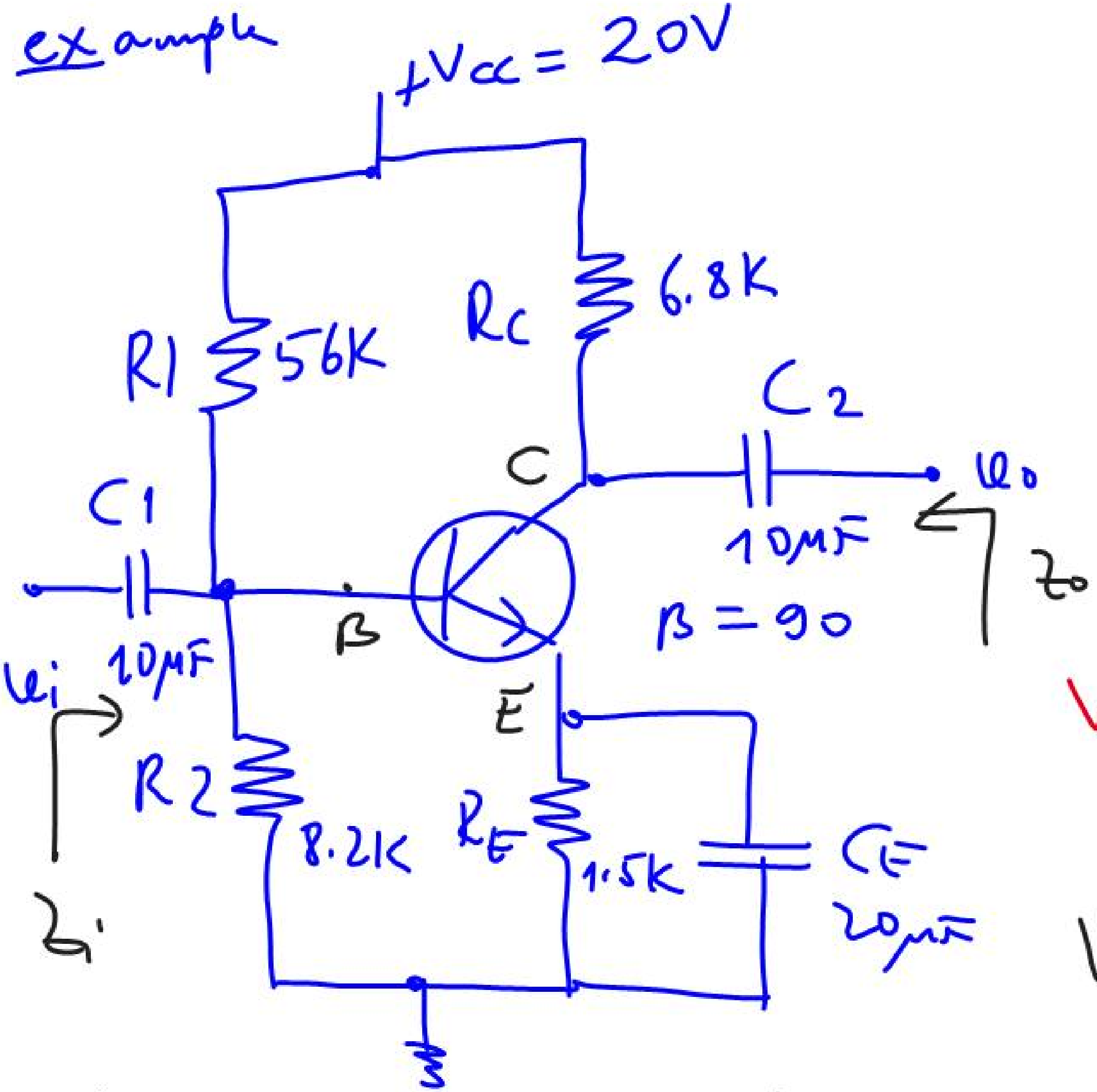
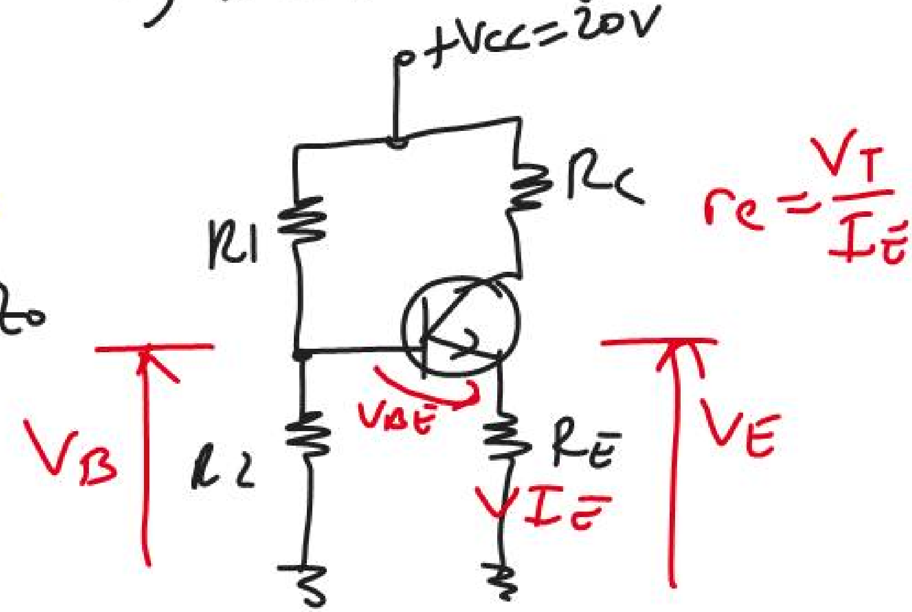
example

