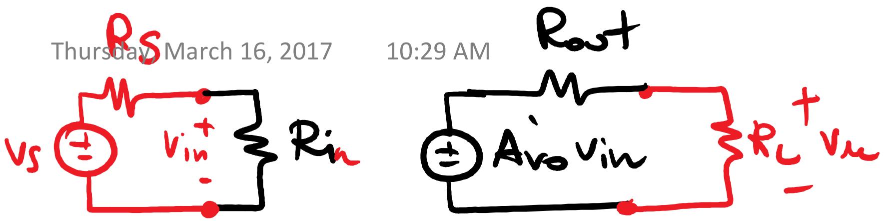

$$v_{in} = v_s \frac{R_{in}}{R_{in}+R_s} \qquad v_u = A'_{vo} v_{in} \frac{R_L}{R_L+R_{out}}$$

$$A_v = \frac{v_u}{v_s} = A'_{vo} \cdot \left(\frac{R_{in}}{R_{in}+R_s}\right) \cdot \left(\frac{R_L}{R_L+R_{out}}\right) \leq A'_{vo}$$

A_v ↑ AMPLIFICAZIONE DI TENSIONE

nel caso CE

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$$A_{Vo}' \cdot \left(\frac{R_L}{R_L+R_{out}}\right)\left(\frac{R_{in}}{R_{in}+R_S}\right) = -\frac{h_{fe}}{h_{ie}}\left(\frac{1}{h_{oe}} /\!/ R_C\right)\left(\frac{R_L}{R_L+R_{out}}\right)\left(\frac{R_{in}}{R_{in}+R_S}\right)$$

$R_{out} = \frac{1}{h_{oe}} /\!/ R_C$ $\quad R_{in} = (R_B /\!/ h_{ie})$

$$A_{CB} = -\frac{h_{fe}}{(h_{ie}+R_S /\!/ R_B)}\left(\frac{1}{h_{oe}} /\!/ R_C /\!/ R_L\right)\left(\frac{R_B}{R_B+R_S}\right)$$

$$\frac{1}{h_{ie}} \cdot \frac{R_B /\!/ h_{ie}}{R_B /\!/ h_{ie} + R_S} = \frac{1}{h_{ie}} \cdot \frac{R_B h_{ie}}{R_B h_{ie} + R_S(R_B + h_{ie})} = \frac{R_B}{h_{ie}(R_B+R_S) + R_S R_B} =$$

$$= \frac{R_B}{\left[h_{ie} + \frac{R_S R_B}{R_S + R_B}\right]} \cdot \frac{1}{(R_B+R_S)} = \frac{1}{h_{ie} + R_B /\!/ R_S} \cdot \left(\frac{R_B}{R_B+R_S}\right)$$

Amplificatore CE con RE

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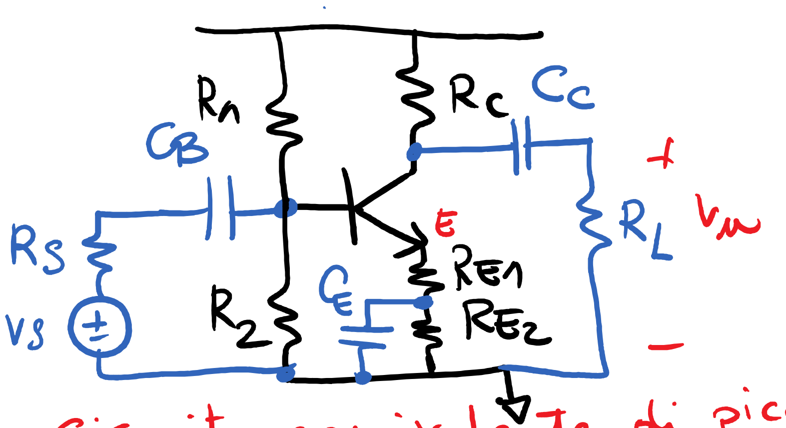
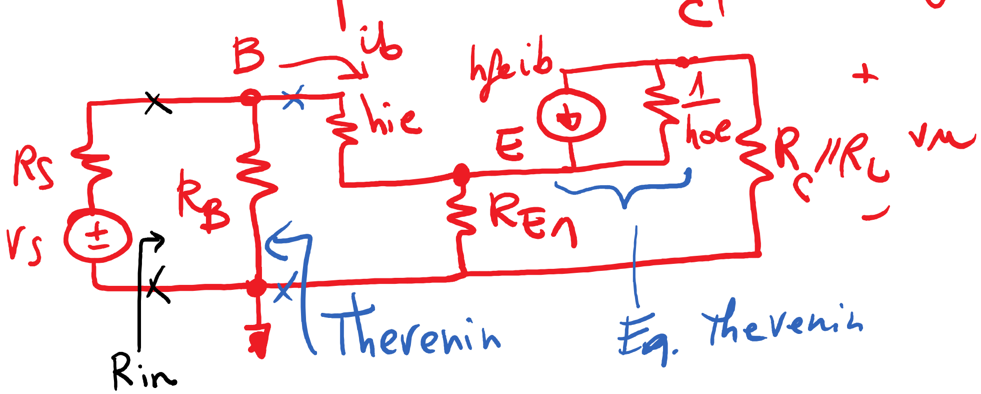
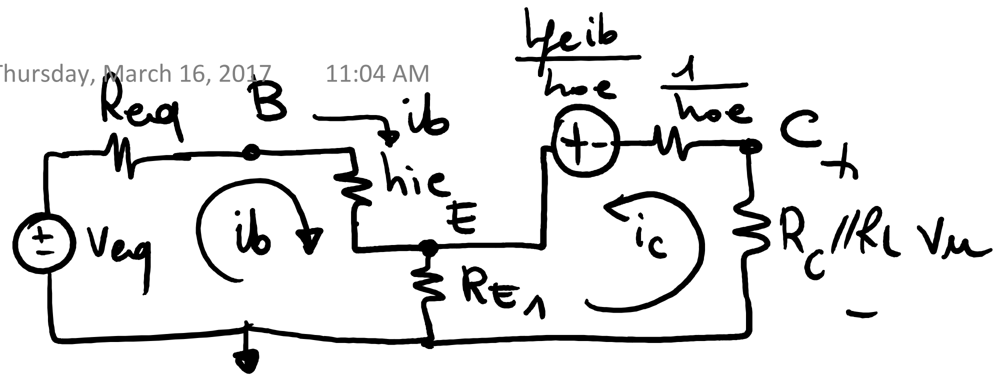


Circuito equivalente di piccolo segnale a CB





$R_{eq} = R_B // R_S$

$V_{eq} = V_S \frac{R_B}{R_B + R_S}$

equazioni alle maglie

$$\begin{cases} V_{eq} = i_b \left[R_{eq} + h_{ie} + R_{E1} \right] + i_c R_{E1} \\ \frac{h_{fe} i_b}{h_{oe}} = i_b R_{E1} + i_c \left[R_{E1} + R_C // R_L + \frac{1}{h_{oe}} \right] \end{cases}$$

$$\frac{i_c}{i_b} = \frac{h_{fe} - R_{E1} h_{oe}}{1 + h_{oe}(R_{E1} + R_C // R_L)} = h_{fe}'$$

$\left[\begin{array}{l} h_{fe}' \leq h_{fe} \\ h_{fe}' = h_{fe} \text{ SE } h_{oe} = 0 \end{array} \right]$

$$V_{eq} = \frac{i_c}{h_{fe}'}\left(R_{eq} + h_{ie} + R_{E1}\right) + i_c R_{E1}$$

$$i_c = \frac{V_{eq}}{R_{E1} + \dfrac{R_{eq} + h_{ie} + R_{E1}}{h_{fe}'}} \Rightarrow \underline{\underline{v_u}} = -i_c\, R_C /\!/ R_L$$

$$A_{VCB} = \frac{v_u}{V_S} = \left[\frac{-R_C /\!/ R_L}{R_{E1} + \left(\dfrac{R_{eq} + h_{ie} + R_{E1}}{h_{fe}'}\right)} \left(\frac{R_B}{R_B + R_S}\right)\right]$$

se $R_{E1} = 0$ devo trovare il caso precedente:

$$A_{CB} = \frac{-R_C /\!/ R_L \; h_{fe}}{(R_{eq} + h_{ie})(1 + h_{oe}(R_C /\!/ R_L))}$$

se hfe è sufficientemente grande da far sì che

$$\frac{R_{eq} + h_{ie} + R_{E1}'}{h_{fe}'} \ll R_{E1}$$

allora

$$A_{CB} \simeq -\frac{R_C /\!/ R_L}{R_{E1}} \frac{R_B}{R_B + R_S}$$

← A_{CB} NON DIPENDE DAI PARAMETRI INTERNI DEL TRANSISTORE.

