Push-Pull Amplifier

In amplifiers, appreciable distortion may result due to non-linearity of transfer characteristics. A large amount of distortion introduced by the non-linearity of the dynamic transfer characteristic may be eliminated by the push-pull configuration shown in Figure 1.

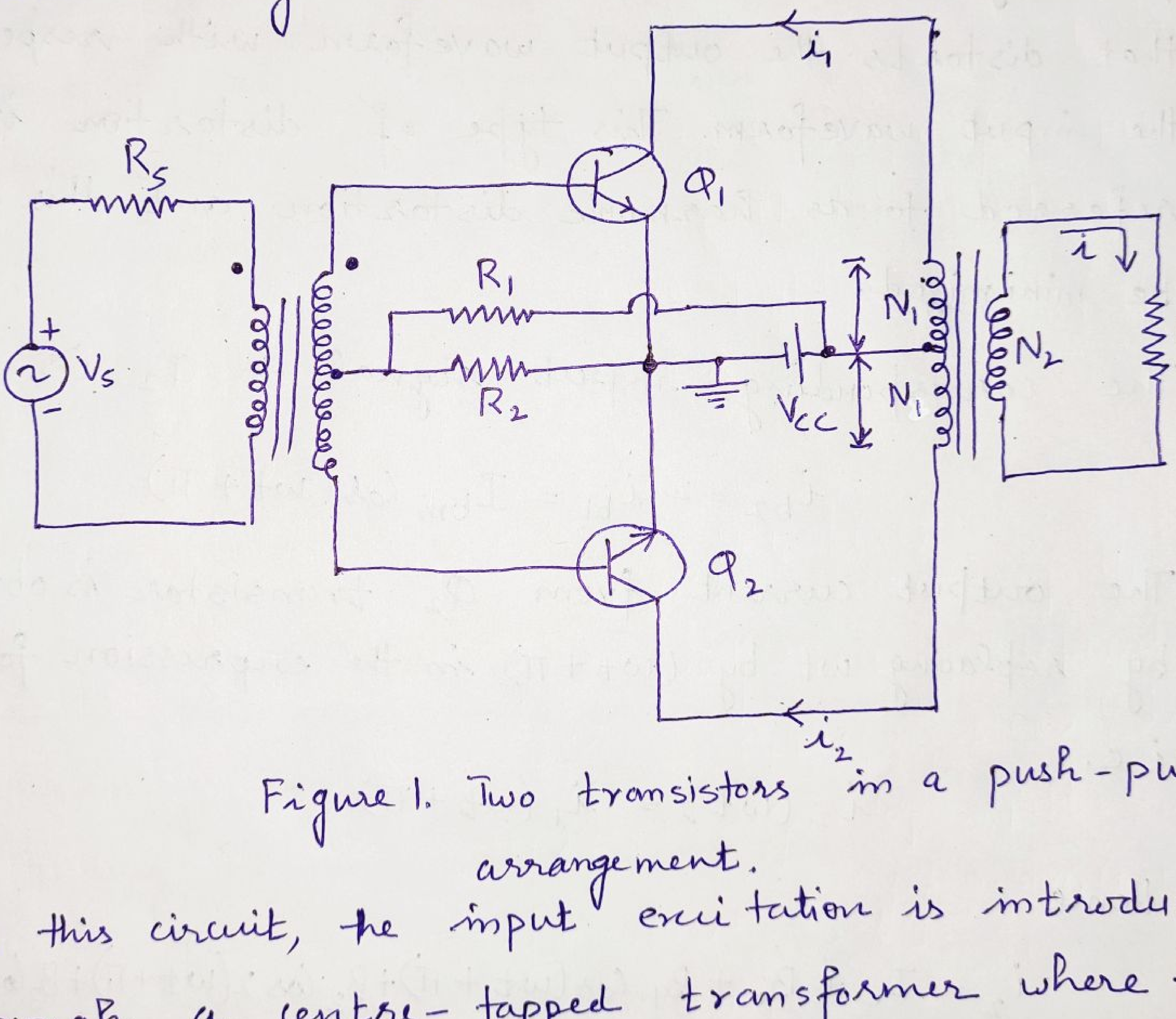

Figure 1. Two transistors in a push-pull arrangement.

In this circuit, the input excitation is introduced through a centre-tapped transformer where two equal voltages which differ in the phase by 180° is produced across the secondary winding. Thus, when the signal on transistor Q_1 is positive, the signal on Q_2 is negative by an equal amount. For an input signal of the form $i_{b_1} = I_{bm} \cos \omega t$

applied to Q_1, the output current from the transistor is given by,

$$i_1 = I_c + B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t + B_3 \cos 3\omega t + \cdots$$

where $B_0, B_1, B_2, B_3, \ldots$ are constants determined by the non-linearity of the transistor. In addition to the input frequency ω, certain higher order terms given by $2\omega, 3\omega, \ldots$ are available in the output that distorts the output waveform with respect to the input waveform. This type of distortion is referred to as harmonic distortion and this should be minimized.

