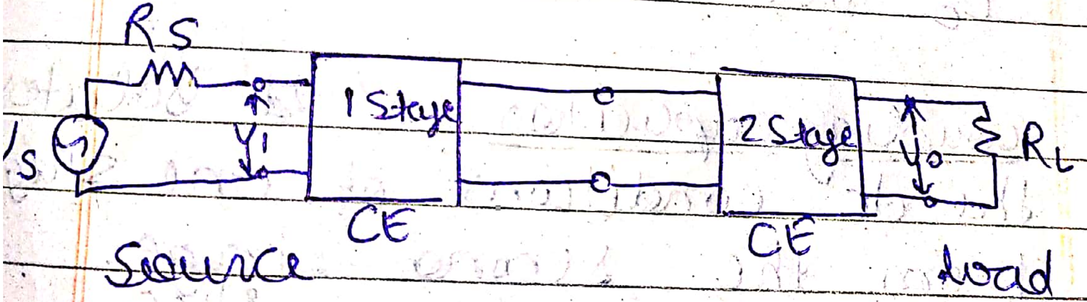
AE Unit - 2

Multistage amplifiers
→ the output of one stage is fed as input to next
→ Such a connection is known as cascading.
→ A multistage amplifier using two or more single stage amplifiers (common emitter) is called as cascaded amplifiers
→ A multistage amplifier with Common emitter as first stage and common base as second stage is called as cascode amplifier



cascade amplifier

When amplifiers are cascaded, it is necessary to use a Coupling network b/w the output of one amplifier and the input of following amplifier

This type of coupling called <u>inter stage coupling</u>.

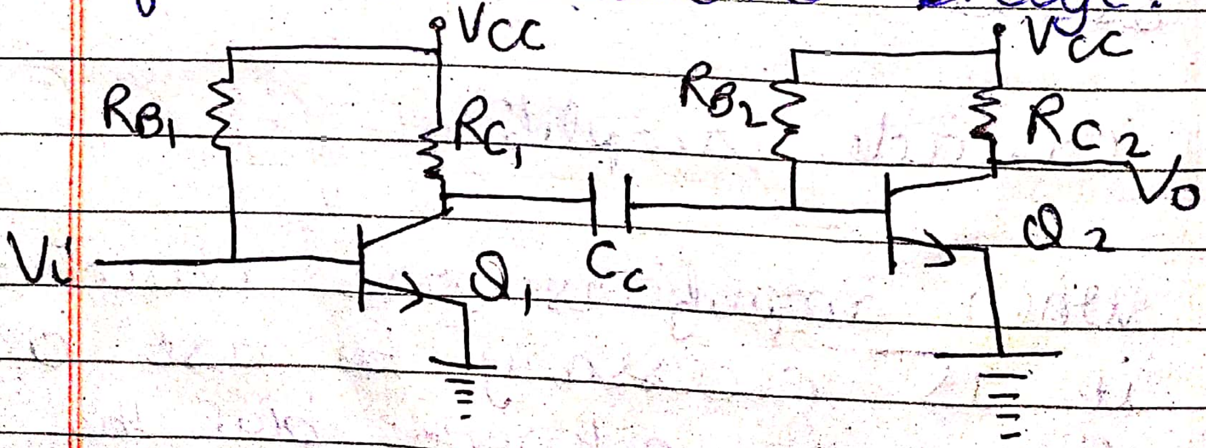
(i) It transfer ac output of one stage to input of next stage

(ii) It isolates the dc conditions of one stage to next.

1. RC coupling

In this method, signal developed across the collector resistance R_C of each stage coupled with coupling capacitor C_C into the base of next stage

<u>coupling capacitor</u> → It isolates the dc conditions of one stage from the second stage.



