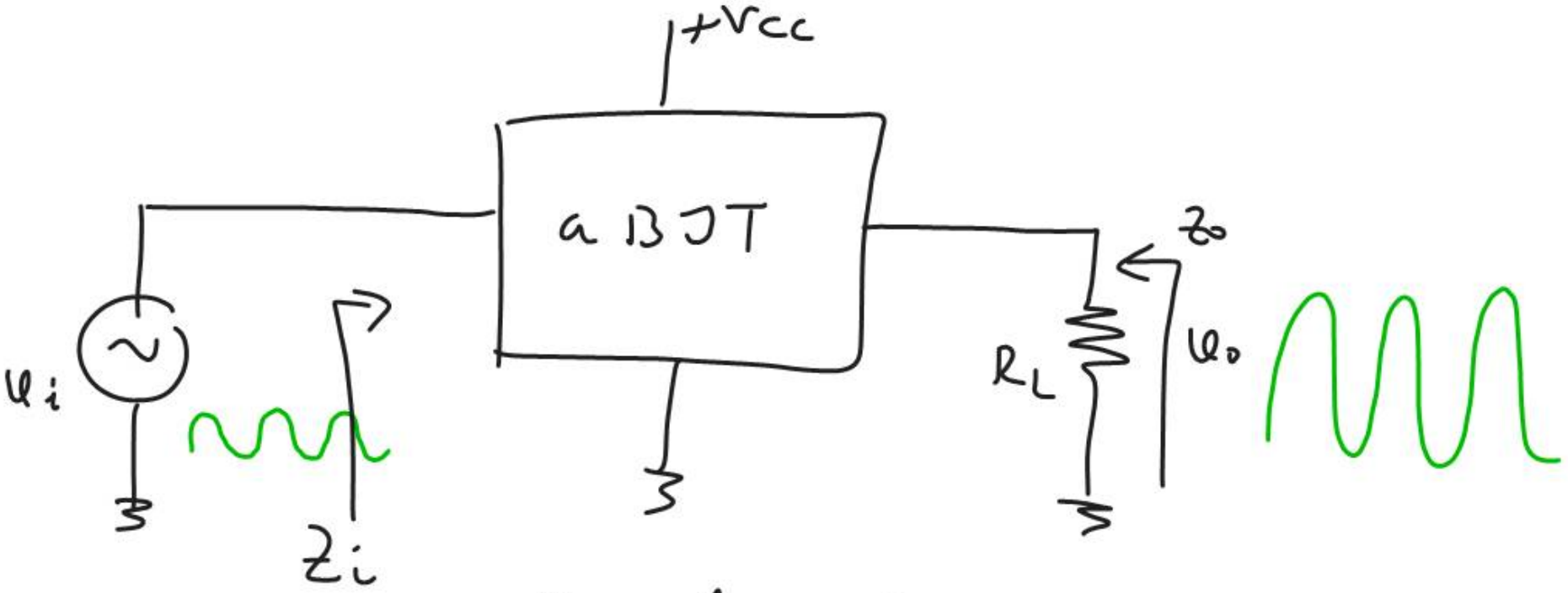
BJT (BIPOLAR JUNCTION TRANSISTORS)

