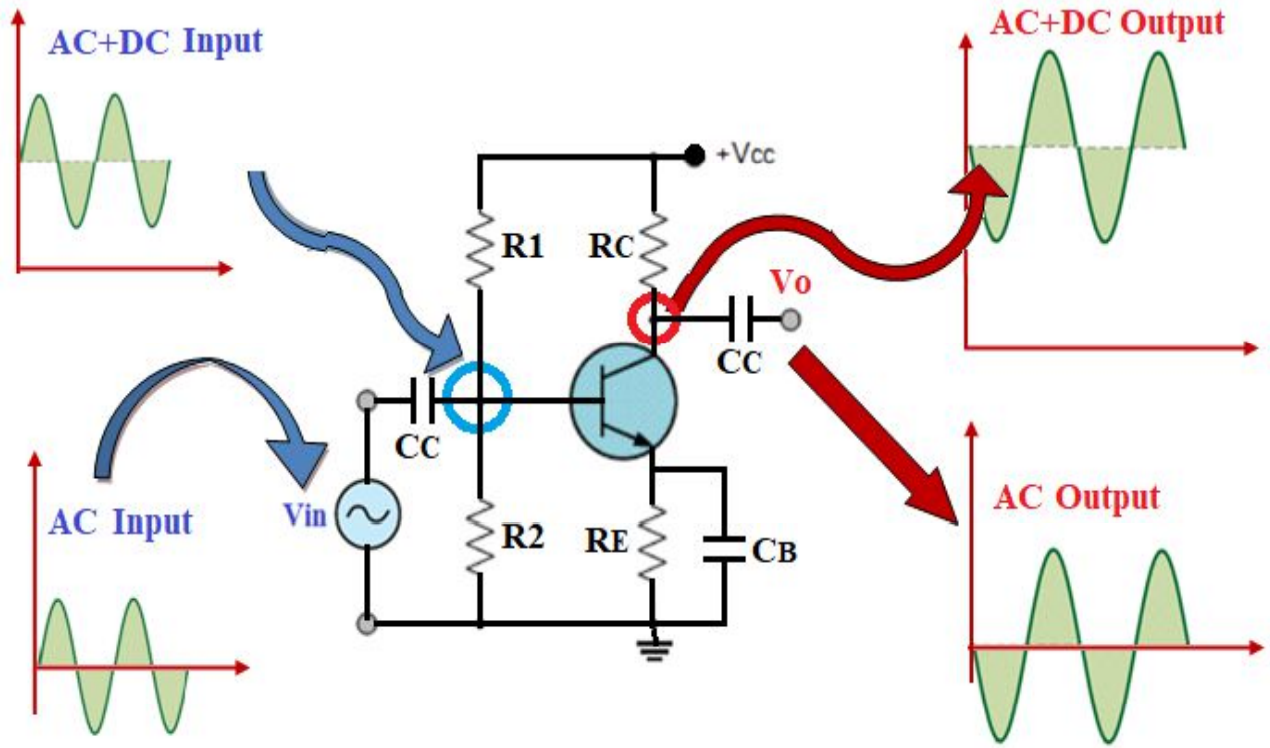
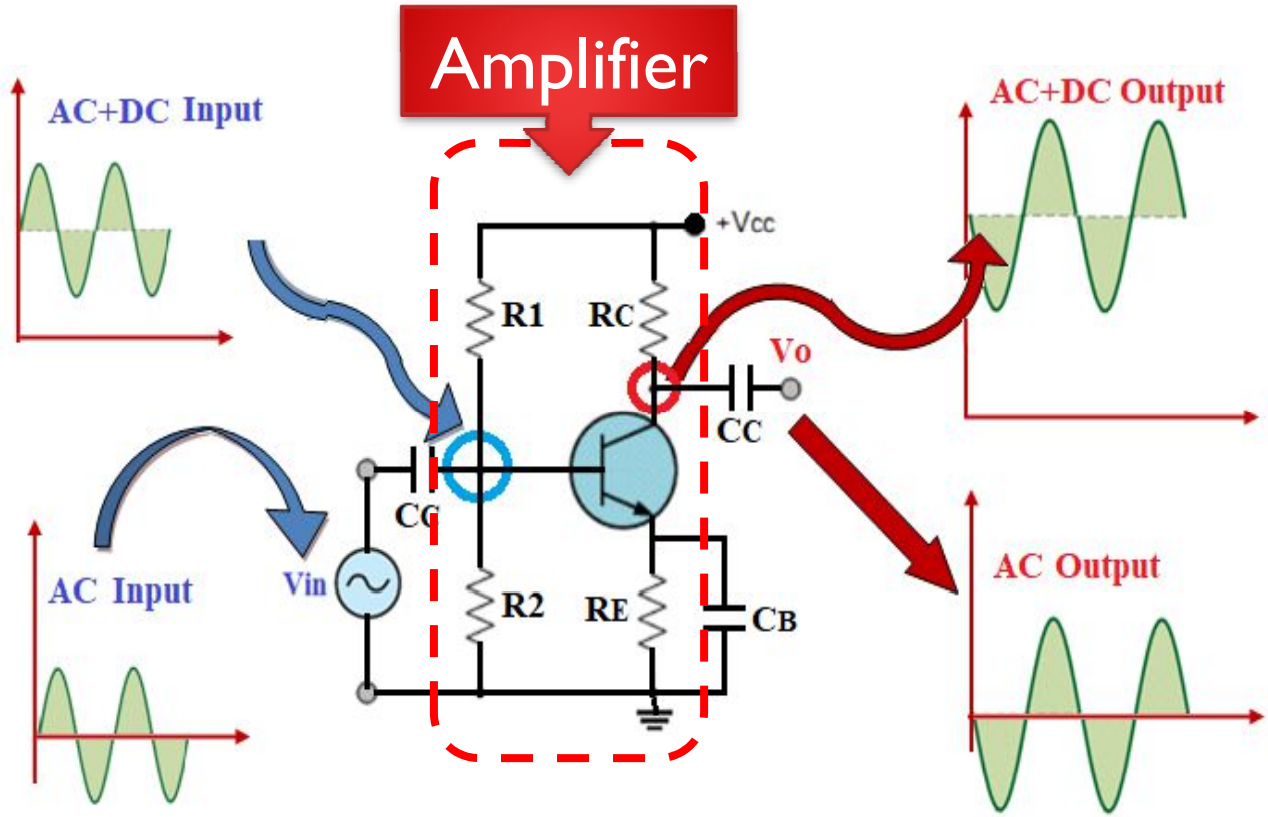
BJT AMPLIFIERS Small signal analysis and design

1. Introduction
2. Two-port system
3. BJT configurations
4. BJT Small signal models
5. Hybrid π model
6. Circuit model of a voltage amplifier
7. App 1: C-E Fixed bias amplifier

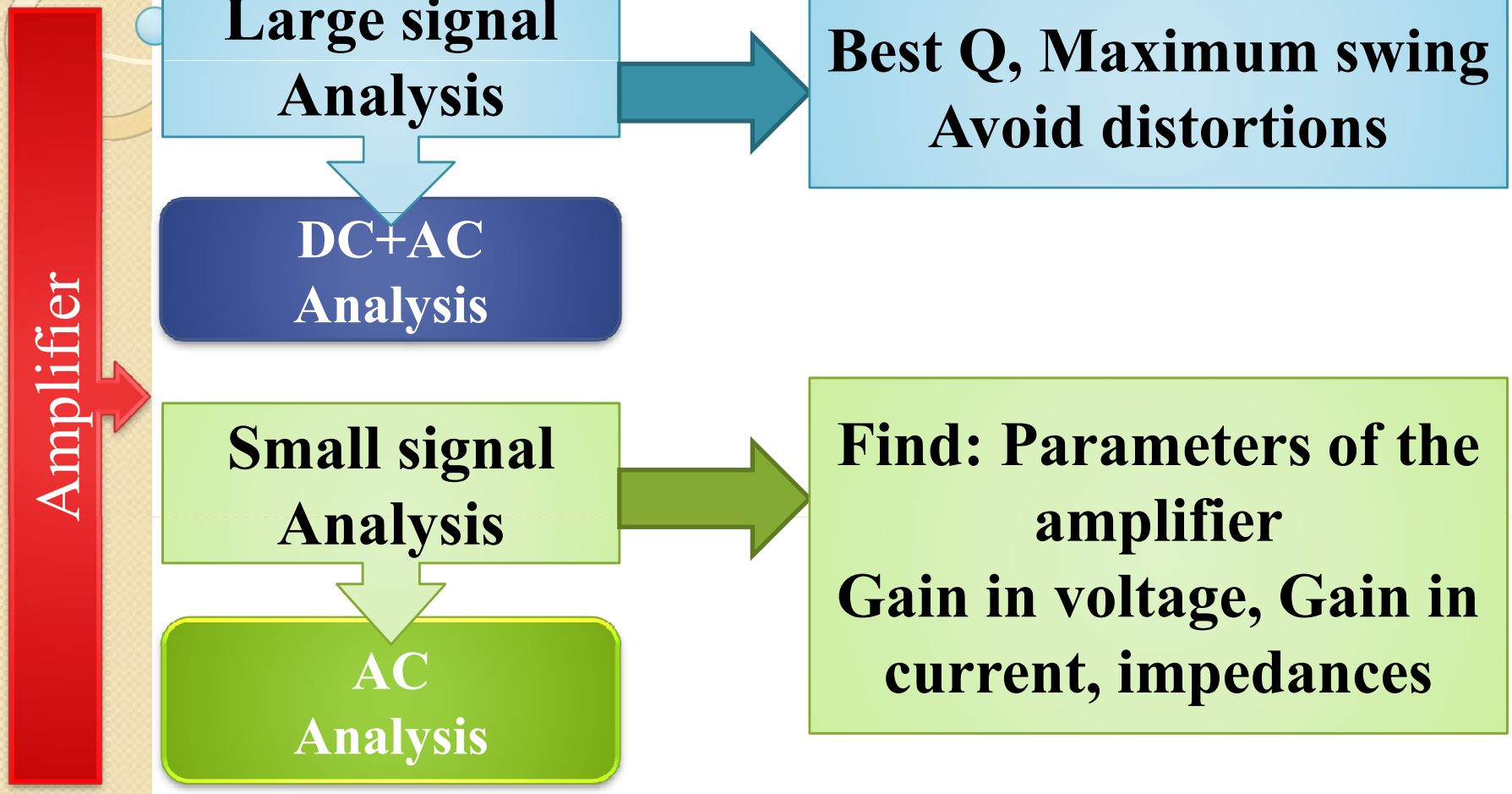
Introduction



Introduction



Introduction



Introduction

Amplifier

Small signal Analysis

1

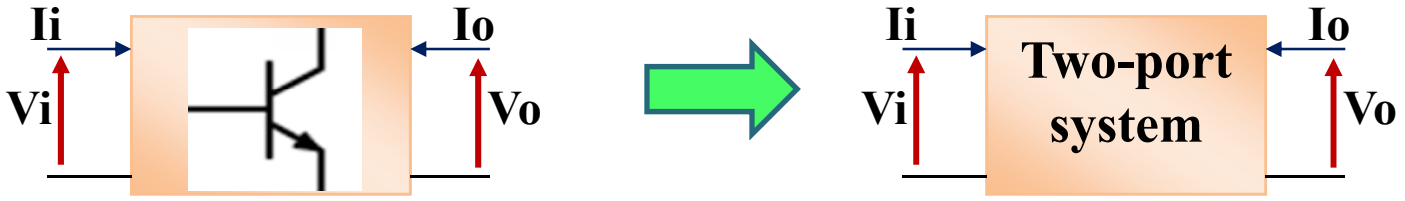
Find Small signal models for the BJT

2

Find Small signal models for the Amplifier

Introduction

- ✓Small signal models is an equivalent circuit (two port system) that represents the AC characteristics of the transistor (Amplifier).
- ✓A model uses circuit elements that approximate the behavior of the transistor.



