Analog Circuits

Day-6

BJT Amplifiers

Introduction

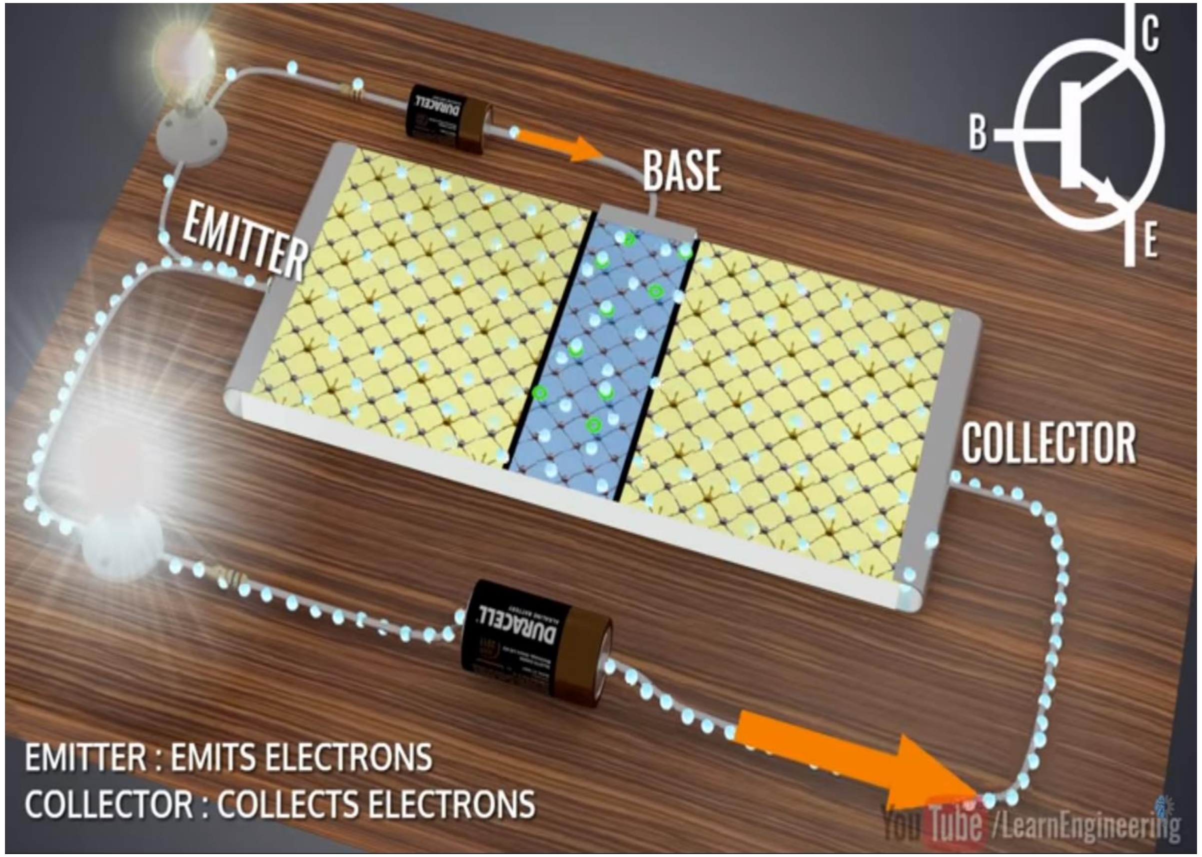
- In this unit we learn about AC response of transistors using different transistor models.
- In AC analysis we have to decide whether to use small signal or large signal technique. In this unit we will use small signal as input.
- Large signal amplifiers are power amplifiers.

Operating Point in Small Signal Analysis:

- In small signal analysis, as the input signal variation is small, the output signal variation is also limited and hence swing in Q-point is also limited.

Small signal is defined as the signal having magnitude sufficiently small to keep transistor in active region.

Transistor as an Amplifier



To use transistor as an amplifier it must be in the active region.

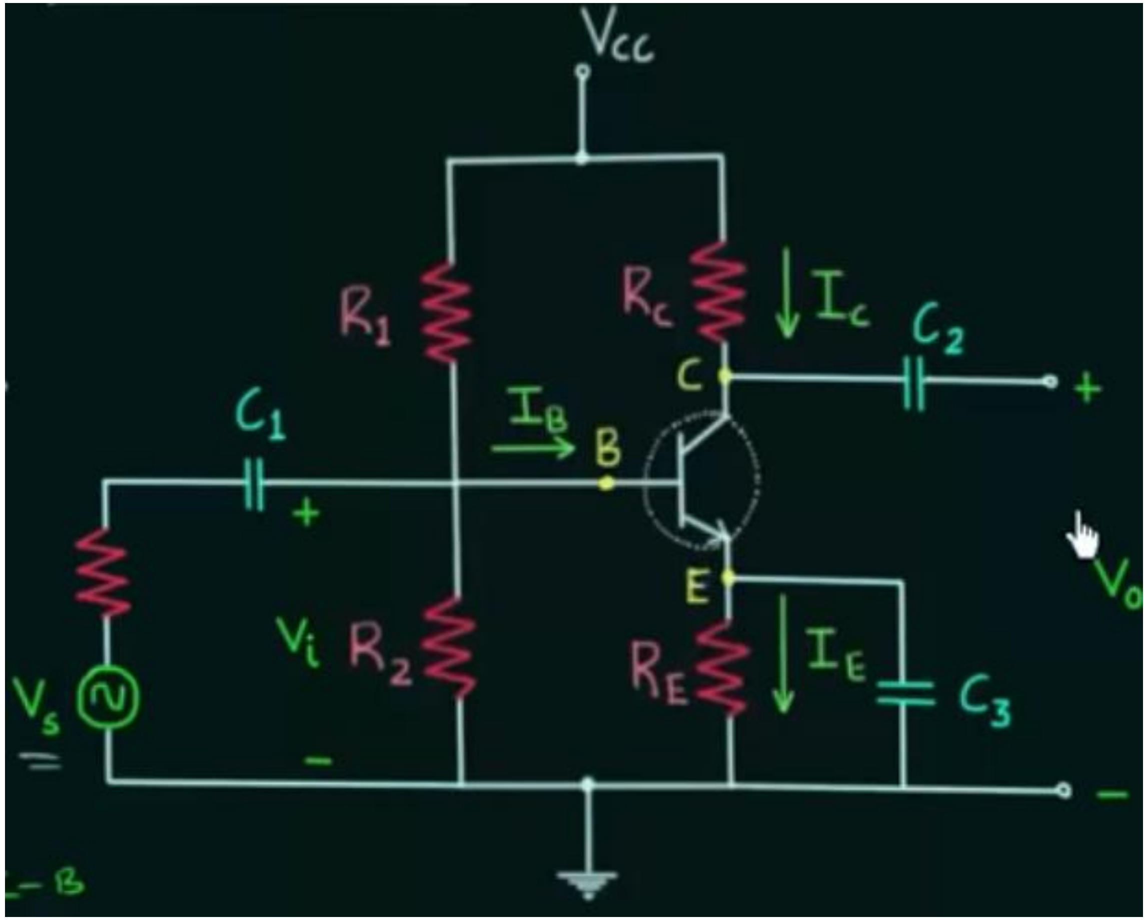
We know that $X_C = 1/2*pi*f*c$

For AC input f≠0(f not equal to zero)

$X_C = 1/\text{large value} = 0$(approximately)

Hence for AC input the capacitors are short circuited.

- C_1, C_2 are coupling capacitors because those are the capacitors which are coupling the input to the amplifier and output to the load respectively.



Why to use coupling capacitors?

In order to prevent the DC from previous stage to interfere with the V_{cc} and hence the operating point will remain constant.

C_3 is bypass capacitor because it bypasses the AC signal as R_E offers some resistance.

To find out AC response we need to do 2 things

1)Obtain AC equivalent circuit.

2)Replace the transistor with equivalent circuit.

Equivalent circuit for AC analysis:

STEP-1

Short circuit the DC sources.

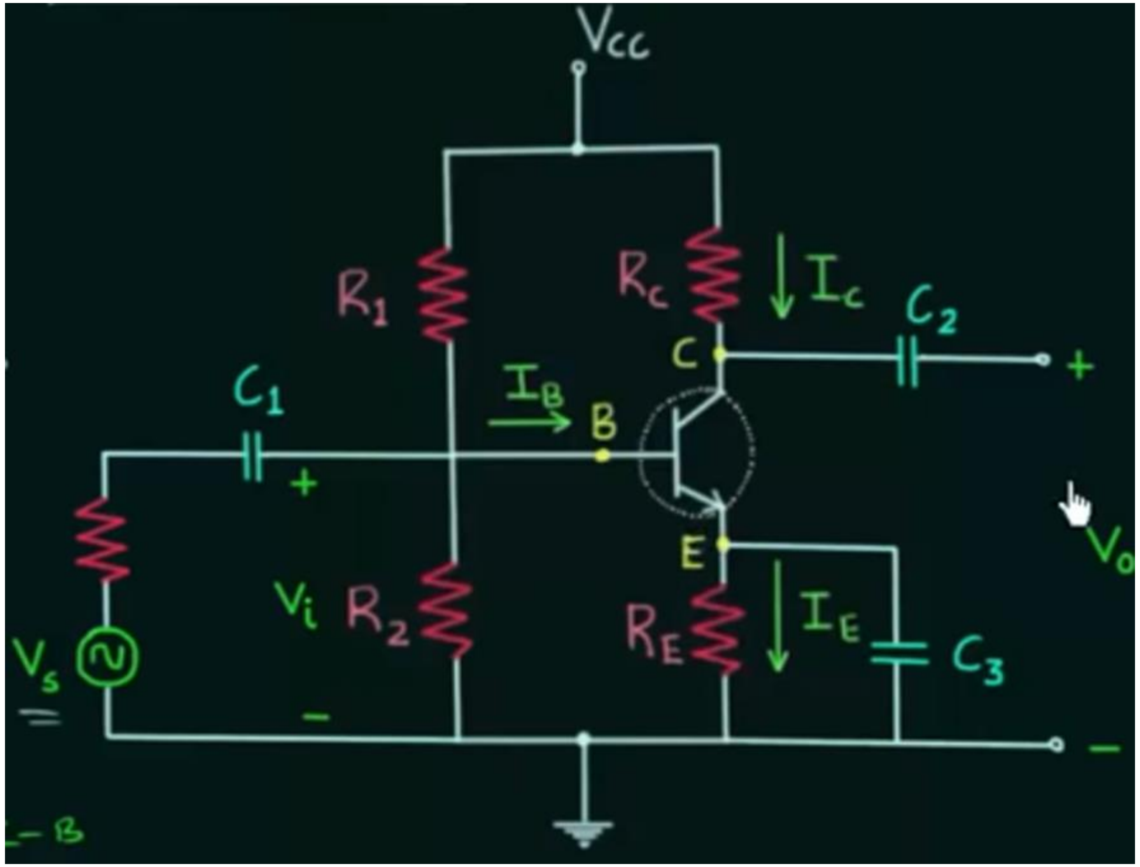
In the figure we have 1 DC source (ie) Vcc and the potential of ground is 0v.

