6. Multistage Ampli

INTRODUCTION :-

The gain of a single amplifier is not sufficient to drive an output. Therefore, to obtain add amplification, two or three stages are necessary. To achieve this, the output of each amplifier stage is c in some way to the input of the next amplifier stage. Hence, amplifiers may be classified into two cla

(i) Single stage amplifiers, and

(ii) Multistage amplifiers.

Amplifiers we had discussed so far are single stage amplifiers. Now the multistage amplifiers further classified into three catagories.

(a) RC coupled amplifiers

(b) Transformer coupled amplifiers

(c) Direct coupled amplifiers.

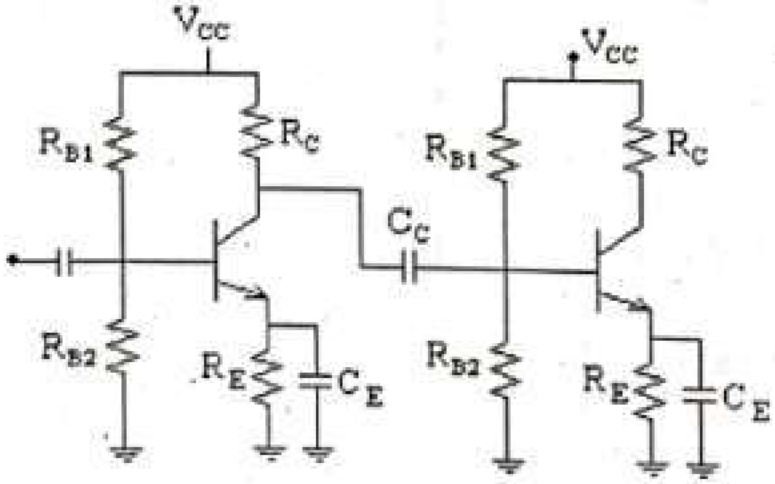
The main purpose of coupling device e.g. capacitor, transformer etc. is :

(i) To transfer AC output of one stage to the input of the next stage.

(ii) To isolate the DC conditions of one stage from the next stage.

(a) RC Coupled amplifiers :-

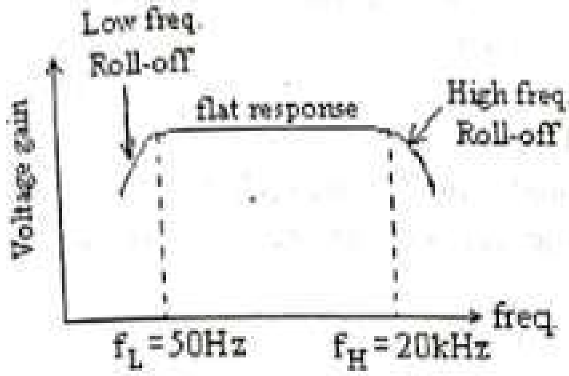
In RC coupling, a capacitor is used as a coupling device. The capacitor connects the output stage to the input of the next stage in order to pass the ac signal while blocking the dc bias current. below shows a two stage RC coupled amplifier.



In RC coupling, a coupling capacitor C_C is used to connect the output of first stage to the (base) of the second stage. The emitter bypass capacitor C_E offers low reactance path to the a.c without it, the voltage gain of each stage,is low. The coupling capacitor C_C transmits ac signal but bl signal.

...uency response :-

Figure below shows the frequency response of an RC coupled amplifier.



The behaviour of amplifier is described below :

At low frequencies (< 50 Hz) :-

The reactance, $\frac{1}{\omega C_C}$ of Coupling capacitor, C_C is very high and hence very small part of signal is transferred ...m one stage to the next. Also, C_E cannot effectively shunt emitter resistance R_E because of large reactance at low ...quencies. These factors cause a falling of voltage gain at low frequencies.

...) At high frequencies (> 20 kHz) :-

The reactance offered by C_C is very small and it behaves as a short circuit. This increases the loading effect of ...st stage and reduce the voltage gain. Also, the capacitance reactance of C_E is low which increases the base current ...hich in turn reduces current amplification factor, β. These factors causes a falling of voltage gain at high frequencies.

...ii) At Mid frequencies (between 50 Hz to 20 kHz) :-

The voltage gain of the amplifier is constant. As frequency increases in this range, reactance offered by C_C ...ecreases which increases the voltage gain. Low reactance means higher loading of first stage and hence lower gain. These ...wo factors cancel each others effect, resulting a uniform gain at mid frequencies.

...dvantages :-

1. It is most popular type of coupling.
2. It is least expensive multistage amplifier
3. It has excellent audio fidelity over a wide range of frequency.
4. It provides less frequency distortion
5. It is usually employed for voltage amplification.
6. The circuit is very compact.

Disadvantages :-

1. Loading effect of successive stages reduce the overall gain.
2. It has tendency to become noisy.

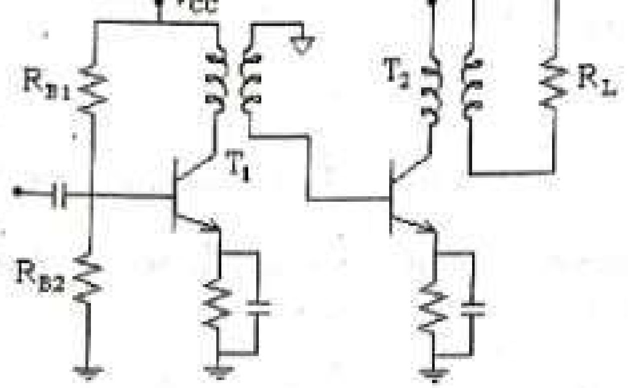
3. It provides poor impedance matching between stages.

Applications :-

RC coupled amplifier have excellent audio fidelity over a wide range of frequency. They are used as a voltage amplifier in initial stages of public address system. RC coupling is rarely used in stages because of its poor impedance matching.

