classification of Amplifiers :

→ A circuit that increases the amplitude of the given input signal is an amplifier.

→ A small ac signal fed to the amplifier is obtained as a larger ac signal of the same frequency at the output.

→ Amplifiers constitute an essential part of radio, television and other communication circuits.

→ In discrete circuits BJTs and FETs are commonly used as amplifying elements. Depending on the nature and level of amplification and impedance matching requirements different types of amplifiers can be considered. ~~and they are~~

→ Amplifiers can be classified as follows,

① Based on active devices
  ⓐ BJT amplifier
  ⓑ FET amplifier

② Based on transistor configuration
  ⓐ CE amplifier
  ⓑ CB "
  ⓒ CC "
  ⓓ CS "
  ⓔ CD "

③ Based on type of load impedance
  ⓐ untuned amplifier
  ⓑ Tuned amplifier

④ Based on frequency range.

Audio freq. (AF) : (40 - 20K) Hz
Radio freq. (RF) : 20KHz - 1MHz
Video freq. (VF) : 5 - 8 MHz
Very Low freq. (VLF) : 10 - 30 KHz
Low freq. (LF) : 30 - 300 KHz
Medium freq. (MF) : 300 - 3000 KHz
High freq. (HF) : 3 - 30 MHz
Very High freq. (VHF) : 30 - 300 MHz
ultra High freq. (UHF) : 300 - 3000 MHz
Super High freq. (SHF) : 3000 - 30,000 MHz

(5) Based on no. of stages
(a) Single stage amplifiers
(b) Multistage amplifiers

(6) Based on method of coupling
(a) Direct Coupled (DC) amplifier
(b) Resistance Capacitance (RC) Coupled amplifier
(c) Inductor Capacitor (LC) Coupled amplifier
(d) Transformer Coupled amplifier

(7) Based on primary function
(a) Small signal amplifiers
(b) Large signal amplifiers (power amplifiers)

(8) Based on Q - point
(a) class A amplifier
(b) class B "
(c) class AB "
(d) class C "

(9) Based on bandwidth
(a) Narrow band amplifier
(b) Wide band amplifier

Distortion in amplifiers :

→ An amplifier should produce an output waveform which does not differ from the input signal waveform in any respect except amplitude i.e the output is an amplified signal of the input.

→ An ideal amplifier will amplify a signal without changing its waveshape at all frequencies. Such an amplifier faithfully amplifies the signal and we say it has a good fidelity, such an amplifier is called Hi-Fi (High Fidelity) amplifier.

→ In practice, it is highly impossible to Construct an ideal amplifier whose output waveform is an exact replica of the input signal wavefo because of the nonlinearity of ~~the~~ characteristics of an active device.
→ The output differs from the input either in its waveform or frequency cont
The difference between the output waveform and the input waveform in a amplifier is called distortion.
→ Distortions are classified into ~~two~~ types. These may exists separately or simultaneously in amplifiers, they are
① Amplitude / Non-Linear / Harmonic distortion
② Frequency distortion
③ phase distortion

Harmonic Distortion:
→ Harmonic distortion occurs when the device is operated in non-linear part of the dynamic transfer characteristics. ~~since the~~
→ In this type of distortion, new frequencies are produced in the outp which are not present in the input signal. This harmonic distortion is also called as amplitude distortion.
→ The Component of frequency at the output same as the input signa is called the fundamental frequency.
→ The frequency Components which are integral multiples of fundamenta frequency are called harmonics.
→ Intermodulation distortion is also a type of non-linear distortion which occurs when the input signal Consists of more than one freque
→ If an input signal Consists two frequencies f_1 and f_2, then the output will contain their harmonics i.e $f_1, 2f_1, 3f_1$ etc and $f_2, 2f_2, 3f_2$ etc
→ In addition there will be Components (f_1+f_2) and (f_1-f_2) and also the sum and differences of the harmonics
→ These sum and difference frequencies are called intermodulation frequencies which are undesirable because they subtract from the origin intelligence

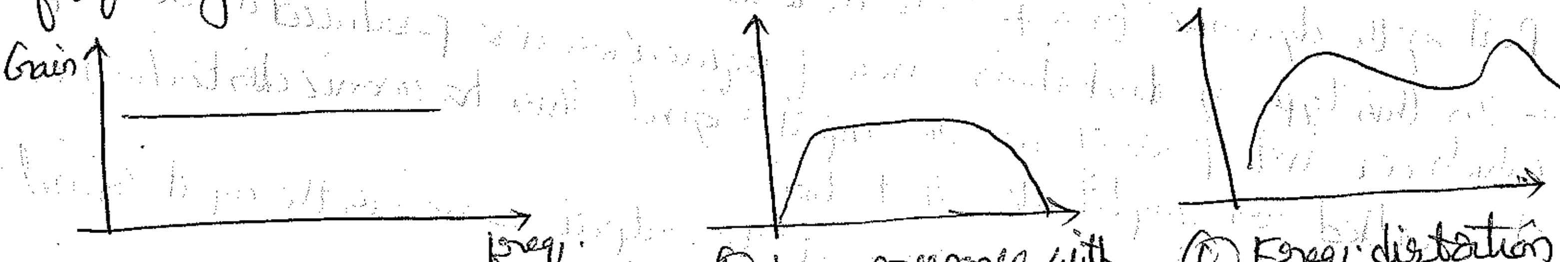
Frequency Distortion:

→ Frequency distortion results when the signal components of different frequencies are amplified differently. This distortion is due to the various frequency dependent reactances (both capacitive and inductive) associated with the circuit or the active device itself.

→ In case of audio signals, the frequency distortion leads to a change in the quality of sound, because all the different frequencies have different amplitudes.

→ Hence in the design of untuned or wideband amplifiers, the amplifier should provide the same gain for all the frequencies so that all the frequencies will have the same relative amplitudes in the output.

→ If the frequency-response characteristic is not flat over the range of frequencies under consideration, the circuit is said to have frequency distortion.



(a) Freq. response without distortion for Ideal amplifier

(b) freq. response with distortion in RC Coupled amplifiers

(c) Freq. distortion in transformer Coupled amplifier

Phase Distortion:

→ phase distortion results from unequal phase shifts of signals of different frequencies. This distortion is due to the fact that the phase angle of the Complex gain 'A' depends upon frequency.

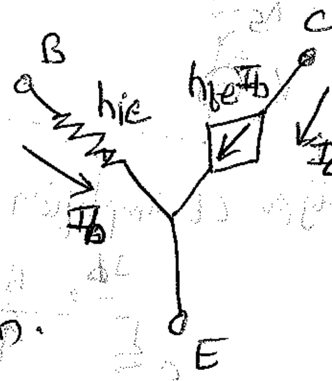
→ phase distortion is said to occur if the phase relationship between the Various frequency Components making up the signal waveform is not the Same in the output as in the input. It means that the time of transmission or the delay introduced by the amplifier is different for Various frequencies. The reactive Components of the circuit are responsible for Causing this type of distortion.

→ This distortion is not important in audio amplifiers. our ears are not capable of distinguishing the relative phases of different frequency components. But this distortion is objectionable in video amplifiers used in television.

Equivalent Simplified Hybrid Model:

→ For a transistor amplifier the detailed calculations of all four parameters A_V, A_I, R_I, R_o are determined using exact h-model.

→ But in most practical cases it is better to calculate above mentioned parameters using approximate h-model rather than cumbersome exact h-model.



→ This is because of the fact that the transistor parameters are unstable, varies with temperature, ageing and so on.

→ Here even with exact analysis one is not assured of obtaining the values of parameters accurately. So approximations may be allowed within tolerable limits.

→ of the four h-parameters, two parameters h_{ie} and h_{fe} are sufficient for the approximate analysis of low frequency circuits provided that the load resistance is small enough to satisfy the condition: $h_{oe} \cdot R_L \leq 0.1$

→ The simplified equivalent h-model of transistor is shown in figure

→ This simplified model can be used for all the transistor configurations by grounding the appropriate node. Connect signal source between the input node and ground, load in between the output node and ground.

→ The error in calculating various parameters A_I, A_V, R_I and R_o for all the configurations will be less than 10%.

CC	CB
$h_{ic} = h_{ie}$	$h_{ib} = h_{ie} / (1+h_{fe})$
$h_{rc} = 1$	$h_{rb} = \frac{h_{ie} h_{oe}}{1+h_{fe}} - h_{re}$
$h_{fc} = -(1+h_{fe})$	$h_{fb} = \frac{-h_{fe}}{1+h_{fe}}$
$h_{oc} = h_{oe}$	$h_{ob} = \frac{h_{oe}}{1+h_{fe}}$

Analysis of CE using simplified h-model:

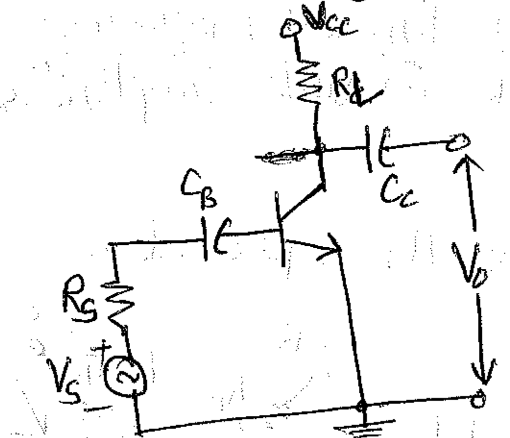


Fig (a) CE Amplifier Circuit

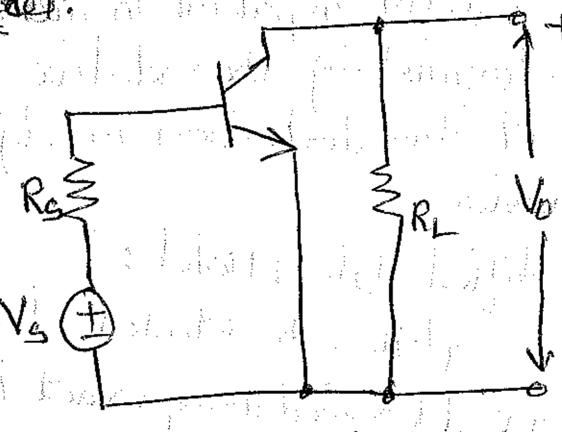


Fig (b) AC equivalent of CE amplifier

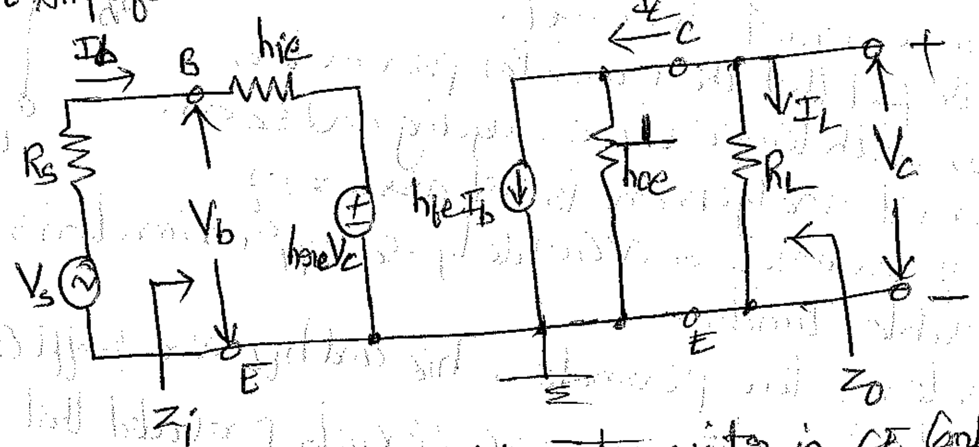


Fig (c) Exact h-parameter model of transistor in CE Configuration.

→ In figure (c) $\frac{1}{h_{oe}}$ and R_L are in parallel. Thus the parallel combination of these resistances produces a resistance value, which is approximately equal to the lower value i.e R_L.

Hence the term $\frac{1}{h_{oe}}$ can be neglected if $\frac{1}{h_{oe}} \gg R_L$ i.e $h_{oe} R_L \ll 1$.

In the absence of h_{oe}, the collector current I_c value is obtained by,

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

Then the magnitude of voltage generator in emitter circuit is given by,

$$h_{re} |V_c| = h_{re} I_c R_L = h_{re} h_{fe} I_b \cdot R_L$$

But $h_{re} \cdot h_{fe} \approx 0.01$, when the load resistance R_L is too large, the above voltage can be neglected in comparison with the voltage across h_{ie} i.e $h_{ie} \cdot I_b$

→ The approximate equivalent circuit can be obtained by neglecting the parameters h_{re} and h_{oe} such that the load resistance R_L is very small.

