Multistage Transistor Amplifier

In a multistage amplifier, a number of single amplifiers are connected in cascade arrangement (cascaded means connected in series), i.e output of first stage is connected to the input of the second stage through a suitable coupling device and so on. The purpose of coupling device (e.g. a capacitor, transformer etc.) is :

1- to transfer a.c. output of one stage to the input of the next stage.

2- to isolate the d.c. conditions of one stage from the next stage.

Figure (1) shows the block diagram of a 3-stage amplifier.

Name of coupling	Name of multistage amplifier
RC coupling	R-C coupled amplifier
Transformer coupling	Transformer coupled amplifier
Direct coupling	Direct coupled amplifier

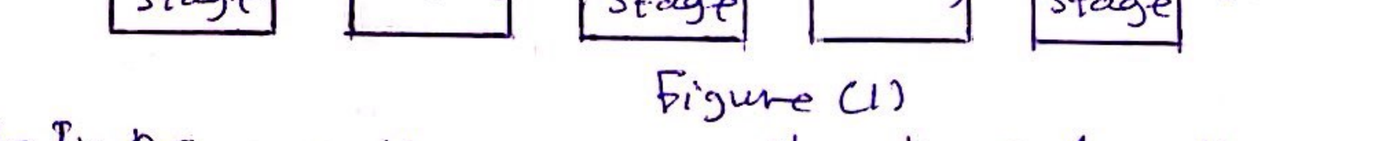


Figure (1)

a- In RC coupling, a capacitor is used as the coupling device. The capacitor connects the output of one stage to the input of the next stage in order to pass the a.c. signal on while blocking the d.c. bias voltages.

b- In transformer coupling, transformer is used as the coupling device. The transformer coupling provides the same two functions (to pass the signal on and blocking d.c.) but permits in addition impedance matching.

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

The gain of a multistage amplifier is equal to the product of gains of individual stages. for instance, if G_1, G_2 and G_3 are the individual voltage gains of a three-stage amplifier, then total voltage gain G is given by:

$$G = G_1 \times G_2 \times G_3$$

suppose the input to first stage is V.

Output of first stage $= G_1 V$

Output of second stage $= (G_1 V) G_2 = G_1 G_2 V$

Output of third stage $= (G_1 G_2 V) G_3 = G_1 G_2 G_3 V$

Total gain, $G = \dfrac{\text{Output of third stage}}{V}$

or $G = \dfrac{G_1 G_2 G_3 V}{V} = G_1 \times G_2 \times G_3$

RC Coupled Transistor Amplifier

This is the most popular type of coupling because it is cheap and provides excellent audio fidelity over a wide range of frequency. It is usually employed for voltage amplification. Figure (2) shows two stages of an RC coupled amplifier. C_c is used to connect the output of first stage to the input of the second stage and so on.

The resistances R_1, R_2 and R_E form the biasing and stabilisation network. The emitter bypass capacitor offers low reactance path to the signal. The coupling capacitor C_c transmits a.c. signal but blocks d.c.. This prevents the shifting of operating point.