(b) Transformer Coupled amplifier :-

In transformer coupling, transformer is used as the coupling device. The transformer couples the ac signal and blocks dc at the same time it provide impedance matching. Figure below shows a transformer coupled amplifier :

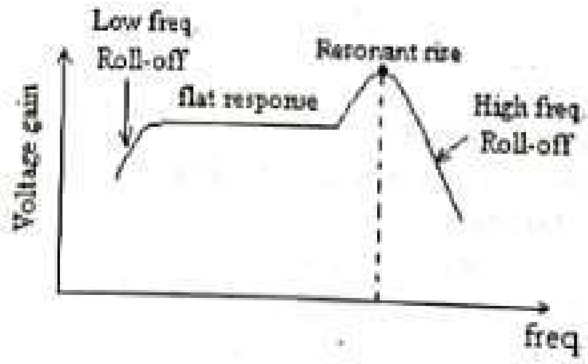


Here, Transformer T_1 couples first stage output to second stage input while T_2 couples second ouptut to load.

If the effective load resistance of each stage is increased, the voltage and power gain will be inc Because of the impedance changing properties of transformer, the low resistance of a stage (or load) reflected as a high load resistance to the previous stage.

Frequency response :-

The frequency response of a transformer coupled amplifier is shown below :



The frequency response is poor. The gain is constant over small range of frequencies. But a pr designed transformer, is capable of achieving a constant gain over the audio frequency range. But

...former used to achieve frequency response comparable to RC coupling is about 10 to 20 times costly as ...RC coupled amplifier.

...ages :-

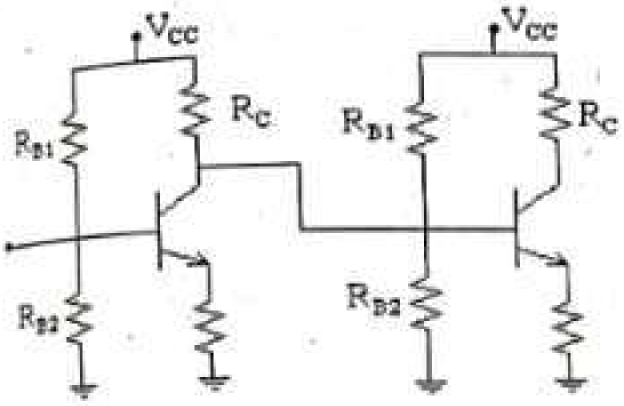
- Power loss in the transformer winding due to d.c. supply is zero.
- It provides higher voltage gain than the RC coupled stage.
- It provides excellent impedance matching

...vantages :-

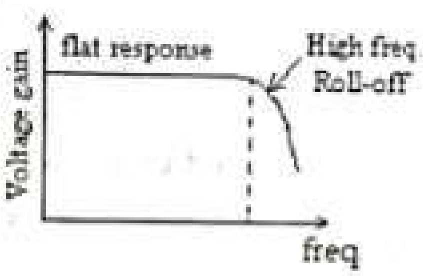
- The coupling transformer is expensive and bulky at audio frequency.
- Reverse frequency distortion at radio frequency.
- It tends to produce hum in the circuit.
- It has poor frequency response.

Direct Coupled amplifiers :-

In direct coupling of DC coupling, the individual amplifier stage bias conditions are so designed that ...two stages may be directly connected without the necessity for DC isolation.



Direct Coupled Amplifier



Frequency response

There are many applications in which extremely low frequencies are to be amplified. Other coupling ...vices like capacitors, transformers etc cannot be used because of their large sizes at lower frequencies. For ...is, one stage is directly coupled to the next stage.

Advantages :-

1. Circuit arrangement is most simple.
2. Circuit cost is low.
3. It can amplify even zero frequency (dc) signals.

Disadvantages :-

1. It cannot amplify high frequency signals.
2. It has poor temperature stability.

Applications :-

1. Analog computation.
2. Power supply regulators.

3. Bio-electric measurement
4. Linear integrated circuits.

Comparison between different types of coupling

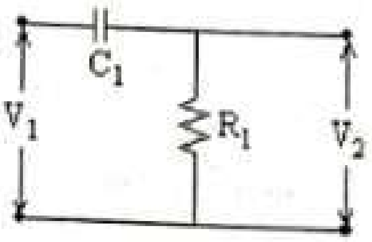
Particular	RC coupling	Transformer coupling	Direct coupling
Frequency response	Excellent in the audio frequency range	Poor	Best
Cost	Less	More	Least
Space and weight	Less	More	Least
Impedance matching	Not good	Excellent	Good
Use	For voltage amplification	For power amplification	For amplifying extremely low fre

Frequency response of an Amplifier :-

The frequency of the applied signal greatly effects the response of single stage and multistage amplifiers. The frequency dependent parameters and the stray capacitive elements associated with the active device will limit the high frequency response of the system. An increase in the number of stages of a cascaded system will also limit both high and low frequency response.

(a) Low Frequency response :-

Figure below shows a high-pass RC circuit used to calculate the low frequency response of a amplifier.



Taking the laplace of the output voltage from the above circuit. We get,

$$V_2(s) = \frac{V_1(s)R_1}{R_1 + 1/sC_1} = V_1(s)\frac{s}{s + 1/R_1C_1}$$

and voltage transfer function at low frequencies is :

$$A_L(s) = \frac{V_2(s)}{V_1(s)} = \frac{s}{s + 1/R_1C_1}$$

For real frequencies, i.e. $s = j\omega = j2\pi f$ above equation becomes,

$$A_L(jf) = \frac{1}{1 - j(f_L/f)} \qquad \text{where, } f_L = \frac{1}{2\pi R_1C_1}$$

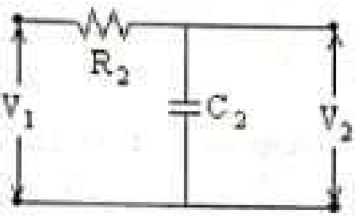
The magnitude $|A_L(jf)|$ and phase angle $\angle A_L(jf)$ of the gain is given by :

$$|A_L(jf)| = \frac{1}{\sqrt{1+(f_L/f)^2}} \quad \text{and} \quad \angle A_L(jf) = \tan^{-1}\frac{f_L}{f}$$

At frequency $f = f_L$, the gain $A_L = 1/\sqrt{2} = 0.707$, whereas in the midband region $(f >> f_L)$ A_L approaches one. Hence, f_L is that frequency at which gain reduces to 0.707 times of its midband gain A_0. In decibel this drop equals to reduction of 3 dB, hence f_L is referred to as lower 3 dB frequency. f_L is that frequency for which the resistance R_1 equals the capacitive reactance, i.e. $\frac{1}{2\pi C_1 f_L}$.