NOTA che se $R_{E1} \uparrow$ $A_{CB} \downarrow$

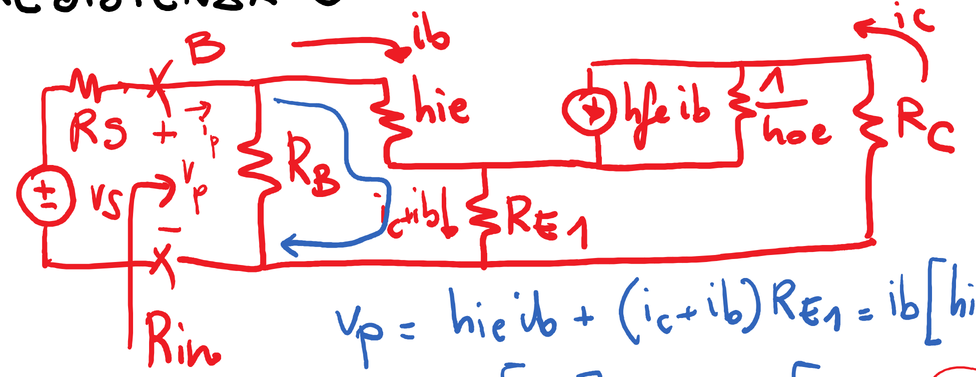
TRADE OFF di Progettazione.

Amplificazione intrinseca a vuoto

$$A'_{vo} = A_{CB}\Big|_{\substack{R_S=0 \\ R_L\to\infty}} = \frac{-R_C}{R_{E1} + \left[\dfrac{h_{ie} + R_{E1}}{h_{fe}'}\right]}$$

[se $h_{fe}' \gg 1$: $A'_{vo} \sim -\dfrac{R_C}{R_{E1}}$]

RESISTENZA DI INGRESSO



$$\frac{i_c}{i_b} = h_{fe}'$$

$$v_p = h_{ie}\, i_b + (i_c + i_b) R_{E1} = i_b \left[h_{ie} + R_{E1}(1 + h_{fe}')\right]$$

$$R_{in} = R_B // \left[\frac{v_p}{i_b}\right] = R_B // \left[h_{ie} + R_{E1}(1 + h_{fe}')\right]$$

RESISTENZA DI USCITA

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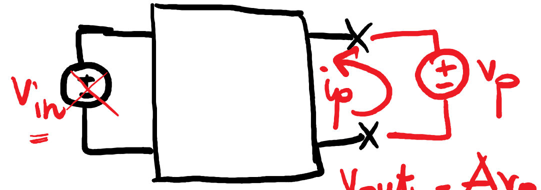
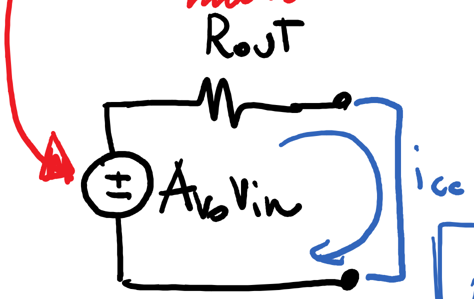


$V_{out} = A_{vo} V_{in}$

Amplificatore di tensione a vuoto



Resistenza equivalente all'uscita

$$R_{out} = \frac{v_p}{i_p} \Bigg|_{\text{GENERATORI INDIPENDENTI SPENTI}}$$

Generatore equivalente di Thevenin

ALTRO METODO PER CALCOLARE LA R_{OUT}

i_{cc} CORRENTE DI USCITA DI CORTO CIRCUITO

$$i_{cc} = \frac{A_{vo} V_{in}}{R_{out}}$$

$$\boxed{R_{out} \triangleq \frac{V_{out}^{o}}{i_{cc}}} = \frac{A_{vo} V_{in} \, R_{out}}{A_{vo} V_{in}} = R_{out}$$

Tensione di uscita a vuoto

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$$v_{uo} = A_v \Big|_{R_L=\infty} v_s = A_{v_o} v_s = \frac{-R_C}{R_{E_1} + \left(\frac{R_{eq} + R_{E_1} + h_{ie}}{h_{fe}'}\right)} v_s \left(\frac{R_B}{R_B + R_S}\right)$$

$$h_{fe}' = \frac{h_{fe} - R_{E_1} h_{oe}}{1 + h_{oe}(R_{E_1} + R_C)}$$

CORRENTE DI USCITA DI CORTO CIRCUITO

$$i_{ucc} = i_u \Big|_{R_L \to 0} = \lim_{R_L \to 0} \frac{v_u}{R_L} = \lim_{R_L \to 0} \left(\frac{A_{vB}}{R_L}\right) v_s = v_s \cdot \lim_{R_L \to 0} \left[\frac{-R_C /\!/ R_L \left(\frac{R_B}{R_B + R_S}\right)}{\left[R_{E_1} + \left(\frac{R_{eq} + R_{E_1} + h_{ie}}{h_{fe}'}\right)\right] R_L}\right]$$

$$= -v_s \frac{\left(\frac{R_B}{R_B + R_S}\right)}{R_{E_1} + \left(\frac{R_{eq} + R_{E_1} + h_{ie}}{h_{fe}'}\right)} \underbrace{\lim_{R_L \to 0} \left[\frac{R_C R_L}{(R_C + R_L) R_L}\right]}_{1}$$

$$h_{fe}' = \frac{h_{fe} - R_{E_1} h_{oe}}{1 + h_{oe} R_{E_1}}$$

$$R_{out} = \frac{v_{uo}}{i_{ucc}} = \frac{+R_C}{R_{E_1} + \left(\frac{R_{eq} + R_{E_1} + h_{ie}}{h_{fe} - R_{E_1} h_{oe}}\right)\left(1 + h_{oe}(R_{E_1} + R_C)\right)} \left[R_{E_1} + \left(\frac{R_{eq} + R_{E_1} + h_{ie}}{h_{fe} - R_{E_1} h_{oe}}\right)(1 + h_{oe} R_{E_1})\right]$$

$$\lesssim R_C$$

Se $h_{oe} R_C \ll 1$ e $h_{oe} R_{E_1} \ll 1$ allora $R_{out} \simeq R_C$

→ $h_{fe}' \simeq h_{fe}$

SE QUESTA CONDIZIONE SI VERIFICA POSSIAMO RIMUOVERE h_{oe} dal CIRCUITO.

Amplificatore a collettore comune (CC common collector)

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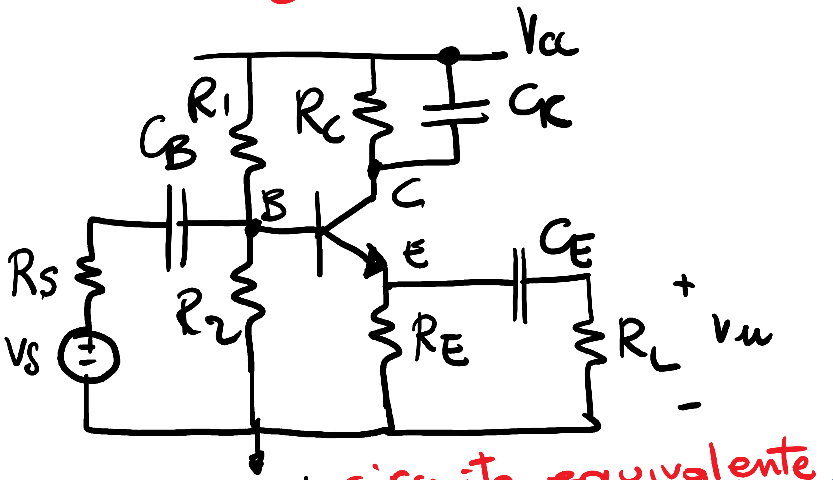
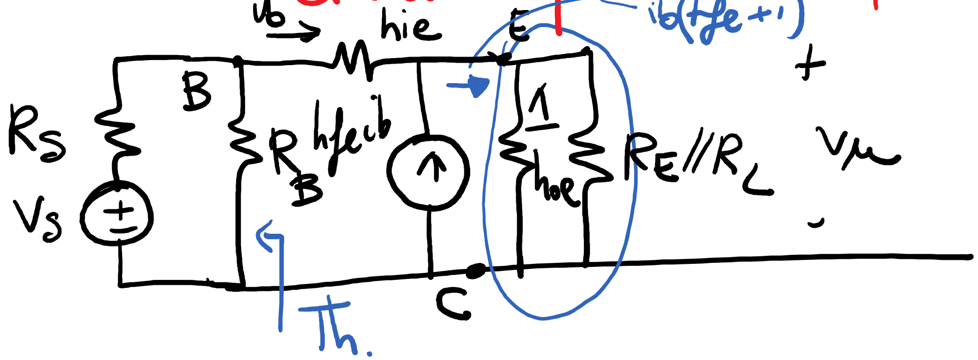


circuito equivalente di piccolo segnale (a CB)