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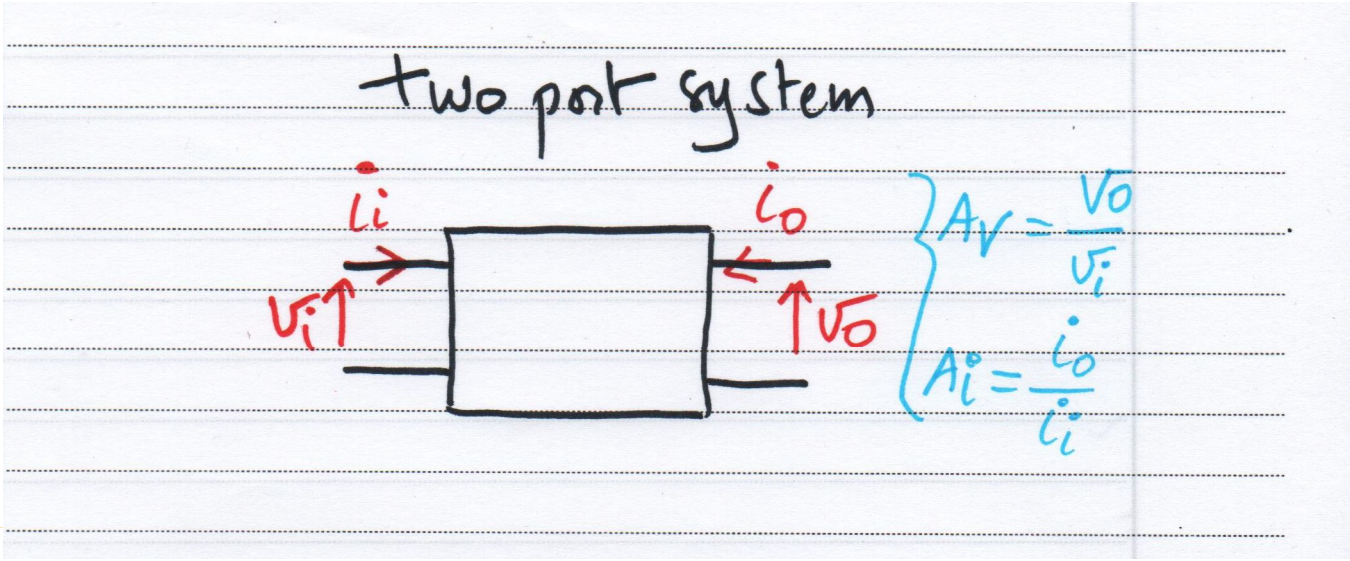
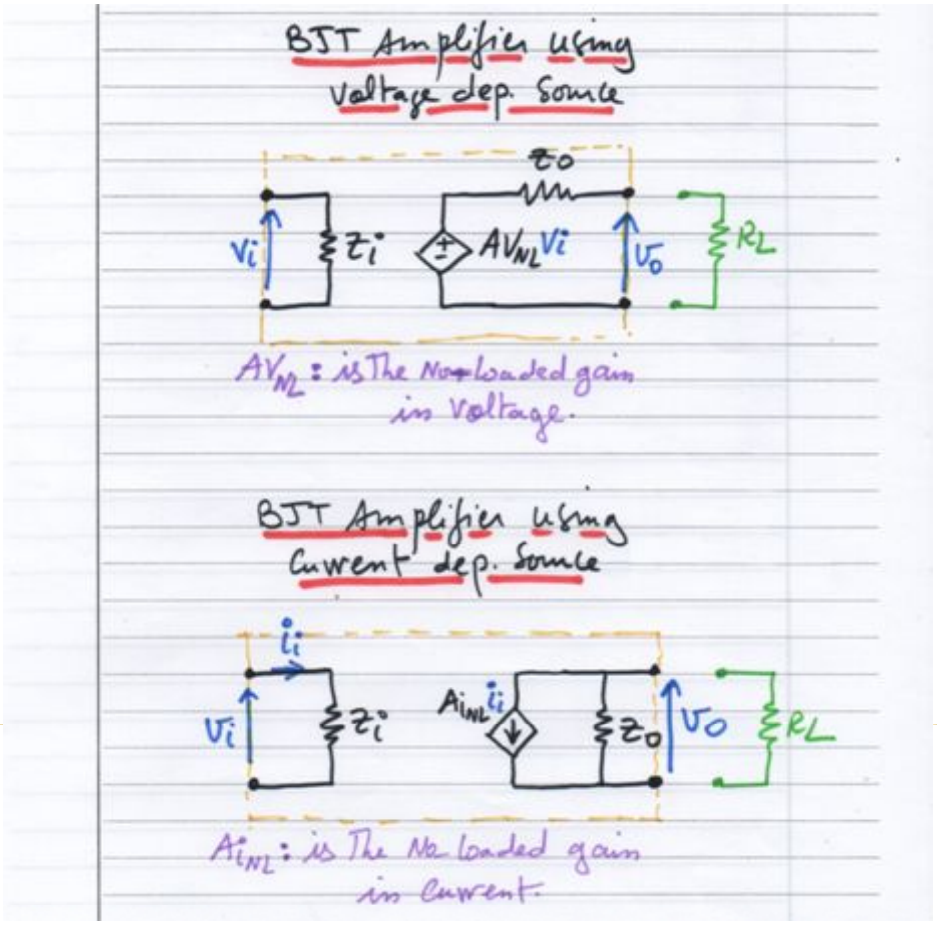

two port system
i_i
i_o
v_i
v_o
$A_v = \frac{v_o}{v_i}$
$A_i = \frac{i_o}{i_i}$


BJT Amplifier using
Voltage dep. Source
z_o
v_i
z_i
$AV_{NL}v_i$
v_o
R_L
AV_{NL} : is The Noo-loaded gain
in Voltage.
BJT Amplifier using
Current dep. Source
i_i
v_i
z_i
$Ai_{NL}i_i$
z_o
v_o
R_L
Ai_{NL} : is The No loaded gain
in Current.

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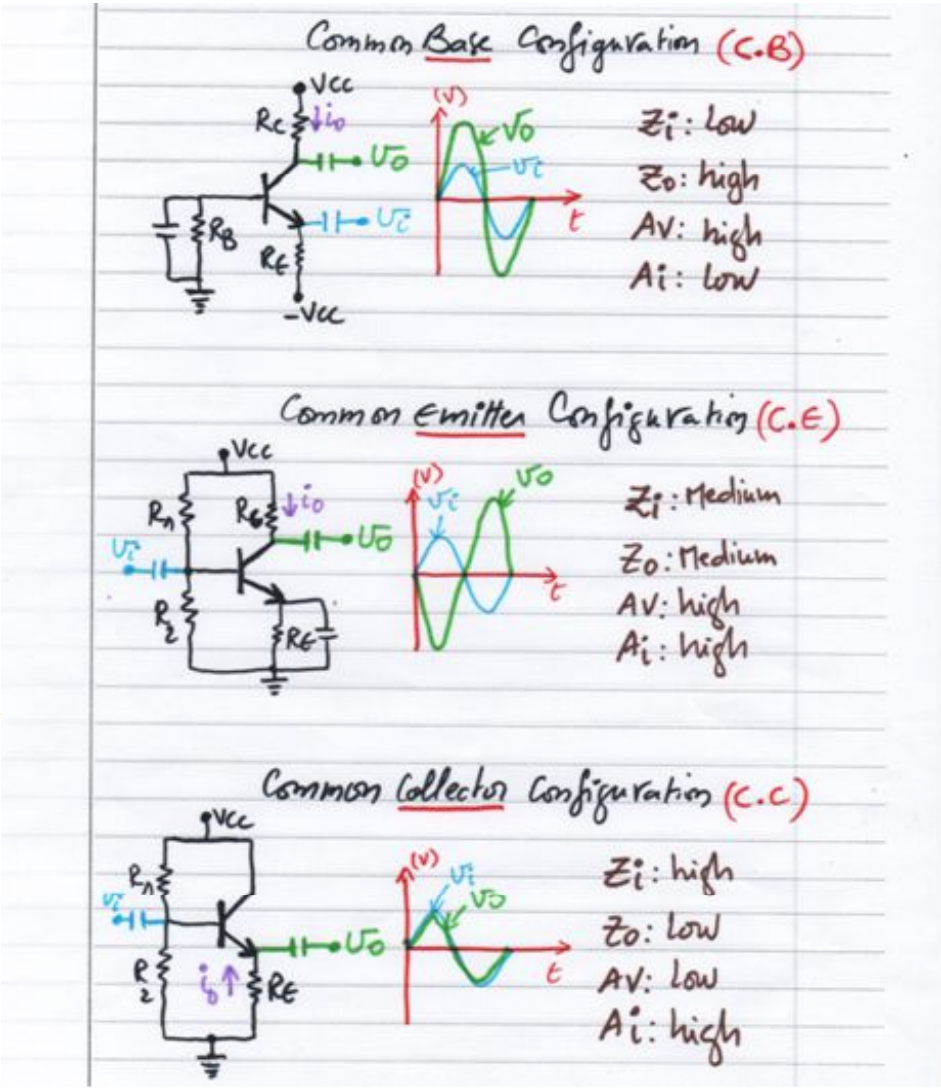
Common Base Configuration (C.B)
Vcc
Rc
io
Vo
Vi
RB
RE
-Vcc
(V)
t
Zi: low
Zo: high
AV: high
Ai: low
Common emitter Configuration (C.E)
Vcc
R1
R2
RE
Zi: Medium
Zo: Medium
AV: high
Ai: high
Common Collector Configuration (C.C)
Vcc
R1
R2
RE
ib
Zi: high
Zo: low
AV: low
Ai: high

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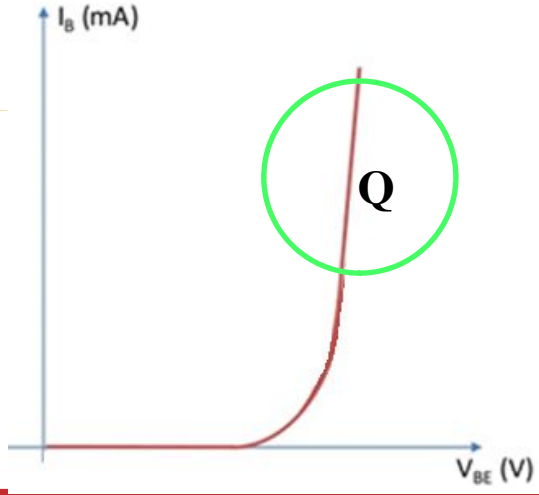
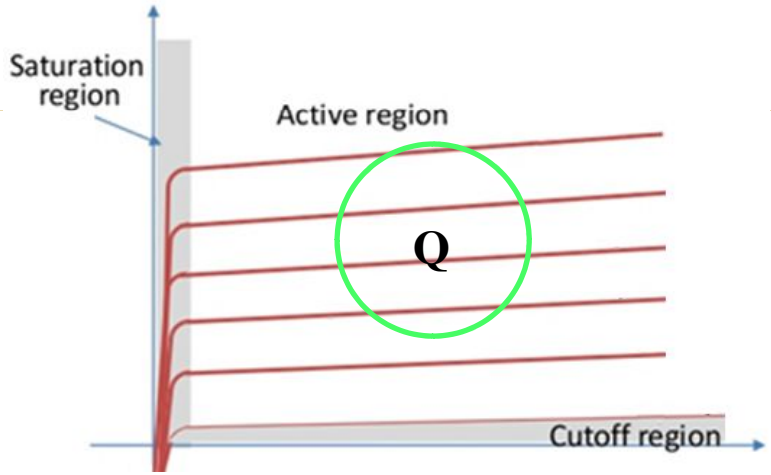
Small signal models

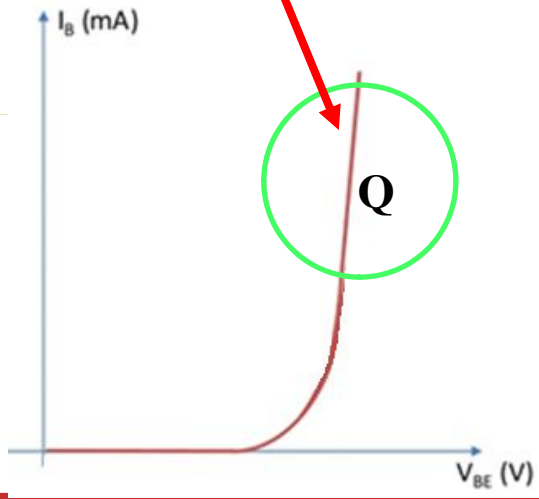
Small signal models for the BJT take advantage of the relative linearity of the base and collector curves in the area or locality of an operating point

