5.2.CLASS B PUSH PULL POWER AMPLIFIER:

- Though the efficiency of class B power amplifier is higher than class A, as only one half cycle of the input is used, the distortion is high. Also, the input power is not completely utilized. In order to compensate these problems, the push-pull configuration is introduced inclass B amplifier.
- In class B amplifier output collector current flows only for half cycle for full cycle of the input hence distortion. To get out for full input signal we use Push Pull circuit. Two transformers are used in Push pull amplifiers. one at the input and the other at the load side.

Construction:

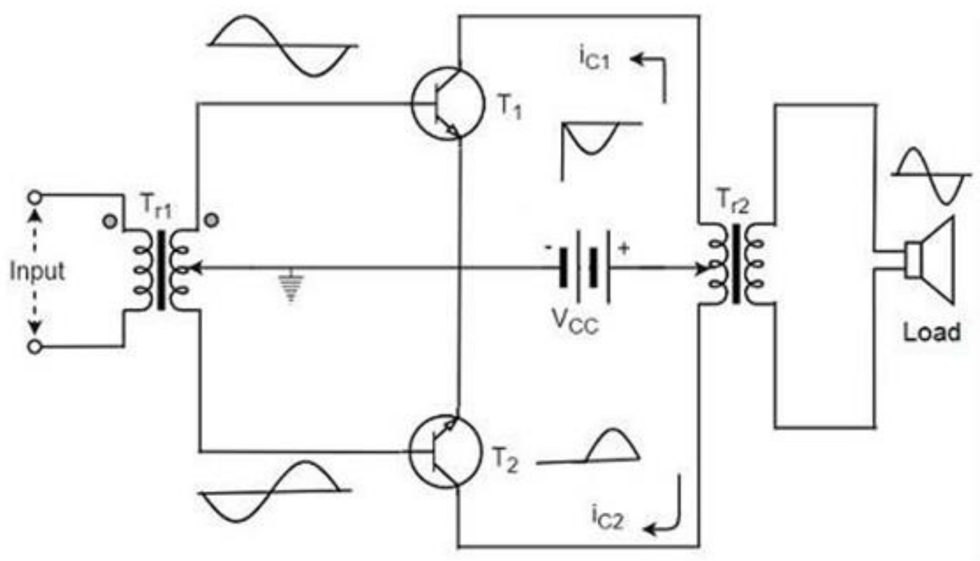


Fig 5.2.1 Push-pull class B power amplifier

(Source: Microelectronics byJ. Millman and A. Grabel, Page-483)

- The circuit of a push-pull class B power amplifier consists of two identical transistors T1 and T2 whose bases are connected to the secondary of the center-tapped input transformer Tr1. The emitters are shorted and the collectors are given the VCC supply through the primary of the output transformer Tr2.
- The circuit arrangement of class B push-pull amplifier, is same as that of class A push-pull amplifier except that the transistors are

biased at cut off, instead of using the biasing resistors. The figure below gives the detailing of the construction of a push-pull class B power amplifier.

- The circuit operation of class B push pull amplifier is detailed below.

Operation

- The circuit of class B push-pull amplifier shown in the above figure clears that both the transformers are center-tapped. When no signal is applied at the input, the transistors T1 and T2 are in cut off condition and hence no collector currents flow. As no current is drawn from V_{CC}, no power is wasted.
- When input signal is given, it is applied to the input transformer Tr1 which splits the signal into two signals that are 180^o out of phase with each other. These two signals are given to the two identical transistors T1 and T2. For the positive half cycle, the base of the transistor T1 becomes positive and collector current flows. At the same time, the transistor T2 has negative half cycle, which throws the transistor T2 into cutoff condition and hence no collector current flows. The waveform is produced as shown in the following figure.