The corresponding input signal to Q_2 is,

$$i_{b2} = -i_{b1} = I_{bm} \cos(\omega t + \pi)$$

The output current from Q_2 transistor is obtained by replacing ωt by $(\omega t + \pi)$ in the expression for i_1.

i.e.

$$i_2(\omega t) = i_1(\omega t + \pi)$$

Hence

$$i_2 = I_c + B_0 + B_1 \cos(\omega t + \pi) + B_2 \cos 2(\omega t + \pi) + B_3 \cos 3(\omega t + \pi) + \cdots$$

which reduces to

$$i_2 = I_c + B_0 - B_1 \cos\omega t + B_2 \cos 2\omega t - B_3 \cos 3\omega t + \cdots$$

As shown in Figure 1, the currents i_1 and i_2 flow in opposite directions through the primary winding of the output transformer. The total output current i, in the secondary winding is then proportional to the difference between the two collector currents.

i.e

$$i = K(i_1 - i_2) = 2K(B_1 \cos \omega t + B_3 \cos 3\omega t + \ldots)$$

This expression shows that a push-pull circuit will balance out all even harmonics in the output and the third harmonic term acts as the principle source of distortion, provided the two n-p-n transistors Q_1 and Q_2 are identical.

Advantages of Push-Pull Amplifier

1. A push-pull arrangement gives less distortion for a given power output.
2. The dc components of the collector current oppose each other magnetically in the transformer core, thereby eliminating any tendency towards core saturation leading to non-linear distortion.
3. The effect of the ripple voltages contained in the power supply caused by inadequate filtering are balanced out because the currents produced by the ripple voltages are in opposite direction in the transformer winding.

Class B Amplifier

In a class B amplifier, the transistor is biased almost at cut-off, so that it remains forward-biased only for one half cycle of the input signal. Hence, its conduction angle is only 180°. The circuit of Figure 1 operates in class B mode if $R_2 = 0$, because the silicon transistor is at cut-off if the base is shorted to the emitter. The advantages of class B are compared with class A operation are

(i) possible to obtain greater power output

(ii) efficiency is higher, and

(iii) negligible power loss (as no output current flows) at no input signal.

For these reasons, in such applications where the power supply is limited, say, operating from solar cells or a battery, the output is usually delivered through a push-pull class B amplifier circuit. The graphical construction for determining the output waveforms of a single class B amplifier stage is shown in Figure 2. In this diagram, the output characteristics are assumed to be equally spaced for equal intervals of excitation so that the dynamic transfer curve is a straight line. It is also assumed that the minimum current is zero. Here, for a given sinusoidal input, the output is sinusoidal during one half of each period and zero during the second half cycle. Load resistance connected in the secondary reflected into primary, i.e., the effective load resistance is $R_L' = \left(\frac{N_1}{N_2}\right)^2 R_L$. Here N_1 represents the number of primary turns from one end to the centre tap as shown in Figure 1.