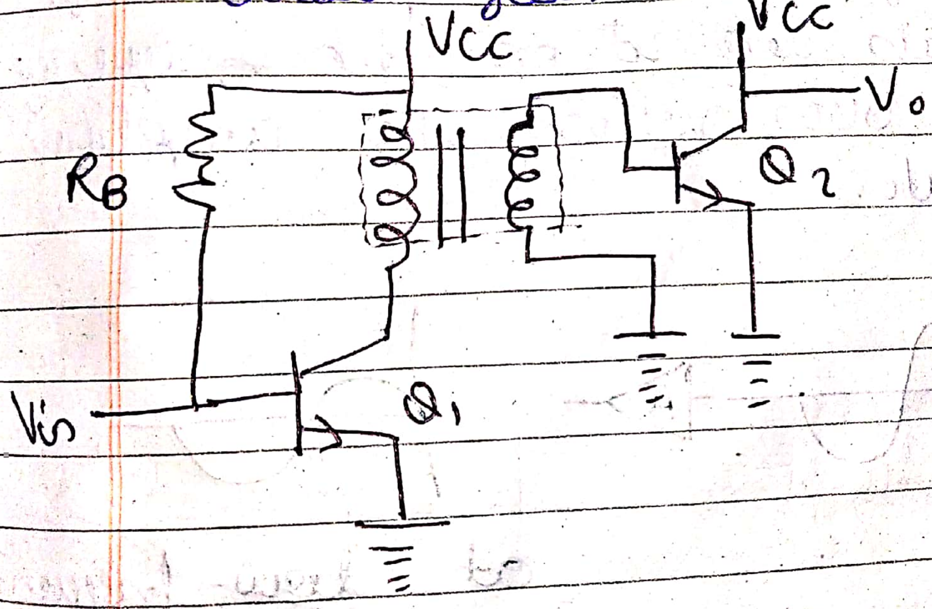
2. Transformer coupling

→ In this method, the primary winding of the transformer acts as a collector load and the secondry winding transfers the ac output signal to the base of next stage

→ transformers are very expensive.

→ mostly use in power amplifiers

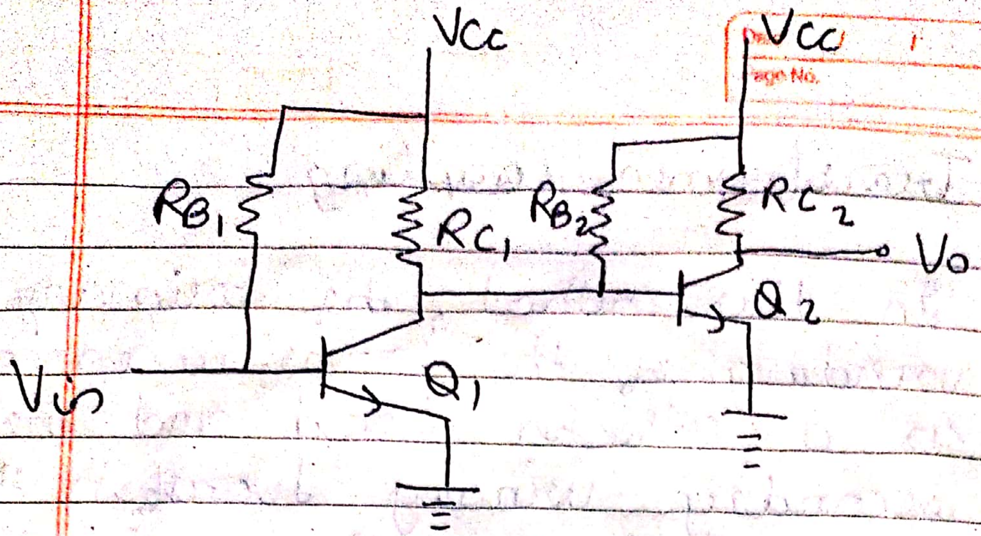
→ this type of coupling increase overall gain.



3. Direct coupling

→ In this method the ac output signal is fed directly to the next stage.

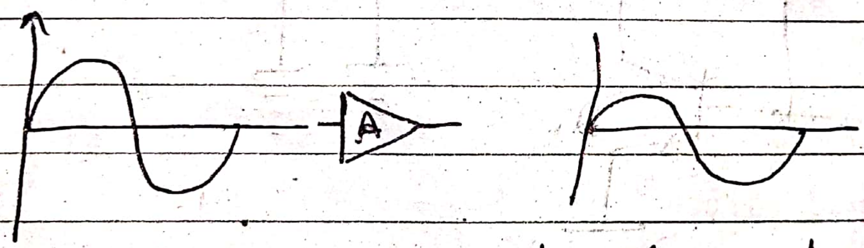
→ It is used for amplification of low frequency signals.