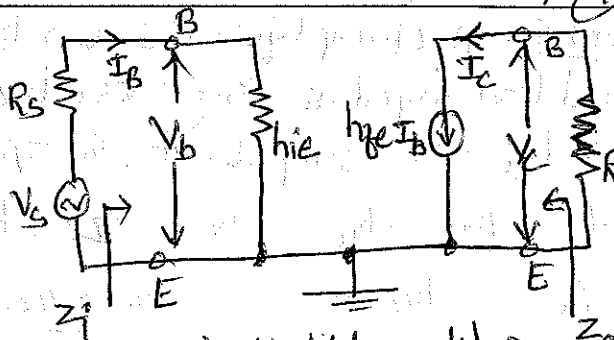


Fig (d) Simplified h-model of CE amplifier

Current gain (A_I): The general expression for Current gain of CE is,

$$A_I = \frac{-h_{fe}}{1+h_{oe}R_L} \quad \text{But } h_{oe}R_L \ll 0.1$$

$$\therefore A_I \approx -h_{fe}$$

Input Impedance (Z_i): The general expression for input impedance of CE Configuration is given by,

$$Z_i = h_{ie} + h_{re}A_I R_L$$

The above equation can also be written as,

$$Z_i = h_{ie}\left[1 - \frac{h_{re}h_{fe}|A_I|h_{oe}R_L}{h_{ie}h_{oe}h_{fe}}\right]$$

By using the typical values of h-parameters, we have

$$\frac{h_{re}h_{fe}}{h_{ie}h_{oe}} \approx 0.5 \qquad \text{and} \qquad |A_I| = h_{fe}$$

$$\therefore Z_i = h_{ie}\left[1 - \frac{0.5\,h_{fe}h_{oe}R_L}{h_{fe}}\right]$$

But $h_{oe}R_L \ll 0.1$ $\therefore$ $Z_i = h_{ie}$.

Voltage gain (A_V): The general expression for Voltage gain of CE Configuration is given by,

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

Output Impedance (Z_o):

→ It is the ratio of V_c to I_c with $V_S = 0$ and R_L excluded. The simplified Circuit has infinite output impedance because with $V_S = 0$ and external Voltage Source applied at the output, it is found that $I_b = 0$ and here $I_c = 0$. So $Z_o = \infty$.

→ with the load resistance R_L included the output resistance R_o calculated using approximate model increases but not more than 10%.

Prob ①: A CE amplifier is driven by a Voltage Source of internal resistance $R_S = 800\Omega$ and load impedance is a resistance $R_L = 1000\Omega$. The h-parameters are $h_{ie} = 1K\Omega$ and $h_{fe} = 50$. Compute A_I, A_V, Z_i and Z_o using approximate analysis.

Sol^n: $A_I = -h_{fe} = -50$, $Z_i = h_{ie} = 1K\Omega$, $R_o = \infty$

$$A_V = -\frac{h_{fe} R_L}{R_i} = \frac{-50 \times 1000}{1000} = -50$$

CE Amplifier with fixed bias :

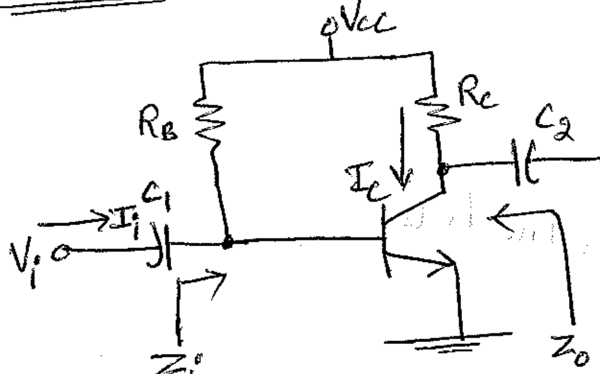


Fig ⓐ CE fixed bias Configuration

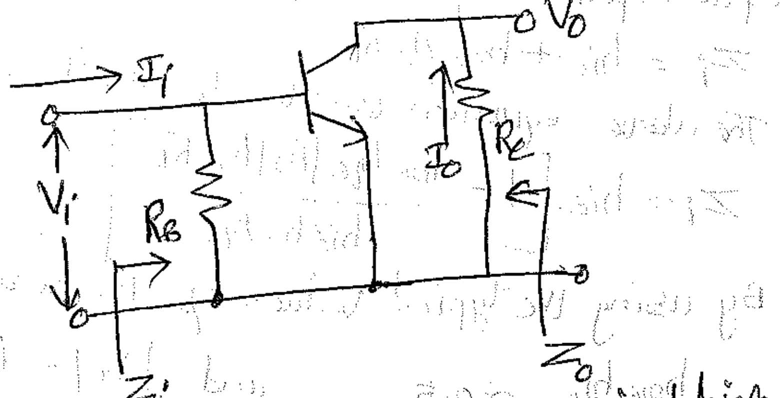


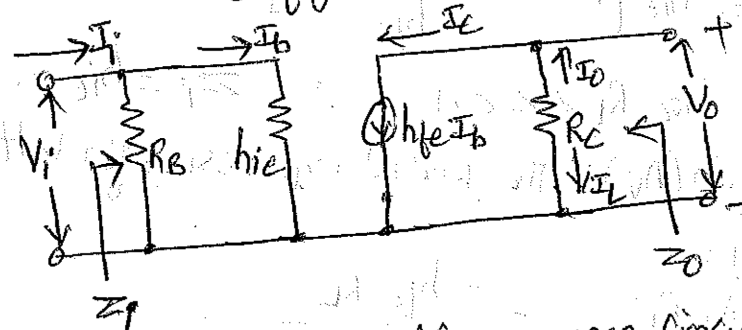
Fig ⓑ AC equivalent Circuit of CE fixed bias Configuration.

Input Impedance :

$Z_i = R_B || h_{ie}$

If $R_B >> h_{ie}$

then $Z_i = h_{ie}$



output Impedance :

It is the impedance determined with $V_i = 0$. with $V_i = 0$, $I_b = 0$ and $h_{fe} I_b = 0$ indicating an open Circuit equivalence for the Current source.

Here $Z_o = R_L = (R_C)$

Voltage gain : $A_V = \frac{V_o}{V_i}$ But $V_o = -I_o R_C$

$I_o = h_{fe} I_b \Rightarrow V_o = -h_{fe} I_b R_C$

Assuming $R_B >> h_{ie}$ $I_i \simeq I_b$ and $V_i = I_b h_{ie}$.

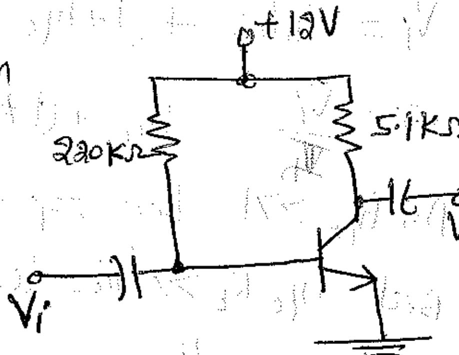
$$\therefore A_V = \frac{-h_{fe} I_b R_C}{I_b h_{ie}} = \frac{-h_{fe} R_C}{h_{ie}}$$

As h_{fe} & h_{ie} are positive, A_V is negative, The negative sign indicates a 180° phase shift between input and output signals.

<u>Current gain</u>: $A_I = \frac{I_L}{I_i} = \frac{-I_o}{I_i} \approx \frac{-h_{fe} I_b}{I_b} \approx -h_{fe}$.

The sign of A_I will be positive if A_I is defined as the ratio of I_o to I_i.

<u>Prob①</u>: Determine Z_i, Z_o, A_V & A_I for CE amplifier shown in figure. $h_{fe} = 60$, $h_{ie} = 500\,\Omega$.



<u>Sol</u>: $R_B = 220\,K\Omega >> h_{ie} = 500\,\Omega$

$\therefore Z_{in} = h_{ie} = 500\,\Omega$

$Z_o = R_C = 5.1\,K\Omega$

$A_V = \frac{-h_{fe} R_C}{h_{ie}} = \frac{-60(5.1 \times 10^3)}{500} = -612$

$A_I = -h_{fe} = -60$

<u>CE Amplifier with unbypassed emitter resistor (R_E)</u>:

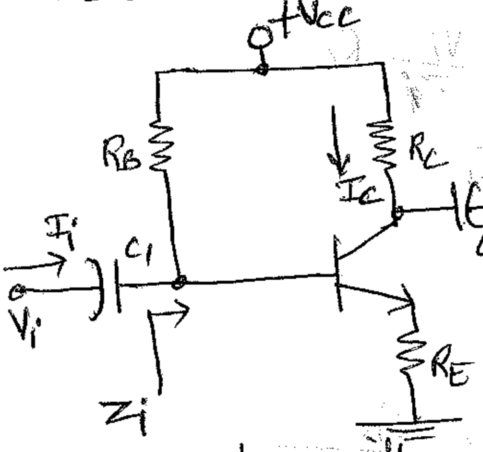


Fig ⓐ: CE Amplifier with unbypassed emitter resistor

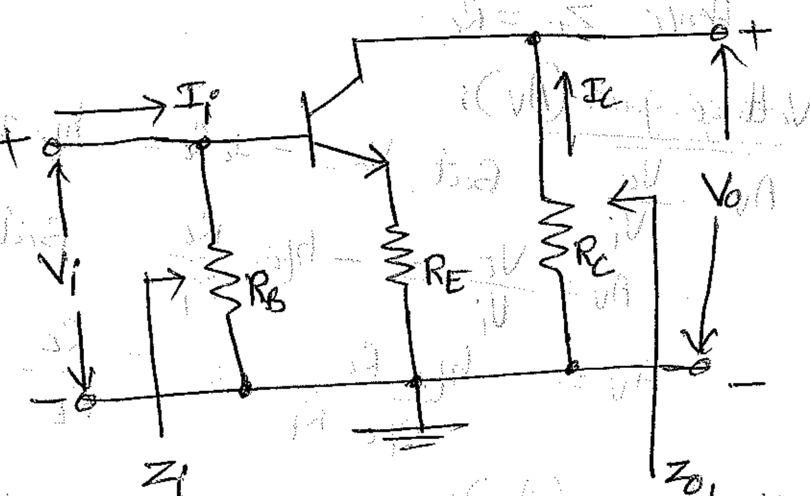


Fig ⓑ AC equivalent circuit for CE amplifier with unbypassed emitter resistor.

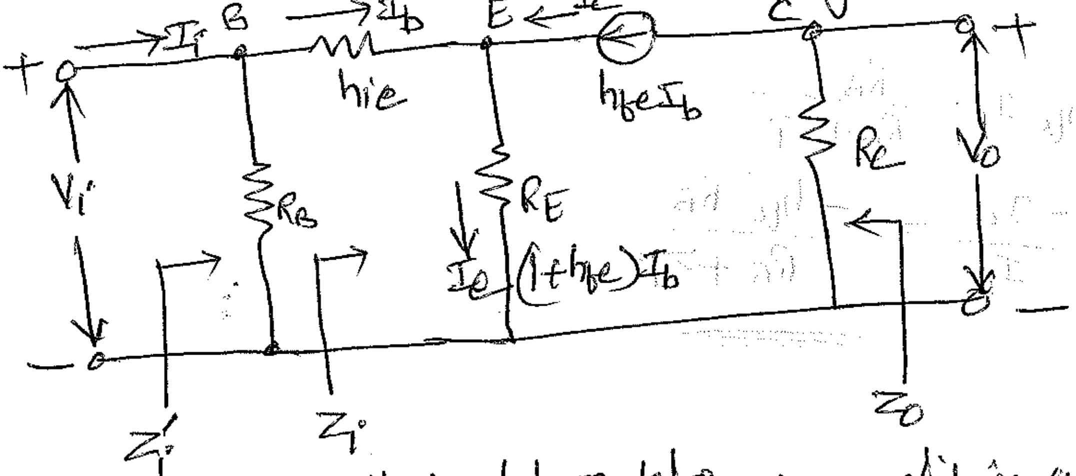


Fig ⓒ Approximate small signal h-model of CE amplifier with unbypassed emitter resistor.

Input Impedance (Z_i):

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

$V_i = I_b h_{ie} + (1+h_{fe}) I_b \cdot R_E$

$Z_i = \frac{V_i}{I_b} = h_{ie} + (1+h_{fe}) R_E$

As $h_{fe} >> 1$ then $Z_i = h_{ie} + h_{fe} R_E$

But $h_{fe} R_E >> h_{ie}$ leading to $Z_i = h_{fe} R_E$.

$Z_i' = R_B \| Z_i$

output impedance (Z_o):

with $V_i = 0$, $I_b = 0$, $h_{fe} I_b = 0$ indicating open Circuit for Current Source

Hence $Z_o = R_C$.