(b) High frequency response :-

High frequency region is the region above the midband region and is calculated by a low pass RC circuit. Such a circuit is shown below :



Taking the laplace of the output voltage from the above circuit. We get,

$$V_2(s) = V_1(s)\frac{1/sC_2}{R_2 + 1/sC_2} = V_1(s)\frac{1}{1+sR_2C_2}$$

and voltage transfer function at low frequencies is :

$$A_H(s) = \frac{V_2(s)}{V_1(s)} = \frac{1}{1+sR_2C_2}$$

For real frequencies, i.e. $s = j\omega = j2\pi f$ above equation becomes,

$$A_H(jf) = \frac{1}{1+j(f/f_H)} \quad \text{where, } f_H = \frac{1}{2\pi R_2 C_2}$$

The magnitude $|A_H(jf)|$ and phase angle $\angle A_H(jf)$ of the gain is given by :

$$|A_H(jf)| = \frac{1}{\sqrt{1+(f/f_H)^2}} \quad \text{and} \quad \angle A_H(jf) = -\tan^{-1}\frac{f}{f_H}$$

At frequency $f = f_H$, the gain $A_H = 1/\sqrt{2} = 0.707$. Hence, f_H is that frequency at which gain reduces to 0.707 times of its midband gain A_0. Hence f_H is referred to as upper 3 dB frequency. f_H is that frequency for which the resistance R_2 equals the capacitive reactance, i.e. $\frac{1}{2\pi C_2 f_H}$.

Two Pole Transfer function :-

The transfer function having two poles at f_{p1} and f_{p2} given by :

$$A(jf) = \frac{A_0}{\left[1 + j(f/f_{p1})\right]\left[1 + j(f/f_{p2})\right]}$$

Its magnitude in decibels is given by :

$$|A|(dB) = 20\log A_0 - 20\log\sqrt{1+\left(\frac{f}{f_{p1}}\right)^2} - 20\log\sqrt{1+\left(\frac{f}{f_{p2}}\right)^2}$$

and its phase angle is given by :

$$\angle A(jf) = -\tan^{-1}\frac{f}{f_{p1}} - \tan^{-1}\frac{f}{f_{p2}}$$

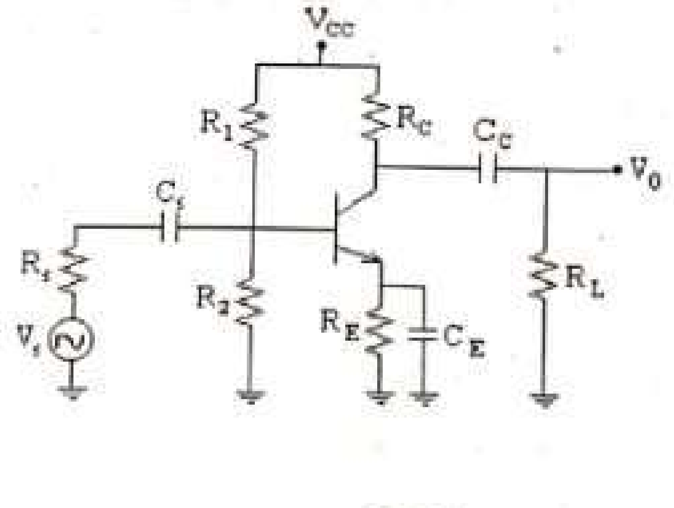
Dominant mode :-

If a transfer function has several poles determining the high frequency response. If the smallest of these is f_{p1} and each other pole is atleast two octaves away from f_{p1}, then amplifier behaves as a single time constant circuit whose 3-dB frequency is governed by f_{p1} and this frequency f_{p1} is called dominant pole.

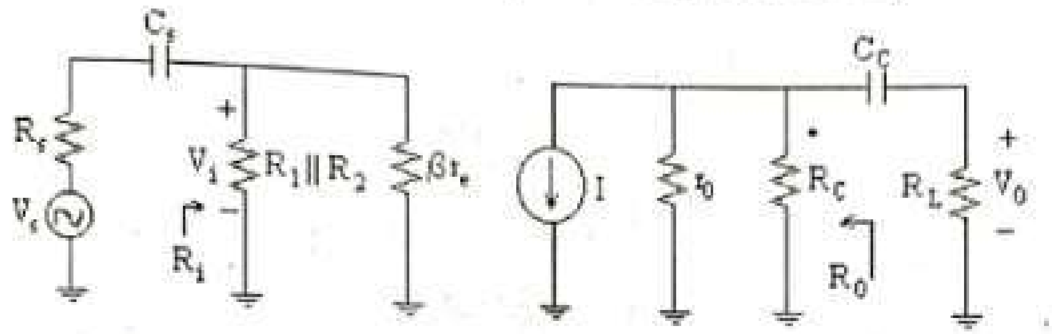
Hence, if f_{p1} is much smaller than f_{p2} then upper 3-dB frequency is given approximately by f_{p1}.

Low Frequency Response of BJT Amplifier :-

To start the analysis, let us take a loaded voltage divider BJT bias configuration. Such an amplifier is shown in figure below :



In the above amplifier, the capacitors C_s, C_C and C_E will decide low frequency behaviour. In order to determine the effect of these capacitors, the ac equivalent circuit of above amplifier is drawn below :



While examining the effect of one capacitor on the frequency response, it is assumed that other capacitor are performing their alloted work.

