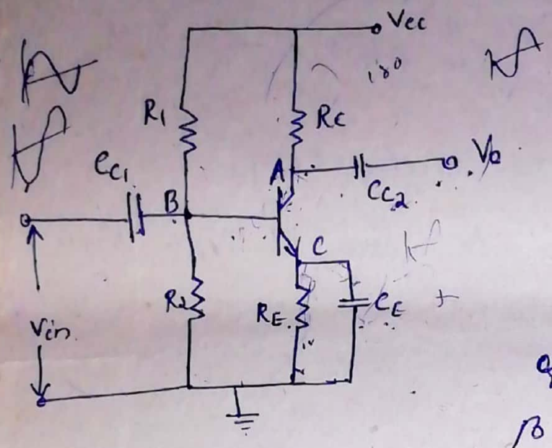
Single stage RC Coupled amplifier

It is a voltage amplifier.



Here an npn transistor is connected in the CE configuration. It uses the voltage divider method of biasing using the resistors R_1 & R_2 and the supply V_{cc}. So we can acquire better stabilization of Q point against temperature and β variations. We apply an ac voltage between the base and the emitter terminals to produce fluctuations in the collector current. An amplified o/p signal is obtained when the fluctuating collector current flows through a collector resistance R_C. The voltage across R_2 is forward bias the EB junction (pt B is $+^{ve}$ w.r.t pt C). The voltage across R_1 is connected to the CB junction. It reverse biases the CB junction (pt B is $-^{ve}$ w.r.t pt A).

The capacitors C_C are called the coupling capacitors. A coupling capacitor passes an ac signal from one side to the other. At the same time it blocks the dc voltage through it. Hence it is also called the blocking capacitor. So due to C_{C2} the o/p voltage is free from collector dc voltage.

The capacitor C_E works as bypass capacitor. It bypasses all the ac current from the emitter to the ground. Otherwise it will reduce the o/p voltage due to negative feedback. Thus lesser o/p voltage is obtained. We select a value of C_E that gives a low impedance compared to R_E at the lowest frequency present in the i/p signal. Usual value is $X_{CE} \leq \frac{R_E}{10}$.

When the i/p signal voltage increases in the $+^{ve}$ half cycle, the base voltage increases, the base current I_B also increases. Then collector current also increases ($I_C = \beta I_B$).

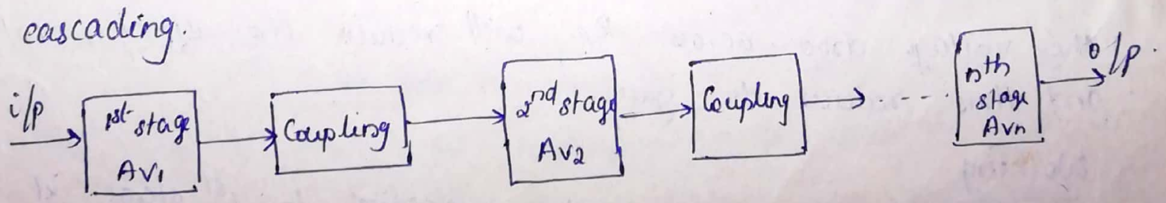
This large current flows through Rc and hence the voltage drop I_cR_c increases. As Vcc is const, the o/p voltage V_0 reduces ($V_0 = V_{cc} - I_cR_c$). During the -ve half cycle when the i/p signal voltage decreases, the base current thereby the collector current decreases. The voltage drop across I_cR_c also reduces, then V_0 increases. In other words, as the signal voltage is increasing in the +ve direction then the o/p voltage is increasing in the negative sense and vice versa, ie the output is 180° out of phase with the input signal.

The collector current variation is large compared to the base current variation. Hence the voltage variation across the resistor Rc is also very large compared to with the small input signal amplitude at the base. Thus the amplified version of input signal is developed across the resistor Rc.

A good amplifier stage is one which has high i/p resistance and low o/p resistance. In CE configured it has high i/p resistance and low o/p resistance decreases voltage gain and power gain are high. So CE configured is commonly used.

Multistage Amplifier

Voltage or power gain obtained from a single stage amplifier is limited. A greater volt or power gain is needed for all practical purposes. Therefore multistage amplifier is used to increase overall gain. In multistage amplifier o/p of one stage is coupled to the input of next stage. This is known as cascading.



Ratio of o/p to i/p is known as gain.

voltage gain of a multistage amplifier is equal to the product of gains of individual stages.

Voltage gain of a multistage amplifier is equal to the product of gains of individual ~~gain~~ stages.

ie. Overall gain $A_V = A_{V_1} \times A_{V_2} \times A_{V_3} \ldots A_{V_n}$.

when the gains are expressed in dB the overall gain of a multistage amplifier is given as the sum of gains of individual stages in decibels (dB).

ie. $20\log_{10} A_V = 20\log_{10} A_{V_1} + 20\log_{10} A_{V_2} + \ldots + 20\log_{10} A_{V_n}$.