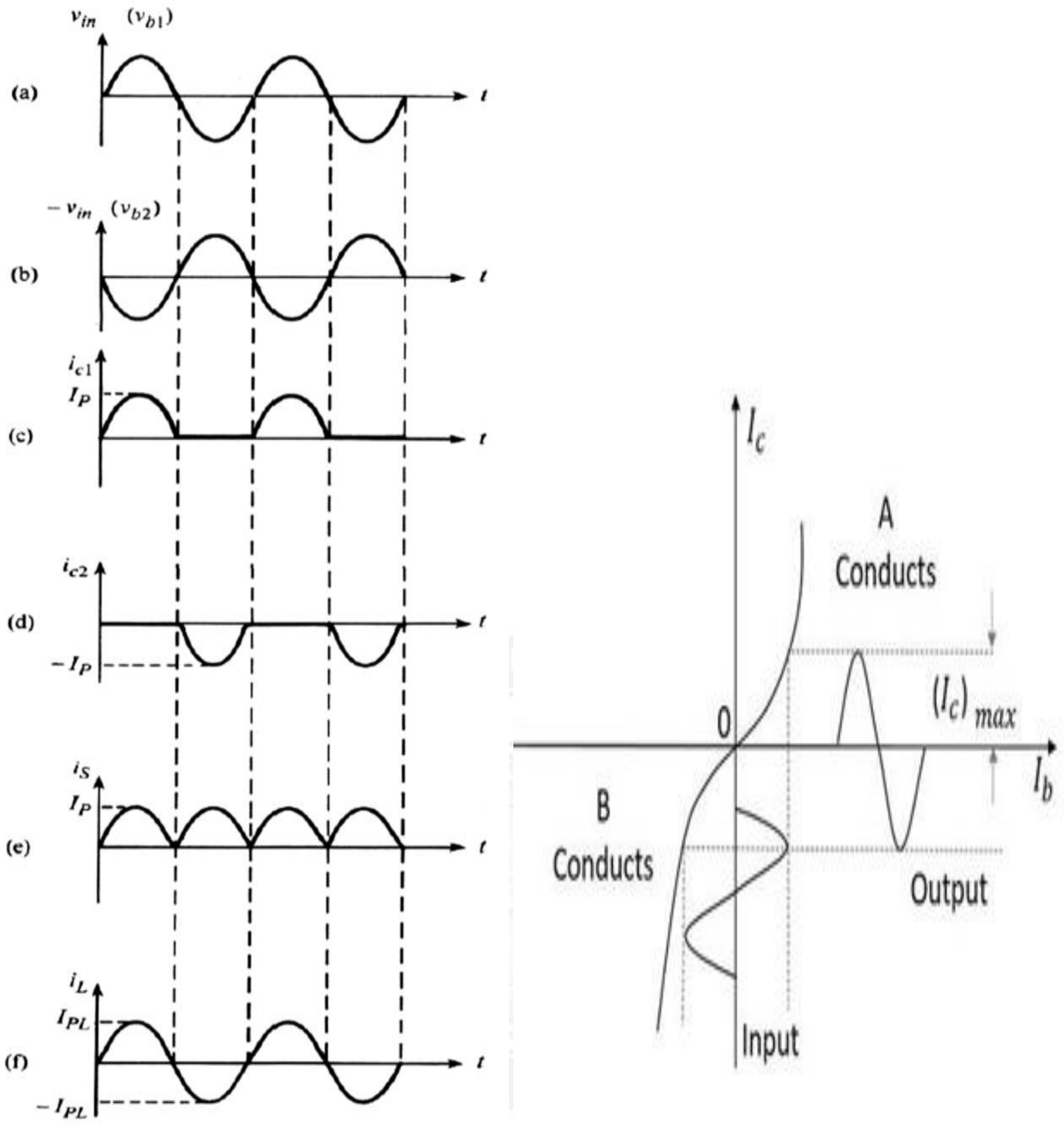


Fig.5.2.2 Push-pull class B power amplifier wave forms

(Source: Microelectronics byJ. Millman and A. Grabel, Page-489)

- For the next half cycle, the transistor T1 gets into cut off condition and the transistor T2 gets into conduction, to contribute the output. Hence for both the cycles, each transistor conducts alternately. The output transformer Tr3 serves to join the two currents producing an almost undistorted output waveform.

Power Efficiency of Class B Push-Pull Amplifier

- The current in each transistor is the average value of half sine loop.

