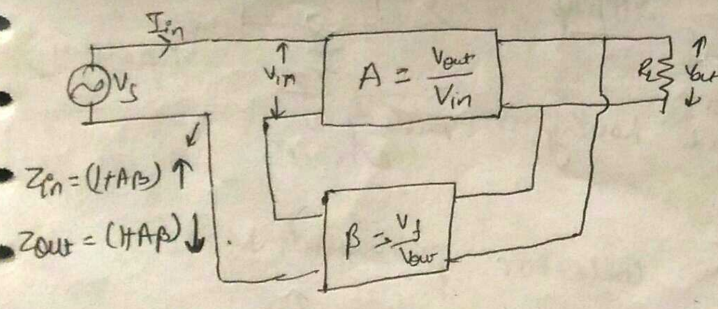
feedback in Amplifier

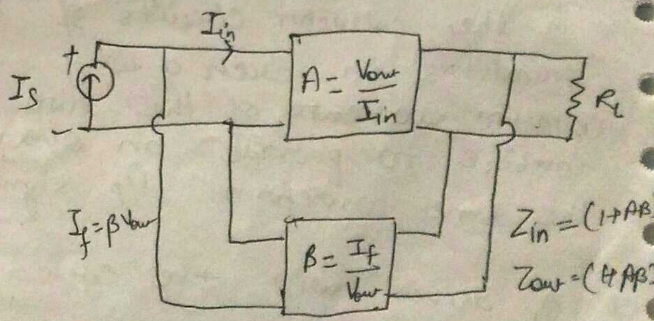
* when a part or fraction of o/p is combined to the input, is feedback.
* Positive feedback causes excessive distortion and instability. However, because of its capability of increasing the power of the original signal it is used in Oscillator circuits.
* when the feedback voltage is so applied as to weaken the i/p signal, it is called negative feedback.
* Negative feedback weaken the i/p signal, reduce the amplifier gain but it has numerous advantages [such as gain stability, reduction in non-linear distortion, reduction in noise, increase in B.W. or improvement in freq. response, increase in input impedance and decrease in output impedance]

feedback n/w :-

① Voltage Series feedback



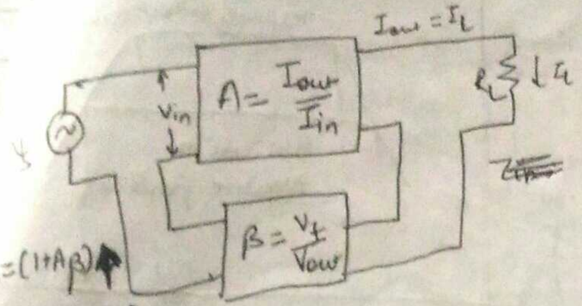
② Voltage - Shunt feedback



Voltage feedback tends to reduce the output impedence

Current " " " increase " " "

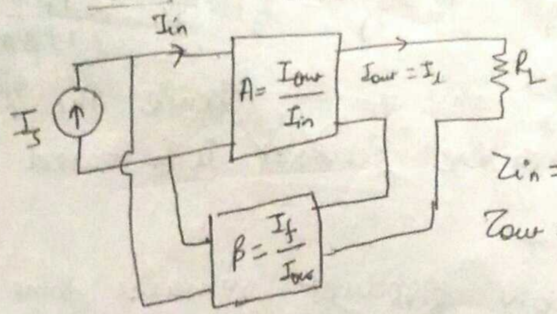
Current Series



$Z_{in} = (1+A\beta)\uparrow$

$Z_{out} = (1+A\beta)\uparrow$

Current Shunt



$Z_{in} = (1+A\beta)\downarrow$

$Z_{out} = (1+A\beta)\uparrow$

Positive feedback $= \frac{A}{1-\beta A}$

Negative feedback $= \frac{A}{1+\beta A}$

Every amplifier stage introduces a phase shift of 180°.

Gain ↑ but reduces stability and ↑ distortion

1. $(1-\beta A) < 1$, Gain ↑
2. $(1-\beta A) = 0$, Gain $= \infty$ possible when i/p is zero
3. $(1-\beta A) > 1$ Gain $= \downarrow$ (same as -ve feedback).