16.05.2011 ©

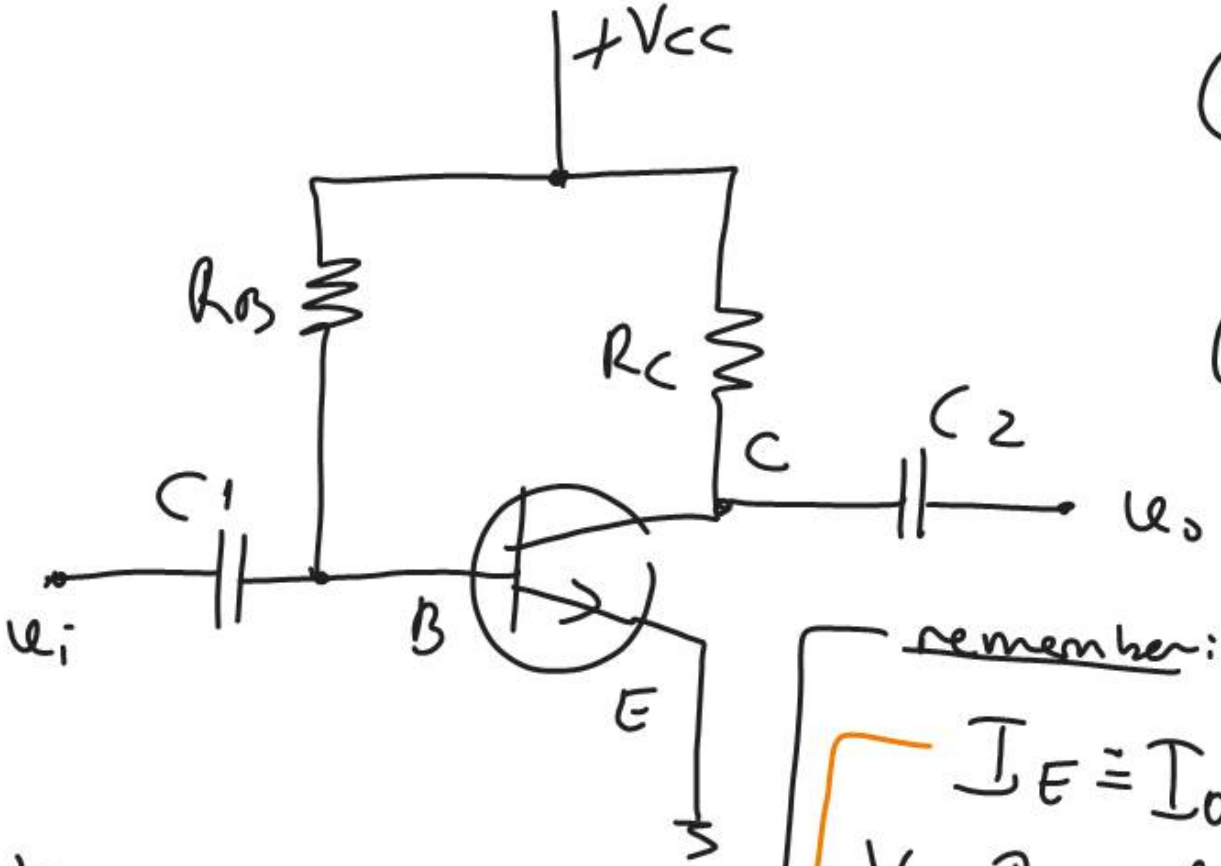
LINEAR AMPLIFIERS



$$v_o = A_v \cdot v_i$$

$$A_v = \frac{v_o}{v_i} \quad \text{Voltage gain}$$

A common-emitter BJT amplifier:



① DC analysis to find the r_e (Base emitter dynamic resistance)

$$r_e = \frac{dV_{BE}}{dI_E}\Big|_{V_{CE}=\text{const}}$$

remember:

$$I_E \cong I_{0} \cdot e^{V_{BE}/V_T}$$

V_T = Thermal voltage $= \frac{kT}{q} \cong 26\text{mV}$ at $300^\circ K$

$$\frac{dI_E}{dV_{BE}} = \frac{I_0}{V_T} \cdot e^{V_{BE}/V_T} \quad (I_E)$$

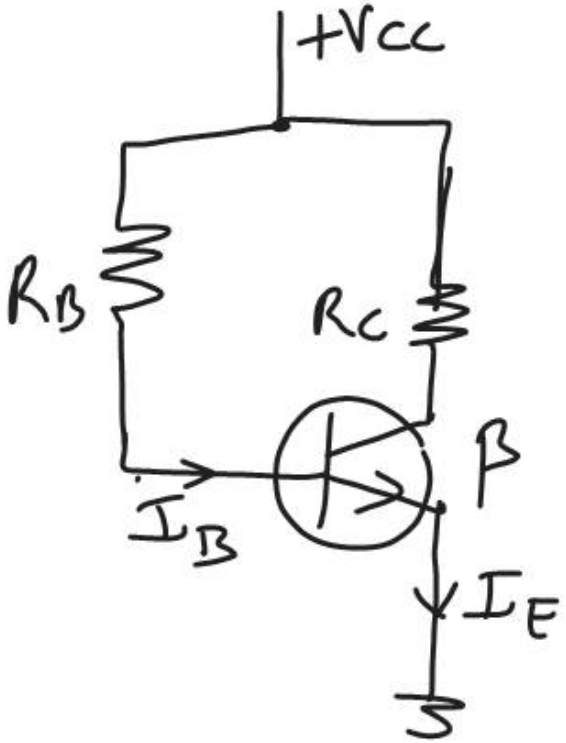
$$\frac{dI_E}{dV_{BE}} = \frac{I_E}{V_T}$$