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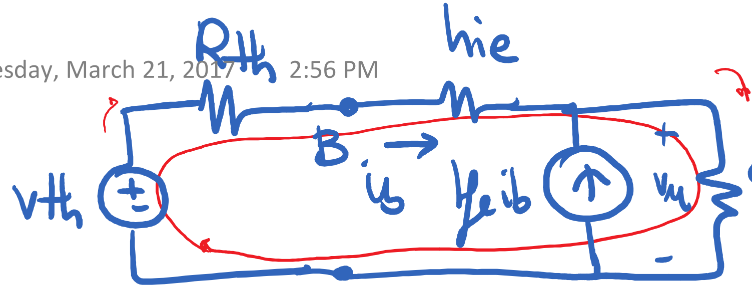

$$\frac{1}{h_{oe}} // R_C // R_L = R^*$$

$$R_{th} = R_S // R_B$$

$$v_{th} = \frac{R_B}{R_B + R_S} v_S$$

$$v_{th} = (R_{th} + h_{ie}) i_b + (h_{fe}+1) i_b R^*$$

$$v_u = (h_{fe}+1) i_b R^*$$

$$A_{CB} = \frac{v_u}{v_S} = \left(\frac{v_u}{v_{th}}\right)\left(\frac{v_{th}}{v_S}\right) = \left(\frac{(h_{fe}+1)R^*}{(h_{fe}+1)R^* + R_{th} + h_{ie}}\right)\left(\frac{R_B}{R_B + R_S}\right)$$

$* A_{CB} > 0$
$* A_{CB} < 1$

AMPLIFICAZIONE INTRINSECA A VUOTO

$$A'_{CBo} = \frac{(h_{fe}+1)\left[\frac{1}{h_{oe}} // R_C\right]}{(h_{fe}+1)\left[\frac{1}{h_{oe}} // R_C\right] + h_{ie}}$$

Resistenza di ingresso

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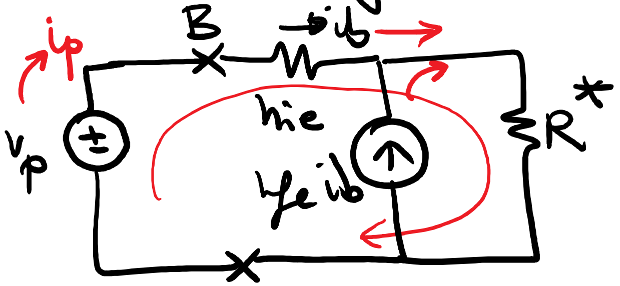

- Applico il generatore ideale di prova
- Rimuovo R_B
- Risolvo

$v_p = h_{ie} i_b + (h_{fe}+1) i_b R^*$

$\frac{v_p}{i_p} = \frac{v_p}{i_b} = h_{ie} + R^*(h_{fe}+1)$

- Re-inserisco R_B

- $R_{IN} = R_B // [h_{ie} + R^*(h_{fe}+1)]$

Rout

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$$R_{out} = \frac{V_{uo}}{i_{ucc}}$$

$$V_{uo} = A_v\Big|_{R_L\to\infty} v_s = \frac{(h_{fe}+1)\left[\frac{1}{h_{oe}} \,//\, R_C\right]}{(h_{fe}+1)\left[\frac{1}{h_{oe}} \,//\, R_C\right] + R_{eq} + h_{ie}} \left(\frac{R_B}{R_B+R_S}\right)$$

$$i_{ucc} = \lim_{R_L\to 0}\left[\frac{V_u}{R_L}\right] = \lim_{R_L\to 0}\left[\frac{A_v}{R_L}\right] v_s =$$

$$= \lim_{R_L\to 0}\left[\frac{(h_{fe}+1)\left[\frac{1}{h_{oe}} // R_C // R_L\right]\frac{1}{R_L}}{(h_{fe}+1)\left[\frac{1}{h_{oe}} // R_C // R_L\right] + R_{eq} + h_{ie}}\right]\left(\frac{R_B}{R_B+R_S}\right) v_s = \frac{(h_{fe}+1)}{R_{eq}+h_{ie}}\left(\frac{R_B}{R_B+R_S}\right)$$

$$R_{out} = \frac{V_{uo}}{i_{ucc}} = \frac{(R_{eq}+h_{ie})\left[\frac{1}{h_{oe}} // R_C\right]}{(h_{fe}+1)\left[\frac{1}{h_{oe}} // R_C\right] + R_{eq}+h_{ie}} \simeq \left(\frac{R_{eq}+h_{ie}}{h_{fe}+1}\right)$$

	A_{vo}'	R_{in}	R_{out}
CE	<0 alta	media	media
CE con R_E	<0 media	alta	media
CC	>0 bassa $(0<A_{vo}'<1)$	alta	bassa

Amplificatore a più stadi

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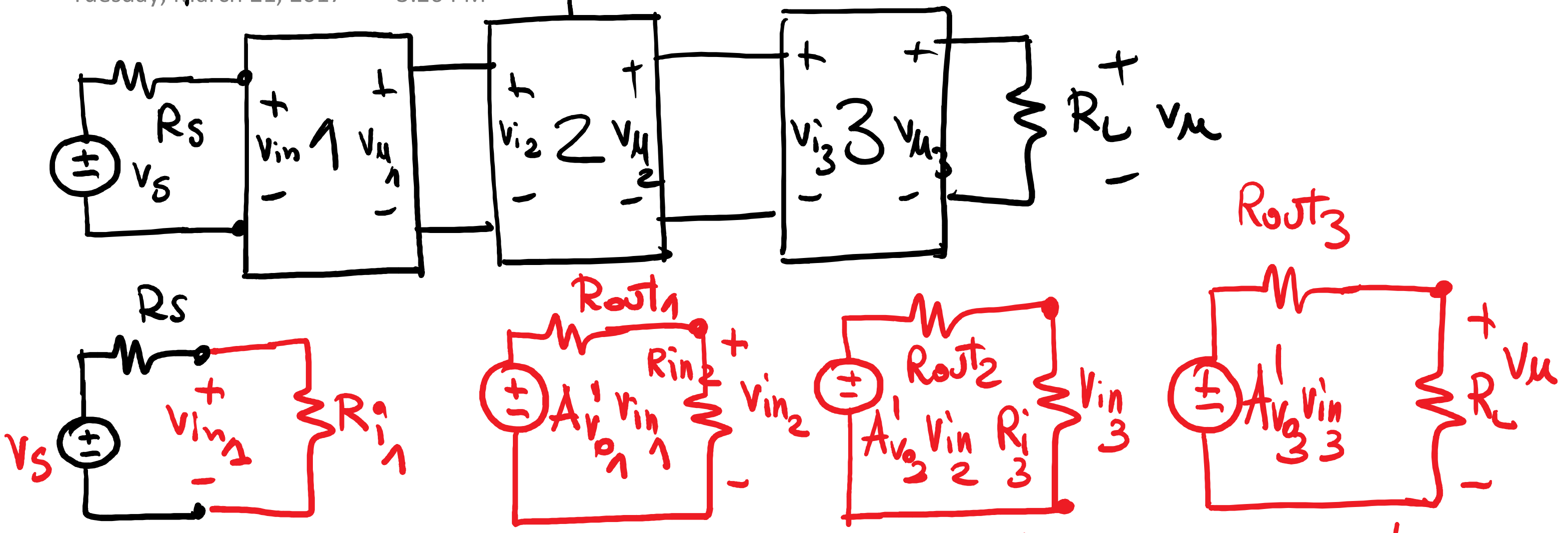