Voltage gain (A_V):

$A_V = \frac{V_o}{V_i}$ But $V_o = -I_c R_C = -h_{fe} I_b R_C = -h_{fe} \frac{V_i}{Z_i} \cdot R_C$

$\therefore A_V = \frac{V_o}{V_i} = -h_{fe} \frac{R_C}{Z_i}$ But $Z_i \approx h_{fe} R_E$

$\therefore A_V = \frac{-h_{fe} \cdot R_C}{h_{fe} \cdot R_E} \approx \frac{-R_C}{R_E}$

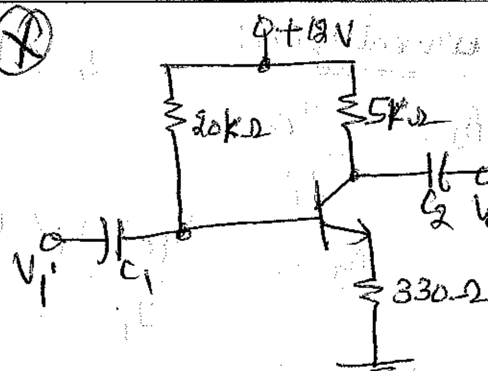
Current gain (A_I):

$A_I = \frac{-I_c}{I_i}$ But $I_c = h_{fe} I_b$ where $I_b = I_i \cdot \frac{R_B}{R_B + Z_i}$

$\therefore I_c = h_{fe} I_i \cdot \frac{R_B}{R_B + Z_i}$

$\therefore A_I = \frac{-I_c}{I_i} = \frac{-h_{fe} R_B}{R_B + Z_i}$

Prob①: Determine Z_i', Z_o, A_I and A_V for CE amplifier shown.
$h_{ie} = 1K\Omega$ & $h_{fe} = 50$.



Soln: $Z_i = h_{fe} R_E = 50 \times 330 = 16.5\,K\Omega$

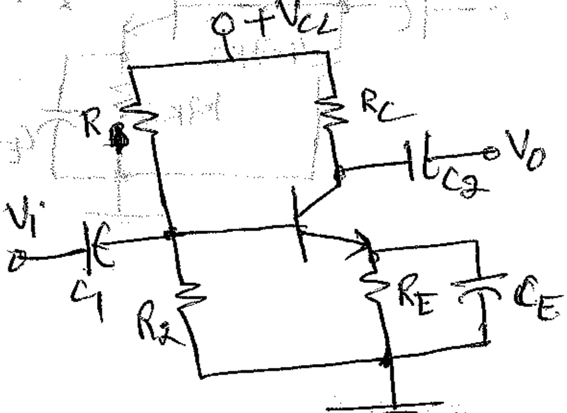
$Z_i' = R_B || Z_i = 20K || 16.5K = 9.04K\Omega$

$Z_o = R_C = 5K\Omega$

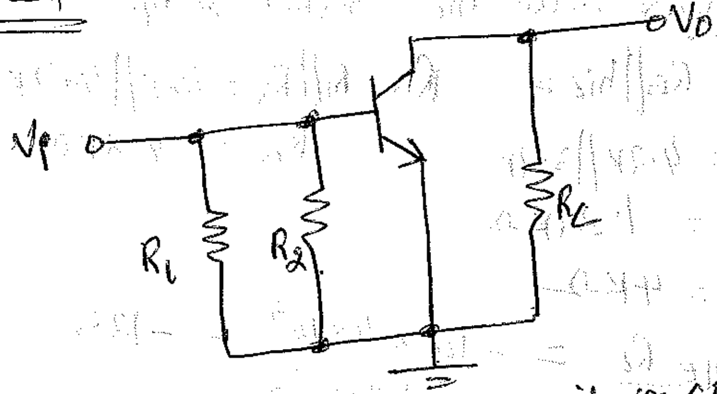
$$A_V = \frac{-R_C}{R_E} = \frac{-5K}{330} = -15.15$$

$$A_I = \frac{-h_{fe} R_B}{R_B + h_{fe} R_E} = \frac{-50 \times 20 \times 10^3}{20 \times 10^3 + 50 \times 330} = -27.39.$$

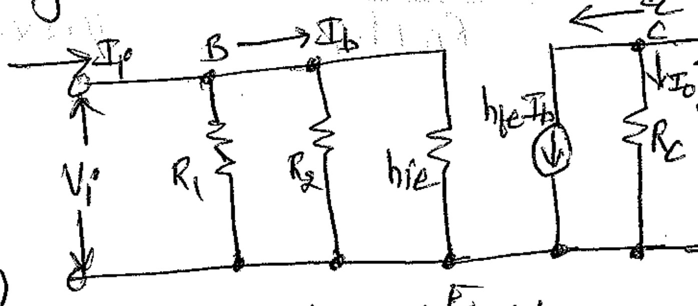
CE Amplifier with Voltage Divider bias:



Fig(a) CE Amplifier with Voltage divider bias.



Fig(b): AC equivalent circuit for CE amplifier using Voltage divider bias.



Fig(c) Simplified hybrid model of CE amplifier with voltage divider bias.

Voltage gain:

$$A_V = \frac{V_o}{V_i}$$

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

$V_i = I_i [(R_1 || R_2) || h_{ie}]$

$V_i = I_i h_{ie}$ {neglecting $R_1 || R_2$}

$V_i = h_{ie} I_b$ {$\because I_i = I_b$}

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

$$A_V = -\frac{h_{fe} R_C}{h_{ie}}$$

Current gain:
$$I_o = -h_{fe} I_b \quad ; \quad I_b = I_i \frac{R_B}{R_B + h_{ie}} \quad ; \quad R_B = R_1 \| R_2 .$$

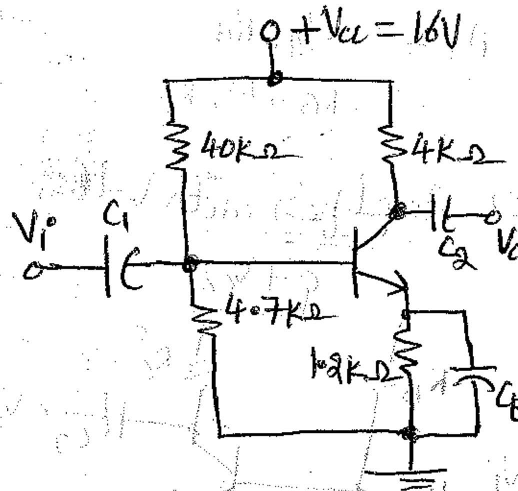
$$A_I = \frac{+I_o}{I_i}$$

$$\therefore A_I = \frac{-h_{fe} I_i \left(\frac{R_B}{R_B + h_{ie}}\right)}{I_i} = -h_{fe} \frac{R_B}{R_B + h_{ie}}$$

Input Impedance: $Z_i = R_B \| h_{ie}$ where $R_B = R_1 \| R_2$.

output Impedance: $Z_o = R_C$

Prob①: Determine Z_i, Z_o, A_V and A_I of CE amplifier shown in figure with $h_{ie} = 3.2K\Omega$ & $h_{fe} = 100$.



Soln: $Z_i = R_B \| h_{ie}$ $\quad R_B = R_1 \| R_2 = 40K \| 4.7K$

$= 4.2K \| 3.2K$ $\quad R_B = 4.2K\Omega$

$Z_i = 1.82K\Omega$

$Z_o = R_C = 4K\Omega$

$$A_V = -h_{fe} \frac{R_C}{R_E} = \frac{-100 \times 4 \times 10^3}{1.2 \times 10^3} = -125$$

$$A_I = \frac{-h_{fe} R_B}{R_B + h_{ie}} = \frac{-100 \times 4.2 \times 10^3}{4.2 \times 10^3 + 3.2 \times 10^3} = -56.76$$

Analysis of CB Configuration using approximate model:

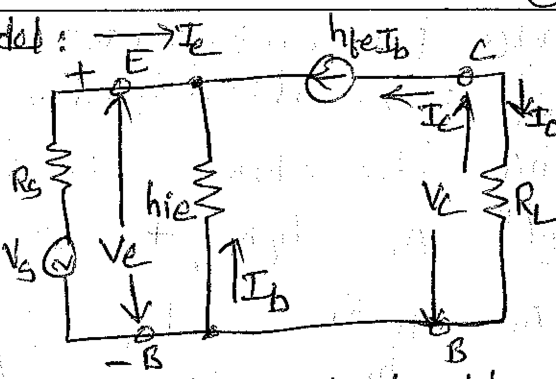


Fig: Simplified hybrid model of CB Circuit.

Current gain:

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

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

$$A_I = -h_{fb}$$

Input Resistance:

$$R_i = \frac{V_e}{I_e} = \frac{-I_b h_{ie}}{-(1+h_{fe}) I_b} = \frac{h_{ie}}{1+h_{fe}} = h_{ib}$$

Voltage gain:

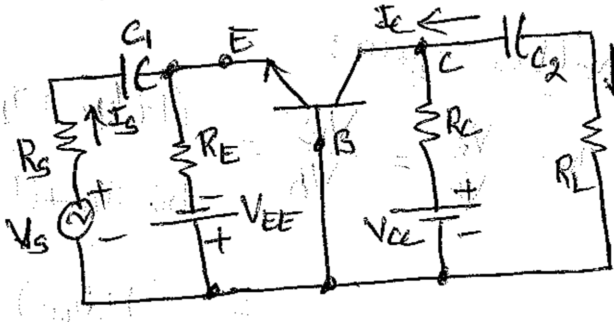
$$A_V = \frac{V_c}{V_e} = \frac{-h_{fe} I_b R_L}{-h_{ie} I_b} = \frac{h_{fe} R_L}{h_{ie}}$$

output Impedance:

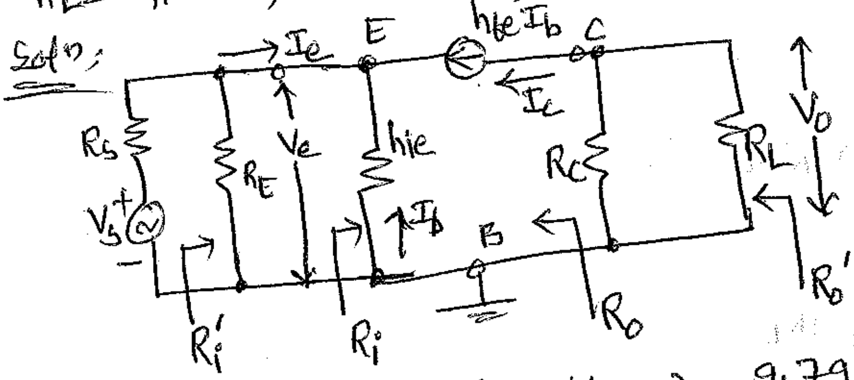
$$R_o = \frac{V_c}{I_c} \text{ with } V_s = 0,\ R_L = \infty.$$

But with $V_s = 0$, $I_e = 0$ & $I_b = 0$ $\therefore I_c = 0.$ $\Rightarrow R_o = \infty.$

Prob①: A CB amplifier as shown in figure has $R_S = 600\Omega$, $R_C = 5.6K\Omega$, $R_E = 5.6K$, $R_L = 39K\Omega$, $h_{ie} = 1K\Omega$, $h_{fe} = 85$ and $h_{oe} = 2\mu A/V$. Calculate R_i, R_o, A_V & A_I



Soln:



$h_{oe} \times (R_C \| R_L) = 2\times10^{-6} \times (5.6K \| 39K) = 9.79\times10^{-3} \ll 0.1$ So use approximate analysis.

$$A_I = \frac{h_{fe}}{1+h_{fe}} = \frac{85}{1+85} = 0.988$$

$$R_I = \frac{h_{ie}}{1+h_{fe}} = \frac{1000}{1+85} = 11.627\Omega$$

$$R_I' = R_I \| R_E = 11.627 \| 5.6K = 11.6\Omega$$

$$A_V = \frac{h_{fe} R_L'}{h_{ie}} = \frac{85\times(5.6K\|39K)}{1K} = 416.2$$

$$R_o = \infty$$

$$R_o' = R_o \| R_C \| R_L = \infty \| 5.6K \| 39K$$

$$= 4.89K$$

prob(2): For a CB transistor amplifier driven by a voltage source of internal resistance $R_s = 1200\Omega$ and load impedance is a resistor $R_L = 1000\Omega$. The h-parameters are $h_{ib} = 22\Omega$ & $h_{fb} = -0.98$. Compute R_i, R_o, A_i & A_V using approximate analysis.