$$r_e = \frac{dV_{BE}}{dI_E} = \frac{V_T}{I_E}$$

Our objective is to find I_E

DC analysis

Bypass capacitors, coupling capacitors → OPEN



Input KVL:

$$V_{CC} - I_B R_B - V_{BE} = 0$$

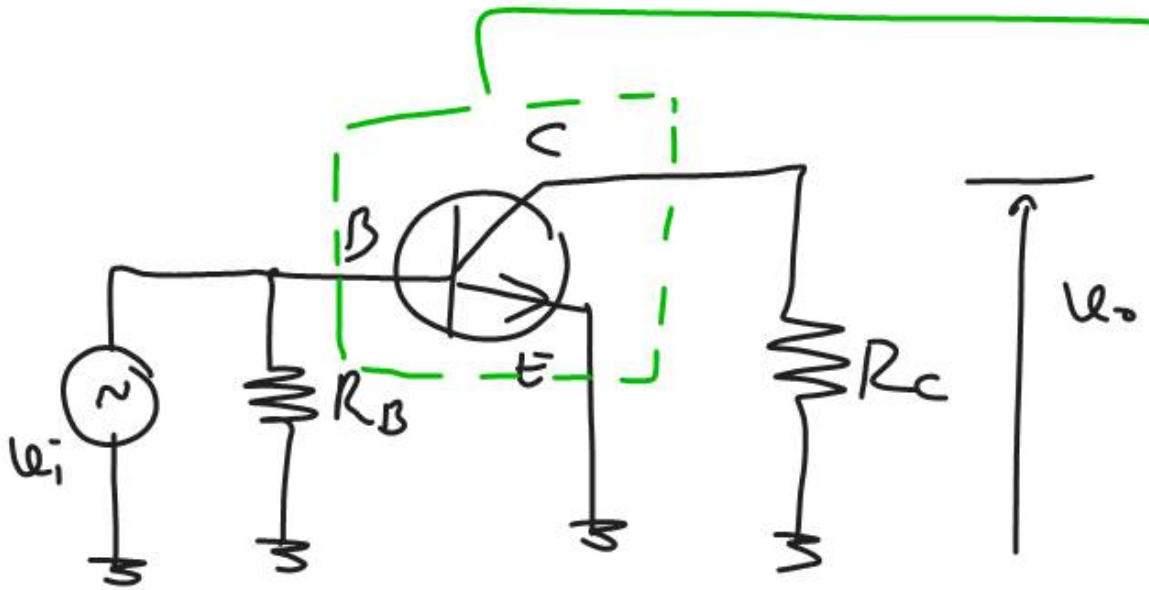
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_E = (\beta + 1) I_B \approx \beta \cdot I_B$$

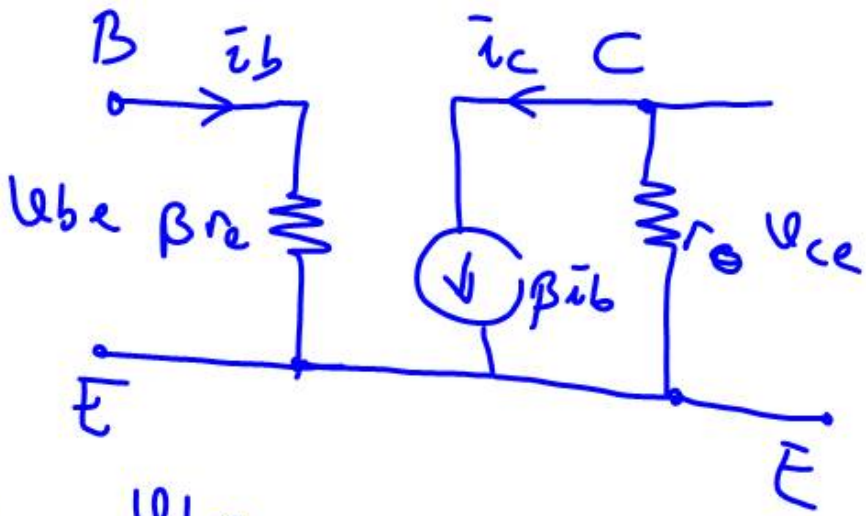
$$r_e = \frac{V_T}{I_E}$$ so r_e is found.

