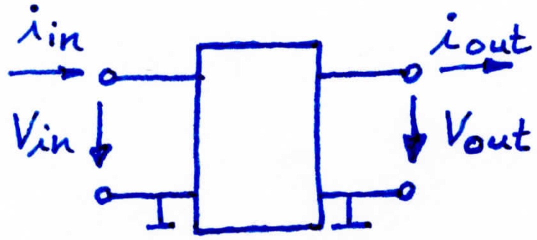
ITE – Homework 6

Problem 1 BJT Common-E, -B, and -C circuit
Basic version of circuit

(a) Definition of small-signal quantities



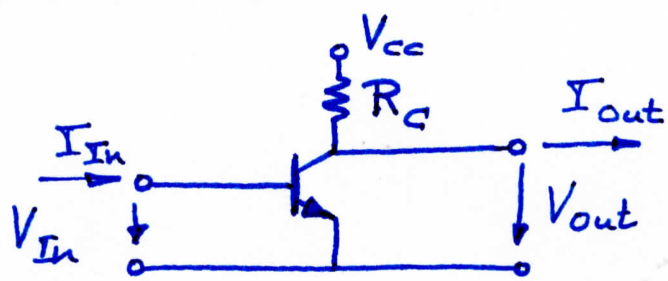
$$Z_{in} = \frac{V_{in}}{i_{in}}$$

$$Z_{out} = \frac{V_{out}}{i_{out}}$$

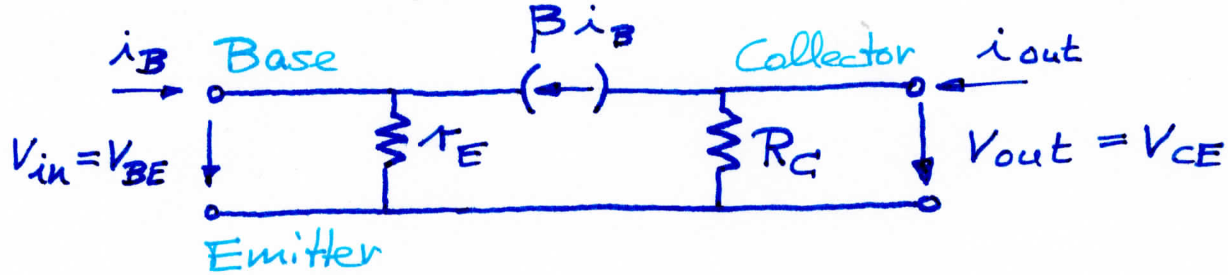
$$A_{VOC} = \frac{V_{out}}{V_{in}}\Big|_{\text{OC output}}$$

$$A_{ISC} = \frac{i_{out}}{i_{in}}\Big|_{\text{SC output}}$$

(b) Common-E circuit



Small-signal equivalent circuit



$$Z_{in} = \frac{V_{in}}{i_{in}} = \frac{i_B r_E + \beta i_B r_E}{i_B} = r_E + \beta r_E = r_E(\beta+1)$$

$$\approx \underline{r_E \beta}$$

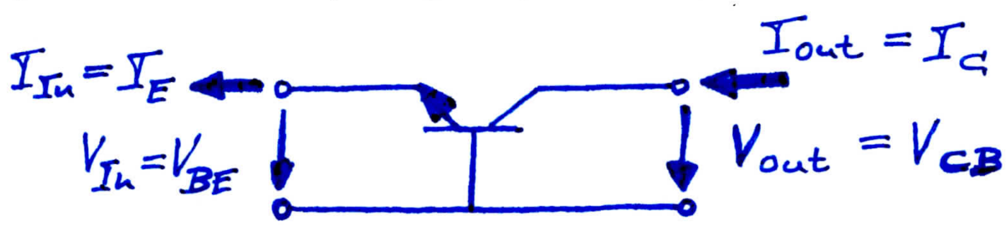
$$z_{out} = \frac{V_{out}}{i_{out}} = \frac{R_C\, i_{out}}{i_{out}} = \underline{\underline{R_C}}$$

$$A_{VOC} = \frac{V_{out}}{V_{in}} = \frac{\beta i_B R_C}{i_B r_E + \beta i_B r_E} = \frac{\beta R_C}{r_E(\beta+1)} \approx \underline{\underline{\frac{R_C}{r_E}}}$$

