$$A_r = \frac{v_o}{v_s} = \left(\frac{r_\pi + R_1 // R_2 // R_s}{1+\beta}\right) // R_E // r_o$$

$= 0.962 \approx 1$

lecture 10: 23/3/2014

last example continues:-

$$R_o = \frac{V_x}{i_x}$$

Kcl at node x:

$$I_x + g_m V_\pi = \frac{V_x}{R_E} + \frac{V_x}{r_o} + \frac{V_x}{r_\pi + r_s // R_1 // R_2} \rightsquigarrow ①$$

~~$V_\pi = -V_x$~~

$$V_\pi = -V_x \frac{r_\pi}{r_\pi + R_s // R_1 // R_2} \rightsquigarrow ②$$

⇝ Sub 2 in 1

$$R_o = \frac{V_x}{i_x} = \left(\frac{r_\pi + R_1 // R_2 // R_s}{1+\beta}\right) // R_E // r_o$$

$\boxed{R_o = 36.6\ \Omega}$ ⇝ very low value.

⇝ Current gain:

$$A_i = \frac{i_o}{i_{in}}$$

$$i_o = (1+\beta)\, i_b \frac{r_o}{r_o + R_E}$$

$$i_b = i_{in} \frac{R_1//R_2}{R_1//R_2 + \underbrace{R_{ib}}_{r_\pi + (1+\beta)(r_o//R_E)}} \quad \text{②}$$

Sub 2 in 1

$$A_i = \frac{i_o}{i_{in}} = (1+\beta)\left(\frac{R_1//R_2}{R_1//R_2 + R_{ib}}\right)\left(\frac{r_o}{r_o + R_E}\right)$$

typically , $r_o \gg R_E$

So the term $\frac{r_o}{r_o + R_E} \approx 1$

& $R_1//R_2 \gg R_{ib}$

also the term $\frac{R_1//R_2}{R_1//R_2 + R_{ib}} \approx 1$

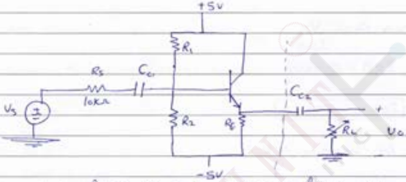
So $A_i \approx (1+\beta) \approx \beta$

Ex: design a Common Collector amplifier that Connects a Voltage Source (Microphone) with $R_S = 10\ k\Omega$ with a load ~~(speaker)~~ that has R_L changes from $4\ k\Omega$ to $20\ k\Omega$.

we want to design CC amplifier such that the output Voltage does not vary by more than 5%.

given $V_{CC} = 5V$

$\beta = 100$



we want to find R_1, R_2 & R_E that satisfied the requirement.

⇝ 5% means that 95% $\le V_L \le V_o$

$$.95\,V_o = V_o \frac{\overset{4k\Omega}{R_L}}{\underset{4k\Omega}{R_L}+R_o} \rightarrow R_o = 200\,\Omega$$

for CC.

$$R_o = \left(\frac{r_\pi + R_1 \| R_2 \| R_S}{1+\beta}\right) \| R_E \| r_o$$

Usually $R_1 \| R_2 \gg R_S$

⇝ $\frac{r_\pi + R_1 \| R_2 \| R_S}{1+\beta} \ll R_E \| r_o$

⇝ $R_o \approx \frac{r_\pi + R_S}{1+\beta}$

⇝ $\boxed{r_\pi = 10.2\ k\Omega}$

$\rightsquigarrow r_\pi = \frac{V_T}{I_{BQ}}$

$I_{BQ} = 2.55 \mu A$

$\rightsquigarrow \boxed{I_{CQ} = .255 mA}$

let $V_{CEQ} = 5 V$

output loop:

$-5 + V_{CEQ} + I_E R_E - 5 = 0$

$\rightsquigarrow R_E = 19.6 k\Omega$

for stability:

$R_{th} = 0.1(1+\beta) R_E$

So $\underset{R_1 \parallel R_2}{R_{th}} = 198 k\Omega$

$-V_{th} + R_{th} I_{BQ} + .7 + I_{EQ} R_E - 5 = 0$

we can find V_{th}

$V_{th} = \left(\frac{R_2}{R_1 + R_2}\right)(10) - 5$

$= \overbrace{\frac{R_1}{R_1}\left(\frac{R_2}{R_1+R_2}\right)}^{R_{th}}(10) - 5$

$R_1 = 344 k\Omega$

$R_2 = 467 k\Omega$

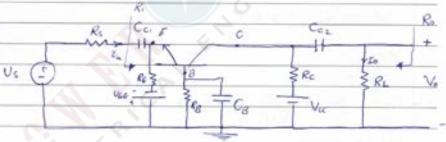
No.

lecture 10 25/3/2014

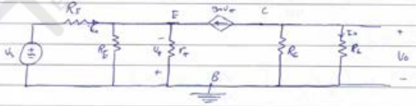
* Common Base Amplifier (CB)

→ Features:-

1. $A_v > 1$
2. $A_i \approx 1$
3. Small R_i
4. high R_o
5. CB amplifier ≡ Ideal current Source.
6. used if the input signal is a current.



find: $A_v = \frac{V_o}{V_s}$, $A_i = \frac{i_o}{i_i}$, R_o, R_i



* Coupling capacitor Features:-

1. protect load & the source.
2. protect the location of Q point

$A_v = \frac{V_o}{V_s}$.