Advantage of Negative feedback :-

1) Gain stability :- $A_f = \frac{A}{1+A\beta}$ if $A\beta >> 1$, $A_f = \frac{1}{\beta}$

so A_f is independent of internal gain its only depends on β which in turn depends on passive elements such as resistors. Resistors remain fairly constant so the gain is stabilised.

2. Reduced Non-linear Distortion :- ↓ by $(1+A\beta)$
3. " Noise = ↓ by $(1+A\beta)$
4. increased BW = ↑ by $(1+A\beta)$
5. Increased i/p impedance = ↑ by $(1+A\beta)$
6. Decrease o/p " = ↓ by $(1+A\beta)$

Reduction in Noise with Negative feedback :- $(1+\beta A)$ factor reduces the noise

Input Impedance :- $Z_{inf} = Z_{in}(1+A\beta)$

Output Impedance :- $Z_{outf} = \frac{Z_{out}}{(1+A\beta)}$

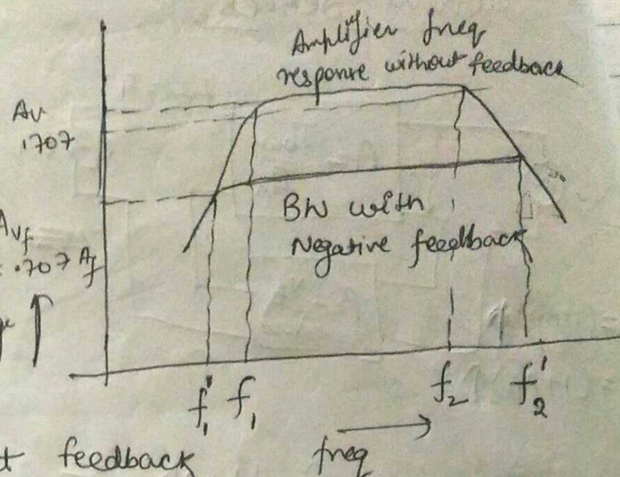
Negative feedback on BW :- $f_1' = \frac{f_1}{(1+\beta A)}$ $f_2' = f_2(1+A\beta)$

$BW_f = f_2' - f_1' = f_2(1+A\beta) - \frac{f_1}{(1+\beta A)}$

$f_2' > f_2$ and $f_1' < f_1$ hence the BW with negative feedback is increased

~~BW_f =~~

Gain × BW ~~product~~ product remains same



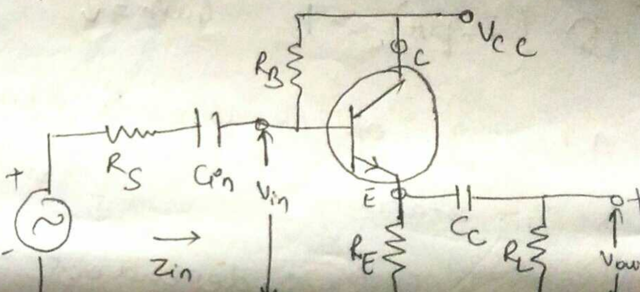
Emitter follower :- ① It is negative current feedback ckt

② Large i/p impedance & a small output impedance

③ Voltage gain ≃ 1

④ output voltage tends to be in phase with the i/p voltage, hence the term follower.

⑤ The emitter resistance R_E itself acts as the load and the ac output voltage V_{out} is taken across it.



$V_{out} = I_C R_E$ across the R_E

* This voltage opposes the ac signal voltage V_S as it is inphase opposition to V_S. Thus it provides -ve current feedback.

* V_{out} feedback to the i/p is proportional to I_E hence this ckt is called a negative current feedback circuit.

Advantage :- * High i/p impedance & Low o/p impedance so can be used for impedance matching (impedance transformer).

* Because of 100% feedback, o/p is distortionless & BW is very large.

* ↑ Current gain & ↑ power gain

* o/p & i/p ac voltages are in phase,

Application :- It is capable of transferring maximum power from high impedance source to low impedance load.

* It is called a buffer ampr.

* Provide better freq. response than transformer.

Negative feedback

1) Negative feedback is used in voltage amplifier.
2) The feedback network is always resistive and network act as voltage divider.