17.05.2011 ©



a) DC Analysis



Au, Zi, Zo
Ai

$$V_B \cong \frac{V_{CC}}{R_1 + R_2} \cdot R_2$$

$$V_B = \frac{20}{64.2 \times \cancel{10^3}} \times 8.2 \times \cancel{10^3}$$

$$V_B = 2.55V \cong 2.6V$$

$$V_E = V_B - V_{BE}$$

$$V_E = 2.6 - 0.7$$

$$\underline{V_E = 1.9V}$$

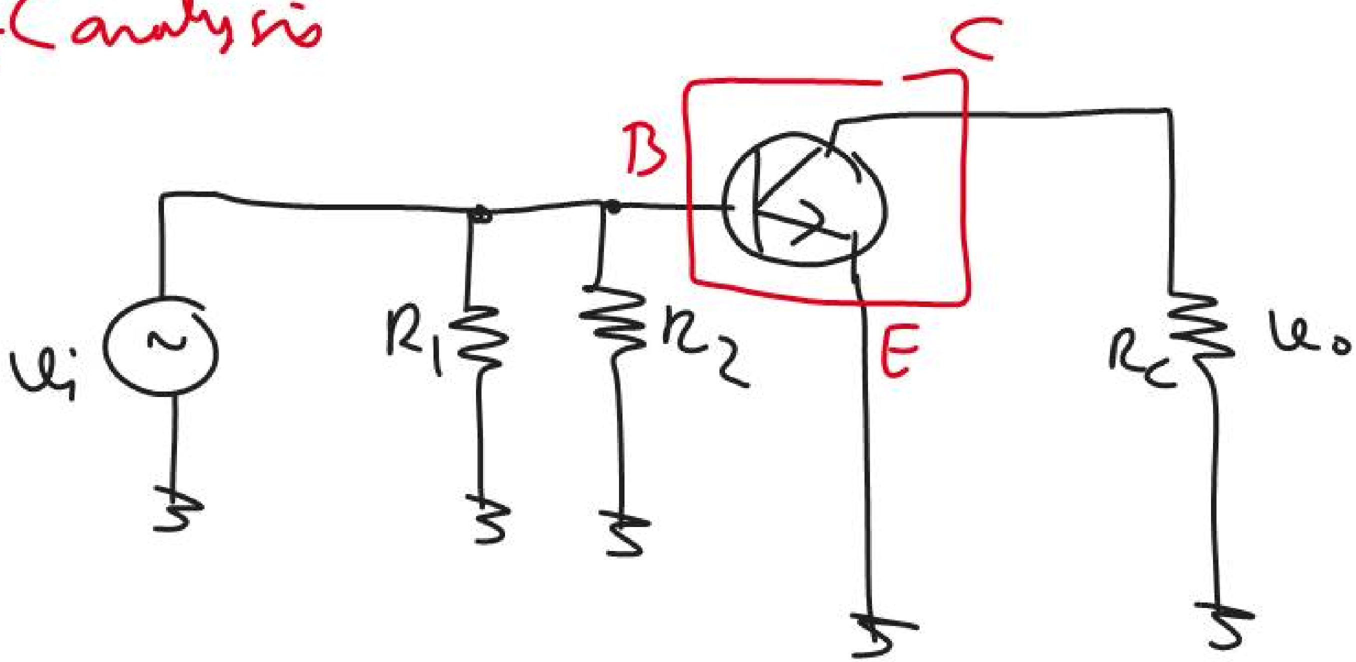
$$I_E = \frac{V_E}{R_E}$$

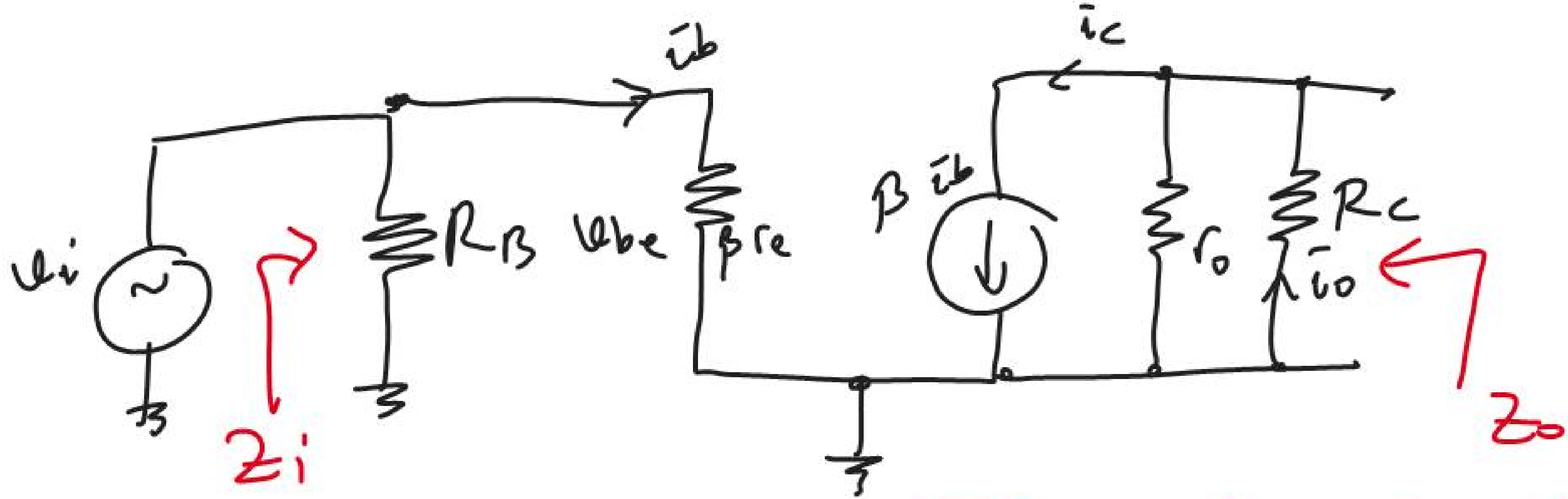
$$I_E = \frac{1.9}{1.5 \times 10^3}$$

$$\underline{I_E = 1.27\,mA}$$

$$r_e = \frac{26\,mV}{1.27\,mA} = \frac{26 \times \cancel{10^{-3}}}{1.27 \times \cancel{10^{-3}}} \doteq 21\,\Omega.$$