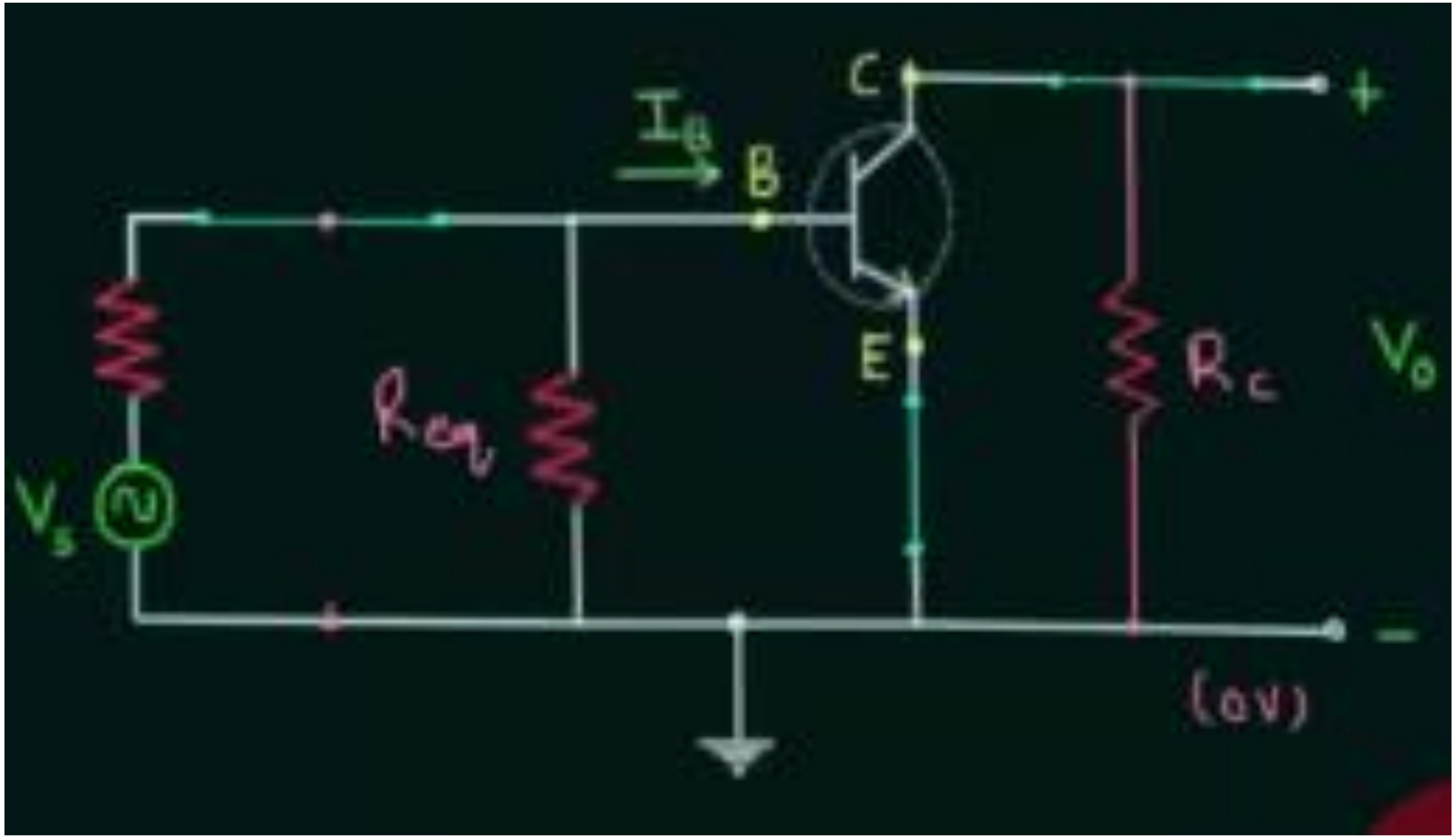
STEP-2

Short all the capacitors C1,C2 and C3

STEP-3

Redraw the network removing all the elements which are short circuited in STEP-1 and STEP-2.





I_B
B
C
E
+
R_{eq}
R_c
V_o
V_s
−
(0V)

Problems

1) If the emitter resistance in a common-emitter voltage amplifier is not bypassed, it will GATE-2014

A) Reduces voltage gain and input impedance

B) Reduces voltage gain and increase the input impedance

C) Increases voltage gain and reduces the input impedance

D) Increases both voltage gain and the input impedance

Solution: B

Reduces voltage gain and increases input impedance due to feedback.

The equivalent model of transistor:

Equivalent model is the combination of circuit elements properly chosen to best represent the actual behaviour of the device under specific Operating Point.

We need equivalent models to use these network theorems in order to find out different network parameters like in case of P-N diode.

There are three equivalent models of transistors. They are

1)Hybrid model (for low frequencies)

2)r_e –model (for low and high frequencies)

3)Hybrid ∏-model (for low and high frequencies)

All the three models are used for small signal analysis.

Hybrid model

It is also known as h-parameters model

1) It is widely used before the popularity of r_e-model.
2) Parameters are defined in general terms for any operating point conditions.

In hybrid model we have to calculate h-parameters and using them we will draw the equivalent circuit.

- These parameters have mixed dimensions hence these are known as hybrid parameters.

Need for Hybrid parameters:

Before transistors, vacuum tubes are used to design circuits. We have four parameters in small signal amplifiers. All these are obtained only by z-parameters or by y-parameters in case of vacuum tubes. In case of transistors there was problem determining z-parameters, so a new set of parameters called as hybrid parameters are introduced.

Port 1 current is I_1 Potential difference across port-1 is V_1

Port 2 current is I_2 Potential difference across port-2 is V_2

Total current or voltage value=ac value + dc value

We can define parameters by taking any 2 parameters out of 4 as dependent and rest 2 as independent.

Let V_1 and I_2 be dependent quantities.

I_1 and V_2 are independent quantities.

Say V_1 and I_2 are functions of I_1 and V_2

$V_1=f_1(I_1,V_2)$; $I_2=f_2(I_1,V_2)$

$v_1=h_{11}*i_1+h_{12}*v_2$---------------------------**(1)**

$i_2=h_{21}*i_1+h_{22}*v_2$---------------------------**(2)**

These equations are applicable to all 3 transistor configurations(CC,CB,CE)

If we substitute $v_2=0$ in Eq-1 and Eq-2, then

$h_{11}=v_1/i_1$; where h_{11} is input impedance when output is short circuited

Hence h_{11} can be represented as h_i

$h_{21}= i_2/i_1$; where h_{21} is forward current gain when the output is short circuited

Hence h_{21} can be represented as h_f

If we substitute $i_1=0$ in Eq-1 and Eq-2, then

$h_{12}=v_1/v_2$; where h_{12} is reverse voltage gain when input is open circuited

Hence h_{12} can be represented as h_r

$h_{22}= i_2/v_2$; where h_{22} is admittance with input open circuited

Hence h_{22} can be represented as h_o

Nomenclature of h-parameters for various transistor configurations

We can add ‘e’ or ‘b’ or ‘c’ as second suffix to all h-parameters for CE, CB and CC configurations respectively

Example: For CE, the h-parameters are

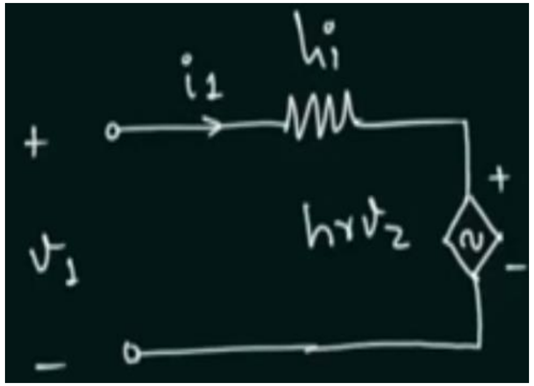
$h_i \rightarrow h_{ie}$ $h_f \rightarrow h_{fe}$ $h_r \rightarrow h_{re}$ $h_o \rightarrow h_{oe}$

To draw equivalent circuit for Eq-1 and Eq-2

Let us consider Eq-1,

$v_1=h_{11}*i_1+h_{12}*v_2$

Unit of each term in the equation is volts. Hence by applying KVL we can obtain equivalent circuit,