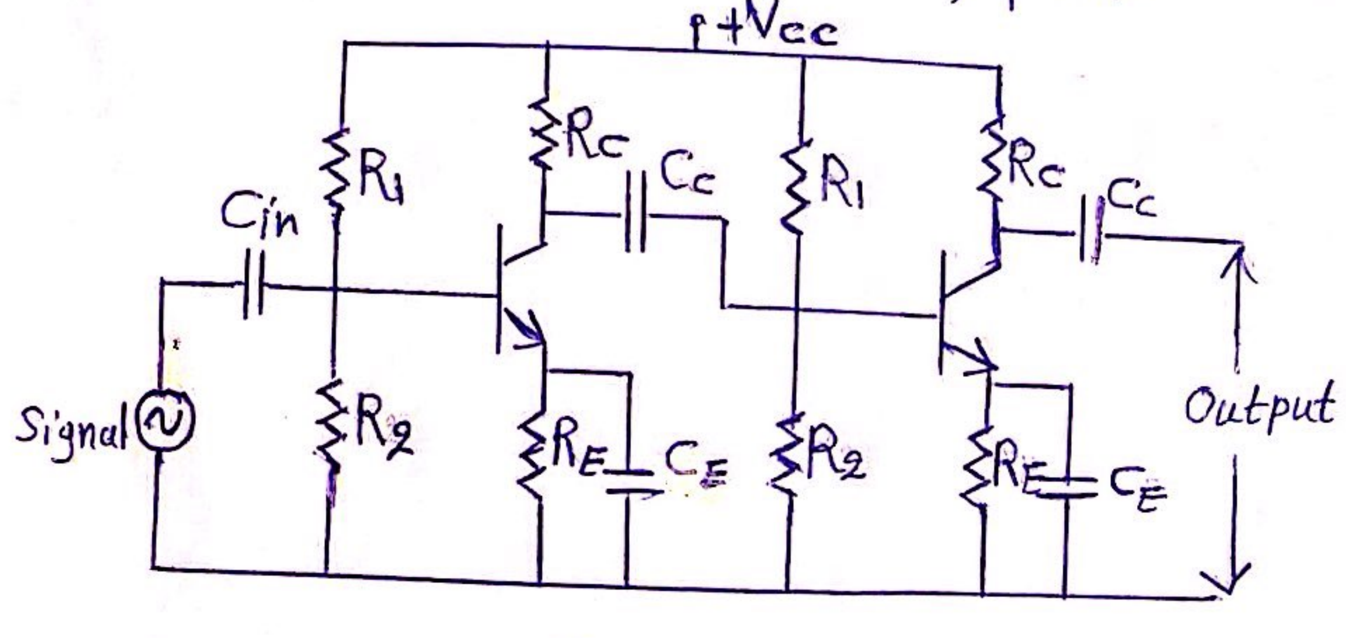


Figure (2)

It may be mentioned here that total gain is less than the product of the gains of individual stages. It is because when a second stage is made to follow the first stage, the effective load resistance of first stage is reduced due to the shunting effect of the input resistance of second stage. This reduces the gain of the stage which is loaded by the next stage. In a 3-stage amplifier, the gain of first and second stages will be reduced due to loading effect of next stage. However, the gain of the third stage which has no loading effect of subsequent stage, remains unchanged.

For the circuit shown in Figure (1)

1- Substitute the r_e equivalent circuit into the a.c. equivalent network of Figure (1).

2- Calculate the overall no-load voltage gain and output voltage V_o.

3- Calculate the input impedance of the first stage and the output impedance of the second stage.

4- Calculate the overall gain and output voltage if a 4.7 kΩ load is applied to the second stage.

5- Determine the maximum input voltage ($V_{i(p-p)}$) for maximum output voltage ($V_{o(p-p)}$) without distortion.

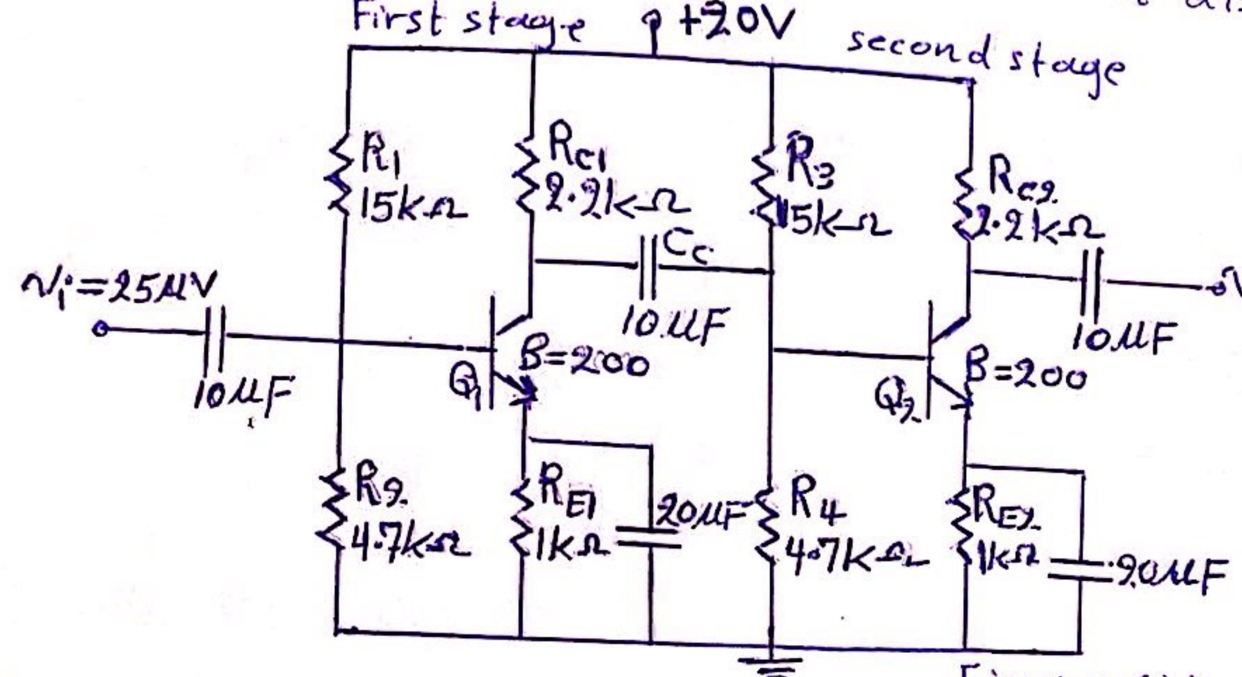
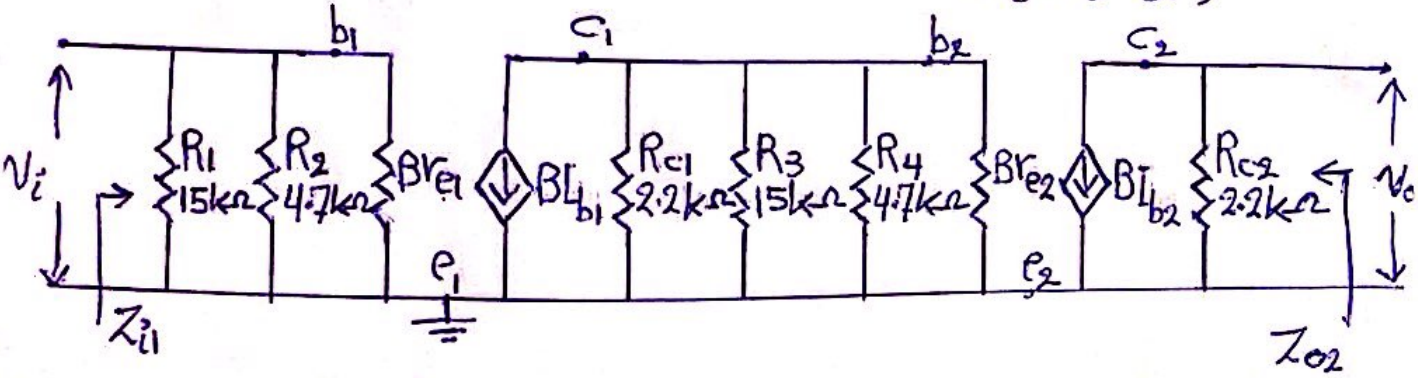