AC analysis





$Z_o = R_C // r_o \approx R_C$

$$\boxed{A_u = \frac{u_o}{u_i} = -\frac{R_C}{r_e}}$$

$A_u = -\frac{6,8\times10^3}{21}$

$\underline{A_u \cong -300}$

$R_B = R_1 // R_2$

$Z_i = R_B // \beta r_e$

$A_u = \frac{u_o}{u_i}$

$u_i = u_{be}$

$i_b = \frac{u_{be}}{\beta r_e}$

$u_o = -i_o \cdot R_C$

if $r_o >> R_C \Rightarrow i_o \approx i_c$

$u_o \cong -i_c \cdot R_C$

$u_o = -\beta i_b \cdot R_C \Rightarrow u_o = -\cancel{\beta} \cdot \frac{u_{be}}{\cancel{\beta} r_e} \cdot R_C$

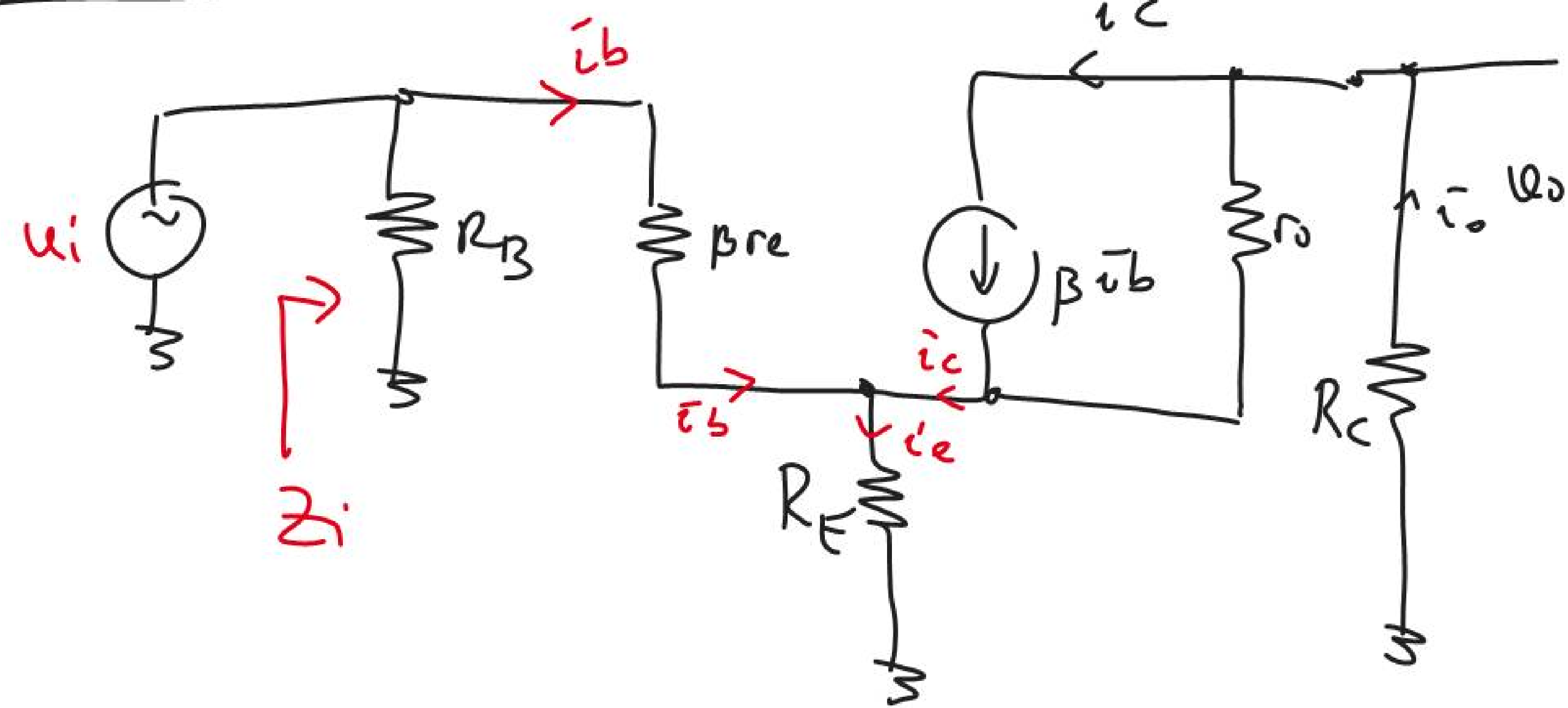
$u_{be} = u_i$

$u_o = -u_i \cdot \frac{R_C}{r_e}$ $\Rightarrow A_u = \frac{u_o}{u_i} = \frac{-R_C}{r_e}$