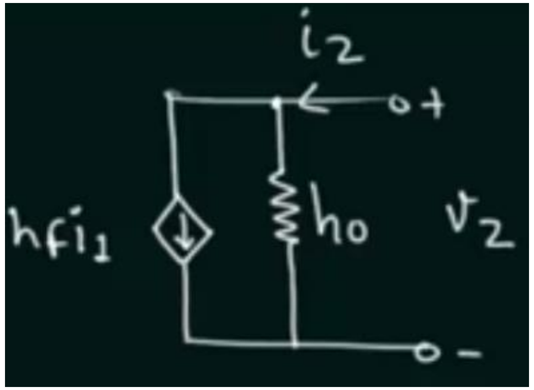


$v_1 = h_i*i_1+h_r*v_2$

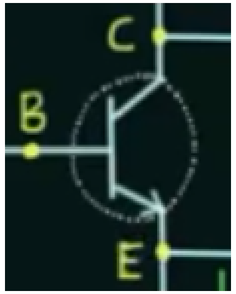
Let us consider Eq-2,

$i_2=h_{21}*i_1+h_{22}*v_2$

Use KCL to obtain equivalent circuit,



$i_2=h_f*i_1+h_o*v_2$



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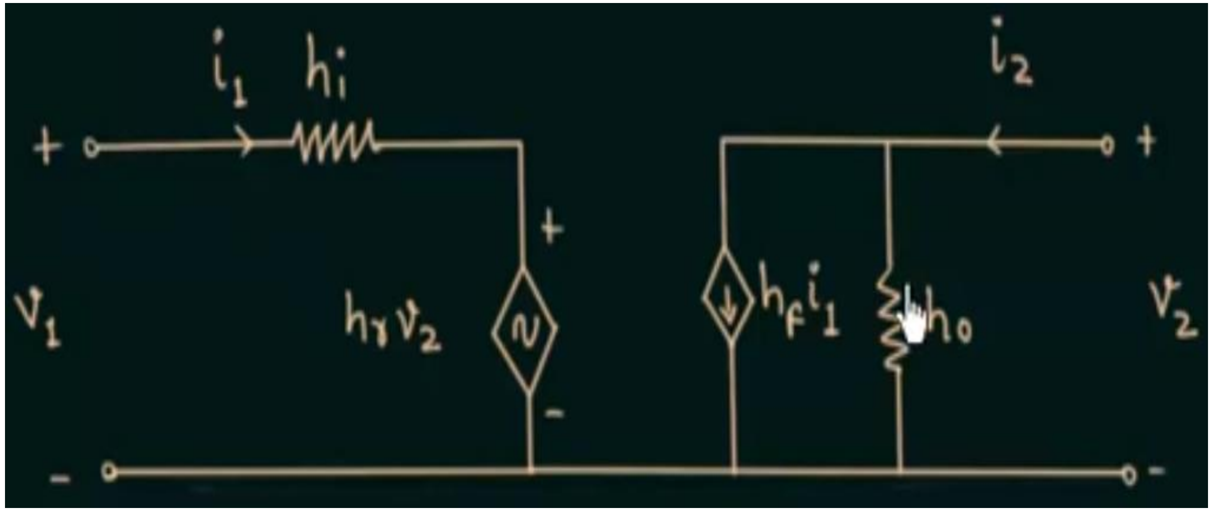
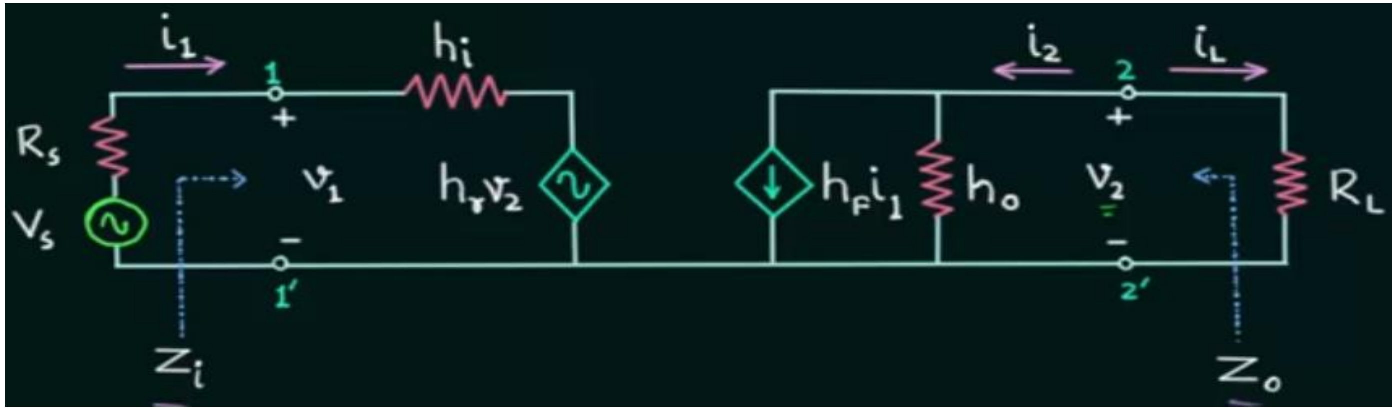


Note: Whenever we have the transistor in the circuit and you have to perform AC analysis then the conventional transistor symbol is replaced by equivalent model. If we want to make the equivalent model according to transistor configuration, an other subscript will be added.

Let CE be the transistor, h_i➔h_{ie}; h_f➔h_{fe}; h_r➔h_{re}; h_o➔h_{oe}

Analysis of transistor amplifier using h-parameter



In the equivalent circuit of the transistor, introduce source voltage V_s and resistance R_s on the input side.

On the output side, introduce a load resistance R_L and i_L is current through load resistance.

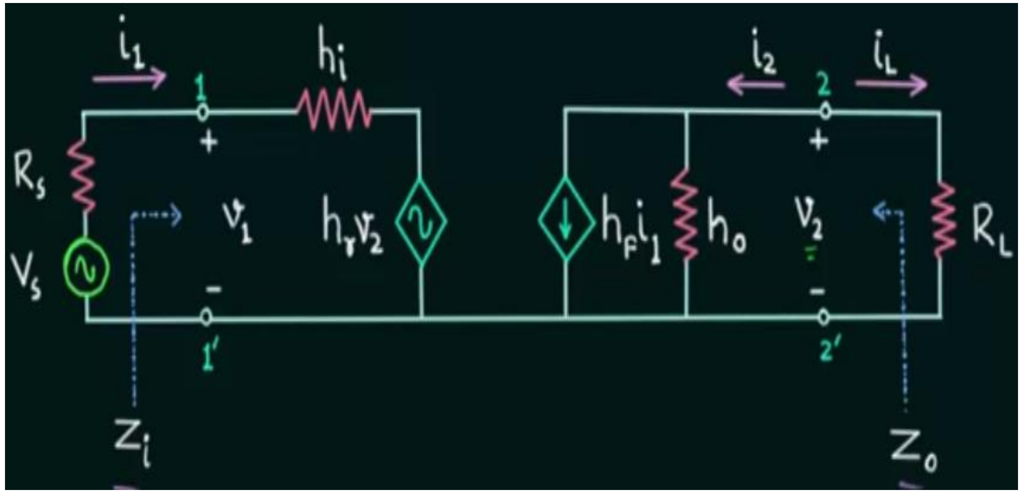
Z_o-output impedance; Z_i-input impedance

Expression for current gain:

Current gain is defined as the ratio of output current to input current. It is denoted by A_i.

$$A_i = i_L / i_1$$

$i_L = -i_2$ (from above figure)



Voltage drop across R_L is V_2

$$V_2 = i_L * R_L = -i_2 * R_L$$

Consider the equation from equivalent model of transistor

$$i_2 = h_f * i_1 + h_o * v_2 \Rightarrow h_f * i_1 + h_o * (-i_2 * R_L)$$

By solving the above equation we get, $i_2/i_1 = h_f/(1+h_o * R_L)$

Therefore, $A_i = i_L/i_1 = -h_f/(1+h_o * R_L)$

This is true for all transistor configurations.

Expression for Input impedance:

Input impedance is defined as the impedance seen from terminals 1 and 1^1

According to ohms law, $V_1=i_1*Z_i$

$$Z_i=\frac{V_1}{i_1}$$

Consider Eq-1, $v_1=h_i*i_1+h_r*v_2= h_i*i_1+h_r*(-i_2*R_L)$

By solving we get $Zi=\frac{v1}{i1} = hi + Ai * hr * R_L$

By substituting Ai value we will get $Z_i=h_i-(\frac{h_r*hf*RL}{1+hoRL})$

Expression for Voltage gain:

It is defined as the ratio of output voltage to input voltage. It is represented by A_v.

$A_v = V_o/V_i = V_2/V_1 = (-i_2 * R_L)/V_1$ (since $V_2 = -i_2 * R_L$)

Multiply and divide by i1 on R.H.S

$$A_v = \left(\frac{-i_2 * RL}{V_1}\right) * (i_1/i_1)$$

$$= \left(\frac{-i_2}{i_1}\right) * \left(\frac{i_1 * RL}{V_1}\right) = A_i * \left(\frac{R_L}{Z_i}\right)$$

Where $Z_i = h_i - \left(\frac{h_r * hf * RL}{1 + hoRL}\right)$ and $A_i = -h_f/(1 + h_o * R_L)$

Finally, $A_v = \left(\frac{-hf * RL}{h_i + \Delta h * RL}\right)$ Where $\Delta h = h_i * h_o - h_r * h_f$

Expression for Output Impedance:

To calculate Zo we need to short input source V_s and open output terminal i.e.