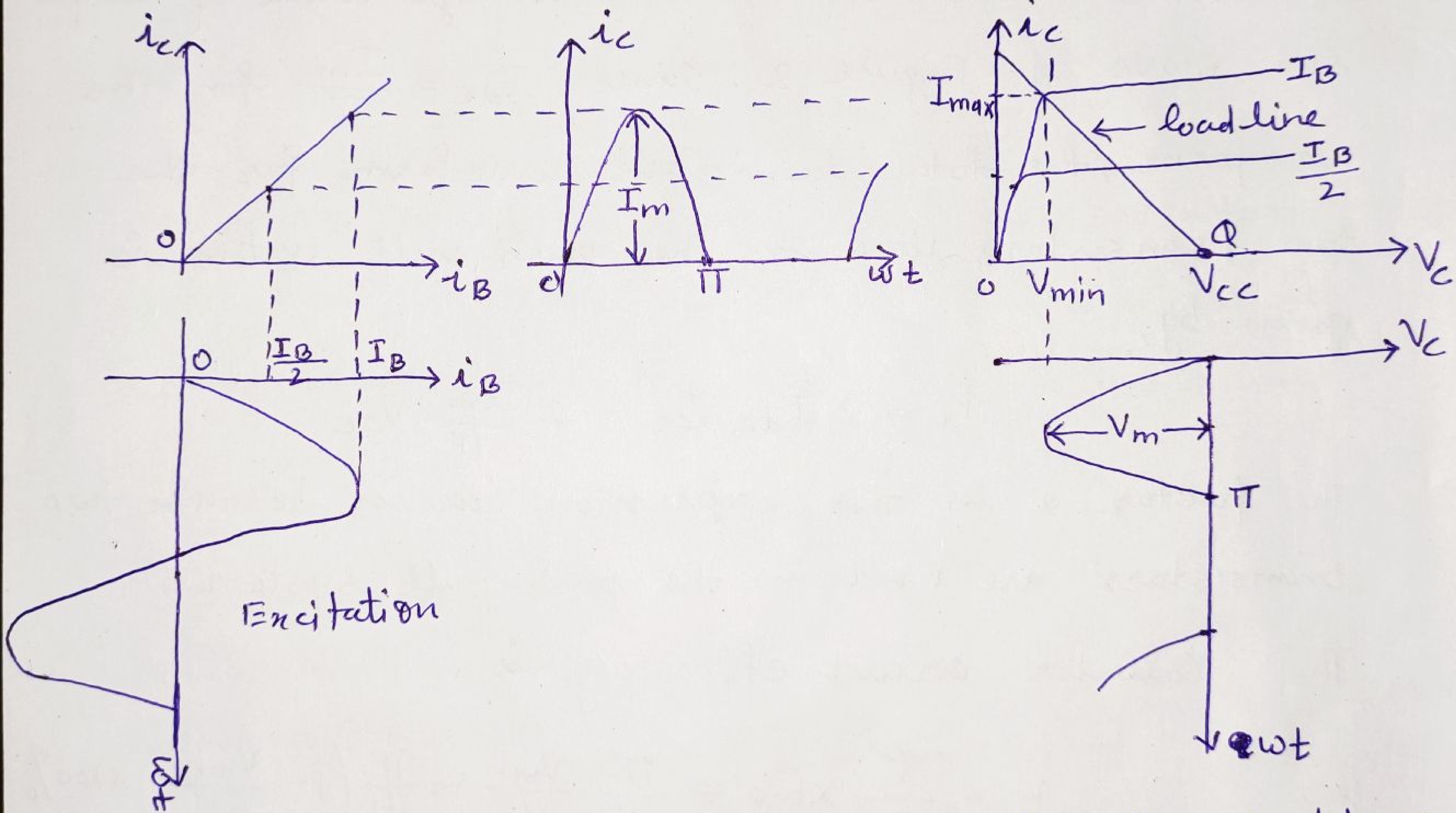

Figure 2. Graphical construction to determine the output waveform of a class B amplifier.

The wave forms shown in Figure 2 are for one transistor (Q_1) only. The output of Q_2 is a series of sine loop pulses that are 180° out of phase with those of Q_1. The load current which is proportional to the difference between the two collector currents is therefore a perfect sinewave for the ideal conditions assumed.

The Power Output is,

$$P = I_{rms} V_{rms} = \frac{I_m}{\sqrt{2}} \cdot \frac{V_m}{\sqrt{2}} = \frac{I_m V_m}{2}$$

$$P = \frac{I_m}{2}(V_{CC} - V_{min})$$

The corresponding direct collector current in each transistor under load is the average value of half-sine wave of Figure 2. Since $I_{dc} = \frac{I_m}{\pi}$ for this waveform, the total dc input waveform for the two transistors used in the push-pull system is given by,

$$P_i = 2 I_{dc} V_{CC} = 2 \frac{I_m}{\pi} V_{CC}$$

The factor 2 in this expression arises because two transistors are used in the push-pull system.

The Collector circuit efficiency is,

$$\eta = \frac{P}{P_i} \times 100 = \frac{\pi}{4} \frac{V_m}{V_{CC}} = \frac{\pi}{4}\left(1 - \frac{V_{min}}{V_{CC}}\right) \times 100\%$$

For a transistor circuit, where $V_{min} << V_{CC}$, it is possible to approach maximum possible conversion efficiency given by $\eta_{max} = 25\pi\,\% = 78.5\%$ for a class B system compared with 50% for class A operation.

Such a large value of efficiency results from the fact that when there is no excitation, there is no current in a Class B system, whereas in a Class A system even when there is no excitation (at zero input signal) there is a drain I_{CQ} from the power supply.

The collector dissipation P_c (in both transistors) is the difference between the power input to the collector circuit and the power delivered to the load.

Since $I_m = \frac{V_m}{R_L'}$

$$\therefore \quad P_c = P_i - P = \frac{2 V_{cc} V_m}{\pi R_L'} - \frac{V_m^2}{2 R_L'}$$

The above equation shows that the collector dissipation is zero at no signal ($V_m = 0$), rises as V_m increases and passes through a maximum at $V_m = 2 V_{cc}/\pi$.

$$\therefore \quad P_{c(max)} = \frac{2 V_{cc}^2}{\pi^2 R_L'}$$

The maximum power which can be delivered is obtained for $V_m = V_{cc}$ (for $V_{min} = 0$) as

$$P_{max} = \frac{I_m V_{cc}}{2} = \frac{V_m}{R_L'} \frac{V_{cc}}{2} = \frac{V_{cc}^2}{2 R_L'}$$

Hence $P_{c(max)} = \frac{4 P_{max}}{\pi^2} = 0.4 P_{max}$.