BASIC DIFFERENTIAL AMPLIFIER

The two identical emitter biased circuits are used to form the differential amplifier. The transistors Q_1 and Q_2 have identical characteristics $R_{E1} = R_{E2}$, $R_{C1} = R_{C2}$ and $V_{CC} = |-V_{EE}|$.

Fig. 3.7 shows two identical emitter biased circuits. These two emitter biased circuits are combined by connecting + V_{CC} supply voltages of the two circuits together and -V_{EE} Supply voltages together.

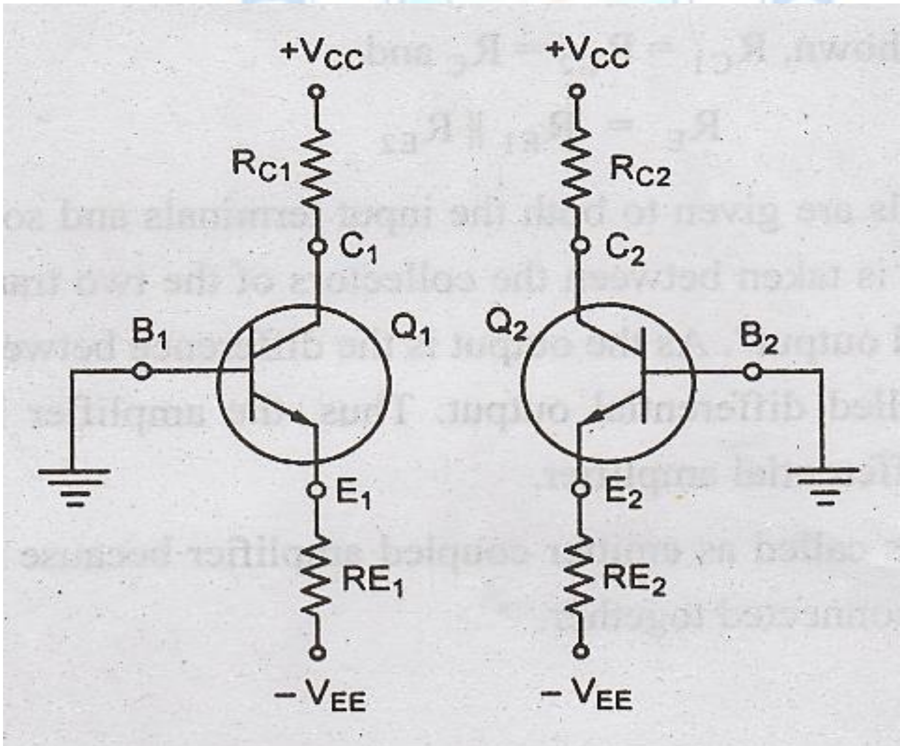

Fig. 3.7. Two identical emitter based circuits

The emitter E_1 of transistor Q_1 is connected to the emitter E_2 of transistor Q_2. Thus, R_{E1} is connected in parallel with R_{E2}.

The input signal V_1 is applied to the base B_1 of transistor Q_1 and V_2 is applied to the base B_2 of transistor Q_2. The output voltage is obtained between the collectors C_1 and C_2.