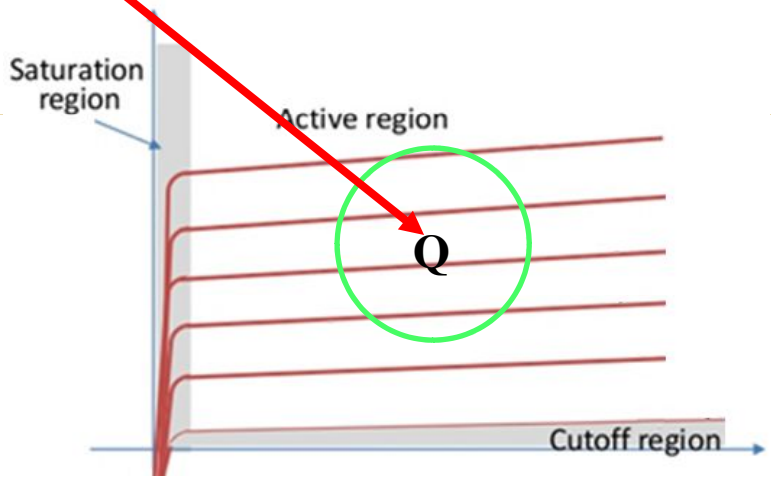




Small signal models

Small signal models for the BJT take advantage of the relative linearity of the base and collector curves in the area or locality of an operating point





Small signal models

There are two models commonly used in small signal AC analysis of a transistor:

- **Hybrid π equivalent model.**
- **r_e model.**

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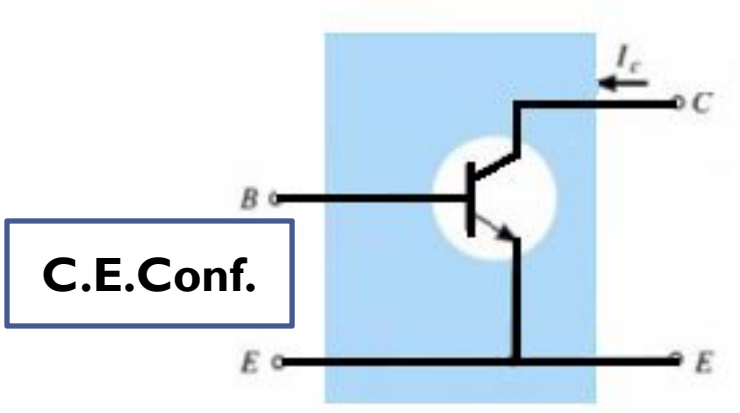
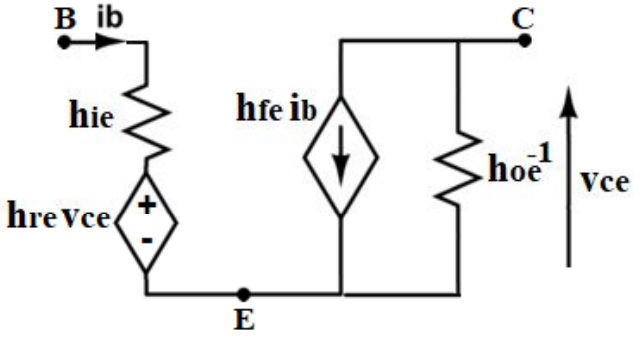
➢Hybrid π model.

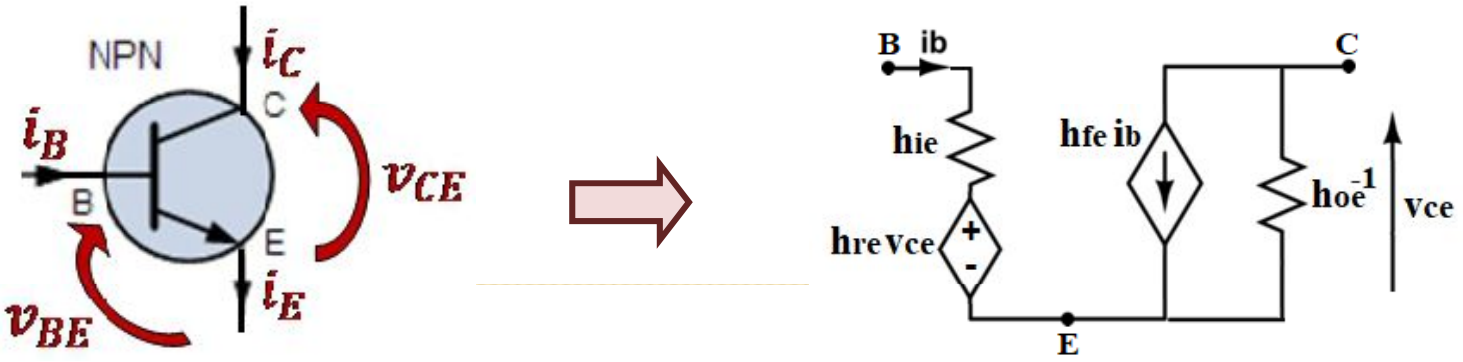
The parameters can be found on the specification sheet of the transistor.



C.E.Conf.



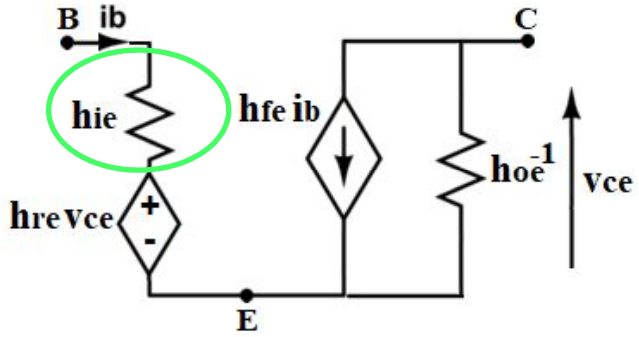
➢Parameters of the Hybrid model.

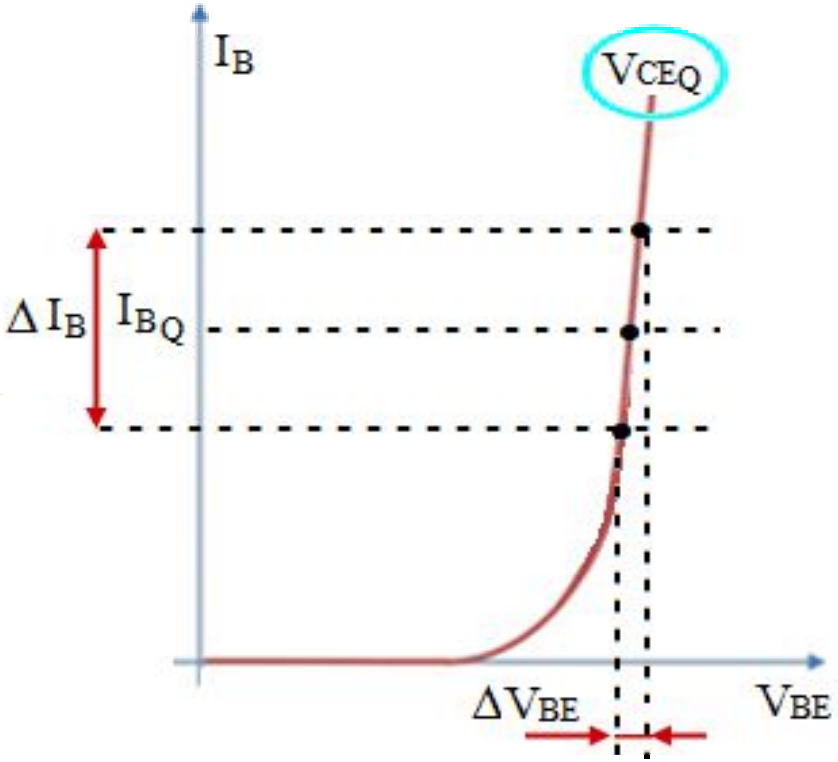


➢Parameters of the Hybrid model.

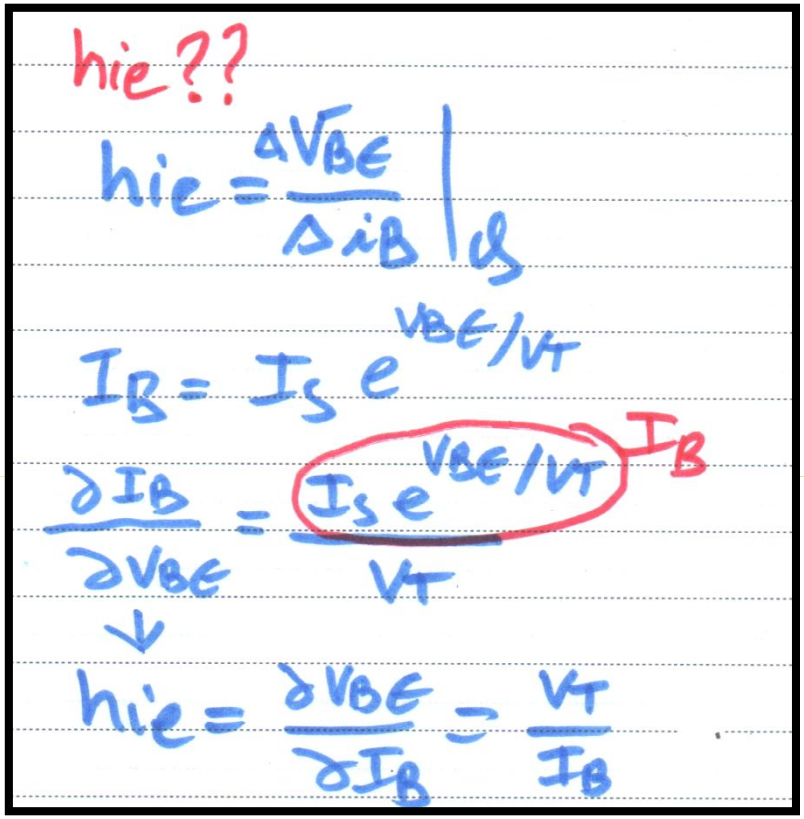
- Input impedance h_{ie}

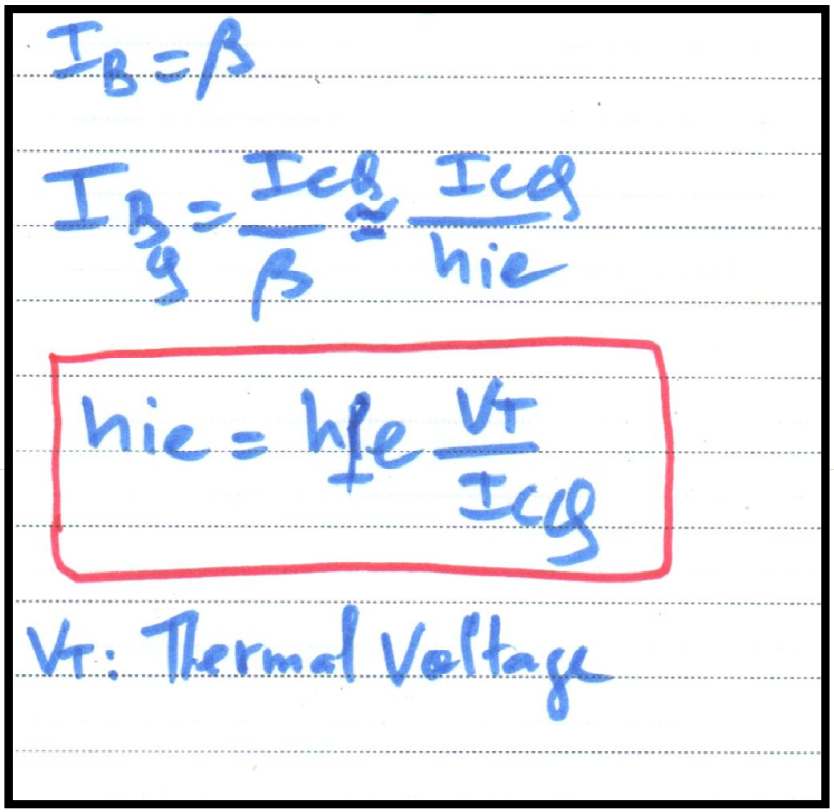
$$h_{ie} = \left.\frac{\Delta v_{BE}}{\Delta i_B}\right|_{V_{CEQ}}$$





➢Parameters of the Hybrid model.