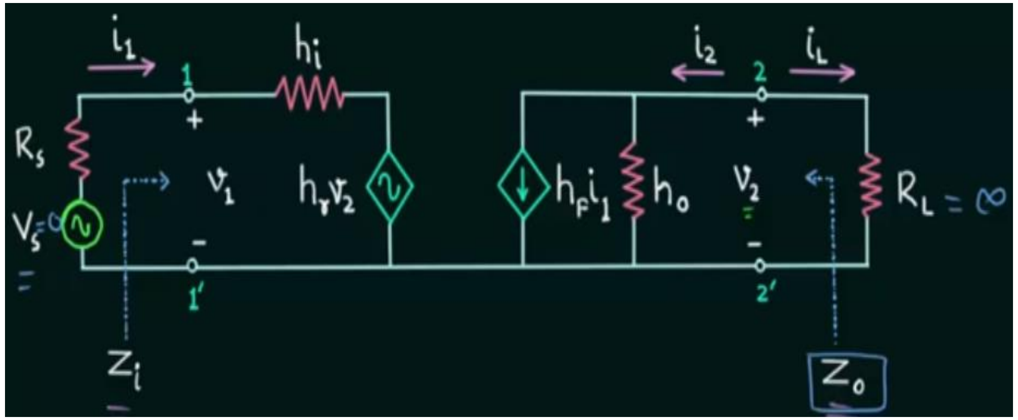
RL=∞ and $V_s=0$

$Z_o=\frac{v_2}{i_2}$; Substitute i_2 value from h-parameter equation then we will get one equation

$$Z_o=\frac{v_2}{h_f*i_1+ho*v_2} ------ -(1)$$

Now apply KVL in input loop to get 2nd equation

$-i_1*R_s-i_1*h_i-h_r*v_2=0$



$i_1 = \frac{-hr*v_2}{(Rs+hi)}$----------------(2)

Substitute Eq-(2) in Eq-(1)

$Z_o = \frac{R_s+hi}{\Delta h+ho*Rs}$

Overall voltage gain:

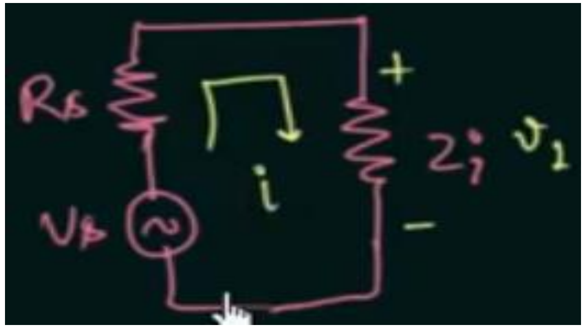
It is defined as ratio of output voltage to source voltage

$A_{vs} = \frac{V_2}{V_s}$

Multiply and divide it by v_1

$A_{vs} = \frac{V_2}{V_s} * \frac{V_1}{V_1}$

$A_v = \frac{V_2}{V_1} = \left(\frac{-hf*RL}{h_i+\Delta h*RL}\right)$



Therefore, $A_{vs} = A_v * \frac{V_1}{V_s}$ -------(3)

From the above loop

$V1/Vs = \frac{Zi}{R_s+Zi}$ --------(4)

Therefore, $A_{vs}=A_v\left(\frac{Z_i}{R_s+Zi}\right)$

If Vs is ideal==>$R_s=0$

Therefore, $A_{vs}=A_v$

Overall current gain:

It is defined as the ratio of output current to the current delivered by the source. It is denoted by A_{is}.

$$A_{is} = \frac{i_l}{i_1} * \frac{i2}{i_s} = \text{Ai} * \frac{i_1}{i_s}$$

Convert voltage source at the input into current source.

Now, use current divider rule,

$$i_1 = \frac{i_s * Rs}{R_s + Zi} ==> \frac{i1}{is} = \frac{R_s}{R_s + Z_i} ------ -(5)$$

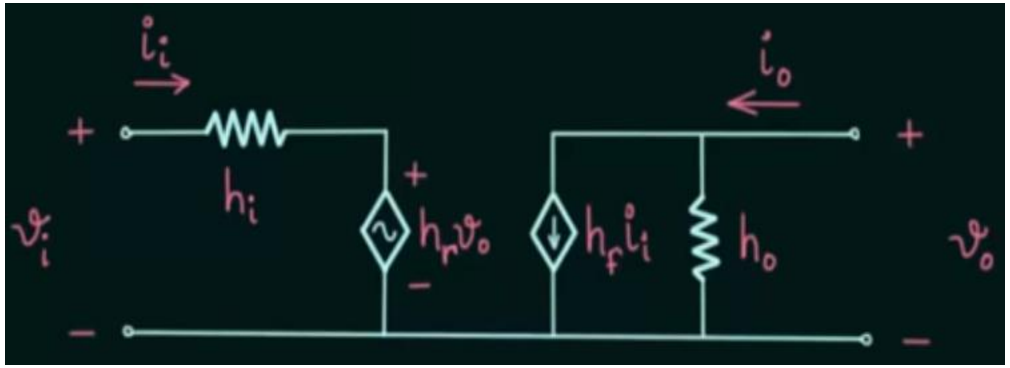
Therefore, $A_{is} = A_i * \left(\frac{R_s}{R_s + Zi}\right)$

In case of ideal current source, $R_s = \infty$

Therefore, $A_{is} = A_i$

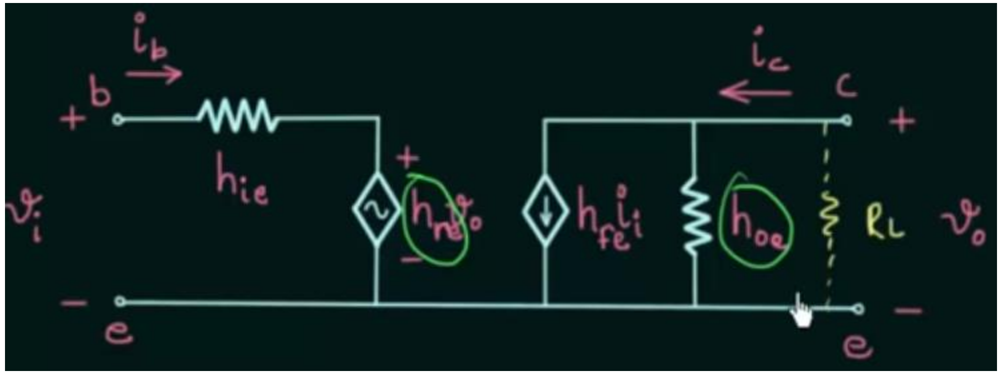
Approximate hybrid equivalent model of transistor:

Lets consider CE transistor



For CE and CB the magnitude of h_r and h_o are such that the results obtained for the parameters like input Z, Output Z, voltage gain and current gain are slightly effected, if not included in the circuit. Hence we can remove it from the circuit.

h_{oe} is output admittance and $\frac{1}{h_{oe}}$ is output impedance which is very large compared to the load resistance R_L. Hence we can neglect the output impedance as no chance of flowing current through it.



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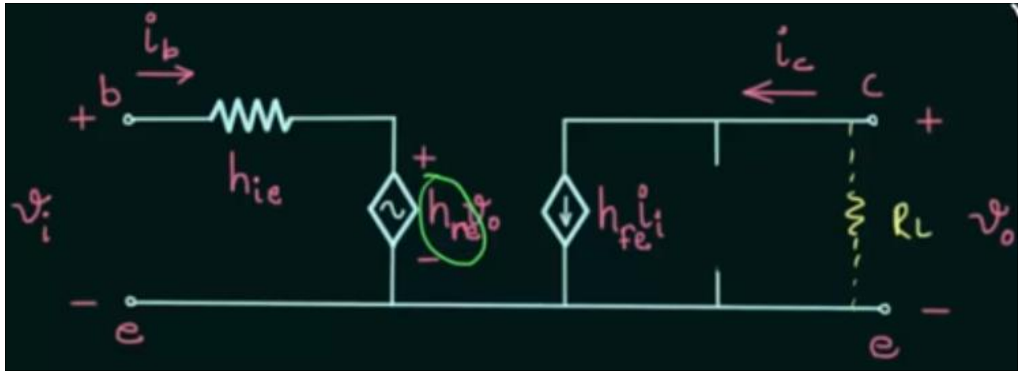
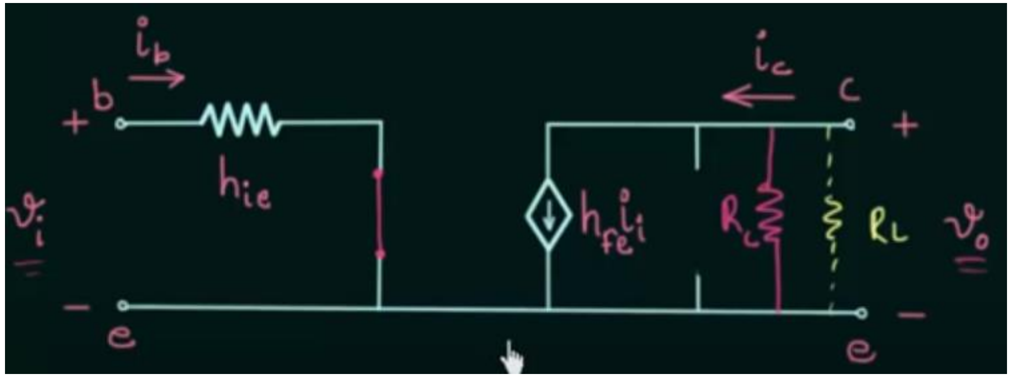


If transistor is connected in fixed bias configuration then there is one more resistance connected in parallel to R_L which is R_C then also $\frac{1}{h_{oe}}$ is greater than equivalent resistance so we can neglect in that case too.