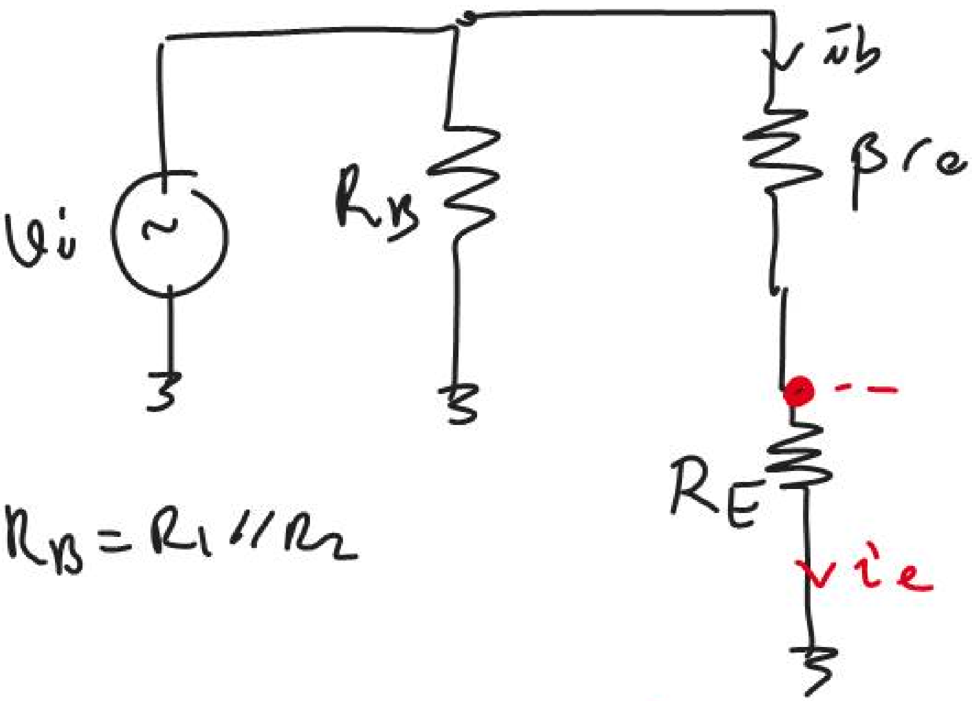
ex If there were no C_E:

DC analysis is the same. $\Rightarrow r_e = 21\,\Omega$

AC Analysis



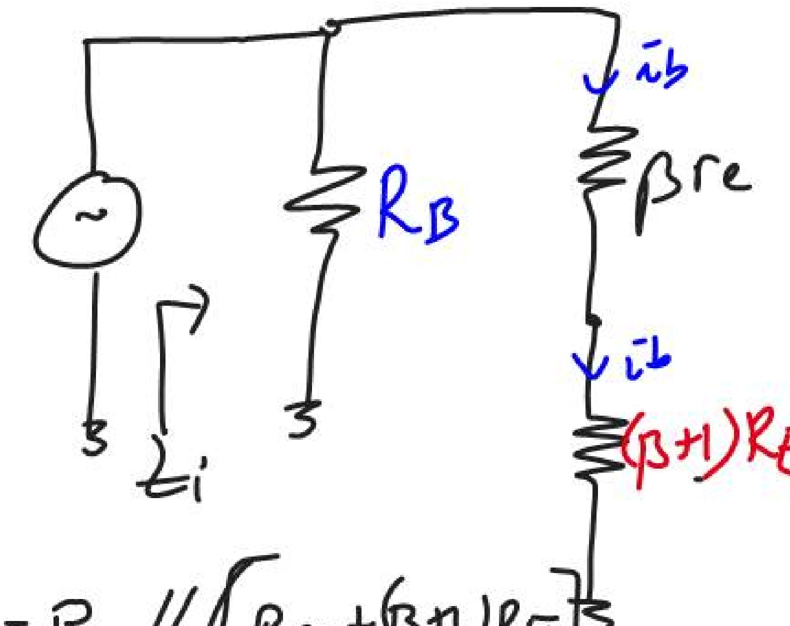
Input circuit:



$R_B = R_1 // R_2$

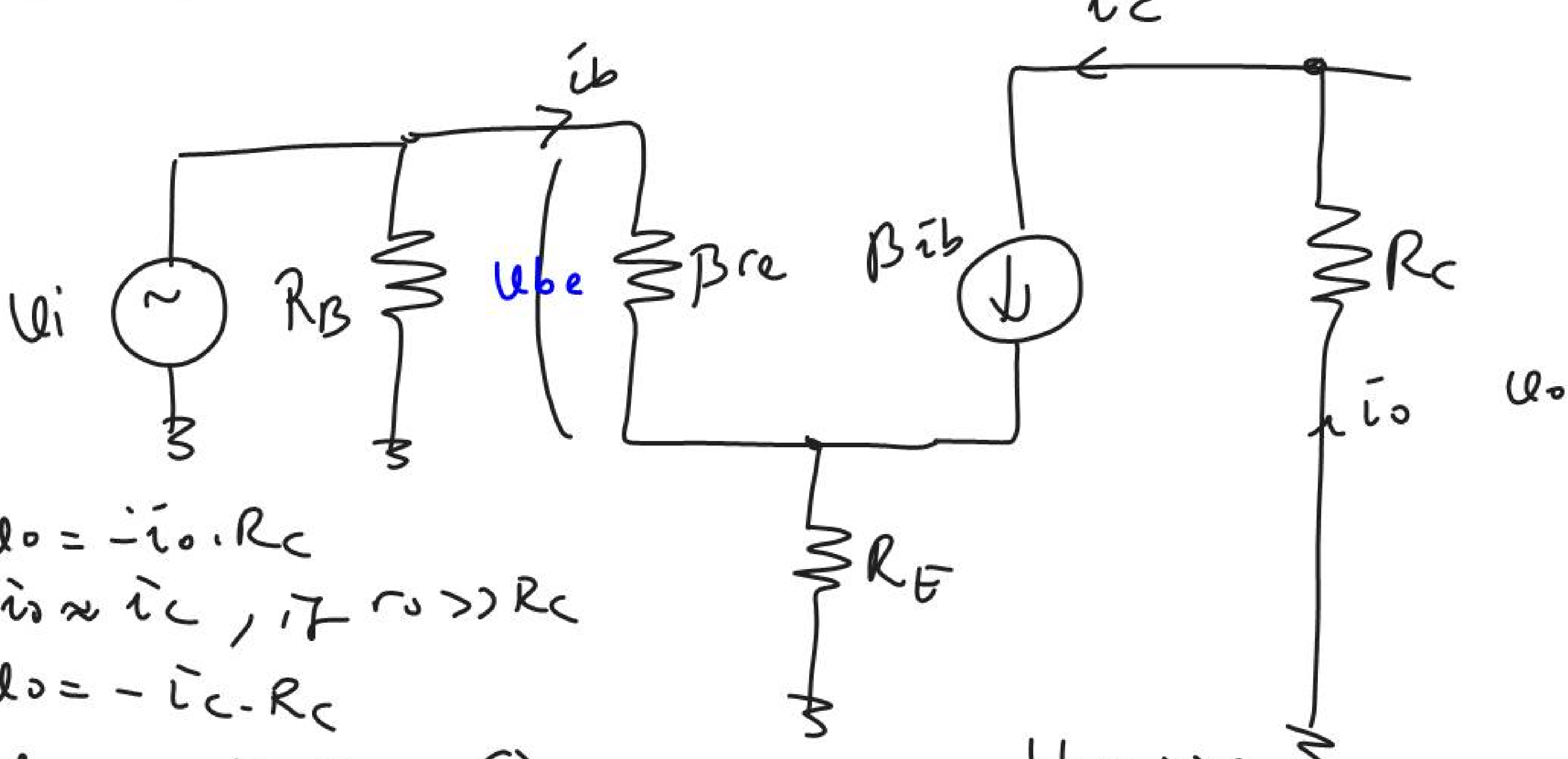
$i_e = (\beta+1)\, i_b$

$\equiv$



$Z_i = R_B // \left[\beta r_e + \underline{(\beta+1)R_E}\right]$

Voltage Gain $= A_v = \dfrac{u_o}{u_i}$



If $r_o >> R_C$

$u_o = -i_o \cdot R_C$

$i_o \approx i_c$, if $r_o >> R_C$

$u_o = -i_c \cdot R_C$

$u_o = -\beta i_b \cdot R_C$ (1)

$\beta + 1 \cong \beta$

$u_i = u_{be} + i_e \cdot R_E$

$u_i = i_b \cdot \beta \cdot r_e + i_b(\beta+1) \cdot R_E$

$u_i = i_b\left[\beta r_e + (\beta+1) R_E\right] \cong \beta \cdot i_b (r_e + R_E) \Rightarrow i_b \cong \dfrac{u_i}{\beta(r_e + R_E)}$ (2)

If we insert ② into ①:

$$v_o = -\beta\, i_b \cdot R_C$$

$$v_o \cong -\cancel{\beta} \cdot \frac{v_i \cdot R_C}{\cancel{\beta}(r_e + R_E)}$$

$$A_v = \frac{v_o}{v_i} \cong -\frac{R_C}{r_e + R_E}$$

$$A_v = -\frac{6.8\times10^3}{21 + 1.5\times10^3}$$

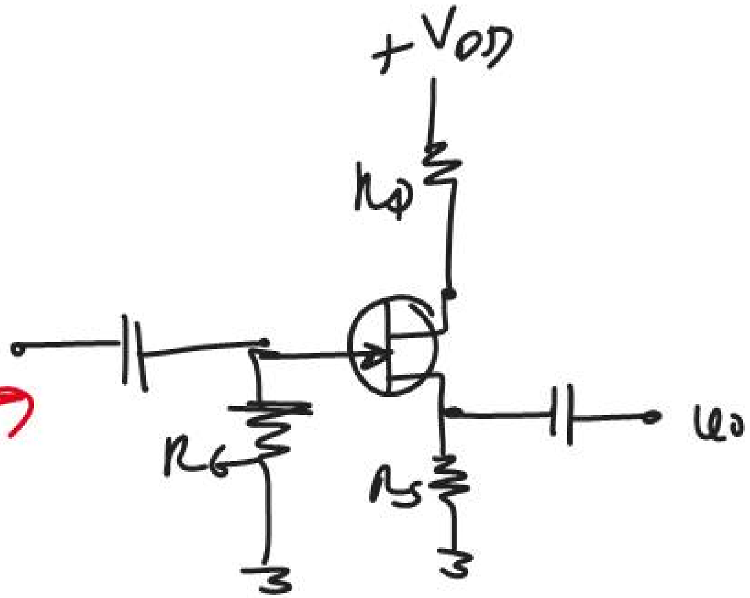
$$\boxed{A_v \cong -4}$$

$\therefore$ with $C_E \Rightarrow A_v \cong -300$

without $C_E \Rightarrow A_v \cong -4$

Unbypassed R_E will reduce the voltage gain too much, although it provides some benefit for Z_i.