$$V_{in_1} = V_S \frac{R_{i_1}}{R_{i_1}+R_S}$$

$$V_{in_2} = A'_{vo_1} V_{in_1} \frac{R_{in_2}}{R_{in_2}+R_{out_1}}$$

$$V_{i3} = A'_{vo_2} V_{in_2} \frac{R_{in_3}}{R_{in_3}+R_{out_2}}$$

$$V_u = \frac{A'_{vo_3} V_{in_3} R_L}{R_L+R_{out_3}}$$

$$A_V = \frac{V_u}{V_S} = A'_{vo_3} A'_{vo_2} A'_{vo_1} \cdot \left(\frac{R_L}{R_L+R_{out_3}}\right)\left(\frac{R_{in_3}}{R_{in_3}+R_{out_2}}\right)\left(\frac{R_{in_2}}{R_{in_2}+R_{out_1}}\right)\left(\frac{R_{i_1}}{R_{i_1}+R_S}\right)$$

$R_{in} = R_{i1}$

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$R_{out} = R_{out3}$

↳ il PRIMO STADIO impone la **Rin**

L'ULTIMO STADIO impone la **Rout**

GLI STADI INTERMEDI consentono di ottenere la **Av** richiesta

Amplificatore differenziale con BJT

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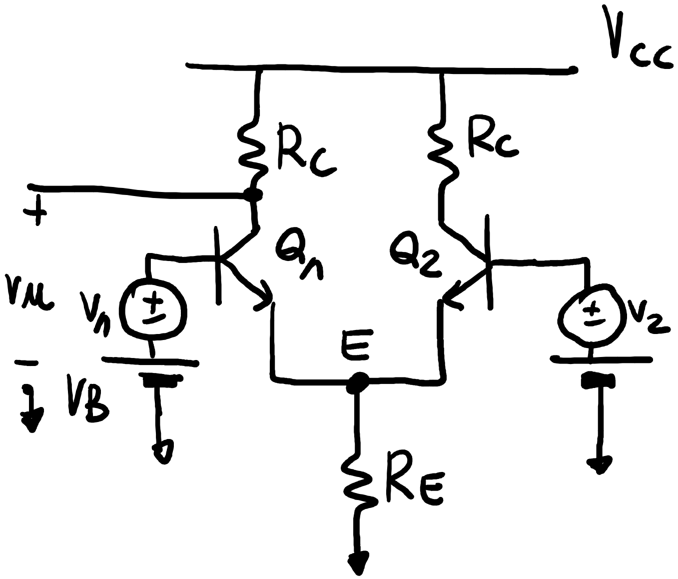

CIRCUITO PERFETTAMENTE SIMMETRICO

$$v_c = \frac{v_1 + v_2}{2}$$ ← tensione di ingresso in modo comune

$$v_d = v_1 - v_2$$ ← tensione di ingresso in modo differenziale

$$v_1 = v_c + \frac{v_d}{2}$$

$$v_2 = v_c - \frac{v_d}{2}$$

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$v_u = A v_1 + B v_2$

combinazione lineare

$$v_u = \left(\frac{A-B}{2}\right)(v_1 - v_2) + (A+B)\left(\frac{v_1+v_2}{2}\right)$$

$\frac{A-B}{2}$ → A_d AMPLIFICAZIONE DIFFERENZIALE

$(v_1 - v_2)$ → v_d

$(A+B)$ → A_c AMPLIFICAZIONE DI MODO COMUNE

$\frac{v_1+v_2}{2}$ → v_c

$v_u = A_d v_d + A_c v_c$

AMPLIFICATORE SI DICE DIFFERENZIALE SE

$A_d \gg A_c$

Rapporto di Reiezione del modo comune [Common mode rejection ratio] $CMRR = \frac{A_d}{A_c}$

Funzionamento in modo differenziale

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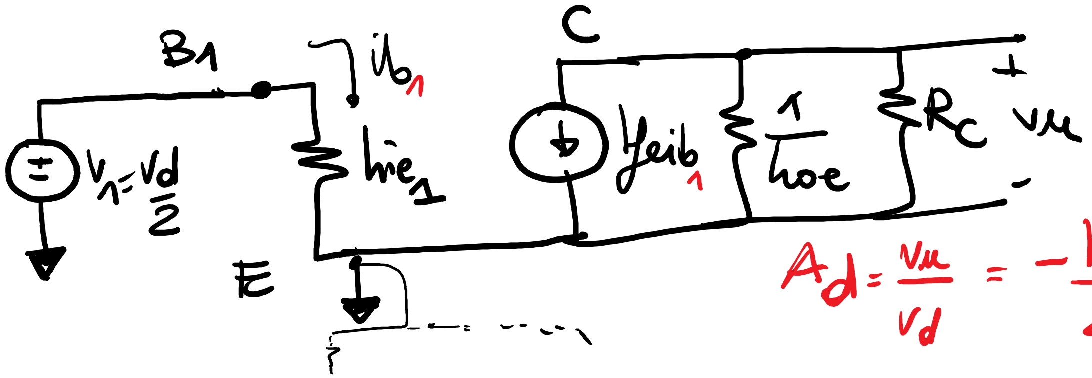
$v_c = 0$ $\qquad v_u = A_d v_d \qquad v_1 = v_d/2$, $\; v_2 = -v_d/2$

PER SOVRAPPOSIZIONE DEGLI EFFETTI I NODI CHE SI TROVANO NELLA STESSA POSIZIONE RISPETTO AI DUE GENERATORI DI INGRESSO HANNO UNA VARIAZIONE DI TENSIONE NULLA [per il piccolo segnale sono a MASSA]



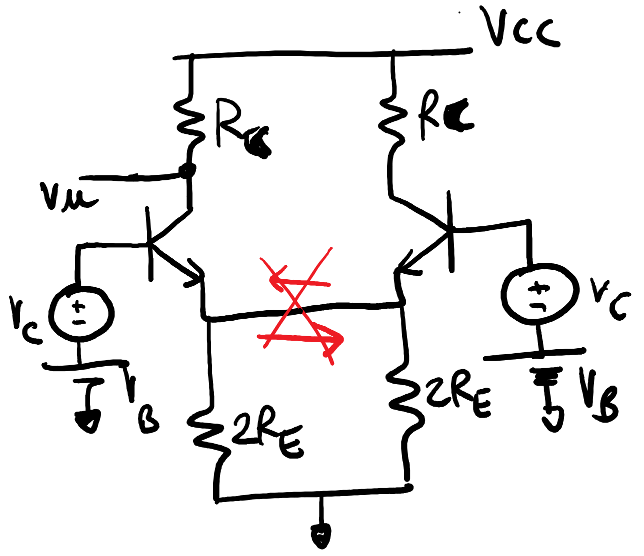
$$i_{b_1} = \frac{v_d}{2}\frac{1}{h_{ie_1}}$$

$$v_u = -h_{fe} i_{b_1}\left(R_C // \frac{1}{h_{oe}}\right)$$

$$A_d = \frac{v_u}{v_d} = -\frac{h_{fe}}{2}\frac{\left[R_C // \frac{1}{h_{oe}}\right]}{h_{ie_1}}$$