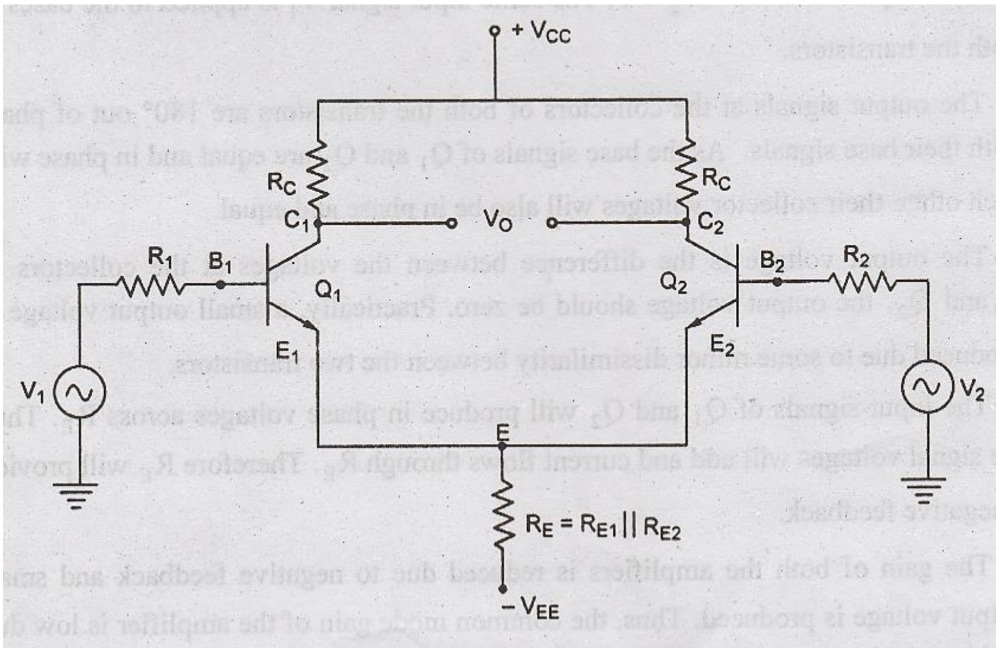

Fig. 3.8. BJT differential amplifier

In the Fig. 3.8 shown, $R_{C1} = R_{C2} = R_C$ and

$R_E = R_{E1} \parallel R_{E2}$

The input signals are given to both the input terminals and so it is called as "dual input". The output is taken between the collectors of the two transistors. Hence, it is called as "balanced output". As the output is the difference between the output of two collectors, it is called differential output. Thus, the amplifier is called dual input balanced output differential amplifier.

This amplifier is called as emitter coupled amplifier because the emitter of bothe the transistors are connected together.

Operation

The operation of emitter coupled differential amplifier has two operating modes.

i. Common mode

ii. Differential mode

Common Mode Operation

For common mode, the signals with same magnitude and phase are applied to both the inputs. i.e., $V_1 = V_2 = V$. The same input signal V_1 is applied to the bases of both the transistors.

The output signals at the collectors of both the transistors are 180° out of phase with their base signals. As the base signals of Q_1 and Q_2 are equal and in phase with each other, their collector voltages will also be in phase and equal.

The output voltage is the difference between the voltages at the collectors of Q_1 and Q_2, the output voltage should be zero. Practically, a small output voltage is produced due to some minor dissimilarity between the two transistors.

The input signals of Q_1 and Q_2 will produce in phase voltages across R_E. Thus the signal voltages will add and current flows through R_E. Therefore R_E will provide a negative feedback.

The gain of both the amplifiers is reduced due to negative feedback and small output voltage is produced. Thus, the common mode gain of the amplifier is low due to this negative feedback provided by R_E.

Hence, in the common mode operation, the input signal with some magnitude and phase is applied to both the transistors. A small output voltage is produced at the output and the common mode gain is very low.

Fig.3.9 shows the operation of the emitter coupled differential amplifier under common mode signal.