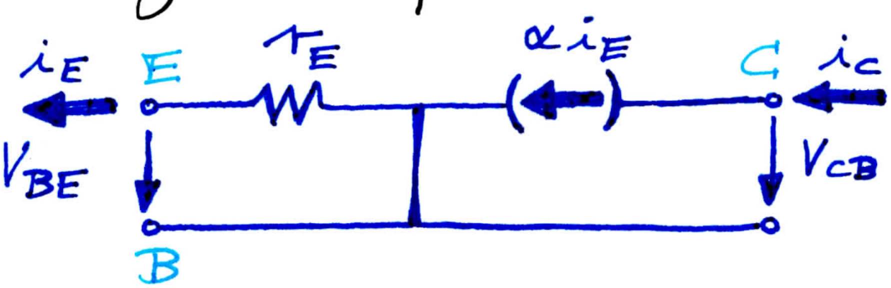
A_{VOC} has a large value since r_E is small.

$$A_{ISC} = \frac{i_{out}}{i_{in}} = \frac{\beta\, i_B}{i_B} = \underline{\underline{\beta}}$$

(c) Common - B circuit



Small - signal equivalent circuit



$$z_{in} = \frac{V_{in}}{i_{in}} = \frac{r_E\, i_E}{i_E} = r_E$$ (small value)

any value

$$z_{out} = \frac{V_{out}}{i_{out}} = \frac{V_{out}}{\alpha\, i_E} = \infty$$

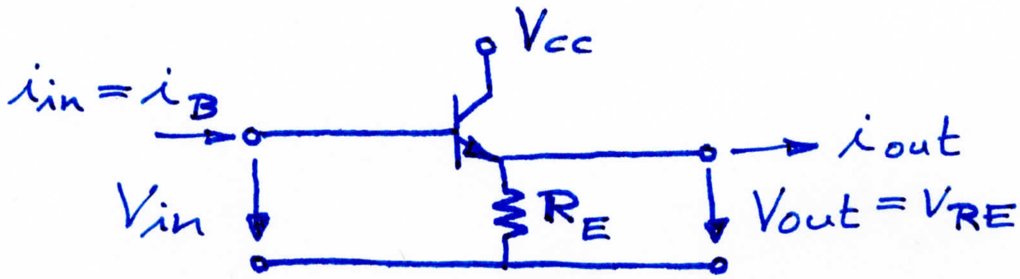
⇒ Current source has ∞ resistance

$$A_{VOC} = \frac{V_{out}}{V_{in}} = \frac{\infty}{i_E r_E} = \infty$$

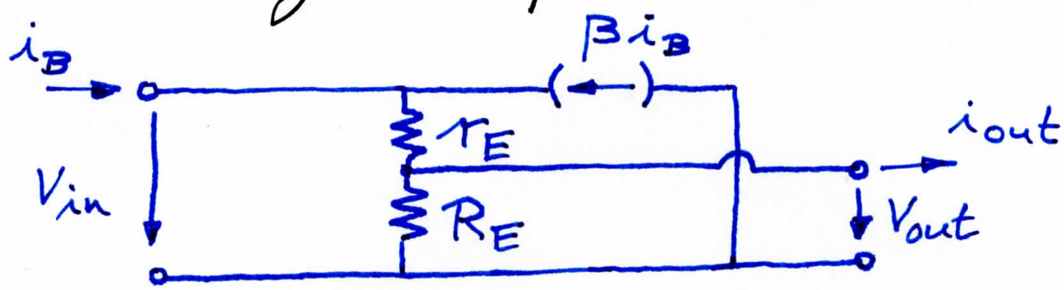
For OC at output, V_{out} increases to ∞.

$$A_{ISG} = \frac{i_{out}}{i_{in}} = \frac{\alpha i_E}{i_E} = \underline{\underline{\alpha}} \approx \underline{\underline{1}}$$

(d) Common - C circuit



Small-signal equivalent circuit



$$z_{in} = \frac{V_{in}}{i_{in}} = \frac{i_B(r_E + R_E) + \beta i_B (r_E + R_E)}{i_B}$$

$$= (\beta + 1)(r_E + R_E) \approx \underline{\underline{\beta (r_E + R_E)}}$$

$$\approx \underline{\underline{\beta R_E}}$$ (highest value of the three circuits)

$$z_{out} = \frac{V_{out}}{i_{out}} = \frac{i_{out} R_E}{i_{out}} = \underline{\underline{R_E}}$$

$$A_{VOC} = \frac{V_{out}}{V_{in}} = \frac{(i_B + \beta i_B) R_E}{(i_B + \beta i_B)(r_E + R_E)} = \frac{R_E}{\underbrace{r_E}_{\text{small}} + R_E} \approx \frac{R_E}{R_E} \approx \underline{\underline{1}}$$

$$A_{ISG} = \frac{i_{out}}{i_{in}} = \frac{(\beta + 1) i_B}{i_B} = \beta + 1 \approx \underline{\underline{\beta}}$$