EMITTER FOLLOWER



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

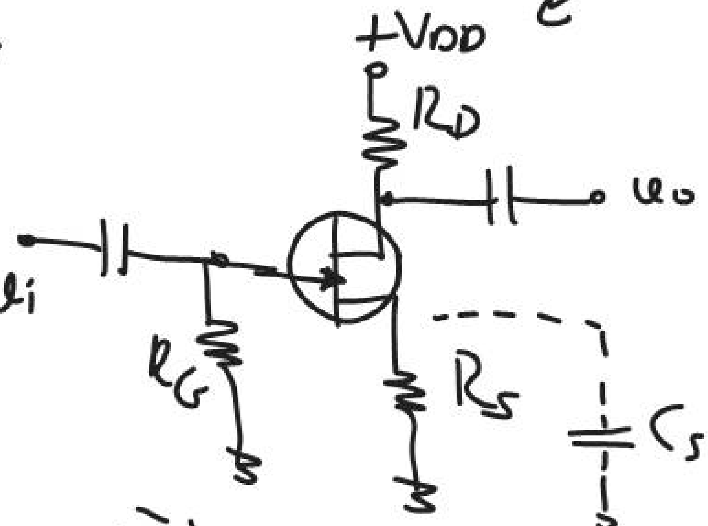
$$A_v = -\frac{g_m R_D}{1 + g_m R_S}$$

without C_S

REMEMBER.

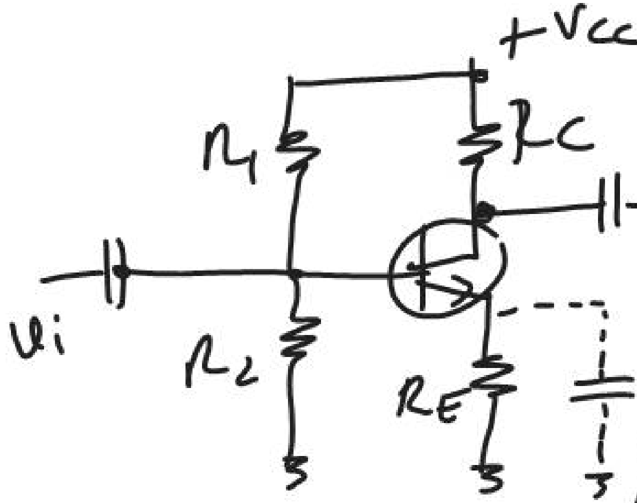
The SOURCE FOLLOWER in FETs.

(common drain configuration)



$A_v = -g_m R_D$

with C_S.



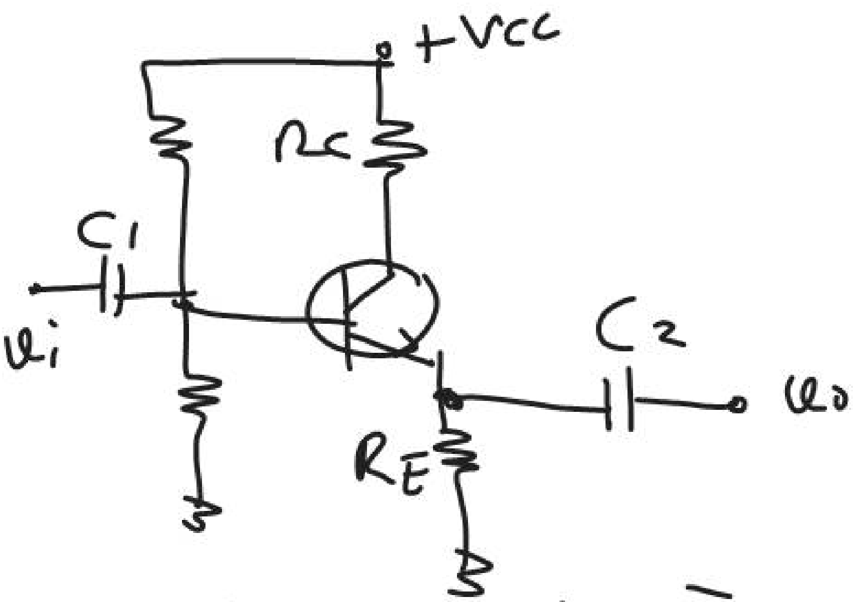
CE amplifier

$A_v = -\frac{R_C}{r_e}$

if R_E is bypassed by a C_E.

$A_v = -\frac{R_C}{r_e + R_E}$

if there were no C_E.