Features :- (i) voltage gain decreases :-

$$A_{VF} = \frac{A_V}{1+KA_V}$$

(ii) Stability increase :-

$$A_{VF} = \frac{A_V}{1+KA_V}$$

if $KA_V >> 1$

$$A_{VF} = \frac{A_V}{KA_V} \cong \frac{1}{K}$$

[A_{VF} depends on only K not in A_V. K is not dependent on h parameter and h parameter depends on temp.]

(iii) Lower cut-off frequencies decreases :-

$$f_1' = \frac{f_1}{1+KA_V}$$

(iv) Upper cut-off frequencies increases :-

$$F_2' = F_2(1+KA_V)$$

(v) Bandwidth increases :- $BW' = BW(1+KA_V)$

(vi) Gain bandwidth remain constant.

(vii) Noise decreases :-

$$N' = \frac{N}{1+KA_V}$$

(viii) Distortion decreases :-

$$D' = \frac{D}{1+KA_V}$$

(ix) Input impedence may increase or decreases :-

$Z_{inF} = Z_{in}(1+KA_V)$ for → Voltage series (Best), → Current series } Increase

$Z_{inF} = \frac{Z_{in}}{1+KA_V}$ for → voltage shunt, → current shunt } decrease

(x) output impedence :-

$Z_{oF} = Z_o(1+KA_V)$ for → Current series, → current shunt (worst) } Increase

$Z_{oF} = \frac{Z_o}{1+KA_V}$ for → Voltage series, → Voltage shunt } Decrease

Various feedback Configurations

1) Voltage - Series :- [Series - Shunt] {best Configuration}
I/O O/P

(i) Z_{in} ↑ (ii) Z_{out} ↓

e.g. Common Collector / Emitter follower

2) Voltage - Shunt :- [Shunt - Shunt]
I/O O/P

(i) Z_{in} ↓ (ii) Z_{out} ↓

e.g. fixed biased

3) Current - Series :- [Series - Series]

(i) Z_{in} ↑ (ii) Z_{out} ↑

e.g. Common emitter with R_E

4) Current - Shunt :- [Shunt - Series] {Worst Case]

(i) Z_{in} ↓ (ii) Z_{out} ↑

Features of Negative feedback:-

1: voltage gain is decreases:-

$$A_{vf} = \frac{A_v}{1+KA_v}$$

2. Stability increases:-

$$A_{vf} = \frac{A_v}{1+KA_v}.$$

if $KA_v >> 1$

$$A_{vf} = \frac{A_v}{KA_v} \cong \frac{1}{K}.$$

A_{vf} depends on only k not in A_v.
K is not dependent of h parameter.
[h parameter depends on temp.]

The overall voltage gain A_{vf} depends only upon the externally connected feedback n/w and does not depend upon the voltage gain of the original amplifier. Since A_v depends upon the h parameters which are temp. dependent therefore insusceptive of the variation in the temp. the overall voltage gain remains almost constt., hence the thermal stability of the overall amplifier increases.

3. Lower cut off frequencies is decreas:—

$$f_1' = \frac{f_1}{1+KA_V}$$

4. Upper cutoff frequencies is increases:—

$$f_2' = f_2[1+KA_V]$$

5. Bandwidth increases:—

$$BW' = BW\ [1+KA_V]$$

6. GBW —

remains const.