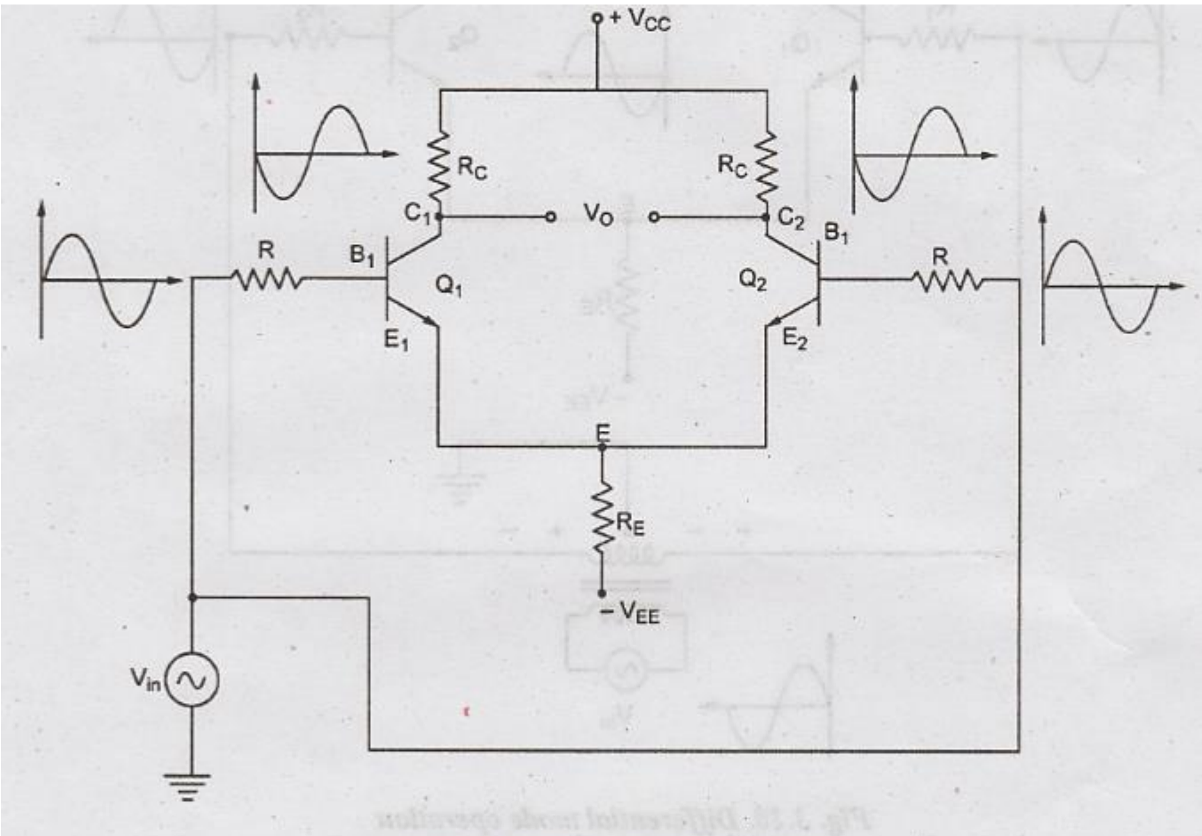

Fig. 3.9. Common mode operation

Differential Mode Operation

In differential mode of operation, the two input signals V_1 and V_2 are of equal magnitude but opposite phase. i.e., $V_1 = -V_2$. For these input signals to be same magnitude and opposite phase, a center tapped transformer is used.

During positive half cycle of V_1, the input to Q_1 is positive sinusoidal signal and the input to Q_2 is negative sinusoidal signal. This can be achieved due to centre tapped transformer.

At the collector of Q_1 and Q_2, the signals are 180° out of phase with respect to their input signals. The output voltage is the difference between the output of the individual transistors.