  For half sine loop,

- Idc is given by

$$I_{dc} = \frac{(I_C)_{max}}{\pi}$$

Therefore,

$$(p_{in})_{dc} = 2 \times \left[\frac{(I_C)_{max}}{\pi} \times V_{CC}\right]$$

Here factor 2 is introduced as there are two transistors in push-pull amplifier.

R.M.S. value of collector current = $(I_C)_{max}/\sqrt{2}$

R.M.S. value of output voltage = $V_{CC}/\sqrt{2}$

Under ideal conditions of maximum power

Therefore,

$$(P_O)_{ac} = \frac{(I_C)_{max}}{\sqrt{2}} \times \frac{V_{CC}}{\sqrt{2}} = \frac{(I_C)_{max} \times V_{CC}}{2}$$

Now overall maximum efficiency

$$\eta_{overall} = \frac{(P_O)_{ac}}{(P_{in})_{dc}}$$

$$= \frac{(I_C)_{max} \times V_{CC}}{2} \times \frac{\pi}{2(I_C)_{max} \times V_{CC}}$$

$$= \frac{\pi}{4} = 0.785 = 78.5\%$$

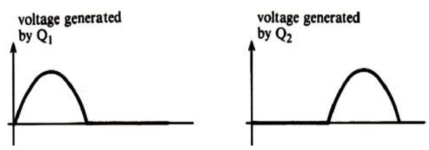
- The collector efficiency would be the same.
- Hence the class B push-pull amplifier improves the efficiency than the class A push-pull amplifier.

Distortion in Push-Pull Amplifiers:

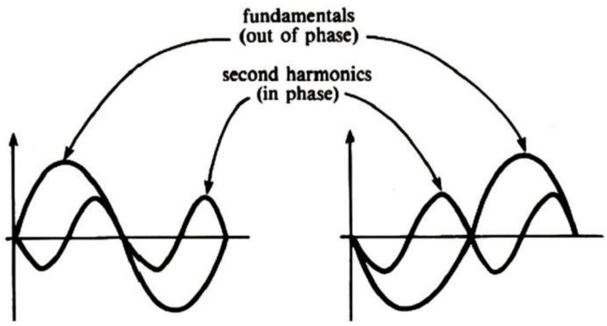
Cancellation of Even Harmonics:

- Recall that push-pull operation effectively produces in a load a waveform proportional to the difference between two input signals. Under normal operation, the signals are out of phase, so their waveform is reproduced in the load. If the signals were in phase, cancellation would occur. It can be shown that a half-wave-rectified sine wave contains only the fundamental and all even harmonics.

- Fig. (a) shows the two out-of-phase half-wave-rectified sine waves that drive the load, and Fig. (b) shows the fundamental and second-harmonic components of each. The fundamental components are out of phase. Therefore, the fundamental component is reproduced in the load, as we have already seen (Fig.). However, the second-harmonic components are in phase, and therefore cancelin the load.
- Although not shown in Fig. (b), the fourth and all other even harmonics are also in phase and therefore also cancel.
- Our conclusion is an important property of push-pull amplifies: even harmonics are cancelled in push-pull operation. The cancellation of even harmonics is an important factor in reducing distortion in push-pull amplifiers. However, perfect cancellation would occur only if the two sides were perfectly matched and perfectly balanced: identical transistors, identical drivers, and a perfectly center-tapped transformer. Of course, this is not the case in practice, but even imperfect push-pull operation reduces even harmonic distortion. Odd harmonics are out of phase, so cancellation of those components does not occur.



(a)