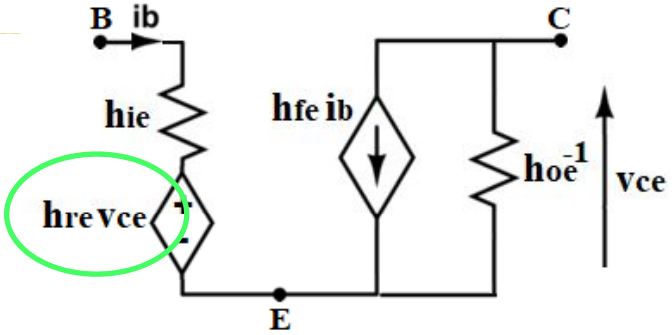


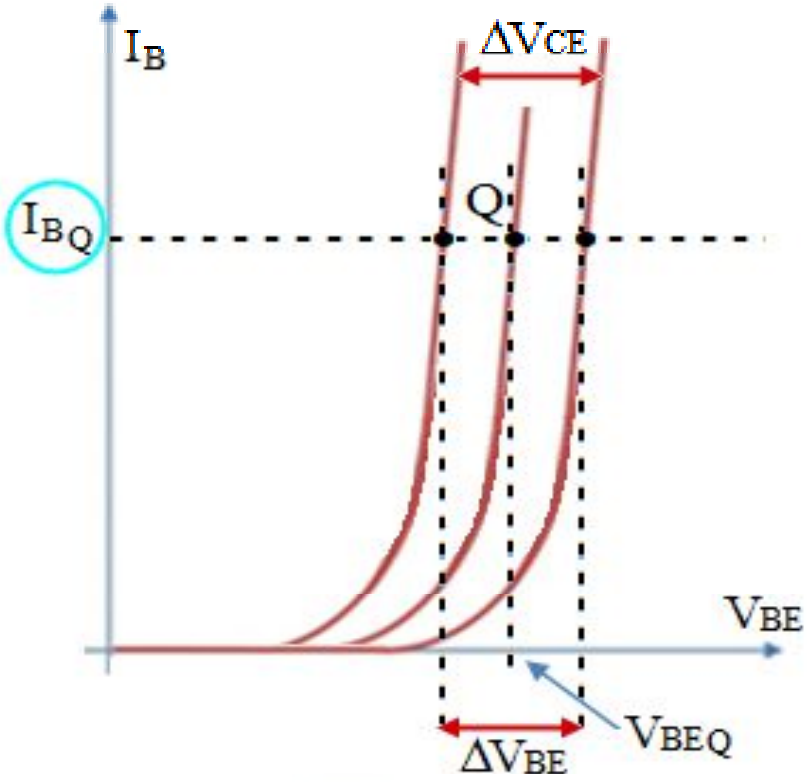


➢Parameters of the Hybrid model.

- Reverse voltage gain h_{re}

$$h_{re} = \left.\frac{\Delta v_{BE}}{\Delta v_{CE}}\right|_{I_{BQ}}$$

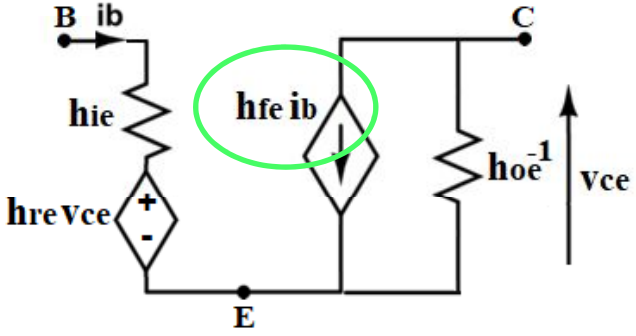


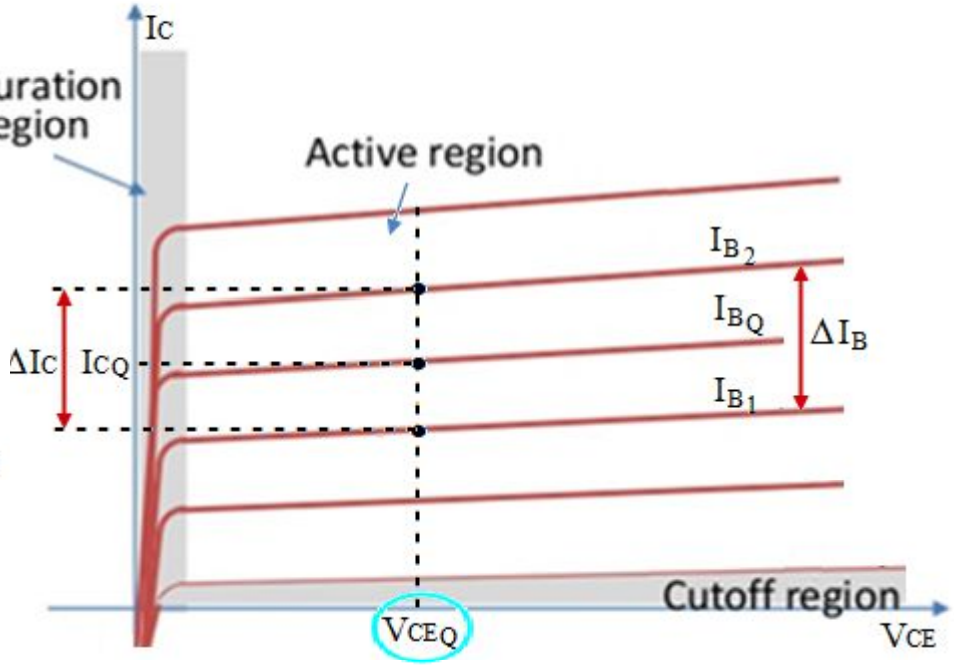


➢Parameters of the Hybrid model.

- **Forward current gain h_{fe}**

$$h_{fe} = \left.\frac{\Delta i_C}{\Delta i_B}\right|_{V_{CEQ}}$$

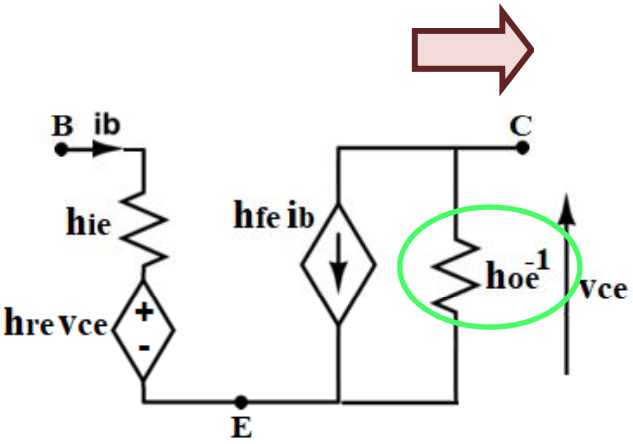


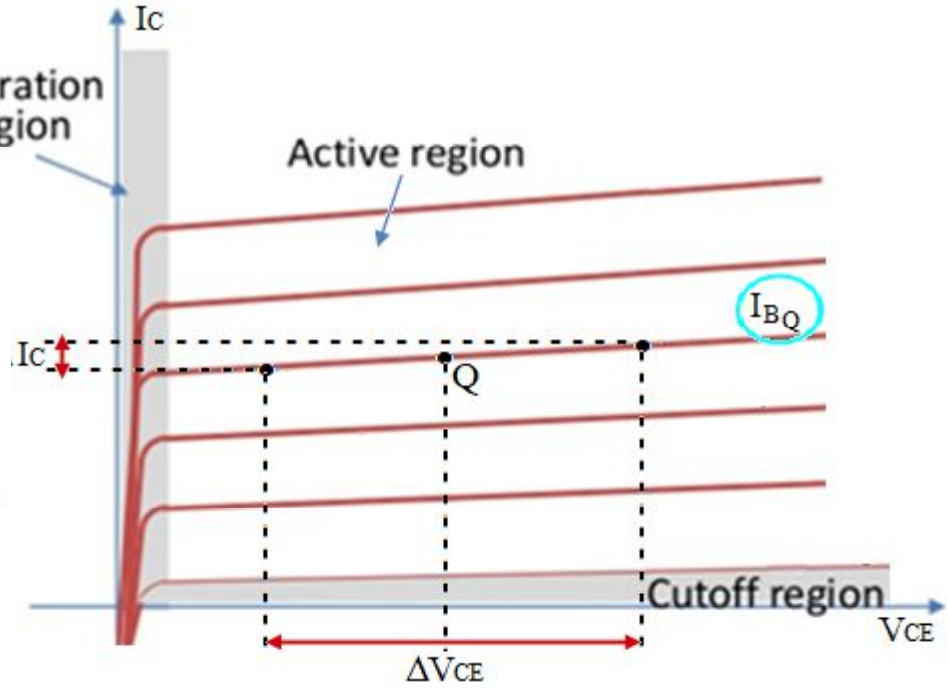


➢Parameters of the Hybrid model.

- Output admittance h_{oe}

$$h_{oe} = \left.\frac{\Delta i_C}{\Delta v_{CE}}\right|_{I_{BQ}}$$



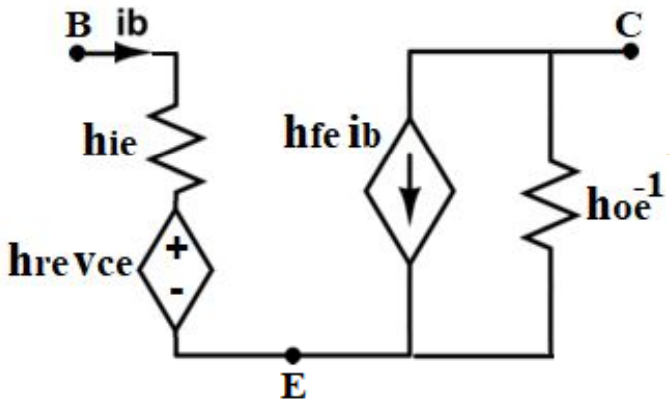


Small signal models

➢Example about Hybrid model

The hybrid parameters are drawn from the specification sheet for the **2N2222A** BJT.

Parameter	Min	Max
h_{ie} (KΩ)	2	4
h_{re} (x 10^{-4})	-	8
h_{fe}	50	300
h_{oe} (μS)	5	35



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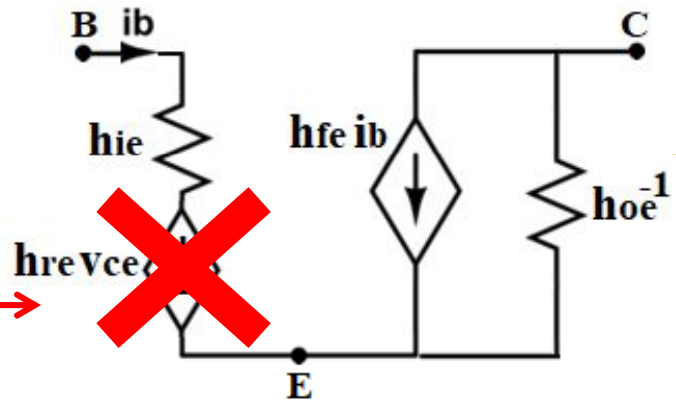
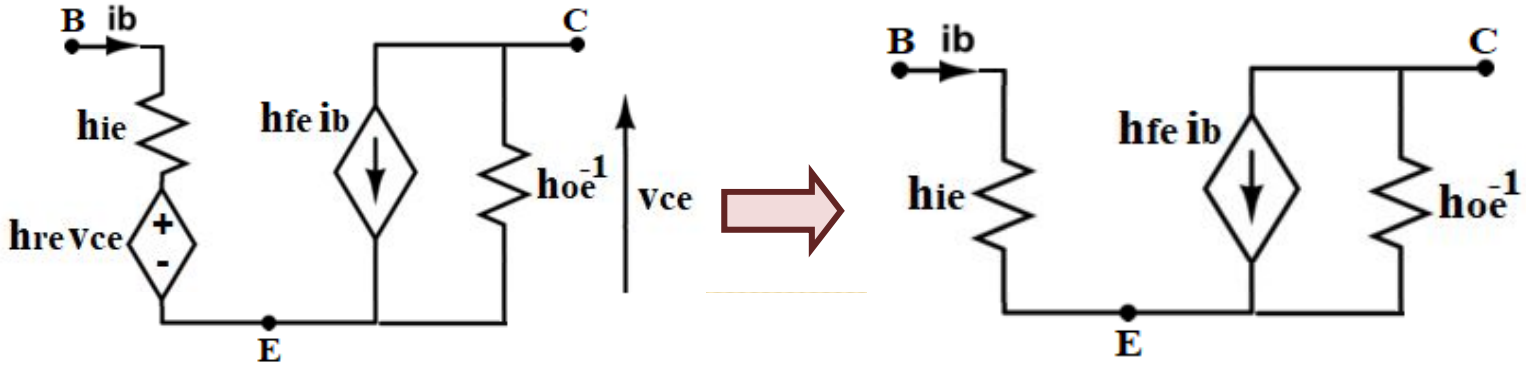