$$GBW' = A_{Vf} \times BW'$$

$$= \frac{A_V}{1+KA_V}\ BW\ [1+KA_V]$$

$$GBW' = A_V\ BW$$

$$= GBW.$$

7. noise decreases:—

$$noise' = \frac{N}{1+KA_V}.$$

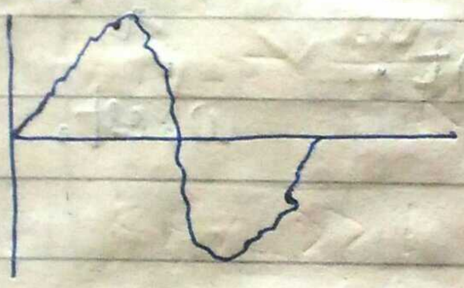
$$N' = \frac{N}{1+KA_V}$$

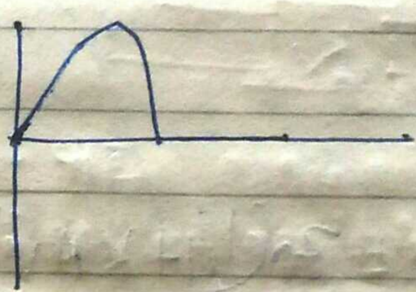
N = noise

8. **Distortion decreases:—**

$$D' = \frac{D}{1+KA_v}$$

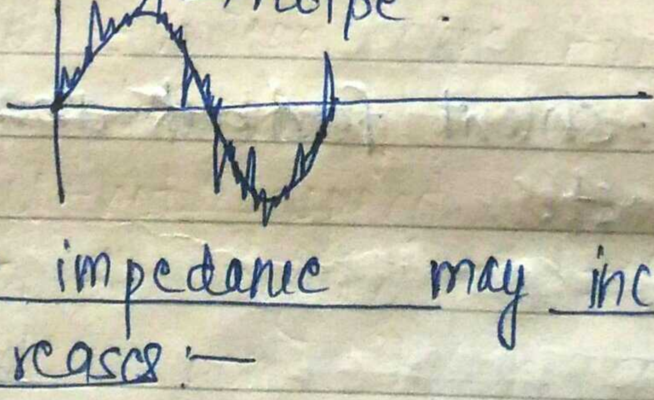
* fundamental difference b/w noise and distortion:—





distortion - some portion of sig is distored or clipped.

noise = undesired signal which are superimposed with the desired signal.



9. **I/P impedance may increase or decreases:—**

$$Z_{inf} = Z_{in}(1+KA_v)$$ — Voltage-series / Current series (ser →)

Z_{inf} ↑.

Z_{inf} will be ↓ :—

current shunt type

voltage shunt and arrange ment.

10) o/p impedance:—
may increase or decrease.

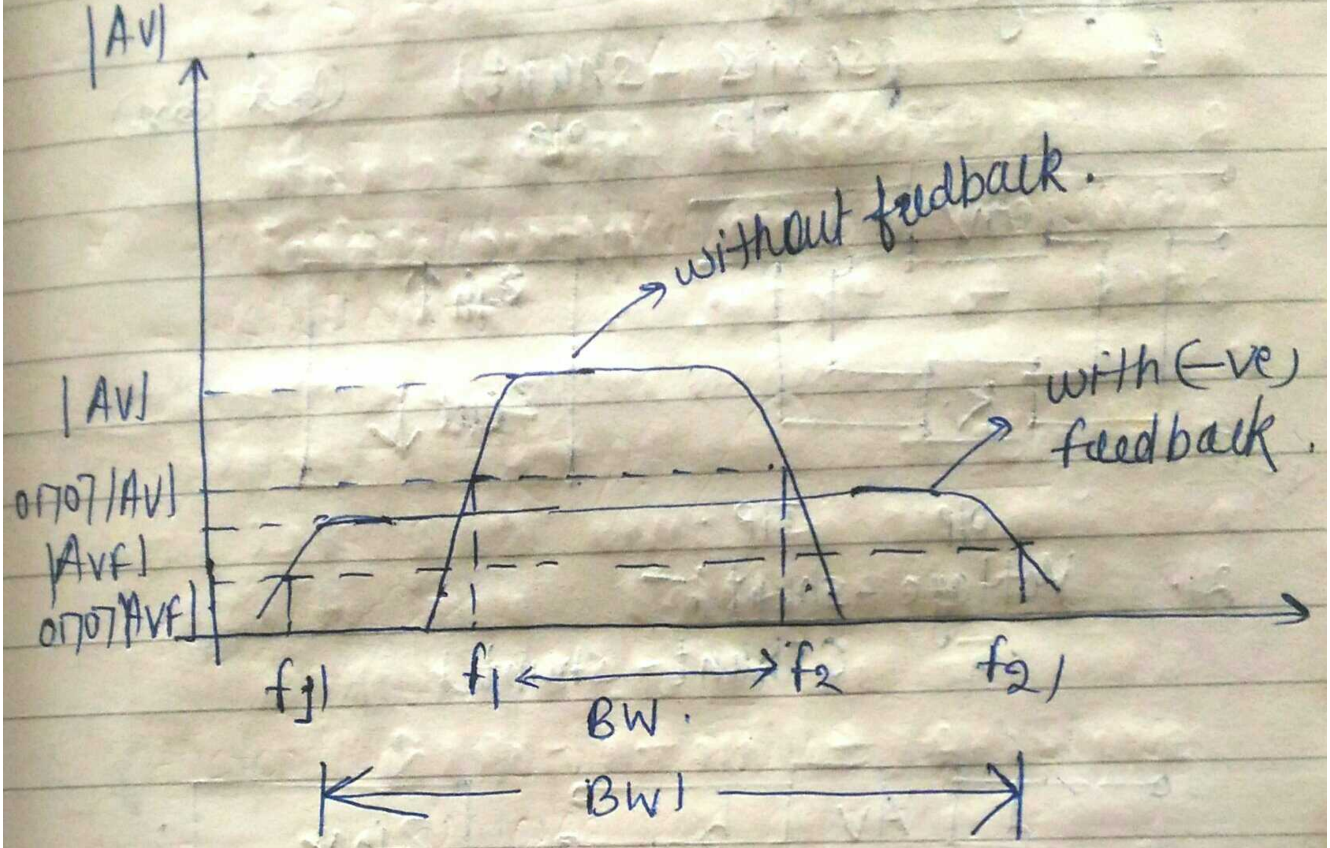
$Z_{out\,f} = Z_{OF} = Z_o(1+KA_V)$ = due to current series and current shunt.