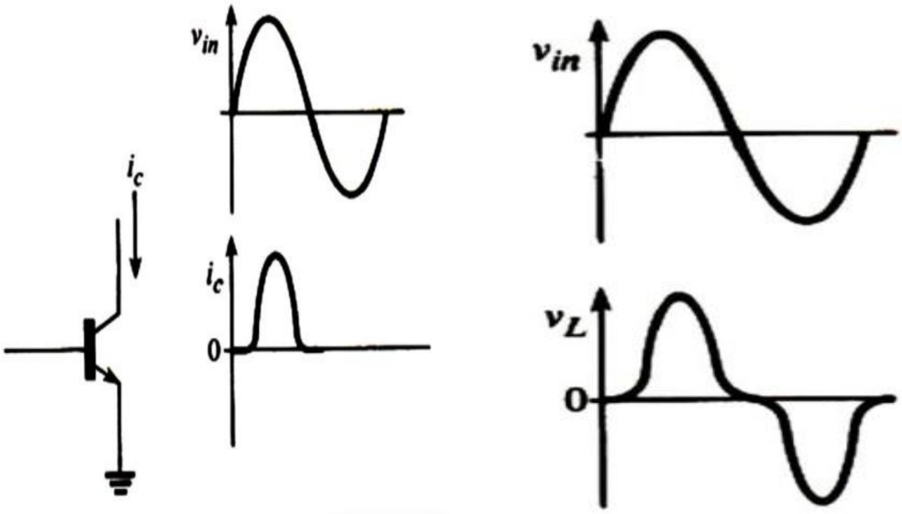
5.2.3 Cross over Distortion

(Source: Microelectronics byJ. Millman and A. Grabel, Page-493)

<u>Crossover Distortion:</u>

- A forward-biasing voltage applied across a PN junction must be raised to a certain level (about 0.7 V for silicon) before the junction will conduct any significant current.
- Similarly, the voltage across the base-emitter junction of a transistor must reach that level before any appreciable base current, and hence collector current, can flow.
- As a consequence, the drive signal applied to a class-B transistor must reach a certain minimum level before its collector current is properly in the active region. This fact is the principal source of distortion in a class-B, push-pull amplifier, as illustrated in Fig.
- Fig. shows that the initial rise of collector current in a class-B transistor lags the initial rise of input voltage, for the reason we have described.
- Also, collector current prematurely drops to 0 when the input voltage approaches 0.
- Fig. (b) shows the voltage wave form that is produced in the load of a push-pull amplifier when the distortion generated during each half-cycle by each class-B transistor is combined. This distortion is called ***crossover distortion***, because it occurs where the composite waveform crosses the zero voltage axes.

- Clearly, the effect of crossover distortion becomes more serious as the signal level becomes smaller.



(a) (b)

Fig. 5.2.4 Cross over distortion

(Source: Microelectronics byJ. Millman and A. Grabel, Page-495)

This results in one main fundamental problem with push-pull amplifiers in that the two transistors do not combine together fully at the output both halves of the waveform due to their unique zero cut-off biasing arrangement.

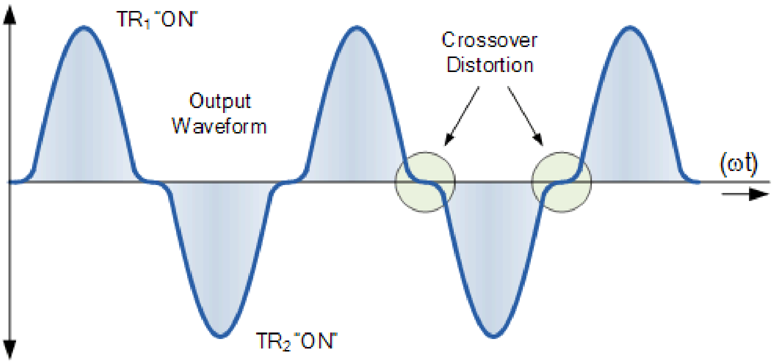
As this problem occurs when the signal changes or “crosses-over” from one transistor to the other at the zero voltage point it produces an amount of “distortion” to the output wave shape. This results in a condition that is commonly called **Crossover Distortion**.

Crossover Distortion produces a zero voltage “flat spot” or “deadband” on the output wave shape as it crosses over from one half of the waveform to the other.

The reason for this is that the transition period when the transistors are switching over from one to the other, does not stop or start exactly at the zero crossover point thus causing a small delay between the first transistor turning “OFF” and the second transistor turning “ON”.

This delay results in both transistors being switched “OFF” at the same instant in time producing an output wave shape as shown below.