Example 14.1. A multistage amplifier consists of three stages. The voltage gains of stages are 60, 100, 160. Calculate the overall voltage gain in dB. [*Pb. Technical Univ. Analog Electronics May 2005*]

Solution : Voltage gain of first stage in dB $= 20 \log_{10} 60 = 35.563$ dB

Voltage gain of second stage in dB $= 20 \log_{10} 100 = 40$ dB

Voltage gain of third stage in dB $= 20 \log_{10} 160 = 44.082$ dB

Overall voltage gain of the amplifier $= 35.563 + 40 + 44.082$

$= 119.645$ dB **Ans.**

Alternative Method :

$$\text{Overall voltage gain, } A_v = A_{v_1} \times A_{v_2} \times A_{v_3}$$

$$= 60 \times 100 \times 160 = 960{,}000$$

$$\text{Overall voltage gain in dB} = 20 \log_{10} 960{,}000$$

$= 119.645$ dB **Ans.**

Example 14.2. The overall gain of a 2-stage R-C coupled amplifier is 80 dB. If the voltage gain of the second stage is 150, calculate the voltage gain of the first stage in dB.

[*G.G.S.I.P. Univ. Analog Electronics December 2009*]

Solution : Overall voltage gain of 2-stage R-C coupled amplifier

$= 80$ dB

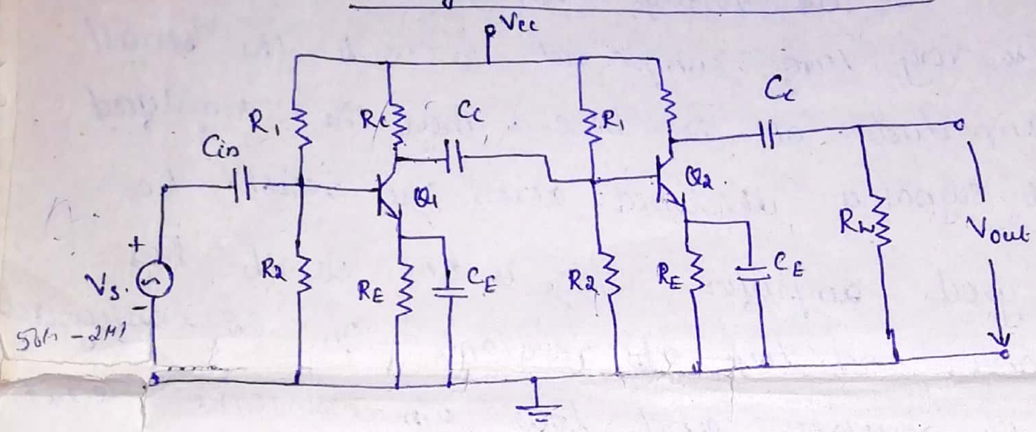
Voltage gain of second stage in dB $= 20 \log_{10} 150 = 43.52$ dB

Voltage gain of first stage $= 80 - 43.52 = 36.48$ dB **Ans.**

Different Coupling methods are used

1) RC Coupled amplr. (2) Transformer coupled amplr.
(3) Direct coupled amplr.

Two stage RC coupled amplifier



The ckt consists of two single stage CE transistor amplifier.

Here the two transistors used are identical and use a common power supply Vcc. The resistors R_1, R_2 and R_E form the biasing and stabilization network. The signal developed across collector resistor R_C of the first stage is coupled to the base of the second stage through the coupling capacitor C_C. The i/p capacitor C_{in} couples ac signal voltage to the base of transistor Q_1. In the absence of C_{in} the bias voltage of the base will be affected. The C_{in} allows only the flow of ac current onto the input circuit.

C_E is the bypass capacitor. If it is not present, then the voltage drop across R_E will reduce the effective voltage and thus reduces the gain.

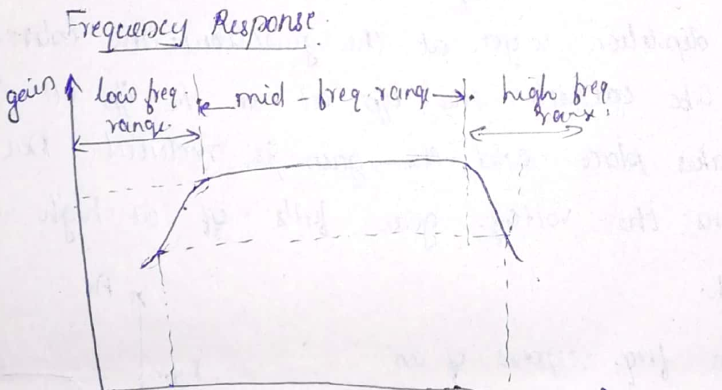
Working

When an ac signal is applied to 1st stage it is amplified by the 1st stage and appears across collector load R_C. This is given to the i/p of 2nd stage through C_C which blocks dc. So only ac signal is fed to next stage. 2nd stage further amplifies the signal. Thus the cascaded stages amplify the signal and overall gain is equal to product of individual gain. o/p of 2 stage RC coupled amplifier is in phase with i/p signal because its phase has been reversed twice by amplifier. Practically it is seen that the overall gain is less than the product of gain of individual stages due to the following reasons.