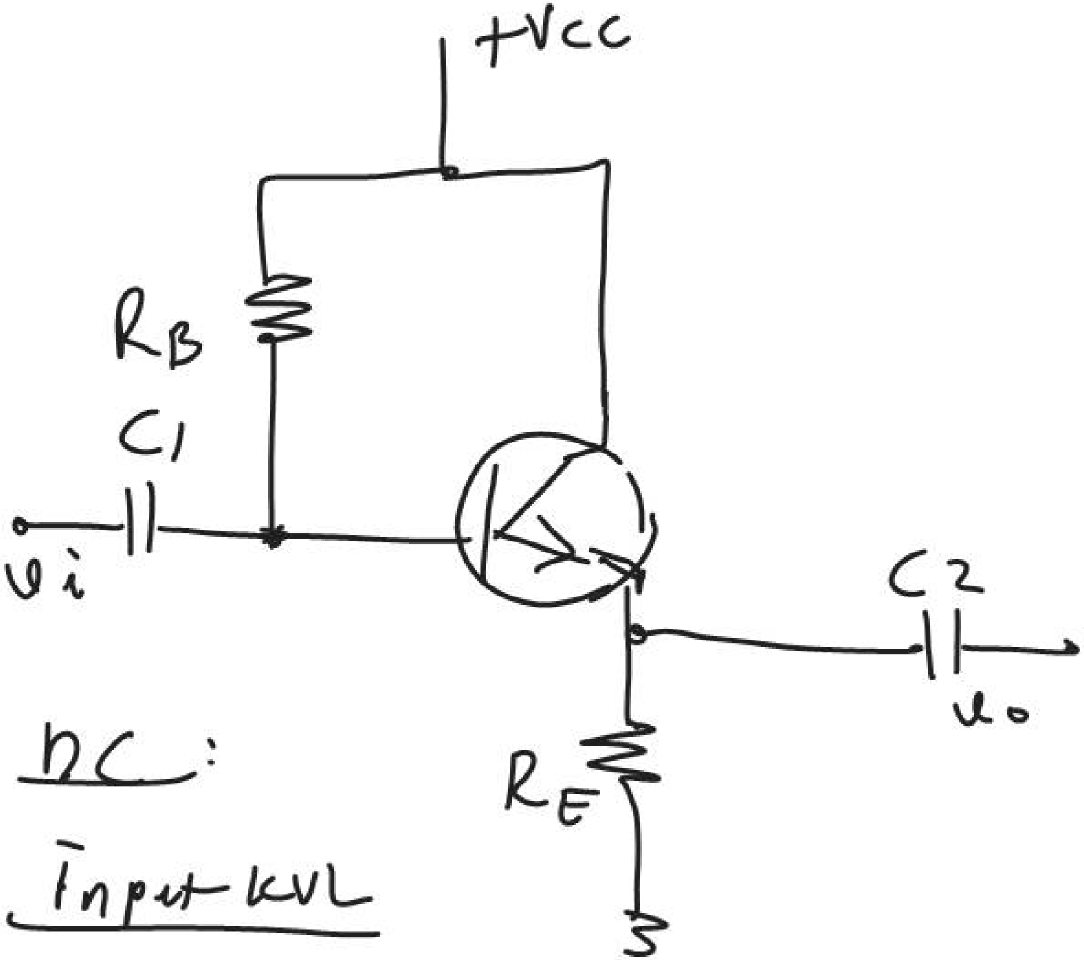


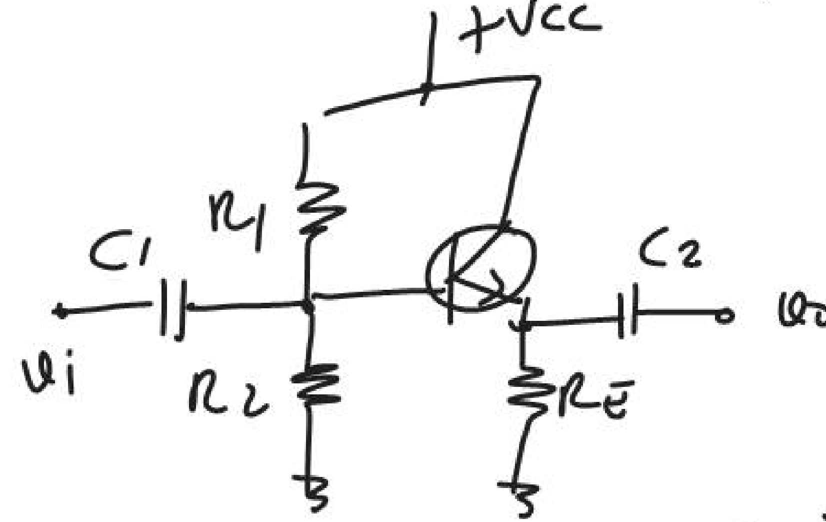
when we are taking output voltage across R_E →

EMITTER FOLLOWER

(common collector CC)

EMITTER FOLLOWER (Common Collector)





DC:

Input KVL

$$V_{CC} - I_B R_B - V_{BE} - I_E \cdot R_E = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) \cdot R_E} \quad 0.7$$

$$\Rightarrow I_E = (\beta+1) I_B$$

$$r_e = \frac{V_T}{I_E}$$

DC (Voltage Divider)

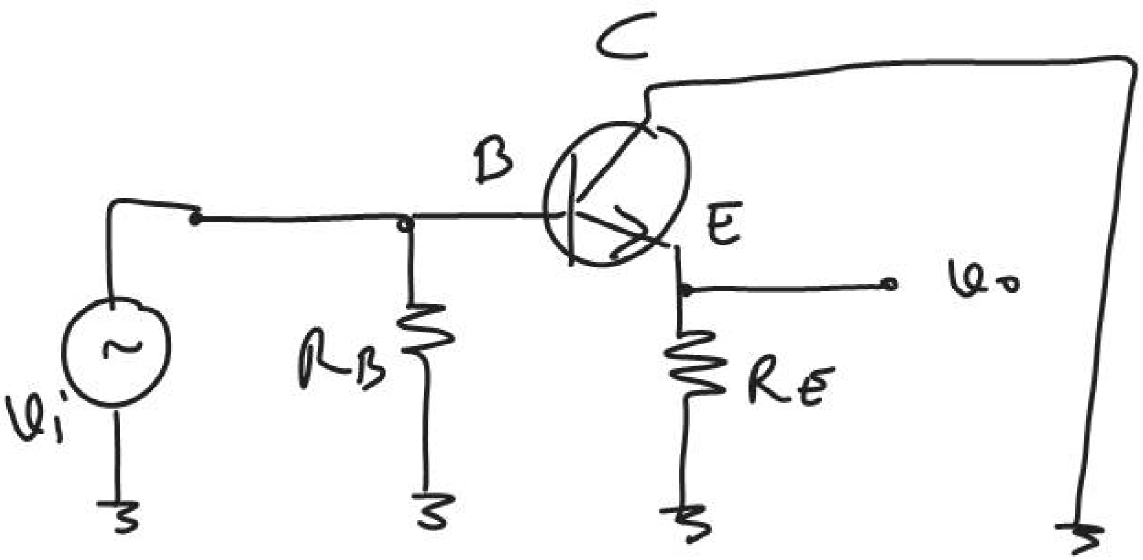
$$V_B = \frac{V_{CC}}{R_1 + R_2} \cdot R_2$$