Funzionamento in modo comune

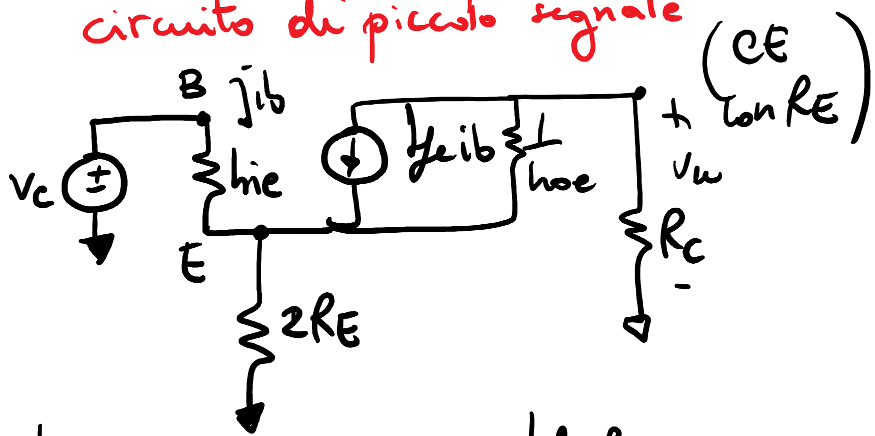
Tuesday, March 21, 2017 4:12 PM



$V_1 = V_c$

$V_2 = V_c$

circuito di piccolo segnale



$$A_C = \frac{v_u}{v_c} = \frac{-h_{fe}' R_c}{h_{ie} + 2R_E(1+h_{fe}')} \simeq \frac{-h_{fe} R_c}{h_{ie} + 2R_E(1+h_{fe})}$$

se $h_{fe}' \simeq h_{fe}$

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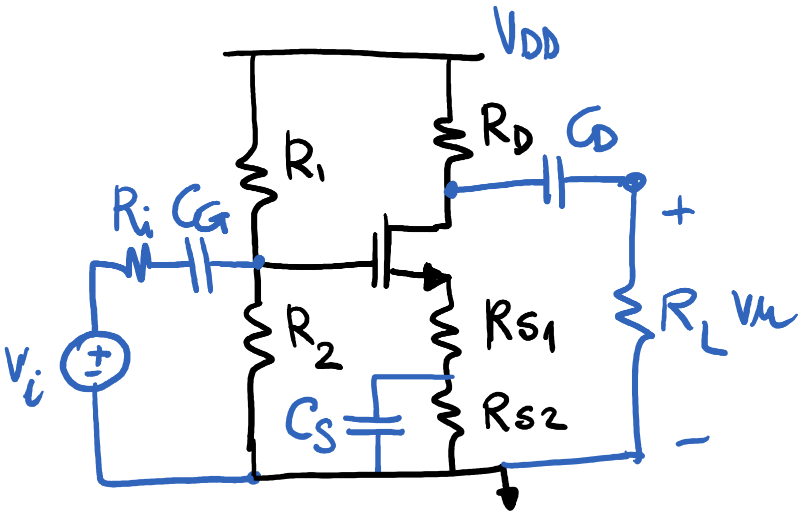
$$CMRR = \frac{A_d}{A_c} = \frac{-h_{fe} R_C}{2 h_{ie}} \cdot \frac{h_{ie} + 2R_E(h_{fe}+1)}{-h_{fe} R_C} = \frac{1}{2} + \frac{R_E}{h_{ie}}(h_{fe}+1)$$

$\uparrow$ ~ 100

Stadi amplificatori con FET

Wednesday, March 22, 2017 1:53 PM

- Stadio a Source comune con R_S



C_G, C_D capacità di accoppiamento

C_S capacità di bypass

Circuito equivalente di piccolo segnale

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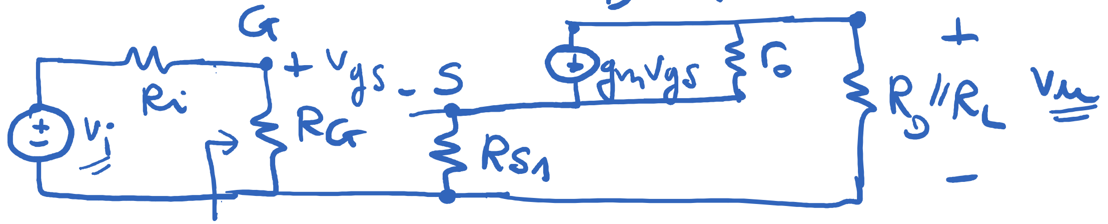

$R_G = R_1 // R_2$

$$v_g = v_i \frac{R_G}{R_G + R_i}$$

$$v_s = g_m v_{gs} r_o \cdot \frac{R_{S1}}{R_{S1} + r_o + R_D // R_L} \Rightarrow v_{gs} = v_g - v_s = v_g - g_m v_{gs} r_o \frac{R_{S1}}{(R_{S1} + r_o + R_D // R_L)}$$

$$v_{gs} = \frac{v_g (R_{S1} + r_o + R_D // R_L)}{(R_{S1} + r_o + R_D // R_L) + g_m R_{S1} r_o}$$

$$v_u = -\frac{g_m v_{gs} r_o \; R_D // R_L}{(R_D // R_L + R_{S1} + r_o)}$$

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$$v_u = \frac{-g_m r_o (R_D /\!/ R_L)\, v_g}{(R_{S_1} + r_o + R_D /\!/ R_L) + g_m r_o R_{S_1}}$$

$$A_v = \frac{v_u}{v_i} = \frac{v_u}{v_g} \cdot \frac{v_g}{v_i} = \frac{-g_m r_o (R_D /\!/ R_L)}{(R_{S_1} + r_o + R_D /\!/ R_L) + \underbrace{g_m r_o}_{30 \simeq 50} R_{S_1}} \cdot \left(\frac{R_G}{R_G + R_i}\right)$$

- SE R_{S_1} È ABBASTANZA GRANDE DA FAR DOMINARE AL DENOMINATORE IL TERMINE $g_m r_o R_{S_1}$

$$A_v = -\left(\frac{R_D /\!/ R_L}{R_{S_1}}\right)\left(\frac{R_G}{R_G + R_i}\right)$$

NON DIPENDE DAI PARAMETRI INTERNI DEL FET

- SE $R_{S_1} = 0$ $\quad A_v = -g_m \left[r_o /\!/ R_D /\!/ R_L\right]\left(\frac{R_G}{R_G + R_i}\right)$

Amplificazione intrinseca a vuoto

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$$A'_{vo} = A_v \Big|_{\substack{R_i = 0 \\ R_L \to \infty}} = \frac{-g_m r_o R_D}{R_{S1} + r_o + R_D + g_m r_o R_{S1}} \quad \left[\text{se } R_{S1} \text{ è abb. grande} \;\sim \frac{-R_D}{R_{S1}}\right]$$

↖ se R_{S1} ↑ A'_{vo} ↓

Resistenza di ingresso

$$R_{in} = R_G$$

Resistenza di uscita

$$R_{out} = \frac{v_{uo}}{i_{ucc}} = \frac{\lim_{R_L \to \infty} \left[A_v\right] v_s}{\lim_{R_L \to 0} \left[\frac{A_v}{R_L}\right] v_s} = \frac{\dfrac{-g_m r_o R_D}{R_{S1} + r_o + R_D + g_m r_o R_{S1}} \cdot \left(\dfrac{R_G}{R_G + R_i}\right)}{\dfrac{-g_m r_o R_D /\!/ R_L}{\left(R_{S1} + r_o + g_m r_o R_{S1}\right) R_L} \left(\dfrac{R_G}{R_G + R_i}\right)}$$

$$= \frac{R_D \left(R_{S1} + r_o + g_m r_o R_{S1}\right)}{R_{S1} + r_o + g_m r_o R_{S1} + R_D} = R_D /\!/ \left(R_{S1} + r_o + g_m r_o R_{S1}\right)$$