② AC Analysis

Coupling, bypass capacitors → SHORT CIRCUIT
Short circuits the DC power supply to the GROUND.



≡ replace with ac equivalent

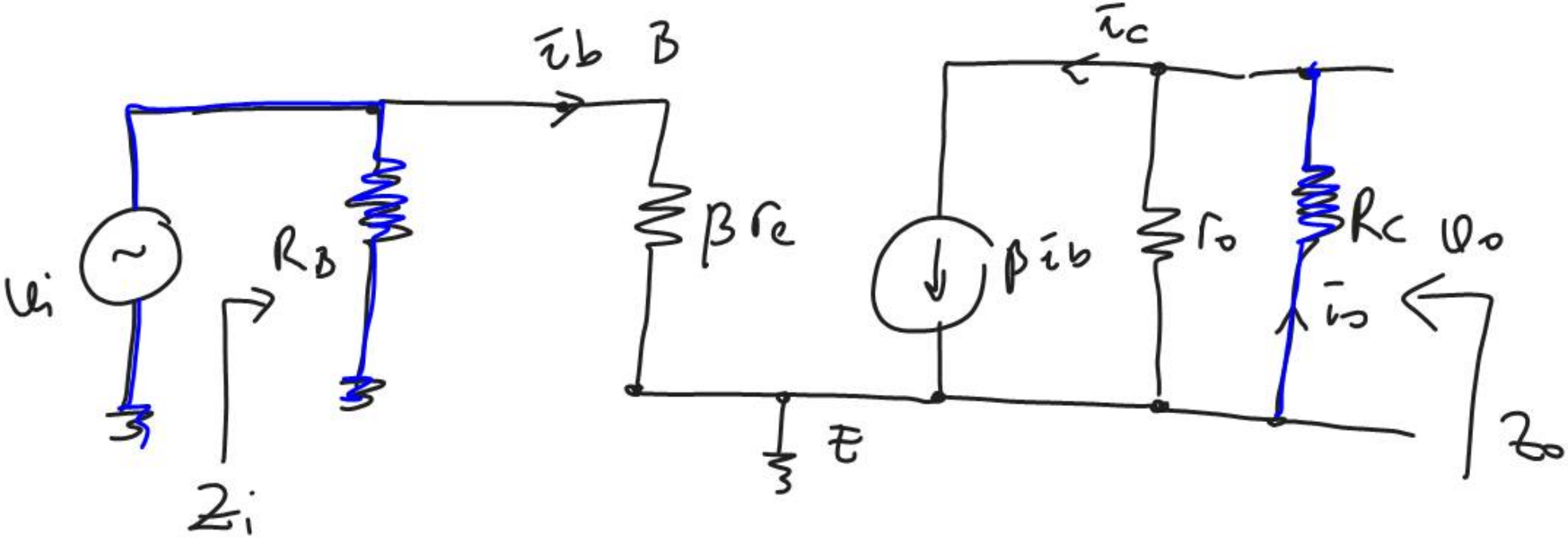


$h_{ie} = h_{fe}\, r_e$

$h_{fe} \approx \beta$

{ HYBRID PARAMETERS

$\frac{v_{be}}{\bar{i}_b} = \beta r_e$



$$Z_i = R_B // \beta r_e$$

$$Z_o \cong r_o // R_C \quad ; \text{ if } r_o \gg 10 R_C \Rightarrow Z_o \cong R_C$$

$$\left.\begin{array}{l} v_o = -\bar{i}_o \cdot R_C \\ \text{If } r_o \gg R_C \Rightarrow \bar{i}_o \approx \bar{i}_c \end{array}\right\} \Rightarrow \left.\begin{array}{l} v_o \cong -\bar{i}_c \cdot R_C \\ \bar{i}_c = \beta \bar{i}_b \end{array}\right\} \Rightarrow \begin{array}{l} v_o = -\beta \bar{i}_b \cdot R_C \\ v_i = \bar{i}_b \cdot \beta \cdot r_e \\ \bar{i}_b = \dfrac{v_i}{\beta r_e} \end{array}$$