Frequency response

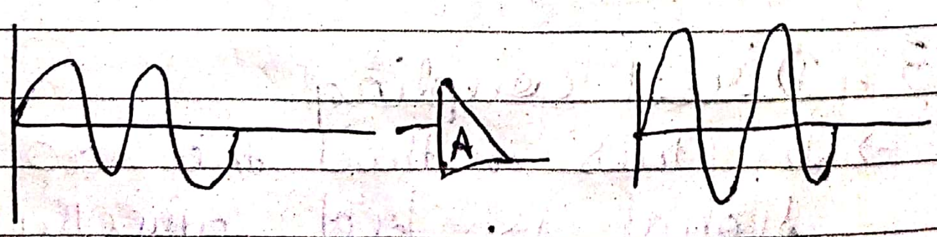
The voltage gain of the amplifier and the phase shift of gain depend on the frequency range over which the amplifier operate.

①



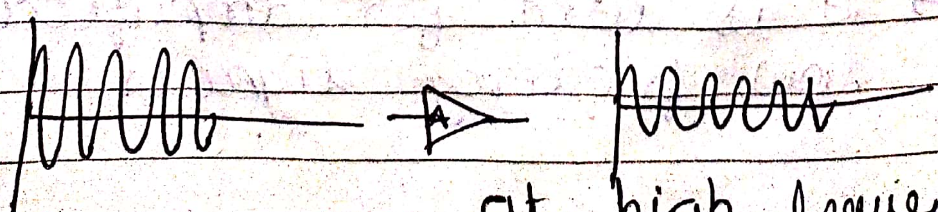
at low frequency

②

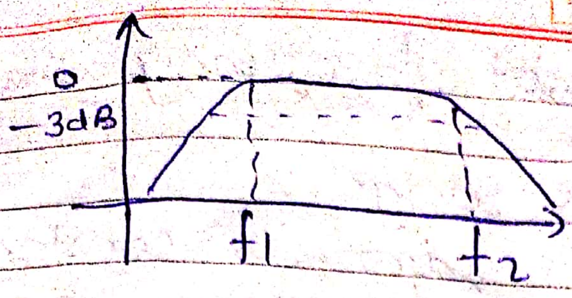


at mid frequency

③



at high frequency



① At low frequency

Voltage gain fall
→ because coupling and bypass capacitor no longer act as a short circuit

Voltage gain (A_{VL})

$$A_{VL} = \frac{V_o}{V_i} = \frac{R_1}{R_1 - j\left(\frac{1}{\omega C_1}\right)}$$

$$A_{VL} = \frac{1}{1 - j\left(\frac{1}{\omega R_1 C_1}\right)}$$

$A_{VL} = 0.707$ $\boxed{A_{VL} = \frac{1}{1 - j\left(\frac{f_L}{f}\right)}}$, $f_L = \frac{1}{2\pi R_1 C_1}$

$$|A_{VL}| = \frac{1}{\sqrt{1 + \left(\frac{f_L}{f}\right)^2}}$$

$$\boxed{\theta_1 = -\tan^{-1}\left(\frac{f_L}{f}\right)}$$

2. At mid frequency

In this range
→ Voltage gain is constant
→ In mid frequency range all the capacitive reactances are neglected as compared with associated resistances. ($A_{vm} = 1$)

3. High frequency range

$$A_{VH} = \frac{V_o}{V_i} = \frac{\frac{1}{j\omega C_2}}{R_2 + \left(\frac{1}{j\omega C_2}\right)}$$

$$= \frac{1}{1 + j\omega R_2 C_2}$$

$$A_{VH} = \frac{1}{1 + j2\pi f R_2 C_2}$$

Voltage gain, $\boxed{A_{VH} = \frac{1}{1 + j\left(\frac{f}{f_H}\right)}}$ $A_{VH} = 0.707$

$$\theta = -\tan^{-1}\left(\frac{f}{f_H}\right)$$

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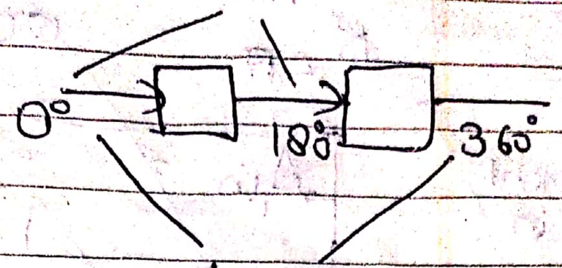
General Analysis