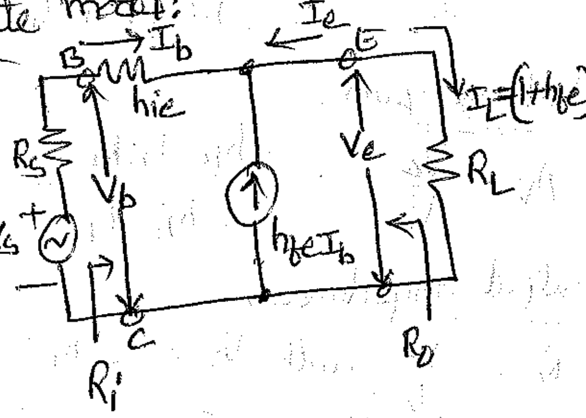
Sol^n: $A_i = -h_{fb} = +0.98$ $\quad R_i = h_{ib} = 22\Omega$ $\quad R_o = \infty$

$$A_V = \frac{h_{fe} R_L}{h_{ie}} \qquad h_{fe} = \frac{-h_{fb}}{1+h_{fb}} = \frac{-(-0.98)}{1-0.98} = 49$$

$$h_{ib} = \frac{h_{ie}}{1+h_{fe}} \Rightarrow h_{ie} = h_{ib}(1+h_{fe}) = 22(1+49) = 1100\Omega$$

$$\therefore A_V = \frac{49 \times 1000}{1100} = 44.54$$

Analysis of CC Configuration using the approximate model:



Current gain:

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

Input Resistance:

$$R_i = \frac{V_b}{I_b} \quad \text{But } V_b = h_{ie} I_b + (1+h_{fe}) I_b \cdot R_L$$

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

Voltage gain:

$$A_V = \frac{V_e}{V_b} = \frac{V_e}{V_b} = \frac{(1+h_{fe}) I_b R_L}{h_{ie} I_b + (1+h_{fe}) I_b \cdot R_L}$$

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

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

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

output Impedance:

output admittance $Y_o = \dfrac{\text{short circuit current in output terminals}}{\text{open circuit voltage between output terminals}}$

short circuit current in output terminals $= (1+h_{fe})I_b = \dfrac{(1+h_{fe})V_s}{h_{ie}+R_s}$

open circuit voltage between output terminals $= V_s$

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

prob①: A voltage source of internal resistance $R_s = 900\,\Omega$ drives a CC amplifier using load resistance $R_L = 2000\,\Omega$. The CE parameters are $h_{ie} = 1200\,\Omega$ & $h_{fe} = 60$. Compute A_I, A_V, R_I and R_o using approximate analysis.

Sol^n: $A_I = 1+h_{fe} = 1+60 = 61$

$R_i = h_{ie} + (1+h_{fe})R_L = 1200 + 61 \times 2000 = 123.2\,K\Omega$

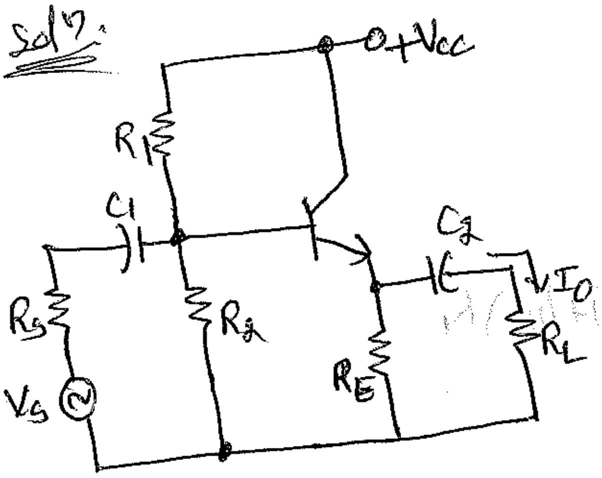
$$A_V = 1 - \frac{h_{ie}}{R_i} = 1 - \frac{1200}{123.2\times10^3} = 0.9903$$

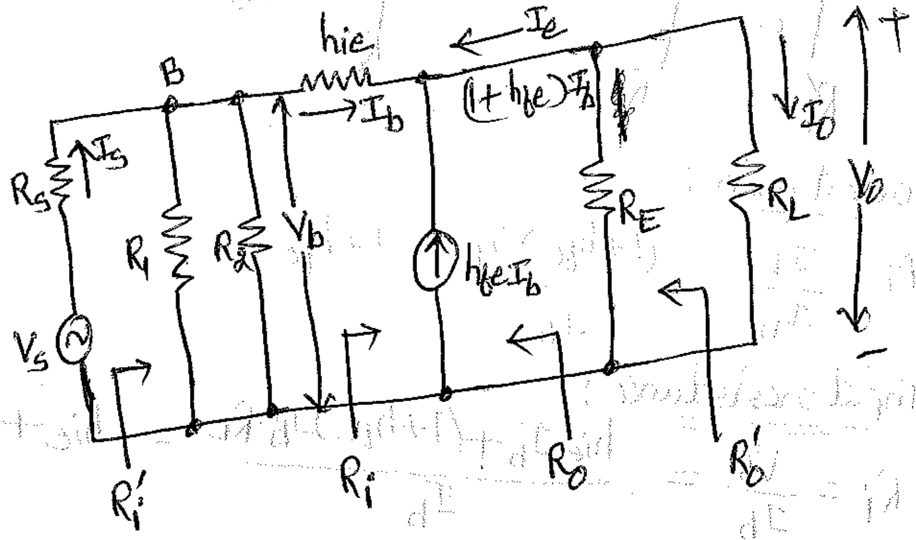
$$Y_o = \frac{1+h_{fe}}{h_{ie}+R_s} = \frac{1+60}{1200+900} = 0.029\,℧$$

$R_o = 34.43\,\Omega$

prob②: A CC circuit has the following components $R_1 = 27K\Omega$, $R_2 = 27K\Omega$, $R_E = 5.6K\Omega$, $R_L = 47K\Omega$, $R_S = 600\,\Omega$. The h-parameters are $h_{ie} = 1K\Omega$, $h_{fe} = 85$ & $h_{oe} = 2\mu A/V$. Calculate A_i, R_i, R_o & A_V.

Sol^n:





$h_{oe} \times R_L' = 2\times10^{-6} \times (5.6K \| 47K) = 0.01 < 0.1$ thus we use approximate h-model

$A_i = 1 + h_{fe} = 1 + 85 = 86$

$R_i = h_{ie} + (1+h_{fe}) R_L' = h_{ie} + (1+h_{fe})(R_E \| R_L)$

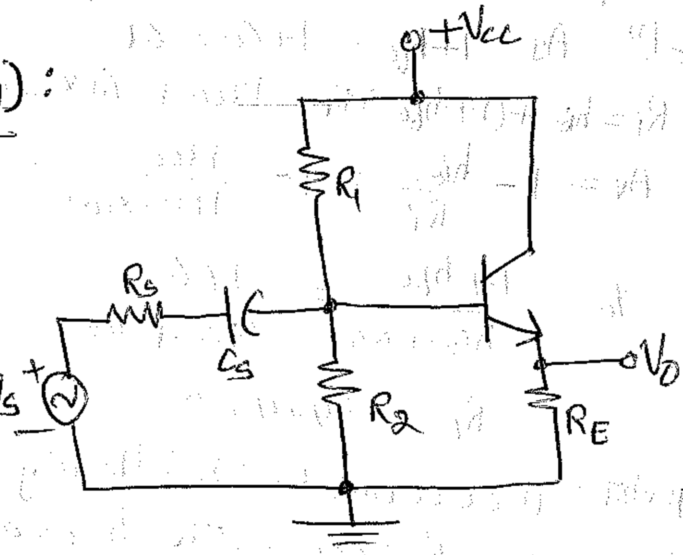
$R_i = 1K + (1+85)(5.6K \| 47K) = 431.33 K\Omega$

$R_i' = R_i \| R_1 \| R_2 = 431.33K \| 27K \| 27K = 13.09 K\Omega$

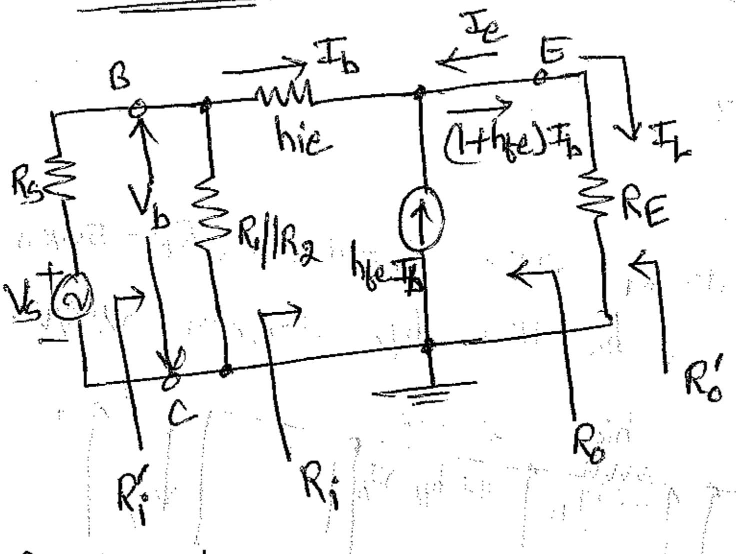
$A_V = 1 - \frac{h_{ie}}{R_i} = 1 - \frac{1K}{431.33K} = 0.997$

$R_o = \frac{h_{ie} + R_s'}{1+h_{fe}} = \frac{h_{ie} + (R_1 \| R_2 \| R_s)}{1+h_{fe}} = \frac{1K + (27K \| 27K \| 600)}{1+85} = 18.3\,\Omega$

$R_o' = R_o \| R_E \| R_L = 18.3 \| 5.6K \| 47K = 18.23\,\Omega$



Emitter Follower (Common Collector Amplifier) :



Current gain :

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

Input resistance :

$R_i = \frac{V_b}{I_b} = \frac{h_{ie} I_b + (1+h_{fe}) I_b \cdot R_L}{I_b} = h_{ie} + (1+h_{fe}) R_L$

$R_i' = R_i \| R_1 \| R_2$

Voltage gain:

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

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

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

$$\Rightarrow \frac{R_i - h_{ie}}{R_L} = A_i$$

$$\therefore A_V = \frac{R_i - h_{ie}}{R_i} = 1 - \frac{h_{ie}}{R_i}$$

output admittance:

$$Y_o = h_{oc} - \frac{h_{fc} h_{rc}}{h_{ic} + R_s'} \quad \text{where } R_s' = R_s || R_1 || R_2$$

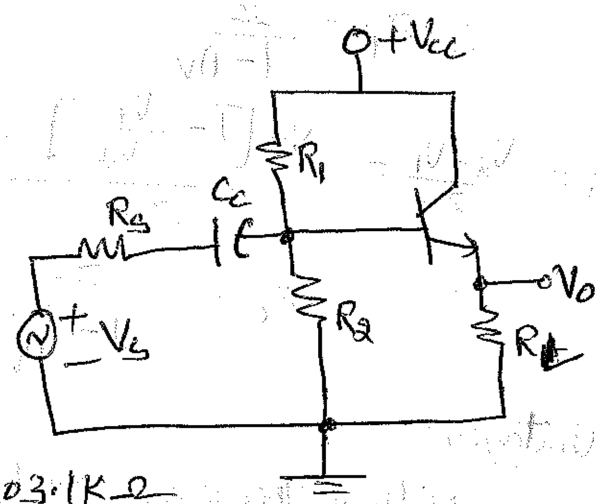
Neglecting h_{oc} and assuming $h_{rc} \approx 1$, $h_{fc} = -(1+h_{fe})$ we get,

$$Y_o = \frac{1+h_{fe}}{h_{ie} + R_s'} \quad \{\because h_{ic} = h_{ie}\}$$

$$\therefore R_o = \frac{h_{ie} + R_s'}{1+h_{fe}}.$$

$$R_o' = R_o || R_E$$

prob(1): For the emitter follower shown in figure $R_s = 500\,\Omega$, $R_1 = R_2 = 50K\Omega$, $R_L = 2K\Omega$, $h_{fe} = 100$ and $h_{ie} = 1.1K\Omega$. Find R_i, R_o, A_i, A_V.



Sol^n:

$$R_i = h_{ie} + (1+h_{fe})R_L = 1.1\times10^3 + (1+100)\times 2\times10^3 = 203.1K\Omega$$

$$R_i' = R_i || R_1 || R_2 = 203.1K || 50K || 50K = 22.26K\Omega$$

$$R_o = \frac{h_{ie} + R_s'}{1+h_{fe}} = \frac{1.1\times10^3 + (500||50K||50K)}{1+100} = 15.74\,\Omega$$

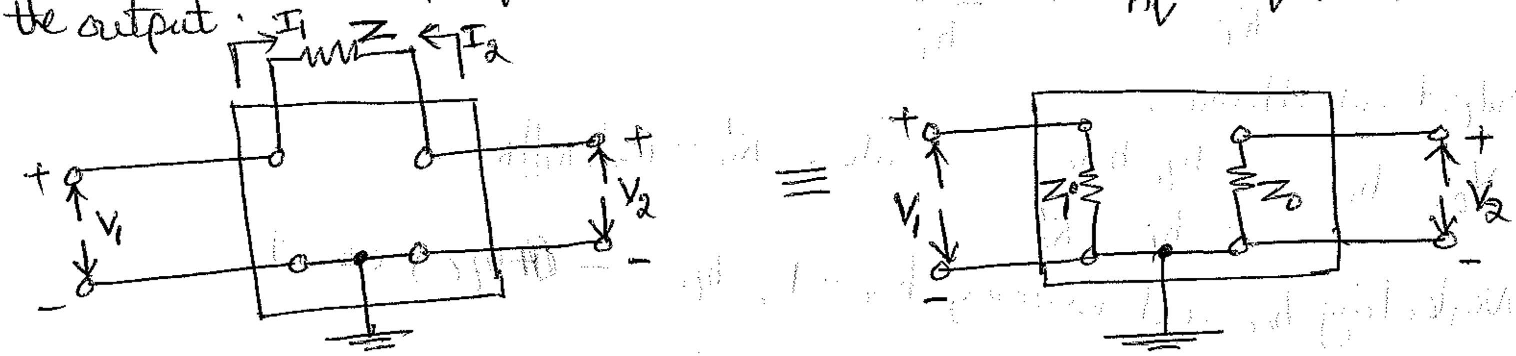
$$R_o' = R_o || R_L = 15.74 || 2K = 15.62\,\Omega$$

$$A_i = 1 + h_{fe} = 1 + 100 = 101.$$

$$A_V = 1 - \frac{h_{ie}}{R_i} = 1 - \frac{1.1\times10^3}{203.1\times10^3} = 0.9946$$

Miller's Theorem :

→ Miller's theorem states that if an impedance 'Z' is connected between input and output terminals of a network which provides a voltage gain 'A_v' an equivalent circuit that gives the same effect can be drawn by removing 'Z' and connecting an impedance $Z_i = \frac{Z}{1-A_V}$ across the input and $Z_0 = \frac{Z}{1-\frac{1}{A_V}} = \frac{ZA_V}{A_V-1}$ across the output.