➢Simplified hybrid model



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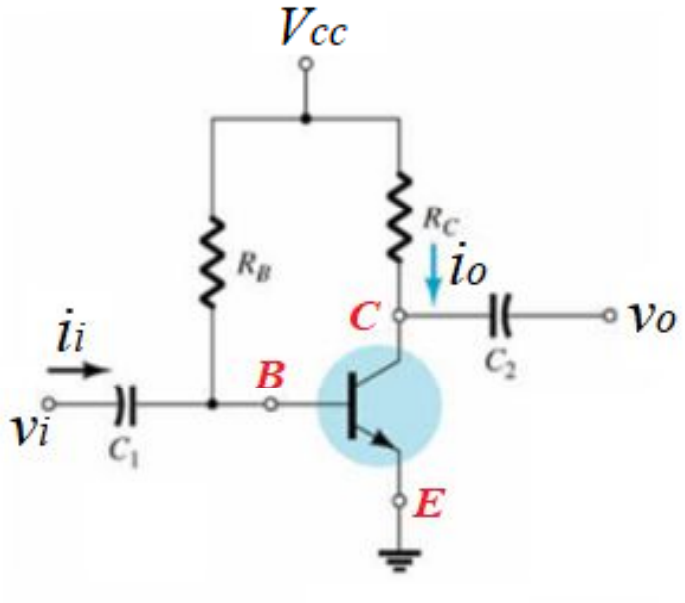
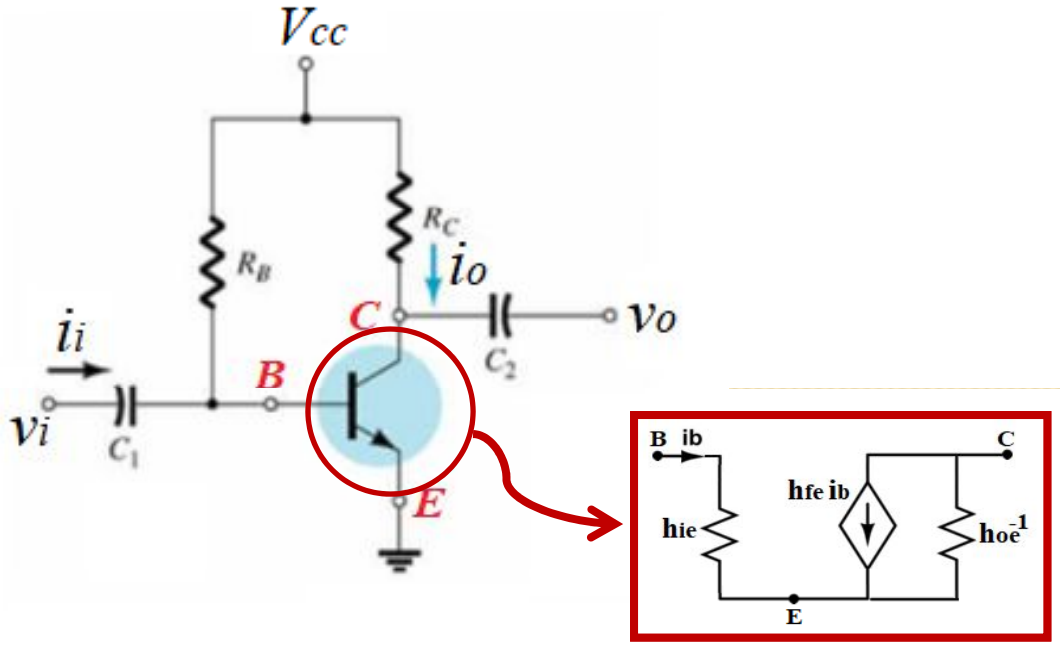
Circuit model of a voltage amplifier

- **Amplifier circuit**



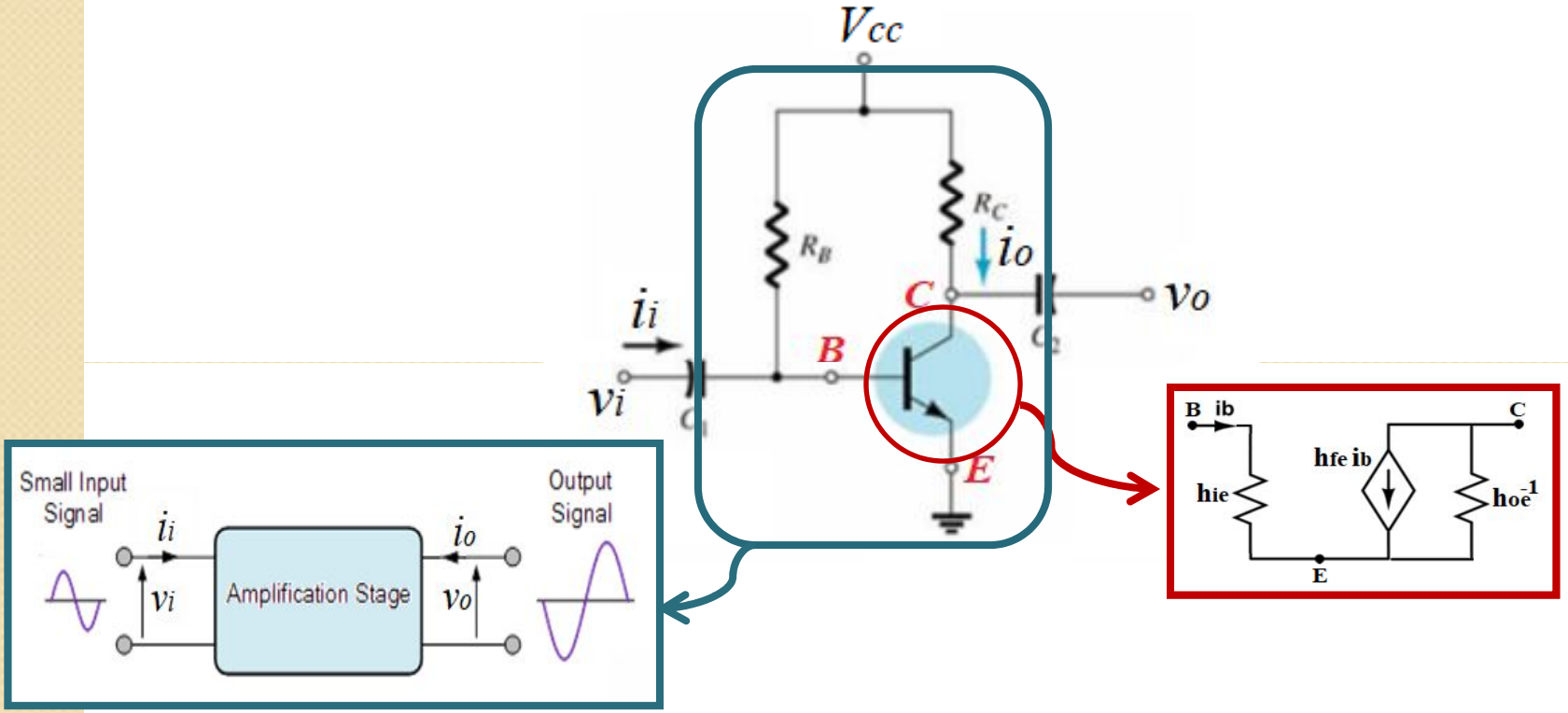
Circuit model of a voltage amplifier

- **Amplifier circuit**



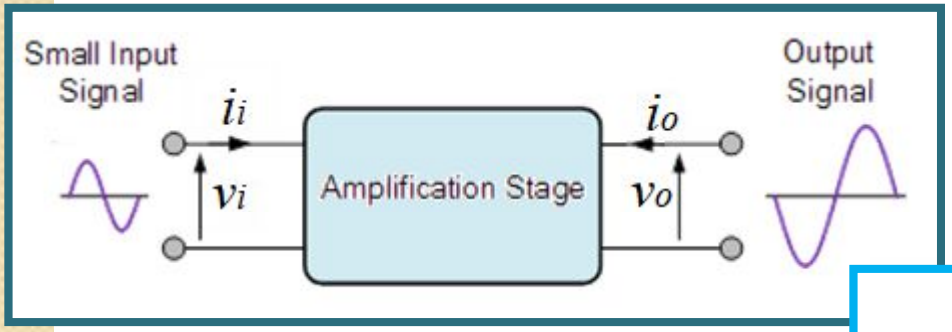
Circuit model of a voltage amplifier

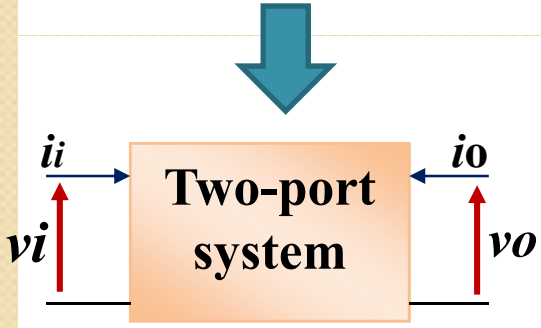
- **Amplifier circuit**



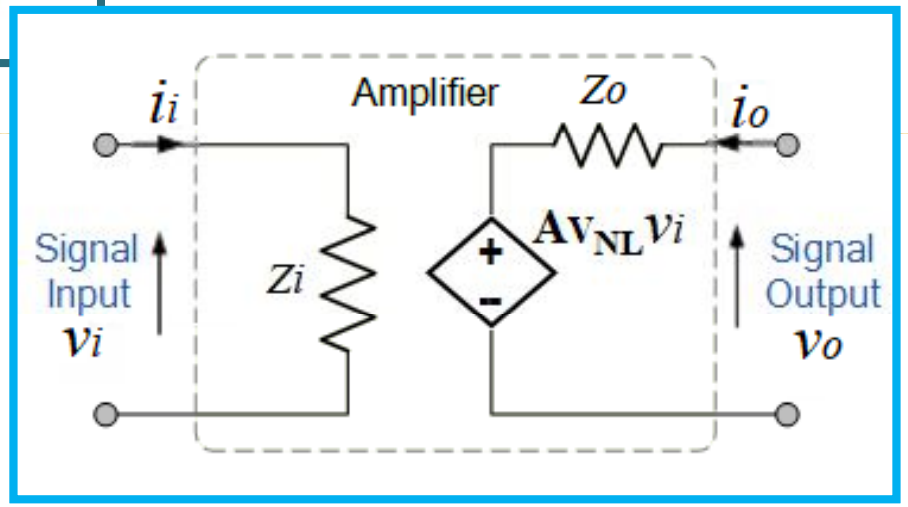
Circuit model of a voltage amplifier

➢Amplifier circuit





Voltage amplifier



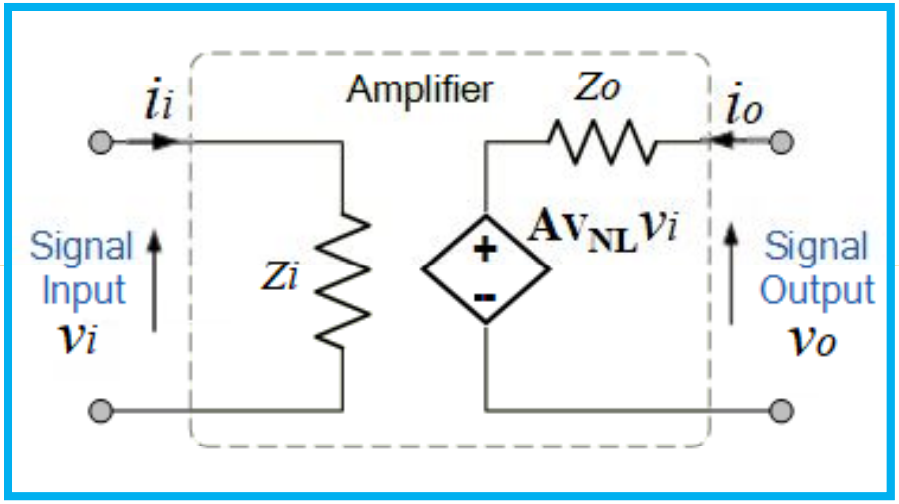
Circuit model of a voltage amplifier

➢Parametres of a voltage amplifier

Input impedance:

Zi= vi/i_i

Voltage amplifier

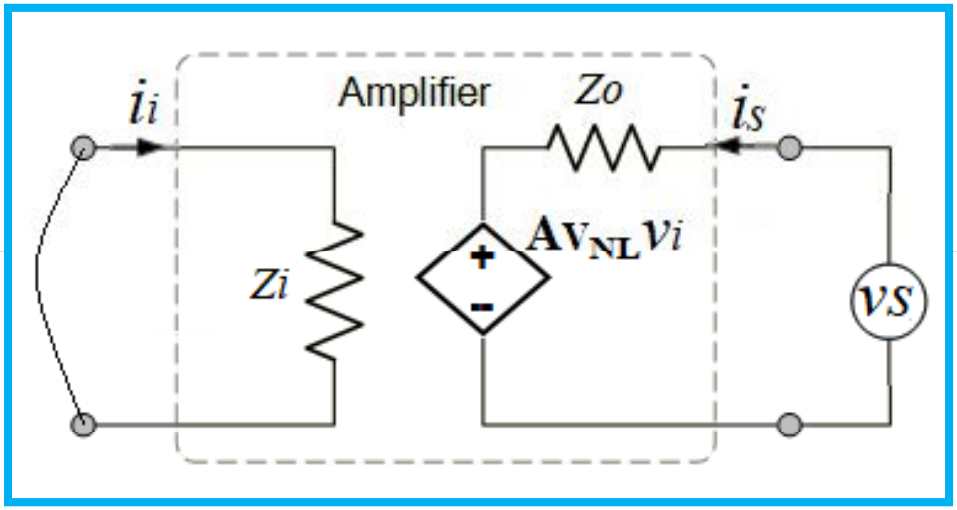


Circuit model of a voltage amplifier

➢Parametres of a voltage amplifier

Output impedance:

Zo= *vs*/*is* (*vi*=0)

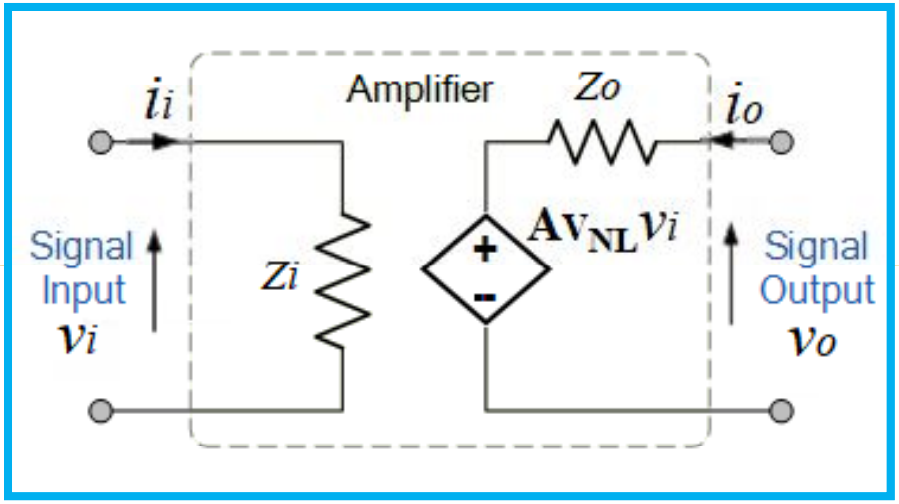


Circuit model of a voltage amplifier

➢Parametres of a voltage amplifier

No loaded voltage Gain: ($R_L=\infty$)

$Av_{NL}=vo/vi$

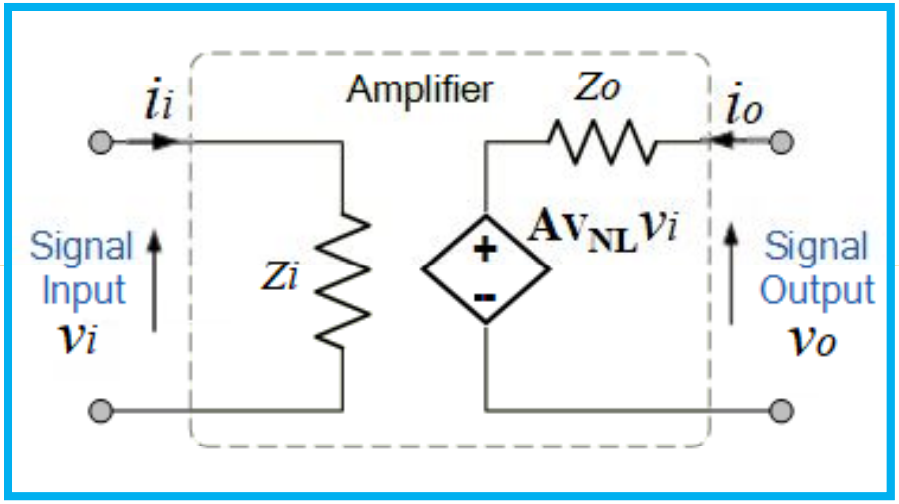


Circuit model of a voltage amplifier

➢Parametres of a voltage amplifier

No loaded Current Gain: ($R_L=\infty$)

$Ai_{NL}=io/ii$

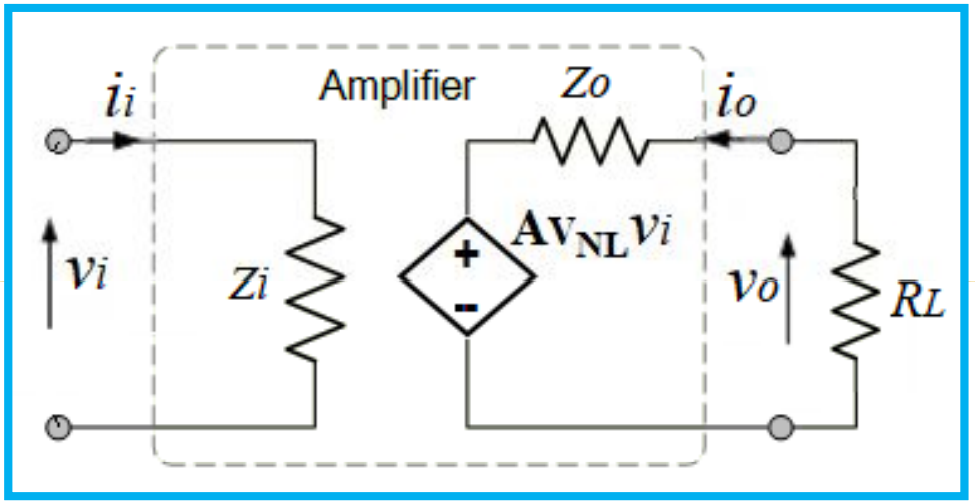


Circuit model of a voltage amplifier

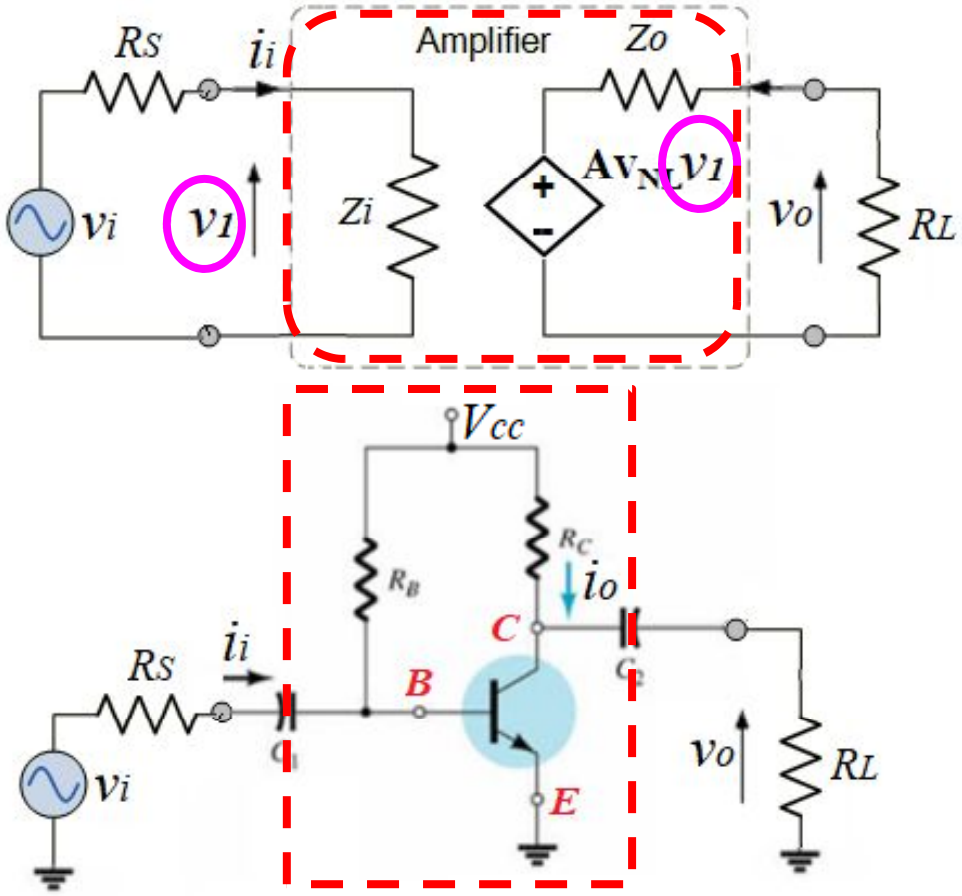
➢Parametres of a voltage amplifier

Loaded voltage Gain: ($R_L \neq \infty$)