Voltage gain

The voltage gain of the complete cascade amplifier is equal to the product of the voltages gain of individual stages

for first stage, $A_{V_1} = \frac{V_2}{V_1}$

for second stage, $A_{V_2} = \frac{V_3}{V_2}$

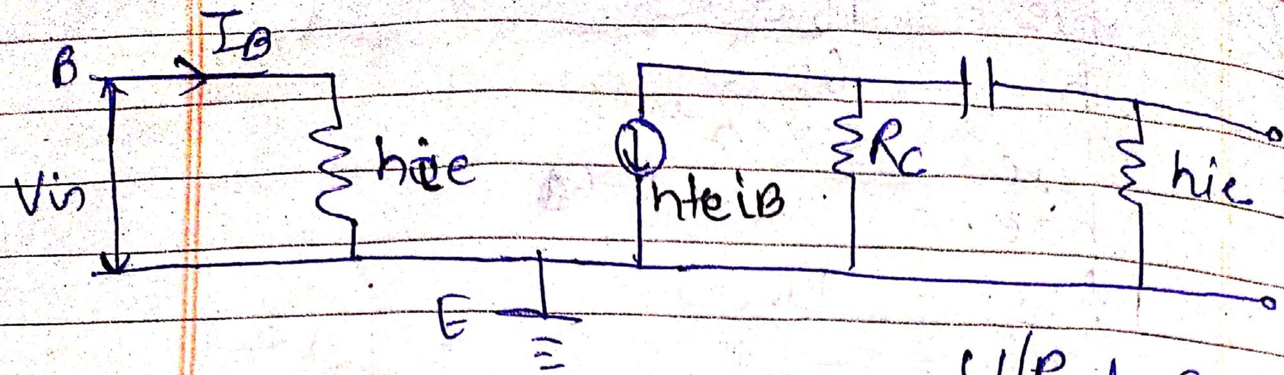
The resultant voltage gain

$$A_V = \frac{V_o}{V_1}$$

$$\frac{V_o}{V_1} = \frac{V_2}{V_1} \times \frac{V_3}{V_2} \times \frac{V_4}{V_3} \times \cdots \frac{V_o}{V_n}$$

$$\boxed{A_V = A_{V_1} \times A_{V_2} \times A_{V_3} \cdots A_{V_n}}$$

$$\boxed{\theta = \theta_1 + \theta_2 + \theta_3 + \cdots \theta_n}$$

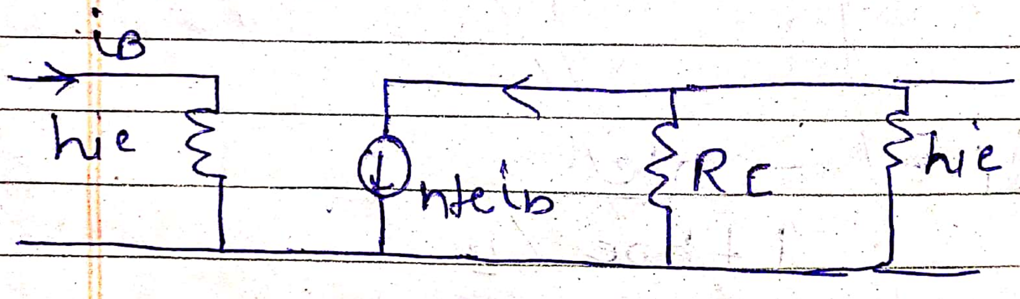


(I/P of second stage)

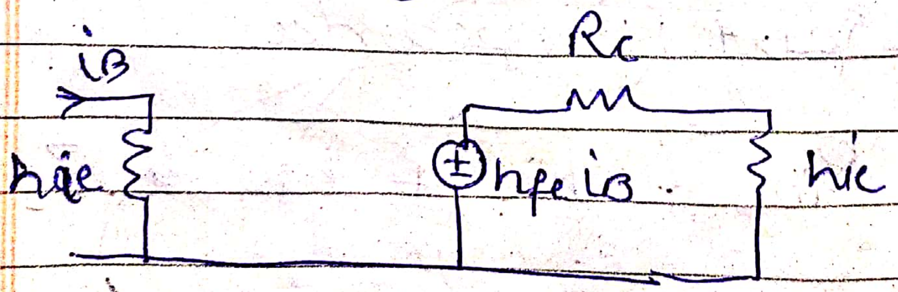
gain calculation

- mid frequency
- low frequency
- high frequency

① Mid frequency: X_C is small & it can be short circuited



⇓



$$I = I_L = \frac{h_{fe} i_B R_C}{R_C + h_{ie}}$$

$$A_i = -\frac{I_L}{I_B} \Rightarrow \boxed{A_i = -\frac{h_{fe} R_C}{R_C + h_{ie}}}$$