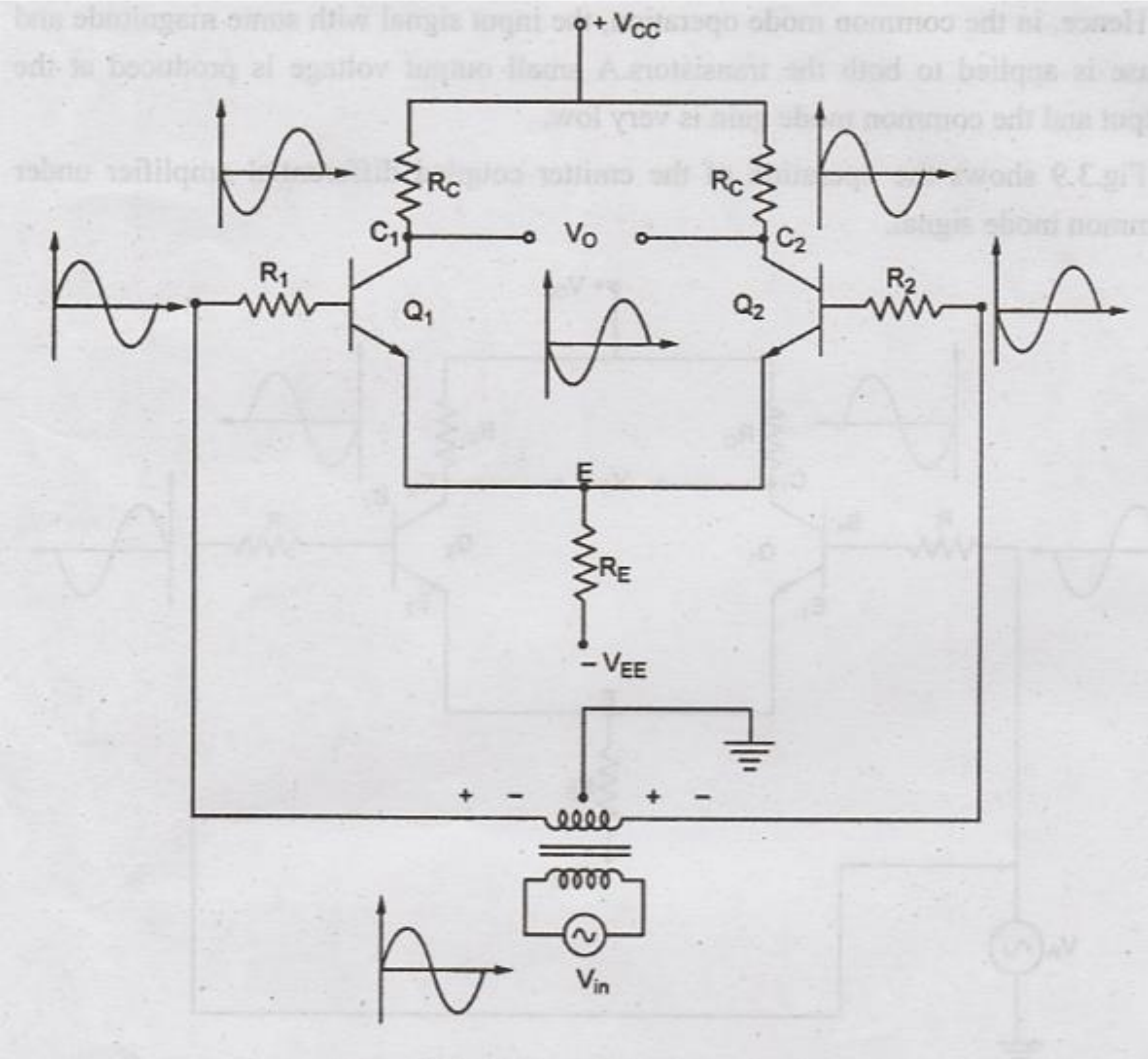

Fig. 3.10. Differential mode operation

The amplitude of the output will be twice the amplitude of the voltage obtained at either collector to ground.

Fig.3.10 shows the output voltage waveform at the collector of Q_1 with respect to collector of Q_2. In positive half cycle, the input to Q_1 is positive; so a positive voltage is developed across R_E. i.e., Q_1 acts as the emitter follower. The input signal to Q_2 is negative and thus it produces a negative voltage across R_E due to emitter follower action. Therefore, the equal and opposite signal voltages appear across R_E and these two voltages cancel each other. Thus two voltages across R_E is zero. i.e., the signal current flowing through R_E is equal to zero. Hence, R_E will not introduce negative feedback.

Thus, in the differential mode, the signal applied at the bases of the two transistors are equal in magnitude but opposite in sign. The output voltage is the difference between these two input signals.

$$\boxed{I_{CQ} = \frac{V_{EE} - V_{BE}}{2\,R_E}}$$

For a given value of V_{EE}, the emitter current I_E and I_{CQ} is determined by the emitter resistance R_E. The emitter current is independent of the collector resistance R_C. Then we have to find the expression for V_{CEQ} transistor Q_1.

Assumption

The voltage drop across the resistance R is negligibly small.

The emitter voltage of Q_1 is approximately equal to $-V_{BE}$

Then

$$V_C = V_{CC} - I_C R_C$$
$$V_{CE} = V_C - V_E = (V_{CC} - I_C R_C) - (-V_{BE})$$
$$V_{CE} = V_{CC} + V_{BE} - I_C R_C$$
$$\therefore\ V_{CEQ} = V_{CC} + V_{BE} - I_C RC$$

At the operating point $V_{CE} - V_{CEQ}$ & $I_E = I_{CQ}$

$$\text{i.e.,}\ \boxed{V_{CEQ} = V_{CC} + V_{BE} - I_{CQ} R_C}$$

$$I_{CQ} = I_{EQ} = \frac{V_{EE} - V_{BE}}{2\,R_E}$$