Analog Electronic Circuits-BEE303

Module 2: Transistor at Low Frequencies

Module 2: Contents

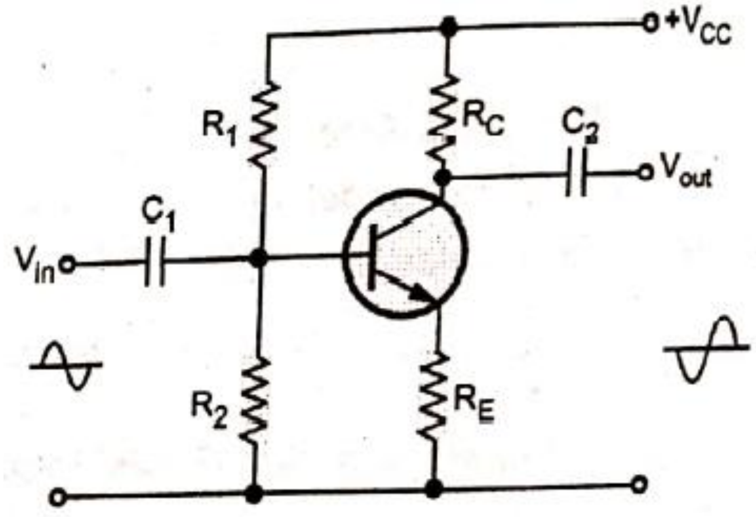
Transistor at low frequencies:

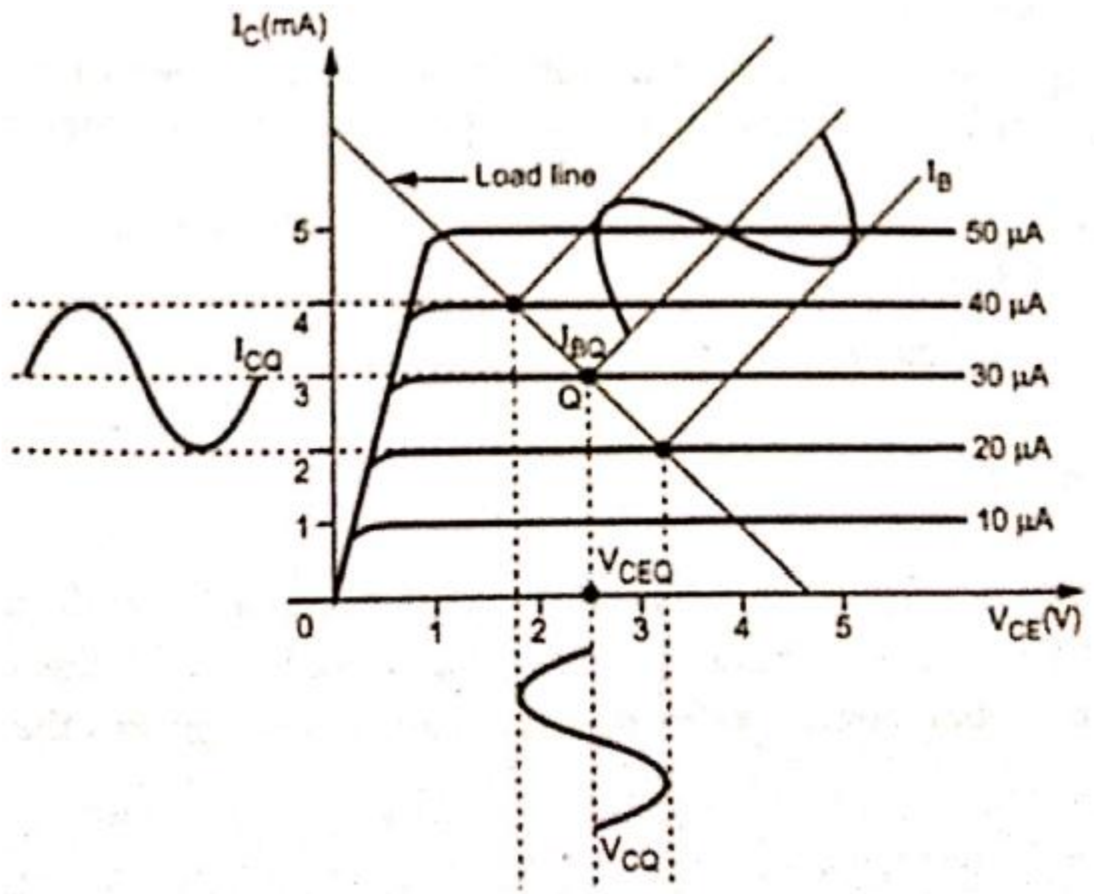
Hybrid model, h-parameters for CE, CC and CB modes, mid-band analysis of single stage amplifier, simplified hybrid model, analysis for CE, CB and CC(emitter voltage follower circuit) modes, Millers Theorem and its dual, analysis for collector to base bias circuit and CE with un bypassed emitter resistance.

Basic Concepts

In the absence of input signal only dc voltages are present in the circuit. This is called zero signal condition.

With small input signals, the transistor can be replaced by a small linear model called small signal equivalent circuit.

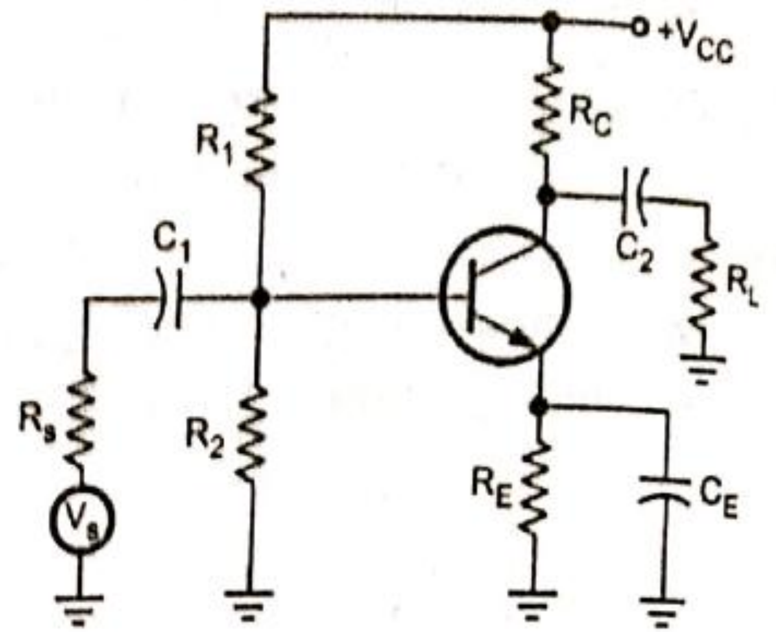




Basic Amplifiers

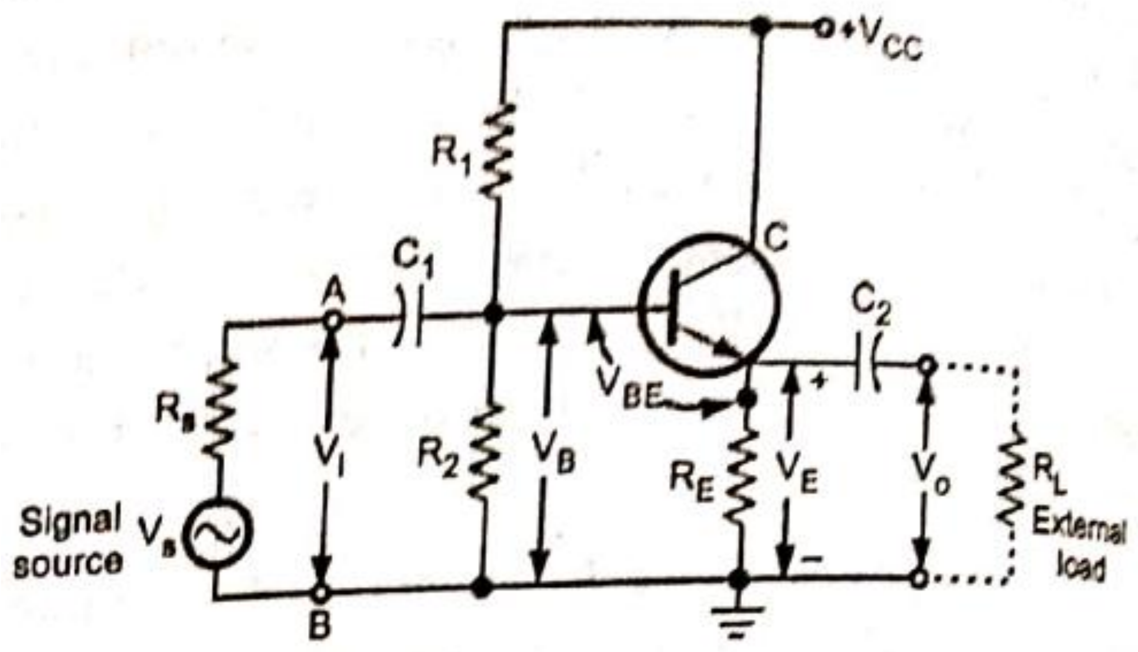
Common Emitter Amplifier

1. **Biasing Circuit: R_1, R_2 and R_E**
2. **Input Capacitor C_1**
3. **Emitter bypass capacitor C_E**
4. **Output Coupling Capacitor C_2**

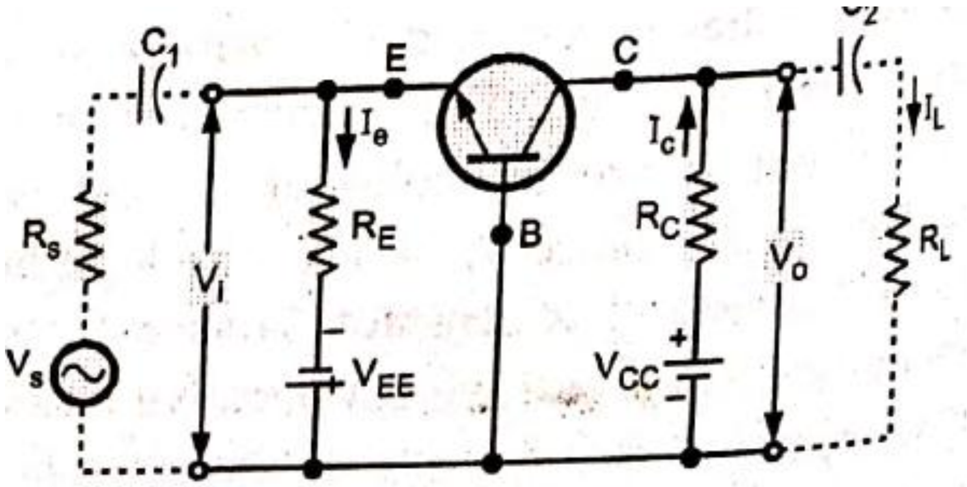


Basic Amplifiers

Common Collector Amplifier



Common Base Amplifier



Hybrid Equivalent Model of Transistor

To develop hybrid equivalent circuit we consider;

I_I and V_O as independent variables.

V_I and I_O as dependant variables

$V_I = f(I_I , V_O)$; $V_I = h_{11}*I_I + h_{12}*V_O$; $V_i = h_i*I_i + h_r*V_o$ ----- (1)

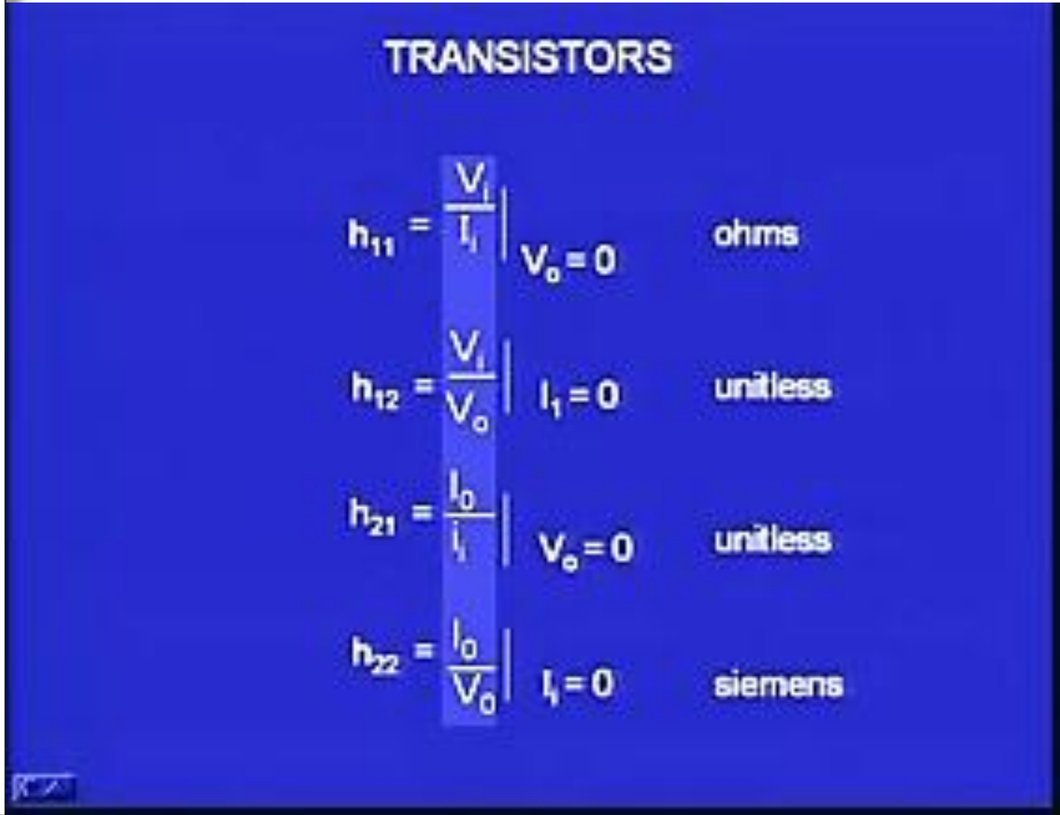
$I_O = f(I_I , V_O)$; $I_O = h_{21}*I_I + h_{22}*V_O$; $I_o = h_f*I_i + h_o*V_o$ ------ (2)

h_i = h_{11}= Input impedance with output short circuited, unit is ohm.

h_{12}= h_r = open circuit reverse transfer voltage ratio, no unit

h_{21}= h_f = short circuit forward transfer current ratio, no unit.

h_{22} = h_o = open circuit output admittance, unit is per ohms.



Hybrid Equivalent Model of Transistor

$V_I = h_{11}*I_I + h_{12}*V_O$ $V_i = h_i*I_i + h_r*V_o$ ----- (1)

$I_O = h_{21}*I_I + h_{22}*V_O$ $I_o = h_f*I_i + h_o*V_o$ ------ (2)

$h_i = h_{11}$ = Input impedance with output short circuited, unit is ohm.

$$h_{11} = \frac{V_I}{I_I} \ at\ V_O = 0$$

$h_r = h_{12}$ = open circuit reverse transfer voltage ratio, no unit.

$$h_{12} = \frac{V_I}{V_O} \ at\ I_I = 0$$

$h_f = h_{21}$ = short circuit forward transfer current ratio, no unit.

$$h_{21} = \frac{I_O}{I_I} \ at\ V_O = 0$$

$h_o = h_{22}$ = open circuit output admittance, unit is per ohms.

$$h_{22} = \frac{I_O}{V_O} \ at\ I_I = 0$$

Hybrid Equivalent Model of Transistor

$V_I = h_{11}*I_I + h_{12}*V_O$

$I_O = h_{21}*I_I + h_{22}*V_O$

$$V_i = h_i*I_i + h_r*V_o \text{ ----- } (1)$$

$$I_o = h_f*I_i + h_o*V_o \text{ ------ } (2)$$

From equation (1);

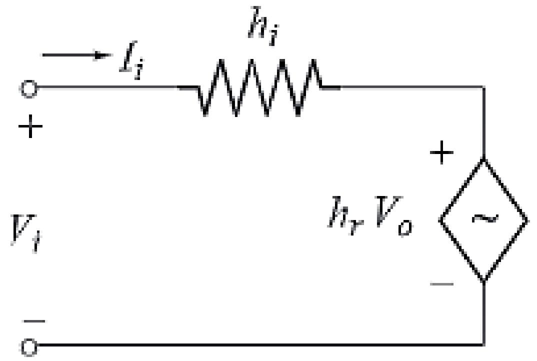
h_I*I_I = Voltage drop across the impedance h_I

h_r*V_O = Controlled voltage source

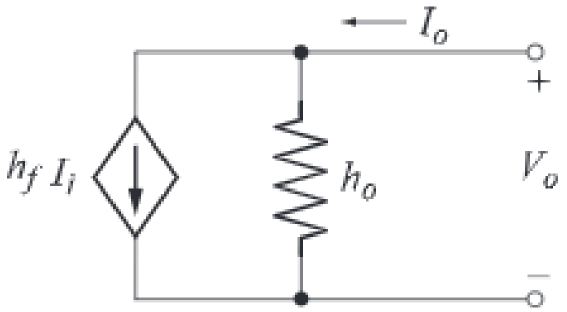
From equation (2);

h_f*I_I = Controlled current source

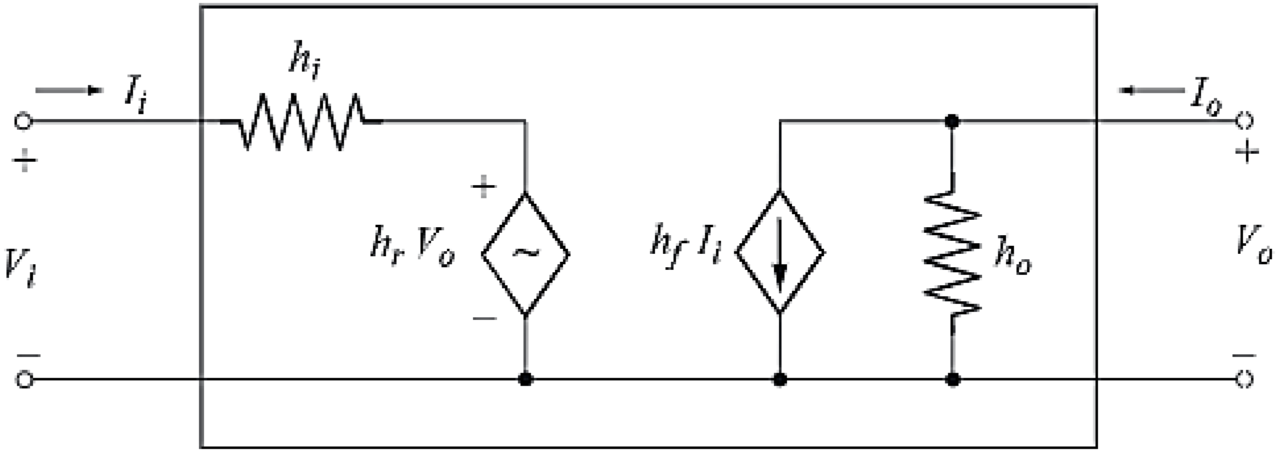
h_O*V_O = Current through admittance h_O



Circuit model of $V_i = h_i I_i + h_r V_o$



Circuit model of $I_o = h_f I_i + h_o V_o$



Hybrid equivalent circuit of Transistor

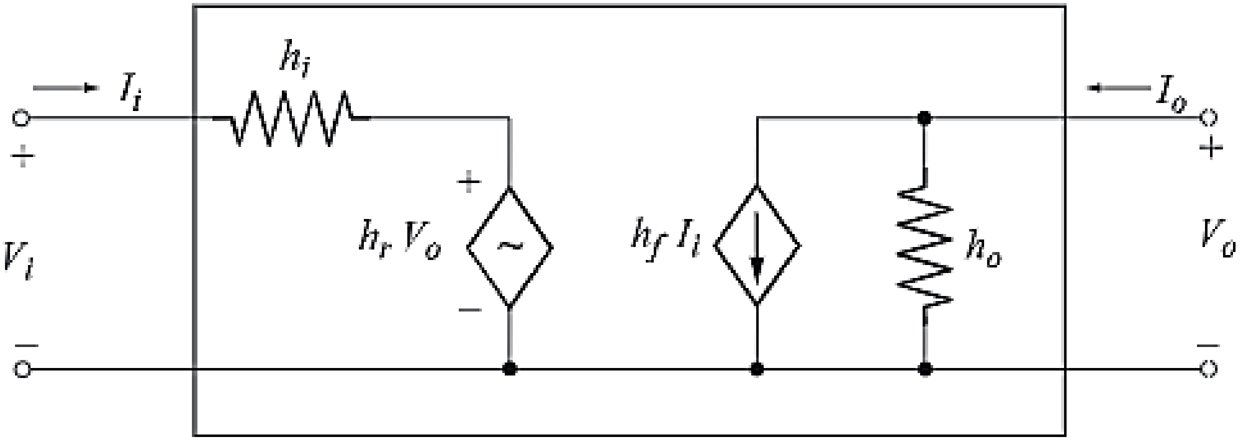
Hybrid Equivalent Model of Transistor

$V_I = h_{11}*I_I + h_{12}*V_O$

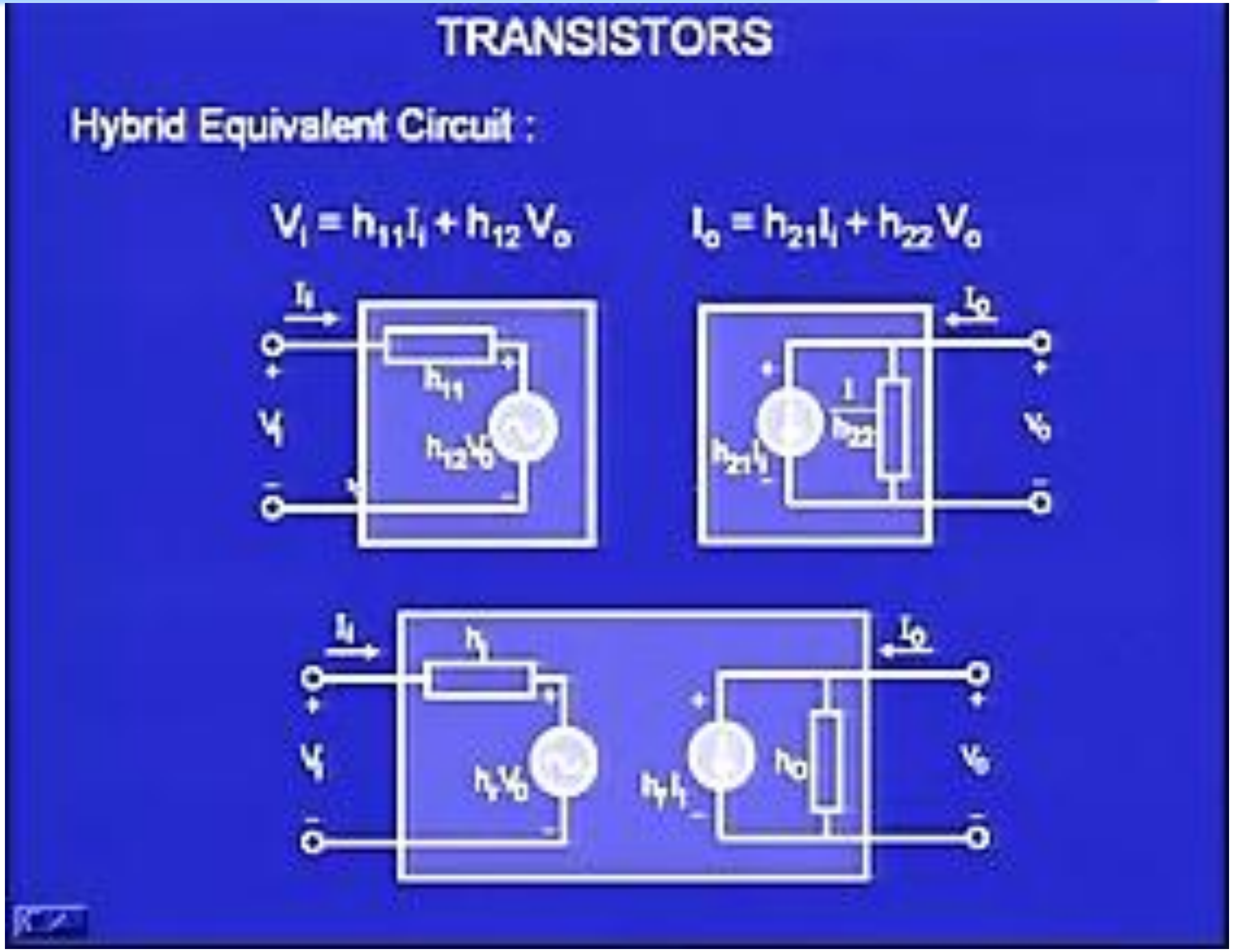
$I_O = h_{21}*I_I + h_{22}*V_O$

$V_i = h_i*I_i + h_r*V_o$ ----- (1)

$I_o = h_f*I_i + h_o*V_o$ ------ (2)



Hybrid equivalent circuit of Transistor

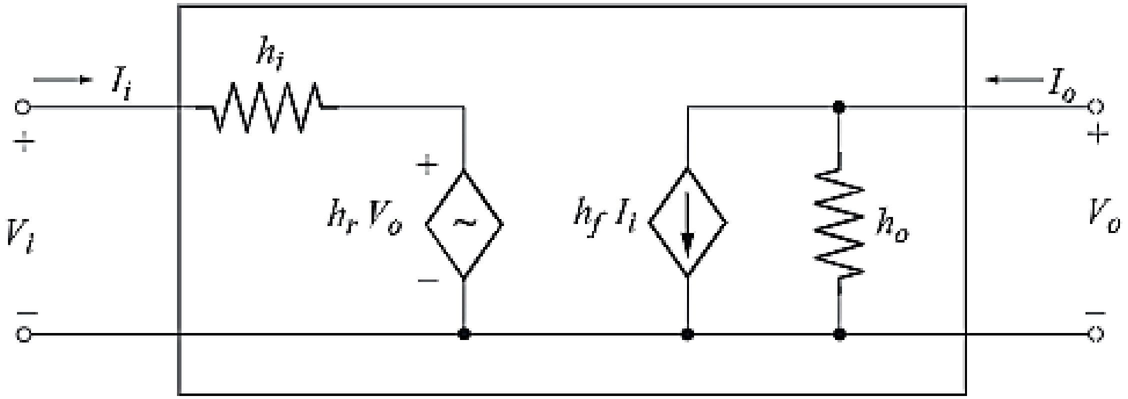


Hybrid parameters nomenclature

Hybrid Parameters	*Configuration*		
	CE	*CB*	*CC*
h_i	h_{ie}	h_{ib}	h_{ic}
h_f	h_{fe}	h_{fb}	h_{fc}
h_r	h_{re}	h_{rb}	h_{rc}
h_o	h_{oe}	h_{ob}	h_{oc}

Hybrid Equivalent Model of Transistor

Hybrid Parameters Nomenclature



Hybrid equivalent circuit of Transistor

h_i = h_{11} = Input resistance with output shorted

h_r = h_{12} = Reverse voltage gain with input open

h_f = h_{21} = Forward current gain with output shorted

h_o = h_{22} = Output conductance with input open.

SL. No	General Parameter	Transistor configuration		
		Common Emitter	Common Base	Common collector
h_i	h_{11}	h_{ie}	h_{ib}	h_{ie}
h_r	h_{12}	h_{re}	h_{rb}	h_{re}
h_i	h_{21}	h_{ic}	h_{fb}	h_{fe}
h_o	h_{22}	h_{oe}	h_{ob}	h_{oe}

Hybrid Model of Common Emitter Configuration

Basic equations:

$$V_i = h_i*I_i + h_r*V_o \text{ ----- } (1)$$

$$I_o = h_f*I_i + h_o*V_o \text{ ------ } (2)$$

$V_i = V_{be}$,

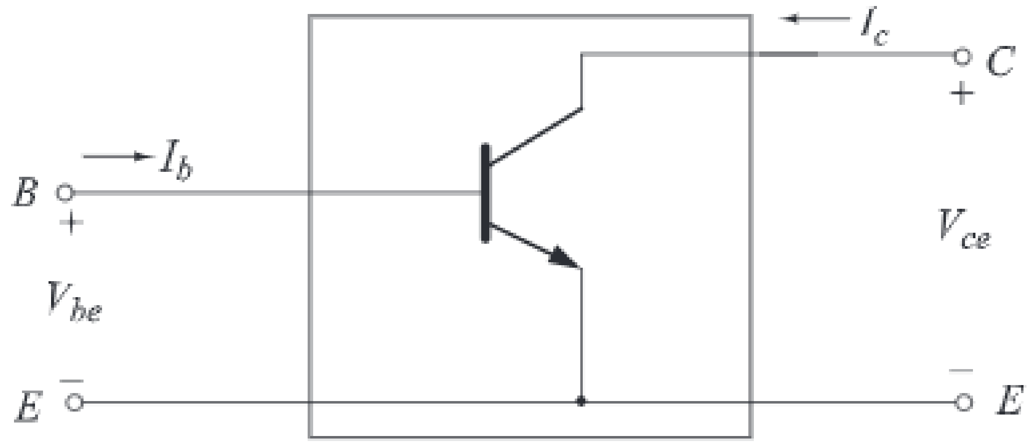
$I_i = I_b$,

$V_o = V_{ce}$

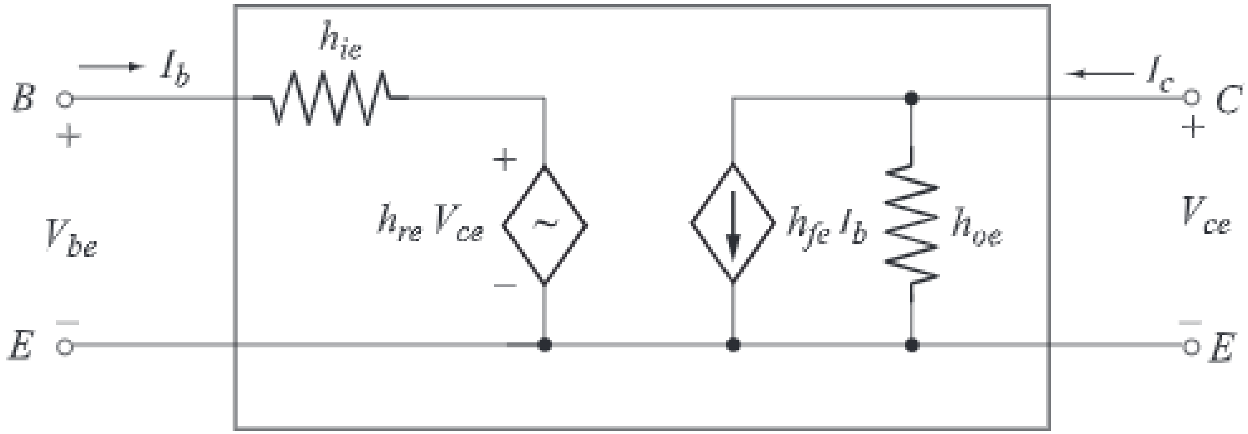
$I_o = I_c$

$$V_{be} = h_{ie}*I_b + h_{re}*V_{ce}$$

$$I_c = h_{fe}*I_b + h_{oe}*V_{ce}$$



Two port network of CE configuration



Hybrid equivalent circuit of CE configuration

Hybrid Model of Common Base Configuration

Basic equations:

$$V_i = h_i{*}I_i + h_r{*}V_o \text{ ----- } (1)$$

$$I_o = h_f{*}I_i + h_o{*}V_o \text{ ------ } (2)$$

$V_i = V_{eb}$,

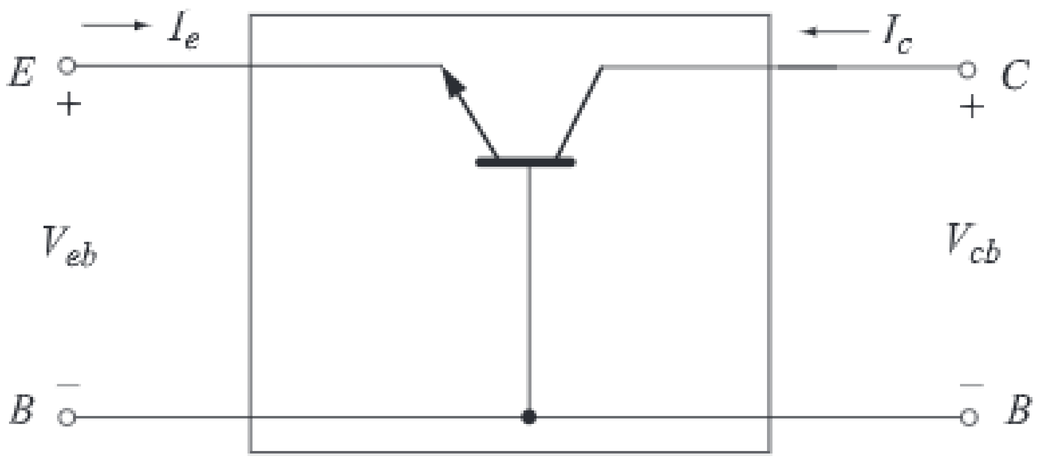
$I_i = I_e$,

$V_o = V_{cb}$

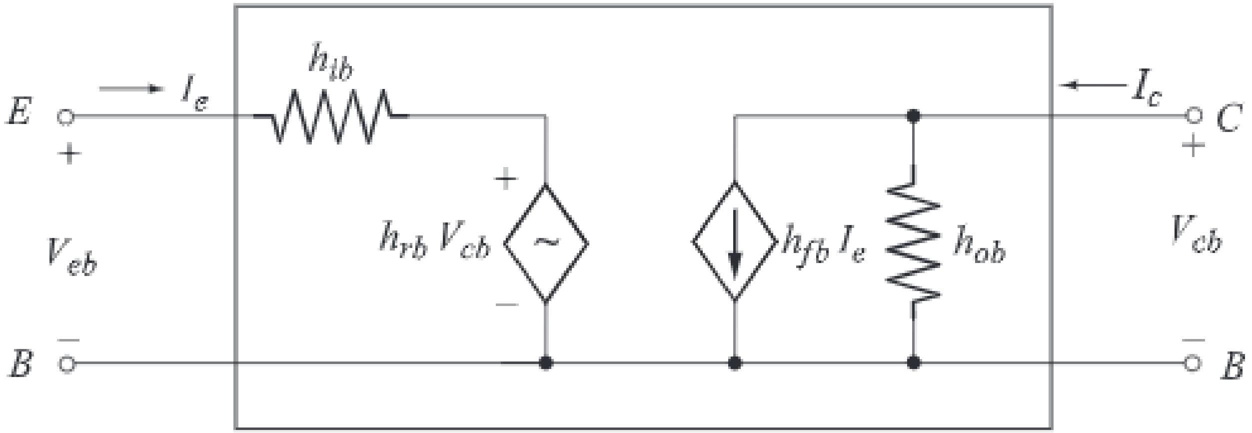
$I_o = I_c$

$$V_{eb} = h_{ib}{*}I_e + h_{rb}{*}V_{cb}$$

$$I_c = h_{fb}{*}I_e + h_{ob}{*}V_{cb}$$



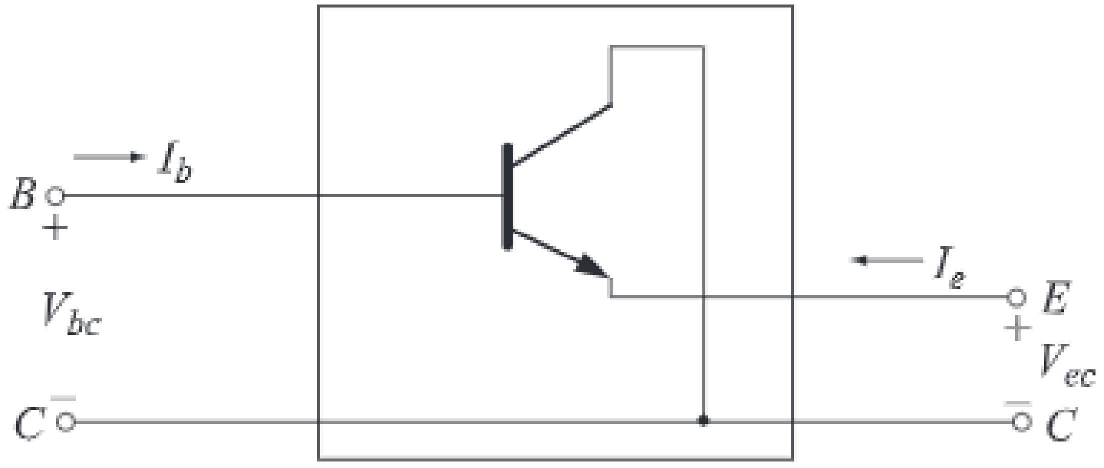
Two port network of CB configuration



Hybrid equivalent circuit of CB configuration

Common Collector Configuration (Emitter Voltage follower circuit)

- The input signal is applied to the base terminal of the transistor, and the output is taken from the emitter terminal.
- It is known as an Emitter Follower circuit because the output or emitter voltage exactly follows the changes in the base or input voltage



Hybrid Model of Common Collector Configuration

Basic equations:

$$V_i = h_i * I_i + h_r * V_o \text{ ----- } (1)$$

$$I_o = h_f * I_i + h_o * V_o \text{ ------ } (2)$$

$V_i = V_{bc}$,

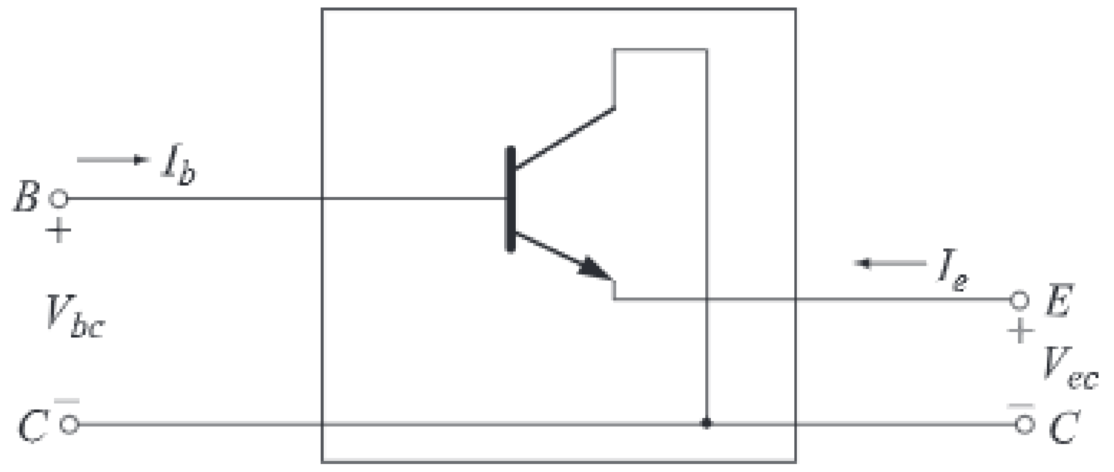
$I_i = I_b$,

$V_o = V_{ec}$

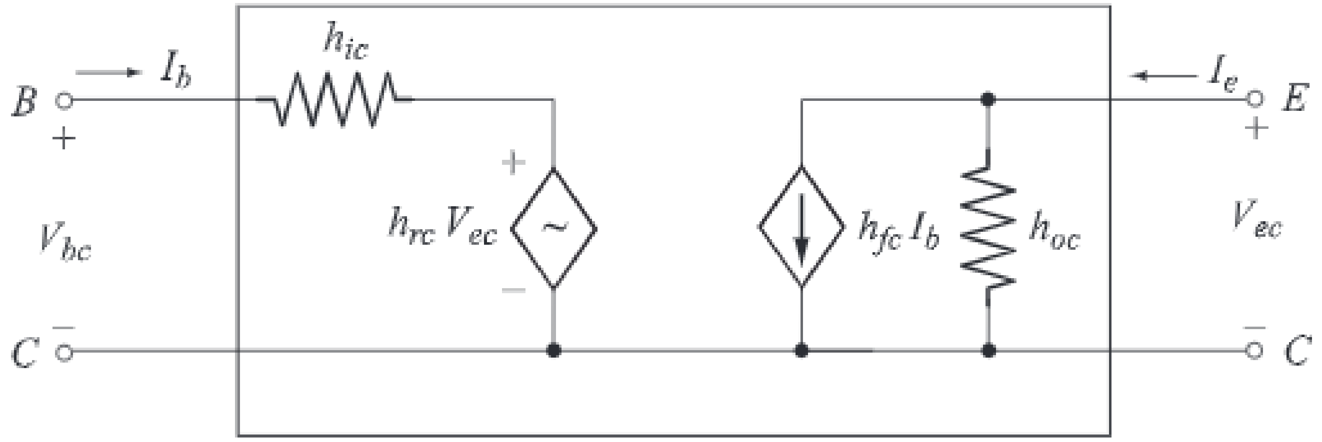
$I_o = I_e$

$$V_{bc} = h_{ic} * I_b + h_{rc} * V_{ec}$$

$$I_e = h_{fc} * I_b + h_{oc} * V_{ec}$$



Two port network of CC configuration



Hybrid equivalent circuit of CC configuration

Relationship between h-parameters

The h-parameters for the transistor are h_{ie} = 1.1 kΩ, h_{fe} = 99, h_{re} = 2.5*10-4 and h_{oe} = 25 µA/V. Find the h-parameters for common base and common collector configuration.

For Common base configuration:

$$h_{ib} = \frac{h_{ie}}{1 + h_{fe}}$$

$$h_{ib} = \frac{1.1\,k}{1 + 99} = 11$$

$$h_{rb} = \frac{h_{ie} h_{oe}}{1 + h_{fe}} - h_{re}$$

$$h_{rb} = \frac{1.1k * 25\mu}{1 + 99} - 2.5 * 10^{-4}$$
$$= 2.5 * 10^{-5}$$

For Common base configuration:

$$h_{fb} = \frac{-h_{fe}}{1 + h_{fe}}$$

$$h_{fb} = \frac{-99}{1 + 99} = -0.99$$

$$h_{ob} = \frac{h_{oe}}{1 + h_{fe}}$$

$$h_{ob} = \frac{25\mu}{1 + 99} = 0.25 * 10^{-6}$$

Relationship between h-parameters

The h-parameters for the transistor are h_{ie} = 1.1 kΩ, h_{fe} = 99, h_{re} = 2.5*10-4 and h_{oe} = 25 μA/V. Find the h-parameters for common base and common collector configuration.

For Common collector configuration:

$$h_{ic} = h_{ie} = 1.1\ k\Omega$$

$$h_{rc} = 1 - h_{re} = 1 - 2.5 * 10^{-4} = 1$$

$$h_{fc} = -(1 + h_{fe}) = -(1 + 99) = -100$$

$$h_{oc} = h_{oe} = 25\ \mu A/V$$

Analysis of Common Emitter Configuration

Derive the expressions for A_V, A_I, R_I and R_O for common emitter configuration using h-parameter model.

1. Current Gain

$$A_i = \frac{I_L}{I_b} = -\frac{I_c}{I_b}$$

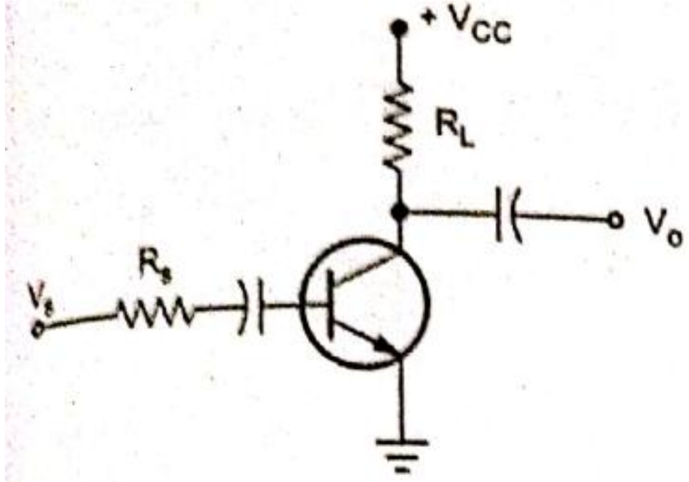
$$I_C = h_{fe}*I_b + h_{oe}*V_C$$

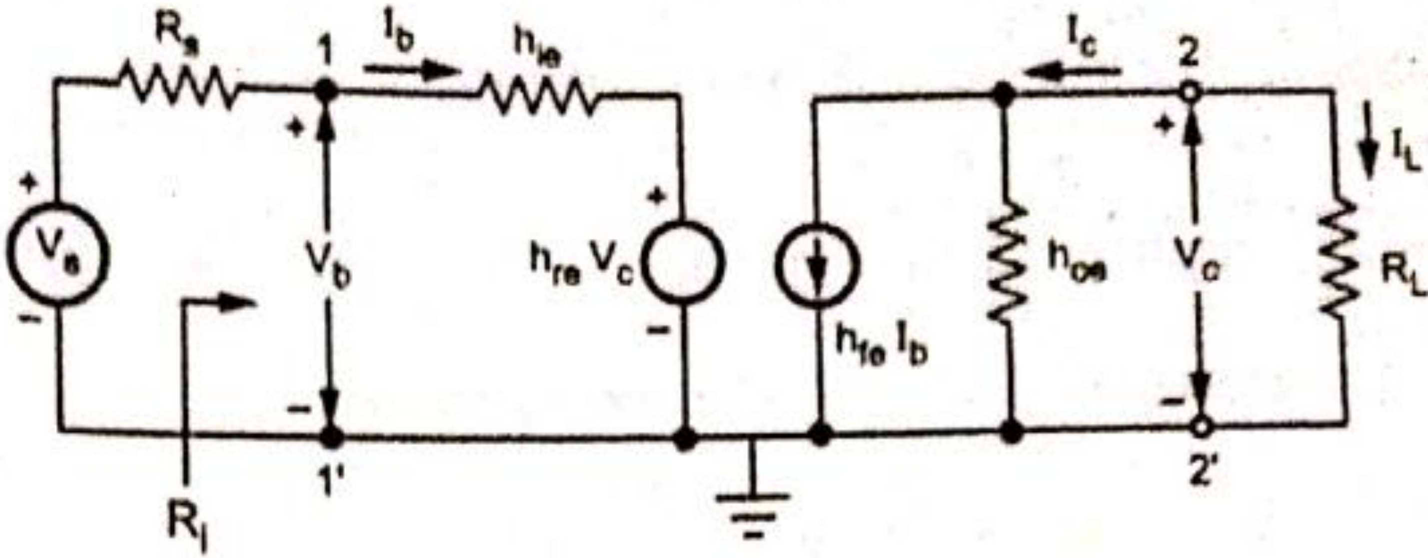
$$V_C = - I_C*R_L$$

$$I_C = h_{fe}*I_b + h_{oe}*(- I_C*R_L)$$

$$I_C + h_{oe}*I_C*R_L = h_{fe}*I_b$$

$$I_C (1+ h_{oe}*R_L) = h_{fe}*I_b$$





Analysis of Common Emitter Configuration

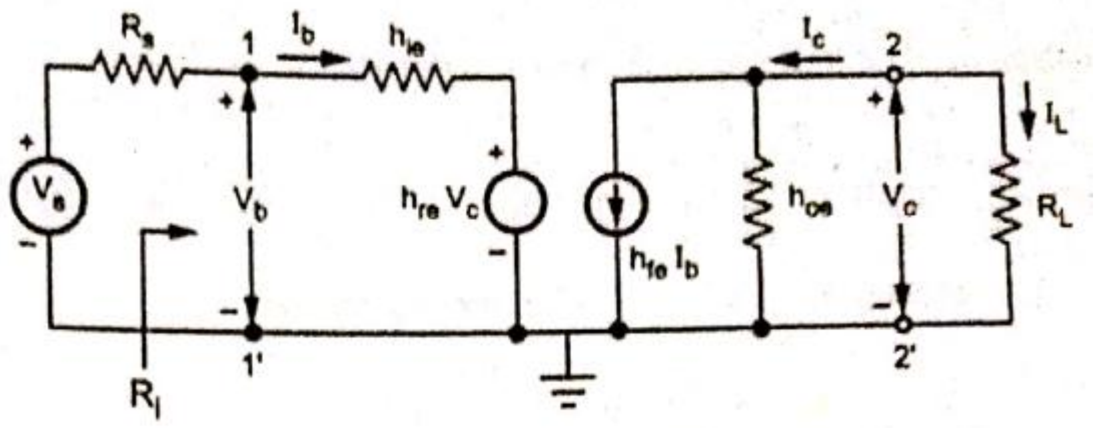
1. Current Gain

$$A_i = \frac{I_L}{I_b} = -\frac{I_c}{I_b}$$

$I_C (1+ h_{oe} *R_L) = h_{fe} *I_b$

$$\frac{I_c}{I_b} = \frac{h_{fe}}{1 + h_{oe} * R_L}$$

$$A_i = \frac{I_L}{I_b} = -\frac{I_c}{I_b} = \frac{-h_{fe}}{1 + h_{oe} * R_L}$$



Analysis of Common Emitter Configuration

2. Input resistance

$$R_i = \frac{V_b}{I_b}$$

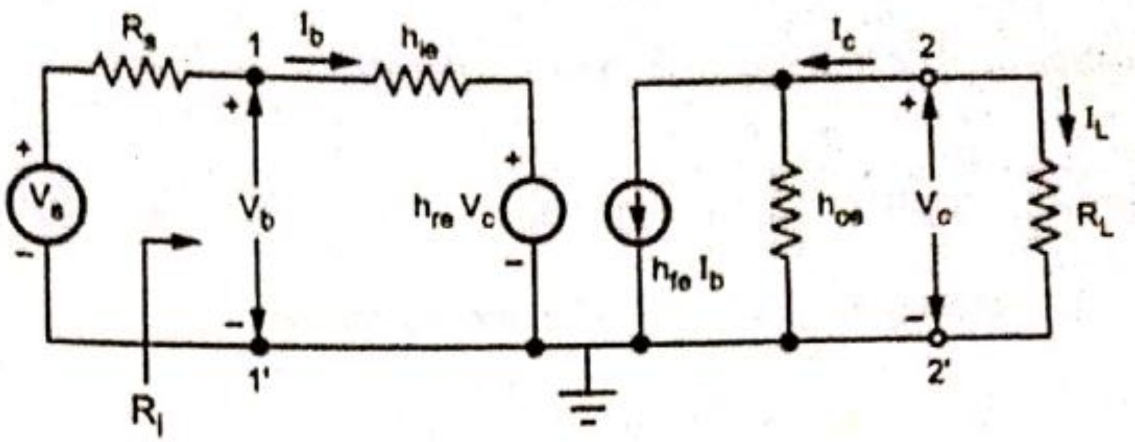
$$V_b = h_{ie} * I_b + h_{re} * V_c$$

$$V_c = -I_C * R_L = I_b * A_i * R_L$$

$$V_b = h_{ie} * I_b + h_{re} * A_i * I_b * R_L$$

$$R_i = \frac{h_{ie} * Ib + hre * Ai * Ib * RL}{I_b} = h_{ie} + hre * Ai * RL$$

$$R_i = h_{ie} - h_{re} * \frac{h_{fe}}{1 + h_{oe} * R_L} * RL$$



Analysis of Common Emitter Configuration

3. Voltage Gain

$$A_V = \frac{V_c}{V_b}$$

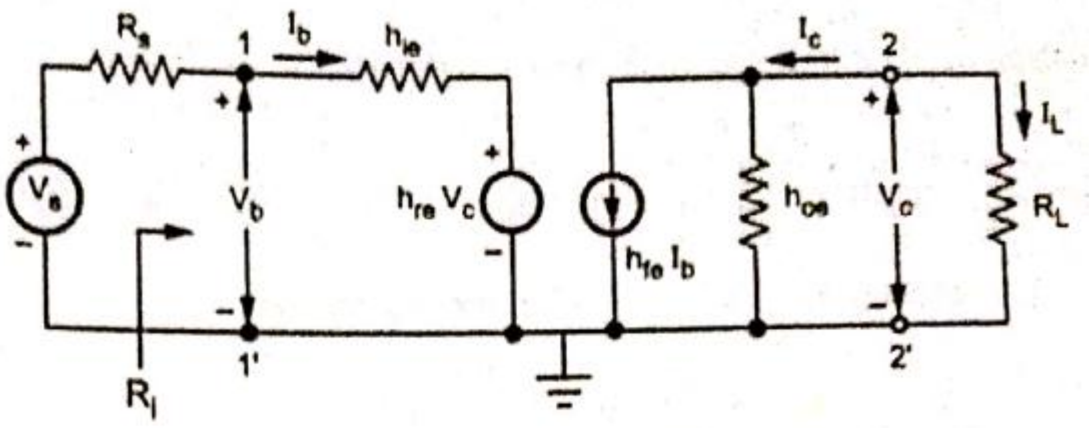
$$A_V = \frac{A_i I_b R_L}{V_b} = \frac{A_i R_L}{R_i}$$

4. Output Admittance

$$Y_O = \frac{I_c}{V_c} \text{ at } V_S = 0$$

$$I_C = h_{fe} * I_b + h_{oe} * V_C$$

$$Y_O = \frac{I_c}{V_c} = h_{fe} * Ib / V_C + hoe$$



Analysis of Common Emitter Configuration

4. Output Admittance

$$Y_O = \frac{I_c}{V_c} \text{ at } V_S = 0$$

$$I_C = h_{fe}*I_b + h_{oe}*V_C$$

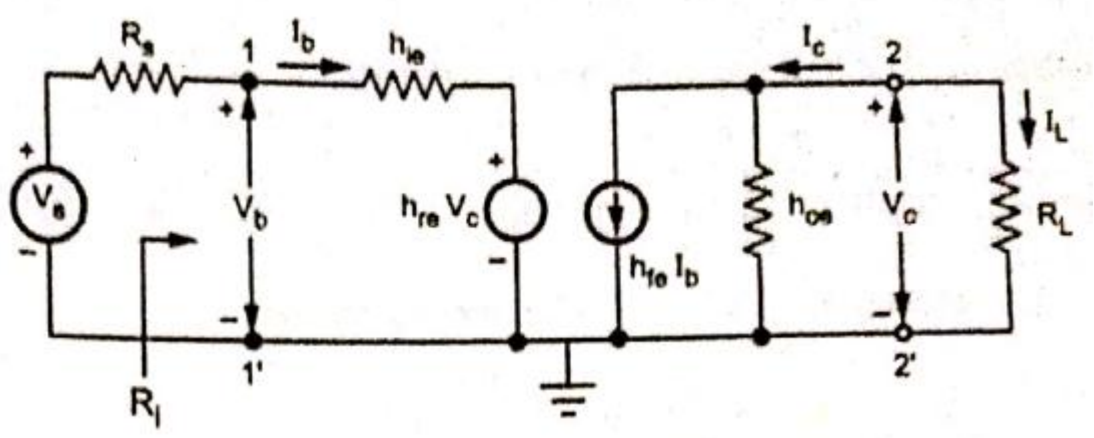
$$Y_O = \frac{I_c}{V_c} = h_{fe}*Ib/V_C + hoe$$

$$R_S I_b + h_{ie}*I_b + h_{re}*V_c = 0$$

$$(R_S + h_{ie})I_b = - h_{re}*V_c$$

$$I_b / V_c = - h_{re}/(R_S + h_{ie})$$

$$Y_O = h_{oe} - \frac{h_{fe}h_{re}}{R_S + h_{ie}}$$



$$R_O = \frac{1}{Y_O}$$

Analysis of Common Collector Configuration
(Emitter Voltage follower circuit)

Derive the expressions for A_V, A_I, R_I and R_O for common collector configuration using h-parameter model.

1. Current Gain

$$A_i = \frac{I_L}{I_b} = -\frac{I_e}{I_b}$$

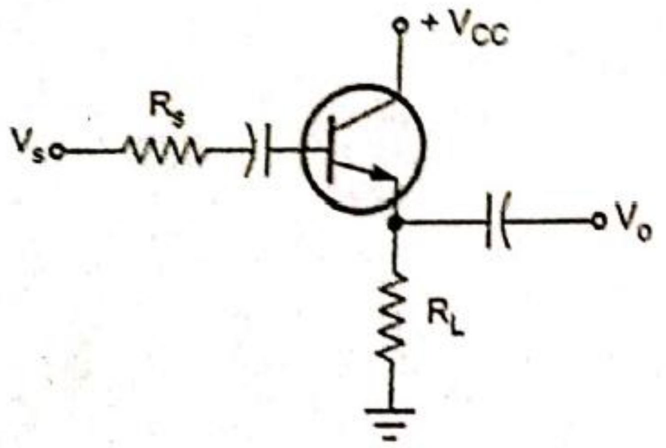
$$I_e = h_{fc}*I_b + h_{oc}*V_e$$

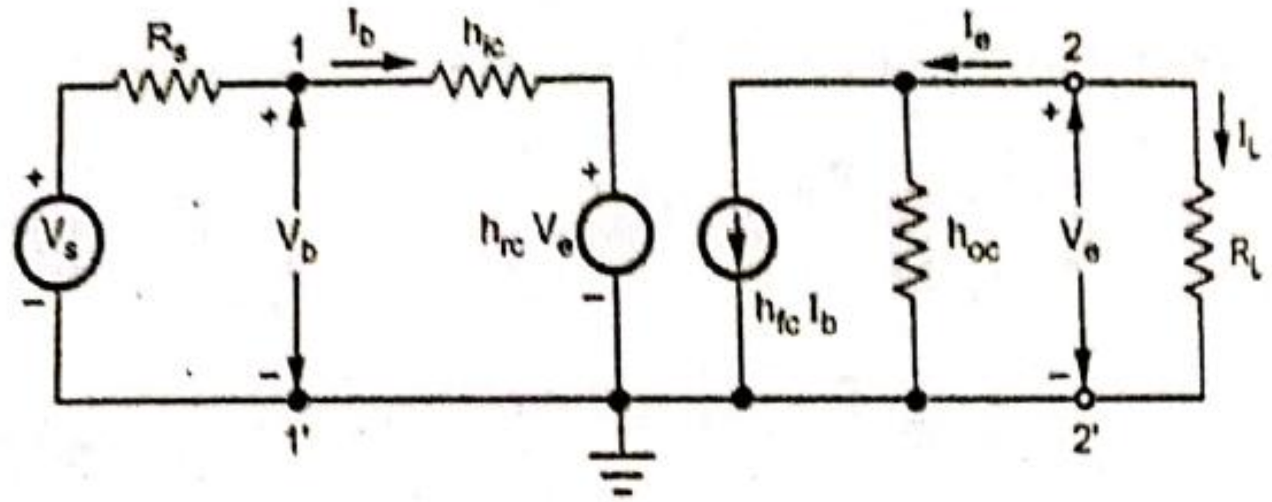
$$V_e = - I_e*R_L$$

$$I_e = h_{fc}*I_b + h_{oc}*(- I_e*R_L)$$

$$I_e + h_{oc}*I_e*R_L = h_{fc}*I_b$$

$$I_e (1+ h_{oc}*R_L) = h_{fc}*I_b$$





Analysis of Common Collector Configuration

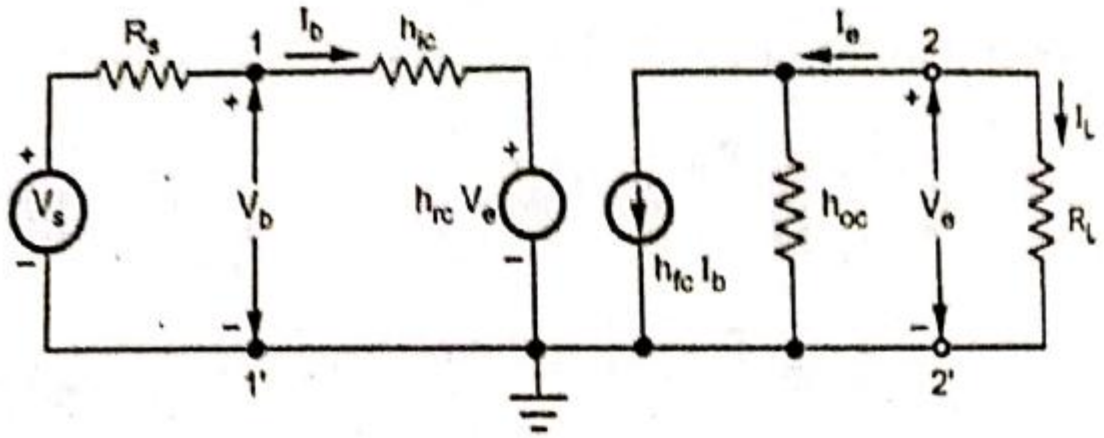
1. Current Gain

$$A_i = \frac{I_L}{I_b} = -\frac{I_e}{I_b}$$

$I_e\,(1 + h_{oc} * R_L) = h_{fc} * I_b$

$$\frac{I_e}{I_b} = \frac{h_{fc}}{1 + h_{oc} * R_L}$$

$$A_i = \frac{I_L}{I_b} = -\frac{I_e}{I_b} = \frac{-h_{fc}}{1 + h_{oc} * R_L}$$



Analysis of Common Collector Configuration

2. Input resistance

$$R_i = \frac{V_b}{I_b}$$

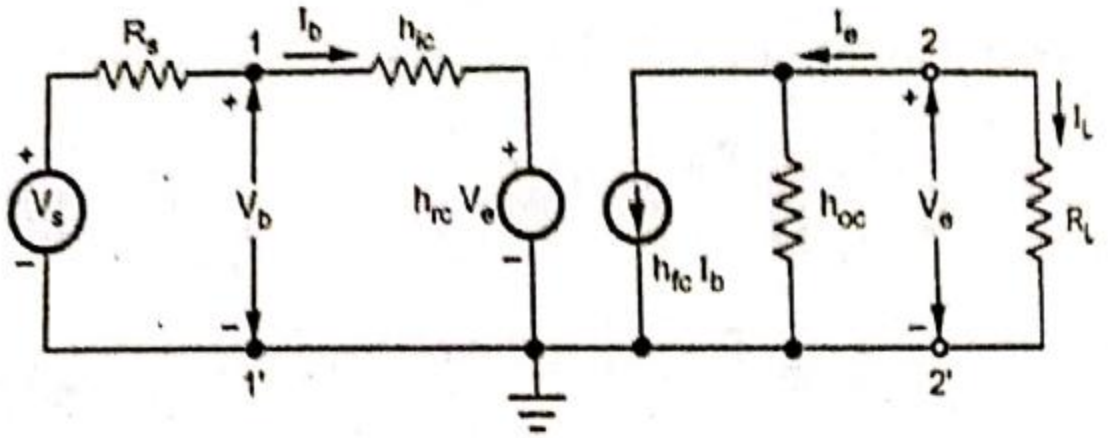
$$V_b = h_{ic} * I_b + h_{rc} * V_e$$

$$V_e = -I_e * R_L = I_b * A_i * R_L$$

$$V_b = h_{ic} * I_b + h_{rc} * A_i * I_b * R_L$$

$$R_i = \frac{h_{ic} * I_b + h_{rc} A_i I_b R_L}{I_b} = h_{ic} + h_{rc} A_i R_L$$

$$R_i = h_{ic} - h_{rc} * \frac{h_{fc}}{1 + h_{oc} * R_L} * R_L$$



Analysis of Common Collector Configuration

3. Voltage Gain

$$A_V = \frac{V_e}{V_b}$$

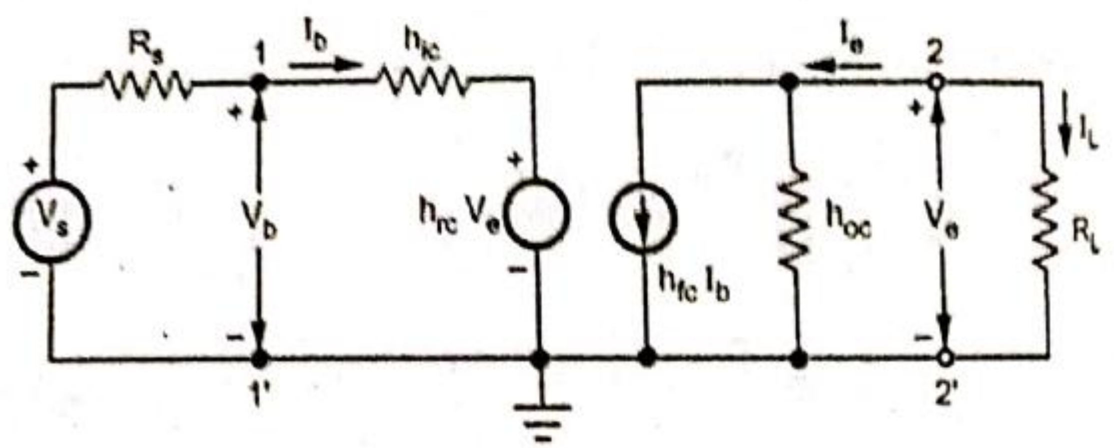
$$A_V = \frac{A_i I_b R_L}{V_b} = \frac{A_i R_L}{R_i}$$

4. Output Admittance

$$Y_O = \frac{I_e}{V_e} \text{ at } V_S = 0$$

$$I_e = h_{fc} * I_b + h_{oc} * V_e$$

$$Y_O = \frac{I_e}{V_e} = \frac{h_{fc} I_b}{V_e} + h_{oc}$$



Analysis of Common Collector Configuration

4. Output Admittance

$$Y_O = \frac{I_e}{V_e} \text{ at } V_S = 0$$

$I_e = h_{fc}*I_b + h_{oc}*V_e$

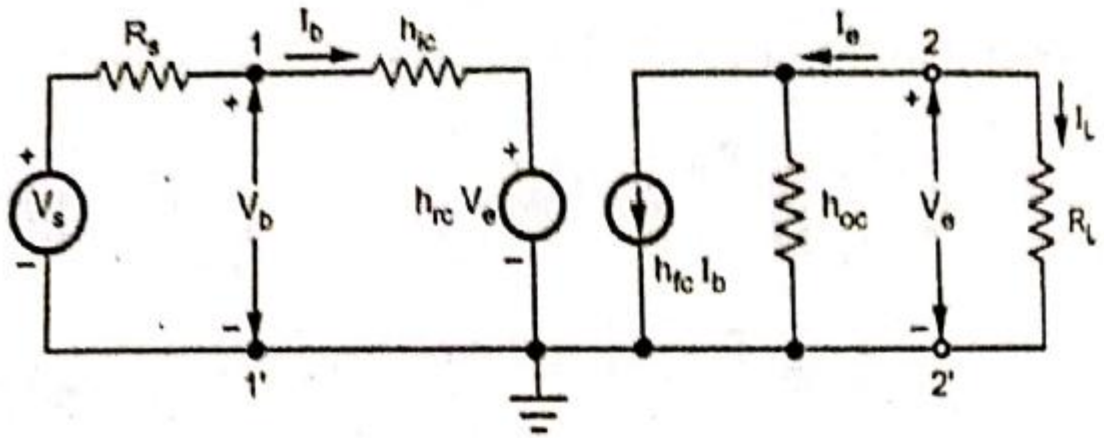
$$Y_O = \frac{I_e}{V_e} = \frac{h_{fc}I_b}{V_e} + h_{oc}$$

$R_S I_b + h_{ic}*I_b + h_{rc}*V_e = 0$

$(R_S + h_{ic})I_b = - h_{rc}*V_e$

$I_b / V_e = - h_{rc}/(R_S + h_{ic})$

$$Y_O = h_{oc} - \frac{h_{fc}h_{rc}}{R_S + h_{ic}}$$



$$R_O = \frac{1}{Y_O}$$

Analysis of Common Base Configuration

Derive the expressions for A_V, A_I, R_I and R_O for common Base configuration using h-parameter model.

1. Current Gain

$$A_i = \frac{I_L}{I_e} = -\frac{I_c}{I_e}$$

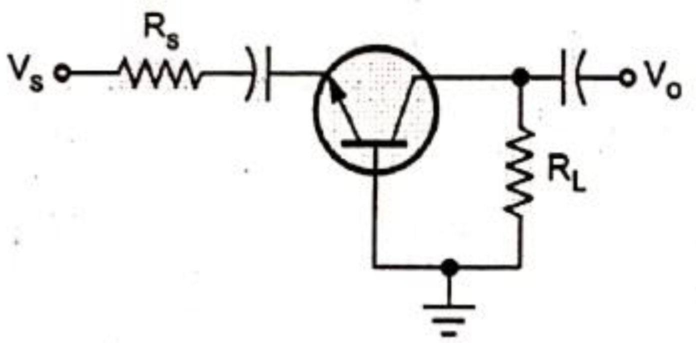
$$I_c = h_{fb} * I_e + h_{ob} * V_c$$

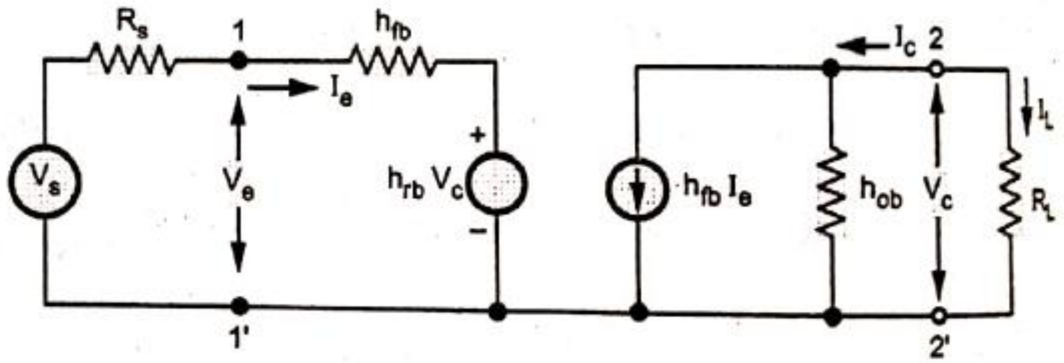
$$V_c = - I_c * R_L$$

$$I_c = h_{fb} * I_e + h_{ob} * (- I_c * R_L)$$

$$I_c + h_{ob} * I_c * R_L = h_{fb} * I_e$$

$$I_c (1 + h_{ob} * R_L) = h_{fb} * I_e$$





Analysis of Common Base Configuration

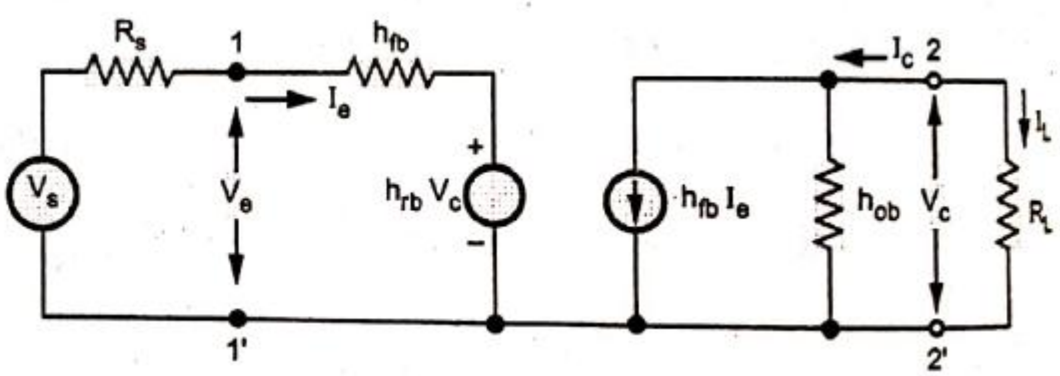
1. Current Gain

$$A_i = \frac{I_L}{I_e} = -\frac{I_c}{I_e}$$

$I_c\,(1+ h_{ob} * R_L) = h_{fb} * I_e$

$$\frac{I_c}{I_e} = \frac{h_{fb}}{1 + h_{ob} * R_L}$$

$$A_i = \frac{I_L}{I_e} = -\frac{I_c}{I_e} = \frac{-h_{fb}}{1 + h_{ob} * R_L}$$



Analysis of Common Base Configuration

2. Input resistance

$$R_i = \frac{V_e}{I_e}$$

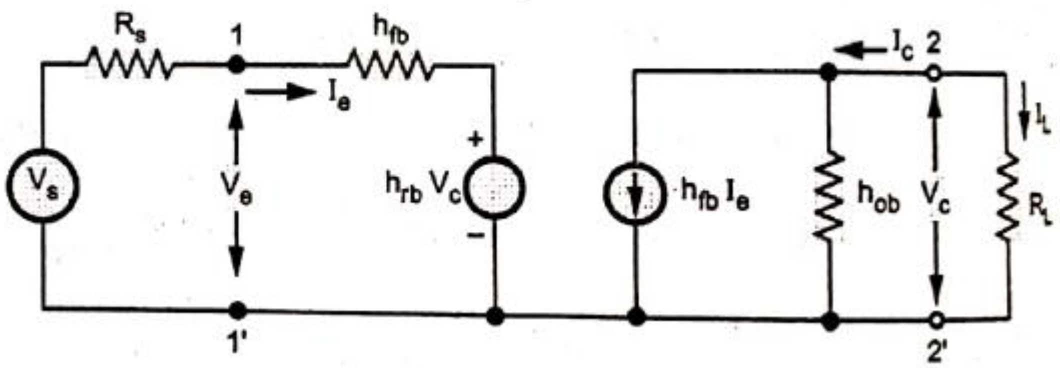
$$V_e = h_{ib} * I_e + h_{rb} * V_c$$

$$V_c = -I_c * R_L = I_e * A_i * R_L$$

$$V_e = h_{ib} * I_e + h_{rb} * A_i * I_e * R_L$$

$$R_i = \frac{h_{ib} * I_e + h_{rb} A_i I_e R_L}{I_e} = h_{ib} + h_{rb} A_i R_L$$

$$R_i = h_{ib} - h_{rb} * \frac{h_{fb}}{1 + h_{ob} * R_L} * R_L$$



Analysis of Common Base Configuration

3. Voltage Gain

$$A_V = \frac{V_c}{V_e}$$

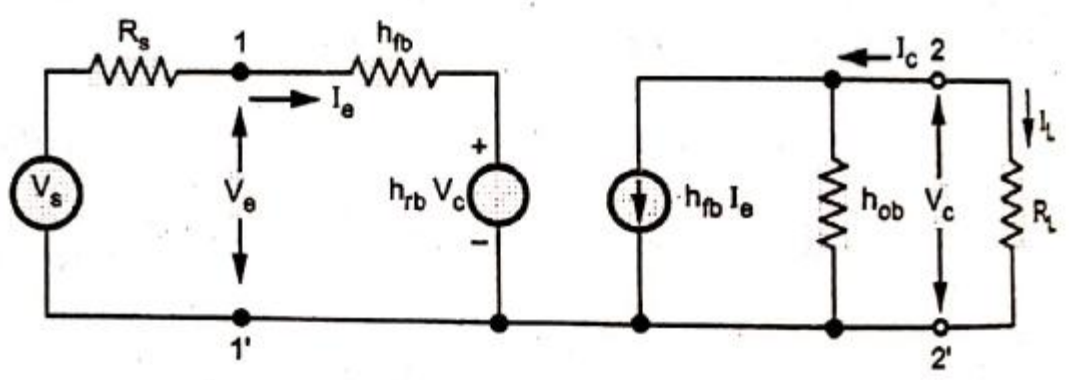
$$A_V = \frac{A_i I_e R_L}{V_e} = \frac{A_i R_L}{R_i}$$

4. Output Admittance

$$Y_O = \frac{I_c}{V_c} \text{ at } V_S = 0$$

$$I_c = h_{fb} * I_e + h_{ob} * V_c$$

$$Y_O = \frac{I_c}{V_c} = \frac{h_{fb} I_e}{V_c} + h_{ob}$$



Analysis of Common Collector Configuration

4. Output Admittance

$$Y_O = \frac{I_c}{V_c} \text{ at } V_S = 0$$

$$I_c = h_{fb} * I_e + h_{ob} * V_c$$

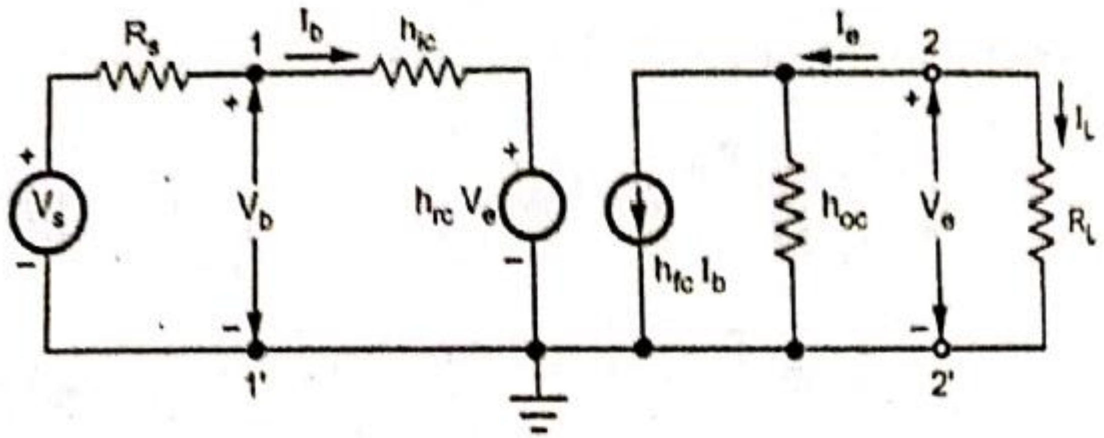
$$Y_O = \frac{I_c}{V_c} = \frac{h_{fb} I_e}{V_c} + h_{ob}$$

$$R_S I_e + h_{ib} * I_e + h_{rb} * V_c = 0$$

$$(R_S + h_{ib}) I_e = - h_{rb} * V_c$$

$$I_e / V_c = - h_{rb} / (R_S + h_{ib})$$

$$Y_O = h_{ob} - \frac{h_{fb} h_{rb}}{R_S + h_{ib}}$$



$$R_O = \frac{1}{Y_O}$$

Solved Examples

1. For the transistor connected in CE configuration, determine A_V, A_I, R_I & R_O using complete hybrid equivalent model.
$R_L = R_S = 1k\Omega$, hie = 1kΩ, hre = $2*10^{-4}$, hfe = 100, hoe = 20 μA/V.

1. Current Gain

$$A_i = \frac{-h_{fe}}{1 + h_{oe} * R_L}$$

$$A_i = \frac{-100}{1 + 20 * 10^{-6} * 1k} = -98$$

2. Input resistance

$$R_i = h_{ie} + hre * Ai * RL$$

$$R_i = 1k + 2*10^{-4} * -98 * 1k = 980.4\ \Omega$$

3. Voltage Gain

$$A_V = \frac{A_i R_L}{R_i}$$

$$A_V = \frac{-98 * 1k}{980.4} = -99.9$$

Solved Examples

1. For the transistor connected in CE configuration, determine A_V, A_I, R_I & R_O using complete hybrid equivalent model.
$R_L = R_S = 1k\Omega$, hie = $1k\Omega$, hre = $2*10^{-4}$, hfe = 100, hoe = 20 µA/V.

4. Output resistance

$$Y_O = h_{oe} - \frac{h_{fe}h_{re}}{R_S + h_{ie}}$$

$$Y_O = 20\mu - \frac{100 * 2 * 10^{-4}}{1k + 1k} = 1.9 * 10^{-5}$$

$$R_O = \frac{1}{Y_O}$$

$$R_O = \frac{1}{1.9*10^{-5}} = 52.64\ k\Omega$$

Solved Examples

1. A voltage source of negligible internal resistance drives a common collector transistor amplifier. The load resistance is 2.5kΩ. Determine A_V, A_I, R_I & R_O using complete hybrid equivalent model. hic = 1kΩ, hrc = 1, hfc = -50, hoc = 25 μA/V.

1. Current Gain

$$A_i = \frac{-h_{fc}}{1 + h_{oc} * R_L}$$

$$A_i = \frac{-(-50)}{1 + 25 * 10^{-6} * 2.5k} = 47$$

2. Input resistance

$$R_i = h_{ic} + hrc * Ai * RL$$

$$R_i = 1k + 1 * 47 * 2.5k = 118.5k\Omega$$

3. Voltage Gain

$$A_V = \frac{A_i R_L}{R_i}$$

$$A_V = \frac{47 * 2.5k}{118.5k} = 0.99156$$

Solved Examples

2. A voltage source of negligible internal resistance drives a common collector transistor amplifier. The load resistance is 2.5kΩ. Determine A_V, A_I, R_I & R_O using complete hybrid equivalent model. hic = 1kΩ, hrc = 1, hfc = -50, hoc = 25 µA/V.

4. Output resistance

$$Y_O = h_{oc} - \frac{h_{fc}h_{rc}}{R_S + h_{ie}}$$

$$Y_O = 25\mu - \frac{-50 * 1}{1k} = 0.050025$$

$$R_O = \frac{1}{Y_O}$$

$$R_O = \frac{1}{0.050025} = 19.99\Omega$$

Solved Examples

3. Consider a single stage CE amplifier with R_L = 1.2 kΩ and R_S = 1kΩ. Calculate Ai, Ri, Av, Avs, Ais and Ro if, hie = 1.1kΩ, hre = $2.5*10^{-4}$, hfe = 50, hoe = 25 μA/V.

1. Current Gain

$$A_i = \frac{-h_{fe}}{1 + h_{oe} * R_L}$$

$$A_i = \frac{-50}{1 + 25 * 10^{-6} * 1.2k} = -48.54$$

2. Input resistance

$$R_i = h_{ie} + hre * Ai * RL$$

$$R_i = 1.1k + 2.5 * 10^{-4} * -48 * 54 * 1.2k = 1085.44\ \Omega$$

3. Voltage Gain

$$A_V = \frac{A_i R_L}{R_i}$$

$$A_V = \frac{-48.54 * 1.2k}{1085.44} = -53.663$$

$$A_{VS} = \frac{A_V R_i}{R_i + R_S}$$

$$A_{VS} = \frac{-53.663 * 1085.44}{1085.44 + 1000} = -27.93$$

Solved Examples

3. Consider a single stage CE amplifier with R_L = 1.2 kΩ and R_S = 1kΩ. Calculate Ai, Ri, Av, Avs, Ais and Ro if, hie = 1.1kΩ, hre = 2.5*10^{-4}, hfe = 50, hoe = 25 μA/V.

$$A_{iS} = \frac{A_i R_S}{R_i + R_S}$$

$$A_{iS} = \frac{-48.54 * 1000}{1085.44 + 1000} = -23.28$$

Output resistance

$$Y_O = h_{oe} - \frac{h_{fe} h_{re}}{R_S + h_{ie}}$$

$$Y_O = 25\mu - \frac{50 * 2.5 * 10^{-4}}{1k + 1.2k} = 19 * 10^{-6}$$

$$R_O = \frac{1}{Y_O}$$

$$R_O = \frac{1}{19 * 10^{-6}} = 52.6\ k\Omega$$

Solved Examples

4. For the common base cirucit shown, the transistor parameters are hib = 22 Ω, hrb = $2.9*10^{-4}$, hfb = -0.98, hoe = 0.49 µA/V. Calculate Ai, Ri, Av, and Ro.

1. Current Gain

$$A_i = \frac{-h_{fb}}{1 + h_{ob} * R_L{}^1}$$

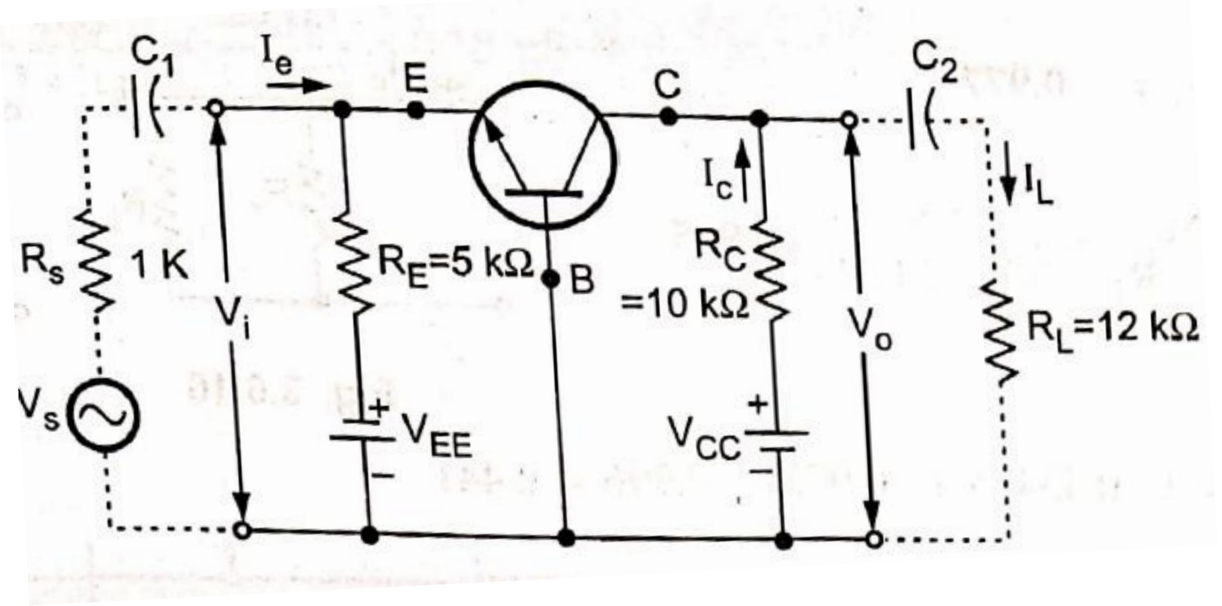
$R_L{}^1 = R_C \parallel R_L$ = 10k ∥ 12 k = 5.45 kΩ.

$$A_i = \frac{-(-0.98)}{1 + 0.49 * 10^{-6} * 5.45k} = 0.977$$

2. Input resistance

$$R_i = h_{ib} + hrb * Ai * RL^1$$

$$R_i = 22 + 2.9*10^{-4}*0.977*5.45k = 23.54\ \Omega$$



$R_i{}^1 = R_i \parallel R_S$ = 23.54 ∥ 5 k = 23.43 Ω.

Solved Examples

4. For the common base cirucit shown, the transistor parameters are hib = 22 Ω, hrb = $2.9*10^{-4}$, hfb = -0.98, hoe = 0.49 μA/V. Calculate Ai, Ri, Av, and Ro.

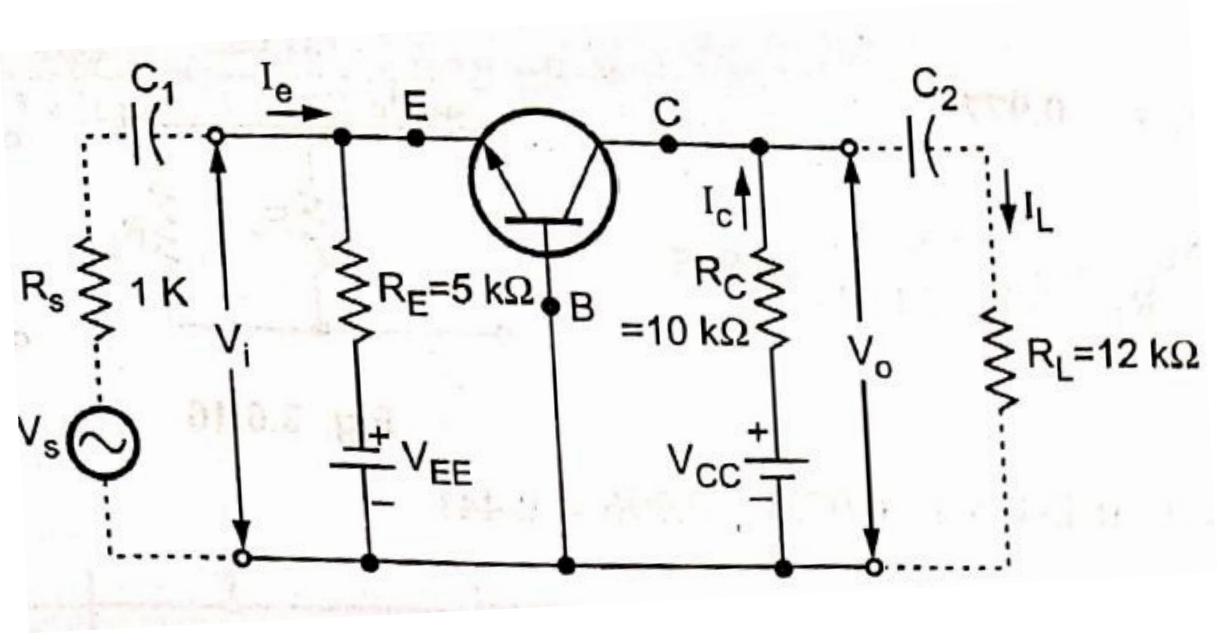
3. Voltage Gain

$$A_V = \frac{A_i R_L{}^1}{R_i}$$

$$A_V = \frac{0.977 * (5.45k)}{23.54} = 226$$

$$A_{VS} = \frac{V_O}{V_S} = \frac{V_O}{V_e} * \frac{V_e}{V_S}$$

$$\frac{V_O}{V_e} = A_V \qquad \frac{V_e}{V_S} = \frac{R_i{}^1}{R_i{}^1 + R_S}$$



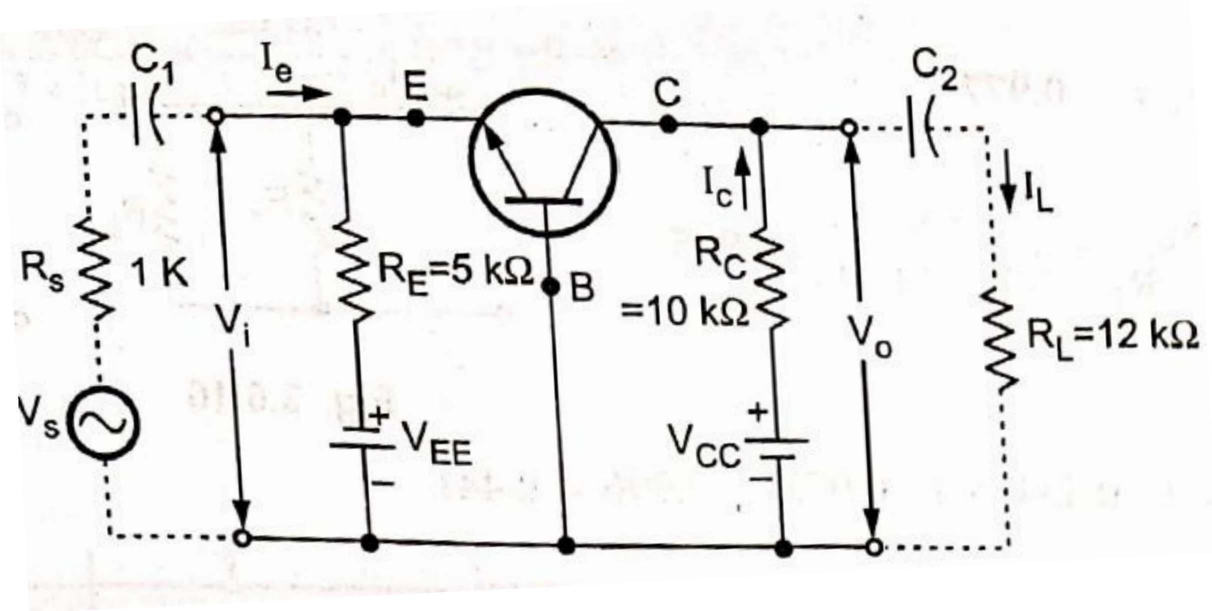
Solved Examples

4. For the common base cirucit shown, the transistor parameters are hib = 22 Ω, hrb = $2.9*10^{-4}$, hfb = -0.98, hoe = 0.49 μA/V. Calculate Ai, Ri, Av, and Ro.

3. Voltage Gain

$$A_{VS} = \frac{V_O}{V_S} = A_V * \frac{{R_i}^1}{{R_i}^1 + R_S}$$

$$A_{VS} = \frac{V_O}{V_S} = 226 * \frac{23.43}{23.43 + 1k} = 5.174$$



Solved Examples

4. For the common base cirucit shown, the transistor parameters are hib = 22 Ω, hrb = $2.9*10^{-4}$, hfb = -0.98, hoe = 0.49 µA/V. Calculate Ai, Ri, Av, and Ro.

4. Overall Current Gain

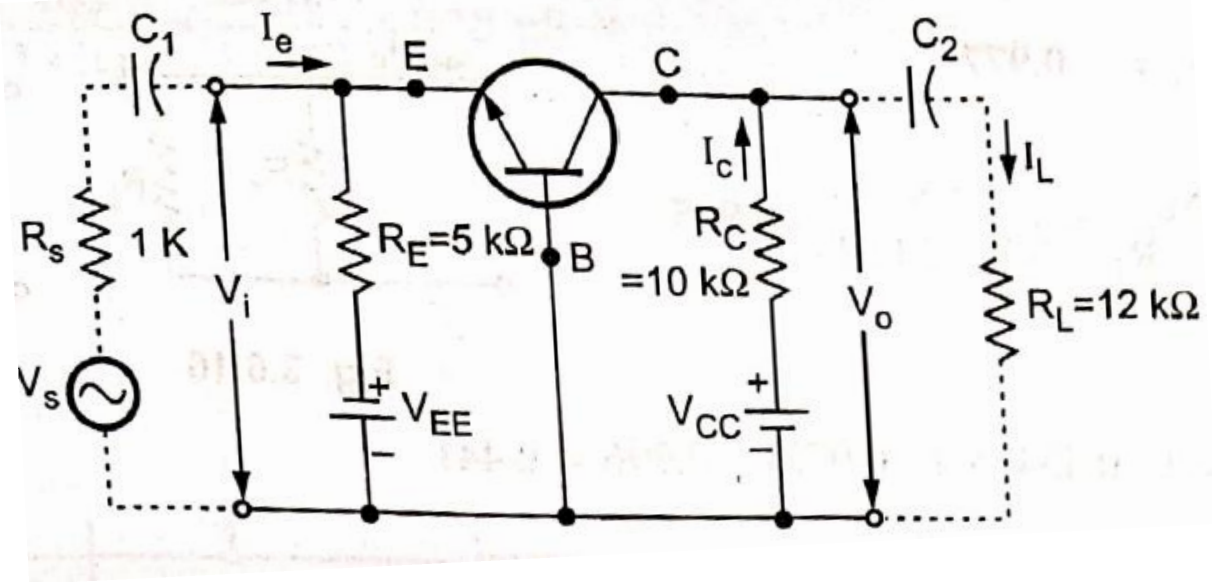
$$A_{iS} = \frac{I_L}{I_S} = \frac{I_L}{I_C} * \frac{I_C}{I_e} * \frac{I_e}{I_S}$$

$$\frac{I_L}{I_C} = -\frac{R_C}{R_C + R_L} = -\frac{10k}{10k + 12k} = -0.454$$

$$\frac{I_C}{I_e} = -A_i = -0.977$$

$$\frac{I_e}{I_S} = \frac{R_E}{R_E + R_i} = \frac{5k}{5k + 23.54} = 0.995$$

Ais = (-0.454)*(-0.977)*(0.995) = 0.441



Solved Examples

4. For the common base cirucit shown, the transistor parameters are hib = 22 Ω, hrb = $2.9*10^{-4}$, hfb = -0.98, hoe = 0.49 μA/V. Calculate Ai, Ri, Av, and Ro.

Output resistance

$$Y_O = h_{ob} - \frac{h_{fb}h_{rb}}{R_S{}^1 + h_{ib}}$$

$$R_S{}^1 = R_S \parallel R_E = 1k \parallel 5k = 833.33$$

$$Y_O = 0.49\mu - \frac{-0.98 * 2.9 * 10^{-4}}{833.33 + 22} = 0.826\mu$$

$$R_O = \frac{1}{Y_O}$$

$$R_O = \frac{1}{0.826\mu} = 1.21\ M\Omega$$

$$R_O{}^1 = R_O \parallel R_L{}^1 = 1.21\ M \parallel 5.45k = 5.425k\Omega$$

THANK YOU