$$A_v = \frac{V_{out}}{V_{in}}$$

$$V_{out} = -\frac{h_{ie} h_{fe} i_B R_c}{R_c + h_{ie}}$$

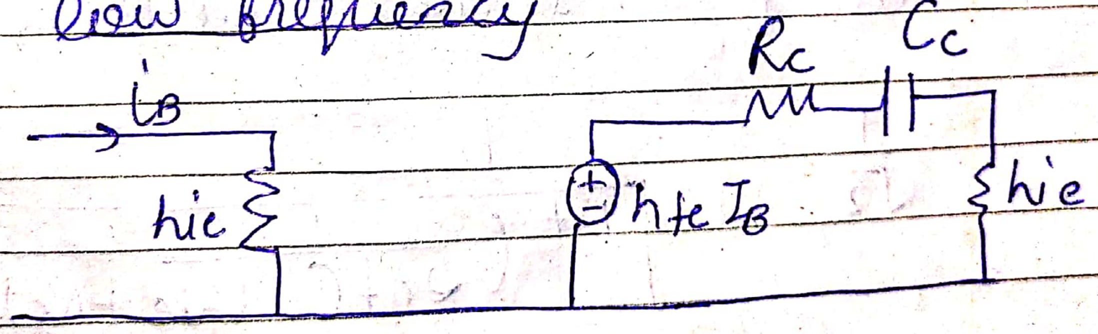
$$V_{in} = h_{ie} i_B$$

$$A_v = -\frac{h_{fe} \cancel{h_{ie} i_B} R_c}{(R_c + h_{ie}) \cancel{h_{ie} i_B}}$$

$$\boxed{A_v = -\frac{h_{fe} R_c}{R_c + h_{ie}}}$$

$\boxed{A_v = A_i}$ is equal

(2) Low frequency



$$I = \boxed{I_c = \frac{h_{fe} i_B R_c}{R_c + h_{ie} - j\frac{1}{\omega C_c}}}$$

$$\boxed{A_i = -\frac{I_c}{I_B} = \frac{h_{fe} R_c}{R_c + h_{ie} - \frac{j}{\omega C_c}}}$$

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$$\boxed{A_V = \frac{h_{fe} R_C}{h_{ie} + R_C - \frac{j}{\omega C_C}}}$$

$$|A_{VL}| = \frac{h_{fe} R_C}{\sqrt{(h_{ie} + R_C)^2 + \left(\frac{1}{2\pi f C_C}\right)^2}}$$

$$\left|\frac{A_{VL}}{A_{Vm}}\right| = \frac{\cancel{h_{fe} R_C} \times (R_C + h_{ie})}{\sqrt{(h_{ie} + R_C)^2 + \left(\frac{1}{2\pi f C_C}\right)^2}\ \cancel{h_{fe} R_C}}$$

$$= \frac{\cancel{R_C + h_{ie}}\ 1}{\sqrt{1 + \left(\frac{1}{2\pi f C_C \cdot (h_{ie} + R_C)}\right)^2}}$$

at f_1 = lower cutt of fre

$$\frac{1}{\sqrt{2}} = \frac{1}{\sqrt{1 + \left(\frac{1}{2\pi f C_C (h_{ie} + R_C)}\right)^2}}$$

$$1 + \left(\frac{1}{2\pi f C_C (h_{ie} + R_C)}\right)^2 = 2$$

$$\frac{1}{2\pi f C_C (h_{ie} + R_C)} = 1$$

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$$\boxed{f_L = \frac{1}{2\pi f C_c (h_{ie} + R_c)}}$$

low cutt off frequency

phase $\tan\theta = \frac{f_L}{f}$

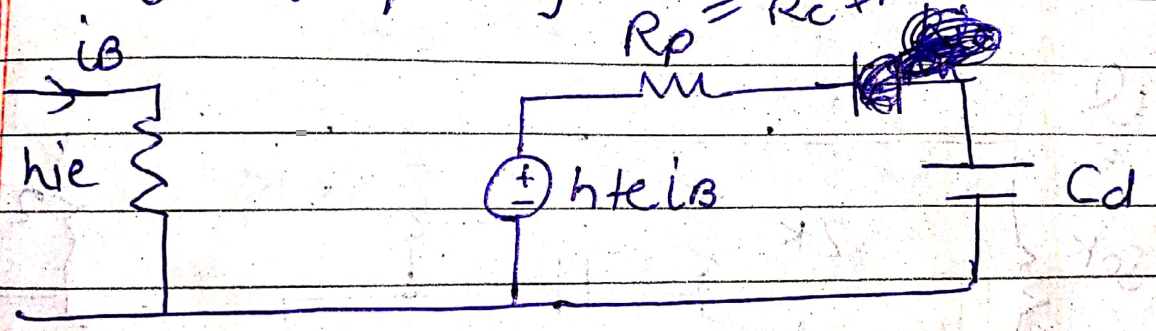
$$\theta_l = 180 + \tan^{-1}\left(\frac{f_L}{f}\right)$$