Proof :

$$I_1 = \frac{V_1 - V_2}{Z} = \frac{V_1\left[1 - \frac{V_2}{V_1}\right]}{Z} = \frac{V_1(1-A_V)}{Z} = \frac{V_1}{Z/(1-A_V)} = \frac{V_1}{Z_i}$$

$$\therefore Z_i = \frac{Z}{1-A_V}$$

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

$$\therefore Z_0 = \frac{Z}{1-\frac{1}{A_V}} = \frac{ZA_V}{A_V-1}$$

Advantages :

→ using Miller's theorem, complex circuit can be easily simplified.

Disadvantages :

→ This theorem will be useful in making calculations only if it is possible to find the value of A_V by some independent means.

Miller Effect Capacitance :

→ In inverting amplifiers, the capacitive element 'C_f' is connected between input and output terminals of the active device i.e $X_{C_f} = \frac{1}{j\omega C_f}$.

→ The large capacitors will control the low frequency response due to their low reactance levels.

Therefore, the Miller effect input capacitance C_{Mi} is derived as,

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

$$\text{i.e } \frac{1}{j\omega C_{Mi}} = \frac{1}{j\omega C_f(1-A)} \quad \text{Therefore, } C_{Mi} = (1-A)C_f .$$

→ Hence it is evident that in any inverting amplifier the input capacitance will be increased by a Miller effect capacitance sensitive to the gain of the amplifier and the interelectrode capacitance 'C_f' between the input and output terminals of the active device.

The Miller output capacitance C_{MO} is derived as,

→ The Miller output capacitance

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

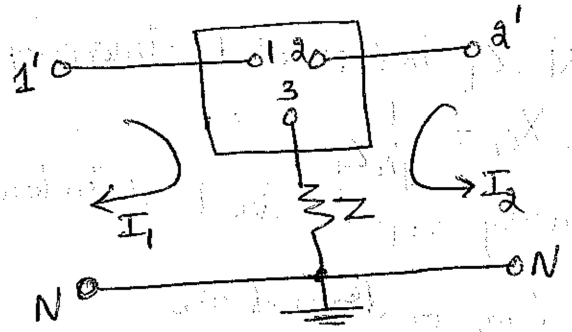
$$\text{i.e } \frac{1}{j\omega C_{MO}} = \frac{1}{j\omega C_f\left(1-\frac{1}{A}\right)}$$

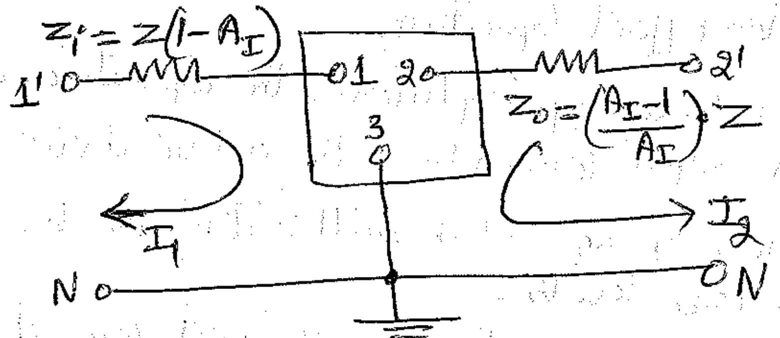
$$\text{Therefore, } C_{MO} = \left(1-\frac{1}{A}\right)C_f$$

$$\text{If } A>>1 \text{ then } C_{MO} = \underline{\underline{C_f}} .$$

Dual of Miller's theorem:

→ Dual of Miller's theorem states that if an impedance 'Z' connected as shunt element between input and output terminals can be replaced by an impedance $Z_i = Z(1-A_I)$ at the input side and $Z_o = Z\left(1-\frac{1}{A_I}\right) = \frac{Z(A_I-1)}{A_I}$ at the output side where the current ratio $A_I = -\frac{I_2}{I_1}$.





Proof:

Voltage across Z_i is $V_1 = I_1 Z_i$

Voltage drop across 'Z' is $(I_1 + I_2) Z$

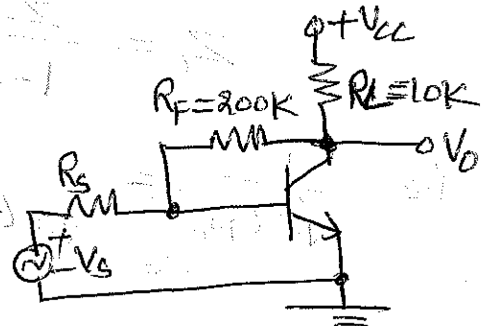
$$\therefore I_1 Z_i = (I_1 + I_2) Z \Rightarrow Z_i = \left(1 + \frac{I_2}{I_1}\right) Z = (1 - A_I) Z.$$

Illy Voltage across Z_0 is $V_2 = I_2 Z_0$

$$\therefore I_2 Z_0 = (I_1 + I_2) Z$$

$$\Rightarrow Z_0 = \left(1 + \frac{I_1}{I_2}\right) Z = \left(1 - \frac{1}{A_I}\right) Z = \left(\frac{A_I - 1}{A_I}\right) Z.$$

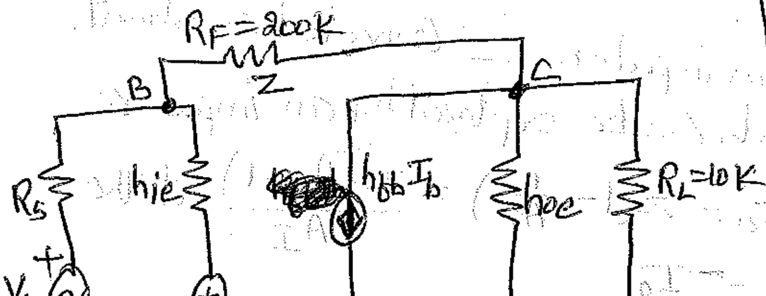
prob①: Common-emitter amplifier with collector to base bias is as shown in figure. The h-parameters are, $h_{ie} = 1.1K$, $h_{fe} = 50$, $h_{oe} = 25 \times 10^{-6}$ A/V, $h_{re} = 2.5 \times 10^{-4}$. Calculate R_i, A_i, A_v, R_i'.



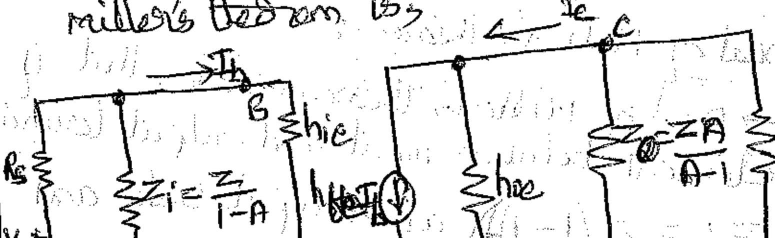
Soln: $h_{oe} \cdot (R_L || R_F) = 25 \times 10^{-6} (10K || 200K) = 0.238$

which is greater than 0.1 so we use exact analysis.

h-parameter equivalent circuit is,



h-parameter equivalent circuit using miller's theorem is,



$$z_0 = \frac{Z \cdot A}{A-1} \quad \text{If } A >> 1 \text{ then } Z_0 = Z = 200K\Omega.$$

$$A_i = \frac{-h_{fe}}{1 + h_{oe} R_L'} \quad \text{where } R_L' = R_L \| Z_0 = 10K \| 200K = 9.52K\Omega$$

$$A_i = \frac{-50}{1 + 25\times10^{-6} \times 9.52 \times 10^3} = -40.3$$

$$R_i = h_{ie} + h_{re} A_i R_L' = 1.1\times10^3 + 2.5\times10^{-4} \times 9.52\times10^3 \times (-40.3) = 1004$$

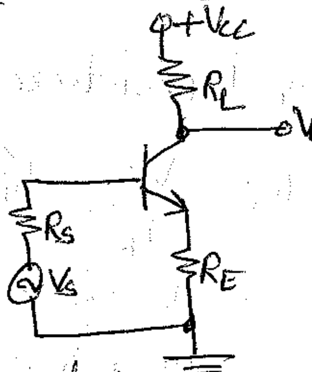
$$A_V = \frac{A_i R_L'}{R_i} = \frac{-40.3 \times 9.52\times10^3}{1004} = -382.13$$

$\therefore$ $A_V >> 1$ is justified

$$\therefore z_i = \frac{Z}{1-A} = \frac{200\times10^3}{1+382.13} = 522\Omega$$

$$R_i' = R_i \| z_i = 1004 \| 522 = 343.44\Omega$$

Analysis of Common Emitter amplifier with an Emitter resistance using Dual of Miller's theorem



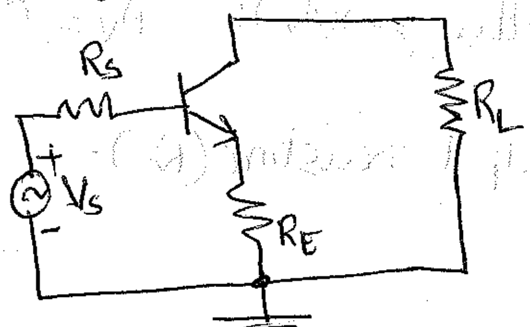
→ whenever the gain provided by a single stage amplifier is not sufficient, it is necessary to cascade the no. of stages of the amplifier.

→ In such situations it becomes important to stabilize the voltage amplification of each stage because instability of the first stage is amplified in the second stage and it is further amplified in the next. This is not desired.

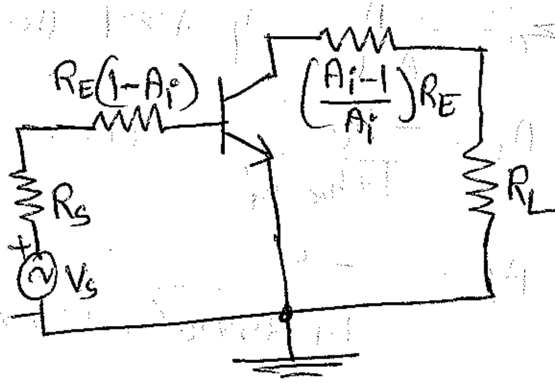
→ The simple and effective way to obtain voltage gain stabilization is to add an emitter resistance R_E to a CE stage as shown in figure.

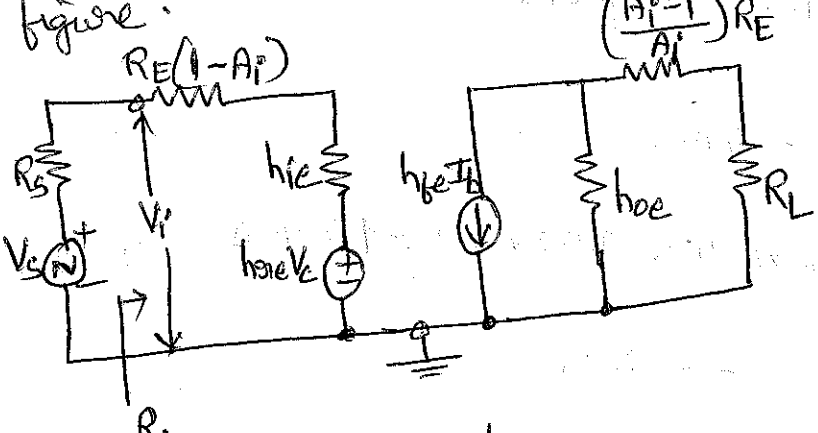
→ The presence of emitter resistance has no. of better effects on the amplifier performance.

→ Figure shows an ac equivalent circuit for CE circuit with unbypassed emitter resistance.