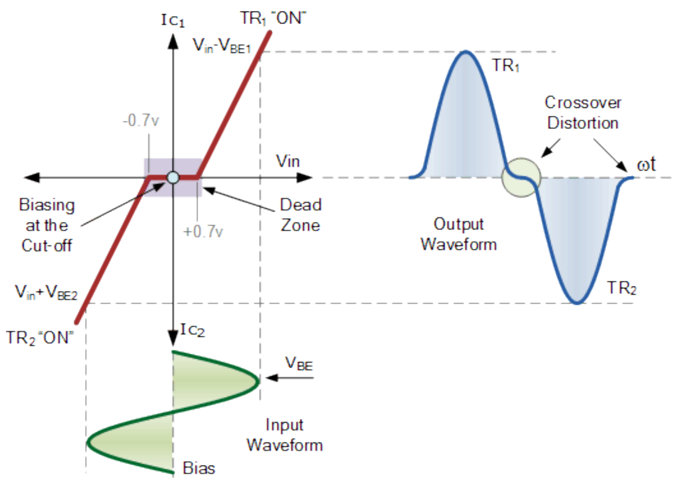
Crossover Distortion Waveform



(Source: Microelectronics byJ. Millman and A. Grabel, Page-495)

In order that there should be no distortion of the output waveform we must assume that each transistor starts conducting when its base to emitter voltage rises just above zero, but we know that this is not true because for silicon bipolar transistors, the base-emitter voltage must reach at least 0.7v before the transistor starts to conduct due to the forward diode voltage drop of the base-emitter pn-junction, thereby producing this flat spot. This crossover distortion effect also reduces the overall peak to peak value of the output waveform causing the maximum power output to be reduced as shown below.

Non-Linear Transfer Characteristics



5.2.5 Non linear Transfer Characteristics

(Source: Microelectronics byJ. Millman and A. Grabel, Page-493)

This effect is less pronounced for large input signals as the input voltage is usually quite large but for smaller input signals it can be more severe causing audio distortion to the amplifier.

Pre-biasing the Output

The problem of **Crossover Distortion** can be reduced considerably by applying a slight forward base bias voltage (same idea as seen in the **Transistor** tutorial) to the bases of the two transistors via the center-tap of the input transformer, thus the transistors are no longer biased at the zero cut-off point but instead are "Pre-biased" at a level determined by this new biasing voltage.

Push-pull Amplifier with Pre-biasing

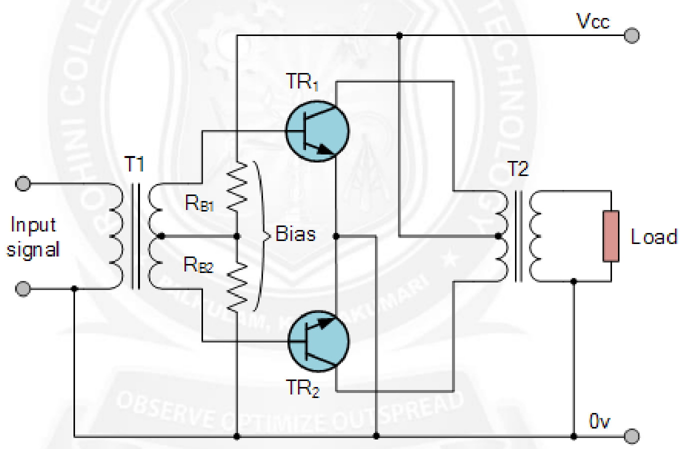


Fig 5.2.6 Push pull amplifier with pre biasing

(Source: Microelectronics byJ. Millman and A. Grabel, Page-498)

This type of resistor pre-biasing causes one transistor to turn "ON" exactly at the same time as the other transistor turns "OFF" as both transistors are now biased slightly above their original cut-off point. However, to achieve this the bias voltage must be at least twice that of the normal base to emitter voltage to turn "ON" the transistors. This pre-biasing can also be implemented in transformerless amplifiers that use complementary transistors by simply replacing the two potential divider resistors with **Biasing Diodes** as shown below.