at $f = f_L$

$$\theta_l = 180 + 45$$
$$= 225$$

③ High frequency

$$R_p = \frac{R_c h_{ie}}{R_c + h_{ie}}$$



$$A_i = - \frac{\dfrac{h_{fe} i_B R_c h_{ie}}{R_c + h_{ie}}}{\dfrac{R_c h_{ie}}{R_c + h_{ie}} + \dfrac{1}{j\omega C_d}}$$

$$= - \frac{h_{fe} h_{ie} R_c}{R_c h_{ie} + \frac{1}{j\omega C_d}(R_c + h_{ie})}$$

$$V_{out} = I \times \frac{1}{j\omega C_d}$$

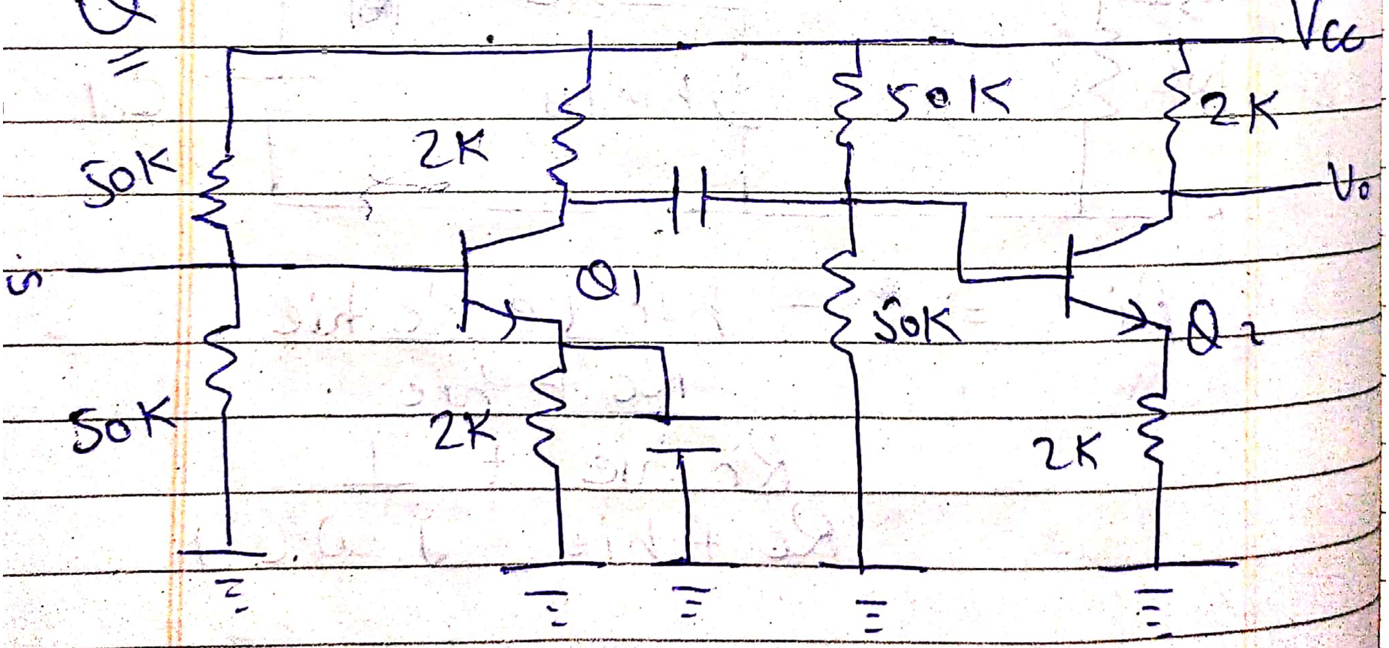
$$= \frac{h_{fe}\, h_{ie}\, I_b\, R_c}{j\omega C_d\, h_{ie} R_c + h_{ie} + R_c}$$

$$V_{in} = h_{ie}\, i_B$$

$$A_{VH} = \frac{h_{fe}\, R_c}{j\omega C_d\, h_{ie} R_c + h_{ie} + R_c}$$

$$|A_{VH}| = \frac{1}{\sqrt{1 + \left(\frac{2\pi f\, C_d\, h_{ie} R_c}{h_{ie} + R_c}\right)^2}}$$