se R_{S1} ↑ allora R_{out} ↑

Stadio amplificatore a Drain Comune

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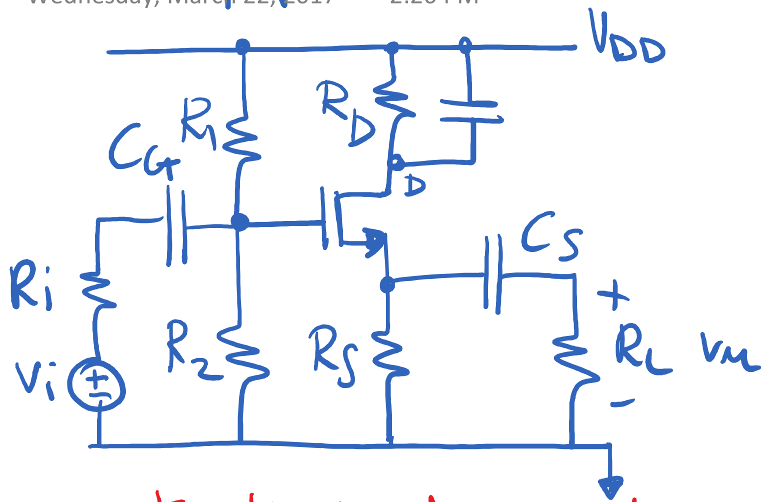
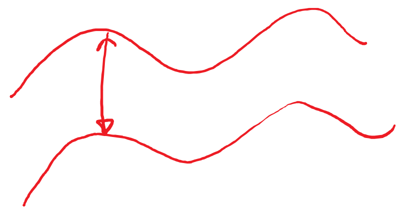
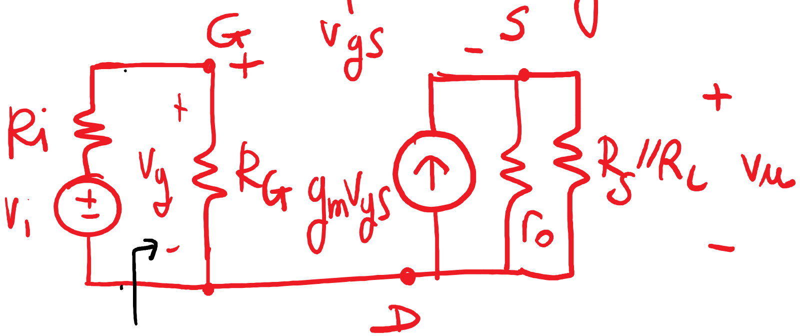




circuito di piccolo segnale a centro banda



$$v_g = v_i \frac{R_G}{R_G + R_i}$$

$$v_u = g_m v_{gs} \left(r_o // R_S // R_L \right)$$

$$v_{gs} \rightarrow (v_g - v_u)$$

$$v_u = g_m (v_g - v_u)(r_o /\!/ R_S /\!/ R_L)$$

$$\frac{v_u}{v_g} = \frac{g_m(r_o /\!/ R_S /\!/ R_L)}{1 + g_m(r_o /\!/ R_S /\!/ R_L)}$$

$$A_V = \frac{v_u}{v_i} = \frac{v_u}{v_g} \cdot \frac{v_g}{v_i} = \left(\frac{g_m(r_o /\!/ R_S /\!/ R_L)}{1 + g_m(r_o /\!/ R_S /\!/ R_L)}\right) \cdot \left(\frac{R_G}{R_G + R_i}\right)$$

$$0 < A_v < 1$$

Se caso $A_V \simeq 1$ il circuito si chiama SOURCE FOLLOWER (INSEGUITORE DI SOURCE)

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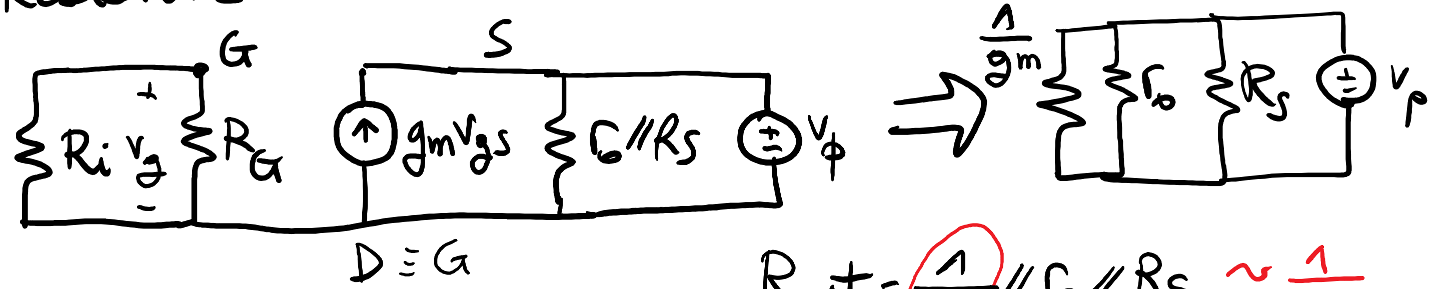
Amplificazione intrinseca a vuoto

$$A'_{vo} = A_v\Big|_{\substack{R_L \to \infty \\ R_i = 0}} = \frac{g_m (r_o // R_S)}{1 + g_m (r_o // R_S)} \leftarrow$$

Resistenza di ingresso

$$R_{in} = R_G$$

Resistenza di uscita



$$R_{out} = \frac{1}{g_m} // r_o // R_S \sim \frac{1}{g_m}$$

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	A'_{vo}	Rin	Rout
CS	<0 alta	alta R_G	media
CS con R_S	<0 media	alta R_G	alta
CD	>0 bassa ($0<A'_{vo}<1$)	alta R_G	bassa

Frequenza di Taglio di un transistore

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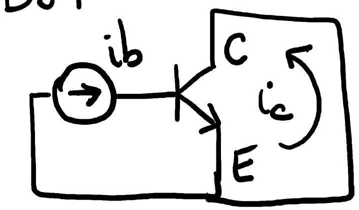
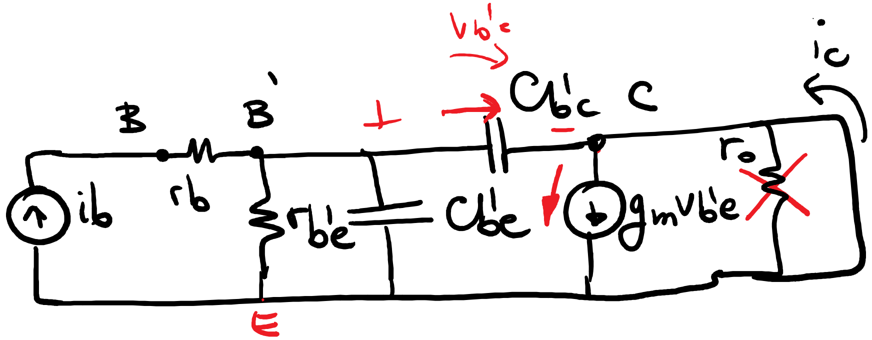
[cut off frequency f_T]

DEF $\left| \frac{i_c}{i_b}(f_T) \right|_{cc} = 1$, $\left| \frac{i_d}{i_g}(f_T) \right|_{cc} = 1$

BJT



circuito per le variazioni



$i_b = v_{b'e}\left[\frac{1}{r_{b'e}} + C_{b'e}s + C_{b'c}s\right]$; $i_c = g_m v_{b'e} - v_{b'e}C_{b'c}s$

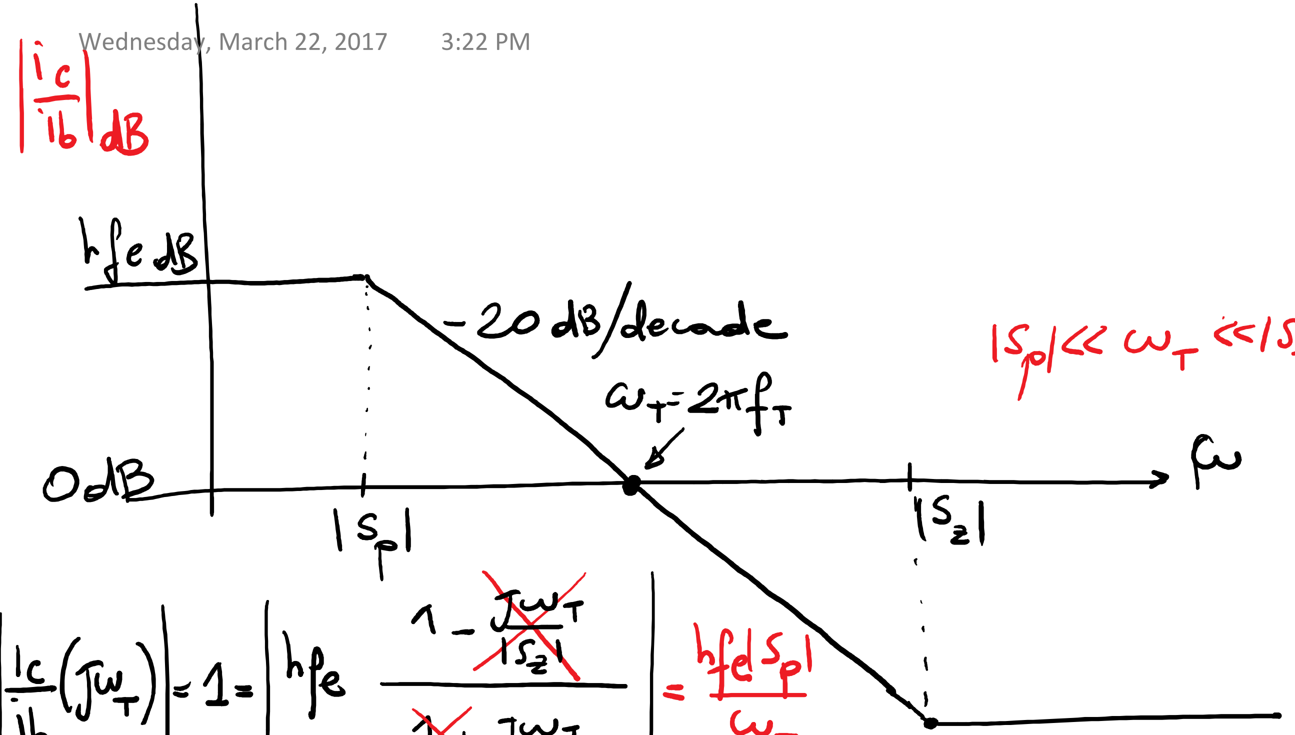
$$\frac{i_c}{i_b} = \frac{g_m - C_{b'c}\, s}{\frac{1}{r_{b'e}} + (C_{b'e} + C_{b'c})\, s} = \frac{h_{fe}\left(1 - \frac{C_{b'c}}{g_m} s\right)}{1 + r_{b'e}(C_{b'e} + C_{b'c})\, s}$$