$h_r=\frac{V_i}{V_o}$=0(approx.)   (Since when transistor acts as an amplifier $V_o>V_i$)

Therefore, $h_{re}V_o=0$ So we can replace this branch with an short circuit.

Final Equivalent Circuit:



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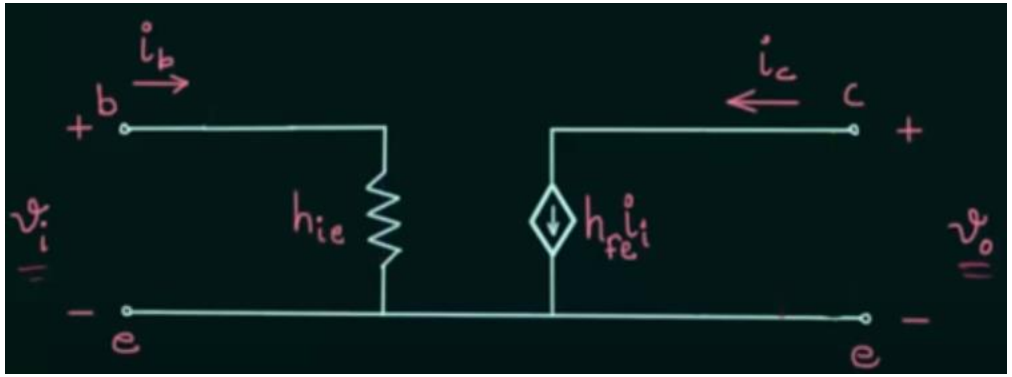


Conversion of h-parameters:

The need for the conversion is, generally the transistor manufacturer provides the h-parameters of transistors in CE model because its mostly used.

Conversion requires following formulae:

For CE→CB

$h_{ib}=\frac{h_{ie}}{1+hfe}$; $h_{rb}=\frac{h_{ie}*hoe}{1+hfe}-h_{re}$; $h_{fb}=\frac{-hfe}{1+hfe}$; $h_{ob}=\frac{h_{oe}}{1+hfe}$

For CE→CC

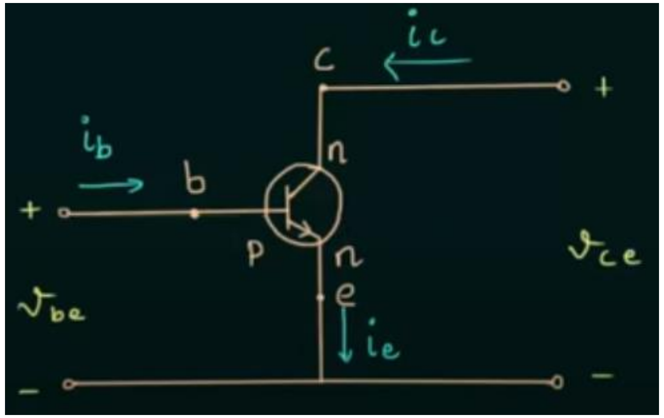
$h_{ic}=h_{ie}$; $h_{rc}=1-h_{re}$; $h_{fe}=-(1+h_{fe})$; $h_{oc}=h_{oe}$

For CB→CC

$h_{ie}=\frac{h_{ib}}{1+hfb}$; $h_{re}=\frac{h_{ib}*hob}{1+hfb}-h_{rb}$; $h_{fe}=\frac{-hfe}{1+hfb}$; $h_{oe}=\frac{h_{ob}}{1+hfb}$

r_e Transistor model

Lets find out r_e model for CE transistor



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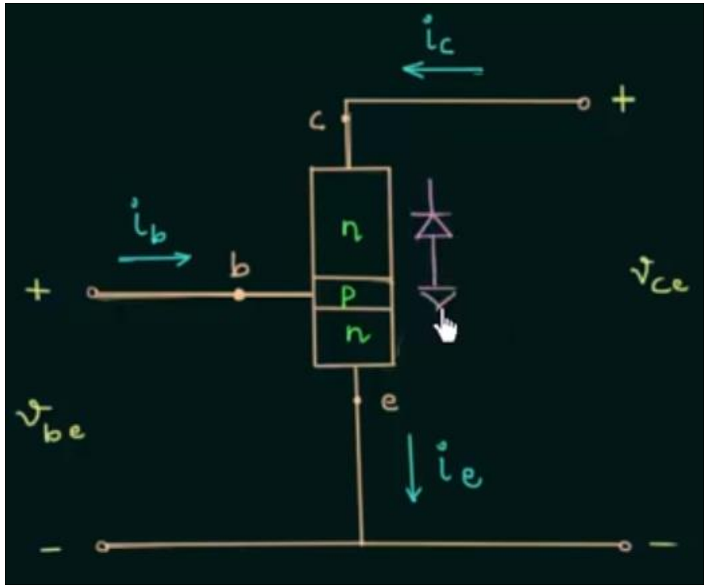
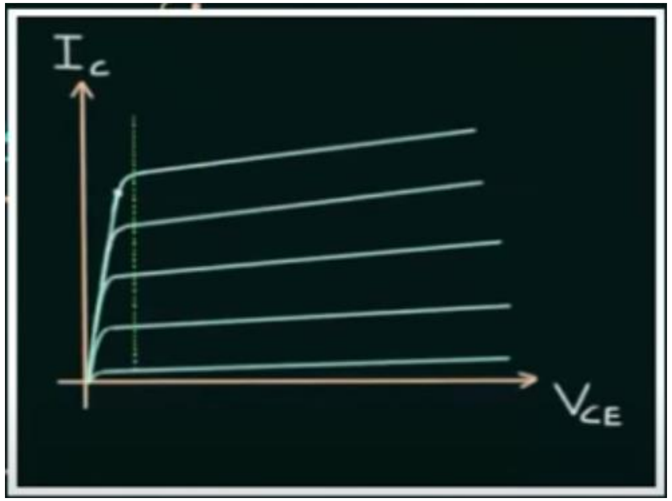


- Modify the above circuit by placing a dependent current source in the collector branch and the emitter branch will have forward biased diode.
- We have dependent current source because current $i_c = \beta * i_b + (\beta+1) * I_{CBO}$

Here we neglected the reverse saturation current as it is very small.

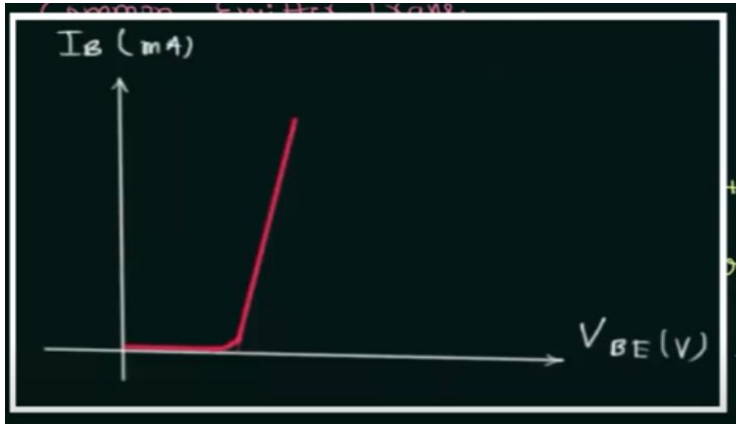
From the output characteristics of CE transistor, we find that the output resistance is very large because resistance $(r_o) = \frac{1}{slope}$ (Since slope =0(approx.))

$$r_o = \infty$$



In the collector branch place a forward biased diode because the input characteristics of CE transistor is similar to the input characteristics of a forward biased diode.

There are three types of diode resistances:



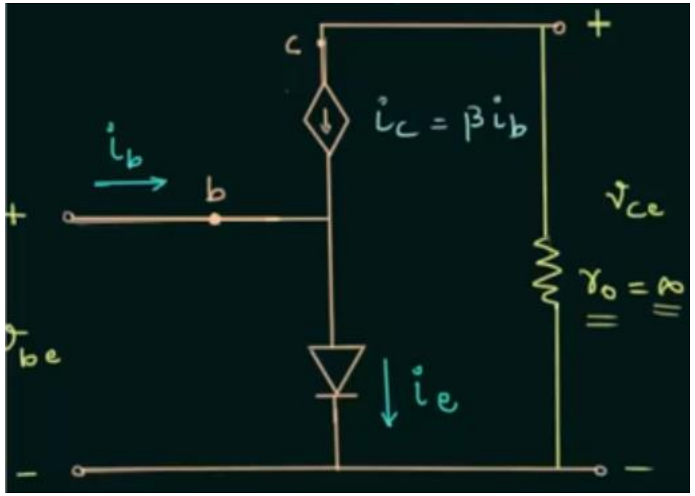
i)DC resistance

ii)AC resistance(dynamic resistance)

iii)Average AC resistance

For AC analysis we will consider second type of diode resistance which is represented as r_d. Where $r_d = \frac{\Delta VBE}{\Delta I_B}$

Now again replace diode by dynamic resistance r_e($r_e = r_d$) where i_e is the current flows through it.