(e) Common-B amplifier has lowest input impedance (r_E). Generally <u>not</u> desirable (may overload source)

(f) Common-E and common-C circuits have low output impedance. This is desirable (load will not overload circuit)

(g) The common-C-circuit has lowest A_{voc} ($A_{voc} \approx 1$)

(h) The common-B circuit has lowest A_{Isc} ($A_{Isc} \approx 1$)

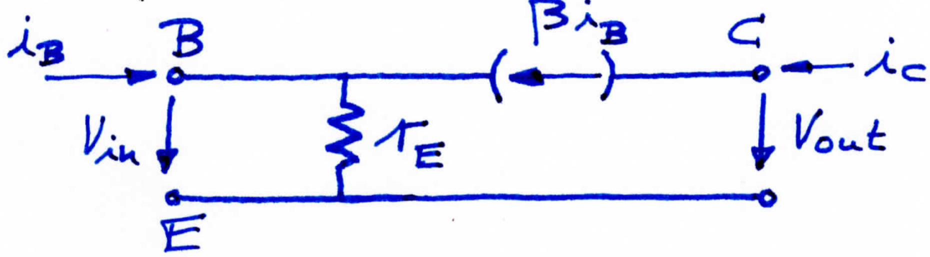
(i) Common-C $\Rightarrow$ Impedance transformation (i.e. changing a high-impedance source to a low-impedance source)

Common-E $\Rightarrow$ Amplifier (i.e. amplifying a signal)

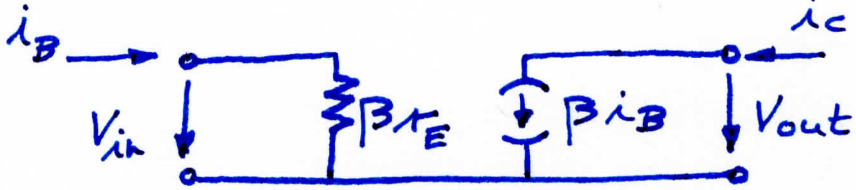
Common-B $\Rightarrow$ If we wish to convert a V-source to an I-source, the common-B circuit will accomplish this.

Problem 2 "T" and "π" equivalent circuit of BJT

(a) "T" equivalent circuit



"π" - equivalent circuit



Three conditions

$Z_{in} = \dfrac{V_{in}}{i_{in}}$ must be the same

$Z_{out} = \dfrac{V_{out}}{i_{out}}$ must be the same

$A_{Isc} = \dfrac{i_{out}}{i_{in}}$ must be the same

(b) **T**: $Z_{in} = \dfrac{V_{in}}{i_{in}} = \dfrac{(i_{in} + \beta i_{in}) r_E}{i_{in}} = (1+\beta) r_E \approx \beta r_E$

π : $Z_{in} = \dfrac{V_{in}}{i_{in}} = \beta r_E$

$\Rightarrow$ Same result

$T: \quad Z_{out} = \dfrac{V_{out}}{i_{out}} = \infty$

$\pi: \quad Z_{out} = \dfrac{V_{out}}{i_{out}} = \infty$

$\Rightarrow$ Same result

$T: \quad A_{ISC} = \dfrac{i_{out}}{i_{in}} = \dfrac{\beta i_B}{i_B} = \beta$

$\pi: \quad A_{ISC} = \dfrac{i_{out}}{i_{in}} = \dfrac{\beta i_B}{i_B} = \beta$

$\Rightarrow$ Same result

$\Rightarrow$ T and π circuits are equivalent

(c) T circuit (LHS) advantage:

The circuit is closer to the real physical device.

π circuit (RHS) advantage:

The circuit decouples the input side from the output side thereby facilitating our thinking and our analysis.

Problem 3 True / false questions

(a) True $V_{BE,DC}$ must be 0.7V for the BJT to operate normally.
$V_{BE,AC}$ must be $\ll 0.7V$ to allow for a linear circuit model.

(b) True The BJT has 2 diodes: BE diode and CB diode.

(c) False $A_{VOC} \approx 1$ for common-C circuit.
$\hookrightarrow$ = low

(d) False Common-B configuration is rarely used due to low Z_{in} and low A_{ISC}.