Q =



(i) mid frequency gain

(ii) C_b nessary to give 3-dB freque of 20 Hz

$h_{ie} = 1.1\,K\Omega$

$h_{re} = h_{oe} = 0$

$h_{fe} = 50$

$$A_{vm} = \frac{h_{fe}\, R_c}{R_c + h_{ie}}$$

$$32.26 = \frac{50 \times R_c}{R_c + (1.1 \times 10^3)}$$

$$32.26 R_c + 32.26 \times 1100 = 50 R_c$$

$$17.74\, R_c$$

$$35486$$

$$R_c = \frac{35486}{17.74}$$

$$= 2K\Omega$$

$$R_c = 2K$$

$$= \frac{50 \times 2 \times 10^3}{2 \times 10^3 + 1.1 \times 10^3}$$

$$= \frac{100 \times \cancel{10^3}}{(2 + 1.1) \times \cancel{10^3}}$$

$$= \frac{100}{3.1} = 32.25$$

$$f_1 = \frac{1}{2\pi C_b (h_{ie} + R_c)}$$

$C_b = ?$

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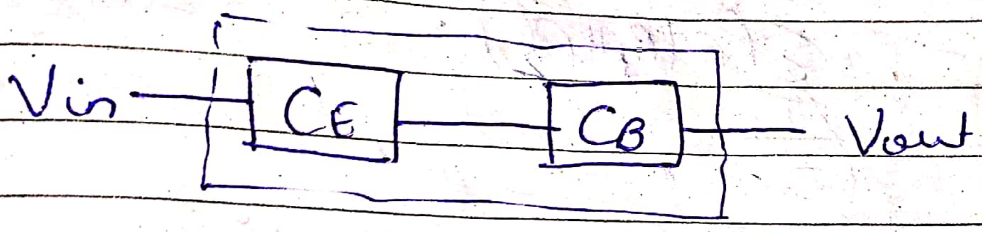
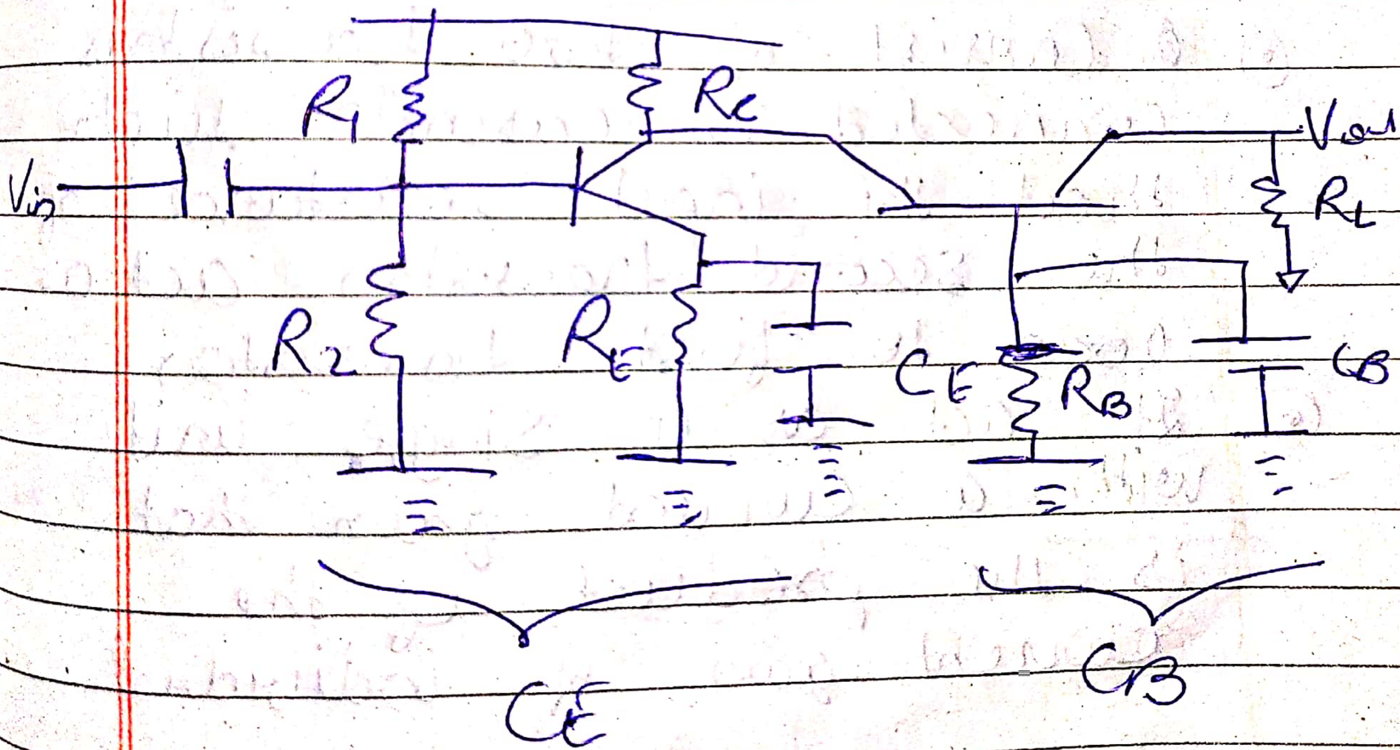
Cascode Amplifier