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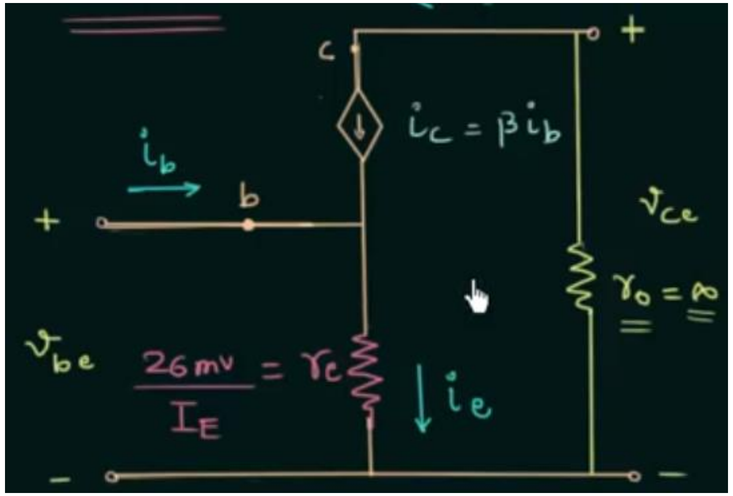
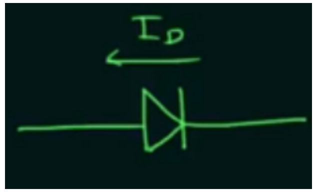


Calculating r_e:

Consider a PN junction diode



Where I_D is diode current and I_S be the reverse saturation current.

From diode current equation we know that $I_D = I_S(e^{\frac{V_D}{\eta V_T}} - 1)$

Differentiate with respect to V_D

$$\frac{dI_D}{dV_D} = I_S * \frac{d}{dV_D}(e^{\frac{V_D}{\eta V_T}} - 1)$$

For high diode currents $\eta=1$

And $\frac{dI_D}{dV_D} = \frac{1}{r_d}$; Substituting these values and by the above equation we will get

$$\frac{1}{r_d} = \frac{I_S\,(e^{\frac{V_D}{\eta V_T}})}{V_T} = \frac{I_D+IS}{V_T} = \frac{I_D}{V_T}$$

Therefore, $r_d = \frac{VT}{ID} = \frac{26mV}{ID}$ (Since at room temperature V_T=26mV)

$$r_e = \frac{26mV}{I_E}$$

r_e model for CE transistor further modification:

CE is mostly used because amplification is large in this configuration.

But in the above circuit for CE model input and output sides are not properly separated.

We know that $i_e = i_b + i_c$

Substitute $i_c = \beta i_b$ then we will get $i_e = i_b(1+\beta)$

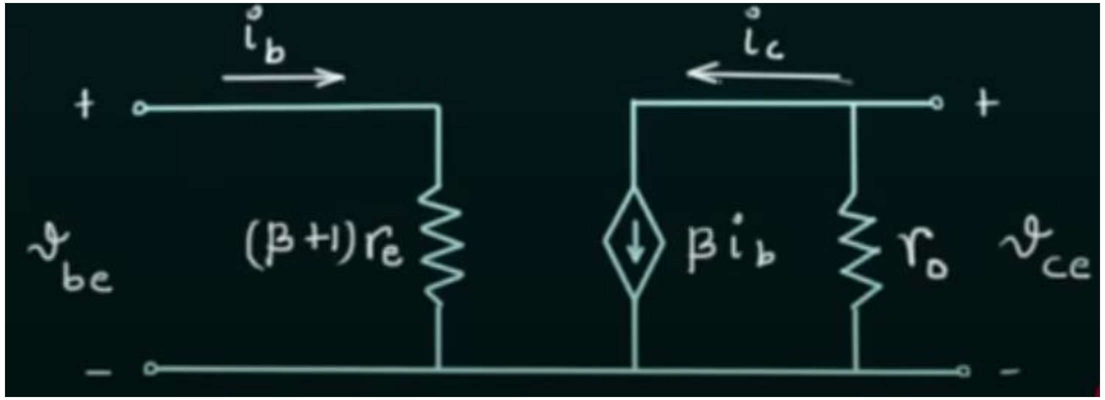
Find drop across resistance r_e

Drop across $r_e = r_e * i_e = r_e * i_b(1+\beta)$

To separate input and output circuit we will take r_e and $(1+\beta)$ together and ib is the current flowing through the resistance $r_e(1+\beta)$

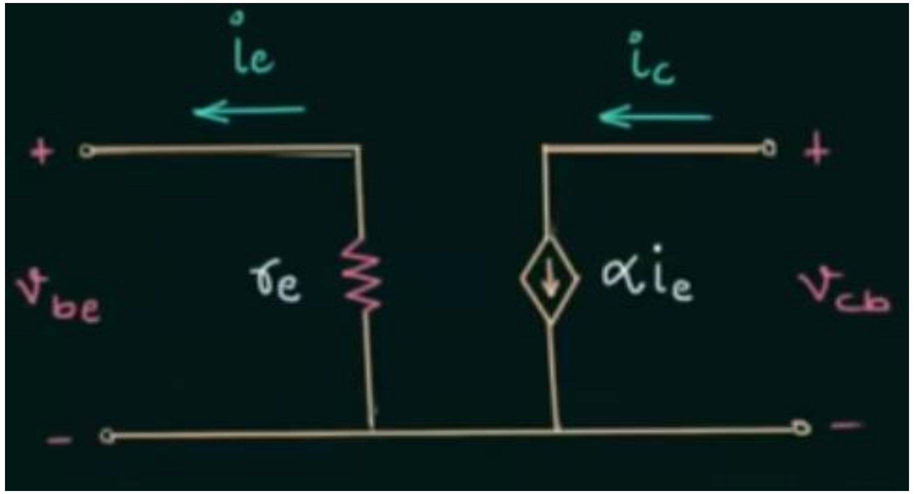
And at the output side we have a dependent current source and a resistor r_o

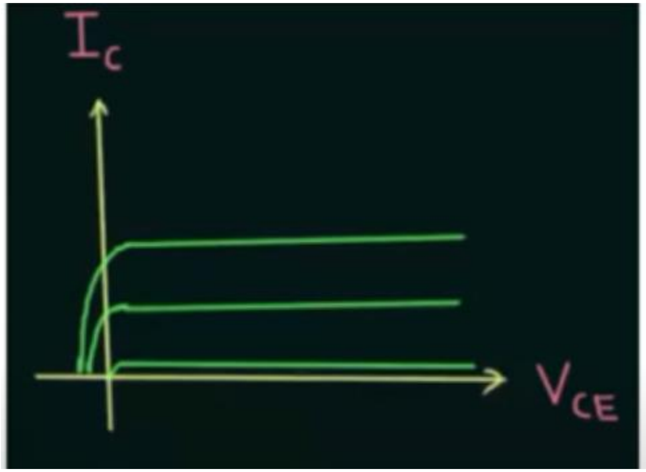
Therefore the final equivalent r_e model for CE configuration is



And we can further simplify it by placing ß in place of (1+ ß)

r_e model for Common Base Transistor:





In this CB, the output characteristics have 0 slope

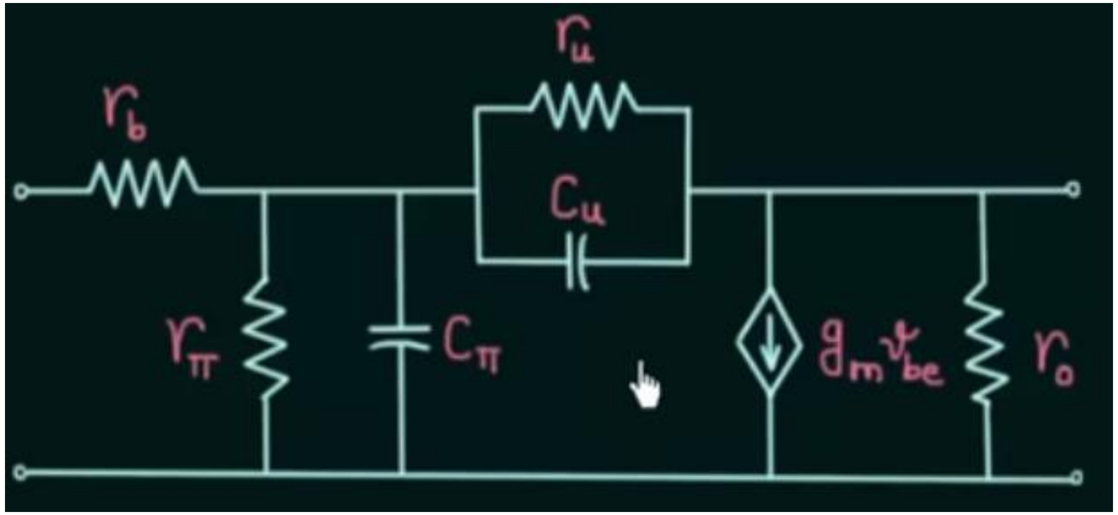
$$r_o = \frac{1}{slope} = \frac{1}{0} = \infty$$

So we neglected the output resistance in r_e model of CB transistor.

Hybrid-∏ model

- Widely used because we can use it for high frequency small signals and we can also use it for low frequency small signals.
- At low frequencies it is assumed that transistor responds instantaneously to changes in the input voltage or current.
- If frequency of the input is high (MHz) and the amplitude of the input signal is changing the Transistor amplifier will not be able to respond. It is because; the carriers from the emitter side will have to be injected into the collector side. These take definite amount of time to travel from Emitter to Base, however small it may be.

- But if the input signal is varying at much higher speed than the actual time taken by the carries to respond, then the Transistor amplifier will not respond instantaneously. Thus, the junction capacitances of the transistor, puts a limit to the highest frequency signal which the transistor can handle.