$$V_E = V_B - 0.7V$$

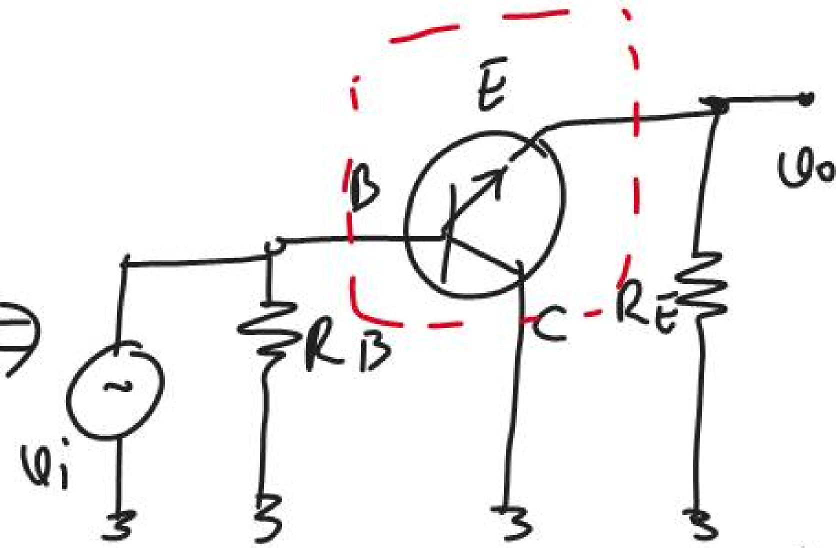
$$I_E = \frac{V_E}{R_E}$$

$$r_e = \frac{V_T}{I_E}$$

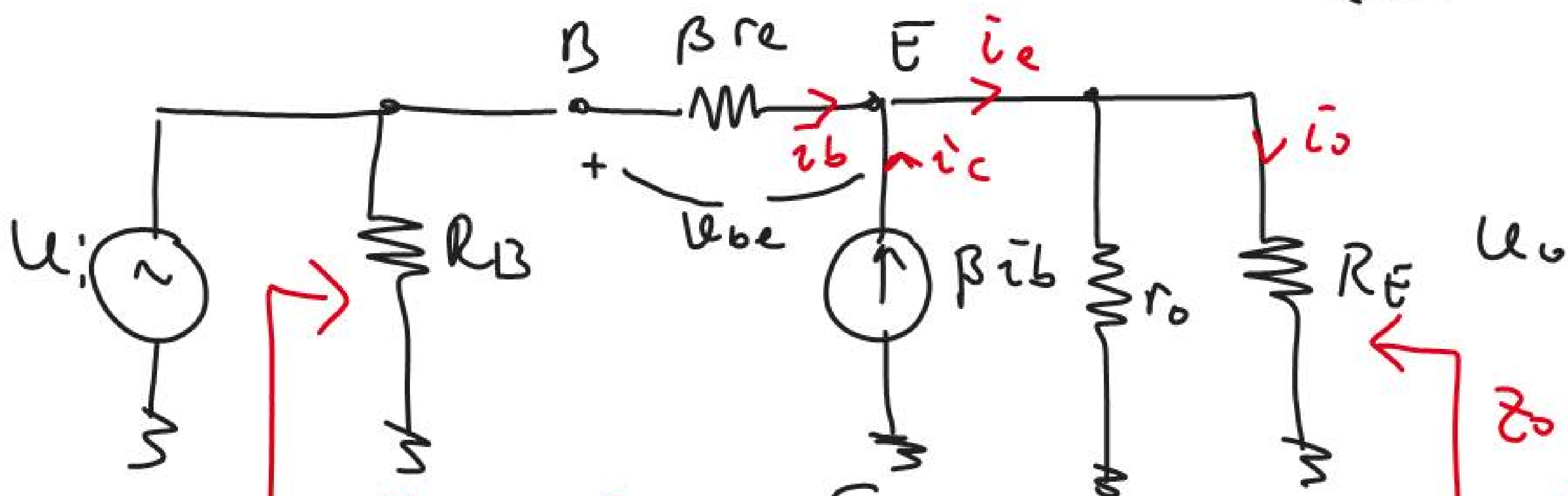
ac analysis



$\Rightarrow$



(Common collector)



$Z_i \cong R_B // [\beta r_e + (\beta+1) R_E]$

$r_o >> R_E$

$Z_o = R_E // r_e \cong r_e$

$$v_i = v_{be} + v_o$$

$$v_o = + i_e \cdot R_E$$

$$v_o \cong \frac{v_i}{r_e + R_E} \cdot R_E$$

$$\boxed{\frac{v_o}{v_i} \cong \frac{R_E}{r_e + R_E}}$$

$$\boxed{A_v \cong \frac{R_E}{r_e + R_E}} < 1$$

No phase shift

$$v_i = i_b \beta \cdot r_e + (\beta+1) i_b \cdot R_E$$

$$i_b = \frac{v_i}{\beta r_e + (\beta+1) R_E}$$

$$i_e = (\beta+1) i_b$$

$$i_e = \frac{(\beta+1) v_i}{\beta r_e + (\beta+1) R_E}$$

$$i_e \cong \frac{v_i}{r_e + R_E}$$