$$h_{fe} = g_m r_{b'e}$$

1 polo reale negativo $\quad s_p = -\frac{1}{r_{b'e}(C_{b'e} + C_{b'c})}$

1 zero reale positivo $\quad s_z = \frac{g_m}{C_{b'c}}$

$$\left|\frac{s_z}{s_p}\right| = \left|\frac{\overbrace{g_m r_{b'e}}^{h_{fe}}(C_{b'e} + C_{b'c})}{C_{b'c}}\right| \gg 1$$



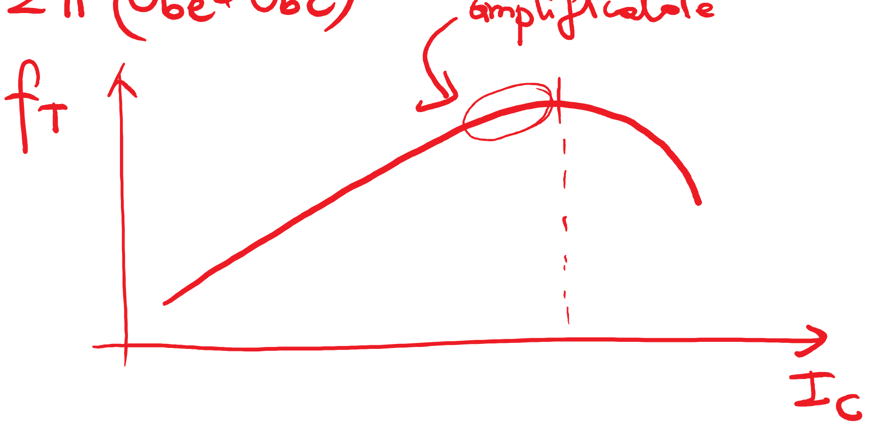
$$|S_p| \ll \omega_T \ll |S_z|$$

$$\left|\frac{i_c}{i_b}(j\omega_T)\right| = 1 = \left| h_{fe} \frac{1 - \frac{j\omega_T}{|S_z|}}{1 + \frac{j\omega_T}{|S_p|}} \right| = \frac{h_{fe}|S_p|}{\omega_T}$$

$$\omega_T = |S_p| h_{fe} = \frac{h_{fe}}{r_{b'e}(C_{b'e} + C_{b'c})} = \frac{g_m}{(C_{b'e} + C_{b'c})}$$

$$f_T = \frac{1}{2\pi} \frac{g_m}{(C_{b'e} + C_{b'c})}$$

dipende da I_C



FET

$$f_T = \frac{1}{2\pi} \frac{g_m}{(C_{gd} + C_{gs})}$$

PARAMETRI DI PICCOLO SEGNALE PER UN BJT

Wednesday, March 22, 2017 3:30 PM

r_b, $r_{b'e}$, g_m, r_o, $C_{b'e}$, $C_{b'c}$, h_{fe}

$$g_m = \frac{I_C}{V_T}$$

$$h_{ie} = r_b + r_{b'e}$$

$$f_T = \frac{g_m}{2\pi(C_{b'e} + C_{b'c})}$$

HP.

ALCUNI PARAMETRI DIPENDONO POCO DAL PUNTO DI RIPOSO

r_b, h_{fe}, V_A, f_T

ALCUNI PARAMETRI DIPENDONO MOLTO DAL PUNTO DI RIPOSO

$g_m = \frac{I_C}{V_T}$ $r_o = \frac{V_A}{I_C}$ $r_{b'e} = \frac{h_{fe}}{g_m}$

$C_{b'e}$, $C_{b'c}$.

$\hookrightarrow C_{b'c}(V_{bc})$

2N2222

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Punto di riposo

$I_C = 1mA$

$V_{CE} = 5V$

$h_{ie}@1mA = \frac{2+8}{2} = 5k\Omega$

$h_{fe}@1mA = \frac{50+300}{2} = 175$

$h_{oe}@1mA = \frac{5+35}{2} = 20\mu S$

$r_{b'e}^{@1mA} = \frac{h_{fe}}{I_C} V_T = \frac{175 \cdot 26 \cdot 10^{-3}}{1 \cdot 10^{-3}} = 4550\,\Omega$

$r_b^{@1mA} = h_{ie} - r_{bb'} = 5000 - 4550 = 450\,\Omega$

$r_o = \frac{1}{h_{oe}} = 50k\Omega$

$g_m = \frac{I_C}{V_T} = \frac{1 \cdot 10^{-3}}{26 \cdot 10^{-3}} = 38.4 \cdot 10^{-3}\,\Omega^{-1}$

$f_T = 90\,MHz$

$f_T = \frac{g_m}{2\pi(C_{b'c} + C_{b'e})} \Rightarrow C_{b'e} = 63pF$

$C_{b'c}|_{V_{BC}=4.4V} = 4.5pF$

2N2222 Punto di Riposo

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$I_C = 2mA$

$V_{CE} = 5V$

$f_T@2mA = 140\ MHz$

PER LE ALTRE QUANTITÀ CHE DIPENDONO POCO DAL PUNTO DI RIPOSO PRENDIAMO IL VALORE A 1 mA

$rb@2mA \sim rb@1mA = \underline{450}\ \Omega$

$\downarrow$

$(hie@1mA - rb'e@1mA)$

$\downarrow$

$\frac{hfe\ V_T}{I_C}$

$hfe@2mA \sim hfe@1mA = 175$

$V_A@2mA \sim V_A@1mA = \frac{1mA}{hoe@1mA} = 50V$

$\hookrightarrow V_A = \frac{I_C}{hoe}$

$gm@2mA = \frac{I_C}{V_T} = 76.8 \cdot 10^{-3}\ \Omega^{-1}$

$r_o@2mA = V_A/I_C = 50/2 = 25\ k\Omega$

$rb'e@2mA = \frac{hfe@2mA \cdot V_T}{I_C} = \underline{2275}\ \Omega$

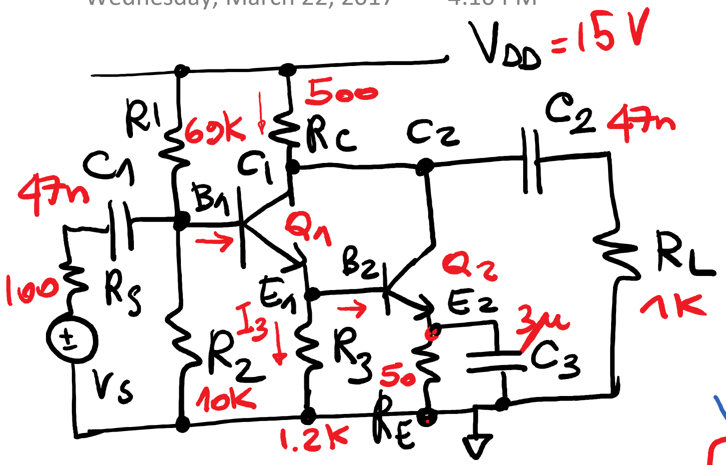
$hie@2mA = rb@2mA + rb'e@2mA = 2725\ k\Omega$

$Cb'c = 4.5pF$

$Cb'e@2mA = \frac{gm@2mA}{2\pi f_T@2mA} - Cb'c = \underline{\underline{82pF}}$

Es 30|1|2003

Wednesday, March 22, 2017 4:10 PM



Q_1, Q_2 2n2222

$h_{oe} = 0$

Hp PARTITORE PESANTE (Coincide $R_B \ll \beta_F R_E$)

$\frac{V_{DD}}{R_1+R_2} \gg I_{B1}$

$V_{B1} = V_{DD}\frac{R_2}{R_1+R_2} = \frac{15 \cdot 10}{79} = 1.9\,V$

Hp Q_1 in Z.A.D.