→ It consist of a CE stage followed by a CB stage directly coupled to each other.

→ It has large bandwidth used for RF applications.



Cascode



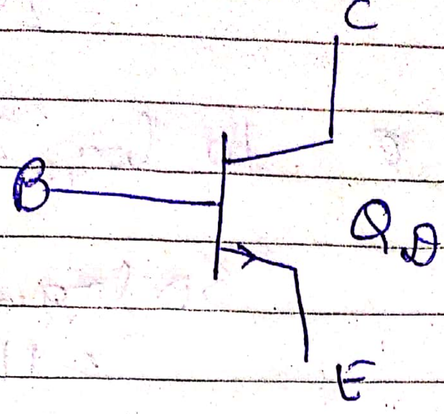
Darlington pair

- A Consist of two transistors connected in cascode such that the input resistance of the second transistor act as load to first transistor
- It act as a single unit with a current gain that is the product of the current gain of individual.

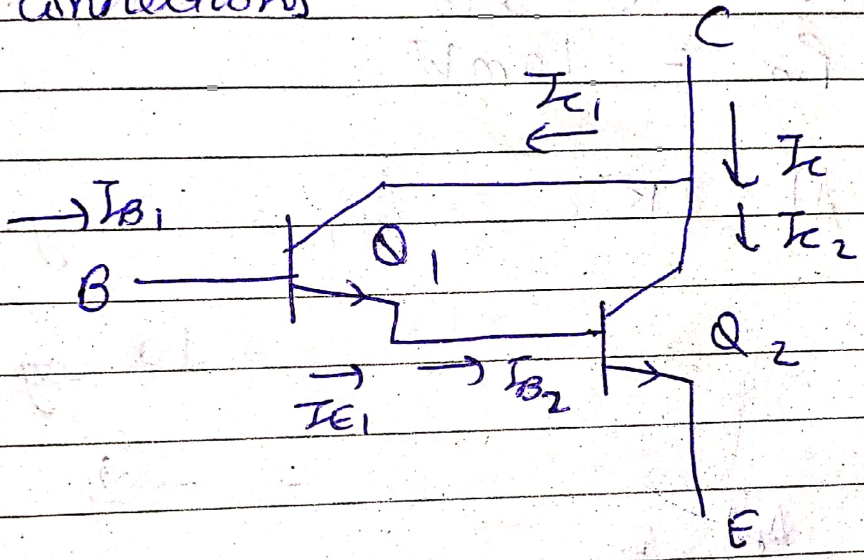
i.e, $\beta_0 = \beta_1 \beta_2$

β_0 = current gain

Single darlington transistor



Connections



$$\beta_D = \frac{I_C}{I_{B_1}} = \frac{I_{C_1} + I_{C_2}}{I_{B_1}}$$

$$\frac{I_{C_1}}{I_{B_1}} + \frac{I_{C_2}}{I_{B_1}}$$

$$\beta_1 + \beta_1 \beta_2 = \beta_1(1+\beta_2)$$

$$\boxed{\beta_D = \beta_1 \beta_2}$$