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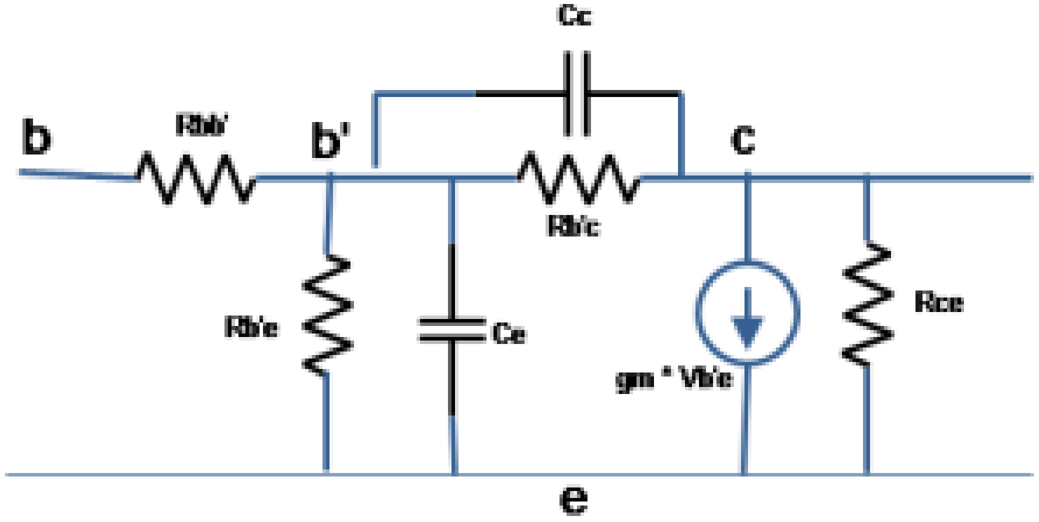


At high frequencies, parameters like junction capacitances come into picture.

C_u – This is the capacitor which represent Early effect and it is of few Pico Farads.

C_π - Diffusion capacitance that represent minority carrier storage in base region and its value lies between 1PF to 2PF.

r_b – This is very small value which represents the resistance due to base connection and other resistances like base spreading resistance is also included. As it is small we can replace it by a short circuit.

r_π - input resistance between base and emitter terminal.

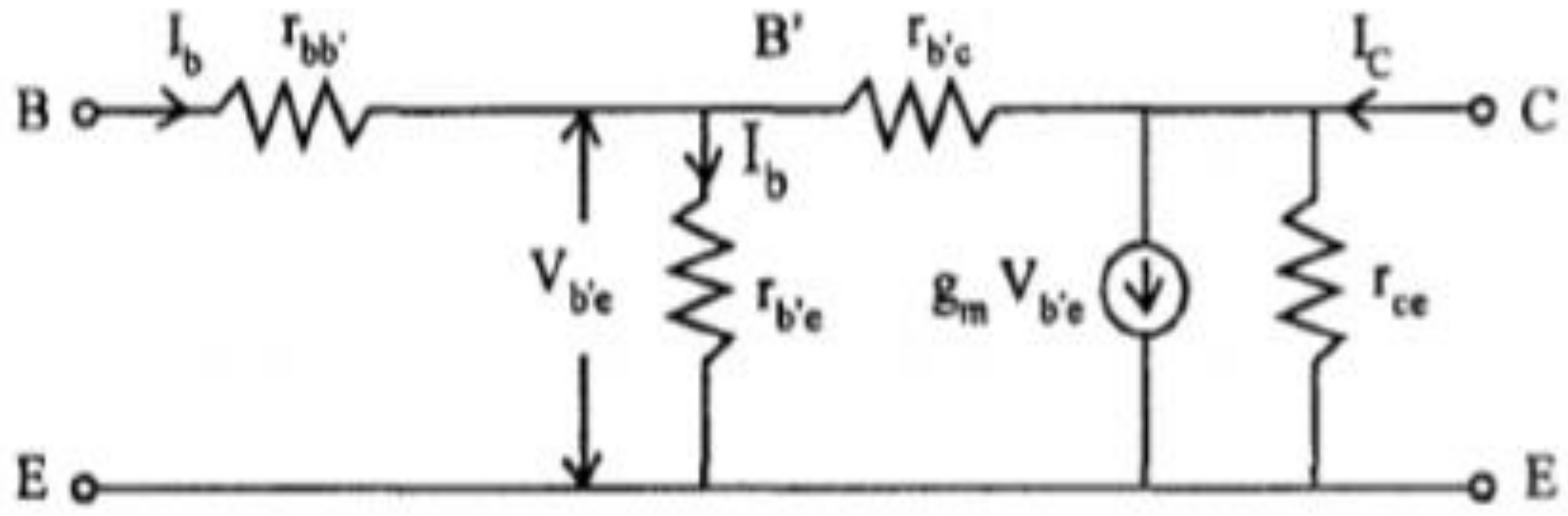
where $r_\pi = \beta r_e$

r_u - resistance between base and collector terminal. It is very large, hence replace it with open circuit.

Parameter calculations at low frequencies:

Input Conductance ($g_{b'e}$):

At low frequencies, capacitive reactance will be very large and can be considered as Open circuit. So in the hybrid-π equivalent circuit which is valid at low frequencies, all the capacitances can be neglected. B’ =internal node in base.



$$I_C = g_m . V_{b'e} ; \qquad V_{b'e} = I_b . r_{b'e}$$

$$I_C = g_m . I_b . r_{b'e}$$

$$h_{fe} = \left. \frac{I_C}{I_B} \right|_{V_{CE}} = g_m . r_{b'e}$$

$$\boxed{r_{b'e} = \frac{h_{fe}}{g_m}}$$

$$g_m = \frac{|I_C|}{V_T}$$

$$r_{b'e} = \frac{h_{fe} . V_T}{|I_C|}$$

$$g_{b'e} = \boxed{\frac{|I_C|}{h_{fe} V_T}} \text{ or } \boxed{\frac{g_m}{h_{fe}}}$$

Base Spreading Resistance (r_b or $r_{bb'}$):

The input resistance with the output shorted is hie. If output is shorted, i.e., Collector and Emitter are joined; $r_{b'e}$ is in parallel with $r_{b'c}$.

$$h_{ie} = r_{bb'} + r_{b'e}$$

$$r_{b'e} = \frac{h_{fe} . V_T}{|I_C|}$$

$$\boxed{r_{bb'} = h_{ie} - r_{b'e}}$$

$$h_{ie} = r_{bb'} + r_{b'e}$$

$$h_{ie} = r_{bb'} + \frac{h_{fe} . V_T}{|I_C|}$$

Output Conductance (g_{ce})

This is the conductance with input open circuited. In h-parameters it is represented as h_{oe}. For $I_b = 0$, we have,

$$I_C = \frac{V_{ce}}{r_{ce}} + \frac{V_{ce}}{r_{b'c} + r_{b'e}} + g_m V_{b'e}$$

$$h_{re} = \frac{V_{b'e}}{V_{ce}} \qquad \therefore \quad V_{b'e} = h_{re} \cdot V_{ce}$$

$$I_C = \frac{V_{ce}}{r_{ce}} + \frac{V_{ce}}{r_{b'c} + r_{b'e}} + g_m \cdot h_{re} \cdot V_{ce}$$

$$h_{oe} = \frac{1}{r_{ce}} + \frac{1}{r_{b'c}} + g_m \cdot h_{re}$$

$$= g_{ce} + g_{b'c} + g_m\, h_{re}$$

$$g_{b'c} = \frac{g_m}{h_{fe}}$$

$$g_m = g_{b'e} \cdot h_{fe}$$

$$h_{re} = \frac{r_{b'e}}{r_{b'e} + r_{b'c}} \approx \frac{r_{b'e}}{r_{b'c}} = \frac{g_{b'c}}{g_{b'e}}$$

$$h_{oe} = g_{ce} + g_{b'c} + g_{b'e}\, h_{fe} \cdot \frac{g_{b'c}}{g_{b'e}}$$

$$g_{ce} = h_{oe} - (1 + h_{fe}) \cdot g_{b'c}$$

$$h_{fe} >> 1, \quad 1 + h_{fe} \approx h_{fe}$$

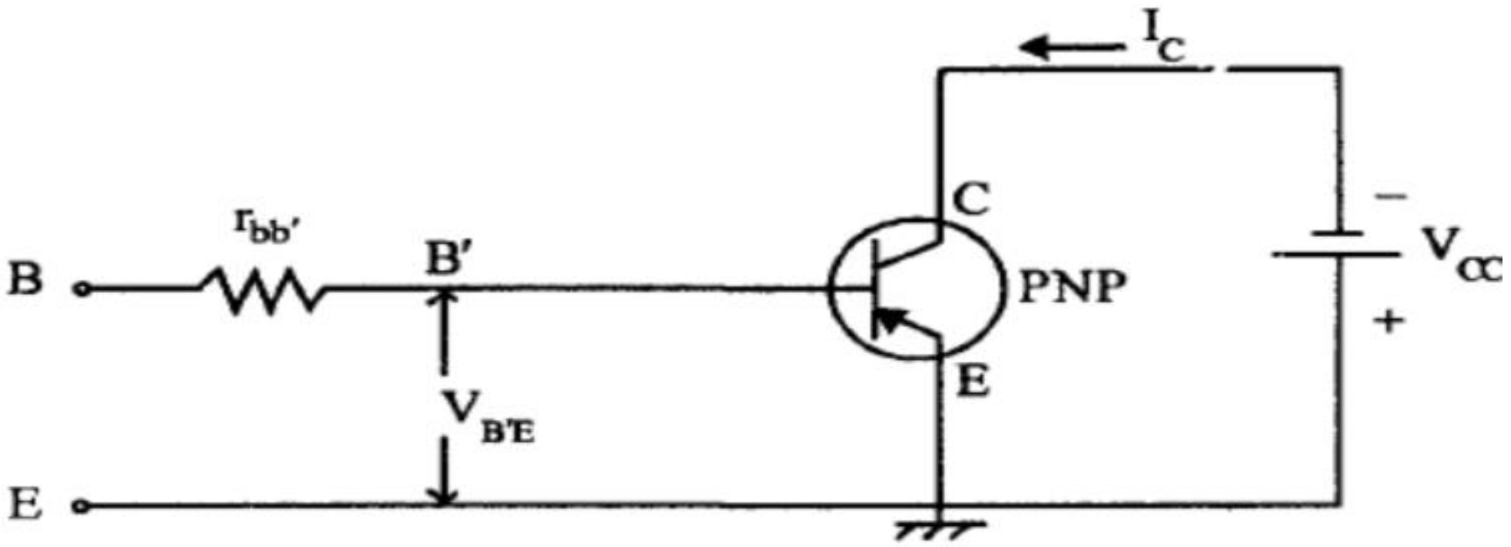
$$\boxed{g_{ce} = h_{oe} - h_{fe} \cdot g_{b'c}}$$

$$g_{b'c} = h_{re} \cdot g_{b'e}$$

$$g_{ce} = h_{oe} - h_{fe} \cdot h_{re} \cdot g_{b'e}$$

Validity of hybrid-π model The high frequency hybrid Pi or Giacoletto model of BJT is valid for frequencies less than the unit gain frequency.