→ To make the analysis of CE amplifier with R_E we use dual of Miller's theorem as shown in figure.





Current gain: $A_i = \frac{-h_{fe}}{1+h_{oe}R_L'} = \frac{-h_{fe}}{1+h_{oe}\left[R_L + \left(\frac{A_i-1}{A_i}\right)R_E\right]}$

$$A_i + A_i h_{oe} R_L + A_i h_{oe} R_E - h_{oe} R_E = -h_{fe}$$

$$A_i\left[1+h_{oe}(R_L+R_E)\right] = h_{oe}R_E - h_{fe}$$

$$A_i = \frac{h_{oe}R_E - h_{fe}}{1+h_{oe}(R_L+R_E)}$$

Input Resistance (R_i):

$$R_i = \frac{V_i}{I_b} = h_{ie} + h_{re}A_i R_L'$$

From the figure the resistance $R_E(1-A_i)$ is in series with h_{ie} and R_L' is $R_L + \left(\frac{A_i-1}{A_i}\right)R_E$.

$$\therefore R_i = (1-A_i)R_E + h_{ie} + h_{re}A_i R_L'$$

Voltage gain (A_V): $A_V = \frac{A_i R_L'}{R_i}$

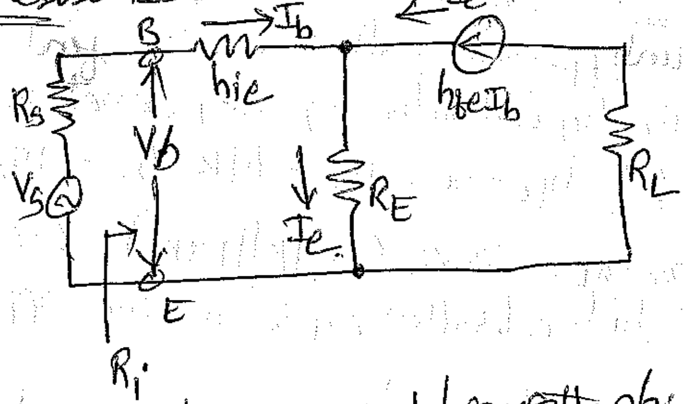
output resistance (R_o): $R_o = \infty$

<u>Approximate Analysis of CE with emitter resistance:</u>

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

$$R_i = \frac{V_b}{I_b} = \frac{h_{ie}I_b + (1+h_{fe})I_bR_E}{I_b}$$

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



The input resistance due to factor $(1+h_{fe})R_E$ may be very much larger than h_{ie}. Hence an emitter resistance greatly increases the input resistance.

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

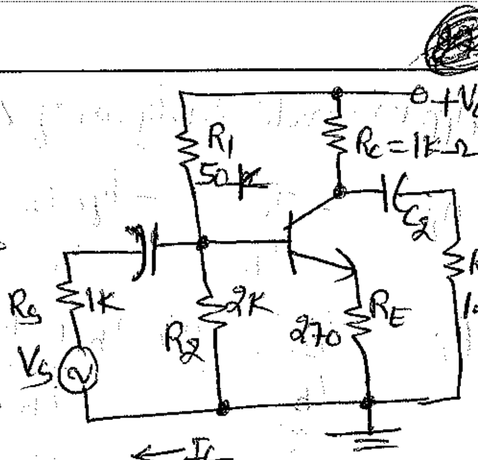
<u>output resistance (R_o)</u>: It is the resistance of an amplifier without considering the source and load (i.e $V_s=0$ & $R_L=\infty$). It is defined as a ratio of output voltage V_o to output current with $V_s=0$.

$$\therefore R_o = \frac{V_o}{I_o}\Big|_{V_s=0}$$

when $V_s=0$, the current through the input loop $I_b=0$, hence I_c and I_e both are zero. Therefore $R_o=\infty$.

The output resistance R_o' of the stage taking the load into account is given as, $R_o' = R_o || R_L = \infty || R_L = R_L$.

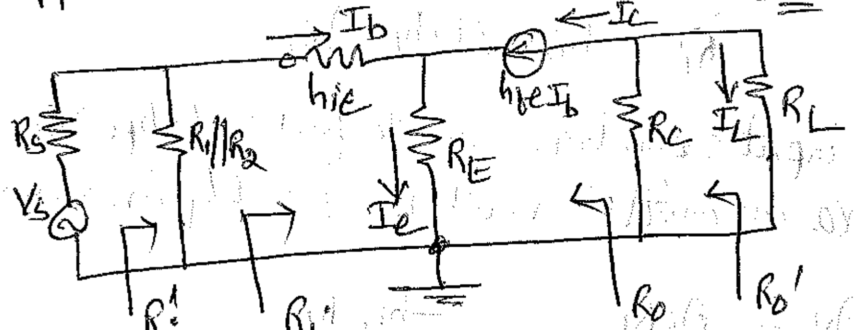
Prob ①: Figure shows a single stage CE amplifier with unbypassed emitter resistance, find A_i, R_i, A_V and R_o. use typical values of h-parameters.



Sol^n: $h_{fe} = 50$, $h_{ie} = 1.1K$, $h_{oe} = 25\mu A/V$, $h_{re} = 2.5\times10^{-4}$

$h_{oe}\cdot R_L = 25\times10^{-6}\times(1K\|1.2K) = 0.0136$

which is less than 0.1 so we use approximate analysis.



$$A_i = -h_{fe} = -50$$

$$R_i = \frac{V_i}{I_b} = h_{ie} + (1+h_{fe})R_E$$

$$= 1.1K + (1+50)\times 270$$

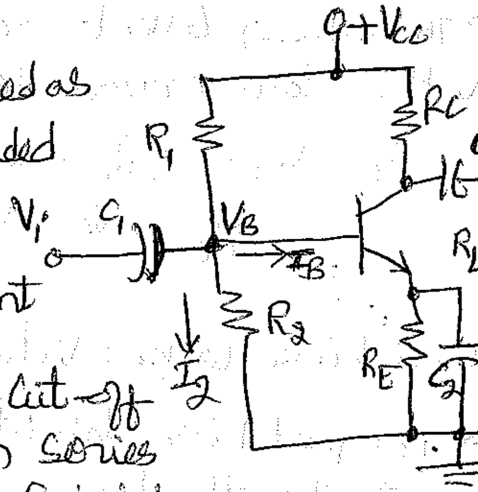
$$R_i = 14.87K$$

$$A_V = \frac{A_i R_L}{R_i} = \frac{-50\times(1.2K\|1K)}{14.87K} = -1.834$$

$$R_i' = R_i\|R_1\|R_2 = 14.87K\|2K\|50K = 1.7K$$

$$R_o' = R_o\|R_C\|R_L = \infty\|1K\|1.2K = 545.45\,\Omega$$

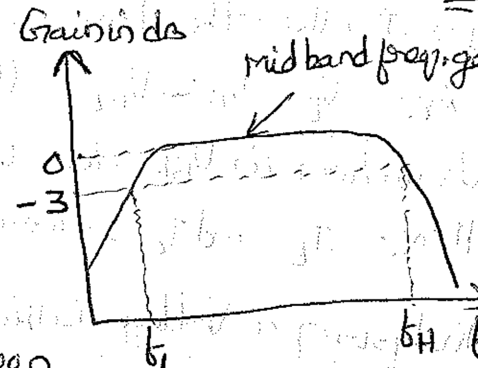
Design of Single stage RC Coupled Amplifier using BJT:



→ A single stage RC Coupled CE amplifier can be employed as a small signal amplifier but a circuit with two cascaded stage gives large amplification.

→ The design of resistor values involves application of ohm's law after selecting suitable voltage and current levels throughout the circuit.

→ The design of capacitor values are based on the lower cut-off frequency of the circuit and the resistance which is in series with the capacitor.



→ In this circuit, the biasing is provided by three resistors R_1, R_2 and R_E. The resistors R_1 and R_2 act as a potential divider giving a fixed voltage to the base.

→ If the collector current increases due to change in temperature or change in h_{fe}, then the emitter current I_E also increases, reducing the voltage difference between base and emitter V_{BE}.

→ Due to reduction in V_{BE}, I_B and hence I_C also reduces. Negative feedback acts in emitter bias circuit.

→ This reduction in collector current I_C compensated for the original change in I_C.

Design of R_C and R_E:

→ The design of single stage RC coupled amplifier is based on the specifications like supply voltage, minimum voltage gain, frequency response, source impedance and load impedance.

→ The circuit has no provision for negative feedback because of bypass capacitor C_E and hence it is designed to achieve the largest possible gain.

The voltage gain of a CE amplifier circuit is given by,

$$A_V = \frac{-h_{fe}(R_C || R_L)}{h_{ie}}$$

→ since A_V is directly proportional to $R_C || R_L$, the design for large voltage gain requires selection of the largest possible collector resistance.

→ But a large value of R_C needs the collector current to be small for satisfactory operation of transistor.

→ The value of collector resistance R_C can be determined by applying Kirchhoff's Voltage law around the collector – emitter circuit.

i.e $V_{CC} = I_C R_C + V_{CE} + V_E$

$$\Rightarrow R_C = \frac{V_{CC} - V_{CE} - V_E}{I_C} \quad \text{where } V_E = I_E R_E \Rightarrow R_E = \frac{V_E}{I_E} \approx \frac{V_E}{I_C}$$

To achieve larger value of R_C, let us assume $V_{CE} = \frac{V_{CC}}{2}$ and $V_E = \frac{V_{CC}}{10}$

→ For good bias stability, the emitter resistor voltage drop 'V_E' should be greater than the base emitter voltage V_{BE} i.e $V_E > V_{BE}$.

Since $V_E = V_B - V_{BE}$, the emitter voltage V_E will be slightly affected by the variation in V_{BE} due to change in temperature.

Hence I_E and I_C remain stable at $I_C \approx I_E = \frac{V_E}{I_E}$.

Analysis of a Voltage Divider Bias Circuit:

By ohm's law the input resistance at the transistor base is

$$R_{in(base)} = \frac{V_{in}}{I_{in}}$$

But $V_{in} = V_{BE} + I_E R_E = V_B$

$\approx I_E R_E$ since $V_{BE} << I_E R_E$

$\approx \beta I_B R_E$ since $I_E \approx I_C = \beta I_B$

and $I_{in} = I_B$.

Therefore, $R_{in(base)} = \frac{V_{in}}{I_{in}} = \frac{\beta I_B R_E}{I_B} \approx \beta R_E$

The total resistance from base to ground is,

$$R_2 \| R_{in(base)} \approx R_2 \| \beta R_E$$

A voltage divider is formed by R_1 and the resistance from base to ground, βR_E is parallel with R_2.

$$\therefore V_B = V_{CC}\left(\frac{R_2 \| \beta R_E}{R_1 + R_2 \| \beta R_E}\right)$$

If $\beta R_E >> R_2$ (at least 10 times greater), then

$$V_B = V_{CC}\left(\frac{R_2}{R_1 + R_2}\right).$$

Design of Bias Resistors :

The Voltage divider Current I_2 is selected as $\frac{I_C}{10}$ which results in good bias stability and high input resistance.

Hence the bias resistors are calculated as,

$$R_2 = \frac{V_B}{I_2} \text{ and } R_1 = \frac{V_{CC} - V_B}{I_2} \text{ where } V_B = V_E + V_{BE} \text{ (or) } V_B = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC}$$

Design of Bypass and Coupling Capacitors :

→ Always the bypass capacitor across the emitter resistor is used to filter out the signal variations at the emitter with respect to ground.

→ Therefore the reactance offered by this capacitor should be low for high frequencies but high for dc and nearby low frequencies.

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

where X_{CE} should be high for dc and very low frequency signals and low for high frequencies.

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

where C_E should be high for high frequencies starting from 100Hz.

Therefore X_{CE} can be fixed at one-tenth of R_E.

→ All capacitors should be selected to have the smallest possible capacitance value mainly to minimize the physical size of the circuit.

→ Each capacitor has its highest impedance at the lowest operating frequency and it is calculated based on the lower cut-off frequency.

→ The bypass capacitor C_E is normally the largest capacitor in the circuit.

The voltage gain for CE circuit with unbypassed emitter resistance given by,

$$A_V = \frac{-h_{fe}(R_C || R_L)}{h_{ie} + R_E(1 + h_{fe})}$$

By including the bypass capacitor in parallel with R_E the voltage gain is given by,

$$A_V = \frac{-h_{fe}(R_C || R_L)}{h_{ie} + (1 + h_{fe})(R_E || X_{CE})}$$

Normally $R_E >> X_{CE}$ so R_E can be neglected and also X_{CE} is capacitive reacta

Hence, $$|A_V| = \frac{+h_{fe}(R_C||R_L)}{\sqrt{h_{ie}^2 + [(1+h_{fe})X_{CE}]^2}}$$

when $h_{ie} = (1+h_{fe})X_{CE}$.

$$|A_V| = \frac{+h_{fe}(R_C||R_L)}{h_{ie}\sqrt{1^2+1^2}} = \frac{A_{vm}}{\sqrt{2}}$$

where A_{vm} is the mid frequency gain.