The capacitor C_s is normally connected between the applied source and the active device. Its cut off frequency is given by :

$$f_{Ls} = \frac{1}{2\pi(R_s + R_i)C_s} \qquad \text{where, } R_i = R_1 \| R_2 \| \beta r_e$$

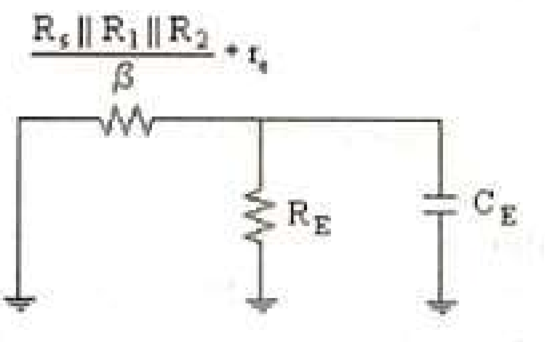
The voltage V_i is obtained by applying voltage divider and is given as :

$$V_i = \frac{R_i V_s}{R_2 + R_i - jX_{cs}}$$

The coupling capacitor C_C is normally connected between the output of the active device and the applied load. Hence the cut-off frequency due to C_C is given by :

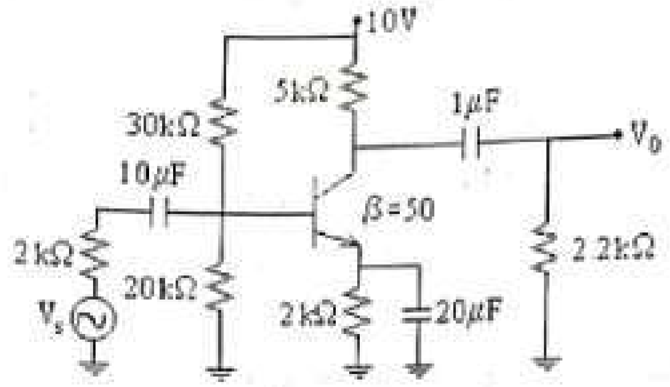
$$f_{Lc} = \frac{1}{2\pi(R_0 + R_L)C_C} \qquad \text{where, } R_0 = R_C \| r_0$$

The emitter bypass capacitor C_E is connected across the emitter resistance. Its cut-off frequency can be determined by the following figure :



$$f_{Le} = \frac{1}{2\pi R_{eq} C_E} \qquad \text{where, } R_{eq} = R_E \| \left(\frac{R_s \| R_1 \| R_2}{\beta} + r_e\right)$$

Question : Determine the lower cut off frequency for the network shown in figure below :



Solution : First calculate r_e for dc conditions :

$$\beta R_E = 50 \times 2k = 100\ k\Omega$$

and, $$V_B = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{20k \times 10}{30k + 20k} = 4V$$

$$I_E = \frac{V_E}{R_E} = \frac{4 - 0.7}{2k} = 1.65\ mA$$

so, $$r_e = \frac{26mV}{1.65mA} = 15.76\ \Omega$$

and, $$\beta r_e = 50 \times 15.76 = 788\ \Omega$$

Midband gain :

$$A_V = \frac{V_0}{V_i} = -\frac{R_C \parallel R_L}{r_e} = -\frac{5k \parallel 2.2k}{15.76} = -97$$

The input impedance is :

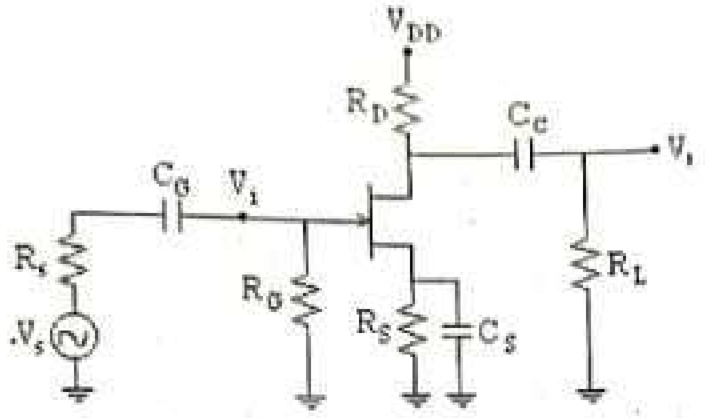
$$Z_i = R_i = R_1 \parallel R_2 \parallel \beta r_e = 30k \parallel 20k \parallel 788 = 740\ \Omega$$

The lower cut off frequency is given by :

$$f_{Ls} = \frac{1}{2\pi(R_s + R_i)C_s} = \frac{1}{2\pi(2000 + 740)10 \times 10^{-6}} = 5.81\ Hz$$

Low Frequency response of FET amplifier :-

The analysis of FET is quite similar to that of BJT amplifier. There are again three capacitors of which affects low frequency analysis. They are C_G, C_C and C_S. Figure below shows a FET configuration:



The coupling capacitor, C_G is between the source and the active device. The cut-off frequency is determined by :

$$f_{LG} = \frac{1}{2\pi(R_{sig} + R_i)C_G} \qquad \text{where, } R_i = R_G$$

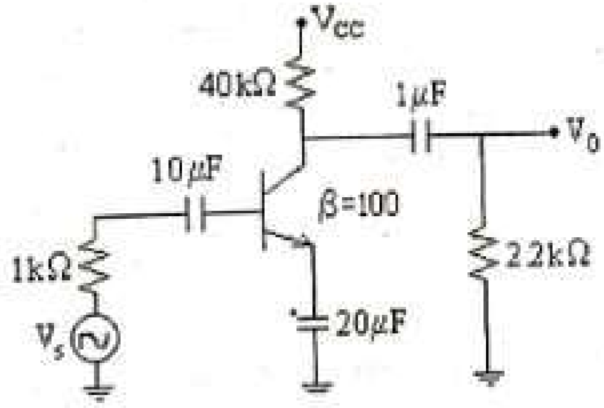
C_C is the coupling capacitor between the active device and the load. Its cut-off frequency is given by:

$$f_{LC} = \frac{1}{2\pi(R_0 + R_L)C_C} \qquad \text{where, } R_0 = R_D \parallel r_d$$

The cut-off frequency of the source capacitor C_S is given by :

$$f_{LS} = \frac{1}{2\pi R_{eq} C_S} \qquad \text{where, } R_{eq} = \frac{R_S}{1 + R_s(1 + g_m r_d)/(r_d + R_D \| R_L)} \cong R_S \| \frac{1}{g_m}$$

Question : Calculate the lower cut off frequencies for the circuit shown below :



Given, $r_e = 15.76\ \Omega$

Solution : We know cut off frequency due to capacitor C_S is given by :

$$\omega_{Ls} = \frac{1}{C_S(R_s + R_i)} \qquad \text{where, } R_i = \beta r_e$$

$R_i = \beta r_e = 100 \times 15.76 = 1.576\ k\Omega$

$$\omega_{LS} = \frac{1}{10 \times 10^{-6}(1 + 1.576)10^3} = 38.81 \text{ radians}$$