↑ worst.

$Z_{out\,f} = Z_o(1/1+KA_V)$
= voltage series
= voltage shunt.

* from i/p and o/p impedance point of view:—
1) Voltage-series feedback arrangement is best.
2) Current-shunt feedback arrangement is the worst.

Frequency response of the feedback amplifier :-



Hence by using -ve feedback :-

1) voltage gain decreases.
2) Lower cutoff frequency ↓
3) Upper ,, ,, ↑.
4) BW ↑.
5) gain bandwidth product before and after negative feedback remains constt.
6) Hence by using appropriate cascading and negative feedback we can obtain the desired value of the voltage gain as well as necessary bandwidth.

Let $f_2^{(n)}$ be the upper 3-db freq. for the complete cascade amplifier.
If all stages are identical. $f_2 = f_2' = f_2'' = f_2''' \cdots\cdots = f_2^n$

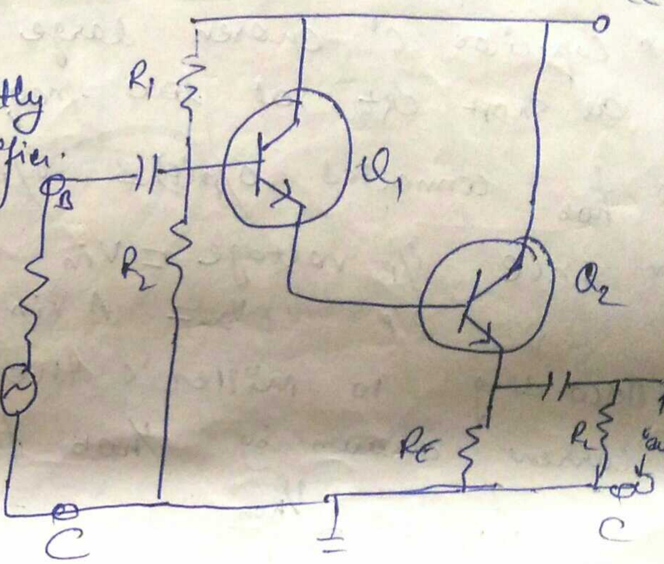
$$\frac{f_2^{(n)}}{f_2} = \sqrt{2^{1/n}-1}$$

If f_1 be the lower 3-db freq. of each of the n identical non-interacting cascade stages.

$$\frac{f_1^{(n)}}{f_1} = \frac{1}{\sqrt{2^{1/n}-1}}$$

So for cascade ampr 3-db BW is reduced.

Darlington Amplifier:-



- In this emitter of one amplifier is directly joined with base of the other amplifier.
- I_E of first transistor becomes the I_B of the second transistor.
- Two cascade emitter follower (CC) with R_E resistance of I^{st} stage

Current Gain $A_i \simeq \beta_1 \beta_2$

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

$$\simeq \beta_1 \beta_2$$

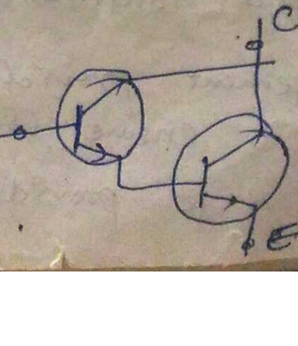
i/p impedance → of the darlington Amplifier is higher than a single amplifier

o/p impedance – is lower than a single ampr.