Pre-biasing with Diodes

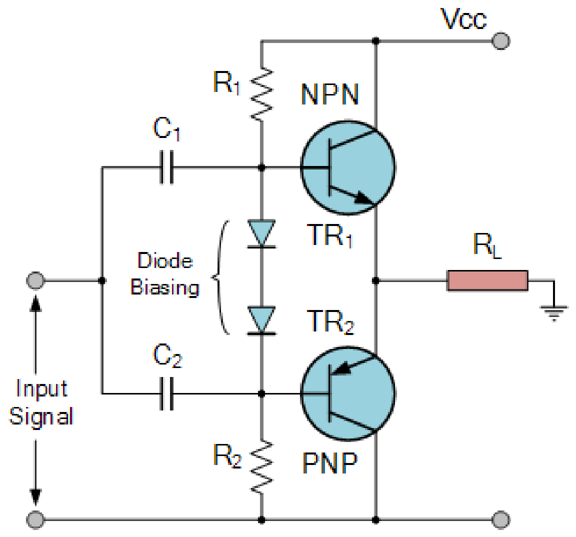
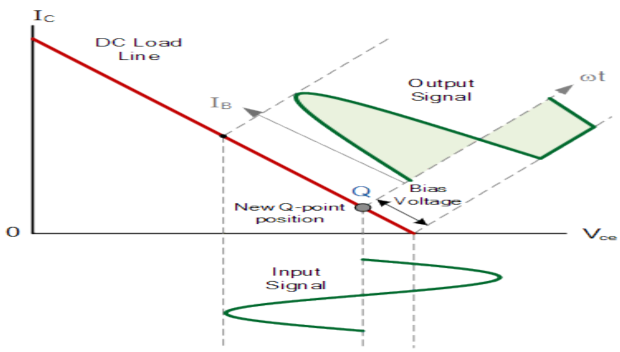


Fig 5.2.6 Push pull amplifier with pre biasing with diodes

(Source: Microelectronics byJ. Millman and A. Grabel, Page-499)

This pre-biasing voltage either for a transformer or transformerless amplifier circuit, has the effect of moving the amplifiers Q-point past the original cut-off point thus allowing each transistor to operate within its active region for slightly more than half or 180^{o} of each half cycle. In other words, 180^{o} + Bias. The amount of diode biasing voltage present at the base terminal of the transistor can be increased in multiples by adding additional diodes in series. This then produces an amplifier circuit commonly called a **Class AB Amplifier** and its biasing arrangement is given below.

Class AB Output Characteristics



5.2.6 Out put Characteristics

(Source: Microelectronics byJ. Millman and A. Grabel, Page-498)

Crossover Distortion Summary

Then to summarise, **Crossover Distortion** occurs in Class B amplifiers because the amplifier is biased at its cut-off point. This then results in BOTH transistors being switched "OFF" at the same instant in time as the waveform crosses the zero axis. By applying a small base bias voltage either by using a resistive potential divider circuit or diode biasing this crossover distortion can be greatly reduced or even eliminated completely by bringing the transistors to the point of being just switched "ON".

The application of a biasing voltage produces another type or class of amplifier circuit commonly called a **Class AB Amplifier**. Then the difference between a pure Class B amplifier and an improved Class AB amplifier is in the biasing level applied to the output transistors. One major advantage of using diodes over resistors is that their PN-junctions compensate for variations in the temperature of the transistors.

Therefore, we can correctly say that the Class AB amplifier is effectively a Class B amplifier with added "Bias" and we can summarise this as follows:

- Class A Amplifiers – No Crossover Distortion as they are biased in the center of the load line.
- Class B Amplifiers – Large amounts of Crossover Distortion due to biasing at the cut-off point.
- Class AB Amplifiers – Some Crossover Distortion if the biasing level is set too low.

As well as the three amplifier classes above, there are a number of high efficiency Amplifier Classes relating to switching amplifier designs that use different switching techniques to reduce power loss and increase efficiency. Some of these amplifier designs use RLC resonators or multiple power-supply voltages to help reduce power loss and distortion.

Complementary Symmetry Push-Pull Class B Amplifier

➢ The push pull amplifier which was just discussed improves efficiency but the usage of center-tapped transformers makes the circuit bulky, heavy and costly. To make the circuit simple and to improve the efficiency, the transistors used can be complemented, as shown in the following circuit diagram.