We know cut off frequency due to capacitor C_E is given by :

$$\omega_{LE} = \frac{1}{R_{eq} C_E} \qquad \text{where. } R_{eq} = R_E \| \left(\frac{R_s \| R_1 \| R_2}{\beta} + r_e \right)$$

$$R_{eq} = \frac{R_s}{\beta} + r_e = \frac{1k}{100} + 15.76 = 25.76\ \Omega$$

$$\omega_{LE} = \frac{1}{20 \times 10^{-6} \times 25.76} = 1940.99 \text{ radians}$$

We know cut off frequency due to capacitor C_C is given by :

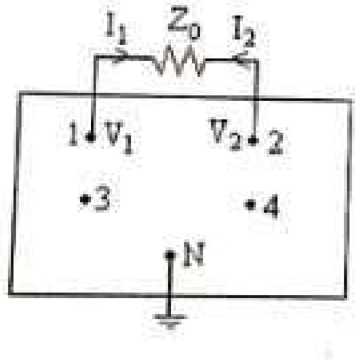
$$\omega_{LC} = \frac{1}{C_C(R_L + R_C)}$$

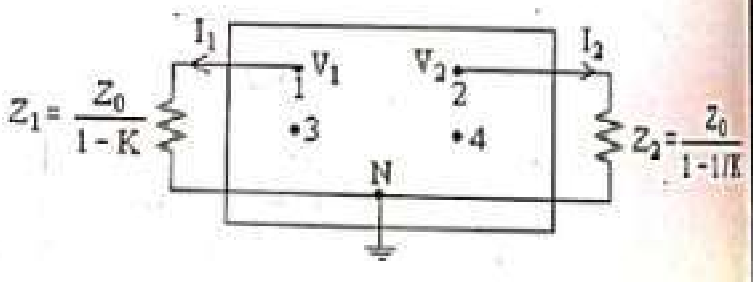
$$\omega_{LC} = \frac{1}{1 \times 10^{-6} \times (2.2 + 40)10^3} = 23.7 \text{ radians}$$

Since, the magnitude of ω_{LS} is minimum. Hence ω_{LS} is the dominant frequency.

Miller's Theorem :-

Consider an arbitrary circuit configuration with N distinct nodes 1, 2, 3 ....N as shown in figure below :





The node voltages be V_1, V_2, V_3 .... V_N where V_N is ground node i.e. $V_N = 0$. Nodes N_1 and N_2 are interconnected with an impedance Z_0. Designate the ratio V_2 / V_1 by K. In the figure it is shown that current I_1 drawn from N_1 through Z_0 is obtained by disconnecting terminal 1 from Z_0 and bridging an impedance $\frac{Z_0}{1-K}$ from N_1 to ground.

i.e. $Z_1 = \frac{Z_0}{1-K}$ where, $K = \frac{V_2}{V_1}$

Similarly, current I_2 drawn from N_2 is calculated by removing Z_0 and by connecting between N_2 and ground an impedance of :

i.e. $Z_2 = \frac{Z_0}{1-1/K} = \frac{KZ_0}{K-1}$ where, $K = \frac{V_2}{V_1}$.

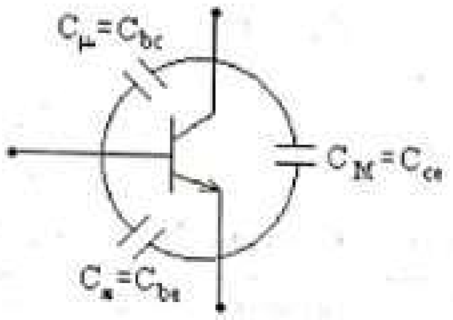
Miller Effect Capacitance :-

If there is a capacitor C_0 is place of Z_0, then Miller capacitances are given by :

$$C_1 = (1-K)C_0 \quad \text{and} \quad C_2 = \left(1-\frac{1}{K}\right)C_0$$

TRANSISTOR AT HIGH FREQUENCIES :-

As we have seen that transistor characteristics are like bandpass filter whose lower frequency is decided by the coupling and bypass capacitors while the higher frequency response of transistor is limited by junction or parasitic capacitances. High frequency capacitances are shown in figure below :

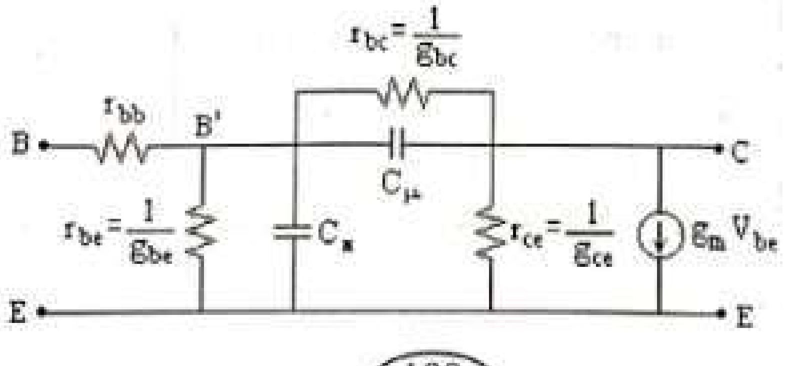


C_μ, C_π and C_M are known as parasitic capacitances and their magnitudes are in the order :

$$C_\pi > C_\mu > C_M$$

h-π model :-

For analysis at high frequencies, h-π or Gia-coletto model is preferred. The h-π model for CE configuration is shown below :



Typical values of all the parameters are shown below :

$$g_m = \frac{I_C}{V_T} = 50\ mA/V \qquad r_{bb'} = 100\ \Omega$$

$$r_{b'c} = \frac{V_T}{I_B} = 4\ M\Omega \qquad r_{b'e} = 1\ k\Omega \qquad r_{ce} = 80\ k\Omega$$

$$C_\mu = 3\ pF \qquad C_\pi = 100\ pF \qquad C_M = \text{negligibly small}$$

If CE h-parameters at low frequencies are known then h-π parameters are calculable from following relations :

Transistor Transconductance, $\quad g_m = \frac{|I_C|}{V_T} = \frac{|I_C|}{26\ mV}$