Therefore at lower cut-off frequency f_L,

$$h_{ie} = (1+h_{fe})X_{CE}$$

Hence, $$X_{CE} = \frac{h_{ie}}{1+h_{fe}} = h_{ib}$$

$$\therefore \quad C_E = \frac{1}{2\pi f_L X_{CE}} = \frac{1}{2\pi f_L h_{ib}}$$

→ The coupling capacitors C_1 and C_2 have negligible effect on the frequency response of the amplifier circuit and to minimize the effects of these capacitors, the reactance of each coupling capacitor is selected to be approximately equal to one-tenth of the impedance in series with it at the lower cut-off frequency f_L.

→ These capacitances can be determined from the equations given by,

$$C_1 = \frac{1}{2\pi f_L X_{C1}} \quad \text{where} \quad X_{C1} = \frac{Z_i}{10} = \frac{(R_1||R_2||h_{ie})}{10}$$

and $$C_2 = \frac{1}{2\pi f_L X_{C2}} \quad \text{where} \quad X_{C2} = \frac{Z_o}{10} = \frac{R_C||R_L}{10}$$

Prob①: Design a single stage RC coupled BJT amplifier circuit. Assume that $V_{CC} = 10V$, $I_C = 4mA$, $h_{fe} = 100$, $h_{ie} = 1K\Omega$, $R_L = 100K\Omega$ and $f_L = 100$

Sol^n: ⓐ To determine R_1, R_2, R_C & R_E.

$$V_E = \frac{V_{CC}}{10} = \frac{10}{10} = 1V, \quad V_{CE} = \frac{V_{CC}}{2} = 5V.$$

$$R_C = \frac{V_{CC} - V_{CE} - V_E}{I_C} = \frac{10-5-1}{4m} = 1K\Omega$$

$$V_E = I_E R_E \approx I_C R_E$$

$$\therefore R_E = \frac{V_E}{I_C} = \frac{1}{4\times10^{-3}} = 250\,\Omega$$

$$V_B = V_{BE} + V_E = 0.7 + 1 = 1.7V$$

$$V_B = \left(\frac{R_2}{R_1+R_2}\right)V_{CC} \Rightarrow \frac{R_2}{R_1+R_2} = \frac{V_B}{V_{CC}} = \frac{1.7}{10} = 0.17$$

$$R_2 = 0.17(R_1+R_2)$$

$$5.88 R_2 = R_1 + R_2$$

$$4.88 R_2 = R_1 \Rightarrow R_1 = 19.52K\Omega \approx 20K\Omega$$

$R_2 = \frac{V_B}{I_2}$ where $I_2 = \frac{V_{..}}{..}$

$R_2 \approx 4K\Omega$

$R_1 = \frac{V_{CC} - V_B}{I_2} \approx 20K\Omega$

R_2 can be selected to satisfy $\beta R_E >> R_2$. Hence R_2 is selected as $2K\Omega$. Therefore $R_1 = 9.76K\Omega \approx 10K\Omega$.

The value of R_2 can be selected as $2K\Omega$. Therefore $R_1 = 9.76K\Omega \approx 10K\Omega$.

ⓑ To determine the bypass capacitor C_E:

$$X_{CE} = \frac{h_{ie}}{1+h_{fe}} = \frac{1\times10^3}{1+100} = 9.9$$

$$C_E = \frac{1}{2\pi f_L X_{CE}} = \frac{1}{2\pi\times100\times9.9} = \frac{1}{6217.2} = 160.8\,\mu F$$

ⓒ To determine coupling capacitors C_1 and C_2:

$$X_{C_1} = \frac{Z_i}{10} = \frac{R_1 \| R_2 \| h_{ie}}{10} = 246.154$$

$$C_1 = \frac{1}{2\pi f_L X_{C_1}} = 6.47\,\mu F$$

$$X_{C_1} = \frac{R_1 \| R_2 \| h_{ie}}{10} = \frac{3.3K \| 1K}{10} = \frac{767.1}{10} = 76.7$$

$$C_1 = \frac{1}{2\pi f_L X_{C_1}} = 2\times10^{-5}F = 0.2\,\mu F$$

$$X_{C_2} = \frac{Z_o}{10} = \frac{R_C \| R_L}{10} = 99.001$$

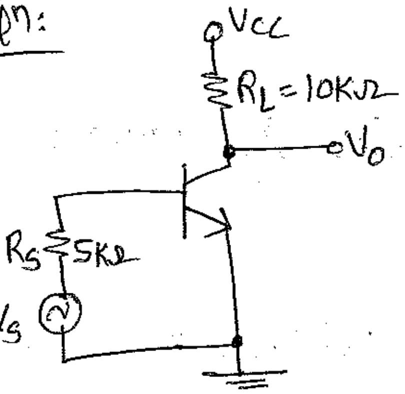
$$C_2 = \frac{1}{2\pi f_L X_{C_2}} = 0.1608\,\mu F.$$

Conversion formulae for hybrid parameters:

CC	CB
$h_{ic} = h_{ie}$	$h_{ib} = \frac{h_{ie}}{1+h_{fe}}$
$h_{rc} = 1$	$h_{rb} = \frac{h_{ie} h_{oe}}{1+h_{fe}} - h_{re}$
$h_{fc} = -(1+h_{fe})$	$h_{fb} = \frac{-h_{fe}}{1+h_{fe}}$
$h_{oc} = h_{oe}$	$h_{ob} = \frac{h_{oe}}{1+h_{fe}}$

1) The hybrid parameters for a transistor used in CE configuration are $h_{ie} = 1K\Omega$, $h_{fe} = 150$, $h_{oe} = 25\times10^{-6}$. The transistor has a load resistance of $10K\Omega$ in the collector and is supplied from a signal source of resistance $5K\Omega$. Compute the values of input impedance, output impedance, current gain and voltage gain. [Dec' 2013] 7

Solⁿ:



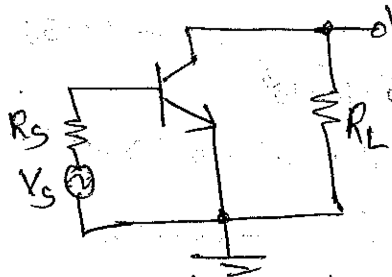
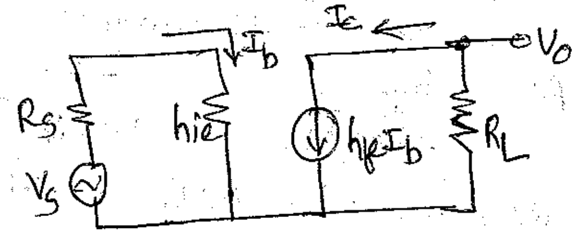


Fig: AC equivalent ckt.



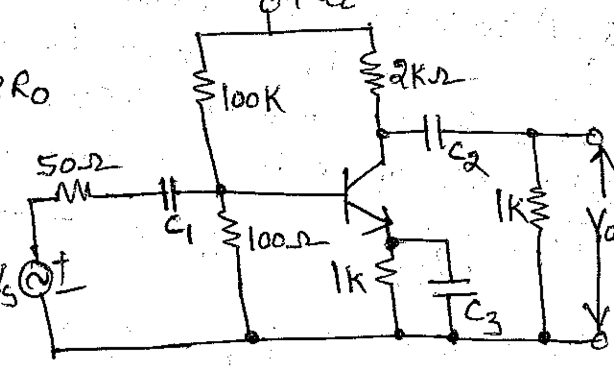
$R_o = \infty$ $\left\{ \because V_s = 0,\ I_b = 0,\ I_c = 0 \Rightarrow R_o = \frac{V_o}{I_c} = \infty \right.$

$$A_i = \frac{I_o}{I_i} = \frac{-h_{fe} I_b}{I_b} = -h_{fe} = -150$$

$$R_i = \frac{V_i}{I_i} = \frac{h_{ie} I_b}{I_b} = h_{ie} = 1K\Omega$$

$$A_V = \frac{V_o}{V_i} = \frac{-h_{fe} I_b R_L}{h_{ie} I_b} = \frac{-h_{fe} R_L}{h_{ie}} = \frac{-150\times10\times10^3}{1\times10^3} = -1500$$

2) For the circuit shown in figure estimate A_i, A_v, R_i & R_o using reasonable approximations. The h-parameters for the transistor are given as $h_{fe} = 100$, $h_{ie} = 2K\Omega$, h_{re} is negligible & $h_{oe} = 10^{-5}$ mhos.



[May' 2012] 8M

Solⁿ:

$$h_{oe}\times R_L' = h_{oe}(R_c \| R_L) = 10^{-5}\times(2K\|1K) = 0.666\times10^{-2} < 0.1$$

so use approximate analysis.

$$A_i = -h_{fe}\frac{R_B}{R_B + h_{ie}}, \quad R_B = R_1 \| R_2 = 100K \| 100 = 99.9\Omega$$

$$A_i = \frac{-100\times 99.9}{99.9 + 2\times10^3} = -4.76$$

$$R_i = R_B \| h_{ie} = (99.9 \| 2K)\,\Omega = 95.14\,\Omega$$

$$A_V = \frac{-h_{fe}(R_c \| R_L)}{h_{ie}} = \frac{-100\times(2K\|1K)}{2\times10^3} = -33.3$$

$$R_o = \infty$$

3) Draw the circuit diagram of Emitter follower and derive the equation for A_V & A_I. [May' 2012] 7M

4) Draw the simplified hybrid model for the CC circuit and derive expressions for R_i, R_o, A_V and A_i. [May' 2012] 8M

5) State and prove dual of Miller's theorem. $\boxed{\text{May'2012}}$ 7M

6) For a CE amplifier calculate A_V, R_i, R_o and A_i if $R_L = 10K\Omega$, $h_{ie} = 1.1K\Omega$, $h_{re} = 2.5\times10^{-4}$, $h_{fe} = 50$ and $h_{oe} = 24\,\mu A/V$. $\boxed{\text{May'2012}}$ 8M

Soln: $h_{oe} \times R_L = 24\times10^{-6} \times 10\times10^{3} = 0.24 > 0.1$

So use exact analysis.

$$A_i = \frac{-h_{fe}}{1+h_{oe}R_L} = \frac{-50}{1+24\times10^{-6}\times10\times10^{3}} = -40.32$$

$$R_i = h_{ie} + h_{re}A_iR_L = 1.1\times10^{3} + 2.5\times10^{-4}\times(-40.32)\times10\times10^{3} = 999.2\,\Omega$$

$$A_V = \frac{A_iR_L}{R_i} = \frac{-40.32\times10\times10^{3}}{999.2} = -403.52.$$

$$Y_o = h_{oe} - \frac{h_{fe}h_{re}}{h_{ie}+R_s} = 24\times10^{-6} - \frac{50\times2.5\times10^{-4}}{1.1\times10^{3}+0} = 12.64\times10^{-6}$$

$$R_o = \frac{1}{Y_o} = 79.11K\Omega$$

7) Draw the CE amplifier with unbypassed emitter resistance and derive expressions for R_i & A_V. $\boxed{\text{Jan'2012}}$ 7M

8) A transistor in CB circuit has the following set of h-parameters $h_{ib} = 20\,\Omega$, $h_{fb} = -0.98$, $h_{rb} = 3\times10^{-4}$, $h_{ob} = 0.5\,\mu A/V$. Find the values of R_i, R_o, A_i & A_V if $R_s = 600\,\Omega$ and $R_L = 1.5K\Omega$. $\boxed{\text{Jan'2012}}$ 8M.

Soln: Use approximate analysis.

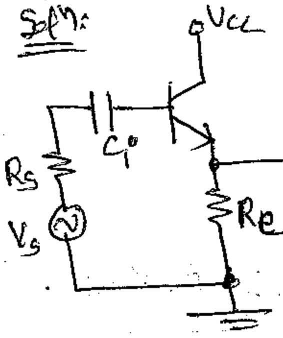
$$A_i = \frac{h_{fe}}{1+h_{fe}} = -h_{fb} = -(-0.98) = 0.98 \qquad R_o = \infty$$

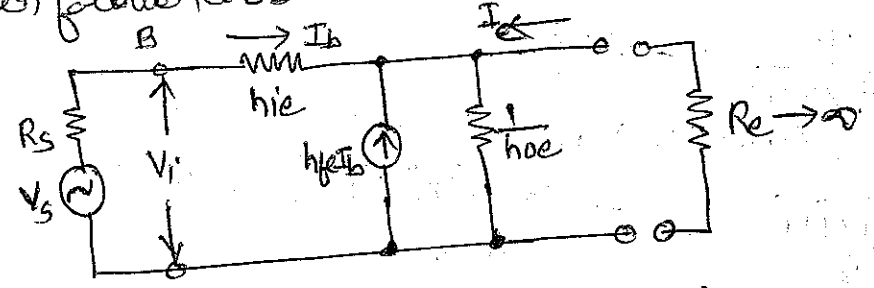
$$R_i = \frac{h_{ie}}{1+h_{fe}} = h_{ib} = 20\,\Omega$$

$$A_V = \frac{A_iR_L}{R_i} = \frac{0.98\times1.5\times10^{3}}{20} = 73.5$$

9) Consider an emitter follower and show that as $R_e \to \infty$, $R_i = h_{ie} + \frac{1+h_{fe}}{h_{oe}}$. $\boxed{\text{Jan'2012}}$ 7M

Soln:



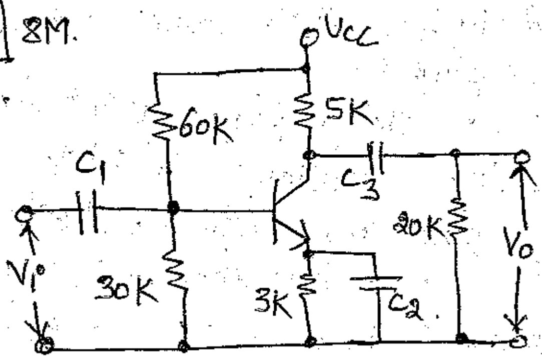


$$R_i = \frac{V_i}{I_i} = \frac{h_{ie}I_b + \frac{1}{h_{oe}}\times(I_b + h_{fe}I_b)}{I_b}$$

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

10) State Miller's theorem and its dual. $\boxed{\text{Jan'2012}}$ 8M.