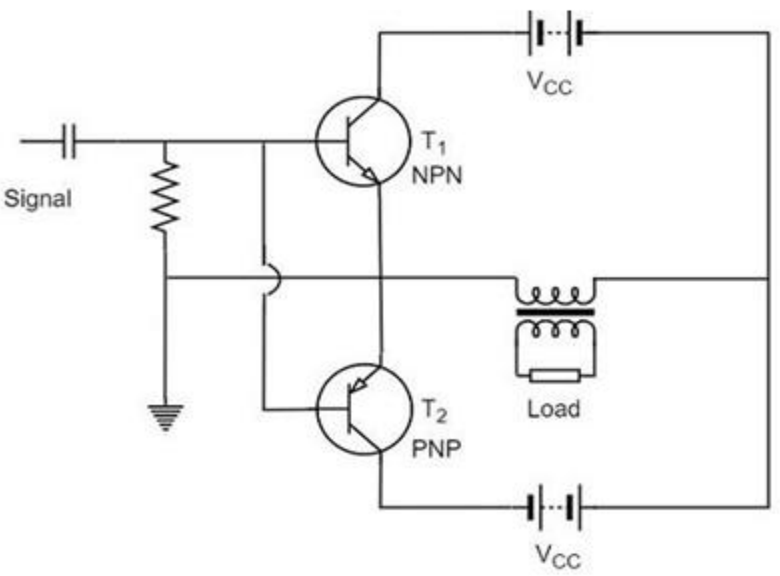


Fig 5.2.7.Complementary Symmetry Push-Pull Class B Amplifier

(Source: Microelectronics byJ. Millman and A. Grabel, Page-498)

- The above circuit employs a NPN transistor and a PNP transistor connected in push pull configuration. When the input signal is applied, during the positive half cycle of the input signal, the NPN transistor conducts and the PNP transistor cuts off. During the negative half cycle, the NPN transistor cuts off and the PNP transistor conducts.
- In this way, the NPN transistor amplifies during positive half cycle of the input, while PNP transistor amplifies during negative half cycle of the input. As the transistors are both complement to each other, yet act symmetrically while being connected in push pull configuration of class B, this circuit is termed as **Complementary symmetry push pull class B amplifier**.
- The circuit diagram for complementary symmetry type is shown in

Figure**.** This circuit uses two transistors of different type. One is NPN and another PNP. It is a transformer less circuit. For better impedance matching the tow transistors Q1 & Q2 are connected as emitter follower configuration. Positive half cycle Q1 is in Active region so ON & Q2 in cut off So OFF. In negative half cycle Q2 is ON & Q1 is OFF. Thus for a complete input cycle output is developed as shown in fig.The difference between complementary symmetry and push pull models is in complementary model there is no output transformer.

Analysis:

- All results for push pull amplifiers are applicable for complementary symmetry model. Only change is replace R_L' with real load R_L value. (Since, no output transformer is used).

Advantages

The advantages of Complementary symmetry push pull class B amplifier are as follows.

- As there is no need of center tapped transformers, the weight and cost are reduced.
- Equal and opposite input signal voltages are not required.

Disadvantages

The disadvantages of Complementary symmetry push pull class B amplifier are as follows.

- It is difficult to get a pair of transistors (NPN and PNP) that have similar characteristics. We require both positive and negative supply voltages.
- The class A and class B amplifier so far discussed has got few limitations. Let us now try to combine these two to get a new circuit which would have all the advantages of both class A and class B amplifier without their inefficiencies.

Comparison of Push Pull & Complementary Symmetry circuits:

S.N	Parameter	Push Pull	Complementary Symmetry
1	Type of Transistor	Both should be of NPN or PNPtype	One is PNP and other NPN
2	Use of transformers	Used at both i/p & o/p side	Not needed
3	Impedance matching	Possible due to use of twotransformers	Possible due to operation oftransistors in CC configuration
4	Transistor Configuration	Both transistors Operates inCE mode	Both transistors Operates inCC mode
5	Conduction Angle	180^o	180^o
6	Power dissipation when no input is present	Zero	Zero
7	Efficiency	Low	Higher than Push Pull type.