Input conductance, $\quad g_{b'e} = \frac{g_m}{h_{fe}} = \frac{|I_C|}{V_T h_{fe}} \quad$ or, $\quad r'_{be} = \frac{h_{fe}}{g_m}$

Feedback Conductance, $\quad g_{bc} = \frac{h_{re}}{r'_{be}} \quad$ or, $\quad r'_{bc} = \frac{r_{be}}{h_{re}}$

Base spreading resistance, $\quad r'_{bb} = h_{ie} - r'_{be}$

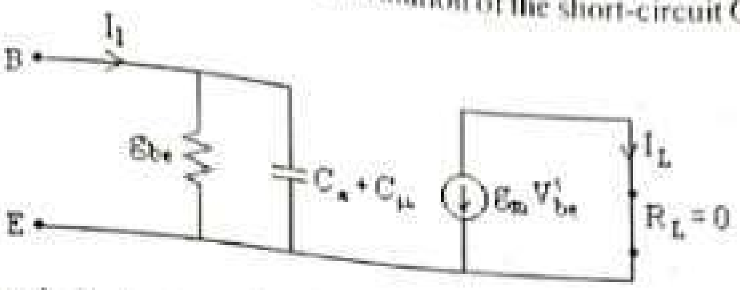
Output Conductance, $\quad g_{ce} = h_{oe} - (1 + h_{fe}) g_{bc} = \frac{1}{r_{ce}}$

Dependence of parameters on Current, Voltage and Temperature

Parameter	Variation with increasing		
	$\lvert I_C \rvert$	$\lvert V_{CE} \rvert$	T
g_m	$\lvert I_C \rvert$	Independent	1/T
r_{bb}	Decreases		Increases
r_{be}	$1/\lvert I_C \rvert$	Increases	Increases
C_π	$\lvert I_C \rvert$	Decreases	
C_μ	Independent	Decreases	Independent
h_{fe}		Increases	Decreases
h_{ie}	$1/\lvert I_C \rvert$	Increases	Increases

CE short circuit current gain :-

Approximate equivalent circuit for the calculation of the short-circuit CE current gain is shown below:



The load current I_L is, $I_L = -g_m V'_{be}$

and,
$$I_1 = V'_{be}\left[\frac{1}{r'_{be}} + j\omega\left(C_\pi + C_\mu\right)\right]$$

Under shorted condition, current gain is given by :

$$A_I = \frac{I_L}{I_1} = \frac{-g_m}{g'_{be} + j\omega\left(C_\pi + C_\mu\right)}$$

$$A_I = \frac{-1/r_e}{1/\beta r_e + j\omega\left(C_\pi + C_\mu\right)} = \frac{-\beta}{1 + j\omega\beta r_e\left(C_\pi + C_\mu\right)} \qquad \because \beta = -h_{fe}$$

$$A_I = \frac{-\beta}{1 + j\frac{\omega}{\omega_b}} \qquad \text{where,} \quad \omega_b = \frac{1}{\beta r_e\left(C_\pi + C_\mu\right)}$$

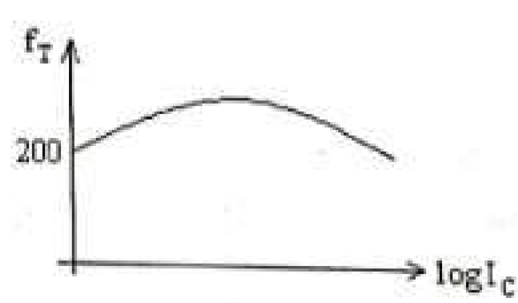
Unit Gain-bandwidth :-

It is defined as the frequency at which the short circuit CE current gain attains unit magnitude. It is calculated by the fact that,

$$\text{Gain} \times \text{B.W.} = \text{constant}$$

i.e. $1 \times f_T = h_{fe} f_b$

$$f_T = h_{fe} f_b = \frac{g_m}{2\pi\left(C_\pi + C_\mu\right)} \cong \frac{g_m}{2\pi C_\pi}$$



or, $C_\pi \cong \dfrac{g_m}{2\pi f_T}$

The capacitance C_π is the sum of emitter diffusion capacitance (C_{De}) and emitter junction capacitance (C_{Te}).

i.e. $C_\pi = C_{De} + C_{Te}$

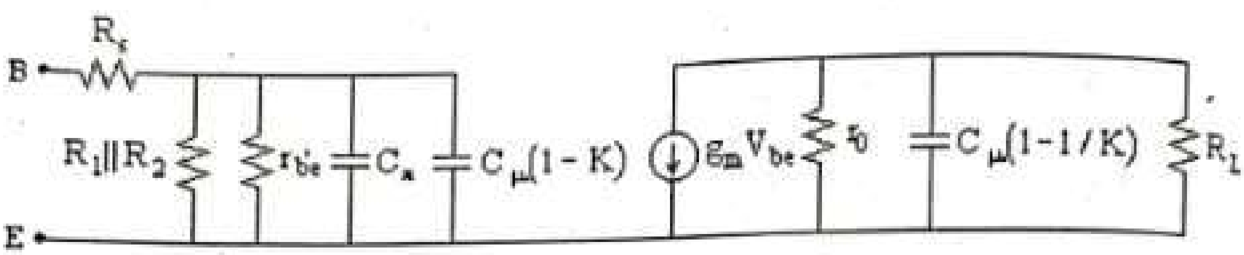
But in forward bias, emitter junction capacitance (C_{Te}) is negligible, therefore,

$$C_\pi \cong C_{De} = \frac{g_m w^2}{2D_B}$$

where, w = base width and D_B = diffusion constant for base.

High frequency calculation :-

Let us consider the equivalent circuit of the CE amplifier, and dividing the capacitance C_μ using Miller effect. This is shown below :



Higher cut-off frequency at input side is given by :

$$f_{H1} = \frac{1}{2\pi R_{eq1}\left[C_\pi + C_\mu(1-K)\right]} \qquad \text{where, } R_{eq1} = R_s + R_1||R_2||r_{b'e}$$

Higher cut off frequency at output side is given by :

$$f_{H2} = \frac{1}{2\pi R_{eq2} C_\mu(1-1/K)} \qquad \text{where, } R_{eq2} = R_L||r_0$$

Unity gain Bandwidth :-

f_T is a unity gain bandwidth at which the short circuit current gain becomes unity, which is given by

$$f_T = \frac{g_m}{2\pi(C_\pi + C_\mu)} \qquad \text{and} \qquad g_m = \frac{1}{r_e} = \frac{I_C}{V_T}$$

Beta Frequency :-

Beta frequency f_β is the frequency which decides the Bandwidth. It is the frequency at which the gain becomes 3 dB down to its midband value.