⇝ $V_o = -g_m V_\pi \left(R_L // R_c \right)$

⇝ Kcl at node E

$$g_m V_\pi + \frac{V_\pi}{r_\pi} + \frac{V_\pi}{R_E} + \frac{V_s - (-V_\pi)}{R_s} = 0 \rightsquigarrow ②$$

use 1 & 2

$$A_v = g_m \left(\frac{R_c // R_L}{R_s} \right) \left[\left(\frac{V_\pi}{1+\beta} \right) // R_E // R_s \right]$$

if $R_s = 0\,\Omega$

$$A_v = g_m \left(R_c // R_L \right)$$

$A_i = \frac{i_o}{i_{in}}$

⇝ $I_o = -g_m V_\pi \frac{R_c}{R_c + R_L}$ ⇝ ①

Kcl at Emitter

$$i_{in} + g_m V_\pi + \frac{V_\pi}{R_E} + \frac{V_\pi}{r_\pi} = 0$$

$$V_\pi = -i_{in} \left[\left(\frac{r_\pi}{1+\beta} \right) // R_E \right] \rightsquigarrow ②$$

from 1 & 2

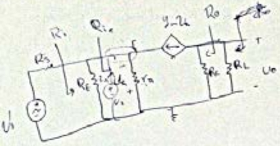
$$A_i = g_m \left(\frac{R_c}{R_c + R_L} \right) \left[\left(\frac{r_\pi}{1+\beta} \right) // R_E \right]$$

usually for practical CB , R_E very high Value
R_L very small Value.

$$A_i \approx \frac{g_m r_\pi}{1+\beta} = \frac{\beta}{1+\beta} = \alpha = .99 \approx 1$$

CB amplifier

①



$R_i = R_E \parallel R_{ie}$

$R_{ie} = \frac{v_x}{i_x}$

KCL @ node E :- $i_x + \frac{v_\pi}{r_\pi} + g_m v_\pi = 0$

but $v_\pi = -v_x$ $\Rightarrow$ $i_x - \frac{v_x}{r_\pi} - g_m v_x = 0$

$R_{ie} = \frac{v_x}{i_x} = \frac{r_\pi}{1 + r_\pi g_m} = \frac{r_\pi}{1+\beta}$ small value

$R_i = R_E \parallel R_{ie}$ small value

⇒ R_o:

kill the independent source

KCL @ C :- $i_x - \frac{v_x}{R_C} - g_m v_\pi = 0$ ~ ①

KCL @ E = $g_m v_\pi + \frac{v_\pi}{r_\pi} + \frac{v_\pi}{R_E} + \frac{v_\pi}{R_s} = 0 \Rightarrow v_\pi \left(g_m + \frac{1}{r_\pi} + \frac{1}{R_E} + \frac{1}{R_s}\right) = 0$

from ① $\Rightarrow R_o = \frac{v_x}{i_x} = R_C$ $\therefore v_\pi = 0$

First

*- Multi-stage Amplifier :-

It's used to satisfy some requirement, that can't be satisfied by single stage.

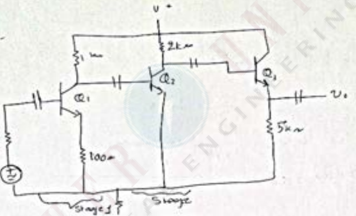
Example :- • CE without R_E
=> has a high A_v but unstable.

- CE with R_E

=> has low A_v but stable

• CC has $A_v = 1$ but high R_i and low R_o

Ex :-



For Q_1 : $\beta = 100$, $r_\pi = 1\,k\Omega$

" Q_2 & Q_3 = $\beta = 100$, $r_\pi = 0.5\,k\Omega$

Find $A_v = \dfrac{v_o}{v_s}$

Solution :-

Stage 1 :- CE w/ R_E :-

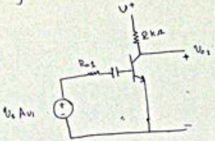
$$A_{v_1} = \frac{-\beta R_C}{r_\pi + (1+\beta) R_E} \left(\frac{R_i}{R_i + R_s} \right) \Rightarrow R_i = [r_\pi + (1+\beta) R_E] // \underbrace{R_1 // R_2}_{\infty}$$

$R_i = r_\pi + (1+\beta) R_E$

$$\boxed{A_{v_1} = -7.63}$$

$\{ \; R_o = R_C = 1\,k\Omega$

Stage2: CE without R_E

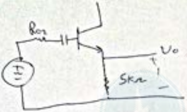


$$A_{v_2} = -g_m\left(\frac{\overset{\infty}{\overbrace{R_1\|R_2}}\|r_\pi}{R_1\|R_2\|r_\pi+\underbrace{R_s}_{R_{o1}}}\right)(\underset{\infty}{r_o}\|R_C)$$

$$\boxed{A_{v_2} = -133}$$

$$R_{o2} = \cancel{r_o}\|R_c = 2k\Omega$$

Stage 3 :- CC



$$A_{v_3} = 1$$

$$v_o = v_s A_{v_1} A_{v_2} A_{v_3}$$

$$\therefore A_v = \frac{v_o}{v_s} = \overset{-768}{A_{v_1}}\,\overset{-13}{\cancel{A_{v_2}}}\,\overset{1}{A_{v_3}}$$

$$= 1010$$