Merits:- It provides excellent characteristics of high input impedance with low o/p impedance and high current gain, all desirable characteristics for a current gain amplifier.

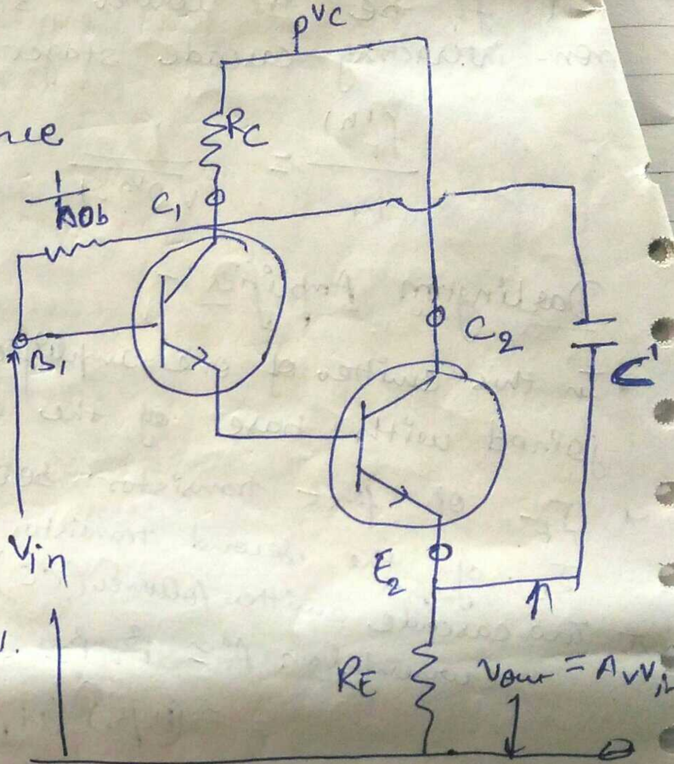
Application:- Used high gain operational ampr which depends on very high i/p impedance for its operation as an integrator or summing ampr.

This is Darlington transistor → with high current gain & high i/p impedance.



Bootstrapped Darlington CKt :- for Darlington ckt the input resis... is limited ($\frac{1}{h_{ob}} \simeq 2M\Omega$) b/w base & collector the i/p resistance can be largely increased by bootstrapping the darlington CKt → through the addition of capacitor C' b/w Ist collector terminal C_1 & IInd emitter terminal E_2

* ~~Consider a self bias ckt~~
* R_C is essential because in its absence R_E would be shorted to ground.
* Capacitor C' chosen large to act as short ckt at low freq.
* $\frac{1}{h_{ob}}$ connected o/p(E) & i/p (B).
* since i/p voltage = V_{in}
  o/p ,, V_{out} = A V_{in}



According to Miller's theorem. current drawn by 1/hob from i/p signal.

$$R_{eff} = \frac{1/h_{ob}}{(1-A_V)}$$

as $A_V \to 1$ $R_{eff} \to \infty$ (extremely large)

is called bootstraping.