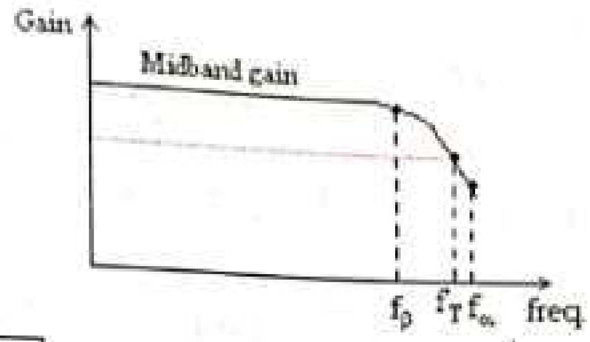
$$f_\beta = \frac{g_{be}}{2\pi(C_\pi + C_\mu)} \qquad \text{and} \qquad g_{be} = \frac{g_m}{\beta}$$

$$\boxed{f_\beta \times \beta = f_T}$$

Alpha frequency :-

Alpha frequency f_α, is the frequency at which gain becomes zero.

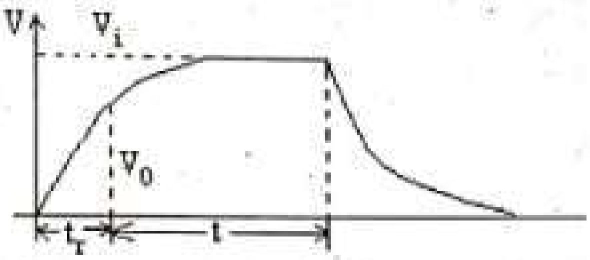
$$f_\alpha = (1+\beta) f_\beta$$



i.e. $f_\alpha > f_T > f_\beta$

p response of an amplifier :-

Of all the possible available waveforms, the most generally useful waveform is step input. The ponse V_0 of the low pass circuit to a step input of amplitude $V_i = V$ and the time constant of low pass er is RC is shown in the figure below :



Then output is given by :

$$v = V\left(1 - e^{-t/RC}\right)$$

The time t_r is an indication of how fast the amplifier can respond to a discontinuity in the input signal.

i.e. $t_r = \frac{0.35}{f_H}$

or Sag :-

The output v_0 when a step input v_i is applied to a high pass RC circuit it exhibits a tilt in the low uency part as shown in figure below :

Percentage tilt or sag, in time t_1 is given by :

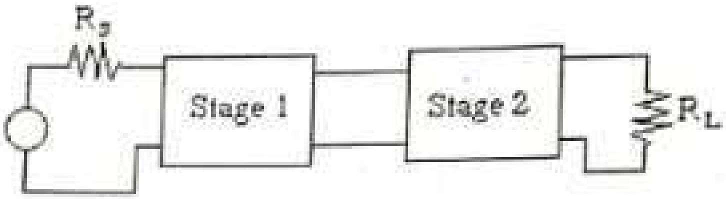
$$P = \frac{V - V'}{V} \times 100 = \frac{t_1}{R_1 C_1} \times 100$$

This expression is also valid for the tilt of each half cycle of a symmetrical square wave of peak value of V and period T provided that, $t_1 = T/2$. If $f = 1/T$ is the frequency of the square wave, then tilt is given by :

$$P = \frac{T}{2R_1C_1} \times 100 = \frac{1}{2fR_1C_1} \times 100 = \frac{\pi f_L}{f} \times 100$$

Cascade Amplifiers :-

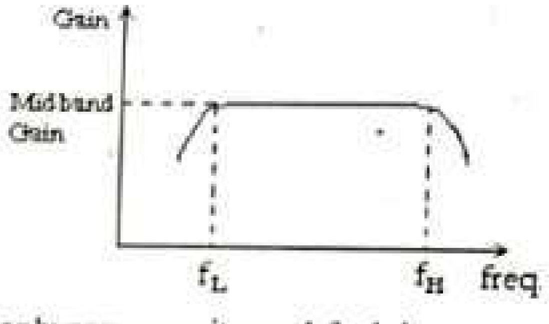
In order to achieve proper amplification we use cascading. It is like connecting two or three CE stages to achieve sufficient amplification.



Overall voltage gain in cascade is :

$$A_V = A_{V1} \times A_{V2}$$

If there are n single stages amplifier with lower cut off frequency f_L and higher cut off frequency as shown in figure below :



f_L is because of coupling or bypass capacitor and f_H is because of junction or parasitic capacitance. The overall frequency response for n such cascaded stages is given by :

$$f_H^* = f_H\sqrt{2^{1/n} - 1} \quad \text{and} \quad f_L^* = \frac{f_L}{\sqrt{2^{1/n} - 1}}$$

So, it is observed that the increase in gain in multistage amplifier is at the cost of bandwidth. interacting stage f_H is given by :

$$\frac{1}{f_H} = 1.1\sqrt{\frac{1}{f_1^2} + \frac{1}{f_2^2} + \dots\dots + \frac{1}{f_n^2}}$$

...response :-

If the rise time of isolated individual cascaded stages are, t_{r1}, t_{r2} .... t_{rn} and if the input ...form rise time is t_{r0} then the output signal rise time t_r is given by :

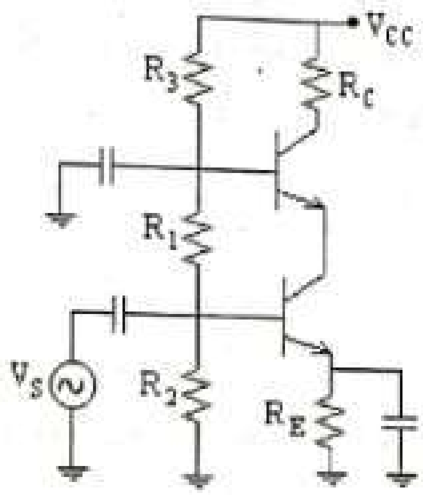
$$t_r = 1.1\sqrt{t_{r0}^2 + t_{r1}^2 + t_{r2}^2 + ... + t_{rn}^2 +}$$

If one circuit produces a tilt of P_1 percent and if second stage gives a tilt of P_2, the effect of cascading ...ber of stages is given as :

$$P = P_1 + P_2 + P_3 + ...$$

...code amplifier :-

In a multistage amplifier if common emitter is a first stage and common base (or common collector) is ...ond stage then the connection is called cascode connection shown below :

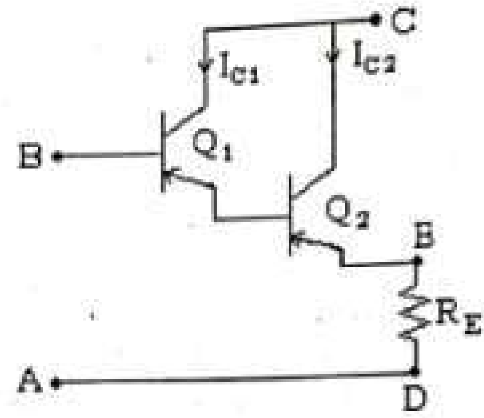


This arrangement is designed to provide a high input impedance with low voltage gain. Cascode ...lifier has :

1. High input impedance (of CE)
2. Low output resistance (of CB)
3. Very good frequency response.
4. The reverse-open circuit voltage amplification is $h_r = h_{re} \times h_{rb} \cong 10^{-7}$. Very low value of h_r makes cascode amplifier useful in tuned-amplifier design. Because, very small reverse internal feedback improves the tuning.

Darlington pair :-

Darlington pair is shown in figure below from where we can see that the emitter current of transistor Q_1 is working as a base current of Q_2. Therefore quescent current of Q_1 is very smaller...



The main feature of Darlington connection is that the composite transistor acts as a single... a current gain proportional to the product of current gains of the individual transistors. If transistors... Q_2 have current gains of β_1 and β_2 respectively, then current gain of Darlington pair is :

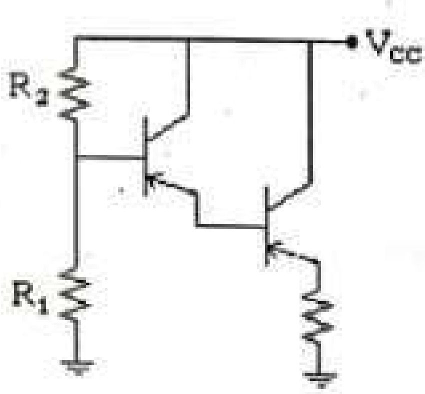
$$\boxed{\beta_D = \beta_1\beta_2}$$

Properties of Darlington pair :-

1. Current gain is high.
2. Input resistance is very high.
3. Available in package form.
4. The drawback is that it has high leakage current and it is present because of the amplification... leakage current.

Bootstrapping :-

When darlington pair is used with biasing resistors as shown below. Its input resistance de...



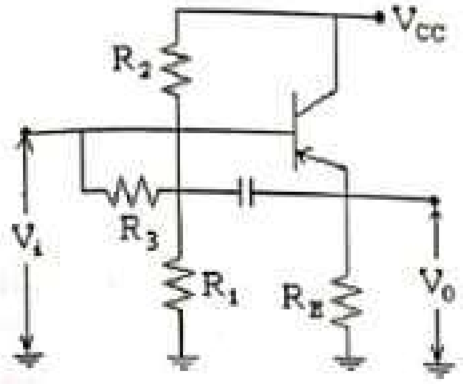
Here input impedance becomes.

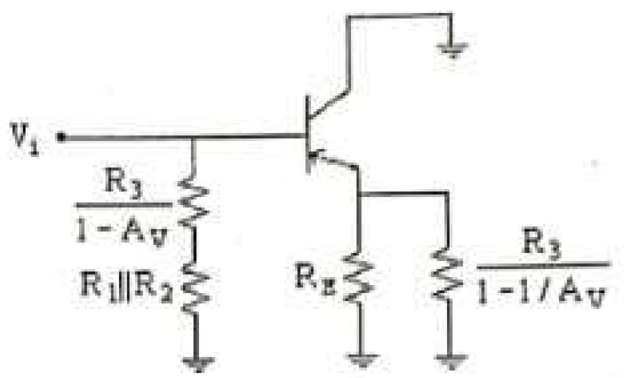
$$R'_i = R_i || R_B$$

where, $R_B = R_1 || R_2$ and $R_i = R_C(1+\beta)^2$

Generally here, $R_i > R_B$ so, $R'_i \cong R_B$ which is low.

In order to overcome this biasing problem, Bootstrapping is used. Bootstrapped arrangement is shown in figure below :





a.c. equivalent circuit using Miller's theorem

Here capacitor works as short circuit even for lowest frequency component of concern. This biasing arrangement gives effective input impedance.

$$R_{eff} = \frac{R_3}{1-A_V}$$

When $A_V \to 1$ will give you very high value of effective resistance.

□□□

Key points :

- RC coupling of multistage amplifier is most widely used as compared to transformer coupled or direct coupled amplifiers.
- RC coupled amplifier has wide frequency response.
- RC coupled amplifier provides less frequency distortion.
- Transformer coupled amplifier has higher voltage gain than RC coupled amplifier.
- Transformer coupled amplifier provides excellent impedance matching.
- Direct coupled amplifier is used for low frequency signals and DC signals.
- The frequencies at which the gain drops to 0.707 of the mid band value are called the cutoff, corner, band, break or half power frequencies.
- Change in frequency by a factor of 2 is equivalent to 1 octave, results in a 6 dB change in gain.
- Change in frequency by a factor of 10 is equivalent to 1 decade, results in a 20 dB change in gain.
- A cascade connection is a series connection.
- For cascade connection, voltage amplification is the product of the stage voltage gains.
- Cascode connection provides a high input impedance and a low output impedance.
- Darlington connection provides two transistors connected as one super transistor.
- Gia-colett0 model is valid upto the frequency $\frac{f_T}{3}$.