$V_{E1} = V_{B1} - V_{BE\,ON} = 1.9 - 0.7 = 1.2\,V$ ($V_{BE\,ON}$ = 0.7)

$I_3 = \frac{V_{E1}}{R_3} = \frac{1.2}{1.2\,k\Omega} = 1\,mA$

Hp $I_3 \gg I_{B2}$

$I_3 = I_{E1} \sim I_{C1}$

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Hp Q_2 in Z. A.D.

$V_{E_2} = V_{B_2} - V_{BE_{ON}} = 1.2 - 0.7 = 0.5\,V$

$I_{E_2} \sim I_{C_2} = \frac{V_{E2}}{R_E} = \frac{0.5}{50} = 10\,mA$

$V_{C_1} = V_{C_2} = V_{CC} - R_C[I_{C_1} + I_{C_2}] = 15 - 0.5[1+10] = 15 - 5.5 = 9.5\,V$

$V_{CE_1} = V_{C_1} - V_{E_1} = 9.5 - 1.2 = 8.3\,V$ ← ok

$V_{CE_2} = V_{C_1} - V_{E_1} = 9.5 - 0.5 = 9\,V$ ← ok

VERIFICA IPOTESI

Q_1 Z.A.D.

Q_2 Z.A.D.

ok

$\beta_F = h_{FE}$

$\beta_{F_1} = 150 \rightarrow I_{B_1} = \frac{I_{C_1}}{\beta_{F_1}} = \frac{10^{-3}}{150} = 6.6 \cdot 10^{-6} A \ll \frac{15}{79k\Omega} = 0.19\,mA$ ok

$\beta_{F_2} = 200 \rightarrow I_{B_2} = \frac{I_{C2}}{\beta_{F_2}} = \frac{10^{-2}}{200} = 5 \cdot 10^{-5} A \ll 10^{-3}$ ok

PARAMETRI DI PICCOLO SEGNALE

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Q1

$I_C = 1mA$

$V_{CE_1} = 8.3\ V$

$V_{CB} = 8.3 - 0.7 = 7.6\ V$

$h_{ie} = 5k\Omega$

$h_{fe} = 175$

$h_{oe} = 20 \cdot 10^{-6}\ \Omega^{-1} \rightarrow r_o = \frac{1}{h_{oe}} = 50k\Omega$

$g_m = \frac{I_C}{V_T} = \frac{1}{26} = 38.4 \cdot 10^{-3}\ \Omega^{-1}$

$f_T = 90\ MHz = \frac{g_m}{2\pi(C_{b'c} + C_{b'e})} \rightarrow C_{b'e} + C_{b'c} = \frac{g_m}{2\pi f_T} = 68\ pF$

$C_{b'c} = 4pF$

$C_{b'e} = 64pF$

Q2

$I_{C_2} = 10\ mA$

$V_{CE_2} = 9V$

$h_{ie}@10mA = \frac{0.25 + 1.25}{2} = 0.75\ k\Omega$

$h_{fe}@10mA = \frac{75 + 375}{2} = 225$

$h_{oe}@10\ mA = \frac{25 + 200}{2} = 112.5 \cdot 10^{-6}\ \Omega^{-1} \rightarrow \frac{1}{h_{oe}} = 8.8\ k\Omega$

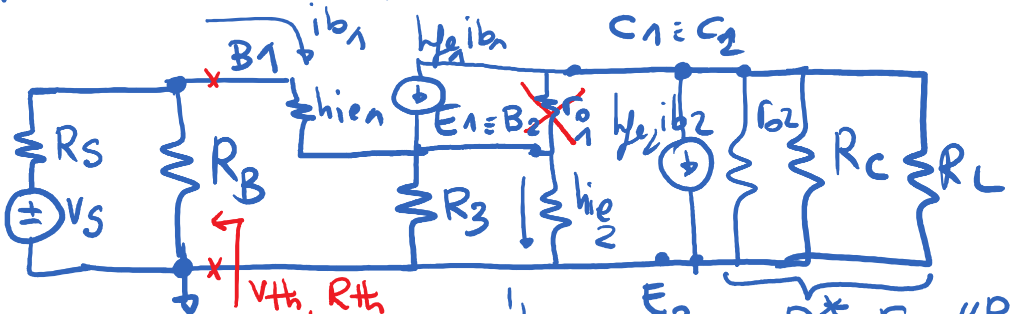
$f_T = 300\ MHz \rightarrow (C_{b'e} + C_{b'c}) = \frac{I_C}{V_T 2\pi f_T} = 204\ pF$

$C_{b'c} = 4pF$

$C_{b'e} = 200\ pF$

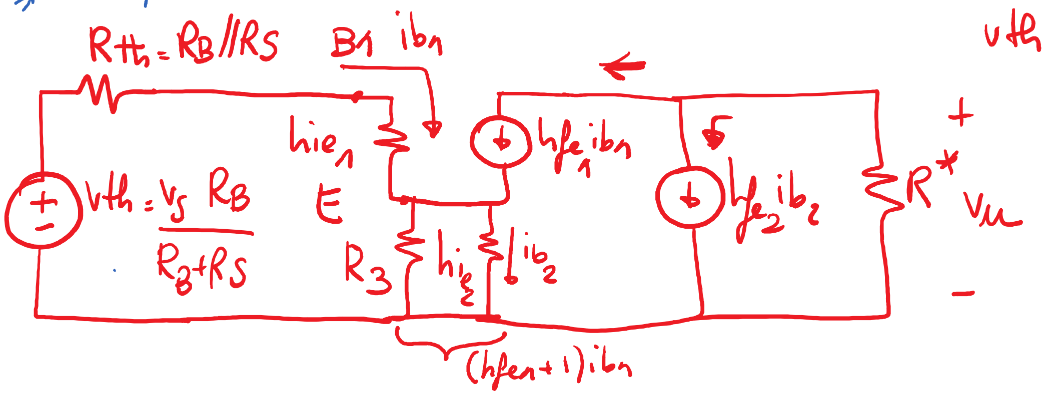
CIRCUITO EQUIVALENTE PER IL PICCOLO SEGNALE

Thursday, March 23, 2017 9:18 AM



$r_{o1} \gg R_3, R_C$ quindi può essere trascurata

$r_{o2} \gg R_S$



maglia di ingresso

$v_{th} = i_{b1}(R_{th} + h_{ie1}) + (h_{fe1}+1) i_{b1} (R_3 // h_{ie2})$

$$i_{b1} = \frac{v_{th}}{(R_{th} + h_{ie1}) + (h_{fe1}+1)(R_3 // h_{ie2})}$$

$$i_{b2} = (h_{fe1}+1)\, i_{b1} \frac{R_3}{R_3 + h_{ie2}}$$

$$v_u = -R^* \left[h_{fe1} i_{b1} + h_{fe2} i_{b2} \right] = -R^* \left[h_{fe1} i_{b1} + h_{fe2} (h_{fe1}+1) \frac{i_{b1} R_3}{R_3 + h_{ie2}} \right] =$$

$$v_u = -R^* \left[h_{fe1} + \frac{h_{fe2}(h_{fe1}+1) R_3}{R_3 + h_{ie2}} \right] \frac{1}{(R_{th} + h_{ie1}) + (h_{fe1}+1)(R_3 // h_{ie2})} \frac{R_B}{R_B + R_S} v_s$$

$$A_{v_{CB}} = \frac{v_u}{v_s} =$$