Trans-conductance or Mutual Conductance (gm):



The transconductance is the ratio of change in the collector current due to small changes in the voltage V_{BE} across the emitter junction. It is given as

$$g_m = \left. \frac{\partial I_c}{\partial V_{B'E}} \right|_{V_{CE}} \quad \text{-----------------(1)}$$

We know that, the collector current in active region is given as

$$I_C = I_{C0} - \alpha_0 \cdot I_E$$

$$\partial I_c = \alpha \partial I_e \quad \because I_{CO} = \text{Constant}$$

Substitute ∂I_c in Eq-(1) we get,

$$g_m = 0 - \alpha_0 \frac{\partial I_E}{\partial V_{b'e}}$$

$V_{b'e} = V_E$

The emitter diode resistance, r_e is given as

$$r_e = \frac{\partial V_E}{\partial I_E}$$

$$\frac{1}{r_e} = \frac{\partial V_E}{\partial I_E}$$

Substituting r_e in place of $\partial I_e / \partial V_E$ we get,

$$g_m = \frac{\alpha}{r_e} \qquad \text{... (3)}$$

The emitter diode is a forward biased diode and its dynamic resistance is given as

$$r_e = \frac{V_T}{I_E} \qquad \text{... (4)}$$

where V_T is the "volt equivalent of temperature", defined by

$$V_T = \frac{kT}{q}$$

where k is the Boltzmann constant in joules per degree kelvin (1.38×10^{-23} J/°K) is the ctronic charge (1.6×10^{-19} C).

Substituting value of r_e in equation (3) we get,

$$\alpha I_E \quad I_{CQ} - I_C$$

For pnp transistor I_c is negative. For an npn transistor I_c is positive, but the foregoing analysis (with $V_E = +V_{BE}$) leads to $g_m = (I_c - I_{CO}) / V_T$.

Hence, for either type of transistor, g_m is positive.

$$\therefore \quad g_m = \frac{I_c - I_{CO}}{V_T} \qquad \because I_c >> I_{CO} \qquad \dots (5)$$

Substituting value of V_T in equation (5) we get

$$g_m = \frac{I_c\, q}{k\, T} = \frac{I_c \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23}\; T}$$

$$= \frac{11600\, I_c}{T} \qquad \dots (6)$$

From equation (6) we can say that transconductance g_m is directly proportional to collector current and inversely proportional to temperature.

At room temperature, 300 °K

$$g_m = \frac{1160\, I_c}{300} = \frac{I_c}{26 \times 10^{-3}}$$

$$= \frac{I_c\, |mA|}{26} \qquad \dots (7)$$

Problems

1) A good transconductance amplifier should have

   (A) high input resistance and low output resistance GATE(2017)

   (B) low input resistance and high output resistance

   (C) high input and output resistances

   (D) low input and output resistances

Solution: (C)

For a transconductance amplifier, input and output resistance is high.

Reason: The transconductance amplifier is also known as Voltage Controlled Current Source. An amplifier is VC when input resistance is high, and an amplifier is CS when output resistance is high.

2) A bipolar transistor is operating in the active region with a collector current of 1mA. Assuming that the ß of the transistor is 100 and the thermal voltage(V_T) is 25mV, the transconductance (g_m) and the input resistance (r_π) of the transistor in the common emitter configuration, are

GATE(2004)

A) g_m=25mA/V and r_π = 15.625KΩ

B) g_m=40mA/V and r_π = 4.0KΩ

C) g_m=25mA/V and r_π = 2.5KΩ

D) g_m=40mA/V and r_π = 2.5KΩ

Solution:

Given,

$$I_c = 1mA;\ ß = 100;\ V_T = 25mV$$

We know that $g_m = \frac{I_C}{V_T} = \frac{1}{25} = \frac{40mA}{}/V$

$$ß = g_m r_\pi \rightarrow r_\pi = \frac{ß}{g_m} = \frac{100}{40*10^{-3}} = 2.5k\Omega$$

3) A BJT is biased in forward active mode. Assume VBE = 0.7 V, $\frac{KT}{q}$ = 25mV and reverse saturation current $I_s = 10^{(-3)}$ A. The transconductance of the BJT (in mA/V) is ___

A)1.425A/V B)5784mA/V GATE(2014)

C)5790mA/V D)2675mA/V

Solution: (B)

Given,

$V_{BE} = 0.7V; \quad V_T = \frac{KT}{q} = 25mV; \quad I_s = 10^{(-3)}$ A

We know that, $I_C = I_S(e^{\frac{V_D}{\eta V_T}} - 1)$ where η = 1 when diode current is high

By substituting we will get I_C = 144.6mA

Therefore, $g_m = \frac{I_C}{V_T} = \frac{144.6mA}{25mV}$ = 5784mA/V

4) The input impedance(Z_i) and the output impedance(Z_o) of an ideal transconductance amplifier is ____________

GATE(2006)

A) $Z_i = 0, Z_o = 0$

B) $Z_i = 0, Z_o = \infty$

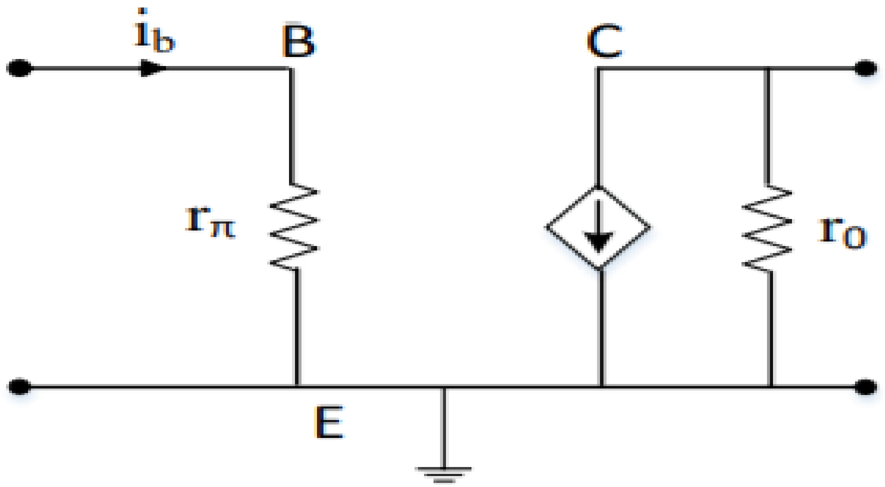
C) $Z_i = \infty , Z_o = 0$

D) $Z_i = \infty , Z_o = \infty$

Solution:

For Transconductance amplifier $Z_i = \infty , Z_o = \infty$

5) The current i_b through base of a silicon npn transistor is 1+0.1 cos (1000πt) ma. At 300K, the r_π in the small signal model of the transistor is GATE-2012



(a) 250Ω (b) 27.5Ω (c) 25Ω (d) 22.5Ω

Solution: (C).

Current i_b through the base of a silicon npn transistor is 1+0.1 cos (10000 πt) ma

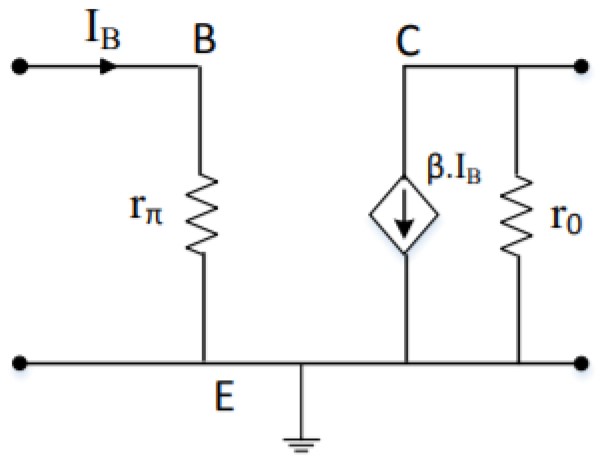
$r_\pi = \boldsymbol{\beta} . \boldsymbol{r_e} = \boldsymbol{\beta}\, \boldsymbol{V_T} / I_E \cong \boldsymbol{\beta}\, \boldsymbol{V_T} / \boldsymbol{\beta i_b} = \boldsymbol{V_T} / \boldsymbol{i}_b$

$\boldsymbol{V_T} = \mathbf{25}\boldsymbol{mv}, \boldsymbol{i_b} = \mathbf{1}\boldsymbol{ma}$

$\boldsymbol{r_\pi} = \mathbf{25}\ \Omega$

6) The current gain of a BJT is GATE-2002

(a) $g_m r_0$ (b) g_m / r_o (c) $g_m r_\pi$ (d) g_m / r_π



Solution:

$g_m = I_C / V_T = \beta I_B / I_B r_\pi \Rightarrow gm = \beta / r_\pi$

so $\beta = g_m r_\pi$