$$v_o = -\beta i_b \cdot R_c$$

$$i_b = \frac{v_i}{\beta r_e}$$

$$v_o = -\cancel{\beta} \cdot \frac{v_i}{\cancel{\beta} r_e} \cdot R_c$$

$$v_o = -\frac{R_c}{r_e} \cdot v_i$$

$$\boxed{A_v = \frac{v_o}{v_i} = -\frac{R_c}{r_e}}$$

Voltage gain

Typical values:

If $R_c = 3K\Omega$

$r_e \cong 5\Omega$

$$A_v = -\frac{3\times10^3}{5} = -\frac{3000}{5}$$

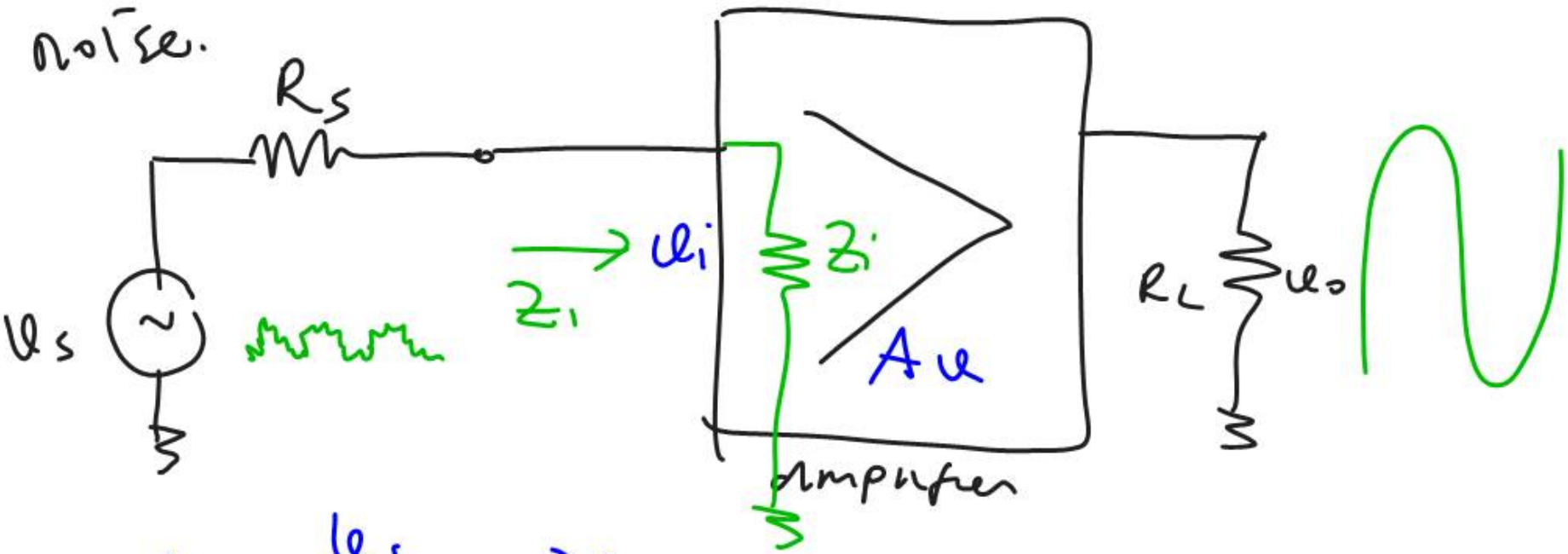
$$\boxed{A_v = -600}$$

BJT can amplify the voltages/signals very effectively

INFORMATION

Normally signals of very small magnitudes are desired to be amplified.

These small signals are generally buried in the noise.



$$v_i = \frac{v_s}{R_s + Z_i} \cdot Z_i \qquad A_v = \frac{v_o}{v_i}$$

if $Z_i >> R_s$ $\quad R_s + Z_i \cong Z_i$; however, if $Z_i \approx R_s$

$v_i \cong v_s$ $\qquad v_i \cong \frac{1}{2} v_s$