11) For the circuit shown in figure estimate A_V and R_i. Assume $\frac{1}{h_{oe}}$ is large compared with load seen by the transistor. All capacitors have negligible reactance at the test frequency, $h_{ie} = 1K\Omega$, $h_{fe} = 99$ and h_{re} is negligible.



$\boxed{\text{Jan'2012}}$ 8M.

Soln: $R_i = (R_1 \| R_2) + h_{ie} = (60K \| 30K) + 1K = 21K\Omega$

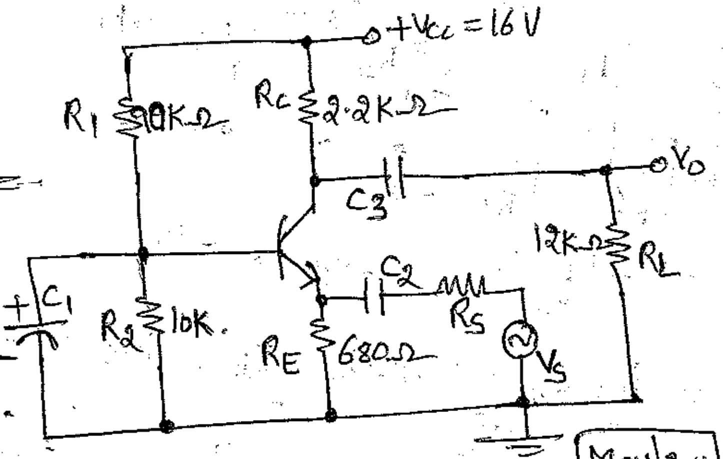
$$A_V = \frac{A_i Z_L}{Z_i} \qquad A_i = -h_{fe} = -99$$

$$Z_L = R_C \| R_L = (5K \| 20K)\Omega = 4K\Omega$$

$$Z_i = R_i$$

$$\therefore A_V = \frac{-99 \times 4 \times 10^3}{21 \times 10^3} = -18.86$$

11) For the CE amplifier circuit shown, compute R_i and R_o if C_1 is (a) connected (b) Not connected. The h-parameters are $h_{ie} = 2.1K\Omega$, $h_{fe} = 81$, $h_{oe} = 1.66\,\mu$ mhos & h_{re} negligible.



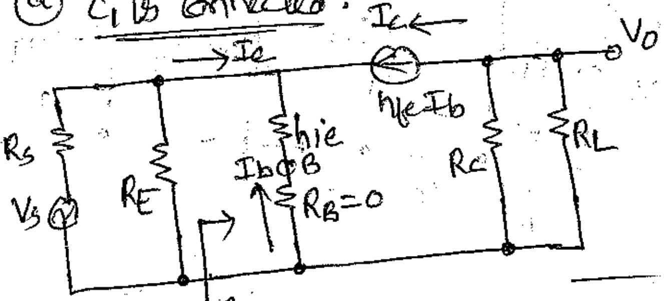
$\boxed{\text{May'2011}}$ 9M

Soln: $h_{oe} \times R_L' = h_{oe} \times (R_C \| R_L) = 1.66 \times 10^{-6} \times (2.2K \| 12K)$

$$= 3.08 \times 10^{-3} < 0.1$$

So use approximate analysis.

(a) C_1 is connected:



$$R_i = \frac{V_i}{I_i}; \quad V_i = -h_{ie} I_b$$

$$I_i = I_e$$

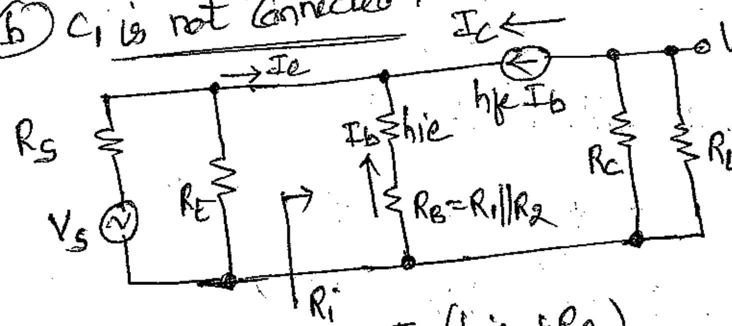
$$I_i = -(1+h_{fe}) I_b$$

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

$$R_i = \frac{h_{ie}}{1+h_{fe}} = \frac{2.1 \times 10^3}{1+81}$$

$$R_i = 25.6\,\Omega$$

(b) C_1 is not connected:



$$R_i = \frac{V_i}{I_i}; \quad V_i = -I_b (h_{ie} + R_B)$$

$$I_i = I_e = -(1+h_{fe}) I_b$$

$$\therefore R_i = \frac{-I_b (h_{ie} + R_B)}{-(1+h_{fe}) I_b} = \frac{h_{ie} + (R_1 \| R_2)}{1+h_{fe}}$$

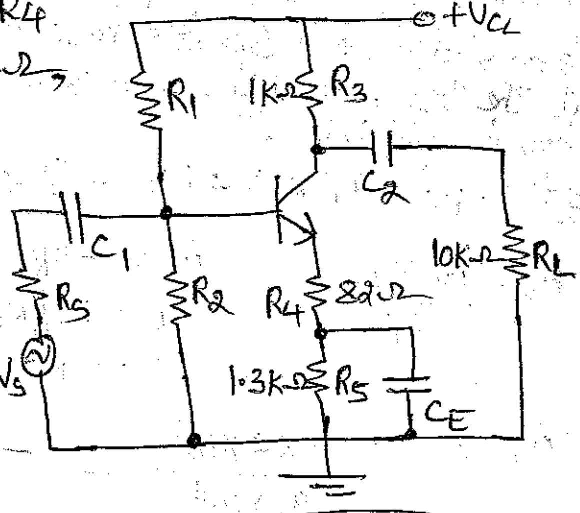
$$\therefore R_i = \frac{2.1 \times 10^3 + (90K \| 10K)}{1+81}$$

$$R_i = \cancel{8\ldots}\ 135.4\,\Omega$$

$R_o = \infty$ in both the cases.

12) Reason out the causes and results of phase & frequency distortions in transistor amplifiers. May 2011 6M

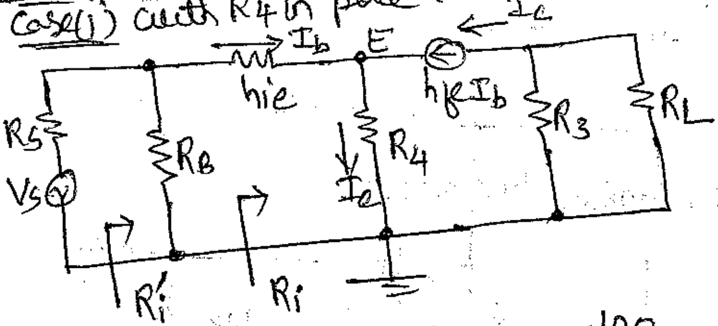
13) For the amplifier circuit shown with partially unbypassed emitter resistance, calculate the Voltage gain with R_4 in place and with R_4 shorted. Consider $h_{ie} = 1.1K\Omega$, $h_{fe} = 100$, h_{re} & h_{oe} are negligibly small.
Assume $R_1 = 100K\Omega$ & $R_2 = 22K\Omega$.



May 2011 10M

Soln:

Case(i) with R_4 in place.



$$A_i = \frac{-h_{fe} I_b}{I_b} = -h_{fe} = -100$$

$$R_i = \frac{h_{ie} I_b + R_4(1+h_{fe}) I_b}{I_b} = h_{ie} + (1+h_{fe})R_4 = 1.1\times10^3 + (1+100)\times 82 = 9.382K$$

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

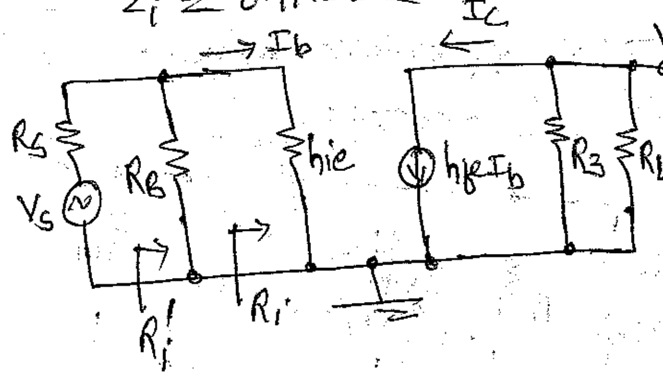
$$Z_L = R_3 || R_L = 1K||10K = 909.09\Omega$$

$$Z_i = R_i' = R_i||R_B = R_i||R_1||R_2 = (9.382K||100K||22K)\Omega$$

$$Z_i = 6.1K\Omega$$

$$A_V = \frac{-100\times 909.09}{6.1\times10^3} = -14.9$$

Case(ii) with R_4 shorted



$$A_i = \frac{-h_{fe} I_b}{I_b} = -h_{fe} = -100$$

$$R_i = \frac{h_{ie} I_b}{I_b} = h_{ie} = 1.1K\Omega$$

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

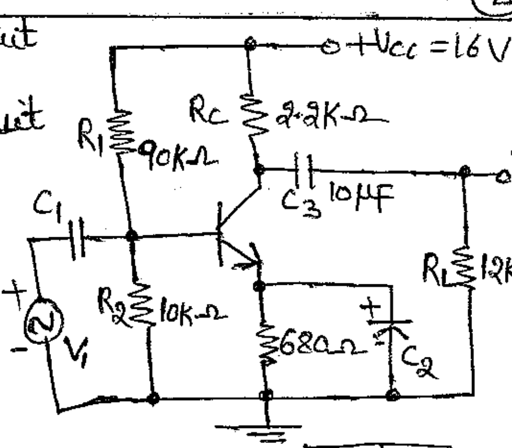
$$Z_L = R_3||R_L = 909.09\Omega$$

$$Z_i = R_i||R_1||R_2 = (1.1K||100K||22K)\Omega = 1.036K\Omega$$

$$A_V = \frac{-100\times 909.09}{1.036\times10^3} = -87.74$$

14). Analyse what the output Voltage should be if the dc power supply given to a CE amplifier is shorted to ground. May 2011 5M.

15) For the CE amplifier shown determine the peak to peak output Voltage for a sinusoidal input Voltage of 30mV peak to peak. Assume C_1, C_2 and C_3 are large enough to act as short circuit at the input frequency. Consider $h_{ie} = 1.1K\Omega$ & $h_{fe} = 100$.



May 2011 7M

Sol^n: $A_V = \frac{V_o}{V_i} \Rightarrow V_o = A_V \cdot V_i$

$A_V = \frac{-h_{fe} Z_L}{Z_i}$; $Z_L = R_C || R_L = 2.2K || 12K = 1.86K\Omega$

$Z_i = h_{ie} || R_1 || R_2 = 1.1K || 90K || 10K = 980.2\Omega$

$A_V = \frac{-100 \times 1.86 \times 10^3}{980.2} = -189.7$

$V_o = |A_V| \cdot V_i = 189.7 \times 30 \times 10^{-3} =$ 5.691 V peak to peak.

16) State Miller's theorem. Specify its relevance in the analysis of a BJT amplifier. May 2011 4M

17) Write expressions for Av and Ri of a CE amplifier. May 2011 4M

18) Draw the circuit diagram of a cc amplifier along with its equivalent circuit. May 2011 7M
Derive expressions for Av and Ri.

19) What is meant by small signal for analysing a BJT based amplifier? May 2011 4M

20) What is non-linear distortion? List the causes for this type of distortion in amplifiers. May 2011 4M

[illegible]

[illegible]