O/p impedance $R_i = \frac{h_{ie}}{(1-A_V)}$

$R_{in} = h_{fe_1} h_{fe_2} R_{eff}$

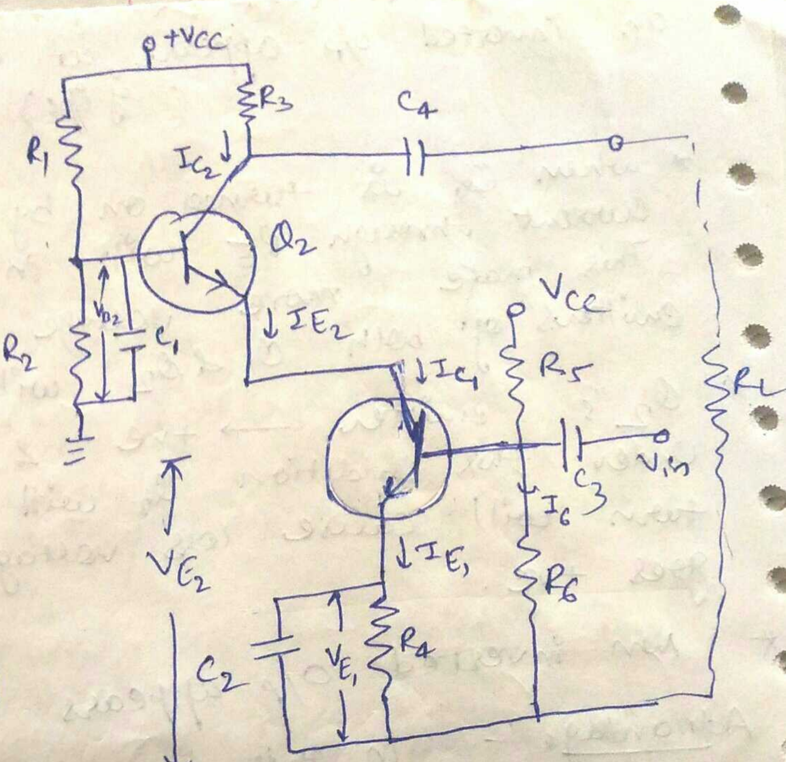
$R_{eff} = R_C \parallel R_E$

Cascode Amplifier :- has one transistor on top of (in series) with another.

first transistor Q_1 → CE in input stage while the circuit of second transistor Q_2 — CB in output state

* Arrangement provides high i/p impedance with low voltage gain to ensure that the i/p miller capacitance is minimum
* CB stage providing good high freq operation.

for DC condition.



Q_1 is CE configuration :-

I_{E_1} is set by V_{E_1} & R_4

$I_{E_1} \simeq I_{C_1}$ & $I_{E_1} \simeq I_{E_2}$

$I_{C_2} \simeq I_{E_1}$. This current remains const. regardless of the level of V_{B_2}

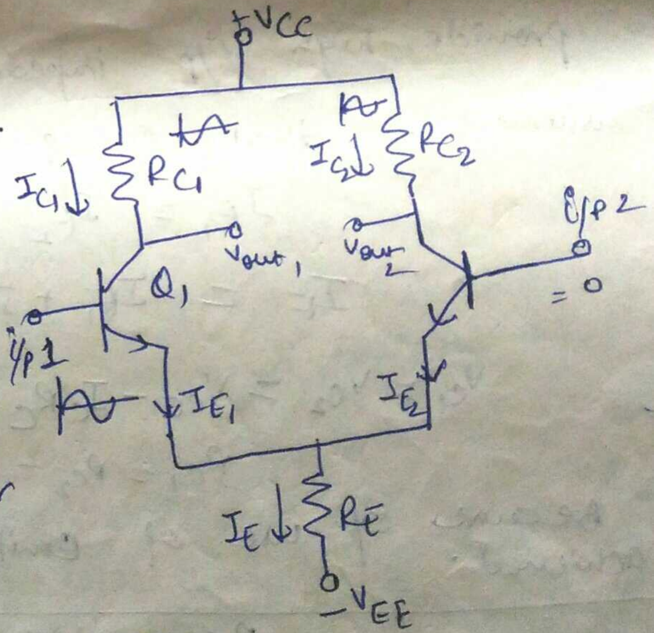
i/p impedance of emitter of transistor Q_2

voltage gain of I $A_{V_1} = -\frac{h_{fe}}{h_{ie}} \times (Z_{in} \text{ to } Q_2)$

$= -\frac{h_{fe}}{h_{ie}} \left[\frac{h_{ie}}{1+h_{fe}}\right] \simeq -1$

voltage gain of IInd $A_{V_2} = \frac{h_{fb} \times (R_3 || R_L)}{h_{ib}}$ overall $= \frac{-h_{fb}(R_3||R_L)}{h_{ie}}$

* <u>Differential Amplifier</u> :-
Give difference b/w the two i/p signals.



* i/p is applied different - different base terminal
* emitters of each are connected with a common emitter resistor so that the two o/p terminals V_{out_1} & V_{out_2} are affected by either or both i/p signals.

* when i/p signal drives transistor Q_1, there will be more voltage drop across R_{C_1} and therefore collector Q_1 will be less +ve.

* when i/p signal is -ve it will turn off the transistor and so voltage drop across R_{C_1} will be negligible and collector Q_1 will be more +ve