Figure (1)



Substituting the r_e equivalent circuit into the a.c. equivalent network of Figure (1)

$$V_{B1} = V_{B2} = \frac{V_{cc}}{R_1+R_2} * R_2 = \frac{20V}{15k+4.7k} * 4.7k = 4.8V$$

$$V_{E2} = V_{B2} - V_{BE2} = 4.8V - 0.7V = 4.1V = V_{E1}$$

$$I_{E2} = \frac{V_{E2}}{R_{E2}} = \frac{4.1V}{1k} = 4.1mA = I_{E1}$$

$$r_e = \frac{26mV}{I_E} \qquad r_{e1} = r_{e2} = \frac{26mV}{4.1mA} = 6.34\Omega$$

$$Z_{i2} = R_3 // R_4 // \beta r_{e2} = 15k // 4.7k // (200 * 6.34)$$

$$Z_{i2} = 3.58k // 1.268k = 0.936k\Omega$$

$$A_{V1} = -\frac{R_{AC1}}{r_{e1}} \qquad R_{AC1} = R_{C1} // Z_{i2} \qquad R_{AC1} = 2.2k // 0.936k$$

$$R_{AC1} = 0.657k\Omega$$

$$\therefore A_{V1} = -\frac{0.657k}{6.34} = -104$$

For the unloaded second stage the gain is

$$A_{V2(NL)} = -\frac{R_C}{r_{e2}} = \frac{-2.2k\Omega}{6.34\Omega} = -347$$

The overall no-load voltage gain $A_{VT(NL)} = A_{V1} A_{V2(NL)}$

$$A_{VT(NL)} = (-104)(-347) = \underline{36.1 * 10^3}$$

The output voltage is:

$$V_o = A_{VT(NL)} V_i = (36.1 * 10^3)(25\mu V) = 902.5 mV$$

The input impedance of the first stage is Z_{i1}

$$Z_{i1} = R_1 // R_2 // \beta r_{e1} = 15k // 4.7k // (200 * 6.34\Omega) = \underline{0.936k\Omega}$$

The output impedance for the second stage is Z_{o2}

$$Z_{o2} = R_C = \underline{2.2k\Omega}$$

If $R_L = 4.7k\Omega$ is connected to the second stage

$$A_{V2} = -\frac{R_C // R_L}{r_{e2}} = \frac{-2.2k // 4.7k}{6.34\Omega} = \frac{-1.498}{6.34\Omega} = -236.4$$

$$\therefore A_{VT} = A_{V1} * A_{V2} = (-104)(-236.4) = \underline{24.58 * 10^3}$$

To find maximum input $V_{s\,(p-p)}$ for maximum output $V_{o\,(p-p)}$ without distortion, we need to find $V_{o\,max\,(p-p)}$ from DC analysis.

$$V_{CE2} = V_{CC} - I_{C2}(R_{C2} + R_{E2})$$
$$= 20V - 4.1m(2.2k + 1k)$$
$$= 6.88V$$

at $V_{CE_2} = 0V$ $\quad I_{C2max} = \frac{V_{CC}}{R_{C2} + R_{E2}} = \frac{20V}{2.2k + 1k} = 6.25\,mA$

at $I_{C2} = 0mA$ $\quad \therefore V_{CE2max} = V_{CC} = 20V$

$$V_{o\,max\,(p-p)} = 2 * 6.88 = 13.76\,V$$

$$V_{i\,max\,(p-p)} = \frac{V_{o\,max\,(p-p)}}{A_{VT}} = \frac{13.76V}{36.1 * 10^{3}} = \underline{\underline{381.2\,\mu V}}$$