1) When signal passes from one stage to second there occurs some loss of signal voltage due to drop across coupling capacitor. This drop is proportional to impedance offered by capacitor ∴ higher the impedance more will be loss across capacitor. $X_C = \frac{1}{2\pi f C}$ so when the freq. of the i/p signal is low, then more will be the impedance and there occur more losses.

2) When amplifiers are cascaded then load resistance of each stage decreases due to shunting effect of i/p resistance of next stage $X_C = \frac{1}{2\pi f C}$ impedance goes on reducing with increase in freq. of i/p signal. Input impedance of 2nd stage comes in ∥ with load impedance of 1st stage so the load impedance of 1st stage decreases. Then o/p voltage developed across load reduces. Hence gain, which is the ratio of o/p voltage to i/p voltage also reduces.

Frequency Response.



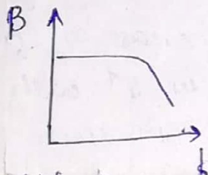
mid freq. range: The gain is const. for a limited band of frequencies. This range is known as mid freq. range and the gain is called mid band gain. In this range, when freq increases, the reactance of the coupling capacitor reduces ($X_c = \frac{1}{2\pi f c}$), thereby increasing the gain. But at the same time decrease in reactance means increase in loading effect and hence gain decreases. Thus these two effects cancel each other and maintain constant gain in this band of frequencies.

At low frequencies (below 50 Hz)

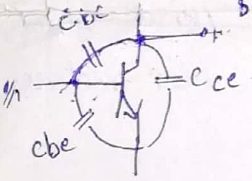
At low frequencies coupling capacitor C_c offers high reactance ($X_C = \frac{1}{2\pi f C}$) and a very small part of signal passes from one stage to next. ie large amount of signal voltage is dropped across coupling capacitor C_c. Due to this voltage gain reduces. At low frequencies bypass capacitor C_E offers high reactance and hence cannot shunt the emitter resistance effectively. So ac signal flows through R_E. This in turn decrease the o/p voltage. Thus the effect of C_c and C_E reduce the gain at low frequencies.

At high frequencies (> 20 kHz)

At higher frequencies the reactance of coupling capacitor is very low and it behaves like short ckt. This increases the loading effect of next stage and reduces the voltage gain.

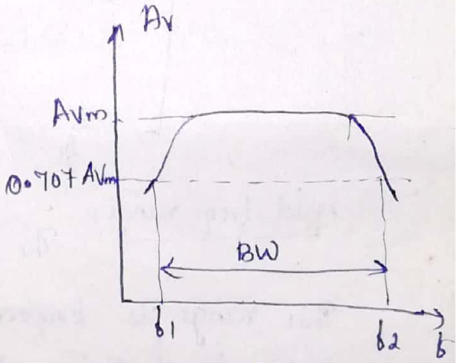


The β of the transistor is frequency dependent. Its value decreases at high frequencies. Because of this the voltage gain of the amplifier reduces as the freq. increases ($I_C = \beta I_B$)



In the case of a transistor, there exist some interelectrode capacitances (due to the formation of a depletion layer at the junction). The interelectrode capacitance C_{bc} connects the o/p ckt to the i/p ckt. Thus -ve feedback takes place and the gain is reduced. Due to all these reasons, the voltage gain falls off at high frequencies.

Band width



In the freq. response of an RC coupled amplifier the gain remains const. for a limited band of frequencies. On both the sides (low freq and high freq) the gain falls. The freq. limit is set at those frequencies at which the voltage gain reduces to ~~70~~ 70.7% of the maximum gain A_{vm}. These frequencies are known as cut-off frequencies of the amplifier. ie at cut off frequencies the voltage gain is $0.707 A_{vm}$ ($= \frac{1}{\sqrt{2}} A_{vm}$).

It means that at that frequencies the output voltage is $\frac{1}{\sqrt{2}}$ times the max. voltage. Power $P \propto V^2$ $\therefore$ the o/p power at these cut off frequencies becomes one half of the power at mid frequency. On db scale this is equal to a reduction in power by 3db. $\therefore$ these frequencies are also known as 3db frequencies.

$BW = f_2 - f_1$

$f_1 \rightarrow$ lower cut-off frequency

$f_2 \rightarrow$ upper cut-off frequency.

$BW \rightarrow$ band width.

gain bandwidth = gain x band width.

Advantages:

* Excellent frequency response (Const gain over the audio frequency range)
* cheaper in cost.
* compact ckt.

Disadvantages:

* low voltage and power gain due to low resistance presented by the i/p of each stage to the preceding stage.
* tendency of becoming noisy with age
* Poor impedance matching