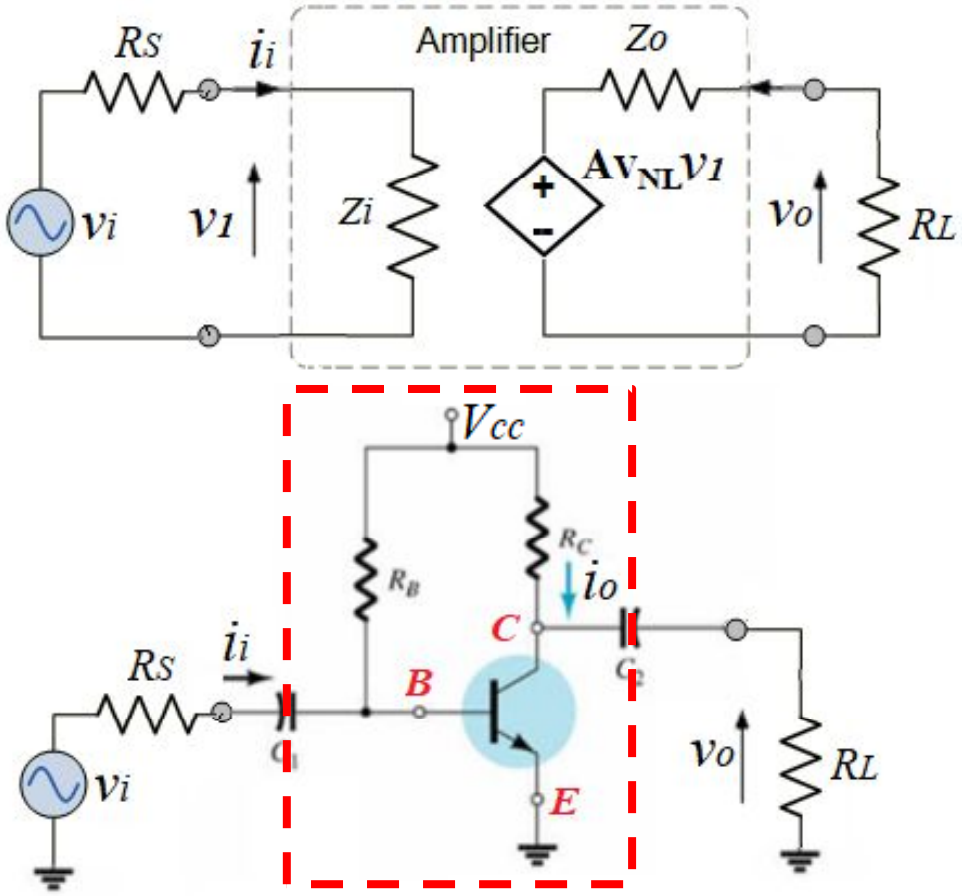
Av=*vo/vi*



Circuit model of a voltage amplifier



Circuit model of a voltage amplifier



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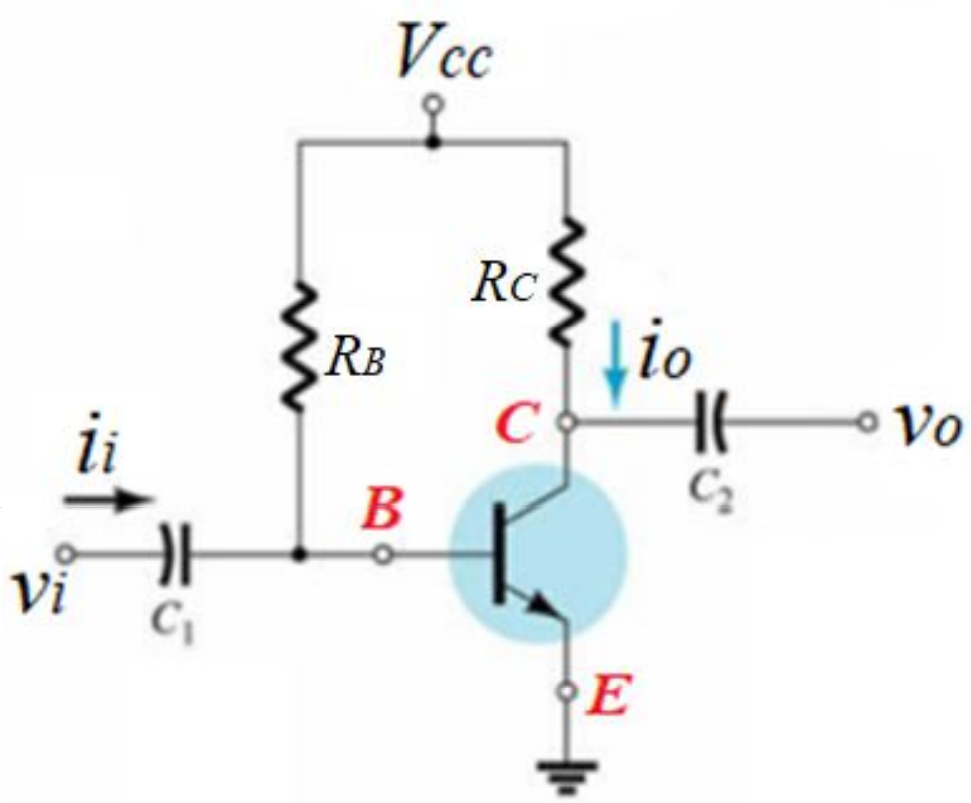
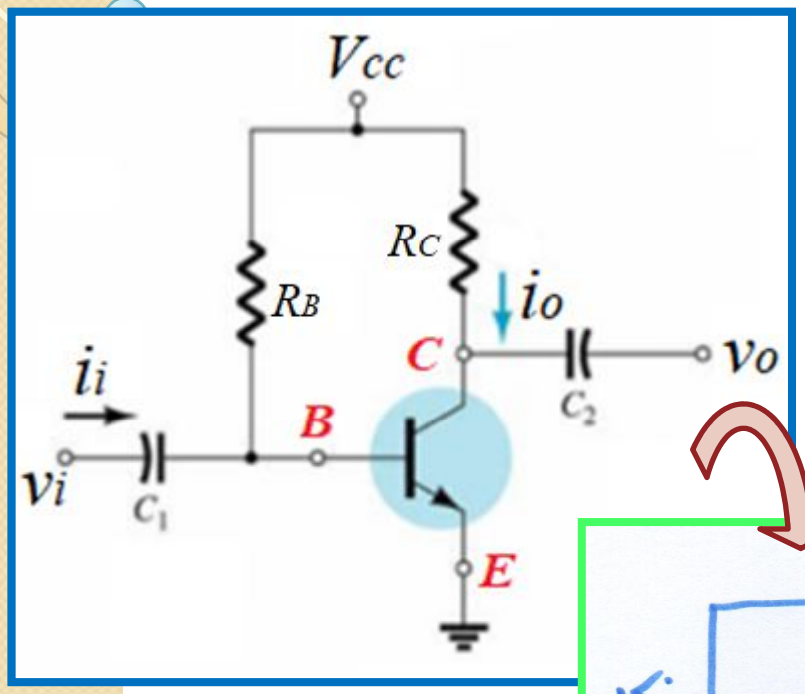
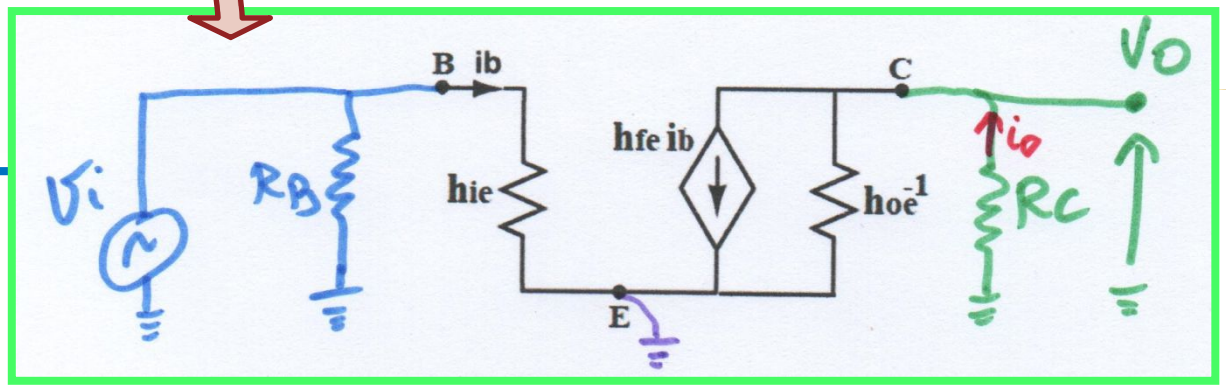
App 1: Common Emitter Fixed bias amplifier

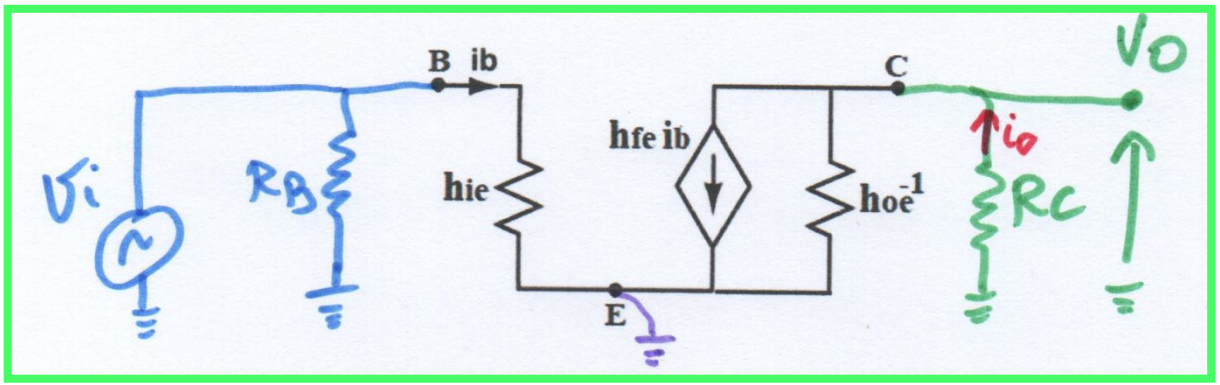


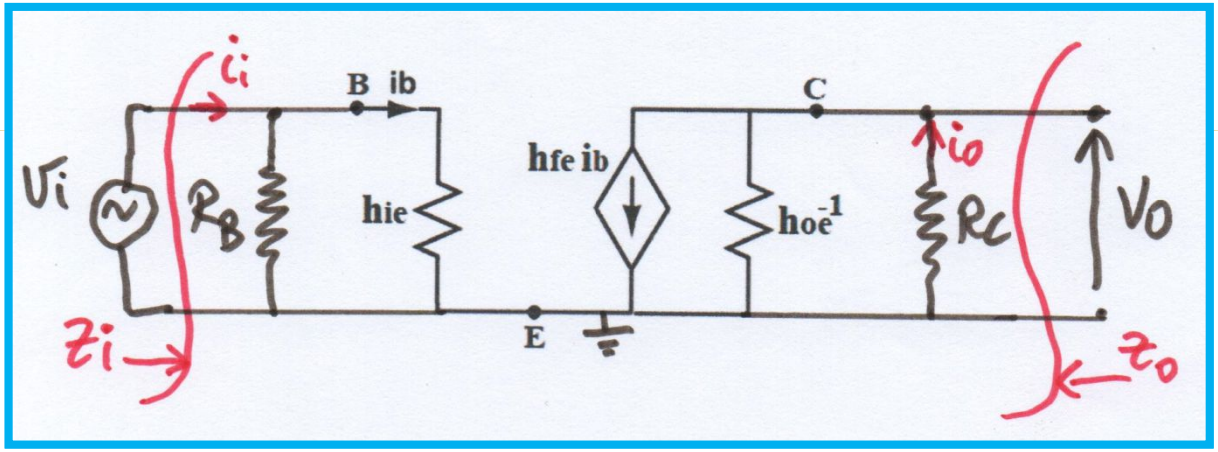
App 1: Common Emitter Fixed bias amplifier



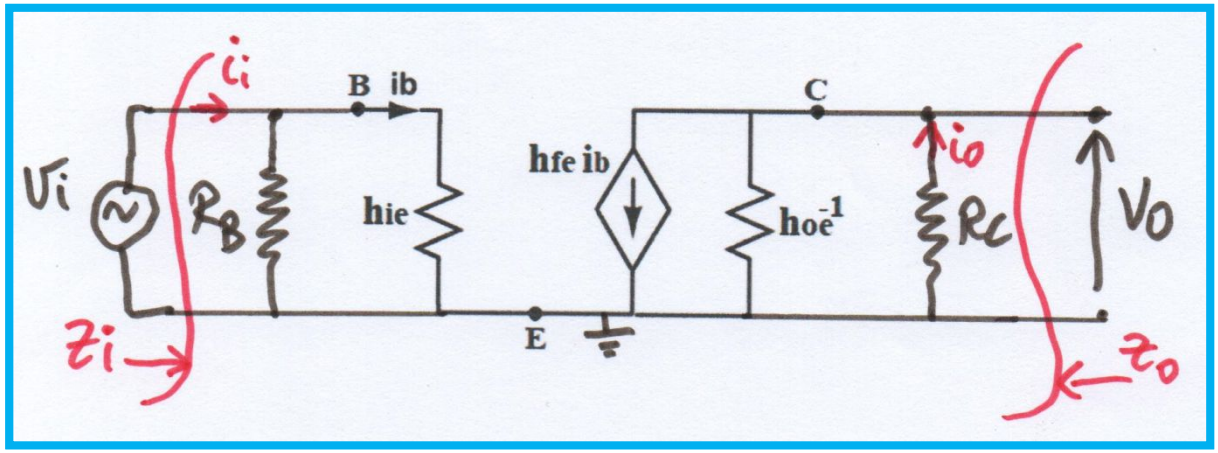


App 1: Common Emitter Fixed bias amplifier





App 1: Common Emitter Fixed bias amplifier



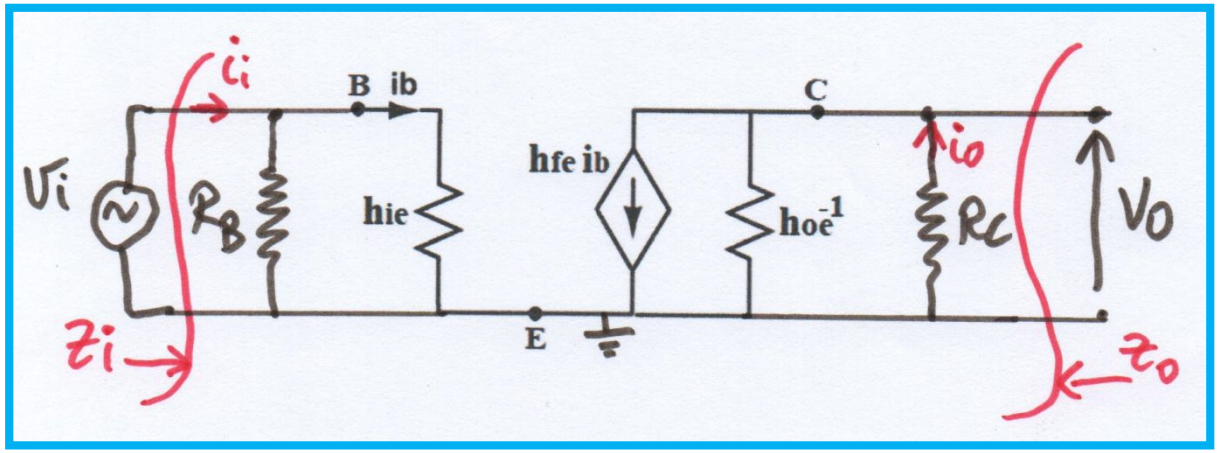
Input impedance:

$$z_i = V_i / i_i$$

$$V_i = i_i (R_B // h_{ie}) \Rightarrow$$

$$\boxed{z_i = R_B // h_{ie}}$$

App 1: Common Emitter Fixed bias amplifier



No loaded voltage Gain:

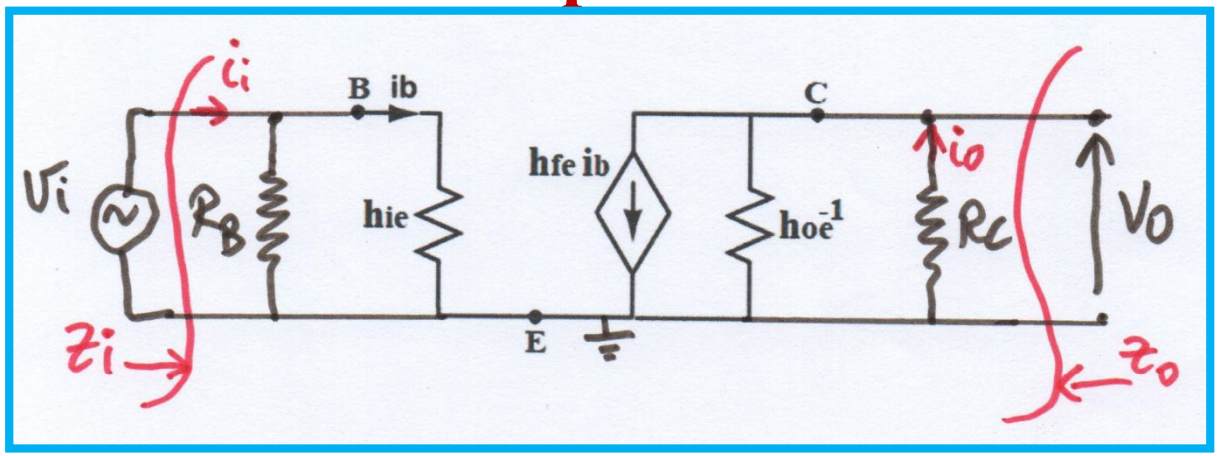
$$A_{V_{NL}} = \frac{V_o}{V_i}$$

$$V_i = h_{ie}\, i_b \quad \ldots\ldots (1)$$

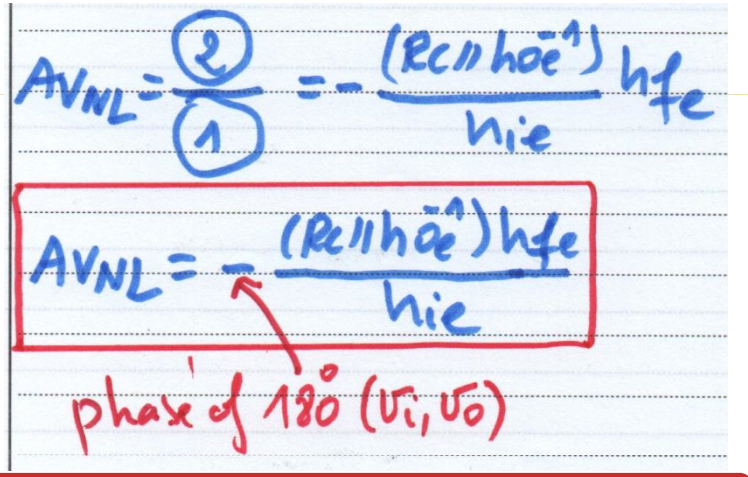
$$V_o = (R_C \,//\, h_{oe}^{-1})(-h_{fe}\, i_b)$$

$$V_o = -(R_C \,//\, h_{oe}^{-1})\, h_{fe}\, i_b \quad \ldots (2)$$

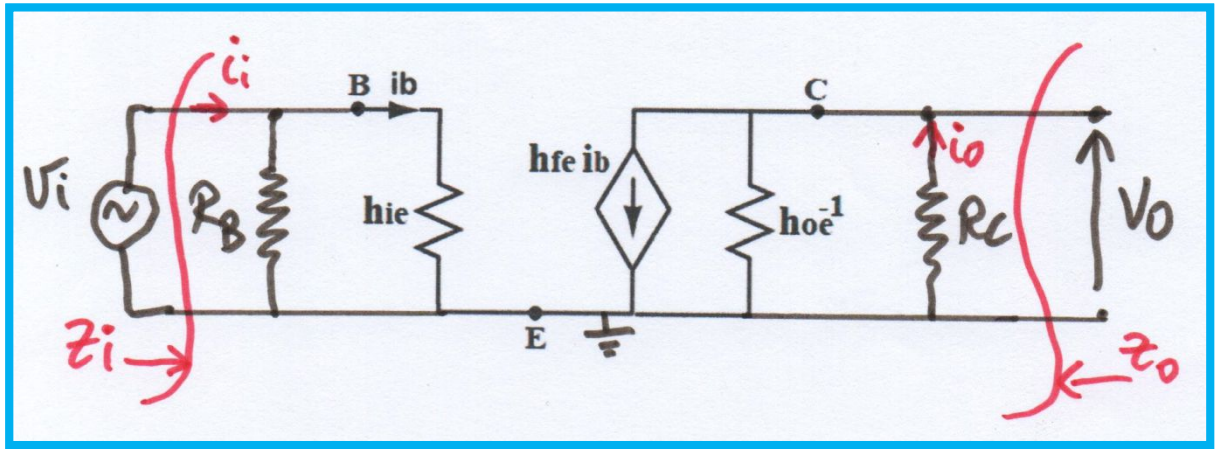
App 1: Common Emitter Fixed bias amplifier



No loaded voltage Gain:



App 1: Common Emitter Fixed bias amplifier



No loaded Current Gain:

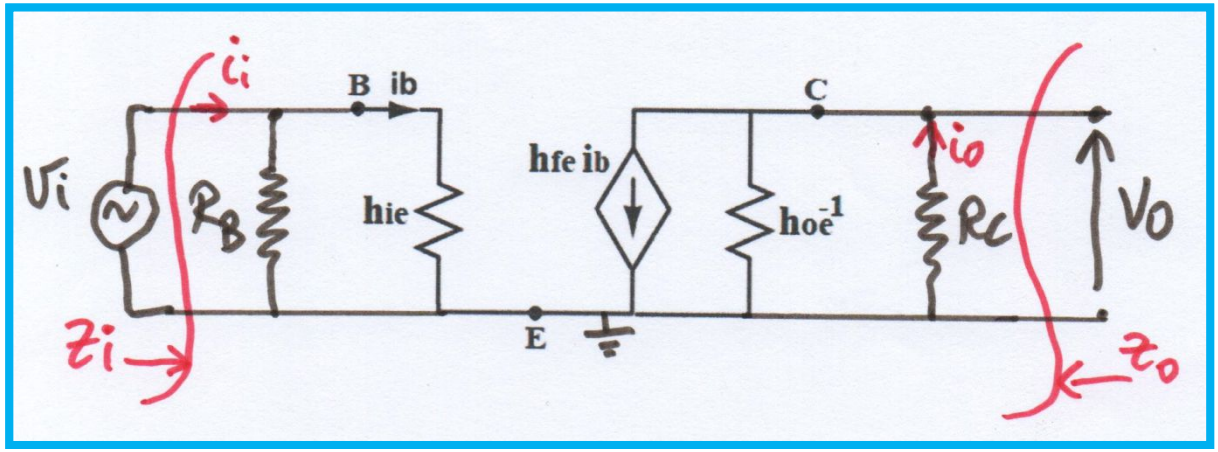
$A_i = i_o / i_i$

$V_i = Z_i i_i = (R_B // h_{ie}) i_i$

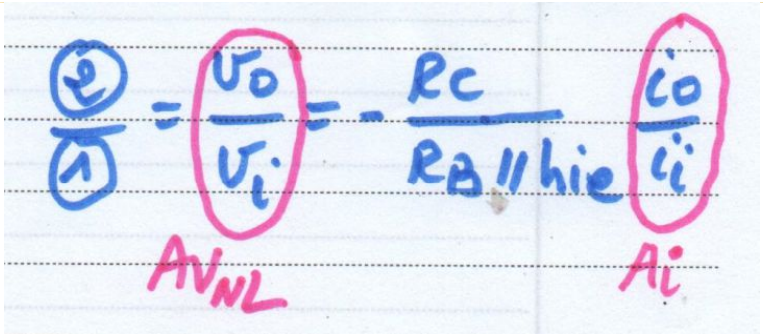
$V_i = (R_B // h_{ie}) i_i$ ..... (1)

$V_o = -R_C i_o$ ..... (2)

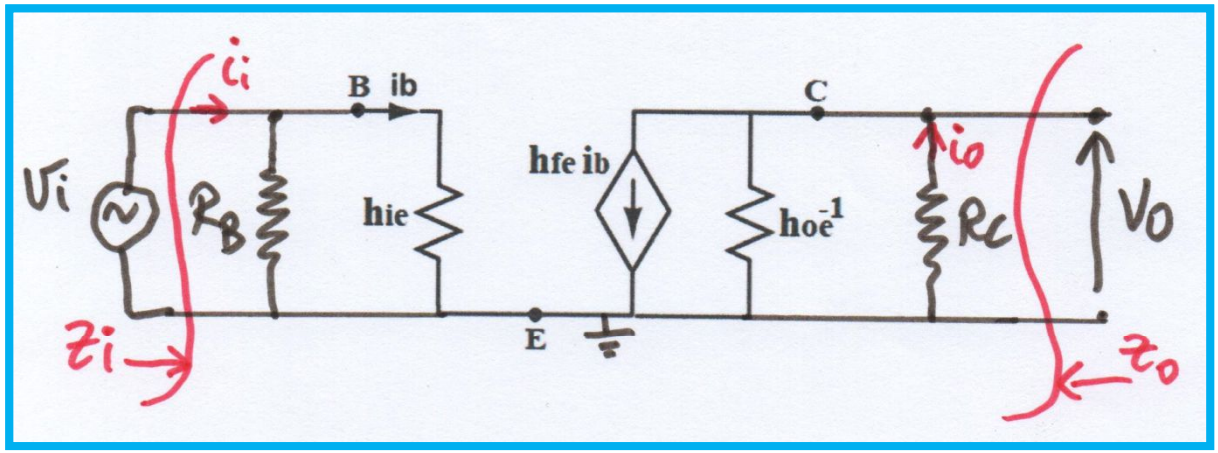
App 1: Common Emitter Fixed bias amplifier



No loaded Current Gain:



App 1: Common Emitter Fixed bias amplifier

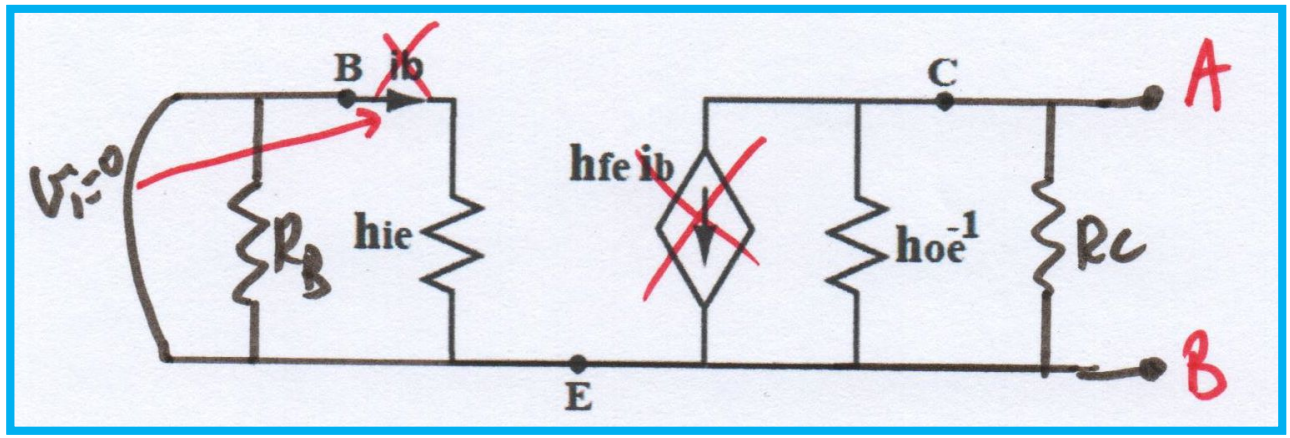


No loaded Current Gain:

$$A_i = -\frac{R_B \| h_{ie}}{R_C} A_{V_{NL}}$$

$A_{V_{NL}} < 0$, $A_i > 0$

App 1: Common Emitter Fixed bias amplifier



Output impedance: