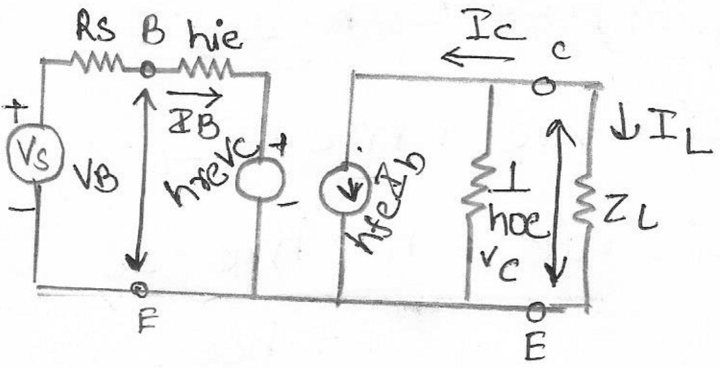
Analysis of CE amplifier:



$$V_B = h_{ie} I_b + h_{re} V_c \quad -(1)$$

$$I_c = h_{fe} I_b + h_{oe} V_c \quad -(2)$$

Current gain (A_i):

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

$$V_c = I_L Z_L = -I_c Z_L$$

$$I_c (1 + h_o Z_L) = h_{fe} I_b$$

$$\boxed{A_i = \frac{-h_{fe}}{1 + h_{oe} Z_L}}$$

Input Impedance (Z_i):

$$V_c = I_L Z_L = -I_c Z_L$$

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

$$V_c = A_i I_b Z_L$$

$$V_b = h_{ie} I_b + h_{re} A_i I_b Z_L$$

divide with I_b

$$Z_i = h_{ie} + h_{re} A_i Z_L$$

$$Z_i = h_{ie} - \frac{h_{fe} h_{re} \cdot Z_L}{1 + h_{oe} Z_L}$$

$$\boxed{Z_i = h_{ie} - \frac{h_{fe} h_{re}}{Y_0 + h_{oe}}}$$

Voltage gain (A_v):

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

$$V_b = I_b Z_i$$

$$V_c = -I_c Z_L$$

$$= A_i I_b Z_L$$

$$\boxed{A_v = \frac{A_i Z_L}{Z_i}}$$

Output admittance (Y_o):

Ratio of output voltage to output current when $V_s = 0$ and Z_L is ∞

$$I_c = h_{fe} I_b + h_{oe} V_c$$

divide with V_c

$$Y_o = \frac{I_c}{V_c} = h_{fe}\frac{I_b}{V_c} + h_{oe} \quad \text{--- (1)}$$

when $V_s = 0$

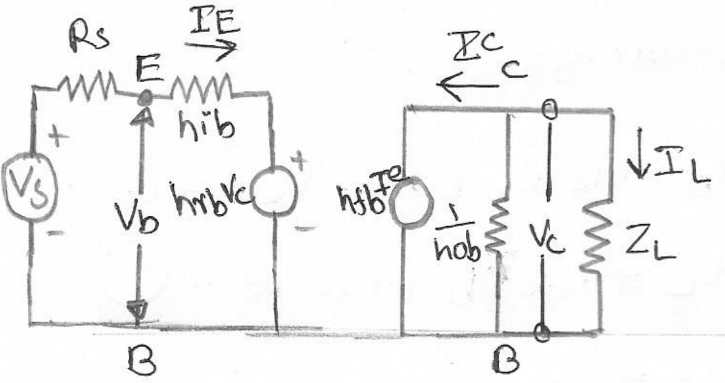
$$I_b R_s + h_{ie} I_b + h_{re} V_c = 0$$

$$\frac{I_b}{V_c} = \frac{-h_{re}}{R_s + h_{ie}} \quad \text{--- (2)}$$

Sub (2) in (1)

$$Y_o = h_{oe} - \frac{h_{re} h_{fe}}{R_s + h_{ie}}$$

Analysis of CB Amplifier



In CB configuration

V_e, I_c are dependent variables

I_e, V_c are independent variables

$$V_e = h_{ib} I_e + h_{rb} V_c \quad -(1)$$

$$I_c = h_{fb} I_e + h_{ob} V_c \quad -(2)$$

Current gain (A_i):

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

$$V_c = I_L Z_L = -I_c Z_L \quad -(3)$$

Sub Eq(3) in Eq(2)

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

$$\boxed{A_i = \frac{-h_{fb}}{1 + h_{ob} Z_L}}$$

Input impedance:

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

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

$$V_c = I_L Z_L = -I_c Z_L$$

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

$$V_c = A_i I_e Z_L$$

$$V_e = h_{ib} I_e + h_{rb} A_i I_e Z_L$$

divide with I_e

$$Z_i = h_{ib} + h_{rb} A_i Z_L$$

$$Z_i = h_{ib} - \frac{h_{fb} h_{rb} Z_L}{1 + h_{ob} Z_L}$$

$$Z_i = h_{ib} - \frac{h_{fb} h_{rb} \cancel{Z_L}}{\cancel{Z_L}\left[1/Z_L + h_{ob}\right]}$$

$$\boxed{Z_i = h_{ib} - \frac{h_{fb} h_{rb}}{Y_L + h_{ob}}}$$

Voltage gain: (A_v)

$$A_v = V_c / V_e$$

$V_e \rightarrow$ Input voltage

$V_c \rightarrow$ output Voltage

$$V_e = I_e Z_i$$

$$V_c = I_L Z_L = -I_c Z_L$$

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

$$V_c = A_i I_e Z_L$$

$$A_v = \frac{V_c}{V_e} = \frac{A_i Z_L}{Z_i}$$

Output admittance

Ratio of output voltage to output current when
$V_s = 0$ & Z_L is ∞

$V_e = h_{ib} I_e + h_{rb} V_c$ — (1)

$I_c = h_{fb} I_e + h_{ob} V_c$ — (2)

divide Eq (2) with "V_c"

$$Y_o = \frac{I_c}{V_c} = h_{fb}\frac{I_e}{V_c} + h_{ob} \quad (3)$$

If $V_s = 0$ then

$I_e R_s + h_{ib} I_e + h_{rb} V_c = 0$

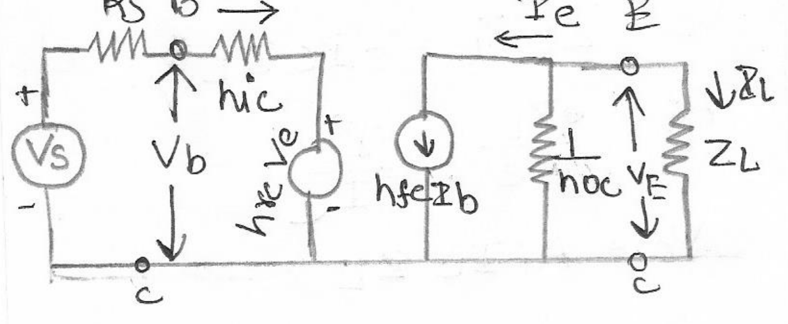
divide with V_c

$$\frac{I_e}{V_c} = \frac{-h_{rb}}{R_s + h_{ib}} \quad (4)$$

sub (4) in (3)

$$\boxed{Y_o = h_{ob} - \frac{h_{fb} h_{rb}}{R_s + h_{ib}}}$$

Analysis of CC Amplifier



V_b, I_e are dependent variables
I_b, V_e are independent variables

$$V_b = h_{ic} I_b + h_{rc} V_e \quad -(1)$$

$$I_e = h_{fc} I_b + h_{oc} V_e \quad -(2)$$

Current gain: (A_i)

$$V_e = I_L Z_L = -I_e Z_L \quad -(3)$$

Sub (3) in (1)

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

$$\boxed{A_i = \frac{-h_{fc}}{1 + h_{oc} Z_L}}$$

Input Impedance (Z_i):

$$V_e = I_L Z_L = -I_e Z_L$$

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

$$V_e = A_i I_b Z_L$$

$$V_b = h_{ic} I_b + h_{rc} A_i I_b Z_L$$

divide with I_b

$$Z_i = h_{ic} + h_{rc} A_i Z_L$$

$$Z_i = h_{ic} - \frac{h_{fc} h_{rc} Z_L}{1 + h_{oc} Z_L}$$

$$\boxed{Z_i = h_{ic} - \frac{h_{fc} h_{rc}}{(Y_L + h_{oc})}}$$

Voltage gain (A_V) :

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

$$V_b = I_b Z_i$$

$$V_e = I_L Z_L = -I_e Z_L$$

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

$$V_e = A_i I_b Z_L$$

$$\boxed{A_V = \frac{A_i Z_L}{Z_i}}$$

Output Admittance :

Ratio of output voltage to output current when $V_s = 0$ and $Z_L = \infty$

$$I_e = h_{fc} I_b + h_{oc} V_e \quad - (1)$$

divide with V_e

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

If $V_s = 0$

$$I_b R_s + h_{ic} I_b + h_{rc} V_e = 0$$

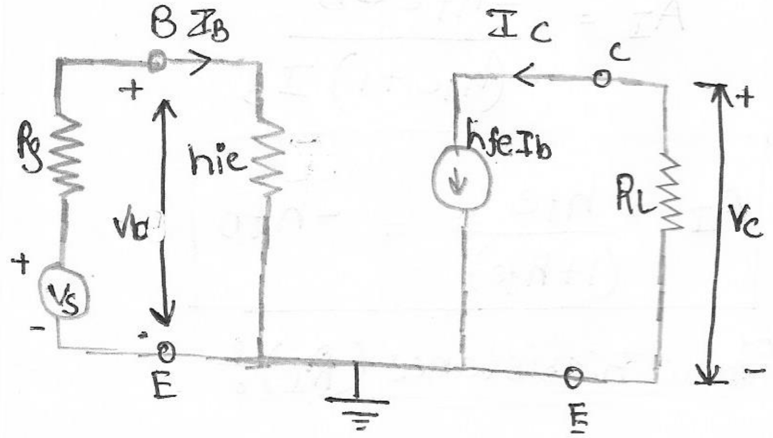
divide with V_e

$$\frac{I_b}{V_c} = \frac{-h_{rc}}{R_s + h_{ic}}$$

$$\boxed{Y_o = h_{oc} - \frac{h_{fc}\, h_{rc}}{R_s + h_{ic}}}$$

①

Analysis of CE amplifier using approximate model :



Current gain (A_I) :

$$A_I = \frac{I_c}{I_b} = \frac{-I_c}{I_b} \quad -①$$

$$\boxed{i_c = h_{fe} I_b} \text{ in eq ①}$$

$$A_I = \frac{-h_{fe}I_b}{I_b}$$

$$\boxed{A_I = -h_{fe}}$$

Input Impedance : (R_I)

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

$$V_b = h_{ie} I_b$$

$$R_I = \frac{h_{ie} I_b}{I_b}$$

$$\boxed{R_I = h_{ie}}$$

Voltage gain (A_V) : ②

$$A_V = \frac{V_c}{V_b} = \frac{I_c R_L}{I_b h_{ie}}$$

$$\Rightarrow \frac{-I_L R_L}{I_b h_{ie}}$$

$$\Rightarrow \frac{-h_{fe} I_b R_L}{I_b h_{ie}}$$

$$\boxed{A_V = \frac{-h_{fe} R_L}{h_{ie}}}$$

Output admittance (R_o) :

$$R_o = 1/Y_o \qquad Y_o = \frac{-I_L}{V_c}$$

$$= \frac{V_c}{-I_c} \qquad I_L = -I_c$$

$$I_b = 0, I_c = 0$$

$$R_o = \infty$$

{output port is open circuited $I_c = 0$ }

Characteristics :

i) It has medium input impedance (1K-Ω)

ii) High current gain

iii) High voltage gain

iv) Moderate output impedance.

v) Used for voltage amplification at audio frequency range

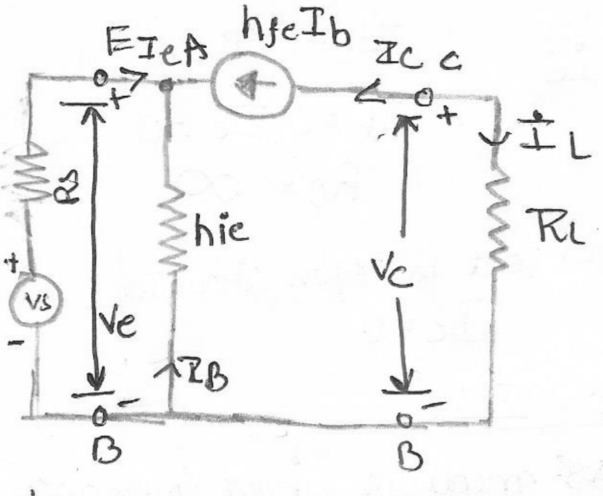
vi) The phase shift is around 180° between input and output voltages

③

Applications :

Of the 3 configurations CE amplifier alone is capable of providing both Voltage gain and power gain. Further the input resistance R_I and output resistance are moderately high. Hence CE amplifier is widely used for amplification.

Analysis of CB amplifier using approximate model :



The above figure shows the Equivalent circuit of CB amplifier using approximate model, with the base grounded.

Current gain (A_I):

$$A_I = \frac{I_c}{I_e} = \frac{-I_c}{I_e}$$

KVL at node "A"

$$I_e + h_{fe} I_b + I_b = 0$$

$$I_c = -h_{fe} I_b - I_b$$

$$\frac{I_c}{I_b} = -(h_{fe}+1) \quad \{\text{current gain} < 1\}$$

$$A_I = \frac{-h_{fe} I_b}{-(h_{fe}+1) I_b}$$

$$\boxed{A_I = \frac{h_{fe}}{(1+h_{fe})} = -h_{fb}}$$

<u>Input Resistance (R_I):</u>

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

$$\left.\begin{aligned} V_e &= -h_{ie} I_b \\ i_e &= -(1+h_{fe}) I_b \end{aligned}\right\} \text{- in defn}$$

$$R_I = \frac{h_{ie}}{(1+h_{fe})}$$

$$\boxed{R_I = h_{ib}}$$

<u>Voltage gain:</u>

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

{ * voltage gain is high
* no phase shift }

$$V_c = I_L R_L = -I_c R_L$$

$$V_e = -I_b h_{ie}, \quad I_c = h_{fe} I_b$$

$$A_V = \frac{-h_{fe} I_b R_L}{-I_b h_{ie}}$$

$$\boxed{A_V = \frac{h_{fe} R_L}{h_{ie}}}$$

(A_I, A_V, R_I don't differ from Exact Values by more than 10%) ⑤

Output Impedance :

$$R_o = \frac{V_c}{I_c} \text{ with } R_L = \infty, V_s = 0$$

with $V_s = 0$, $I_e = 0$ & $I_b = 0$

Hence $I_b = 0$

*) There fore $R_o = \infty$ using approximate model

CB characteristics :

*) It's used as amplifer at high frequency.

*) Current gain less than 1

*) Input impedance low

*) Voltage gain high

*) O/P impedance high.

*) There is no phase shift

Applications :

The CB amplifier used for amplification

Used for

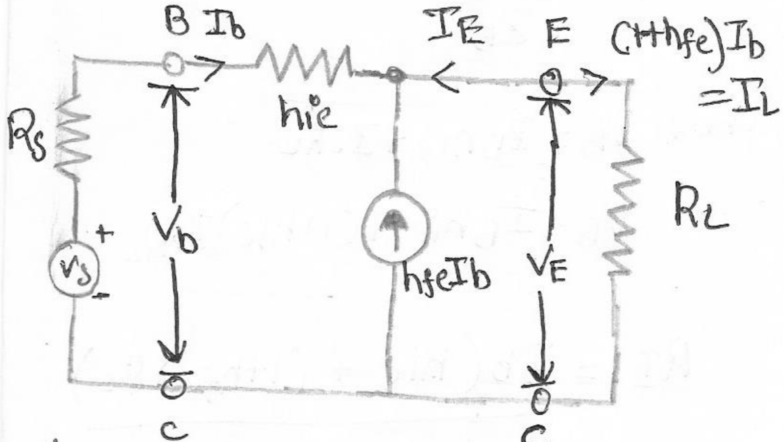
i) Matching a low impedance source

ii) as a non-inverting amplifier with Voltage - gain exceeding unity

iii) for driving a high impedance load

⑥

Approximate hybrid model of CC :
(common amplifier)



The above figure shows the simplified h-parameter Equivalent of a common collector amplifier. In this circuit the collector is grounded and load Resistance R_L is connected between Emitter & the ground.

It's consists hie - Input impedance
hfe - forward current gain

Current gain (A_I):

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

$$= \frac{(1+h_{fe})I_b}{I_b}$$

apply KCL at node "A".

$$I_L = -I_c = h_{fe}I_b + I_b$$

$$I_L = (h_{fe}+1)I_b$$

$$\boxed{A_I = 1+h_{fe}}$$

⑦

Input Resistance (R_I) :-

$$R_I = \frac{V_B}{I_B}$$

where $V_B = I_B h_{ie} + I_L R_L$

$V_B = I_B h_{ie} + (1+h_{fe}) I_b R_L$

$$R_I = \frac{I_B(h_{ie} + (1+h_{fe})R_L)}{I_B}$$

$$\boxed{R_I = h_{ie} + (1+h_{fe})R_L}$$

Voltage gain (A_V) :-

$$A_V = \frac{V_E}{V_B} = \frac{(1+h_{fe}) I_b R_L}{[h_{ie} I_b + (1+h_{fe}) I_b R_L]}$$

$$\Rightarrow \frac{1+h_{fe}}{h_{ie} + (1+h_{fe})R_L}$$

$$= 1 - \frac{h_{ie}}{h_{ie} + (1+h_{fe})R_L}$$

$$\boxed{A_V = 1 - \frac{h_{ie}}{R_I}}$$

output admittance (R_O) :

$$R_O = 1/y_o$$

~~Y_o~~ = [illegible]

$$Y_o = \frac{\text{Short ckt current at O/p}}{\text{open ckt voltage at O/p}}$$

$$Y_o = \frac{(1+h_{fe}) I_b}{V_s}$$

$$I_b = \frac{V_s}{R_s + h_{ie}}$$

$$Y_o = \frac{(1+h_{fe})(V_s/R_s+h_{ie})}{V_s}$$

$$Y_o = \frac{1+h_{fe}}{R_s+h_{ie}}$$

$$\boxed{R_o = 1/Y_o = \frac{R_s+h_{ie}}{1+h_{fe}}}$$

Characteristics of CC:

*) It offers high input impedance

*) It offers low output impedance

*) current gain A_I is high

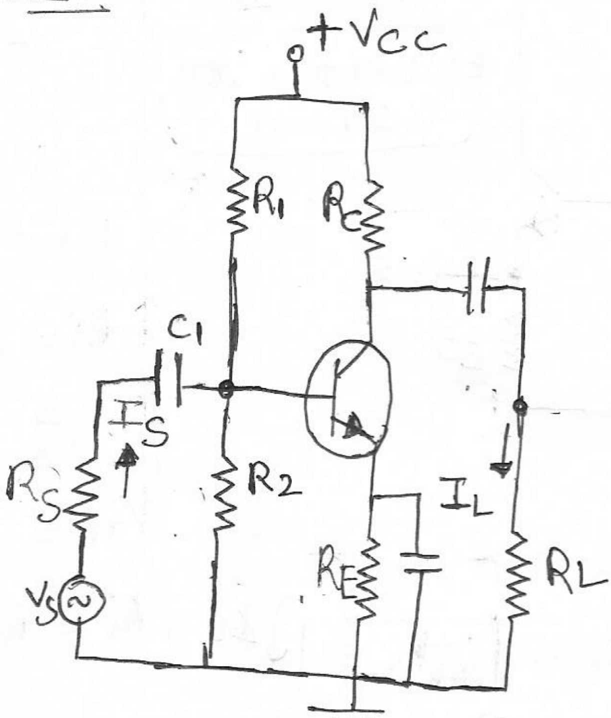
*) $A_v \leq 1$

*) not suitable for voltage amplification

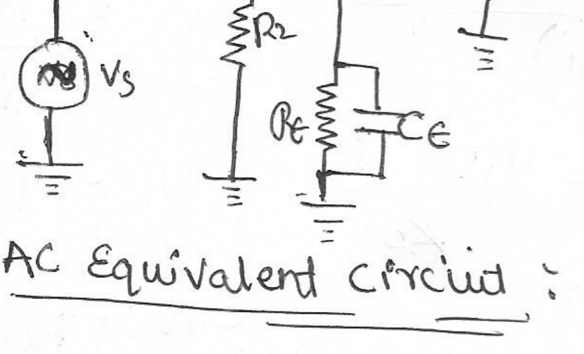
*) It is suitable for impedance matching purpose such it can be used as a buffer between a high impedance source and low impedance load. It doesn't introdu[ce] Phase Shift between i/p, o/p signals

Analysis of CE Amplifier

Analysis of CE amplifier using h-parameter model :



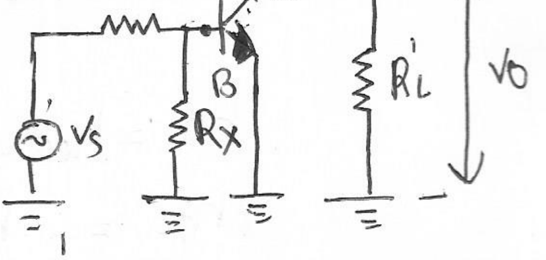
Common Emitter Amplifier



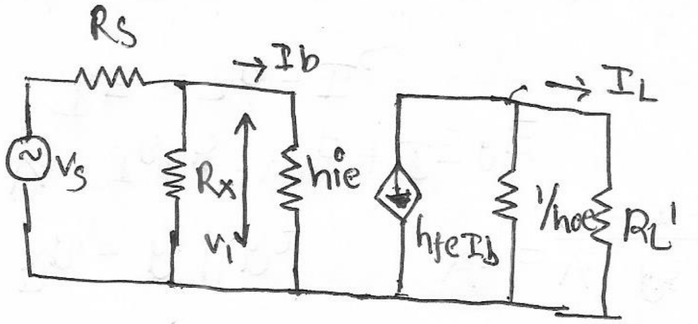
AC Equivalent circuit :

$R_x = R_1 || R_2$

$R_L' = R_c || R_L$



Replace BJT by its h-model :



Current gain

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

If hoe is negligible

then $\boxed{A_i \cong -h_{fe}}$ current gain is high

Input resistance

$$R_i = \frac{V_i}{I_b} = \frac{\cancel{I_b} \times h_{ie}}{\cancel{I_b}}$$

$\boxed{R_i = h_{ie}}$ Ri is high

Voltage gain : $1/h_{oe} \| R_L' = R_L''$

$$A_v = V_o/V_i = \frac{-h_{fe} \cancel{I_b} R_L''}{\cancel{I_b} \cdot h_{ie}}$$

$$\boxed{A_v = \frac{-h_{fe} R_L''}{h_{ie}}}$$ Voltage gain is high

Output Resistance :

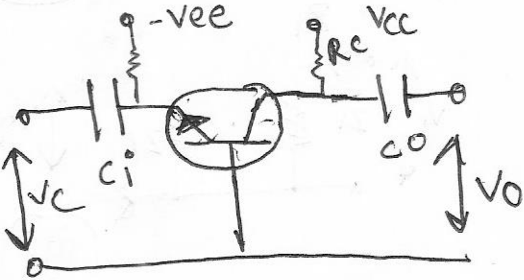
$$\frac{1}{R_O} = h_{oe} - \frac{h_{fe} h_{re}}{R_s' + h_{ie}}$$

If h_r is negligible

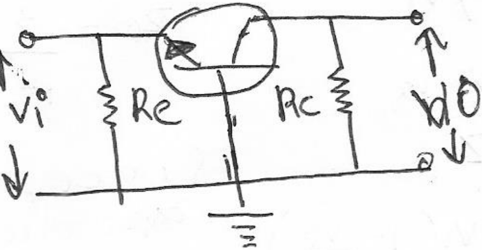
$$\boxed{R_O = \frac{1}{h_{oe}}}$$

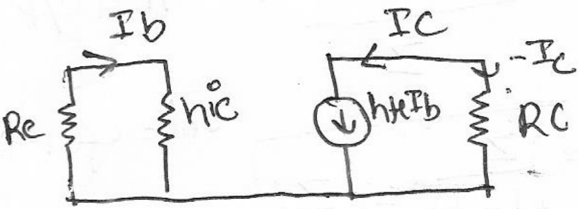
R_o is very high

$R_o' = R_e$



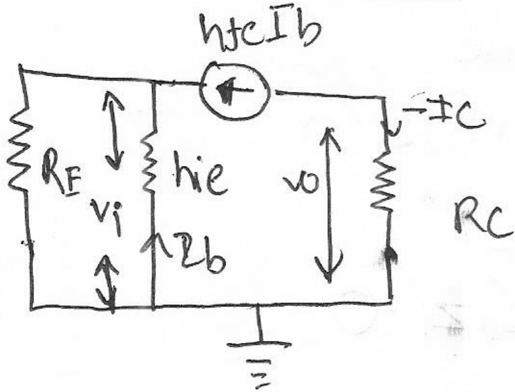
CB amplifier





approxmiatu model ~~using~~ of
CE amplifier

CB amplifier using approximate model



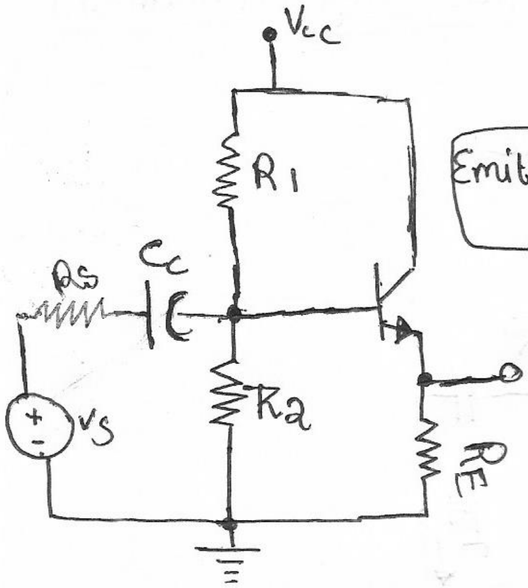
$$R_I = \frac{V_E}{I_E} = \frac{-h_{ie} I_b}{-(1+h_{fe}) I_b}$$

$$A_I = -\frac{I_c}{I_b} = \frac{-h_{fe} I_b}{-(1+h_{fe}) I_b}$$

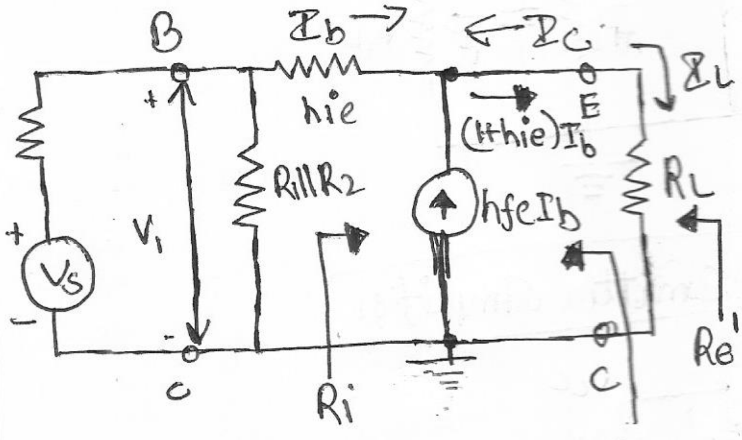
$$A_I = -h_{fe}/1+h_{fe}$$

$$A_v = \frac{V_o}{V_i} = \frac{-h_{fe} \cancel{I_b} R_c}{-h_{ie} \cancel{I_b}}$$

Emitter follower Analysis using approximate model :



Emitter follower circuit



simplified hybrid model for emitter follower circuit

Current Gain : (Ai)

$$A_i = \frac{I_L}{I_b} = \frac{I_E}{I_b} = \frac{(1+h_{fe})\cancel{I_b}}{\cancel{I_b}}$$

$$\boxed{I_E = (1+h_{fe})I_b}$$

$$A_i = 1 + h_{fe}$$

Input Resistance (R_i):

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

[cancelling "I_b" as they are common]

$$= \frac{\cancel{I_b} h_{ie} + \cancel{I_b}(1+h_{fe}) R_L}{\cancel{I_b}}$$

$\boxed{\Omega\text{-ohms}}$

$$R_i = h_{ie} + (1+h_{fe}) R_L$$

$$R_i = 1100\,\Omega + 101 * (2000\,\Omega)$$

$$= 203.1\,K\Omega$$

$$A_i = 1+100 = 101$$

$$R_i' = R_i \| R_b = 203.1\,K\Omega \| 25\,K\Omega$$

$$= 22.25\,K\Omega$$

$$R_b = R_1 \| R_2 = 25\,K\Omega$$

Voltage gain (A_v):

$$A_v = \frac{V_o}{V_i} = \frac{A_i R_L}{R_i}$$

$$= \frac{(1+h_{fe}) R_L}{h_{ie} + (1+h_{fe}) R_L} = \frac{R_i - h_{ie}}{R_i}$$

$$= 1 - \frac{h_{ie}}{R_i} \Big\} \; A_v = 1 - \left(\frac{h_{ie}}{R_i}\right)$$

$$= 1 - \left(\frac{1100}{203100}\right) = 0.99$$

Output Resistance (R_o):

$$\frac{1}{R_o} = h_{oc} - \frac{h_{fc} h_{rc}}{R_s' + h_{ie}}$$

$$h_{oc} = h_{oe} = 25 \times 10^{-6}\ A/V$$

$$h_{fc} = 1 + h_{fe}$$

$h_{rc} = 1$

$h_{ic} = h_{ie}$

$R_S' = R_S || R_1 || R_2$

$= 500\,\Omega \, || \, 25\,K\Omega$

$= 0.9\,K\Omega$

$$Y_0 = \frac{-h_{fc}}{R_S' + h_{ic}}$$

$$R_0 = 1/y_0 = \frac{R_S' + h_{ie}}{1 + h_{fe}}$$

$$= \frac{900 + 1100}{101}$$

$= 19.80\,\Omega$

$R_0' = R_0 || R_L$

Q) In Emitter follower

$R_S = 500\,\Omega,$

$R_1 = R_2 = 2\,K\Omega$

$h_{fe} = 100, h_{ic} = 1.1\,K\Omega$

determine R_i, R_0, A_i, A_v

Single stage CE Amplifier

In CE configuration the operating point is the mid-point of DC load line. Biasing stablizes the operating point in the active region due to change in temperature change in β and change in V_{BE}

Biasing Ensure emitter base junction forward biased and collector base junction reverse biased.

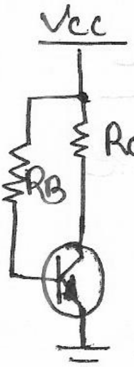
Transistor Biasing Techniques

i) Fixed bias

ii) Collector to Base bias

iii) Self bias

Fixed Bias :



In CE configuration

$$I_c = \beta I_B + (1+\beta) I_{CO}$$

Stability factor

$$S = \frac{dI_c}{dI_{CO}}$$

$$S = \frac{1+\beta}{1 - \beta \frac{dI_B}{dI_c}}$$

In fixed bias

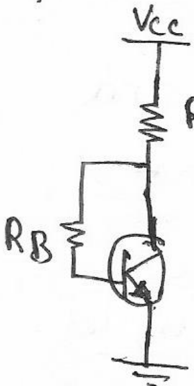
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$\frac{dI_B}{dI_c} = 0$$

$$S = 1 + \beta$$

Fixed bias has Poor stabilization technique but it's simple

Collector to Base Bias :



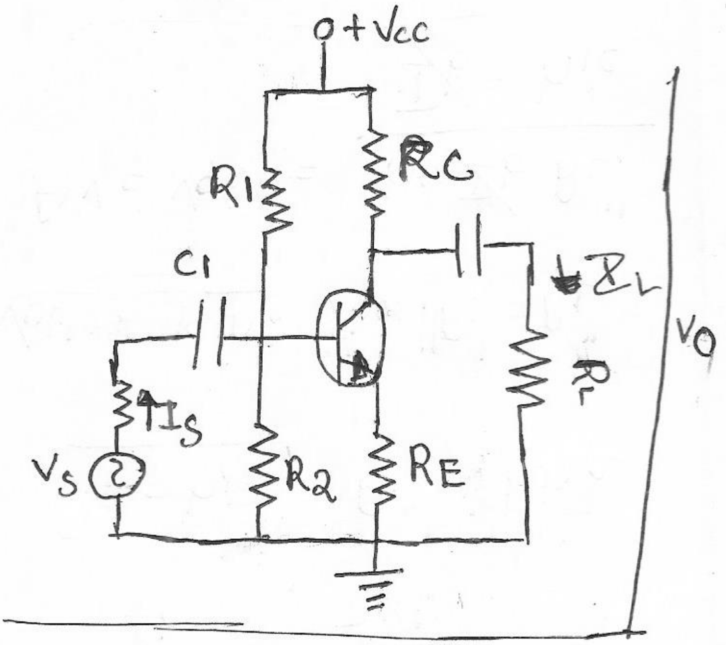
The feedback Resistor is between collector and base cause negative feedback

$$S = \frac{1+\beta}{1 + \frac{\beta R_C}{R_C + R_B}}$$

$$R >>> R_B$$

Stability factor is 1

Common Emitter Amplifier



In self bias CE amplifier the voltage drop across R_2 provides Emitter Base junction forward bias.

The Voltage drop across R_C provides collector base junction Reverse bias

"RE" provides stabilization

The capacitor C_1, C_2 couples input & output signal.

Vo is output observed across load Resistor R_L

Stabilization factor (S) = 1

$R_B = R_1 \| R_2$ $\qquad V_2 = \frac{V_{CC} R_2}{R_1 + R_2}$

$V_2 = I_B R_B + V_{BE} + I_E R_E$

$I_E = I_B + I_C$

$V_2 = I_B R_B + V_{BE} + (I_B + I_C) R_E$

differentiate the above Equation with respect to I_C

$$\frac{dI_B}{dI_C} = \frac{-R_E}{R_E + R_B}$$

$$S = \frac{1+\beta}{1 + \frac{\beta R_E}{R_E + R_B}}$$

R_E is stabilizing resistor

$$I_C = \beta I_B + (1+\beta) I_{CO}$$

$$V_2 = I_B R_B + V_{BE} + I_E R_E$$

$$I_B = (V_2 - V_{BE} - I_E R_E) / R_B$$

As temperature Increases I_C increases, I_E also increases I_B decreases now I_C becomes constant. So operating point is Stable.

here as I_C increases lead to decrease in I_B due to voltage drop across R_E

$$V_{CC} = I_C R_C + V_{CE} + I_E R_E$$

$$I_C \cong I_E$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

Stability factor

$$S = \frac{(1+\beta)(R_B + R_E)}{R_B + R_E(1+\beta)}$$

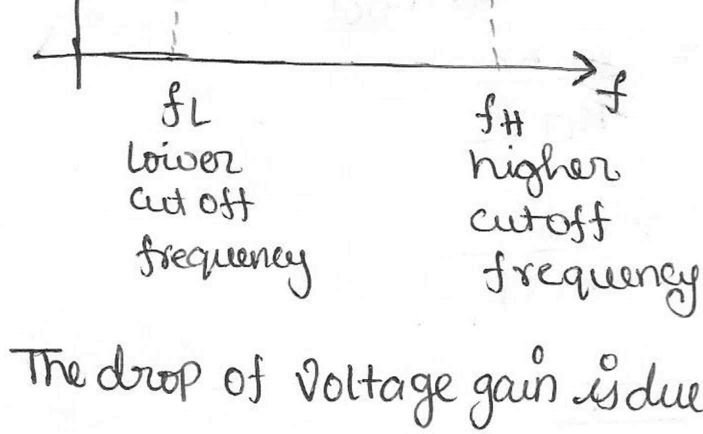
$$R_E = R_1 \| R_2$$

$$S = \frac{(1+\beta)\left(1 + R_B/R_E\right)}{\frac{R_B}{R_E} + (1+\beta)}$$

$$S = \frac{1+\beta}{1+\beta} = 1$$

Frequency Response

$$A_V = A_V(f) \angle \phi(f)$$



The drop of voltage gain is due to:

1.) Increasing reactance of capcitors at low frequency

Desgin of single stage CE amplifier:

$R_C, I, V_{CC}, V_{CE}, S, \beta$ are known:

$I_C = \beta I_B$

$I_B = I_C/\beta$

$V_{CC} - V_{CE} - I_C R_C$

Given I_C:

$$R_C = \frac{V_{CC} - V_{CE} - V_E}{I_C}$$

$V_E = I_E R_E$

$I_E = I_B + I_C$

$$R_E = \frac{V_{CC} - V_{CE} - I_C R_C}{I_C + I_B}$$

$$V_2 = \frac{V_{CC} R_2}{R_1 + R_2}$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2}$$

$$S = \frac{1+\beta}{1 + \frac{\beta R_E}{R_E + R_B}}$$

S, β Given

R_B from S canbe found

$V_2 = I_B R_B + V_{BE} + I_E R_E$

$$\frac{V_2}{V_{cc}} = \frac{R_2}{R_1 + R_2}$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2} \text{ ; so } R_B = \frac{R_2 V_2}{V_{cc}}$$

$$R_1 = \frac{R_B V_{cc}}{V_2}$$

$$V_{cc} - V_2 = I R_1$$

$$V_2 = I R_2 \text{ ; } \frac{V_2}{V_{cc} - V_2} = \frac{R_2}{R_1} \text{ ;}$$

$$R_2 = \frac{V_2 R_1}{V_{cc} - V_2}$$

To find C_E

X_{CE} is $\frac{R_E}{10}$

$$X_{CE} = \frac{1}{2\pi f_1 C_E}$$

$$C_E = \frac{1}{2\pi f_1 X_{CE}}$$

To find C_1:

X_{C1} is $R_i/10$

$R_i = R_1 \| R_2 \| h_{ie}$

$$C_1 = \frac{1}{2\pi f_1 X_{C1}}$$

To find C_2

X_{C2} is $R_C \| R_L / 10$

$C_2 = 1/2\pi f_1 X_{C2}$

The frequency response of CE Amplifier:

The voltage gain (V_o/V_i) decreases due to

1) X_{CE}, X_{CI}, X_{CO} increases at low frequency
2) Parasitic capacitance effect increases at high frequency
3) C_E, C_C diffusion capacitance, transition capacitance exists between emitter & base of transistor, collector base of transistor

Millers theorem

from fig 1

$$I_1 = \frac{V_1 - V_2}{Z}$$

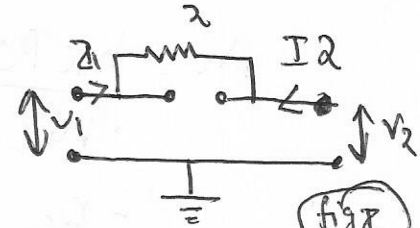


fig I

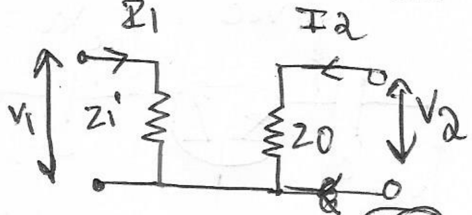


fig II

$$I_2 = \frac{V_2 - V_1}{Z}$$

$$Z_i = \frac{Z}{1-A}$$

$$A = V_2/V_1$$

$$Z_0 = \frac{Z}{1-1/A}$$

$$I_1 = \frac{V_1 - V_2}{Z}$$

$$I_1 = \frac{V_1\left(1 - \frac{V_2}{V_1}\right)}{Z}$$

note C_F capacitor connected b/w I/P & O/P

$$\boxed{\frac{V_1}{I_1} = \frac{Z}{1-A} = Z_i}$$

$$C_{Mi} = C_f(1-A)$$

$$C_{MO} = C_f(1 - 1/A)$$

$$I_2 = \frac{V_2 - V_1}{Z}$$

$$I_2 = \frac{V_2\left(1 - \frac{V_1}{V_2}\right)}{Z}$$

$$\frac{V_2}{I_2} = \frac{Z}{1-1/A} = \frac{A \cdot Z}{A-1}$$

$$\boxed{Z_0 = \frac{Z}{1-A}}$$

Millers theorem states that the impedance b/w input & output can be split towards i/p side impedance z_i & o/p side impedance z_o

Dual of millers theorem:

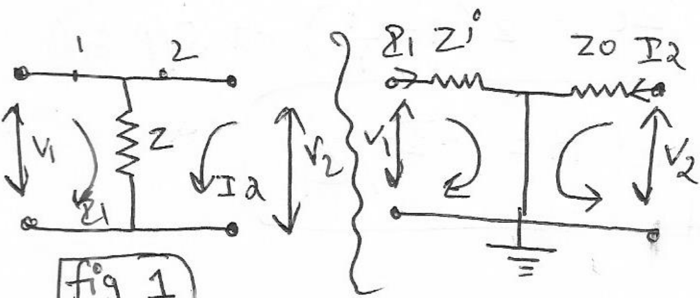


fig 1

fig 2

at i/p side in fig 1

$V_1 = (I_1 + I_2) Z$ — (1)

at o/p side

$V_2 = (I_2 + I_1) Z$ — (2)

from fig 2

$V_1 = I_1 Z_i$ — (3)

$V_2 = I_2 Z_o$ — (4)

(1) = (3)

$(I_1 + I_2) Z = I_1 Z_i$

$Z_i = \left(\frac{I_1 + I_2}{I_1}\right) Z$

$A = -I_2 / I_1$

$Z_i = (1 - A) Z$

$I_2 Z_o = (I_2 + I_1) Z$

$Z_o = \left(\frac{I_2 + I_1}{I_2}\right) Z \Rightarrow \boxed{Z_o = \left(1 - \frac{1}{A}\right) Z}$

Dual of millers theorem states that if an impedance z connected as shunt Element between i/P & O/P can be replaced by

$Z_i = Z(1-A)$ at i/p side

$Z_o = Z\left(1-\frac{1}{A}\right)$ at O/P side

Note: $A = -I_2/I_1$

A → Current gain